# Climate Change and Citriculture on Citrus

Subjects: Agricultural Engineering

Contributor: Júlia Boscariol Rasera, Roberto Fray da Silva, Francisco de Assis Alves Mourão Filho, Alexandre Cláudio Botazzo Delbem, Antonio Mauro Saraiva, Paulo Cesar Sentelhas, Patricia Angélica Alves Marques

A bibliometric analysis of climate change and citrus investigated this research domain's development and current trends. The period studied was from 1992 to 2022, resulting in 178 documents using the Scopus database. The most significant publishers' countries were also the largest citrus producers in the world, besides being G7 members. Three main research areas were identified: modeling, socio-political issues, and plant physiology. A tendency to change interest from modeling and risk analysis to physiology and stress studies was observed. Additionally, some of the most cited papers observed the positive impacts of climate change on certain citrus crops. Despite the multidisciplinary publications, two main gaps were identified: (i) the lack of investigations with combined stresses (abiotic and biotic) instead of isolated studies; and (ii) the lack of studies of predictive models for citrus production in different conditions and climate change scenarios. There was a tendency toward studying water use and irrigation alternatives due to water scarcity and management solutions to improve the production system's resilience, considering the potential impacts of climate change.

Keywords: global warming ; citrus ; agrometeorology

## 1. Introduction

The primary analysis of this work was a network map with keywords relations created using 73 words and 2471 links (Figure 1). The size of each point illustrates the frequency with which a keyword was used. The network map in Figure 1 presents the three clusters obtained. The clusters represent keywords that appear together in the papers on the final dataset. The names for each cluster were given according to an interpretation of the knowledge domains that contained most of its keywords.

The first cluster (in red) was named "Citrus physiology and potential impacts of climate change." It is composed of terms related to a plant's development and the stresses faced during its growth and production, such as "growth", "species", "citrus fruit", "rootstock", "stress", "salinity", "drought", "low temperature", "high temperature", "disease", and "pest".

Most papers in this cluster tended to evaluate or explore how climate change could affect abiotic and biotic stresses and their relations with citrus crops. The papers that studied abiotic stresses focused on three main variables: water (extreme rainfalls and deficit [1][2][3]), temperature (heat and cold[4][5]), and $CO_2$ concentration[6][7]. Except for one paper that simultaneously analyzed the combination of heat and drought[8], all the other articles studied the isolated abiotic stresses.

However, it is critical to consider that the current scenario in citrus farms combines all stresses simultaneously, demanding analyses considering their interrelations. For example, in a drought scenario, which leads to stomatal closure and gas diffusion reduction, the elevated $CO_2$ in the air may counterbalance this effect by increasing the photosynthesis substrate[1].

Nevertheless, water scarcity may intensify salinity, which can be highly damaging to the plant and the production, regardless of $CO_2$ air concentration[2]. In this example, the most accurate analysis would then consider the effects of all those aspects: climate, extreme weather events, water availability, and salinity. The papers that studied biotic stresses analyzed the effect of changing those three variables on pests[9][10][11] and pathogen[12] dynamics.

Much effort was put throughout the years into comprehending the relationship between climatic variables and pests/pathogens to predict crop yield. As HBL disease is one of the most critical issues in citrus production[13], some papers analyzed how climate change may influence the vector (psyllid—*Diaphorina citri*) behavior and cycle, analyzing its expansion in different areas[10][11].

Martini & Stelinski[11] verified that water deficit might reduce the psyllid population. The increase in temperature might have a similar impact due to its effect on flushing, which will start earlier and have a shorter duration[10]. Nevertheless, the authors also point out that increasing temperature might alter the suitability of some areas to the vector and the disease, leading to HBL challenges in currently non-infected areas.

The second cluster (in blue), named "Climate change modeling and scenario analysis", presents keywords connected to: (i) climatic risk analysis, such as "increase", "impact", "factor", "influence"; (ii) variables involved in climate change, such as "temperature" and "rainfall"; and (iii) considering different time windows, such as "period", "time" and "year". Most works in this cluster aimed to predict behaviors and evaluate scenarios to provide tools and insights for improving decision-making.

