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Original Article

Climate Change and Chances for the Cultivation of New Crops

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Abstract

Climate change is one of the greatest environmental, economic and social challenges in the history of mankind and nowadays is considered as the biggest environmental problem of the world. Climate change has a significant global impact and therefore Greece has to deal with its effects as well. Agriculture has been unfavourably affected in recent years, as the current and anticipated conditions in many cases seem to be rather prohibitive for the prosperity of the cultivated crops. On the contrary, these new conditions have made it possible for new plant species previously cultivated only in subtropical regions, to thrive in Greece. Moreover, economic reasons would make it rather necessary for the agricultural industry to cultivate alternative crops, which are thoroughly analysed in the present study. Based on Heating Degree Days (HDD) Greece is divided into four climatic zones. The variations in the mean maximum, mean minimum and mean temperature in each climate zone as well as the rainfall over the last 50 years (from 1964 to 2013) are reviewed in this paper. The outcome of this research is that it is not feasible for the studied alternative crops to thrive in all climate zones or vice versa. However, some of them and particularly crops such as quinoa, maca, psyllium, chia, cassava and pecan can be cultivated in all climate zones. It has also to be noted that adequate water is necessary for almost all the examined crops in order to achieve optimal growth and yield and therefore irrigations are rather necessary for specific species and climate zones.

Keywords: adaptability, agriculture, climatic zones, global warming, precipitation, species

Introduction

Climate variability is a concept that engages several scientists and has been an object of study and major concern. Changes to the world's climate are already taking place with evident impact in various sectors worldwide. The temperature in Europe has increased by almost 1 °C in the last century, faster than the global average. The bulk of the overheating occurred over the last 50 years mainly due to human activities that increase greenhouse gas emissions (GHG) (Forster *et al*., 2007). While the variation does not seem dramatic, it has already affected significantly many physical and biological systems (water, habitats, health), which have become increasingly susceptible. Lately, the climatic conditions are progressively more volatile. Rainfall and snowfall have significantly increased in northern Europe, and therefore there are more frequent (and more severe) floods, while in southern Europe precipitation and rainfall have been significantly reduced resulting to more frequent periods of drought. Moreover, temperatures have become more extreme. Economic losses due to extreme weather conditions have considerably increased in the last decades. Specific forecasting models show a mean temperature rise in various parts of the globe that can range from 2-4 °C until 2050. It is anticipated that in the coming decades agriculture will be affected by climate change not only in the EU but also worldwide. The global alert intensifies as the evidence for the severity of the impacts of climate change is becoming increasingly alarming every year. Agricultural production is at risk due to loss of arable land, smaller growing seasons and uncertainty about the type and the establishment time of specific crops. Europe is already facing the first visible symptoms due to climate change, including extreme weather events and heat waves that are observed more often (Meehl *et al*., 2007). Various changes in precipitation, possible warming increase of CO_2, increase in frequency of extreme weather events and changes in the spread of pests and diseases of crops are expected in the near future (Tubiello *et al*., 2007). Moreover, the augmentation of extreme weather conditions may result in changes in crop yields, increase in prices and changes in trade balances between countries (Lobell *et al*., 2008). Parry *et al*. (2001) argue that developing countries are most vulnerable to climate change because of the dominant

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role of agriculture in their economies, the lack of funds that prevent from dealing with it and the fact that they have warmer climates and consequently greater exposure to extreme weather events.

As the Intergovernmental Panel on Climate Change (IPCC) indicates moderate increase in temperatures is likely to increase crop yields in temperate regions and instead reduce the yields in subtropical and tropical zones during the first half of this century (IPCC, 2007b). Crop yields appear to be favoured in temperate regions, following minor estimates for CO_2 increase and temperature rise of 1-2 °C in the coming decades, compared to tropical areas where cereal yields are negatively affected.

During the last years, several monitoring studies on the impact of climate change have been conducted, providing sufficient data to support significant assessments. Yields of various crops show a noticeable variability, depending on the climate model and occurring from the application of climate scenarios combined with the ability to adapt to changes. Parry *et al.* (2004) evaluated the impact of climate change on main crops such as wheat, maize, rice and soybeans. Similar studies have been conducted in several European countries (Stern for the UK, Alexandrov for Bulgaria) or for entire continents such as PESETA Research Project for Europe or Giannakopoulos *et al.* (2011) for the Mediterranean basin.

