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Original Research

Atmospheric Environment Monitoring in Thailand via Satellite Remote Sensing: A Case Study of Carbon Dioxide

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Abstract

Satellite remote sensing is increasingly applied in the field of environmental protection, especially in atmospheric monitoring. The objective of this study is to monitor Thailand's atmospheric environment by Satellite remote sensing: Carbon Dioxide (CO_2) case study over a 5-year period from 2017 to 2021. Data from Greenhouse gases Observing Satellite (GOSAT) was used to analyze atmospheric CO_2 concentration using Map Algebra and Interpolation. The results were then analyzed together with relevant environmental factors, including altitude, temperature, rainfall and season. The results showed that (1) CO_2 concentration was highest in 2021 with the annual average of 409.903 ppm and lowest in 2017 with the annual average of 401.109 ppm, (2) Analysis based on the height above sea level showed that the lowest CO_2 in 2017 was 403.480 ppm, the highest in 2021 was 412.896 ppm, (3) Analysis together with relevant environmental factors such as altitude, temperature, rainfall and season revealed that Thailand's monthly average CO_2 concentration fluctuates over a year depending on the season. It was found that during winter and summer, CO_2 concentrations fluctuated with temperature values. In addition, during the rainy season, atmospheric CO_2 decreases due to increased plant photosynthetic rates; as a result, CO_2 in the atmosphere is consumed and converted into carbon dioxide in the form of wood.

Keywords: atmospheric environment monitoring, environmental protection, remote sensing, carbon dioxide

Introduction

At present, global climate change is a problem that countries around the world pay attention to because climate affects severe disasters such as floods, droughts and storms, which all have direct and indirect impacts on human life [1]. The main cause of climate change is the increase in global mean temperature or global warming as a result of the greenhouse effect, greenhouse gases trapping heat in the atmosphere. In normal conditions, greenhouse gas maintains the temperature and warms the earth [2]. The greenhouse gas consists of Carbon

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Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Perfluorocarbons (PFC), Hydrofluorocarbons (HFC) and Sulfur Hexafluoride (SF_6) [3]. So far, scientists around the world have focused most on the first three gases comprising CO_2, CH_4 and N_2O, especially CO_2, which accounts for over 70% of total greenhouse gas emissions [4]. Although CO_2 absorbs less heat radiation than CH_4 and N_2O, it is released more and stays in the atmosphere longer, thus CO_2 plays a greater role in climate change [5]. The Intergovernmental Panel on Climate Change (IPCC) has clearly shown that CO_2, the most important greenhouse gas in the atmosphere, has increased dramatically from 280 parts per million (ppm) during the Industrial Revolution in the 1800s to 360 ppm in 2000, and increasing rapidly to 407 ppm in 2017 [6,7]. In 2022, CO_2 measured at Mauna Loa Atmospheric Baseline Observatory peaked at 421 parts per million in May [8]. When the amount of CO_2 in the atmosphere increases, the global temperature increases, causing the greenhouse effect and bringing about global warming and climate change [9].

Measurement of greenhouse gas emissions and levels is important for studies related to climate change [10-12]. Measures to assess the greenhouse gas source and reservoir, based on relevant documents, generally can be done in 4 ways:

(1) Direct sampling - Atmospheric air is directly sampled for analysis in the laboratory. This method is difficult because greenhouse gases are circulating in the atmosphere all the time and it requires a lot of budget and time [13].

(2) Inverse modeling - Atmospheric transport model is used to describe carbon exchange processes to infer carbon flux between terrestrial ecosystems and the atmosphere, which varies by location and time period [14].

