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Application of UAVs and Remote Sensing Technologies for Atmospheric CO2 Capturing: A Study Application of UAVs and Remote Sensing in CO2 Reductions

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Abstract: Human activities are a significant contributor to climate change, with rising levels of CO_2 in the atmosphere. Several carbon capture and sequestration (CCS) methods have been developed to address this issue. Uncrewed Aerial Vehicles (UAVs) and remote sensing technologies are emerging as significant improvements to the efficiency and effectiveness of atmospheric carbon capture initiatives. This research examines using UAVs and remote sensing technologies to monitor, quantify, and manage atmospheric CO_2 levels. Furthermore, the study explores the implications of integrating robotic-drone technology, emphasizing their ability to contribute to a sustainable future. These technologies, incorporating modern data collection and analysis methodologies, provide promising answers for climate change mitigation and long-term environmental sustainability.

Keywords: Unarmed Vehicles, Drones, Remote Sensing, CO2 Capture, Artificial Intelligence

Introduction

The recent enormously quick expansion of the energy and industrial sectors has resulted in a significant increase in stationary sources of CO2. As a result, many concerns have been expressed about preventing global warming and achieving climate mitigation policies by 2050 with a low-carbon and sustainable future (Dziejarski et al., 2023). According to the IPCC predictions, CO2 emissions must be net-zero between 2040 and 2060, or the average temperature rise will surpass the 1.5-2 °C maximum set by the Paris Agreement in 2015 (IPCC, 2018). The rising levels of atmospheric carbon dioxide (CO_2) due to human activities significantly contribute to climate change (Hou, 2024; Kang, 2024). To mitigate this issue, various carbon capture and sequestration (CCS) technologies have been developed (F. Jiang, 2023; Kafy, 2023). Uncrewed Aerial Vehicles (UAVs) and remote sensing technologies are emerging as powerful tools for enhancing the efficiency and effectiveness of atmospheric carbon capturing (Hong, 2023; Liu, 2023). Carbon capture and utilization

(CCU) is sequestering and reusing CO2. Unlike carbon capture and storage (CCS), CCU seeks to convert captured CO2 into more valuable goods such as fuels (methanol, syngas, biodiesel, and sustainable aviation fuel), polymers, and concrete (Bruening, 2023; Y. Wang, 2023). The development of CCU might dramatically reduce greenhouse gas emissions and help to address the global warming crisis (Liu et al., 2023). Carbon Dioxide (CO2) has been harming the environment and the entire planet. Nowadays, it is the primary driver of global warming and the greenhouse effect, posing a severe threat to the well-being of the planet's inhabitants, including plants, animals, and humans (Zhang et al., 2021).

This paper explores the applications of UAVs and remote sensing technologies in monitoring, measuring, and managing atmospheric CO_2 levels. The paper also expands beyond carbon capture and suggests the significance of implementing robotic-drone-oriented technologies for a sustainable future.