Trying to estimate the impact of climate change on crops still remains a challenge due to the complexity in the interpretation of plant physiological functions under different future biotic and abiotic conditions. However, recent research about the effects of climatic condition changes for agricultural production has provided the following indicative remarks. The temperature rise and the increase of CO_2 levels in the atmosphere during the period 1960 to 2000 have affected the crops around the globe. These changes are not visible yet due to the rapid technological development in agriculture. According to studies that have managed to isolate specific effects of climate change (temperature and rainfall only) agricultural production will be either slightly reduced (0.05%) or increased (0.9%). The simultaneous observed increase in CO_2 global level emissions has already increased the agricultural production by 2-4% (Mendelsohn, 2007).

With regard to future estimates for agricultural production, PESETA research project of the European Union predicts variation of production in southern Europe from zero to 27% decrease, depending on the scenario and the climate model used. In particular, at intermediate and higher latitudes of Europe, global warming will extend the length of the potential growing season, allowing earlier planting of crops in the spring and shorter maturation and harvesting period. Less severe winters will also allow more productive cultivars of winter annual and perennial crops to be grown. This is of particular importance for C_4 species since the key enzyme pyruvate phosphate dikinase is sensitive to low temperature (Edwards, 1986).

Cropping areas may expand northwards in countries such as Finland and Russia. The shifts will be most pronounced along the current margins for production of specific crops. In Finland, Carter *et al.* (1996) found a northward shift of areas suitable for spring cereals of 120-150 km $°C^{-1}$ increase in annual mean temperature. Spatial shifts northwards and into central Europe has also been estimated for warmer season crops like grain maize and grapevine (Kenny and Harrison, 1992; Kenny *et al.*, 1993).

In warmer, lower latitude regions of Europe, increased temperatures increase respiration, resulting in lower than optimal conditions for net growth. Another important effect of high temperature is accelerated development, resulting in hastened maturation of determinate crops and reduced yield (Rötter and van de Geijn, 1999). It has to be noted that extensive changes in the dispersal of plant communities are expected as a result of changes in rainfall and temperatures that are directly linked to climate change (Adams *et al.*, 2009; Kane *et al.*, 2011).

Greece as a member of Southern Europe and the Mediterranean basin is expected to be among the most vulnerable countries to climate change and therefore requires adaptation measures in accordance with the Green Paper (CEC, 2007). As a result of climate change, new species and new crops have already imported or may be imported the following years in Greece. The main objectives of the present study were to review the meteorological data and their variation during the last five decades, correlate them with the climatic zones and suggest new crops, suitable for each area, which could be potentially cultivated with success.

Materials and Methods

Meteorological data

For the purposes of the present study, there were used meteorological data on monthly average, mean minimum and mean maximum temperature as well as the average monthly rainfall for each of the 24 meteorological cages featuring the NA (National Weather Service) for years from 1964 to 2013.

Processing of meteorological data

The meteorological data were grouped by chronological decade. In particular, mean, average minimum and average maximum temperature for each month of the year were calculated and also the average monthly rainfall for decades 1964-1973, 1974-1983, 1984-1993, 1994-2003 and 2003-2014 and for the 24 regions where the NA has an installed meteorological cage.

The meteorological data obtained by this treatment were plotted in charts. During the imaging process the area of the emerged parallelograms formed from the curves for each decade was calculated. The values of these areas are listed in Tables 1, 2 and 3. These areas describe the change in the average minimum (Tmin), average maximum (Tmax), mean temperature (Tmean) and rainfall (P) per decade from 1964 to 2013.