(3) Process-based surface models based on knowledge of carbon exchange between the global terrestrial and atmospheric ecosystems, such as DeNitrification and DeComposition (DNDC) focusing on N_2O and CO_2 estimation were used [15]. However, because they are region-specific models, describing the context of a region, such models cannot be applied directly to other regions, and

(4) Measuring with remote sensing technology

Remote sensing is a core technology for earth observation using electromagnetic waves as a medium to acquire information [16-18]. Remote sensing technology has been widely used as a primary tool in the study of spatial phenomena [19-25]. In addition, satellite remote sensing approaches can be used to directly analyze the reflectance and absorption of different reflection infrared and thermal infrared bands of atmospheric greenhouse gas particles, with a high spatial coverage) and a high frequency of re-analysis at the same location (high Temporal) Therefore, remote sensing approaches are useful for estimating, monitoring the distribution and dynamics of atmospheric greenhouse gases [26-32]. Remote sensing technology is a measurement and monitoring tool that will provide independent, accurate and standardized data on atmospheric carbon dioxide changes. For the aforementioned reasons and importance, this study focuses on Atmospheric Environment Monitoring in Thailand via Satellite Remote Sensing: Carbon Dioxide Case Study, as well as analysis of changes in CO_2 concentrations and distributions together with relevant environmental factors including altitude, temperature, rainfall and season. This is for the benefit of monitoring the atmospheric environment, planning for actions to reduce emissions and increase CO_2 absorption potential, as well as laying down appropriate measures for mitigating the effects of climate change in Thailand.

Material and Methods

Study Area

Thailand is part of Southeast Asia, located in the middle of the Indochina Peninsula. Thailand (Fig. 1) covers an area of approximately 500,000 km² between 5°37′N to 20°27′N latitude and 97°21′E to 105°37′E longitude. As a result of the movement of the Earth's crust and the action of rivers and streams, Thailand's topography has many variations – the mountains and valleys in the North, the river plains in the Central, the mountains in the West and the plateau in the Northeast. With a variety of topography, Thailand has a tropical grassland climate with moderate rainfall, short rainy season, and long summer. Natural vegetation areas, grasslands interspersed with forests are located in the northern, central, eastern, and northeastern regions. The southern region has a tropical monsoon climate, almost

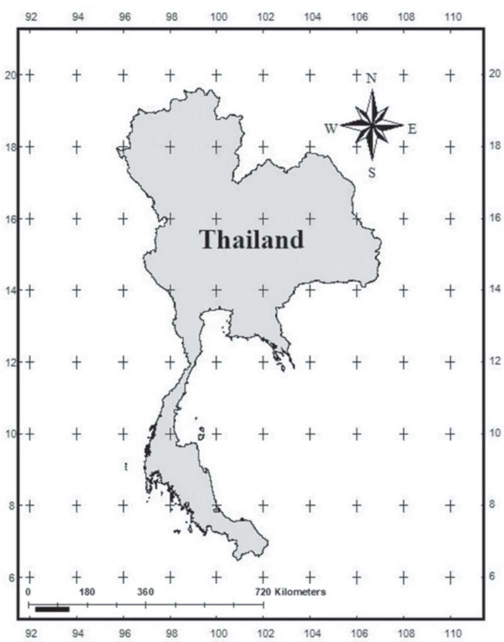

Fig. 1. Thailand.

year-round rainfall, long rainy seasons and its natural vegetation is rainforest. Thailand's natural resources are abundant. Important minerals are tin, tungsten, iron, copper, lead, manganese, gypsum, kaolin, marble, lignite, petroleum, natural gas, etc. There are also forest resources, both deciduous and evergreen forests.

Satellite Data

This study was based on data from Greenhouse gases Observing Satellite (GOSAT). GOSAT, created in collaboration with JAXA, NIES and MOE, was launched in 2009 at the Tanegashima Space Center on the southern island of Kyushu, Japan. The data obtained from GOSAT covered a global area with a spatial resolution of 10.5 km. GOSAT maintains a sun-synchronous orbit with an inclination of 98.06° at an altitude of 666 km, with a period of 1 hour 40 minutes and repeat cycle of three days. GOSAT has a data acquisition device called the Thermal And Near Infrared Sensor for Carbon Observation (TANSO) and two data capture devices: Fourier Transform Spectrometer (FTS) and Cloud and Aerosol Imager (CAI). FTS can measure wave interaction in 4 bands, which are 3 bands of Short Wave-Infrared (SWIR) and 1 band of Thermal Infrared. The GOSAT data between 2017 and 2021 were selected for this study with the L3 global CO_2 distribution (SWIR) dataset.

