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# HOW CLIMATE CHANGE AFFECTS COTTON AND WHEAT CROPS IN GREECE THE LAST FIFTEEN YEARS

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## ABSTRACT

*This paper presents the undoubted change of the Earth's temperature since the past three centuries (18th, 19th and 20th respectively). Climate change and its impact on agriculture and water resources have become a global concern, however, despite that, how does climate change effect common crops, like cotton and wheat?*
*By utilizing and comparing the data of the temperature of the year 1978 and the latest year of the database (2022), the average temperatures are 15,15 °C (59,27 °F) and 16,75 °C (62,15 °F) respectively. The precipitation rate has not been reduced. Although the changes in precipitation are not stable due to specific factors, the increase of the temperature tends to cause increase crop evapotranspiration (ETc) which eventually leads to more precipitation. Since the temperature has been increased, the duration of each growing season is shorter, due to the fact that the desired temperature has been achieved earlier. Increased temperature has an immediate effect on the increase of ETc and therefore at the crop coefficient factor.*

## INTRODUCTION

Climate change, essentially describes the increase of the temperature of our planet in global level. Climate change on a wider range, also includes changes (mostly long-term) in our planet's climate. The current increase in temperature is being accelerated than it used to be in the past decades and is mainly caused by ourselves, by the huge and constant use of fossil fuels (IPCC SR15 Ch. 1 2018, p. 54.) (Mark Lynas et al 2021 Environ. Res. Lett. 16 114005.)

Many climate change impacts are already felt at the current 1.2 °C (34.2 °F) level of warming. Under the 2015 Paris Agreement, nations collectively agreed to keep warming "well under 2 °C (35.6 °F)". However, with pledges made under the Agreement, global warming would still reach about 2.7 °C (36.9 °F) by the end of the century (United Nations Environment Programme 2021, p. 36). Limiting warming to 1.5 °C (34.7 °F) will require halving emissions by 2030 and achieving net-zero emissions by 2050 (Rogelj, J., Shindell, D., Jiang, K., Fifta, S., et al. (2018). "Chapter 2: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development". IPCC SR15 2018. pp. 93–174)

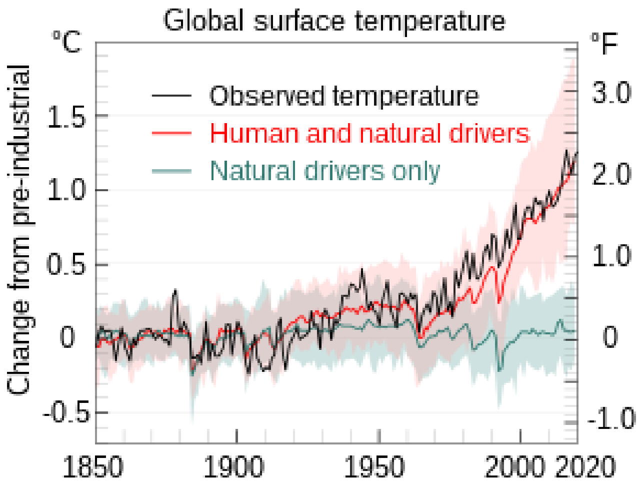


Figure 1. Change in average surface air temperature since the Industrial Revolution, plus drivers for that change. Human activity has caused increased temperatures, with natural forces adding some variability (Source: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., et al., 2021).

The cultivation of cotton, should start just before cotton appears or just immediately after cotton is up to a good stand. Cotton should be cultivated to a depth of 1 to 3 inches (2.54 to 7.62 cm) with one or two row cultivators with sweeps. Cultivation should be continued throughout the plant's normal growing season as often as is necessary to control weeds and grass. Cotton should be chopped when it is up to a stand and after the permanent leaves are present. Chopping should allow a spacing of 12 to 18 inches (30.48 to 45.72 cm) between hills with two to three stalks per hill. Hoeing may be necessary if grass and weeds cannot be controlled by cultivation (E.V Smith, Cotton Production Practices in the Limestone Valley Areas of Alabam, Circular No. 100, June 1951.).