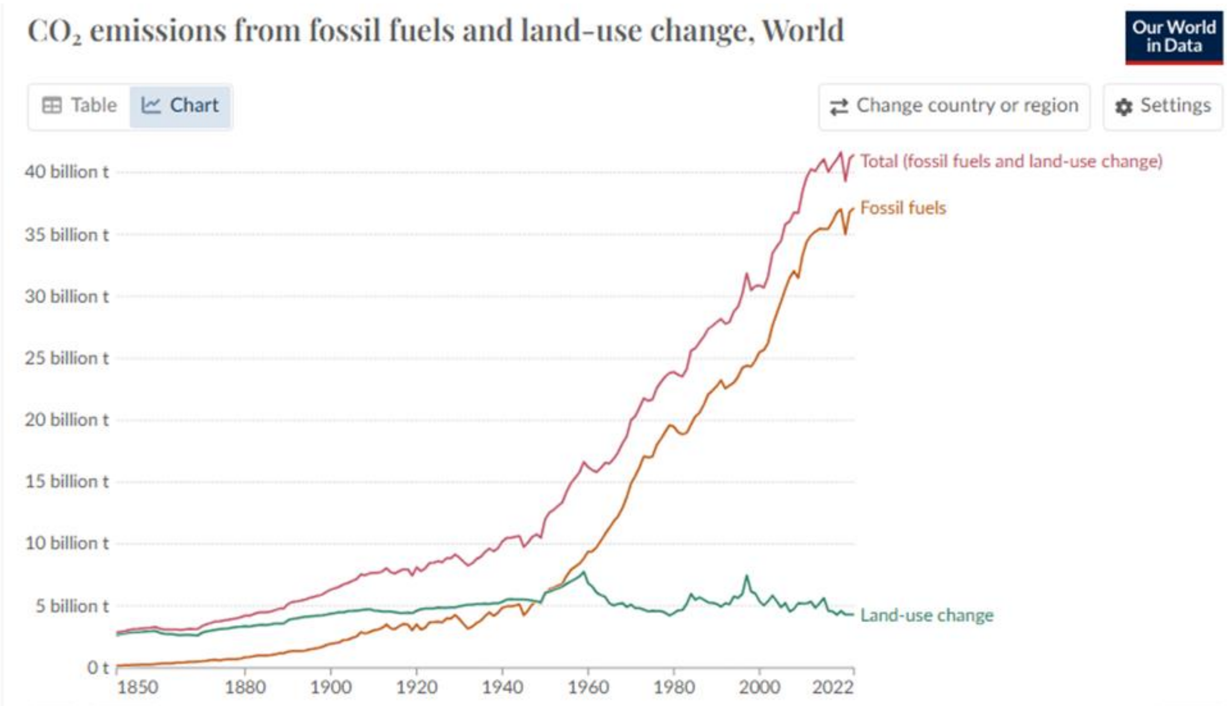

Figure 1. CO2 Emissions from Fossil Fuels and Land-use Change (adapted from ourworldinData)

Methods

The methodology deals with studying previous works and summarizing the procedures into methods that can later be applied to capture carbon CO2 from the atmosphere. Drone—and remote-sensing-based implementations of earlier works are studied and pointed out to contribute to the research field on carbon capturing-related unsolved practices.

We analyzed various reports of carbon capture and utilized analysis and studies to understand mitigation strategies for solving global issues of carbon emission-related hazards.

According to an article published in Moretrees.eco site, the issue is that carbon dioxide is throwing the greenhouse effect out of balance. Before the 1700s, the Earth successfully controlled the greenhouse effect, collecting solar energy while generating greenhouse gases consistently. Then, the Industrial Revolution occurred. Emissions of greenhouse gases, primarily carbon dioxide, have been constantly growing, putting the greenhouse effect out of balance (More Trees, 2023).

The significant hazards can be:

- Melting ice caps and warming oceans will cause sea levels to rise.
- Extreme weather events include heatwaves, torrential rains, and wildfires.
- Changes in where various wildlife populations can dwell and thrive disrupted access to food.
- Malaria and other infections are becoming more prevalent.