Data Analytics

Estimation of atmospheric CO_2 concentration in Thailand basing on data from GOSAT together with factors influencing changes under this study was done using Map Algebra Technique and Interpolation Technique using ArcGIS program, during 5 years starting from 2017 to 2021. A brief analytical process in this study can be described as follows:

(1) Analyze CO_2 concentration from 2017 to 2021,

(2) Analyze CO_2 concentration based on the Metres Above Sea Level (m a.s.l.), and

(3) Analyze CO_2 concentration together with factors of temperature, rainfall and season.

The analytical results obtained in this study were presented in the form of maps and graphs to illustrate the spatial time interval variation of atmospheric CO_2 in Thailand in ppm. The unit for measuring greenhouse gas concentrations in the atmosphere was expressed in a mole fraction. That is, the ratio of the moles of components in a given volume to the total moles of components, expressed as dry air. Atmospheric CO_2 concentration units are mostly expressed in ppt, ppm, and ppb units.

Results and Discussion

Analysis results of CO_2 concentration in the atmosphere of Thailand under the previously presented method can be shown as follows:

Analysis of CO_2 Concentration

The analysis of Thailand atmospheric CO_2 concentrations based on GOSAT data between 2017 and 2021 using Map Algebra and Interpolation Technique in this study can be shown as Fig. 2 and Table 1. From Fig. 2 and Table 1, it was found that the CO_2

Table 1. CO_2 concentration in the atmosphere: a) 2017, b) 2018, c) 2019, d) 2020 and e) 2021

Month	CO_2 Concentration (ppm)	Month	CO_2 Concentration (ppm)	Month	CO_2 Concentration (ppm)	Month	CO_2 Concentration (ppm)	Month	CO_2 Concentration (ppm)
Jan.	399.557	Jan.	402.101	Jan.	403.983	Jan.	406.46	Jan.	408.953
Feb.	400.078	Feb.	402.515	Feb.	404.467	Feb.	406.732	Feb.	409.32
Mar.	401.159	Mar.	403.286	Mar.	405.382	Mar.	407.796	Mar.	410.233
Apr.	402.313	Apr.	404.578	Apr.	406.677	Apr.	409.197	Apr.	411.436
May	402.857	May	405.191	May	407.345	May	410.1	May	412.093
Jun.	401.701	Jun.	404.29	Jun.	406.311	Jun.	408.869	Jun.	410.384
Jul.	399.788	Jul.	402.237	Jul.	404.292	Jul.	406.945	Jul.	409.125
Aug.	399.114	Aug.	401.274	Aug.	403.322	Aug.	406.078	Aug.	408.427
Sept.	404.051	Sept.	401.489	Sept.	404.051	Sept.	406.492	Sept.	408.797
Oct.	400.372	Oct.	402.403	Oct.	404.778	Oct.	407.16	Oct.	409.371
Nov.	400.939	Nov.	402.938	Nov.	405.343	Nov.	407.747	Nov.	410.143
Dec.	401.39	Dec.	403.448	Dec.	N/A	Dec.	408.306	Dec.	410.556
a)		b)		c)		d)		e)	

