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Research Article

Climate Change, CO_2-Concentration, and the Impact on Long-Term Pollen Observation with Implications for Human Health

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Abstract

Climate change has a major impact on nature and influences ecological systems. The increase in the CO_2-concentration in the atmosphere is a major driver of global warming. This study showed that global warming has a major impact on the release of pollen, and hence, on the people suffering from allergies in Switzerland. Basel is a station where long-term pollen observation is conducted, and the data was used to investigate the change during the last 52 years. There are stations throughout the world to measure the atmospheric CO_2 concentration. Data from these stations showed an increase in temperature, which influences the biosphere. We found that the flowering time of Hazel, Birch, and Grass pollen has shifted forward in the corresponding season, inducing hay fever early in spring. Earlier pollen release is strongly correlated with and caused by an increase in temperature. This study showed the relationship between increasing CO_2-concentration in the atmosphere, the increasing air temperature followed by increasing and earlier pollen counts, and finally, increasing prevalence of pollinosis over half a century.

Keywords

Climate change; global warming; CO_2-concentration; epidemiology; pollen release; human health; allergy; pollinosis; prevalence

1. Introduction

Climate change is a major threat to humans. The increase in atmospheric CO_2 concentration is the primary cause of climate change, as mentioned by Arrhenius [1]. However, the first political action against climate change was considerably delayed and was initiated with the establishment of the Intergovernmental Panel on Climate Change in 1988 [2].

Climate change severely affects very different social areas like agriculture, tourism, energy, and health [3]. A major problem regarding mitigation of climate change is the long-term effect that prevents major actions. This was realized during the corona pandemic when the threat of climate change was mostly neglected.

The consequences of increasing CO_2-concentration in the atmosphere by traffic or heating are a large threat.

Health is one of the most important aspects to be strongly influenced by an increase in air temperature. The impacts of climate change on human health include heat-related mortality [4], the appearance of vector-borne (mosquito, sandfly, and tick) and rodent-borne infections in the higher latitudes and altitudes [5], and increasing cases of inflammatory bowel disease and infectious gastroenteritis in hospitals during heatwaves [6]. Finally, the rising air temperatures and carbon dioxide concentrations result in increased pollen production, allergenicity, and the advancement and lengthening of the pollen season in some plant species [7, 8].

Several studies across Europe showed a positive or negative influence of meteorological variables on pollen count and pollen season [9–11].

Advancing and lengthening of the pollen season can only be seriously demonstrated by long-term pollen measurements. The pollen trap of Basel was the first one in Switzerland, and the technology has been unchanged for 52 years [12–14].

The objective of this study was to show the association between the increasing CO_2-concentration in the atmosphere, the increasing air temperatures followed by increasing and earlier pollen counts, and the increasing prevalence of pollinosis in Switzerland.

2. Materials and Methods

2.1 CO_2 Data

The Schauinsland is a mountain in the Black Forest, 1,284 m above sea level. The measurement of CO_2 is operational since 1972 and operated by the German weather service, which is a part of the global atmosphere watch (GAW) of the World Meteorological Organization (WMO).

The Zugspitze at 2,962 m above sea level is the highest peak of the Wetterstein Mountains, as well as the highest mountain in Germany. There, the measurement of CO_2 is operational since 1995.

The Mauna Loa Observatory (MLO) is located on the north flank of Mauna Loa Volcano, on the big island of Hawaii, 3,397 m above sea level and operated by the National Oceanic and Atmospheric Administration (NOAA) since 1952.

The Jungfraujoch research station is situated 3,450 m above sea level, between the peaks of the Jungfrau (4,158 m a.s.l.) and the Mönch (4,099 m a.s.l.) and operated by the University of Bern.

2.2 Meteorological Data

Meteorological data were collected at the meteorological station of Basel-Binningen, 316 m above sea level. The air temperature was measured 2 m above the ground according to the recommendations of the World Meteorological Organization. The temperature at the climatological station in Basel was measured by the automatic monitoring network of the Federal Office of Meteorology and Climatology. The stations deliver a multitude of data on the weather and climate in Switzerland every ten minutes. The data is automatically transmitted to the central database, where various quality assurance checks are performed.

2.3 Pollen Data

Pollen data from Burkard Seven Day Recording Volumetric Pollen and Spore Trap Hirst [15], with a sucking rate of 10 l $minute^{-1}$, were available for 52 years for Basel (1969–2020). The pollen trap in Basel was located at the Kantonsspital building, 260 m above sea level. The distance between the pollen trap and the meteorological station was about 3 km.

The pollen amounts and the release of *Corylus*, *Betula*, and Poaceae were analyzed for 52 years (1969 to 2020). This was one of the longest time series in Europe [16].

The start of the pollen season was defined as the day when the sum of the daily counts reached 2.5% of the annual pollen count, and the end of the pollen season was the day when the sum of daily counts reached 97.5% of the annual pollen count, whereby, the pollen season encompassed 95% of the annual pollen recorded. Different durations have been used to define the start and length of the pollen season [17].

The data for *Corylus* between 1975 and 2019 were not available due to technical problems of the pollen trap in the corresponding years.

2.4 Epidemiological Data

The epidemiological data on the prevalence of pollinosis in Switzerland were used from previous studies [18, 19]. Spring pollinosis is mainly induced by hazel and birch pollen in January/February for Hazel and in March for Birch. Summer pollinosis is mainly induced by grass pollen from May to July. Therefore, this study was focused on these three pollen taxa.