Wheat is one of the very first plants that human domesticated and cultivated. According to archeobotanical finds, wheat cultivates is estimated between 10.000-15.000 B.C and supported the establishment of human communities and the raise of population. In Mediterranean and in Greece, wheat's cultivation begins at Neolithic Age around 7.000 B.C (Valamoti, S.-M. Kostakis, K. 2007 Transitions to agriculture in the Aegean: the archaeobotanical evidence. In: Colledge, S. and Conolly, J. (eds.) The Origins and Spread of Domestic Plants in Southwest Asia and Europe. Left Coast Press, Walnut Creek, pp. 75-92.).

In Greece, 1.5 million acres of soft wheat are cultivated every year with a production of 450 to 550 thousand tons. In the period 1961-1985 the cultivated area of soft wheat prevailed over that of hard, while from 1986 until today the opposite is observed due to the increased demand and higher prices of the product. The average acre yields, are ranged between 280-320 and 260-300 kgr/acre (573.2 – 661.3 lb/acre) for durum and common wheat respectively (Figure 2). The cultivation of wheat (soft and hard) in Greece interests more than 300,000 farms.igure 2. Production and yield quantities of wheat in Greece in the period 1961-2015 (Source: FAOSTAT).

## MATERIALS AND METHODS

In the context of this research, the data obtained from the Hellenic National Meteorological Service (HNMS) were fully utilized. In particular, the purpose and contribution of this research paper is to highlight the effects that climate change has brought to the crops of cotton and wheat since the year 2008, over a decade and a half (fifteen years), i.e. until the year 2022. In this way, we shall be able to understand how climate change affects cotton and wheat crops in depth.

The heat unit concept utilizes accumulated hours above a critical temperature rather than calendar days in describing growth and development. For cotton, the threshold temperature is 60°F (15.55 °C), therefore, the GDD are referred to as "DD60's". The basic formula for calculating heat units involves averaging the maximum and minimum temperatures for each day and subtracting the threshold temperature. Calculation of the accumulated heat units and knowledge of the heat unit requirement for any particular growth stage can be used to explain and predict the occurrence of events or duration of stages in crop development (Kerby, T.A., M. Keeley, and S. Johnson. 1987. Growth and development of Acala cotton. University of Caliofnia, Division of Agriculture and Natural Resources, Bulletin 1921) (Landivar, J. A. and J. H. Benedict. 1996. Monitoring System of the Management of Cotton Growth and Yield. Bull. B2. Texas A&M University Agricultural and Extension Center, Corpus Christi, Texas) (Oosterhuis, D.M. (1990) Growth and Development of the Cotton Plant. In: Miley, W.N. and Oosterhuis, D.M., Eds., Nitrogen Nutrition in Cotton: Practical Issues, Proceedings of Southern Branch Workshop of Practicing Agronomists, Publications of the American Society of Agronomy, Madison, 1-24)

As McMaster has cited, a common base temperature for wheat is 32 °F (0 °C) (McMaster, G.S., Smika, D.E., 1988. Estimation and evaluation of winter wheat phenology in the central Great Plains. Agric. Of. Meteorol. 43, 1-18). Although, other references, like Slafer's have a different $T_{base}$, in this thesis and paper that temperature has been selected (Slafer, G.A., Savin, R., 1991. Developmental base temperature in different phenological phases of wheat (Triticum aestivum). J. Exp. Bot. 42, 1077-1082) Generally, it takes about 100 GDD for each leaf on a cereal plant to grow out. It is being said that the phyllochron for wheat is 100 GDD. Thus, if it is known when the plant emerged, it is possible to calculate about how many leaves it should have on it, after a certain period of time if it is known what the temperature has been.

Greece is located 37° 58′ 0″ N, 23° 43′ 0″ E, Thessaly is located 39.6°N 22.2°E and Larissa, where the research was conducted is located 39°38.5′N 22°25′E.