Each integral has a value that can be geometrically interpreted as a certain area under a curve. The methodology to define it is the following. The interval [a, b], in which n subintervals not need to be of equal length, was divided. Since each of them, shows a variation of x, they can be mentioned as Δx_1, Δx_2 ... Δx_i, respectively. In these subintervals, respectively construct n rectangles, so that the height of each is equal to the largest value of the function obtained in this rectangle. The first rectangle has height $f(x_1)$ and width Δx_1 and generally, the i-th rectangle has height $f(x_i)$ and width Δx_i. Consequently, according to the dimensions of subintervals, the formula for the area A' is given in Equation 1:

$$A' = \sum_{i=1}^{n} f(x_i)\,\Delta x_i$$

To reach the actual area A, the interval [a, b] should be divided into even smaller spaces as pieces of rectangles. This is shown in Equation 2:

$$\lim_{n\to\infty} \sum_{i=1}^{n} f(x_i)\Delta x_i\, dx = \lim_{n\to\infty} A' =$$

Since the integral also symbolizes sum with limits a and b, the definite integral shown in Equation 3 is equivalent to the above limit. That is:

$$\int_a^b f(x)\,dx \equiv \lim_{n\to\infty} \sum_{i=1}^{n} f(x_i)\Delta x_i =$$

This integral is also called Riemann integral and has the meaning of both the area and the sum. If the lower and upper integrals are equal then the integral by Riemann is defined.

Determination of climate zones

According to the Regulation of Energy Performance of Buildings, the Greek territory is divided into four climate zones based on Heating Degree Days (Matzarakis and Balafoutis, 2002), with the schematic representation displaying in Fig. 1.

In this paper, an extensive literature review was conducted and a large number of plant species was evaluated in order to recommend the most suitable for cultivation in Greece. Most of these crops have not been cultivated in Greece yet, while there are some which are cultivated only on a very small scale. For these cases the present study was an attempt to evaluate their possible cultivation in other areas, since most of the plants are tropical and subtropical plants.

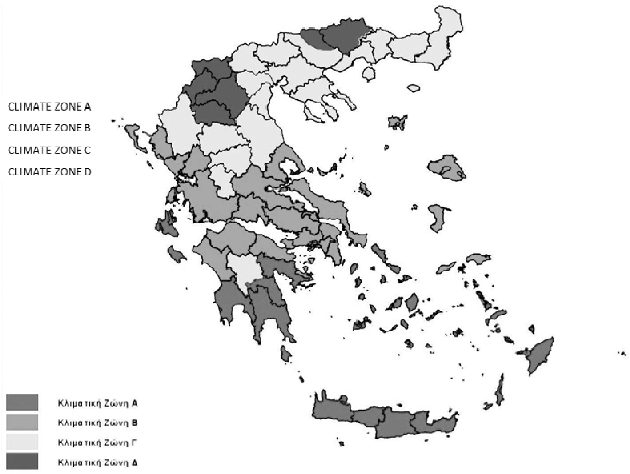

Fig. 1. Climate zones of the Greek territory

Table 1. Variation of the average maximum and average minimum temperature per decade (from 1964 to 2013) for the climate zones A and B

Climate Zone A		
Year	ΔTmax (degree °C * year)	ΔTmin (degree °C * year)
1964-1973	244.13	174.97
1974-1983	238.84	174.30
1984-1993	241.76	178.17
1994-2003	248.44	184.72
2004-2013	247.87	189.88

Climate Zone B		
Year	ΔTmax (degree °C * year)	ΔTmin (degree °C * year)
1964-1973	263.85	159.32
1974-1983	261.13	157.46
1984-1993	263.39	159.53
1994-2003	269.61	166.72
2004-2013	269.98	171.01

Table 2. Variation of the average maximum and average minimum temperature per decade (from 1964 to 2013) for climate zones C and D

Climate Zone C		
Year	ΔTmax (degree °C * year)	ΔTmin (degree °C * year)
1964-1973	251.85	116.53
1974-1983	248.63	112.98
1984-1993	252.16	118.86
1994-2003	257.48	126.71
2004-2013	258.38	132.10

Climate Zone D		
Year	ΔTmax (degree °C * year)	ΔTmin (degree °C * year)
1964-1973	226.69	98.35
1974-1983	224.00	101.47
1984-1993	228.78	109.35
1994-2003	234.73	114.49
2004-2013	235.56	117.73