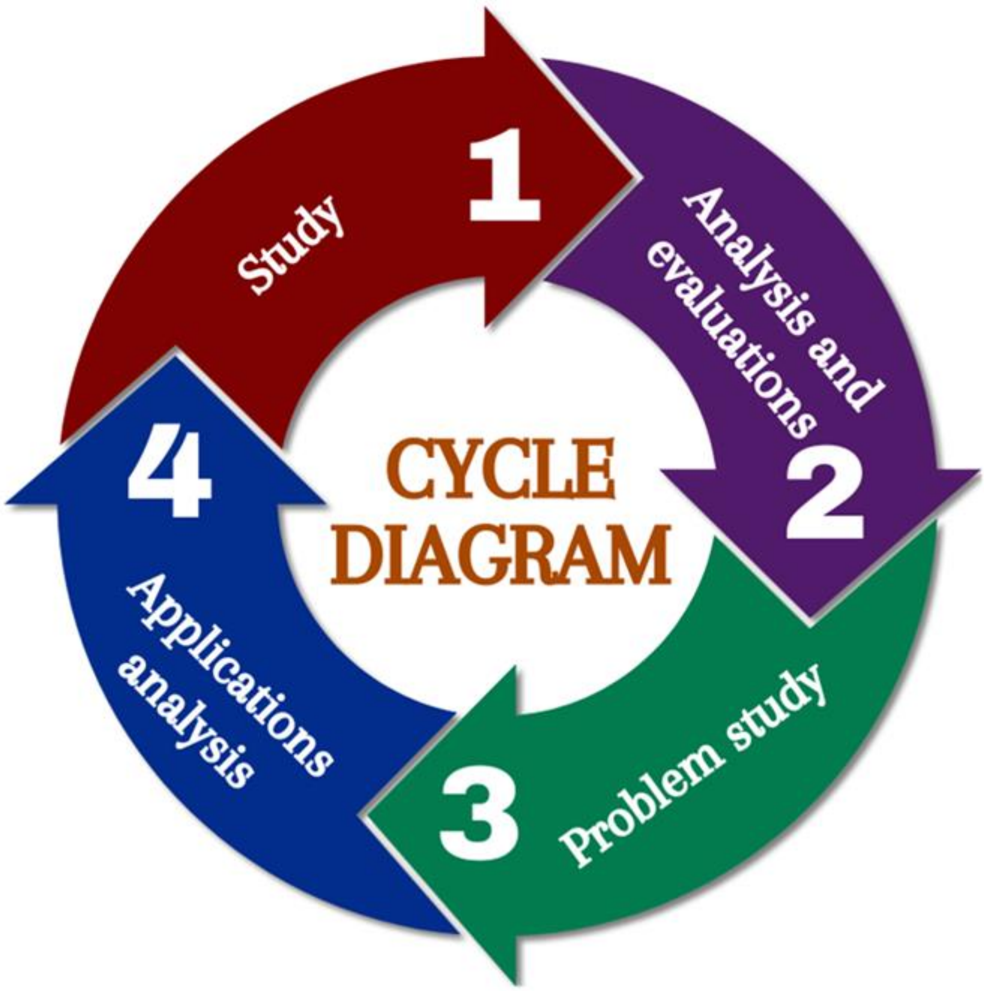

Figure 2. Proposed Strategy for Research

The methodology can be further elaborated with the cyclic diagram in Figure 2. We carry out the global carbon capturing problem, which is very rapid, and shall apply mitigations and strategies to halt or eradicate it. The analysis is carried out by studying works such as (Dziejarski et al., 2023; Liu et al. 2023; Ko et al., 2020) that utilized Machine learning models for sensor technologies as well as remote sensing-based techniques for carbon capturing and review of remote sensing practices further supported this research study to analyze the applications of the remote sensing and UAV based techniques for process of atmospheric carbon capture (Zhang et al., 2021). The analysis shows that remote sensing has a more significant application in carbon capture with the applications of sensors and image processing as well as different methods integrations (Ko et al., 2020).

Result and Discussion

The results have shown various applications of carbon capturing utilizing methods such as UAV and remote sensing, as well as artificial intelligence-based techniques. Systematic studies show that utilizing such technologies for carbon capturing can minimize the availability of different harmful effects (Liu et al., 2023).

UAVs in Carbon Capturing

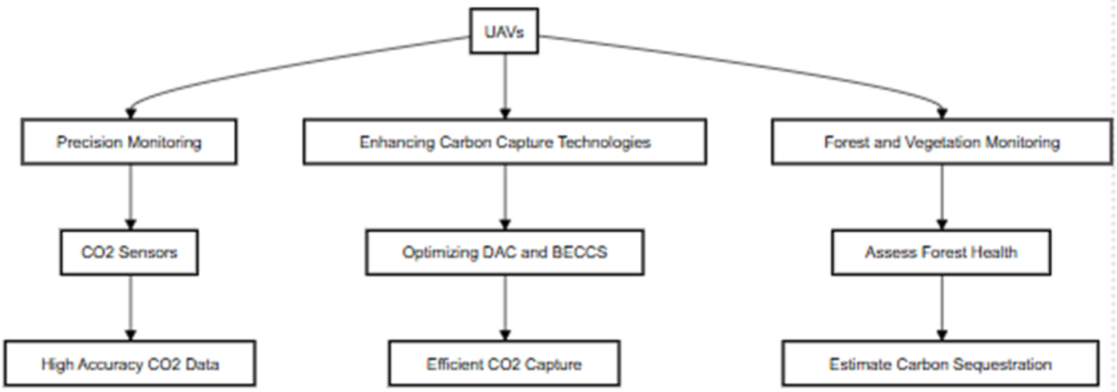

Figure 3. UAV in Carbon Capturing

Precision Monitoring

UAVs, or drones, have improved sensors that accurately detect CO_2 levels in the atmosphere. Sensors, including gas analyzers, LIDAR, and infrared cameras, can accurately detect and monitor CO_2 concentrations. UAVs can rapidly cover huge regions and give real-time data, which is critical for finding high-emission zones and evaluating the effectiveness of carbon capture activities.

