



**Global Warming for High School Students' Chemistry Learning based on Sustainable
Development: Qualitative Content Analysis**

Asep Supriatna and Bachrul Tias
aasupri@upi.edu

Universitas Pendidikan Indonesia

Abstract

Global warming is a phenomenon caused by greenhouse gases. Greenhouse gases are the gases that cause the greenhouse effect. Integrating climate education into classroom learning is one of the mitigations of global warming. This is in line with the Education for Sustainable Development (ESD) campaign. This study aims to create concept maps and teaching-learning sequences (TLS) from the conceptions of scientists in the context of global warming. The method used in this research is qualitative content analysis with four stages including material collection, descriptive analysis, category selection, and material evaluation. The results of this study are a Teaching-Learning Sequence (TLS) which is divided into nine sections including: (1) The impact of global warming, (2) Human and natural activities that affect global warming, (3) Examples of human and natural activities that affect global warming, (4) chemicals produced by human and natural activities, (5) Global Warming Potential, (6) greenhouse effect processes, (7) graphs of the distribution of global warming effects, (8) aspects affected by global warming, and (9) global warming solutions. Global warming can be a topic that integrates chemical concepts and ESD goals. The results of this study can be used as a basis for making a learning design or teaching materials.

Keyword: Teaching-Learning Sequences, Global Warming, Education for Sustainable Development, Qualitative Content Analysis.

Introduction

Global warming is a phenomenon that occurs as a result of human activities that have accumulated over decades. Global warming occurs when human activities increase the amount of greenhouse gases in the atmosphere. Greenhouse gases trap infrared radiation, preventing it from escaping from Earth (Zandalinas, 2021). We can analogy with greenhouse gases as a "blanket" that warms the earth. If the blanket is getting thicker then the earth will be warmer. (Girard, 2013).

In fact, human activities have thickened the blanket. So that the average temperature on earth rises by 0.15 to 0.20°C each year (Global Temperatures, 2023). Significant temperature increases can cause detrimental effects on the climate (Girard, 2013). The impacts of global warming, such as rising sea levels, extreme temperatures, and reduced productivity, are occurring worldwide, including in Indonesia (Sagala, et al., 2019). One of the impacts that we can observe in Indonesia is the rising water level in Jakarta. According to research from the Earth.org website, more than half of Jakarta is projected to sink by 2100 (Mulhern, 2020). In addition, Puncak Jaya's Eternal Ice on Mount Jaya Wijaya is melting which we can see with Google Earth (Rahman, 2022).

In an effort to prevent global warming, Indonesia has a strategy to prevent it from getting worse in the future. One of them is through education. The Ministry of Education and Culture creates a curriculum that integrates climate education into learning in schools. The topic of global warming is included in Learning Outcomes in the Independent Curriculum (Indonesia. Ministry of Education, Culture, Research and Technology, 2021). The learning objectives are for students to understand the concept and have a commitment to make real changes in dealing with climate change. (Ministry of Education and Culture Wants to Link Climate Crisis Material to Pancasila Attitudes, 2021). The purpose of this learning is in line

with the efforts of education for sustainable development (ESD). ESD expects students to have an understanding of the concept of climate change and build a sustainable attitude (Holfelder, 2019).

In order for the learning objectives to be achieved, we need to mapping the concepts to make it easier for students to understand the relationships between concepts, the relationship between a concept and the ones that are already known, and organize these concepts. This process can help students discover new concepts (Hsueh-Chih, et al., 2010). Concept maps are needed in order to stimulate students to think analytically (Barta, et al., 2021). An understanding of the concept of climate change, in this case global warming, is an important requirement in efforts to change an individual's attitude to support a sustainable program. Although, students who understand the concept will not necessarily have this attitude. (Eggert, et al., 2016).

This study uses a concept map as an initial description of the relationship between concepts which is then developed in a Teaching-Learning Sequence (TLS). Meuheut (2004) explains that TLS is both a product and a research. TLS is also effective in integrating research and teaching and learning activities in schools. (Guisasola, et al., 2017).

Previous research has shown that the use of concept maps can help students understand a concept but not develop the concept into a solution to climate change (Eggert, 2016). Concept maps have also been shown to be able to minimize misconceptions in learning about climate change, even concept maps can improve the quality of student graduates (Rabich & Gautier, 2005).