Table 3. Variations of the mean temperature (ΔTmean) and the mean precipitation (ΔP) per decade (from 1964 to 2013) per climate zone and corresponding percentage variation with reference to the decade 1964 to 1973

Climate Zone A				
Year	Δp (Mm * Year)	Percentage Variation P (%)	ΔTmean (degrees * Year)	Percentage Variation Tmean (%)
1964-1973	589.49		221.37	
1974-1983	586.07	-1.18%	219.96	-0.64%
1984-1993	513.54	-12.88%	220.42	-0.43%
1994-2003	556.78	-5.55%	227.30	2.68%
2004-2013	505.74	-14.02%	227.58	2.8%

Climate Zone B				
Year	Δp (Mm * Year)	Percentage Variation P (%)	ΔTmean (degree °C * year)	Percentage Variation Tmean (%)
1964-1973	709.12		215.80	
1974-1983	727.60	2.61%	213.72	-0.96%
1984-1993	582.68	-17.83%	216.48	0.31%
1994-2003	691.48	-2.49%	222.00	2.87%
2004-2013	660.63	-6.84%	220.59	2.22%

Climate Zone C				
Year	Δp (Mm * Year)	Percentage Variation P (%)	ΔTmean (degree °C * year)	Percentage Variation Tmean (%)
1964-1973	646.93		195.63	
1974-1983	602.92	-7.27%	191.01	-2.36%
1984-1993	547.67	-15.34%	196.34	0.36%
1994-2003	558.66	-13.64%	200.96	2.72%
2004-2013	613.74	-5.13%	197.02	0.71%

Climate Zone D				
Year	Δp (Mm * Year)	Percentage Variation P (%)	ΔTmean (degree °C * year)	Percentage Variation ΔTmean (%)
1964-1973	642.08		170.50	
1974-1983	501.19	-21.94%	167.83	-1.56%
1984-1993	439.81	-31.50%	175.86	3.14%
1994-2003	425.15	-33.78%	182.12	6.81%
2004-2013	431.29	-32.83%	182.52	7.05%

Results

Variation of meteorological data

Analysis of the meteorological data showed that, from 1964 up to 2013 there have been changes to all meteorological data and in all climate zones that have been analyzed. Because of the multitude of drawings, it has been chosen to be presented in this paper the most representative one (Fig. 2), which concerns the variance of the average minimum temperature (T_{min}) in the climate zone A.

According to Fig. 2, in climate zone A the average minimum temperature (T_{min}) has an annual increase up to 1 °C. Particularly, the major increase was observed in the months from February to April and during the summer months (June to August) of the last twenty years (from 1994 to 2013).

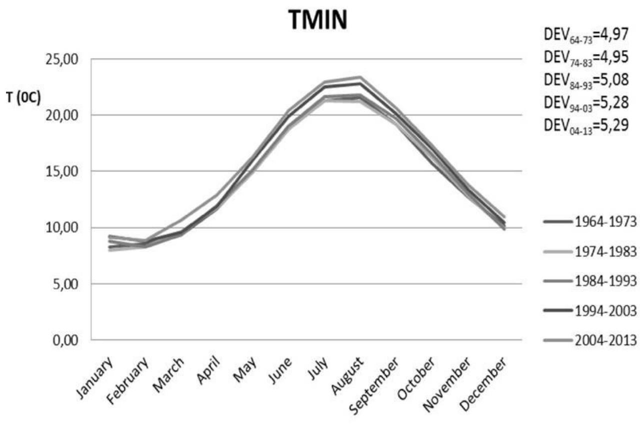

Fig. 2. Monthly fluctuation of minimum temperature (T_{min}) in the climate zone A for five decades (from 1964 to 2013)

