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Monitoring Climate Change and Air Quality Project Initiative: A Case Study of the Collaboration between ECSTAR and TeroSpace in Thailand

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Abstract

In Thailand, the alteration of weather patterns has resulted in an increase in instances of irregular rainfall, contributing to the occurrence of droughts. The decline of water levels in dams, due to the combined effects of climate change and prolonged droughts, has had a significant impact on agricultural productivity. Drought has a profound effect on the terrestrial biosphere and the atmospheric water cycle and can also contribute to air pollution. Researchers have found a strong correlation between air pollution and drought severity. In response to this pressing issue, the Excellence Center of Space Technology and Research (ECSTAR) at King Mongkut's Institute of Technology Ladkrabang has joined forces with TeroSpace company to launch an initiative aimed at promoting sustainable growth in Chiang Rai, a province in Thailand known for its rich biodiversity. ECSTAR and TeroSpace's partnership on the sustainable growth initiative in Thailand's Chiang Rai province focuses on expanding their collaboration to include international organizations such as the Centre National d'Etudes Spatiales (CNES), which will provide access to satellite imagery and climate and weather information to improve decision-making in various areas of development. CNES is a French organization in charge of space-related activities in France. The collaboration between France and Thailand for this project, in the context of the France-Thailand Year of Innovation 2023, will be crucial for the successful initiation and execution of this research project. The project aims to explore the relationship between air pollution and climate change through the deployment of air quality monitoring devices in designated locations, connected to a global data-sharing network. The re-

sults of this research will be valuable to policymakers as they consider the interplay between air pollution and climate change and make efforts to address these challenges.

Keywords

Air Pollution, Climate Change, Monitoring, Collaboration, Project

1. Introduction

It is estimated that the residents of Thailand will be exposed to an annual concentration of PM 2.5 of 21.4 micrograms per cubic meter. This is nearly double the World Health Organization's (WHO) target of 10 micrograms per cubic meter [1]. Chiang Mai and Chiang Rai, two popular tourist destinations in northern Thailand, are frequently featured among the most polluted cities in the world. According to various studies by IQAir [2], the primary source of air pollution in these large northern cities is caused by the burning of agricultural products, rather than the combustion of fossil fuels [3].

There are various terms for agricultural burning, including open burning and the "burning season". From December to April, farmers from the northern region of Thailand, will employ agricultural burning by setting fire to farmlands to prepare the land for the next planting season. Farmers typically use this technique for maize, sugarcane and rice fields. If the agricultural burning season coincides with the driest and coldest months in Thailand, it can lead to a buildup of pollutants and result in poor air quality throughout the region. The smoke from these burning farms often lingers in the air until Songkran, the Thai New Year, but the start of the rainy season helps to clear the sky of smoke and reduce air pollution [2].

Studies show that over 15.2 million people in Thailand are suffering from the adverse effects of air pollution, with an estimated 13,000 deaths projected to occur in 2020. During the agricultural burning season, air quality often reaches hazardous levels, as designated by the World Health Organization and the US Environmental Protection Agency's Air Quality Index (AQI) [2]. Provinces such as Chiang Mai and Chiang Rai are particularly affected, with smoke from crop burning often shrouding the region in a thick, gray haze and hindering visibility. Wipatayotin [4] describes how the Air Quality Index (AQI) can be used to assess the impact of agricultural burning on air quality in specific locations over a five-year period. This data can be analyzed in conjunction with the effectiveness of the crop burning ban established by the Ministry of Agriculture as a key strategy to minimize harmful PM 2.5 levels.

Multiple studies are underway to examine the relationship between air pollution and climate change and devise effective solutions for this global problem [5]. However, establishing a clear link between air pollution and climate change re-

quires the global collaboration of individuals, nations, and organizations to gather and share sensor data and examine it for the benefit of research. This is the collective responsibility of every person and entity focused on environmental or climate change research, which must play their part in resolving this global crisis [6].

The following sections of this paper will delve into the correlation between air pollution and climate change. The issue of PM 2.5 pollution affecting Northern Thailand will be addressed and the purpose and goals of the project will be introduced. Lastly, the future prospects of the project and a conclusion of the research paper will be presented.

2. The Relationship of Air Pollution to Climate Change

"Air pollution" encompasses any substance that alters the quality of the air, both indoors and outdoors. One of the most damaging forms of air pollution is greenhouse gases (GHGs), such as methane and carbon dioxide, both of which are being released into the atmosphere in alarming amounts. These GHGs are disrupting the planet's climate system and changing ecosystems and wildlife populations. Unfortunately, policymakers in charge of GHG regulation often overlook the widespread impact of air pollution. Many studies have shown that GHGs have far-reaching effects on people's health and the environment, and increased air pollution levels are impacting both on a global scale [5] [7].