In ensuring sustainable development, knowledge about global warming needs to be understood by high school students. This research is a critical analysis of the content and context of global warming that needs to be taught in high school chemistry lessons. This

study aims to create concept maps and teaching-learning sequences (TLS) from the conceptions of scientists in the context of global warming that are education for sustainable development (ESD) oriented.

Research Method

Mayring in Forman and Damschroder (2015) explains that content analysis is a series of systematic techniques used to analyze content that has informational value in a text. In this study, the method used is Qualitative Content Analysis based on Mayring (2000). In this method, the analysis is divided into several stages which will be explained in Figure 1.

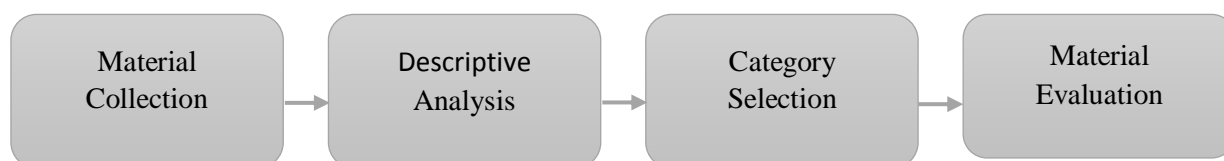


Figure 1. Qualitative Analysis Content Stages

The first stage of this research is the collection of materials. Materials for analysis were collected from various literatures such as books, and review articles. The table 1 used as an instrument that has a title, year, author, and code. Furthermore, the second stage is the descriptive analysis stage. At this stage the materials that have been collected are analyzed. The instrument used is the material collection instrument format in Table 2 consists of content and analysis results. The result of this analysis will be texts that have been reduced to get the basic text that describes a problem. The third stage is the categorization stage. At this

stage, the content that has been analyzed is categorized by involving pedagogical and didactical aspects. The fourth stage is the evaluation stage. In this final stage, a review of research activities is carried out from start to finish so that it can be used as a concept map and a systematic TLS. An overview of all stages can be seen in Figure 2.

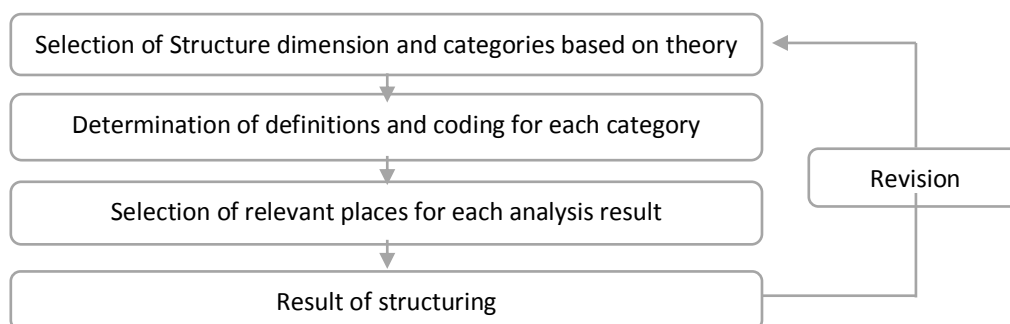


Figure 2. Structuring Process of Qualitative Content Analysis

The instruments in the material collection stage can be seen in Table 1. This table displays the titles of the literature that have been collected along with the year of publication, the author, and the code used for analysis.

Table 1. Material Collection Instrument Format

Title	Year	Author	Code
...
...

Table 2. is the instrument used in the descriptive analysis stage. In this table we can see a summary of the results of the analysis.

Table 2. Descriptive Analysis Instrument Format

Content	Analysis Result
...	...
...	...

Results and Discussion

1. Material Collection

At this stage, materials from various literary sources are collected using search engines such as Google Scholar, Springer, and Elsevier. Ten literature sources were used for further analysis. These sources are categorized by type: (1) codes B1 and B2 are used to indicate book literature, and (2) codes RV1-RV7 are used to indicate journal article literature. For more details can be seen in Table 3.