2.5 Statistical and Graphical Analyses

Statistical analysis (t-test, Pearson's correlation) and graphical representations were made in Microsoft Excel.

3. Results

An overview of the increase in atmospheric CO_2-concentration is provided in (Figure 1). Data for Jungfraujoch was only available since 2010; therefore, the other three stations (Mauna Loa, Schauinsland, and Zugspitze) were included to incorporate the data since 1969 for the content of pollen and the incidence of pollinosis. Generally, all four stations showed a similar increase in CO_2-concentration and explained the observed increase in temperature (Figure 2).

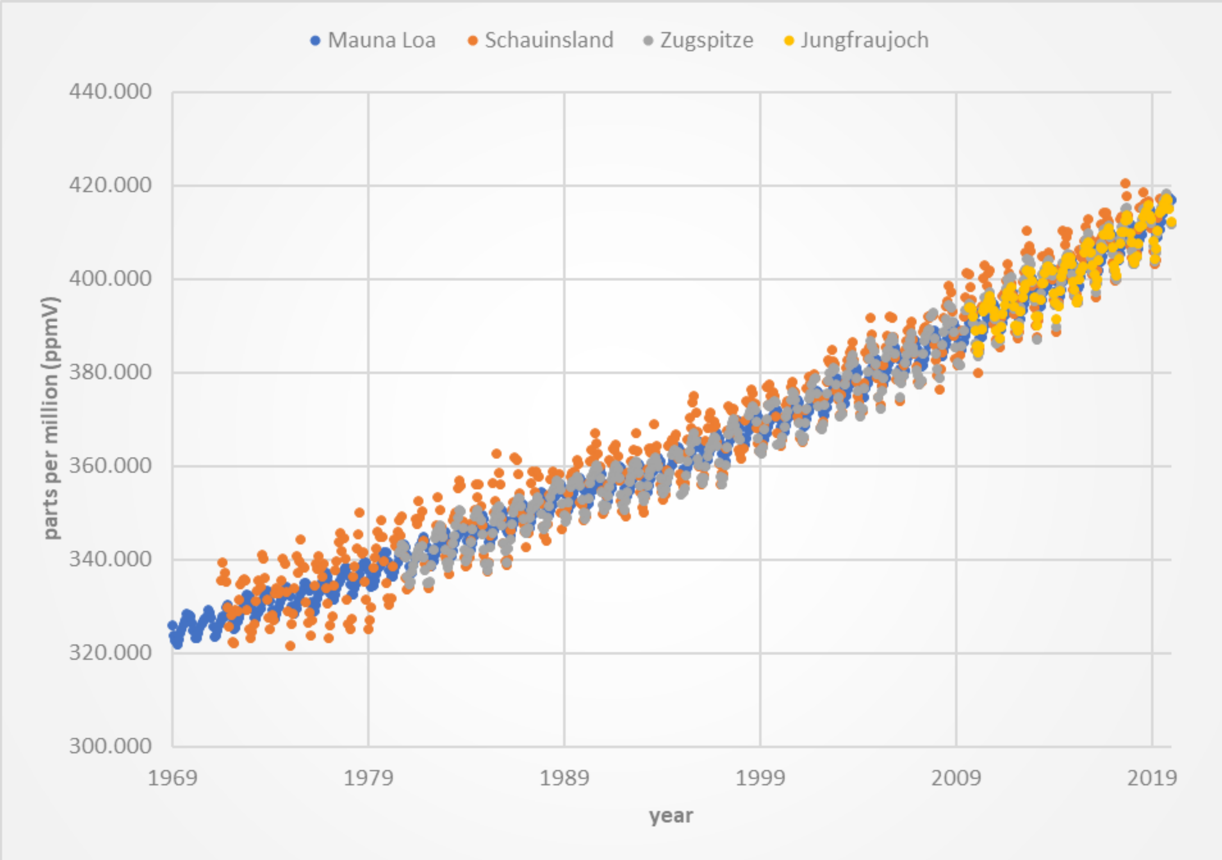

Figure 1 CO_2 concentration at four different sites in the USA (Mauna Loa), Germany (Schauinsland and Zugspitze), and Switzerland (Jungfraujoch).