New research suggests that the relationship between air pollution and climate change may be more interconnected than previously believed. As the climate changes, air quality is predicted to decline, with increased heat and sunlight potentially contributing to higher ozone levels. At the same time, air pollution may also affect the climate in various ways, such as altering cloud formation through higher levels of particle pollution. According to the Environmental Protection Agency (EPA) [8], another result is significant changes in typical rainfall patterns. Despite this, scientists still only have a limited understanding of the relationship between air pollution and climate change.

Particulate matter can impact global warming differently based on its composition. Generally, light-colored particles such as sulfates and nitrates reflect sunlight, reducing the Earth's temperature, while darker particles like black carbon absorb heat, increasing the temperature. The presence of black carbon can be particularly damaging, especially when it accumulates on Arctic ice, causing accelerated melting. The European Environment Agency [9] confirms that this melting also leads to reduced reflection of sunlight and heat back to Earth, ultimately exacerbating the problem with global warming.

Addressing both air pollution and greenhouse gas (GHG) emissions often go hand in hand, since they can be caused by the same source, such as the burning of fossil fuels. Decreasing harmful emissions, such as black carbon and ozone, benefits both human health, air quality, and the climate, although this is not always the case. Some efforts to reduce GHG emissions may negatively affect air quality and vice versa. For instance, using biomass as fuel is considered a "car-

bon neutral" energy source that helps lower CO_2 emissions but increases the emission of hazardous particles. As knowledge of the connection between these two issues grows, policymakers will have a crucial role in addressing both air pollution and climate change comprehensively to ensure that both concerns are effectively addressed [5] [10]. The frequency of extreme weather events, such as heatwaves, droughts, and heavy rains, has significantly increased in recent years, affecting people worldwide. Understanding the role of climate change in these events can aid in more accurate predictions and better preparation, as well as provide insight into the full cost of carbon emissions [11].

It is crucial to consistently reduce air pollution and eliminate GHG emissions, as they pose serious threats to human health and the global environment. Air quality and climate initiatives can be mutually supportive. Measures aimed at mitigating climate change may also improve air quality, and a robust clean air campaign may contribute to the reduction of GHG emissions and reduce global warming. Additionally, air pollution and climate change have complex interactions in the atmosphere. The increase of GHG concentrations can disrupt the energy balance between the atmosphere and the Earth's surface, leading to temperature variations and changes in the atmospheric chemical composition. Black carbon emissions are a direct cause of air pollution, while sulfates and ozone emissions may also have an impact on the energy balance [12] [13].

3. Effect of PM 2.5 Pollution on Northern Thailand

Agricultural burning is a major source of harmful pollution, particularly PM 2.5, which contains particulate matter minuscule in size, ranging 2.5 mm or smaller in diameter. Its small size allows it to penetrate the human respiratory system and reach the bloodstream, causing serious health problems. PM 2.5 is made up of various components including smoke, black carbon, soot, chemicals, dust, and soil. Epidemiological studies have linked exposure to PM 2.5 to various health issues, including asthma, COPD, respiratory tract infections, stroke, heart attack, and even death [14].

A study employed by the US EPA [15], used the Air Quality Index (AQI) and associated PM 2.5 concentration measurements with established health risk criteria, with an added annual mean exposure threshold of 10 g/m^3. It set the standard for acceptable air quality in Thailand, proposing that PM 2.5 levels do not exceed 50 g/m^3 on a 24-hour basis. This threshold is very close to the US EPA's guideline of 55.4 g/m^3 for "unhealthy" air quality. To evaluate air quality, PM 2.5 values are color-coded green, yellow, and orange for acceptable levels, while red, purple, and maroon (151 - 301+) indicate unacceptable levels (as illustrated in **Figure 1** of the US AQI standard) [9] [15].

In Northern Thailand, farmers frequently resort to burning their crops to get rid of residual waste, insects, and weeds. While this method enables farmers to clear their fields quickly and inexpensively, it is damaging to both human health and the environment. In 2021, the Department of Agricultural Extension

launched a program in Northern Thailand aimed at promoting environmentally friendly agricultural waste disposal methods. However, it remains uncertain whether these efforts will effectively reduce air pollution levels in the region. Despite the government's efforts to minimize airborne particulate matter, air pollution continues to pose a significant threat to the health of Thai citizens. Additionally, smoke from agricultural fires can spread over hundreds of kilometers and affect neighboring countries [16].