Table 3. The Sources of Analyzed Material

Title	Year	Author	Code
<i>Environmental Chemistry 9th</i>	2010	Stanley E. Manahan	B1

<i>Edition</i>			
<i>Principles of Environmental Chemistry 3rd Edition</i>	2013	James E. Girard	B2
<i>Greenhouse Gases, Radiative Forcing, Global Warming Potential and Waste Management – an Introduction</i>	2009	Charlotte Scheutz, <i>et al.</i>	RV1
<i>World Greenhouse Gas Emissions in 2005</i>	2009	Tim Herzog	RV2
<i>Greenhouse Effect: Greenhouse Gases and Their Impact on Global Warming</i>	2017	Darkwah Williams Kweku, <i>et al.</i>	RV3
<i>Sea-level rise caused by climate change and its implications for society</i>	2013	Nobuo MIMURA	RV4
<i>Implications of Climate Change for Economic Development in Northern Canada: Energy, Resource, and Transportation Sectors</i>	2009	Terry D. Prowse, <i>et al.</i>	RV5
<i>Social and economic impacts of climate change on the urban environment</i>	2011	Rebecca Gasper, <i>et al.</i>	RV6

<i>Reduction of CO₂ to Chemicals and Fuels: A Solution to Global Warming and Energy Crisis</i>	2018	Sebastian C. Peter	RV7
<i>Global warming threatens human thermoregulation and survival</i>	2020	Rexford S. Ahima	RV8

2. Descriptive Analysis

The next step is to carry out a descriptive analysis of the literature sources obtained, as shown in Table 3. The results of the analysis of the ten literature sources described in Table 3 are further elaborated in Table 4.

Table 4. The Results of The Analysis of Global Warming Content from Various Literature

Content	Analysis Results
Natural Occurrence of Greenhouse Gasses in The Atmosphere	Oxide gases, such as sulfur oxides, nitrogen oxides and carbon dioxide, are important components of the atmosphere. Among these gases, carbon dioxide (CO ₂) is the most abundant. CO ₂ plays an important role in plant photosynthesis and respiration of organisms [B1]. Without it, the plants would not be able to survive.

	<p>In addition, CO₂ plays an important role in regulating the temperature of the earth's surface by trapping heat.</p> <p>However, if the concentration of this gas continues to increase, at the current rate of 2 ppm per year, it will contribute to rapid global warming, which has a devastating effect on the climate [B2]. The gases that play the same role are called greenhouse gases [B1].</p>
Human Activities That Produce Greenhouse Gases	<p>Greenhouse gases are gases that contribute to the greenhouse effect in the atmosphere. In addition to naturally occurring gases, such as CO₂, CH₄, N₂O, and halocarbons, these gases can also be formed due to human activities.</p> <p>Greenhouse gases produced by human activities are known as anthropogenic greenhouse gases. Human activities that produce greenhouse gases are in the fields of transportation, energy, agriculture, and industry. [B2]]</p>
Electromagnetic Radiation and Its Absorption by Greenhouse Gases	<p>Less than 1% of solar energy spread towards the Earth through convection and conduction, while the remaining 99% is received through radiation. This solar radiation takes the form of electromagnetic radiation, which can encapsulate various types such as visible light, infrared, UV light, radio waves, and more, depending on its wavelength.</p> <p>[B1][B2]</p>

	<p>However, roughly half of all the remaining solar radiation can reach the Earth, with some directly reaching the Earth's surface, while the rest is either scattered or reflected [RV1] due to clouds, gases, or particulates present in the atmosphere. This radiation can be immediately reflected or absorbed by the atmosphere and later re-radiated as infrared after a certain period of time. [B1][B2]</p> <p>Infrared radiation does not directly escape the atmosphere. It is reabsorbed by greenhouse gases [RV1]. When radiation is absorbed by a molecule, instead of breaking a covalent bond, it changes the rotational or vibrational motion of the gas. Monoatomic molecules cannot absorb infrared radiation because they cannot undergo the necessary dipole moment changes caused by vibrational or rotational motion. [RV1] In contrast, diatomic molecules like CO, or polyatomic molecules like CO₂ and the rest of greenhouse gases possess dipole moments and undergo vibrations or rotations when they absorb infrared radiation. [B2]</p>
The Greenhouse Effect	Greenhouse gases absorb infrared radiation in the stratosphere. After the absorption, infrared radiation is further re-radiated and reabsorbed by greenhouse gases in a