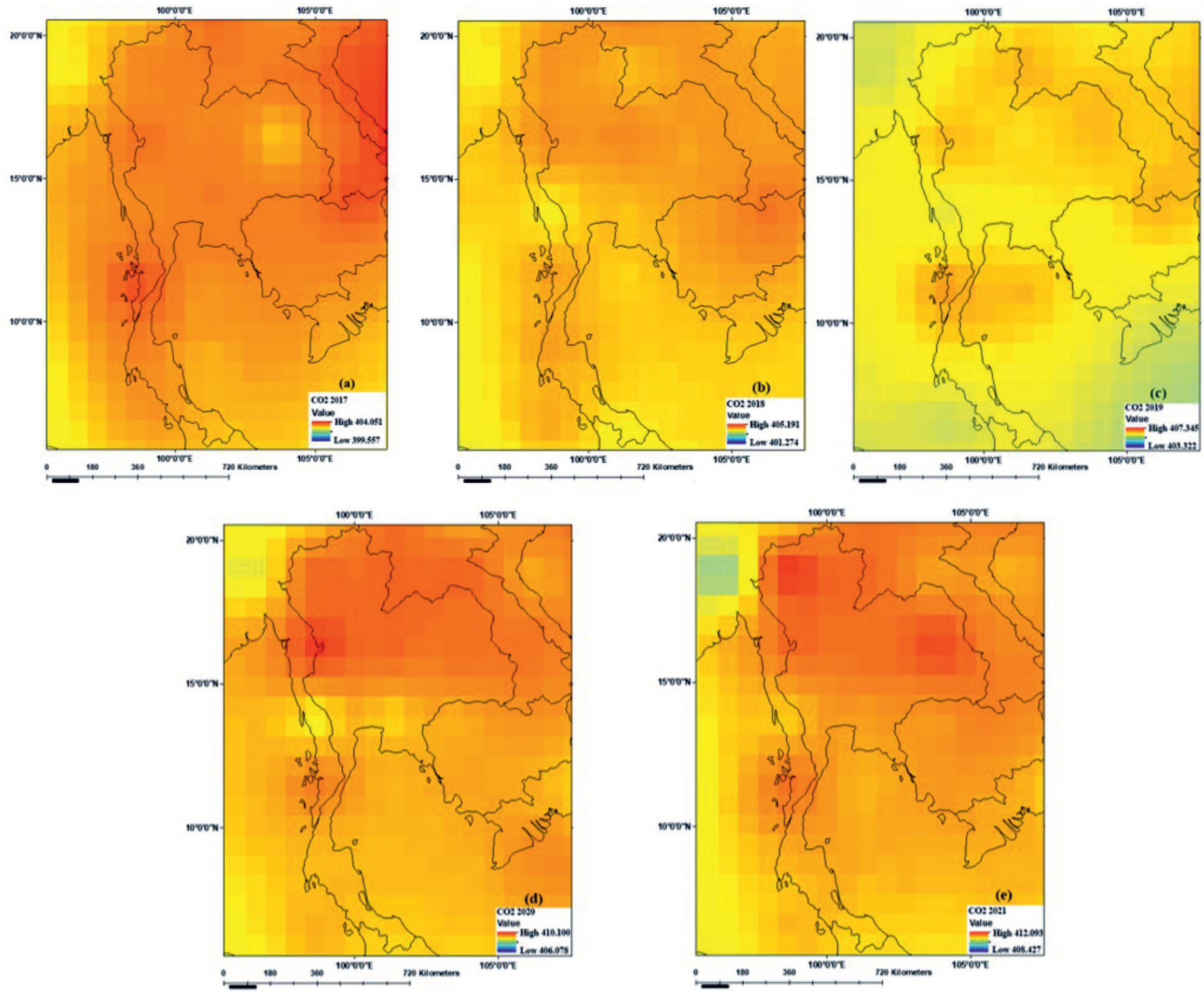

Fig. 2. CO_2 concentration in the atmosphere of Thailand, a) 2017, b), 2018, c) 2019, d) 2020, and e) 2021.

concentration in Thailand's atmosphere fluctuates during one year according to seasons. Seasons in Thailand can be divided into 3 seasons: the summer season starts from mid-February to mid-May, the rainy season starts from mid-May to mid-October, and the winter season starts from mid-October to mid-February. The results of this study explain CO_2 concentrations in the atmosphere of Thailand as follows:

(1) In 2017, the CO_2 concentration in the atmosphere of Thailand was the lowest in August at 399.114 ppm (rainy) and the highest in May at 402.857 ppm (summer).

(2) In 2018, the CO_2 concentration in the atmosphere of Thailand was the lowest in August at 401.274 ppm (rainy) and the highest in May at 405.191 ppm (summer).

(3) In 2019, the CO_2 concentration in the atmosphere of Thailand was the lowest in August at 403.322 ppm (rainy) and the highest in May at 407.345 ppm (summer).

(4) In 2020, the CO_2 concentration in the atmosphere of Thailand was the lowest in August at 406.078 ppm (rainy) and the highest in May at 410.100 ppm (summer), and

(5) In 2021, the CO_2 concentration in the atmosphere of Thailand was the lowest in February at 408.427 ppm (rainy) and the highest in May at 412.093 ppm (summer).

Analysis Based on the Metres Above Sea Level (m a.s.l.)