Recommended plants for each climate zone

In climate zone A, it was noticed that the mean temperature ranges from 11.3 to 27 °C, the average maximum temperature ranges from 14 to 30.5 °C, while the average minimum temperature varies from 8.3 to 23.3 °C. Moreover, the annual precipitation ranges from 502 to 592 mm. Based on these conditions prevailing in regions of climate zone A, cultivation of quinoa (*Chenopodium quinoa*), psyllium (*Plantago psyllium*), chia (*Salvia hispanica*), camelina (*Camelina sativa*), kenaf (*Hibiscus cannabinus*), stevia (*Stevia rebaudiana*), cassava (*Hibiscus cannabinus*), cherimoya (*Annona cherimola*), lychee (*Litchi chinensis*), pecan (*Carya illinoensis*), and guava (*Psidium guajava*) could be feasible. Taking into account the need of these crops for water, it has to be noted that the annual precipitation is not sufficient and consequently the extra supply of water through irrigation is considered essential. On the contrary, aloe (*Aloe vera*) and century plant (*Agave americana*) could be cultivated without irrigation since their water needs are rather covered.

Regarding climate zone B, it can be observed that the mean temperature ranges from 8.6 to 27.5 °C, the maximum temperature from 12.4 to 32.5 °C and the minimum temperature varies from 4.8 to 21.7 °C.

Annual precipitation ranges from 515 to 655 mm. Based on the conditions prevailing in regions of climate zone B, cultivation of quinoa and maca (*Lepidium meyenii*), could be feasible but only as autumn crops. Furthermore, the cultivation of psyllium, chia, stevia, kenaf, cassava and pecan could be also possible. However, in these crops, the addition of water through irrigation is necessary, since the water needs of the specific plants are not solely met by precipitation. Century plant could be also cultivated without further irrigation, since the annual precipitation exceeds the water needs of the plant.

Mean temperature in climate zone C ranges from 4.4 to 26.2 °C, while maximum and minimum temperatures range from 8.6 to 32.5 °C and from 0.1 to 19 °C, respectively. The annual precipitation ranges from 529 to 668 mm. Based on these meteorological conditions prevailing, cultivation of psyllium, chia, stevia, cassava and pecan are proposed for climate zone C. Moreover, crops such as quinoa and maca could be cultivated, but only as autumn crops. In all the above mentioned cases, irrigation is prerequisite, since annual precipitation is not enough. On the contrary, *A. americana* could be probably cultivated without further irrigation since the annual precipitation exceeds the water needs of the plant. However, 1-2 irrigations might be needed during the crucial growth stages of the crop.

In climate zone D, mean temperature ranges from 1.8 to 25.7 °C, with maximum and minimum temperature ranging from 5 to 30.8 °C and from 0 to 18 °C, respectively. Regarding the annual precipitation, it ranges from 412 to 607 mm. Therefore, in climate zone D, the cultivation of crops such as psyllium, chia, kenaf, cassava and pecan seems to be promising. Additionally, the cultivation of quinoa and maca could be also an option, but probably as autumn crops. Like in zone C, irrigation is necessary for the above mentioned crops, with only exception this of century plant.

Discussion

The global financial crisis and the intense competition are two but not the only reasons for the agricultural community to turn to alternative crops. Moreover, the observed trend of consuming food with high biological value could also favour the dispersal of new crops. Consumers are now looking for products rich in nutrients, vitamins and antioxidants and consequently several products of alternative crops find uses in both the food market and the pharmaceutical industry. Climate change, which is already visible around the world, should be also taken into consideration as one important factor. Despite the fact that climate conditions change, directly affecting the survival of the human race, they also affect food production. Water resources are considered to be among the most critical factors that have already been threatened. Agriculture is responsible for the consumption of 80% of the water resources, and therefore crops less demanding in water and adapted to these general climatic changes (severe drought, high temperatures, extreme weather events, etc.) are desirable.

Taking into consideration the Greek territory and the predictions of climate change impact (increase in average temperatures and lower rainfall), some thoughts on the future of traditionally grown cultivated crops (maize, wheat, cotton and vine) are presented below. Regarding the cultivation of maize, it is expected a decline in production of 4-55% (depending on the region and the hybrid). Concerning wheat cultivation, it is expected either reduced production ranging from 1 to 67%, or increasing production up to 15%. In all scenarios including cotton, a reduction of the growth period was revealed, due to the higher mean temperatures. In