	<p>continuous cycle. This process contributes to the stratosphere maintaining an average temperature of 18°Celsius. Without this phenomenon, the Earth's average temperature would likely drop to -15 degrees Celsius. [B1] [B2] [RV2]</p> <p>We can call the atmosphere a blanket that warms the Earth and also protects the Earth from external threats, such as UV radiation [B2]. Gases like CO₂ and water vapor contribute to the warming of the troposphere because they can absorb and re-emit infrared radiation, resulting the greenhouse effect [B1].</p> <p>However, if greenhouse gases, especially CO₂, continue to increase, global warming will persist, as it has already started to occur [B1].</p>
Global Warming Potential	<p>Radiative Forcing (RF) is a commonly used term to describe the magnitude of changes that affect the average radiation measured at the tropopause, which is the outermost layer of the troposphere. [RV1]</p> <p>GWP, which stands for Global Warming Potential, is a measure used to assess the contribution of each greenhouse</p>

	<p>gas to global warming. It represents the value of Radiative Forcing (RF) over a specific period (e.g., 100 years) in units of mass (1 kg) relative to CO₂. [RV1].</p>
Global Warming Impacts	<p>Environment</p> <p>Rising sea levels are one of the most significant impacts of climate change. It is a global concern, particularly for low-lying areas and small islands, as they are at risk of shrinking due to erosion. These factors can force populations to migrate to other regions or countries. [RV4]</p> <p>Economy</p> <p>Countries like Canada, particularly in the northern regions, have specific infrastructure and transportation systems to cope with snow and ice climates. If climate change occurs, it will be an economic challenge for these areas. [RV5]</p> <p>Sociocultural</p> <p>Our body temperature is influenced by the environment and adjusts accordingly. The rise in global temperatures due to global warming poses a significant threat to human populations. In fact, in America, more deaths are attributed to extreme heat compared to any other weather-related disaster. [RV8]</p>
Solution	<p>The primary cause of global warming is the increase in greenhouse gases, which change the radiative forcing value</p>

	<p>and leads to excessive heating of the Earth.[RV1] Among these gases, CO₂ is considered to be the most influential to global warming. [B1] [B2] [RV1]</p> <p>Therefore, the most suitable solution to address global warming is to achieve net zero anthropogenic CO₂ emissions. [RV7]</p>
--	--

3. Category Selection

At this stage, the arrangement is carried out based on the results of the previous stage. Arrangement aims to determine the pattern of relationships and interactions of each component involved. From the results of the analysis of the previous stage, it is categorized into six categories consisting of: (1) The Natural Occurrence of Greenhouse Gases in the Atmosphere, this section explains the presence of greenhouse gases in the atmosphere which are formed naturally and are even very necessary; (2) Human Activities that Produce Greenhouse Gases, this section describes human activities that produce greenhouse gases (anthropogenic); (3) Electromagnetic Radiation and Absorption by Greenhouse Gases, this section explains the absorption of solar electromagnetic radiation by greenhouse gases so that it can warm the earth's surface; (4) Greenhouse Effect, this section explains the greenhouse effect by linking the process of absorption of solar electromagnetic radiation; (5) Global Warming Potential, this section explains the meaning of Global Warming Potential (GWP); (6) The Impact of Global Warming, this section explains the impacts caused by global

warming based on the three pillars of ESD namely environment, economy and socio-culture; and Solutions, this section describes solutions to overcome global warming.

4. Material Evaluation

We describe the concepts that have been obtained from the previous stages into a concept map and teaching learning sequences (TLS). The results of the concept map and TLS can be seen in Figure 1. Each section is connected with questions between each category. In the first question to connect parts 1 and 2, starting with the question "Is there a relationship between human activity or natural activity with global warming?" This question is answered in that section that global warming occurs as a result of both natural and human activities. Next, in the second question to connect sections 2 and 3 with the question "What human activities and natural activities can cause global warming?" This question is answered with an example of each activity. The third question connects sections 3 and 4, namely "What chemical products result from these activities?" Answered by mentioning the gases belonging to the greenhouse gases. The fourth question is to link sections 4 and 5, the question "How much influence does each of these chemicals have on global warming?" answered with an explanation of GWP as a measure of the effect of greenhouse gases on global warming. Furthermore, the fifth question to connect sections 5 and 6 is "How is the process of chemicals resulting from human activities and natural activities that cause global warming?" This question is answered with an explanation of the process of the greenhouse effect. Instead, to link sections (1) 6 and 5, (2) 5 and 7, the questions are "(1) Based on these chemical processes, (2) which chemical has the most effect on global warming? Where do these chemicals come from? This question is answered with an explanation of the greenhouse

gases that have the most effect on global warming and the chemicals from which activities have the most effect. The question "What aspects are affected by global warming?" to connect sections 6 and 8. Answered with the three affected aspects which are included in the three ESD pillars, namely environmental, economic, and socio-cultural aspects. "What is the solution to global warming?" this question is used to link sections 8 and 9. The answer is that human activities are causing global warming, so we should limit activities that can produce greenhouse gases.