Analysis results of CO_2 concentration in the atmosphere of Thailand together with the factor of Metres Above Sea Level (m a.s.l.), which measured the concentration of greenhouse gases in the atmosphere from the level of 10 m to the level of 975 m, can be shown as Fig. 3. There are several means to tell height level. However, generally, we will tell height level of from mean sea level. Since ocean and sea connect with each other with flowing water, sea water will maintain its level to have equipotential line, i.e., if equipotential line of one area is higher than another area, there will be force making both levels to have equal equipotential line. Meters Above Sea Level (m a.s.l.) or Meters Above Mean Sea Level (m a.s.l.)is measurement standard based on matrix system with unit as meter. It is used for showing ground level of any location by referring to recorded mean sea level. This research was conducted to analyze on concentration of CO_2 in atmosphere of Thailand based on height factor from Metres Above Sea Level (m a.s.l.).

From Fig. 3, it was found that at an altitude of 10 m to 200 m, the average CO_2 concentration increased at a high rate but the rate of increase tended to decrease at an altitude from 200 m. When comparing the average annual CO_2 concentration between 2017 and 2021 in the atmosphere of Thailand, it was found that the concentration has been increasing steadily. Based on the annual average in 2017, the lowest CO_2 concentration was 397.459 ppm, while in 2021 the highest CO_2 concentration was 407.129 ppm.

Analysis of CO_2 Concentration Together with the Factors of Femperature, Rainfall and Season

Analysis of CO_2 concentration together with the factors of temperature, rainfall and season in this study explained that CO_2 concentrations varied with temperature as shown in Fig. 4, and CO_2 concentrations also varied with rainfall as shown in Fig. 5. In addition, it was found that during the summer, It can be explained that fuel is consumed increasingly in every region of Thailand during summer and wildfire is often occurred in Thailand as well. With such reason, CO_2 content in atmosphere of Thailand is increased explicitly. In rainy season, it is the time when CO_2 in the atmosphere is decreased due to higher level of photosynthesis. CO_2 in atmosphere will be held for using in photosynthesis of plants before transforming as carbon accumulated in the form of wood. Moreover, before falling rail will absorb CO_2 in atmosphere causing rain contains soft acid whereas such soft acid will dissolve substances in air during raining as well as nutrients in soil. In winter, it is the time when plants have to adjust themselves in several dimensions. This procedure has complex mechanism with involvement of the large content of enzyme as well as chemical process for destroying chlorophyll in plant's leaves causing defoliation. With such reason, CO_2 in atmosphere that is held for using in photosynthesis will be reduced whereas concentration of CO_2 in atmosphere will be higher. Moreover, air humidity will be low in winter reducing content of CO_2 that is converted as carbonic acid (a kind of acid with atom of carbon). Consequently, concentration of CO_2 in atmosphere is increased.

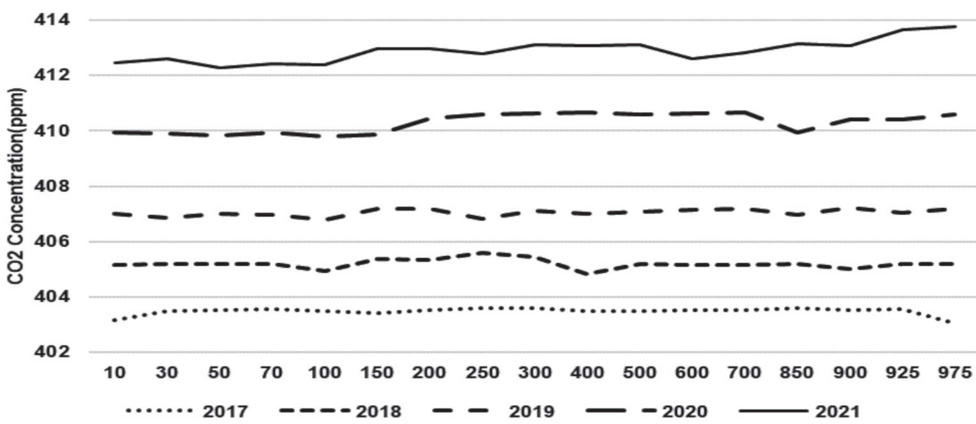

Fig. 3. CO_2 concentration based on the height above sea level.