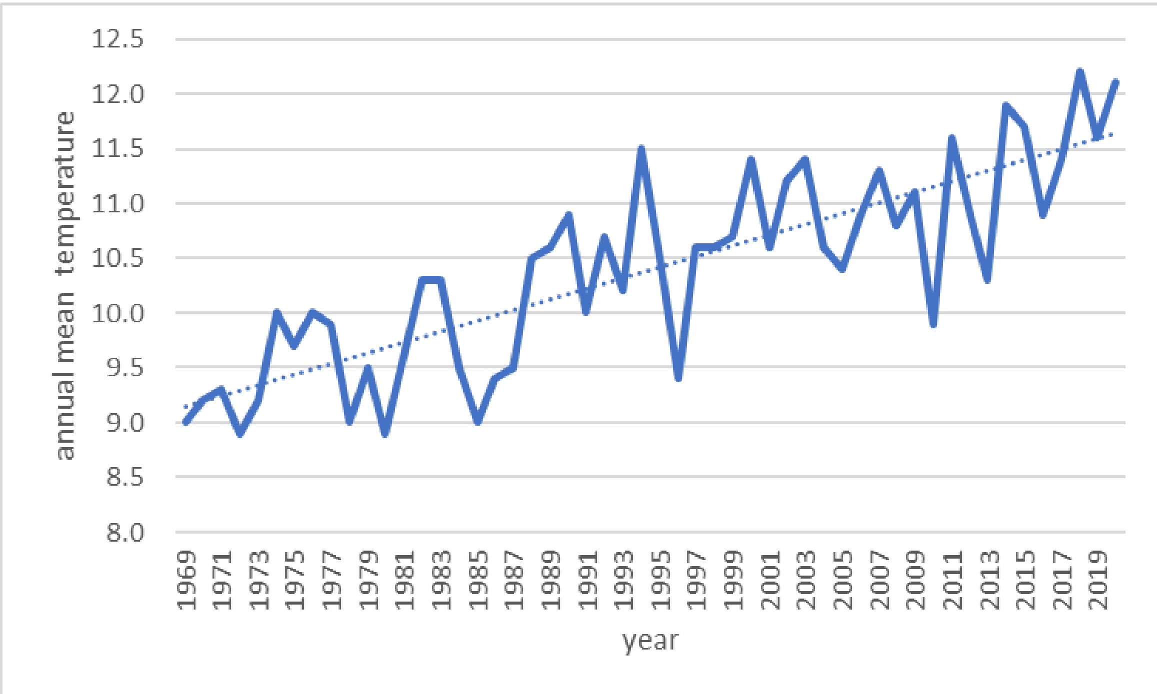

Figure 2 The mean annual temperature in Basel-Binningen from 1969 to 2020.

The increase in the annual mean temperature in Basel-Binningen from 1969 to 2020 is shown in Figure 2. The increase in temperature might partly be due to the urban heat island effect [20].

An overview of the increase in *Corylus* pollen from 1969 to 2020 is shown in Figure 3. The linear trend indicated an increase from approximately 750 annual pollen counts to approximately 2,000 annual pollen counts.

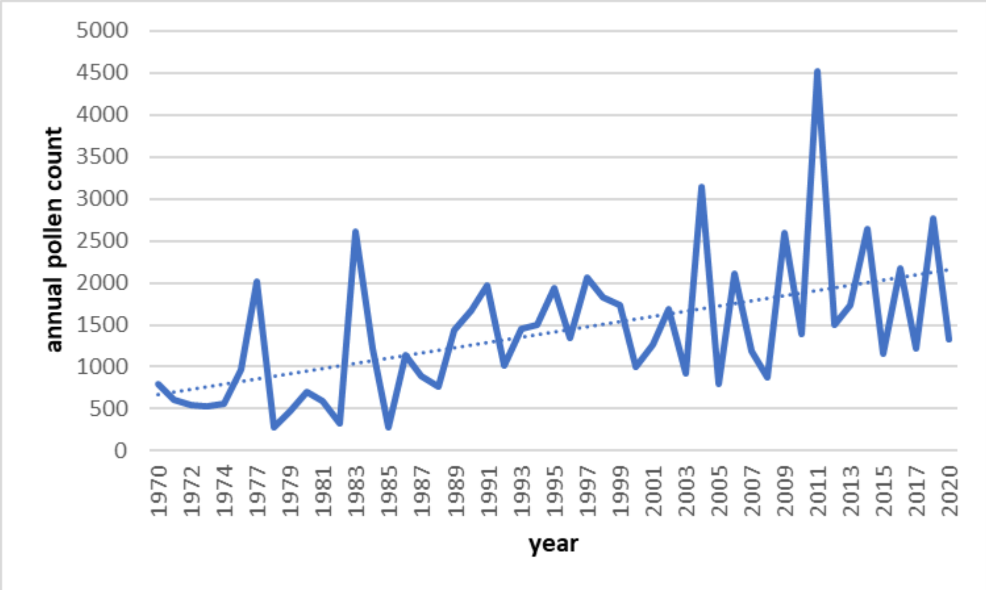

Figure 3 Pollen counts for *Corylus* from 1969 to 2020 in Basel.

The correlation between air temperature and the annual pollen count of *Corylus* in Basel is shown in Figure 4.