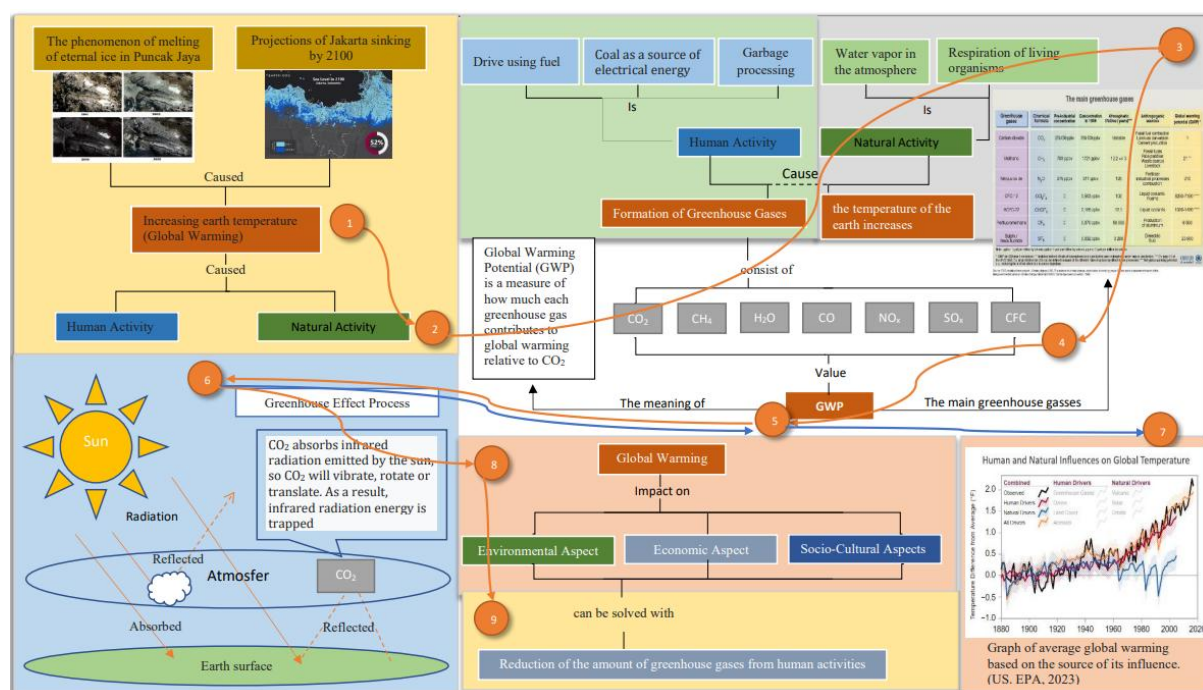


Figure 3: Concept Map and Teaching Learning Sequences (TLS) of Global Warming

Conclusion and Implication

This research uses qualitative content analysis as a research method which has four stages, namely: material collection, descriptive analysis, category selection, and material evaluation. The results of this study are a Teaching-Learning Sequence (TLS) which is

divided into nine sections including: (1) The impact of global warming, (2) natural activities and human activities that affect global warming, (3) examples of natural activities and human activities factors that affect global warming, (4) chemicals produced by natural and human activities, (5) Global Warming Potential, (6) greenhouse effect processes, (7) graphs of the distribution of global warming effects, (8) aspects affected global warming, and (9) global warming solutions. The results of this study can be used as a basis for making a learning design or teaching materials.