Conventional CO2 sensors used to monitor CCS facilities are often costly and require professional maintenance. In this study, we created a portable, low-cost colorimetric CO2 sensor with high soil CO2 detection efficiency for CCS sites. The sensor comprises a detecting solution containing the pH indicator cresol red and enclosed in a gas-permeable membrane (Ko et al., 2020).

Enhancing Carbon Capture Technologies

Drones can support deploying and monitoring various carbon capture technologies, such as direct air capture (DAC) systems and bioenergy with carbon capture and storage (BECCS). By providing detailed data on atmospheric CO_2 levels, UAVs help optimize the placement and operation of these systems, ensuring maximum efficiency in capturing CO_2 from the air (Hemamalini et al., 2022).

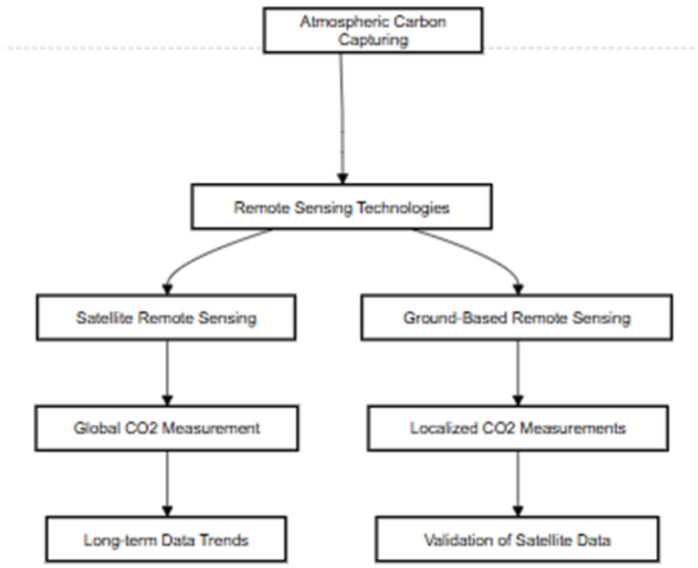

Figure 4. Atmospheric Carbon Capturing Phenomenon

Forest and Vegetation Monitoring

Forests contribute significantly to carbon sequestration. UAVs can track forest health, biomass, and carbon levels. Drone-generated high-resolution imagery can assess forest cover, detect deforestation, and quantify the carbon plants absorb. This information is critical for managing and preserving forests as carbon sinks (Hemamalini et al., 2022).