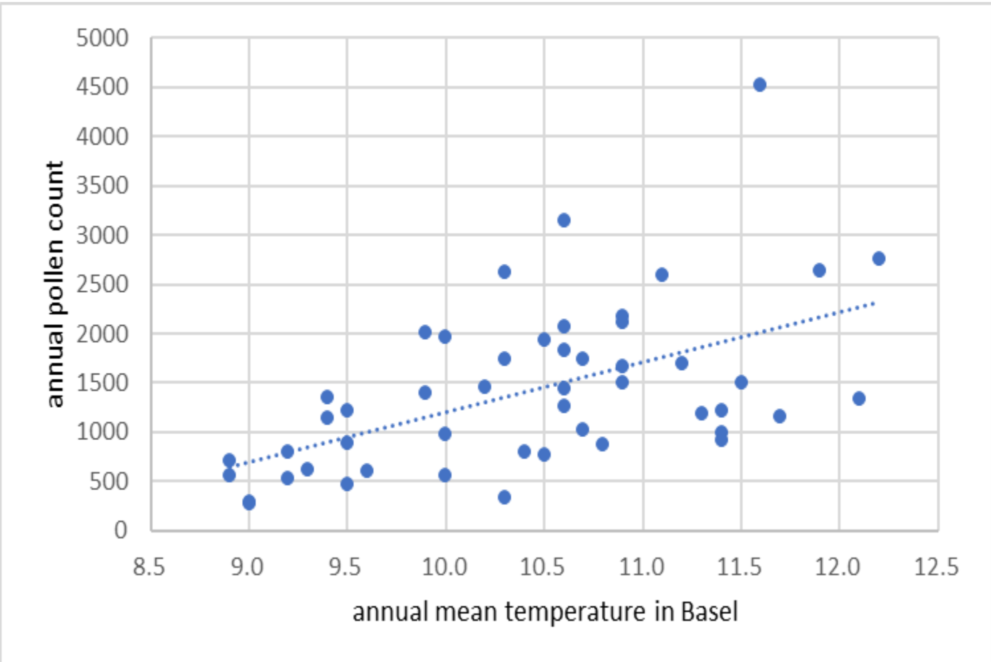

Figure 4 The correlation between the annual mean temperature and the annual pollen count of *Corylus* from 1969 to 2020 in Basel.

Pearson's correlation coefficient for the correlation between the annual mean temperature and the annual pollen count was 0.56, indicating a strong and statistically significant correlation ($p < 0.05$) as shown in Table 1.

Table 1 Statistical analysis of the annual mean temperature and the annual pollen count for *Corylus* from 1969 to 2020 in Basel.

	annual pollen count	annual mean temperature
mean	1390.06	10.386
variance	706609.6086	0.81224898
observations	50	50
Pearson's correlation	0.560508231	
Hypothesized Mean Difference	0	
degrees of freedom	49	
t Stat	11.612684	
P(T<=t) one-tail	5.59817E-16	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	1.11963E-15	
t Critical two-tail	2.009575237	

t-Test: Paired Two Sample for Means

The increase in the annual *Betula* pollen count from 1969 to 2020 is shown in Figure 5. The linear trend indicated an increase in the annual pollen count from 5,500 to 6,500 (approximately).

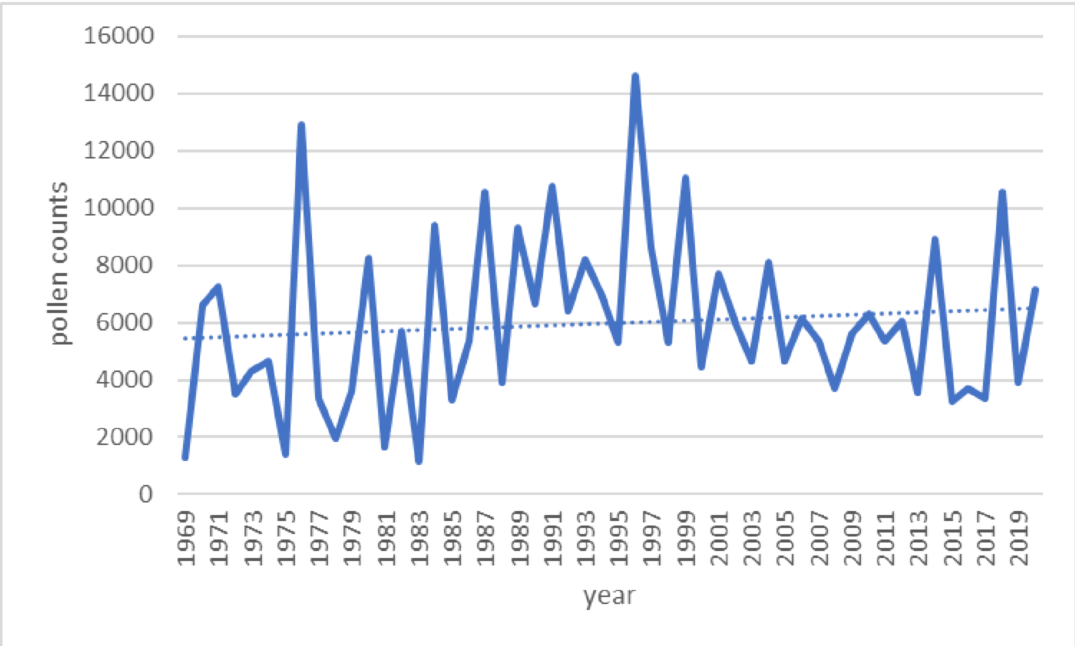

Figure 5 Pollen count for *Betula* from 1969 to 2020 in Basel.

The initiation of the flowering of Betula shifted linearly from Day 97 (April 7th) to Day 87 (March 27th) (Figure 6). This represented a shift of approximately ten days in 52 years.