In the region of Thessaly, Greece, HNMS has a total of 4 observation stations. More specifically, these stations are:

i) Agchialos, with a Longitude (Lon): 22.79, a Latitude (Lat): 39.22 and an Altitude (Alt): 19 m

ii) Kranea, with a Longitude (Lon): 20.747, a Latitude (Lat): 39.246 and an Altitude (Alt): None m

iii) Larissa, with a Longitude (Lon): 22.46, a Latitude (Lat): 39.65 and an Altitude (Alt): 74 m

iv) Sofades, with a Longitude (Lon): 22.09, a Latitude (Lat): 39.336 and an Altitude (Alt): None m

Of the aforementioned observation stations in Thessaly, the data that were used, were obtained by the station of Larissa.

In the region of Central Macedonia, Greece, which is located 40.7°N 23.0°E, HNMS has a total of 4 observation stations. More specifically, these stations are:

i) Edessa, with a Longitude (Lon): 22.05, a Latitude (Lat): 40.8 and an Altitude (Alt): 314 m

ii) Polykastro, with a Longitude (Lon): 23.567, a Latitude (Lat): 40.9 and an Altitude (Alt): None m

iii) Serres, with a Longitude (Lon): 23.53, a Latitude (Lat): 41.08 and an Altitude (Alt): 32 m

iv) Thessaloniki, with a Longitude (Lon): 22.97, a Latitude (Lat): 40.53 and an Altitude (Alt): 2 m

Of the aforementioned observation stations in Central Macedonia, the data that were used, were obtained by the stations of Serres and Thessaloniki.

## RESULTS AND DISCUSSION

Beginning with, the climate change has changed the climate in Greece, the precipitation rate has not been reduced. Although the changes in precipitation are not stable, due to specific factors, the increase of the temperature (United Nations Environment Programme 2021, p. 36.) tends to cause increase evapotranspiration which eventually leads to more precipitation.

According to World Data Info, between 1978 and 2023 the temperature in Greece has been increased by 1.6 °C (34.8 °F), which justifies the temperature raise in global level. By utilizing and comparing the data of the temperature of the year 1978 and the latest year of the database (2022), the average temperatures are 15,15 °C (59,27 °F) and 16,75 °C (62,15 °F) respectively. Also, by adding the mean temperature of each year (2008, 2009, …, 2022) of each area (Larissa, Serres and Macedonia) combined, we observe that indeed the temperature has risen.

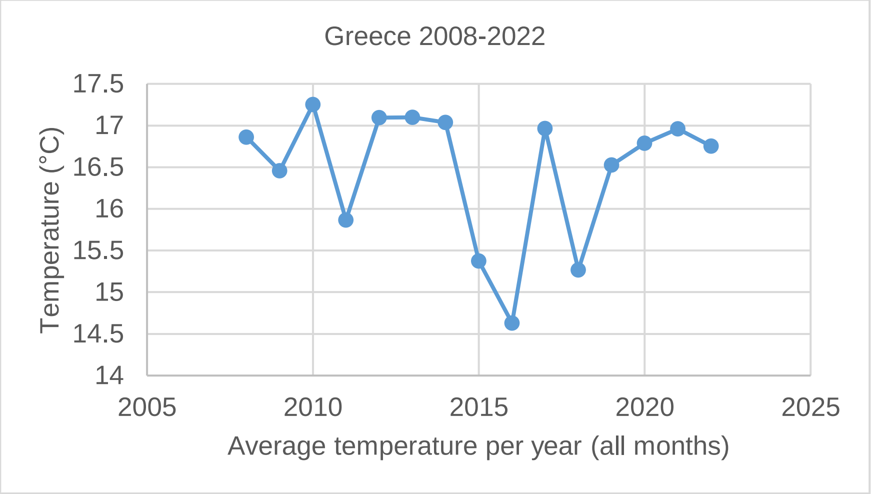


Figure 3. Diagram of the mean temperature of each year (1st of January – 31st of December) for the years 2008-2022 of the areas of Larissa, Serres and Macedonia combined.