Table 4. Plants adaptability per climate zone

Common name	Latin name	Zone A	Zone B	Zone C	Zone D
Century plant	*Agave americana*	++++	++++	++++	++++
Acai	*Euterpe oleracea*	-	-	-	-
Aloe	*Aloe vera*	++++	-	-	-
Abaca	*Musa textilis*	-	-	-	-
Jute	*Corchoruscapsularis*	-	-	-	-
Guava	*Psidium guajava*	+++	-	-	-
Camelina	*Camelina sativa*	+++	-	-	-
Camucamu	*Myrciaria dubia*	-	-	-	-
Cassava	*Manihot esculenta*	+++	+++	+++	+++
Kenaf	*Hibiscus cannabinus*	+++	+++	-	+++
Quinoa	*Chenopodium quinoa*	+++	++	++	++
Lychee	*Litchi chinensis*	+++	-	-	-
Maca	*Lepidium meyenii*		++	++	++
Pecan	*Carya illinoensis*	+++	+++	+++	+++
Sisal	*Agave sisalana*	-	-	-	-
Suma root	*Pfaffia paniculata*	-	-	-	-
Stevia	*Stevia rebaudiana*	+++	+++	+++	-
Cherimoya	*Annona cherimola*	+++	-	-	-
Chia	*Salvia hispanica*	+++	+++	+++	+++
Psyllium	*Plantago psyllium*	+++	+++	+++	+++

++++: Fully covered the plant growth needs (Tmin, Tmax, Tmean, P)
+++: Fully covered the plant growth needs, except from the precipitation (P)
++: Only as an autumn crop the plant growth needs are covered
-: None of the growth plant needs are covered (Tmin, Tmax, Tmean, P)

particular, a decrease in production in the regions of Macedonia and Thessaly is expected and increased production in the region of Thrace, because of the higher temperatures of the anticipated climate change. Finally, regarding vine, the results for the studied areas have shown that the effects are not the same for all varieties and for all regions. The duration of the growth season in some regions was decreased, while in others was increased. Consequently, there were many and significant differences in production per area. This complexity seems to be due to vine's nature as a perennial crop and the cumulative effects of climate change (NCA - Ministry of Environment, 2007).

From the above mentioned remarks and as long as several widely cultivated crops seem to be affected by climate change; studies on the adaptability of new crops in Greece should be conducted. From the analysis of the results it can be concluded that in Greece there are climatic zones more or less suitable for the cultivation of new subtropical crops.

The study of meteorological data from 1964 to 2013 showed that there is an increase in both T_{max} and T_{min}, however this increase is greater for T_{min}, and this observation is valid to all climate zones. Another noticeable finding is related with the reduction of T_{max} and T_{min} during the decade 1974-1983 for all the climatic zones, except climate zone D. In terms of percentage variation in the mean temperature (T_{mean}), there has been a reduction in T_{mean} during the decade 1974-1983 in all climate zones compared with the previous decade. From 1984 to 2013 there has been a rise in temperature in all climate zones, but what differs is the decade in which the largest increase in mean temperature was observed. More specifically, concerning the climatic zones A and D, the largest percent increase in the mean temperature detected during the decade 2004-2013 was 2.8 and 7.05%, respectively. The corresponding values for the climate zones B and C are observed during 1994-2003 decade and were 2.87 and 2.72%, respectively.

The percentage variation in annual precipitation compared with the decade 1964-1973 generally seems to decline for all the decades that followed until 2013. In particular, the largest percentage reduction in precipitation was observed in the decade 1984-1993, with a decrease of 17.83 and 15.34% for the climate zones B and C, respectively. On the contrary, in climate zone A, the largest decrease is observed in the decade 2004-2013(14.02%), while in zone D, it is located in the decade 1994-2003 (33.78%), and it is the largest reduction observed for all climate zones.

Regarding the several species, our study revealed that these crops can be categorized by climate zone. Specifically, most of the mentioned crops can adapt in climate zone A, while zone D is the less suitable for the cultivation of the above-mentioned crops. In zones B and C several of the mentioned crops can be cultivated.