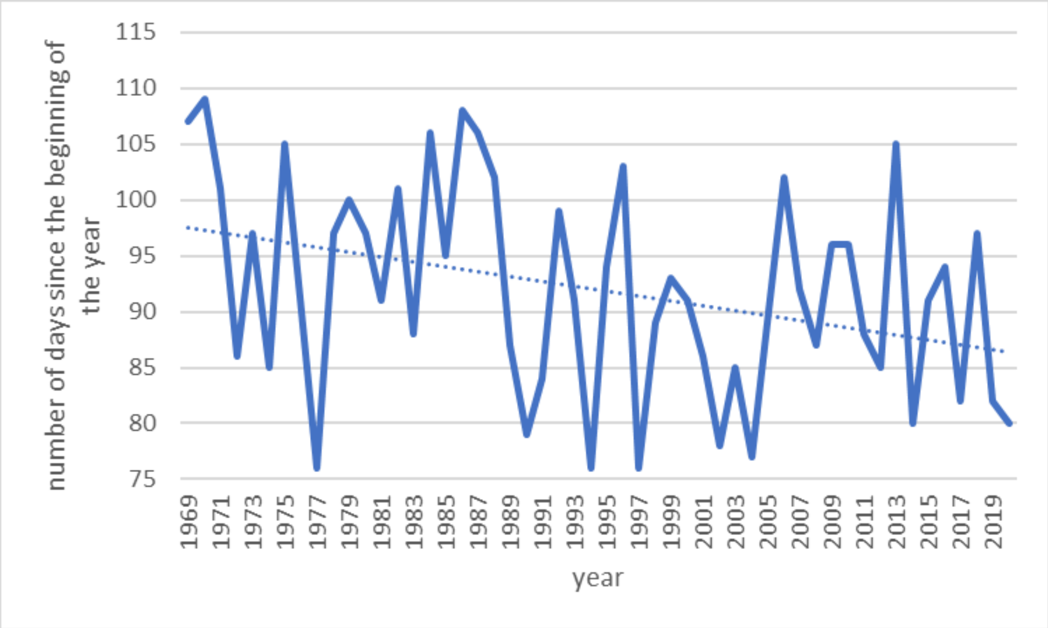

Figure 6 The initiation of flowering of *Betula* from 1969 to 2020.

An overview and the statistical analysis of the correlation between the annual mean temperature and the number of days since the beginning of *Betula* pollen released from 1969 to 2020 in Basel are presented in Figure 7 and Table 2. Pearson's correlation coefficient was -0.49, and the correlation was significant ($p < 0.05$). The correlation suggested that flowering is directly enforced by the rise in temperature [21, 22].

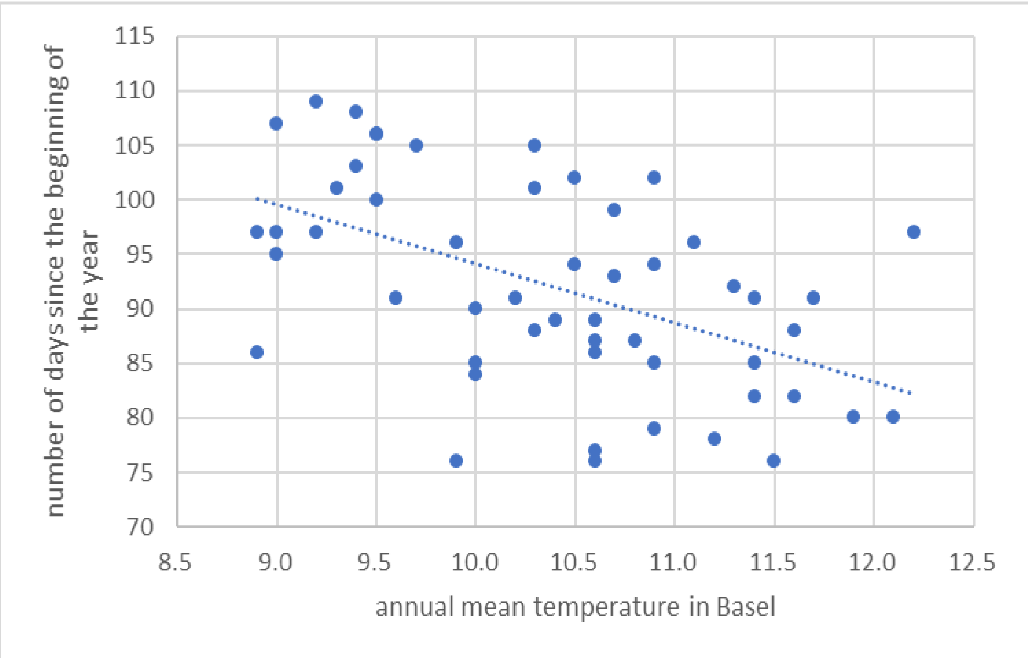

Figure 7 The correlation between the annual mean temperature and the number of days since the beginning of *Betula* pollen release from 1969 to 2020 in Basel.

Table 2 Statistical analysis of the annual mean temperature and the number of days since the beginning of Betula pollen release in Basel.

	number of days since the beginning of pollen release	annual mean temperature
mean	91.64705882	10.42352941
variance	85.03294118	0.795035294
observations	51	51
Pearson’s correlation	-0.498594176	
Hypothesized Mean Difference	0	
degrees of freedom	50	
t Stat	59.81919628	
P(T<=t) one-tail	1.71282E-48	
t Critical one-tail	1.675905025	
P(T<=t) two-tail	3.42564E-48	
t Critical two-tail	2.008559112	

t-Test: Paired Two Sample for Means

The initiation of flowering of Poaceae shifted linearly from Day 135 (May 15th) to Day 127 (May 7th) (Figure 8). This represented a shift of approximately eight days in 52 years.