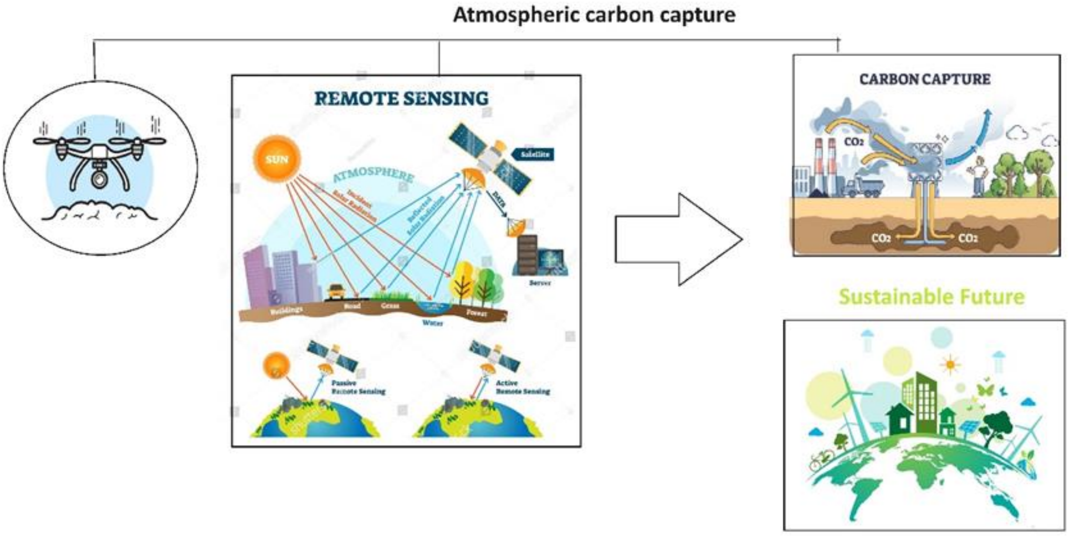

Figure 5. Illustration Highlighting Carbon Capturing using UAV and Remote Sensing

Remote Sensing Technologies

a. Satellite Remote Sensing

Satellites with remote sensing technologies offer a global view of atmospheric CO_2 levels. The Orbiting Carbon Observatory-2 (OCO-2) and the TROPOspheric Monitoring Instrument (TROPOMI) monitor CO_2 concentrations and their changes over time. These satellites provide continuous and long-term data, critical for understanding patterns and the global carbon cycle (Ko et al., 2020).

b. Ground-Based Remote Sensing

Ground-based remote sensing stations, such as those using Fourier-transform infrared (FTIR) spectroscopy, complement satellite data by providing high-resolution, localized measurements of CO_2 levels. These stations can validate satellite data and offer insights into regional carbon dynamics, especially in areas with significant human activity (Ko et al., 2020; Hemamalini et al., 2022).

Integration of UAVs and Remote Sensing

Integrating UAVs with satellite and ground-based remote sensing technologies enhances the overall capability to monitor and manage atmospheric CO_2 (Hemamalini et al., 2022). UAVs can be deployed for targeted observations in areas identified by satellite data as having high CO_2 concentrations. This multi-tiered approach ensures comprehensive coverage and more accurate data for carbon management strategies (Tong et al., 2019).

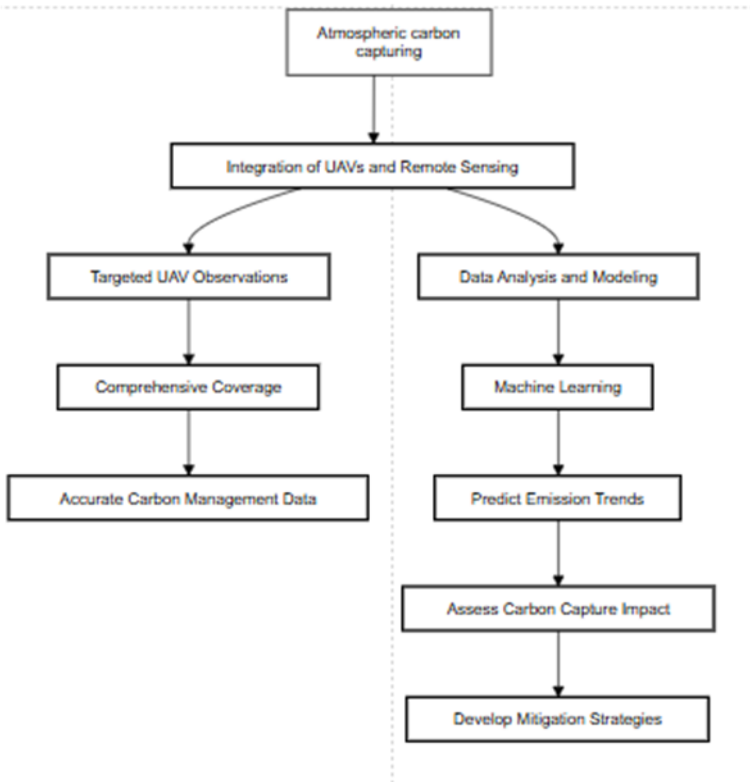

Figure 6. Carbon Capturing using Remote Sensing

Besides, image processing, machine learning implementation, and sensors allow the development of precise monitoring procedures for atmospheric carbon capture. This can be utilized for accurate measurements.