Most of the articles focused on water use because water availability is one of the biggest challenges related to climate change[14]. According to Martínez-Ferri et al.[15] and Aish et al.[16], in future scenarios (2050 and 2080), the evapotranspiration demand will increase for citrus plants. This will increase irrigation demand in different areas, requiring more precise use of this resource. The same scenario was observed by Pereira et al.[17], who also estimated water productivity in current and future scenarios, with and without irrigation.

This cluster also encompasses research on the different regions' suitability for citrus, considering several climate change scenarios and predictions[18]. In some cases, the authors observed an expansion of the suitable area for citrus production. However, more work is needed to understand better how citrus suitability for different regions may change over time.

The third and last cluster (in green), defined as "Socio-political impacts of climate change", consists of key terms related to sociological and political issues regarding climate change and citriculture, such as "strategy", "farmer", "challenge", "problem", "production", "environment", and "effect". The focus of this cluster is to shed light on another essential aspect of climate change and agriculture: the farmers' perceptions, demands, and needs.

## 2. Climate Change and Citriculture

Some papers studied the advantages and possibilities of using agroforestry systems with citrus and other crops as restoration tools with high carbon sequestration and conservation potential[19][20]. Tschora & Cherubini[19] also stated the relevance of an agroforestry system in food security since climate change can reduce food availability and access to the different agri-food chains.

A group of works analyzed how farmers evaluate and consider climate change effects on their production[21] and water use[22]. This is relevant since their decisions are directly connected to the production systems and the use and availability of natural resources.

According to the authors, besides noticing the adverse effects of climate change on production or the crops' cycles, public policies and transparency still need to be improved, especially in water supply management[23]. These results point out the importance of the socio-political aspect of climate change and the necessity of extension activities to bring science to the field and improve the resilience of production systems. Such activities may be based on risk analysis for each local and demographic situation, as Iglesias et al.[24] studied in Spain.

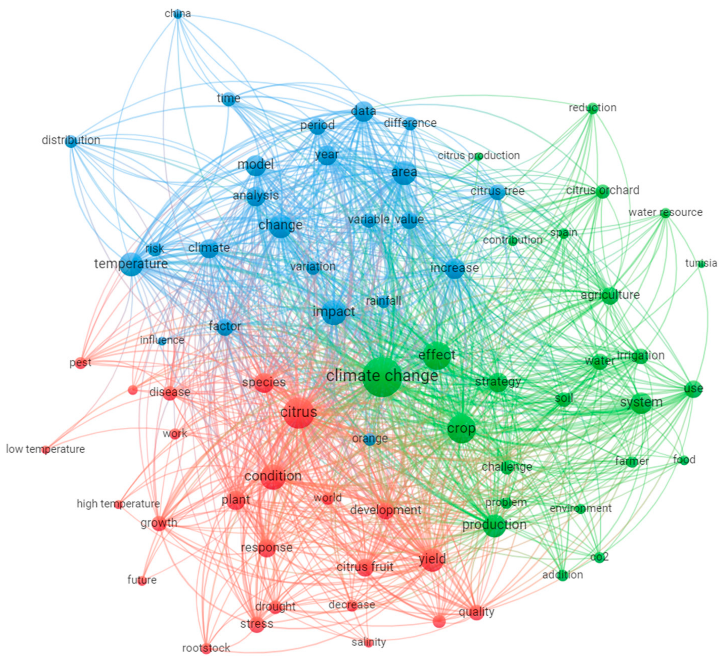


**Figure 1.** Network map based on co-occurrence of terms on titles and abstracts of the final dataset.

Overall, this bibliometric analysis observed two main gaps in the literature concerning citrus and climate change:

(1) The first gap was the combination of abiotic stresses caused by climate change's increasing impacts on extreme climate events. Most recent studies are related to stresses and their result in plant physiology and, consequently, their production. However, with few exceptions, most studies on abiotic stresses in citrus have focused on the individual effect of these factors, which prevents a prediction of what may occur in the field. Therefore, research that seeks to understand the nature of the various stress responses and create pathways for developing plants and processes that maintain high production levels even under stressful conditions becomes necessary;

(2) The second gap is related to predicting production in different climate change scenarios. Since studies encompassing various stress responses are rare, developing predictive models becomes difficult. The few studies with yield estimation models for citrus are limited to the present scenario or simulations that may not reflect important aspects of real-life scenarios. However, combining stress studies and modeling efforts would lead to better decision-making and management. This would result in more sustainable and profitable crop production.