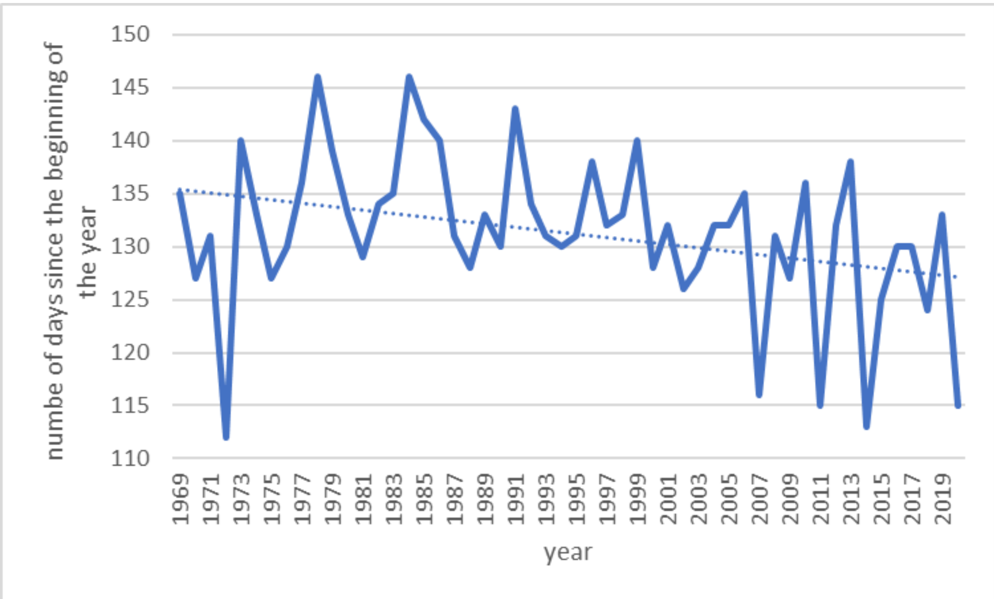

Figure 8 The initiation of flowering for Poaceae from 1969 to 2020.

The overview and the statistical analysis of the correlation between the annual mean temperature and the number of days since the beginning of Poaceae pollen release from 1969 to 2020 in Basel are shown in Figure 9 and Table 3. Pearson’s correlation coefficient was -0.51 and was statistically significant ($p < 0.05$). The correlation suggested that flowering is directly enforced by an increase in temperature.

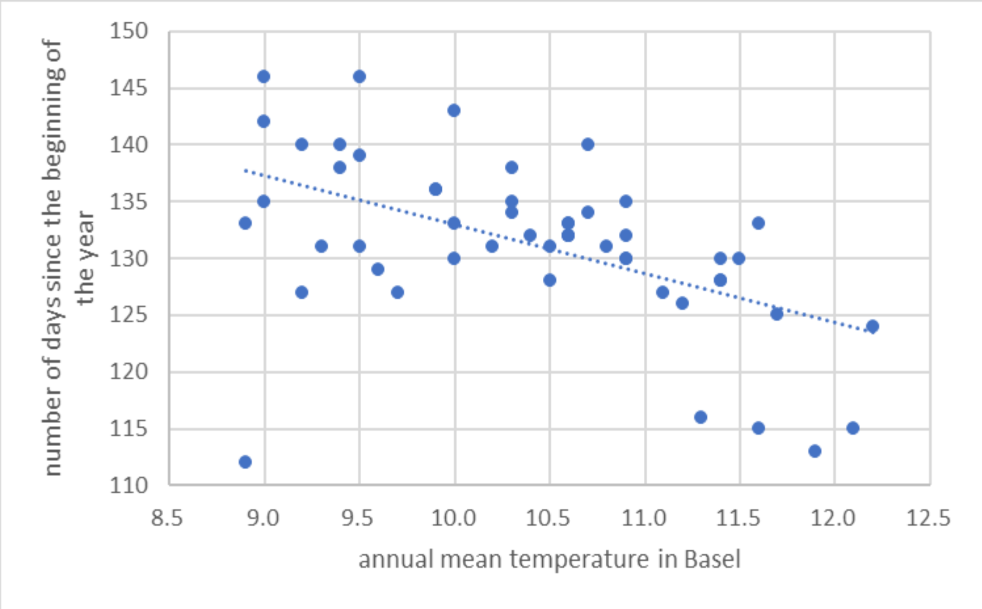

Figure 9 The correlation between the annual mean temperature and the number of days since the beginning of Poaceae pollen release from 1969 to 2020 in Basel.

Table 3 Statistical analysis of the annual mean temperature and the number of days since the beginning of Poaceae pollen release in Basel.

	number of days since the beginning of pollen release	annual mean temperature
mean	131.2156863	10.4235294
variance	57.17254902	0.79503529
observations	51	51
Pearson's correlation	-0.518123802	
Hypothesized Mean Difference	0	
degrees of freedom	50	
t Stat	107.0338343	
P(T<=t) one-tail	5.0243E-61	
t Critical one-tail	1.675905025	
P(T<=t) two-tail	1.00486E-60	
t Critical two-tail	2.008559112	

t-Test: Paired Two Sample for Means

For the results of previous studies (Figure 10), the prevalence of pollinosis is shown in the same time frame as the increase in CO_2-concentration and the increase in temperature and the release of pollen.