Data provided by research from IQAir [2] examines the PM 2.5 levels for January, February, and March of 2021, which is recorded by a ground-level monitoring station located in Chiang Mai, Thailand. The readings from these three months are then compared to the corresponding periods during 2020, 2019, 2018, and 2017. The results indicate that in 2021, there were more hours classified as "unhealthy for sensitive populations" and worse levels than the other years studied (as depicted in **Figure 2**). Although there was an increase in the frequency of "excellent" air quality after 2020, the average PM 2.5 concentration also rose to over 35.4 g/m^3. The three-month period selected for the investigation coincides with the agricultural burning season in Thailand. This time frame was chosen because the start and end dates of this season are subject to fluctuations due to the weather, so comparing the same period each year helps to minimize the impact of these fluctuations on PM 2.5 levels recorded [2].

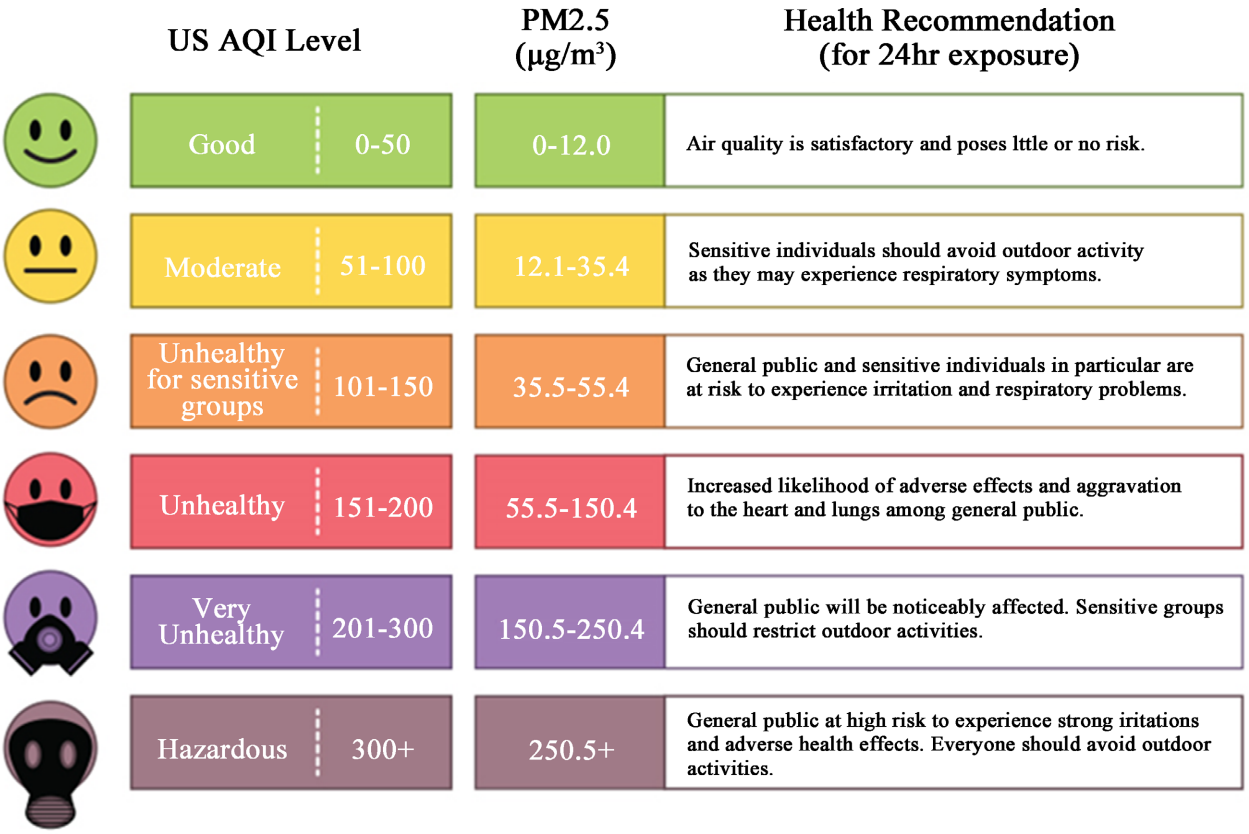

Figure 1. US AQI levels from 0 - 301+, equivalent PM 2.5 standards by μg/m^3, and health recommendations for each level (Source: IQAir-First in air quality).

Figure 2. Average annual and monthly PM 2.5 concentrations, color-coded by US Air Quality Index categories (Source: IQAir-First in air quality).