The analysis observed that the recent relevance of physiology versus stress studies has increased, as understanding how citrus plants respond to stresses is critical in climate change scenarios. Based on the need to adapt to more frequent and impactful extreme weather conditions, the researchers expect an increase in the number of studies in the future related to the following three aspects: (i) rootstocks and their tolerance to environmental conditions; (ii) management practices such as different types of irrigation methods, use of reflective substances, and fertilizing; and (iii) more ecological and less impacting systems, such as agroforestry.

Finally, some of the main limitations that were observed in this study were: (i) the methodology used, which only considers a quantitative analysis of the selected documents; (ii) not considering languages other than English, as some documents may be developed by Governments and institutions in other languages; and (iii) the lack of research focusing specifically on better understanding the connection between citrus and climate change. However, the methodology adopted in the studies provided relevant results to understand better trends, themes, and the state of the art of research on climate change and citrus.

---

## References


1. Fares, A.; Bayabil, H.K.; Zekri, M.; Mattos, D., Jr.; Awal, R.; Potential climate change impacts on citrus water requirement across major producing areas in the world. *J. Water Clim. Chang.* **2017**, *8*, 576–592, .
2. Paranychianakis, N.V.; Chartzoulakis, K.S.; Irrigation of Mediterranean Crops with Saline Water: From Physiology to Management Practices.. *Agric. Ecosyst. Environ.* **2005**, *106*, 171-187, .
3. Bastida, F.; Torres, I.F.; Romero-Trigueros, C.; Baldrian, P.; Větrovský, T.; Bayona, J.M.; Alarcón, J.J.; Hernández, T.; García, C.; Nicolás, E.; et al. Combined Effects of Reduced Irrigation and Water Quality on the Soil Microbial Community of a Citrus Orchard under Semi-Arid Conditions.. *Soil Biol. Biochem.* **2017**, *104*, 226-237, .
4. Zabihi, H.; Vogeler, I.; Amin, Z.M.; Gourabi, B.R.; Mapping the Sensitivity of Citrus Crops to Freeze Stress Using a Geographical Information System in Ramsar, Iran.. *Weather. Clim. Extrem.* **2016**, *14*, 17-23, .
5. Primo-Capella, A.; Martínez-Cuenca, M.-R.; Forner-Giner, M.Á.; Gene Expression under Short-Term Low Temperatures: Preliminary Screening Method to Obtain Tolerant Citrus Rootstocks.. *Horticulturae* **2021**, *7*, 447, .
6. Vu, J.C.V.; Photosynthesis, Growth, and Yield of Citrus at Elevated Atmospheric CO2.. *J. Crop Improv.* **2005**, *13*, 361-376, .
7. Kimball, B.A.; Idso, S.B.; Johnson, S.; Rillig, M.C.; Seventeen Years of Carbon Dioxide Enrichment of Sour Orange Trees: Final Results. . *Glob. Chang. Biol.* **2007**, *13*, 2171-2183, .
8. Zandalinas, S.I.; Mittler, R.; Balfagón, D.; Arbona, V.; Gómez-Cadenas, A.; Plant Adaptations to the Combination of Drought and High Temperatures.. *Physiol. Plant.* **2018**, *162*, 2-12, .
9. Ryan, S.J.; Mapping Thermal Physiology of Vector-Borne Diseases in a Changing Climate: Shifts in Geographic and Demographic Risk of Suitability.. *Curr. Environ. Health Rpt.* **2020**, *7*, 415-423, .
10. Aurambout, J.P.; Finlay, K.J.; Luck, J.; Beattie, G.A.C.; A Concept Model to Estimate the Potential Distribution of the Asiatic Citrus Psyllid (Diaphorina Citri Kuwayama) in Australia under Climate Change—A Means for Assessing Biosecurity Risk.. *Ecol. Model.* **2009**, *220*, 2512–2524, .
11. Martini, X.; Stelinski, L.L.; Drought Stress Affects Response of Phytopathogen Vectors and Their Parasitoids to Infection- and Damage-Induced Plant Volatile Cues: Drought Stress Affects Citrus Signalling.. *Ecol. Entomol.* **2017**, *42*, 721-73

0, .