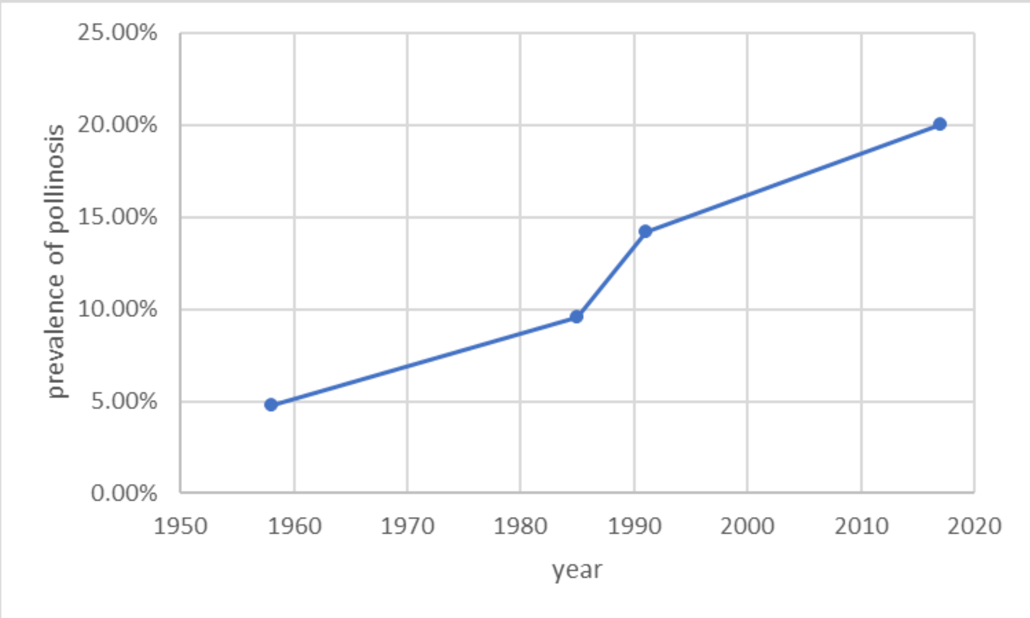

Figure 10 Prevalence of pollinosis in Switzerland from 1958 to 2017.

4. Discussion

The concentration of CO_2 is a major source of global warming, as mentioned by Arrhenius in 1910. Systematic measurements of CO_2-concentration in the atmosphere started in Mauna Loa, Hawaii, in 1952 [23]. The increase in CO_2 from around 320 ppmV in 1969 to around 420 ppmV in 2020 demonstrated the situation worldwide, as well as in Switzerland, and also explained the observed temperature increase in Basel-Binningen.

The phenology of *Betula* showed the heating and chilling requirements that are needed to trigger bud development and to assess how global climate change might influence phenology in this species [24].

Several climate-related parameters, including photoperiod, water availability, temperature, and wind speed and direction, affect plant phenology. In annual grasses, the key factor is the weather that prevails during the growing season [25].

The increase in temperature in Basel-Binningen (Figure 2) is the reason for the earlier flowering of trees and herbs like *Corylus*, *Betula*, and Poaceae. Earlier flowering and the corresponding pollen release cause hay fever symptoms, starting in January for *Corylus* and in March for *Betula*. These findings are similar to those reported from several European countries [26, 27]; thus, indicating the relevance of climate change and its impact on allergy.

Global warming, caused by increasing atmospheric CO_2 concentrations by traffic and heating, has caused earlier flowering and pollen release in plants and thus, affected human health by increasing the instances of allergy and asthma.

Global change impacts agriculture, tourism, assurance, migration, and human health. The effects on human health are very diverse and include aspects like heat-related mortality, vector-borne infections, and an increase in the cases of inflammatory bowel disease and infectious gastroenteritis in hospitals during heatwaves [28].

The epidemiological situation indicated a direct link between increasing CO_2-concentration in the atmosphere; thus, inducing an increase in the air temperature. This, in turn, promotes earlier flowering and increases pollen counts due to the higher availability of CO_2 in the air that has a fertilizing effect. The increasing prevalence of pollinosis might also have additional causes, such as the 'western style of life' (e.g., junk food consumption or increased hygiene requirements) [29, 30].

To cope with these impacts on human health, the only approach is to stabilize and later decrease the CO_2 concentrations in the atmosphere either by reducing anthropogenic emissions or by implementing technical measures to decarbonize the atmosphere.

5. Conclusions

The increase in CO_2-concentration in the atmosphere is a major driver of global warming. Global warming is the cause for the earlier flowering of plants like *Betula* or Poaceae that might be responsible for allergy and asthma. Moreover, the incidence of pollinosis is also increasing. Reducing the CO_2-concentration in the atmosphere is the only strategy to cope with global warming and its negative impacts, as proposed in the Paris agreement in 2015 [31].

Author Contributions

The author did all the research work of this study.

Competing Interests

The author has declared that no competing interests exist.