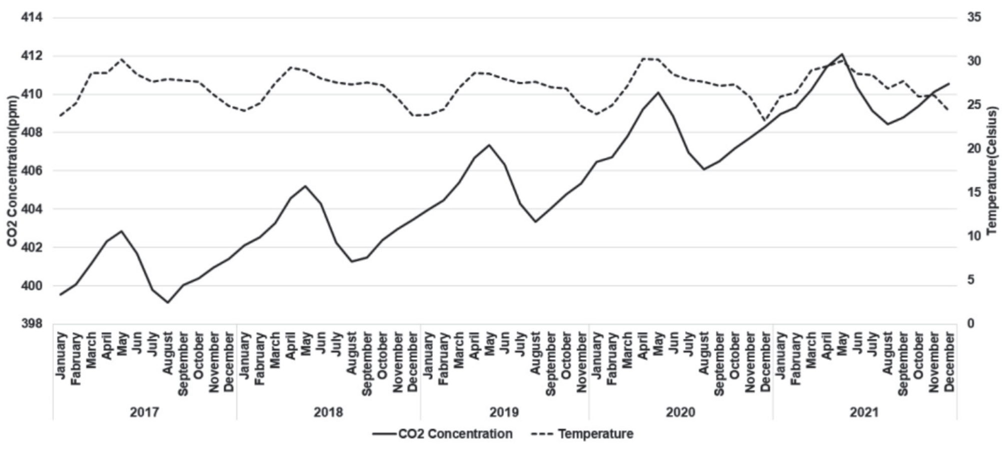

Fig. 4. CO_2 concentration together with the factors of temperature.

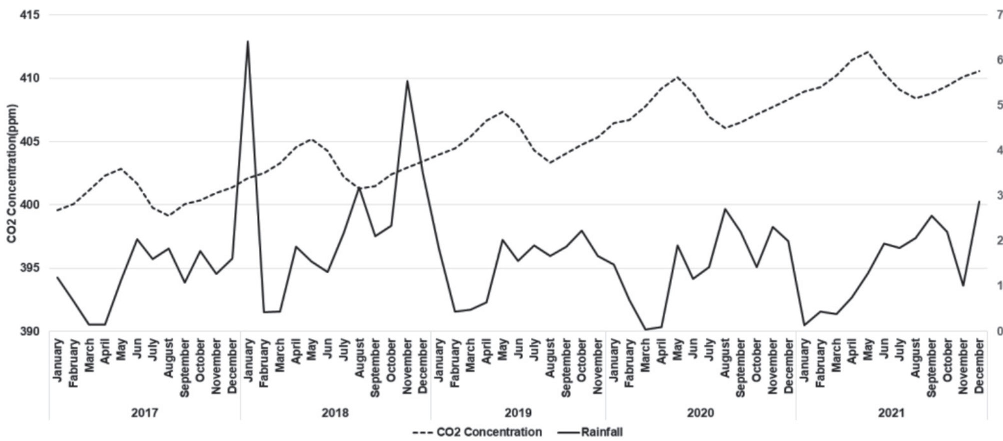

Fig. 5. CO_2 concentration together with the factors of rainfall.

In addition, higher global temperature also causes evaporation of CO_2 dissolved in ocean's sea water.

Conclusions

CO_2, the most emitted greenhouse gas in the atmosphere, causes the greatest accumulation of thermal energy in the atmosphere. CO_2 therefore raises global temperatures the most among other greenhouse gases. Main sources of CO_2 emissions are human activities such as burning fossil fuels, transportation and industrial production. The objective of this study was to monitor atmospheric environment in Thailand via satellite remote sensing: carbon dioxide case study during 2017 to 2021 and analyze the data together with relevant environmental factors including altitude, temperature, rainfall and season. This research can be concluded from the 5-year period of the study that the atmospheric CO_2 concentration in Thailand fluctuates around one year according to the season. The study results can be used as a baseline for monitoring the atmospheric CO_2 situation in Thailand. The study results are useful for the government and related agencies in policy formulation and project planning to reduce emissions and increase effective CO_2 absorption. Finally, it also supports Thailand's adaptation to the impacts of climate change.

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Conflict of Interest

The authors declare no conflict of interest.

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