Thereinafter, the factors affecting the plants' growth have changed, the GDDs depend upon the daily temperature. Since the temperature has been increased, the duration of each growing season is shorter, due to the fact that the desired temperature has been achieved earlier. By calculating the sum of the GDDs (both on °C and °F) and by taking the average temperature of each growing period (1st of May to 31st of October of cotton and 1st of November to 31st of June of wheat) of each year, from 2008 to 2022, the following conclusions have been reached:

i) GDDs (°C/°F) of cotton of Larissa: Tends to decrease

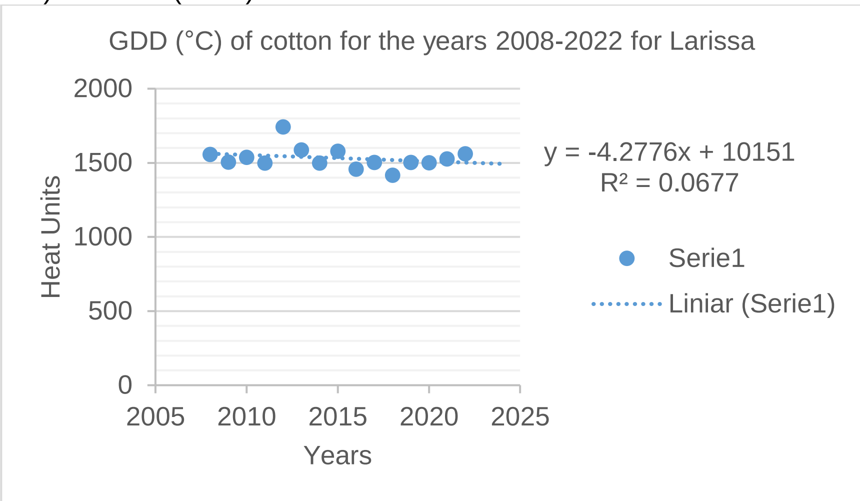


Figure 4. Linear prediction of the GDDs of cotton for Larissa for the years 2008-2022 and for the future.

ii) GDDs (°C/°F) of cotton of Serres: Tends to increase

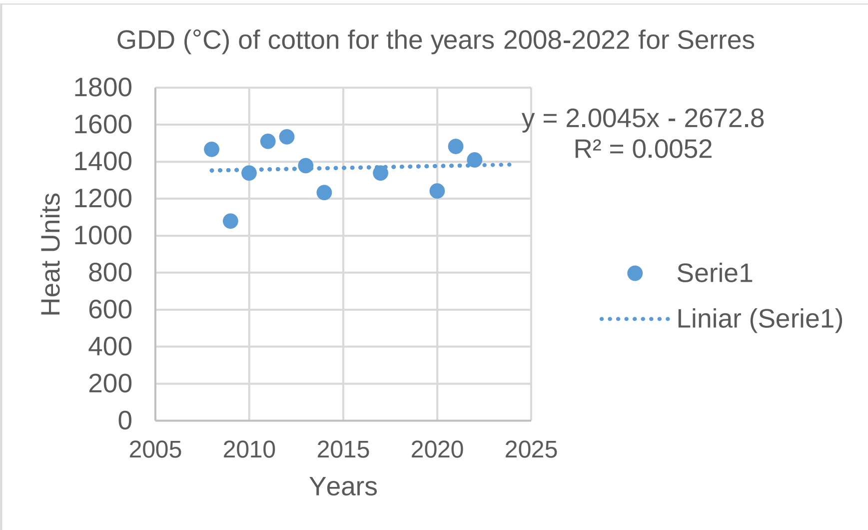


Figure 5. Linear prediction of the GDDs of cotton for Serres for the years 2008-2022 and for the future.