References

- Barta, A., Fodor, L., A., Tamas, B., & Szamoskozi, I. (2022). The development of students critical thinking abilities and dispositions through the concept mapping learning method – A meta-analysis. *Educational Research Review*. 37, 100481.
- Eggert, S., Nitsch, A., Boone, W. J., Nückles, M., & Bögeholz, S. (2017). Supporting Students' Learning and Socioscientific Reasoning About Climate Change—the Effect of Computer-Based Concept Mapping Scaffolds. *Research in Science Education*, 47(1). <https://doi.org/10.1007/s11165-015-9493-7>
- Forman, J., & Damschroder, L. (2015). Qualitative Content Analysis. *Empirical Methods for Bioethics: A Primer*. 11, 39-62. [http://dx.doi.org/10.1016/S1479-3709\(07\)11003-7](http://dx.doi.org/10.1016/S1479-3709(07)11003-7)
- Girard, J., E. (2013). *Principles of Environmental Chemistry*. Jones & Bartlett Publishers
- Global Temperatures. (2023). *Nasa: Earth Observatory*. <https://earthobservatory.nasa.gov/world-of-change/global-temperatures>

- Guisasola, J., Zuza, K., Ametller, J., & Gutierrez-Berraondo, J. (2017). Evaluating and redesigning teaching learning sequences at the introductory physics level. *Phys. Rev. Phys. Educ. Res.*, 13(2), 020139.
<https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.13.020139>
- Holfelder, A. (2019). Towards a sustainable future with education? *Sustainability Science*. 14, 943–952. <https://doi.org/10.1007/s11625-019-00682-z>
- Hsueh-Chih, H. , Chen, C. , Yau-Ting, Y. , Sung, S. , Tsai-Wen, T. , Lin, L. , Hung-Teng, H. , & Chou, C. (2010). Climate Change and Environmental Education: The Application of Concept Map for Representing the Knowledge Complexity of Climate Change. *World Academy of Science, Engineering and Technology, Open Science Index 44, International Journal of Geological and Environmental Engineering*. 4(8), 387 - 389.
<https://doi.org/10.5281/zenodo.1073559>
- Indonesia. Badan Standar dan Asesmen Pendidikan Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2021). *Capaian Pembelajaran Kimia Fase E – Fase F: Untuk SMA/MA/Program Paket C*. <https://kurikulum.kemdikbud.go.id/kurikulum-merdeka/capaian-pembelajaran#mp-preview-t>
- Kemendikbud Ingin Kaitkan Materi Krisis Iklim ke Sikap Pancasila. (2021). *CNN Indonesia*.
<https://www.cnnindonesia.com/nasional/20211117170848-20-722549/kemendikbud-ingin-kaitkan-materi-krisis-iklim-ke-sikap-pancasila>
- Manahan, S., E. (2009). *Environmental Chemistry Ninth Edition*. CRC Press.
- Mayring, P. (2000) Qualitative Content Analysis. *Forum: Qualitative Social Research Sozialforschung*. 1(2).

- Méheut, M., & Psillos, D. (2004). Teaching–learning sequences: aims and tools for science education research. *International Journal of Science Education*, 26(5), 515-535. <http://dx.doi.org/10.1080/09500690310001614762>
- Mulhern, O. (2020). Sea Level Rise Projection Map – Jakarta. *EARTH.ORG*. https://earth.org/data_visualization/sea-level-rise-by-the-end-of-the-century-alexandria-2/
- Rahman, F. (2022). Saksikanlah: Hilangnya Salju Abadi Indonesia di Tahun 2025, *Pusat Studi Lingkungan Hidup Universitas Gadjah Mada*. <https://pslh.ugm.ac.id/saksikanlah-hilangnya-salju-abadi-indonesia-di-tahun-2025/>
- Rebich, S., & Gautier, C. (2005). Concept Mapping to Reveal Prior Knowledge and Conceptual Change in a Mock Summit Course on Global Climate Change. *Journal of Geoscience Education*. 53(4), 355-365. <https://doi.org/10.5408/1089-9995-53.4.355>
- Sagala, R., Nuangchalerm, P., Saregar, A., & El Islami, R. A. Z. (2019). Environment-Friendly Education as A Solution to Against Global Warming: A Case Study at Sekolah Alam Lampung, Indonesia. *Journal for the Education of Gifted Young Scientists*. 7(2), 85-97. <http://dx.doi.org/10.17478/jegys.565454>
- United States. Environmental Protection Agency. (2023). *Causes of Climate Change*. <https://www.epa.gov/climatechange-science/causes-climate-change>
- Zandalinas, S. I., Fritschi, F. B., & Mittler, R. (2021). Global Warming, Climate Change, and Environmental Pollution: Recipe for a Multifactorial Stress Combination Disaster. *Trends in Plant Science*, 26(2), 588. <https://doi.org/10.1016/j.tplants.2021.02.011>