Thailand's Pollution Control Department collected data from 37 public PM 2.5 sensors located in Chiang Mai as well as other standardized non-government air quality monitors. During an average of three months in the burning season, it was observed that Chiang Mai had lower levels of PM 2.5 pollution in 2021 compared to 2020 and 2019, but higher concentrations than in 2018 and 2017. PM 2.5 concentration levels have been steadily rising over the past five years, increasing the risk to people's health, with March being the most polluted month during the 2017-2021 period, with average PM 2.5 concentrations frequently twice as high as in the other months of the three-month monitoring period [2] [17].

The trends suggest that earlier agricultural burns, heightened by the effects of global warming, have led to agricultural workers starting the burning season earlier in an effort to avoid droughts. Additionally, the government's ban on the burning of crops during January-February may have also contributed to the increase in PM 2.5 concentrations. Data gathered confirms that the average PM 2.5 concentration between December and January in 2021 and 2020 was double that of 2017, 2018, and 2019 [17].

4. Target Area of the Project

The target area for this project is Wiang Pa Pao. It is located at 19˚22'0" North and 99˚30'0" East, with an elevation of 838 meters. Wiang Pa Pao is situated in the southwestern district of Chiang Rai province in northern Thailand, as depicted in **Figure 3**. The neighboring districts include Mae Suai and Phan in Chiang Rai province, Wang Nuea and Mueang Pan in Lampang province, and Doi Saket and Phrao in Chiang Mai province. The district is bordered by the

Khun Tan Range to the west, with its highest point, Doi Mae Tho, reaching 2031 m high and located at its southwest end [18] [19].

Wiang Pa Pao is divided into seven sub-districts (tambons), which are further divided into 92 villages (mubahns). There are two sub-district municipalities, Wiang Pa Pao and Mae Khachan, which cover parts of tambons Wiang and Mae Chai, respectively. Additionally, there are seven tambon administrative organizations (TAO) [18].

Advances in research have greatly enhanced scholars understanding of the relationship between climate change and air pollution management. Environmental researchers and the United Nations Environment Program (UNEP) have established a strong link between PM 2.5 air pollution and global warming. The growing body of evidence and data collected over the past five years in the north of Thailand demonstrate the escalating effects of climate change. The warmer and drier climate has particularly exacerbated the smoke and dust problem [20]. Additionally, it has been found that forest fires and PM 2.5 not only feed into each other, but also cause an increase in global temperature.

Burning maize stubble after the harvest, in preparation for the next planting season, is a practice that occurs during the dry season and contributes to both dust pollution and PM 2.5 emissions. These PM 2.5 emissions release a significant

Figure 3. Wiang Pa Pao (19˚22'0" North, 99˚30'0" East), elevation of 838 meters (Source: "Wiang Pa Pao").

amount of greenhouse gases into the atmosphere, thereby raising global average temperatures and exacerbating the impacts of climate change [21].

The study found that climate has a direct impact on the intensity of forest fires and PM 2.5 dust pollution. In northern Thailand, the effects of climate change are particularly severe. This suggests that the problem of forest fires and PM 2.5 dust pollution is likely to worsen in the future. While controlling greenhouse gas emissions is a challenging and complex task, it is important to address global warming by changing consumer behavior and reducing greenhouse gas emissions. This will help to preserve a clean and healthy environment for future generations [22].

5. Air Quality Monitoring Sensors of the Project

The King Mongkut's Institute of Technology, Ladkrabang's Excellence Center of Space Technology and Research (ECSTAR) has partnered with TeroSpace company on a project that seeks to accumulate long-term data for research purposes. The development of smaller, more affordable, and easily portable air sensors is thrilling news for those who desire to monitor local air quality. As a result, air sensors are utilized both inside and outside buildings in polluted areas to monitor air quality resulting from forest fires and crop burning. The sensors can transmit information to a cloud-based platform through various technologies, including cellular, WiFi, and LoRa [15].

The measurement of air quality through using air quality monitoring devices only provides information about the air pollution level at the specific location where the device is placed, and only during the time the measurement is taken. To obtain a comprehensive understanding of the air pollution status in a particular region, such as a city, province, or region, multiple monitoring sites are needed. The sheer volume of data generated by hundreds of thousands of monitoring stations presents a significant challenge for ensuring quality data. Effective management, processing, and sharing of air quality data requires an efficient strategy for archiving, retrieving, and disseminating the information. In this regard, cloud computing (CC) plays a crucial role [23].