References

1. Arrhenius S. On the influence of carbonic acid in the air upon the temperature of the ground. Philos Mag. 1896; 41: 237-276.
2. Agrawala S. Context and early origins of the Intergovernmental Panel on Climate Change. Clim Change. 1998; 39: 605-620.
3. Masson-Delmotte V, Zhai A, Pirani SL, Connors C, Péan S, Berger N, et al. Climate change 2021: The physical science basis. Geneva: IPCC; 2021; 6.
4. Robine JM, Cheung SL, Roy SL, Oyen HV, Griffiths C, Michel JP, et al. Death toll exceeded 70,000 in Europe during the summer of 2003. C R Biol. 2008; 331: 171-178.
5. Frei T. Climate change and its impact on tick-borne encephalitis incidence in Switzerland 2000-2018. Prävent Rehabil. 2020; 32: 1-9.
6. Manser CN, Paul M, Rogler G, Held L, Frei T. Heat waves, incidence of infectious gastroenteritis and relapse rates of inflammatory bowel disease: A retrospective controlled observational study. Am J Gastroenterol. 2013; 108: 1480-1485.
7. Frei T. The effects of climate change in Switzerland 1969-1996 on airborne pollen quantities from hazel, birch and grass. Grana. 1998; 37: 172-179.
8. Frei Th, Gassner E. Climate change and its impact on birch pollen quantities and the start of the pollen seasons, an example from Switzerland for the period 1969-2006. Int J Biometeorol. 2008; 52: 667-674.
9. Khwarahm N, Dash J, Atkinson PM, Newnham RM, Skjøth CA, Adams-Groom B, et al. Exploring the spatio-temporal relationship between two key aeroallergens and meteorological variables in the United Kingdom. Int J Biometeorol. 2014; 58: 529-545.

10. Jato V, Rodríguez-Rajo FJ, Seijo MC, Aira MJ. Poaceae pollen in Galicia (N.W. Spain): Characterisation and recent trends in atmospheric pollen season. Int J Biometeorol. 2009; 53: 333-344.
11. Emberlin J, Detandt M, Gehrig R, Jaeger S, Nolard N, Rantio-Lehtimaki A. Responses in the start of Betula (birch) pollen seasons to recent changes in spring temperatures across Europe. Int J Biometeorol. 2002; 46: 159-170.
12. Frei T. Climate change in Switzerland: Impact on hazel, birch, and grass pollen on the basis of half a century of pollen records (1969-2018). Allergol Select. 2020; 4: 69-75.
13. Gehrig R, Clot B. Fifty years of pollen monitoring in Basel (Switzerland) demonstrate the influence of climate change on airborne pollen. Front Allergy. 2021; 2: 18.
14. Glick S, Gehrig R, Eeftens M. Multi-decade changes in pollen season onset, duration, and intensity: A concern for public health? Sci Total Environ. 2021; 781: 146382.
15. Hirst JM. An automatic volumetric spore trap. Ann Appl Biol. 1952; 39: 257-265.
16. Spieksma FT, Emberlin JC, Hjelmroos M, Jäger S, Leuschner RM. Atmospheric birch (Betula) pollen in Europe: Trends and fluctuations in annual quantities and the starting dates of the seasons. Grana. 1994; 34: 51-57.
17. Bastl K, Kmenta M, Berger UE. Defining pollen seasons: Background and recommendations. Curr Allergy Asthma Rep. 2018; 18: 1-10.
18. Wüthrich B, Schmid-Grendelmeier P, Schindler C, Imboden M, Bircher A, Zemp E, et al. Prevalence of atopy and respiratory allergic diseases in the elderly SAPALDIA population. Int Arch Allergy Immunol. 2013; 162: 143-148.
19. Ballmer-Weber B, Helbling A. Allergische rhinitis. Swiss Med Forum. 2017; 17: 179-186.
20. Santamouris M. Cooling the cities—A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Sol Energy. 2014; 103: 682-703.
21. Meier M, Vitasse Y, Bugmann H, Bigler C. Phenological shifts induced by climate change amplify drought for broad-leaved trees at low elevations in Switzerland. Agric For Meteorol. 2021; 307: 108485.
22. Reid PC, Hari RE, Beaugrand G, Livingstone DM, Marty C, Straile D, et al. Global impacts of the 1980s regime shift. Glob Chang Biol. 2016; 22: 682-703.
23. Keeling RF, Piper SC, Bollenbacher AF, Walker JS. Atmospheric CO_2 records from sites in the SIO air sampling network. In trends: A compendium of data on Global Change [Internet]. Oak Ridge Tennessee: Carbon Dioxide Information Analysis Center; 2012. Available from: https://cdiac.ess-dive.lbl.gov/trends/co2/sio-keel.html.
24. Kramer K. Modelling comparison to evaluate the importance of phenology for the effects of climate change on growth of temperate-zone deciduous trees. Clim Res. 1995; 5: 119-130.
25. White JF, Bernstein DI. Key pollen allergens in North America. Ann Allergy Asthma Immunol. 2003; 91: 425-435.
26. Lake IR, Jones NR, Agnew M, Goodess CM, Giorgi F, Hamaoui-Laguel L, et al. Climate change and future pollen allergy in Europe. Environ Health Perspect. 2017; 125: 385-391.
27. De Weger L, Bruffaerts N, Koenders MM, Verstraeten WW, Delcloo AW, Hentges P, et al. Long-term pollen monitoring in the Benelux: Evaluation of allergenic pollen levels and temporal variations of pollen seasons. Front Allergy. 2021; 2: 30.

28. Bell M, Greenberg MR. Climate change and human health: Links between history, policy, and science. Am J Public Health. 2018; 108: S54-S55.
29. Wang CS, Wang J, Zhang X, Zhang L, Zhang HP, Wang L, et al. Is the consumption of fast foods associated with asthma or other allergic diseases? Respirology. 2018; 23: 901-913.
30. Scudellari M. News feature: Cleaning up the hygiene hypothesis. Proc Natl Acad Sci USA. 2017; 114: 1433-1436.
31. Dimitrov RS. The Paris Agreement on climate change: Behind closed doors. Glob Environ Polit 2016; 16: 1-11.