iii) GDDs (°C/°F) of cotton of Macedonia: Tends to increase

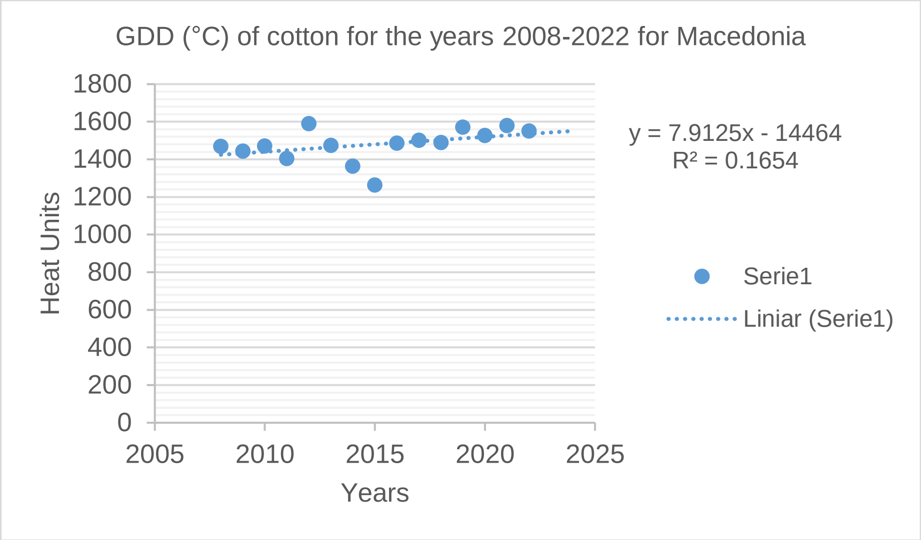


Figure 6. Linear prediction of the GDDs of cotton for Macedonia for the years 2008-2022 and for the future.

iv) GDDs (°C/°F) of wheat of Larissa: Tends to decrease

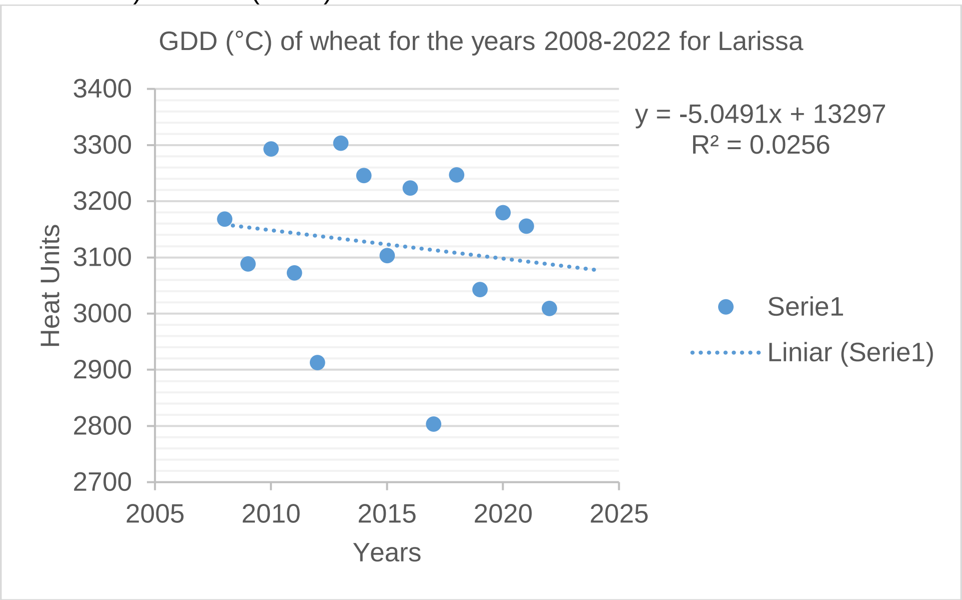


Figure 7. Linear prediction of the GDDs of wheat for Larissa for the years 2008-2022 and for the future.