Data Analysis and Modeling

UAVs and remote sensing technologies capture massive volumes of data, which are then processed using advanced data analytics and modeling techniques like machine learning and artificial intelligence. These tools aid in projecting CO_2 emission patterns (Dziejarski, 2023), evaluating the effectiveness of carbon capture efforts, and devising climate change mitigation plans (IPCC, 2018; Gabrielli et al., 2020).

Different AI and machine learning algorithms can be implemented to forecast atmospheric conditions, similar to carbon production, utilizing data collected through remote sensing technologies. This can be expanded with remote live prediction of atmospheric conditions so that various atmospheric hazards, including CO2 capturing, can be done (Yao et al., 2023).

Challenges and Future Directions

Despite their potential, using UAVs and remote sensing technology to capture atmospheric carbon confronts several hurdles. These include technical limits, legislative barriers, and significant infrastructure and research expenditure requirements. Future advances in sensor technology, data processing capabilities, and international cooperation will be critical in overcoming these obstacles and fully realizing the benefits of these technologies. Advanced sensors can contribute to the precise detection of atmospheric CO2 release (Zhang et al., 2021).

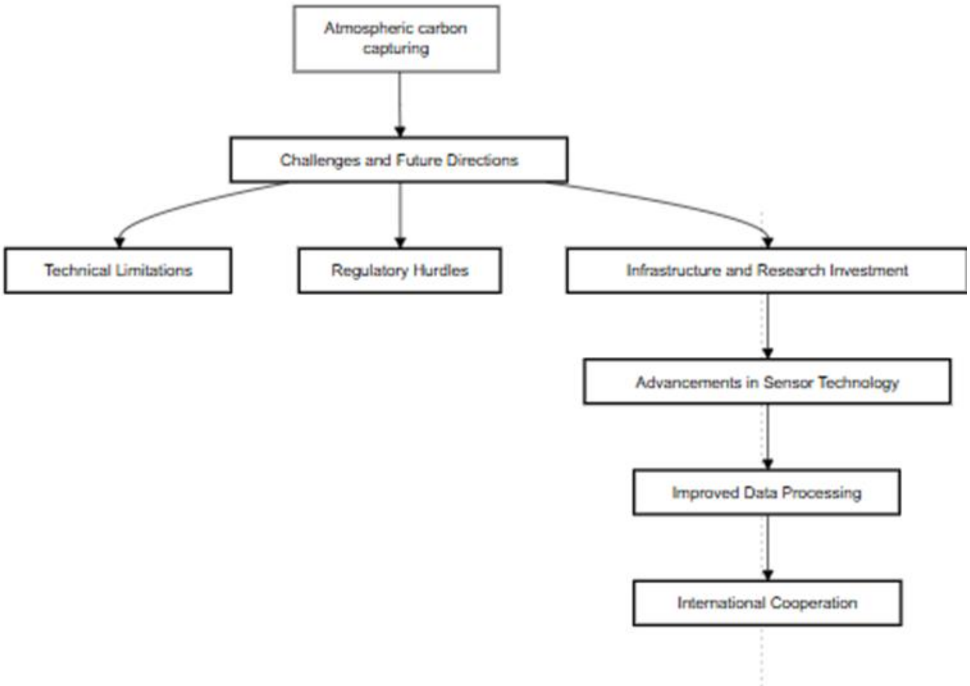

Figure 7. Challenges and Future Directions Representation in Diagram

Conclusion

UAVs and remote sensing technologies represent a promising frontier in the fight against climate change. By providing precise, real-time data on atmospheric CO_2 levels and supporting the optimization of carbon capture technologies, these tools are invaluable for managing and reducing global carbon emissions. Continued innovation and integration of these technologies will be essential for achieving a sustainable and carbon-neutral future.

Both satellite and ground-based remote sensing technologies provide global and localized views of atmospheric CO_2 levels, complementing UAV use. The integration of these technologies allows for complete coverage, guaranteeing that regional and global carbon dynamics are appropriately measured. Advanced data analytics and modeling improve our capacity to forecast emission patterns, assess the effectiveness of carbon capture programs, and create successful climate mitigation plans.

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