Moreover, there are plants that can be cultivated in all climate zones, under certain conditions. These plants are quinoa, maca, psyllium, chia, cassava and pecan. In Greece, the first experiments were conducted in 1995 by N.AG.RE.F. (National Agricultural Research Foundation), however the production of quinoa started in a small area (about 10 ha) near the city of Lamia in 2012 in collaboration with the University of Thessaly. In addition, quinoa crop was also studied in the region of Larissa (Iliadis *et al.*, 1997; Iliadis *et al.*, 2001), in Velestino and Grevena (2008-2010) by the University of Thessaly and in the area of Agrinio in 2010 and 2011 (Bilalis *et al.*, 2012). Pecan is not systematically cultivated in Greece, compared to other Mediterranean countries like Cyprus and Israel with noticeable commercial plantations. Due to its resistance to low winter temperatures it can even grow in areas of central Greece (Lionakis, 2005). Concerning *L. meyenii*, although attempts have been made in many countries for the cultivation of maca it is not clear whether it maintains the same ratio of components or the same properties as it has in Andes.

In addition, kenaf, the century plant and stevia can be grown in most climate zones. Currently, stevia is cultivated in Karditsa, Fthiotida and Aetoloakarnania counties which belong to zones B and C. Moreover, since it is a crop which has similar climate and growing requirements with tobacco (a very well-known crop for the Greek farmers), the transition for the farmers is easier (Zachokostas, 2012). Concerning kenaf, from experiments conducted in Central Greece, it seems that this crop can be very productive, with yields up to 2 tn / acre (Danalatos and Archontoulis, 2010), while in Northern Greece yield was almost 1.3 tn / ha (Kipriotis *et al.*, 2007).

Camelina, cherimoya, lychee, guava and aloe can be grown only in climate zone A. For many of these crops there are already some experimental data available. For example, guava is grown in a small area in the Dodecanese, while the crop was promoted in the southern and shaded areas of Crete islands, Kythera and Antikythera, Messinia, Lakonia, Dodecanese and Cyclades falling in Zone A. Moreover, cherimoya was also consistently grown at experimental level in Greece. Based on these experiments, it appears to be able to achieve satisfactory production and ensure adequate agricultural income in the appropriate areas of southern Greece. Particularly, the crop is promoted to Crete, Cyclades, Dodecanese, Lakonia, Messinia, Kythira, Antikythera, Poros, Trizinia and Thermis, located in distance lower than 400 m from the sea. Furthermore, cultivation of lychee could be promoted in areas of Crete, Kythera, Antikythera, Messinia, Lakonia, Dodecanese and Cyclades, falling in climate zone A. Moreover, lychee is cultivated in a very small area in Western Crete (Lionakis, 2008). Finally, aloe is already commercially grown in several sites and among them over an area of 150 acres in region Soutsoura of Heraklion-Crete (Babilis, 2011).

Concerning the fulfilment of the crops' requirements in water, it is necessary to supply more water through irrigation where precipitation is not enough to cover the crops' water needs. This situation is expected to become worse because of the anticipated reduction of precipitation in the coming years. In contrast, the cultivation of the century plant and aloe does not need irrigation.

Suma root (*Pfaffia paniculata*), camucamu (*Myrciaria dubia*), sisal (*Agave sisalana*), jute (*Corchorus capsularis*), abaca (*Musa textilis*) and acai (*Euterpe oleracea*) seem unable to adapt and be productive in any of the four climatic zones of Greece. However, it has to be noted that probably there are some areas with their own and unique soil and climatic conditions (microclimates), different from the typical of each climatic zone, where the cultivation of some of the above-mentioned crops could be viable and successful. Due to the specific microclimate that these plants require in order to grow, the regions in Europe that are considered suitable for their cultivation are rather limited. It should be also taken into account that the climate of the southern regions of Greece (and especially Crete) start to simulate with that of North Africa, which is already favourable for the cultivation of almost all of the examined plants. Therefore, it is highly suggested for further studies to focus in smaller areas and particular microclimates.

Conclusively, it could be said that the establishment of new crops like the ones mentioned in the present study and even more could be an alternative solution for modern farmers and give them the opportunity to produce tropical or subtropical fruits that are in high demand in the market and are currently imported in our country. Climate change is already here and the big challenge of agriculture is to be systematically and rapidly adapted to the new reality and future worst-case scenarios

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