v) GDDs (°C/°F) of wheat of Serres: Tends to increase

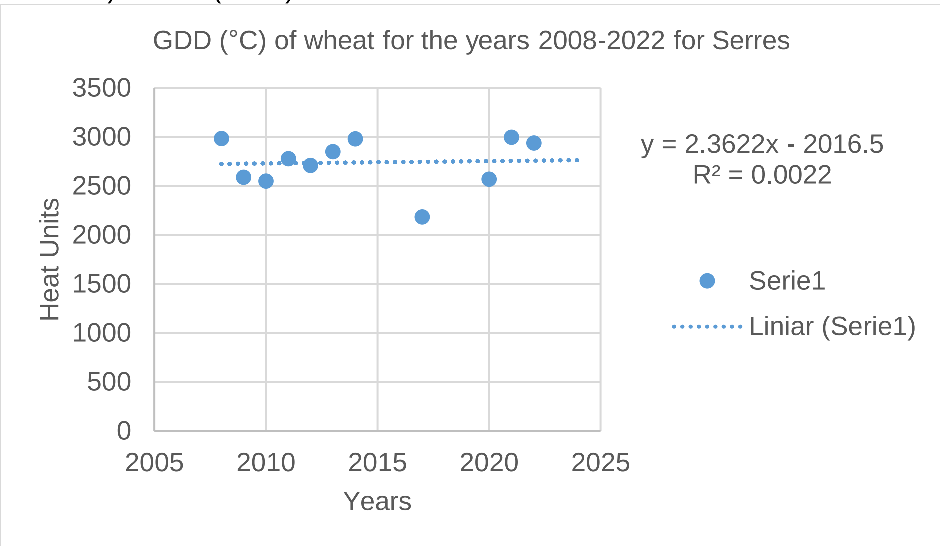


Figure 8. Linear prediction of the GDDs of wheat for Serres for the years 2008-2022 and for the future.

vi) GDDs (°C/°F) of wheat of Macedonia: Tends to increase

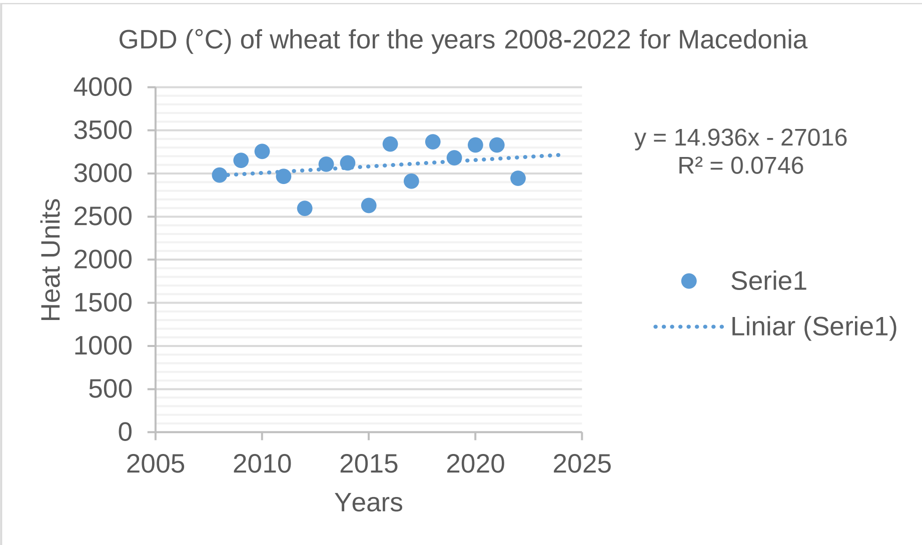


Figure 9. Linear prediction of the GDDs of wheat for Macedonia for the years 2008-2022 and for the future.

## CONCLUSIONS

The need of the creation of new hybrids and/or varieties that can last at higher temperature and maintain their GDDs as the original plants is quite necessary.

Increased temperature has an immediate effect on the increase of ETc and therefore at the crop coefficient factor, a fact that agrees to the aforementioned citations.

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