The development of small and low-cost air monitoring sensors has the potential to address the limitations of traditional air monitoring technology. These lightweight sensors offer a number of advantages, including low cost, compact design, low power consumption, and the ability to be densely deployed. The project utilizes user-friendly tools that don't require technical expertise, making it easier for local residents to use them. These tools aim to increase community engagement and raise awareness about air quality. The success of the project will depend on the community's participation in collecting nearly real-time data that can be readily shared online [23].

In this project, the air quality monitoring devices are connected to the IQAir's AirVisual crowdsourced data system, which has revealed the air pollution present in various communities across the world. Upon deployment and connection to

the global cloud, community members become citizen data scientists, contributing air quality data to the world. Live air data from their communities can be viewed and acted upon by their friends, family, neighbors, and air quality advocates on a global scale [15].

6. The Future Work of the Project

ECSTAR and TeroSpace have been instrumental in networking in creating educational activities about space affairs and sustainable development to stimulate interest in young people. The first project was established at Wiang Pa Pao Technical College, Chiang Rai province. Here, young people learn about space technologies from academics and industry specialists and become fully aware of the impacts of climate change. This project is intended to become part of Thai national policy, including the United Nations on Climate Change.

TeroSpace is in the process of developing a cutting-edge Earth Observation Platform designed to serve a wide range of applications, both in government and private sectors. This platform is built using state-of-the-art Internet of Things (IoT) devices and wireless mobile networks that are integrated with advanced GPS tracking systems. The primary objective of the platform is to collect and analyze critical environmental data, using unprecedented accuracy and speed.

In the near future, TeroSpace intends to further enhance the capability of the platform by linking it to the Low Earth Orbit (LEO) IoT satellite constellation system. This will allow the platform to gather real-time data from a wider geographical area, including remote and inaccessible locations. By leveraging LEO satellites, the platform will be able to provide high-resolution data that can be used to support decision-making and policy-making processes related to environmental management and sustainability. As a highly advanced system, TeroSpace's Earth Observation Platform will play a crucial role in improving our understanding of the Earth's environment and how we can protect it. Furthermore, with its' IoT-based architecture and integration with LEO satellite systems, the platform has the potential to revolutionize the way we collect, analyze, and utilize environmental data.

The collaboration between ECSTAR and TeroSpace on this project aims to expand their partnership to include international organizations. In the future, we plan to collaborate with the Centre National d'Etudes Spatiales (CNES) to leverage their capabilities in providing access to satellite imagery and climate and weather information to improve decision-making in various areas of development, benefiting people in many countries across the globe. CNES, which stands for the French National Centre for Space Studies, is a government agency that specializes in space activities and plays a major role in France's space program, including the development and operation of satellites for Earth observation, climate and weather monitoring, and scientific research. Through this partnership, the project intends to integrate science and create practical products and tools to support informed decisions in the fields of smart agriculture, live-

lihoods, disaster management, and economic development [24].

According to the French Embassy in Thailand, the year 2023 is designated as, "France-Thailand Year of Innovation 2023 (YOI)". France hopes to develop its relationship with Thailand, its ally in the Indo-Pacific region, into a strategic partnership, in terms of transportation and space technology development. Therefore, the collaboration between France and Thailand for this project will be imperative in initiating and conducting this research project together [25].

7. Conclusions

The relationship between air pollution and climate change is complex and multifaceted. The impact of air pollution on the climate and the effects of the changing climate on air quality are not well understood, but research indicates that they are closely intertwined. The King Mongkut's Institute of Technology, Ladkrabang's Excellence Center of Space Technology and Research and TeroSpace have launched an initiative to explore the relationship between air pollution and climate change through air quality monitoring in Chiang Rai. This research is critical for policymakers as they work to address the challenges posed by air pollution and climate change.

Addressing both air pollution and greenhouse gas emissions is crucial to ensuring the health and well-being of people and the environment globally. The use of air quality monitoring devices, connected to a global data-sharing network, provides valuable data that can aid in the fight against air pollution and global warming. The management, processing, and sharing of air quality data requires efficient strategies, in which cloud computing plays a crucial role. The findings and data collected from this project will provide valuable insight into the impact of air pollution and climate change, and the precise steps that need to be taken to mitigate their effects.

In addition to discussing the sustainable growth initiative in Thailand's Chiang Rai province, this paper highlights international collaboration in the near future involved in the project. ECSTAR and TeroSpace's partnership aims to expand to include international organizations, such as CNES, to provide access to satellite imagery and climate and weather information that will enhance decision-making across various development sectors. Notably, the collaboration between France and Thailand for this project during the France-Thailand Year of Innovation 2023 is essential for its successful initiation and execution.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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