12. Ghini, R.; Bettiol, W.; Hamada, E.; Diseases in Tropical and Plantation Crops as Affected by Climate Changes: Current Knowledge and Perspectives: Climate Change and Diseases of Tropical and Plantation Crops.. *Plant Pathol.* **2011**, *60*, 122-132, .
13. Melgar, J.C.; Issues in Citrus Fruit Production.. *Stewart Postharvest Rev.* **2014**, *10*, 1-4, .
14. Intergovernmental Panel on Climate Change.; Summary for Policymakers. In Climate Change 2022: Impacts, Adaptation and Vulnerability. Con-Tribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; . *Cambridge University Press: Cambridge, UK; New York, NY, USA,* **2022**, , , .
15. Martínez-Ferri, E.; Muriel-Fernández, J.L.; Díaz, J.A.R.; Soil Water Balance Modelling Using SWAP: An Application for Irrigation Water Management and Climate Change Adaptation in Citrus. . *Outlook Agric.* **2013**, *42*, 93-102, .
16. Aish, A.; Ayesh, K.; Al-Najar, H.; Modelling of Long-Term Effects of Climate Change on Irrigation Water Requirement in the Gaza Strip, Palestine.. *Arab J. Geosci.* **2020**, *14*, 650, .
17. Pereira, F.F.S.; Sánchez-Román, R.M.; Orellana González, A.M.G.; Simulation Model of the Growth of Sweet Orange (Citrus Sinensis L. Osbeck) Cv. Natal in Response to Climate Change.. *Clim. Chang.* **2017**, *143*, 101-113, .
18. Sugiura, T.; Sakamoto, D.; Koshita, Y.; Sugiura, H.; Asakura, T.; Changes in Locations Suitable for Satsuma Mandarin and Tankan Cultivation Due to Global Warming in Japan.. *Acta Hortic.* **2016**, *1130*, 91-94, .
19. Tschora, H.; Cherubini, F.; Co-Benefits and Trade-Offs of Agroforestry for Climate Change Mitigation and Other Sustainability Goals in West Africa.. *Glob. Ecol. Conserv.* **2020**, *22*, e00919, .
20. Coelho, G.C.; Ecosystem Services in Brazilian's Southern Agroforestry Systems.. *Trop. Subtrop. Agroecosystems* **2017**, *20*, 475–492, .
21. Lahlali, R.; Jaouad, M.; Moinina, A.; Mokrini, F.; Belabess, Z.; Farmers' Knowledge, Perceptions, and Farm-Level Management Practices of Citrus Pests and Diseases in Morocco.. *J. Plant. Dis. Prot.* **2021**, *128*, 1213-1226, .
22. Lasram, A.; Dellagi, H.; Dessalegn, B.; Dhehibi, B.; Ben Mechlia, N.; Farmers' Willingness to Adapt to Climate Change for Sustainable Water Resources Management: A Case Study of Tunisia.. *J. Water Clim. Chang.* **2018**, *9*, 598-610, .
23. Lasram, A.; Dellagi, H.; Dessalegn, B.; Dhehibi, B.; Ben Mechlia, N.; Farmers' Willingness to Adapt to Climate Change for Sustainable Water Resources Management: A Case Study of Tunisia.. *J. Water Clim. Chang.* **2018**, *9*, 598-610, .
24. Iglesias, A.; Quiroga, S.; Schlickenrieder, J.; Climate Change and Agricultural Adaptation: Assessing Management Uncertainty for Four Crop Types in Spain.. *Clim. Res.* **2010**, *44*, 83-94, .