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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 major contributor to climate change, with rising levels of CO_2 in the atmosphere. To address this essential issue, several carbon capture and sequestration (CCS) methods have been developed. Unmanned Aerial Vehicles (UAVs) and remote sensing technologies are emerging as major improvements to the efficiency and effectiveness of atmospheric carbon capture initiatives. This research examines the use of UAVs and remote sensing technologies to monitor, quantify, and manage atmospheric CO_2 levels. Furthermore, the study explores the broader implications of integrating robotic-drone technology, emphasizing their ability to contribute to a sustainable future. These technologies, which incorporate modern data collection and analysis methodologies, provide promising answers for both 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 CO_2. As a result, many concerns have been expressed about the prevention of global warming and the achievement of climate mitigation policies by 2050, with a low-carbon and sustainable future (Dziejarski et al., 2023). According to the IPCC predictions, CO_2 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 are a major contributor 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). Unmanned Aerial Vehicles (UAVs) and remote sensing technologies are emerging as powerful tools in enhancing the efficiency and effectiveness of atmospheric carbon capturing (Hong, 2023; Liu, 2023). Carbon capture and utilization (CCU) is the process of sequestering and reusing CO_2. Unlike carbon capture and storage (CCS), CCU seeks to convert captured CO_2 into more value 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 (CO_2) has been inflicting harm to the environment and potentially the entire planet. Nowadays, it is the major driver of global warming and the greenhouse effect, posing a serious threat to the wellbeing 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 the carbon capture and suggests many kind of significance of implementing robotic-drone oriented technologies for sustainable future.

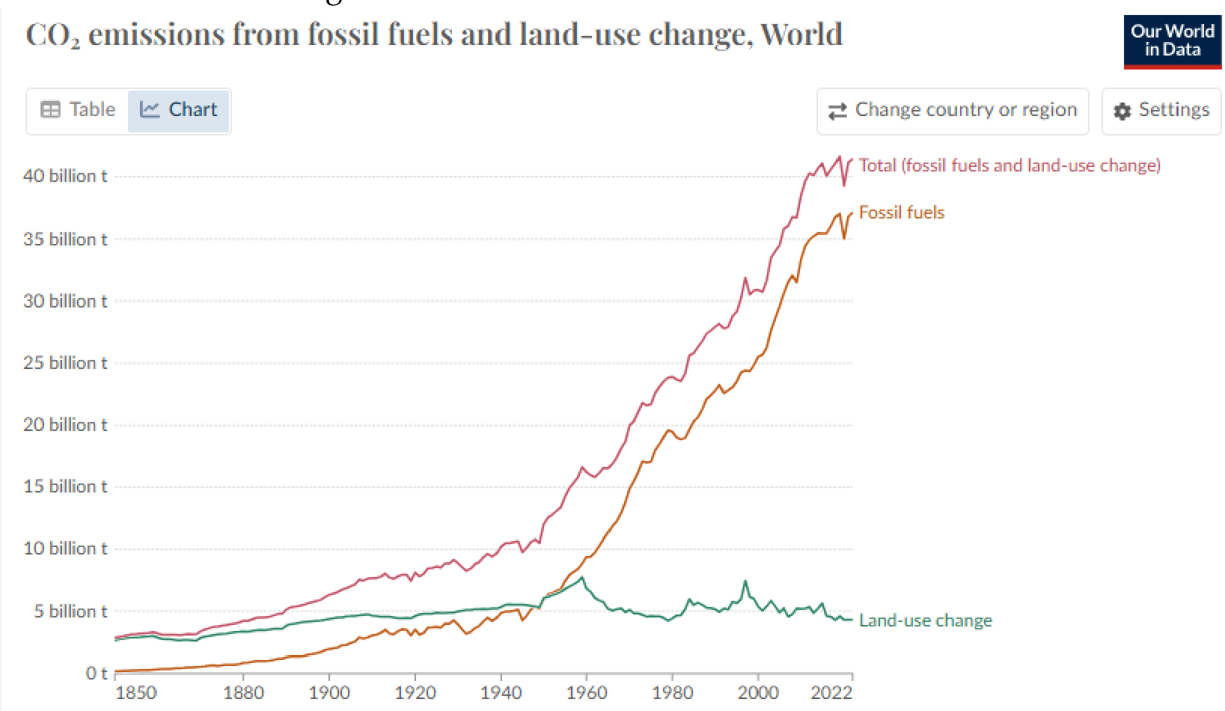

Figure 1. CO_2 emissions from fossil fuels and land-use change (adapted from: ourworldinData)

Literature Review

This paper provides a comprehensive evaluation of the literature regarding the CCUS system's problems that must be overcome in order to elevate numerous low TRL technologies and facilitate their commercial adoption. Finally, our research aims to inform the continued scaling up and formation of global CO_2 emission reduction initiatives (Dziejarski et al., 2023). This research intends to contribute to a very heated and topical debate by providing both a conceptual analysis and a quantitative comparative assessment of three potential technology chains (Kuttippurath, 2023; Pramulya, 2023). These three paths are widely regarded to be the only viable ways to a net-zero-CO_2 emissions (C-based) chemical sector (Gabrielli et al., 2020). This study focuses on the present development status, research hotspots, obstacles, and upcoming carbon capture, utilization, and storage (CCUS) systems. Solvent absorption technology is currently the most mature and frequently used CO_2 capture technique, with ionic liquid technology having promising application potential due to its molecular structure and ability to connect diverse functional groups (Liu et al., 2023). The purpose of this study was to identify CCUS supply chain hazards and create a conceptual framework (CF) that outlines a systematic approach to ensuring safe and reliable CCUS supply chain operations. As a result, this study reviewed the literature on SCs in several industries and identified SC hazards, which served as the foundation for CCUS SC risk identification (J. Jiang, 2023; S. Wang, 2023). This study shows that there is no research paper that gives a comprehensive CCUS SC risk management framework that is linked to risk management techniques (Liu et al, 2023). This study summarizes and discusses several remote sensing monitoring technologies, including their merits and limitations in applications, future development trends, and promising remote sensing monitoring systems for the safety of different CO2 injection stages (Zhang et al., 2021). In this study, the authors created a portable and low-cost colorimetric CO_2 sensor with high soil CO_2 detection efficiency for CCS sites (He, 2023; Hua, 2023; Yang, 2023). The sensor is made up of a detecting solution containing the pH indicator cresol red and enclosed in a gas-permeable membrane (Ko et al., 2020). This paper presented a detailed analysis of ML applications in CCS, drawing on classical ML approaches and major CCS research directions. The study found that machine learning (ML) algorithms such as artificial neural network (ANN) and convolutional neural network (CNN) were commonly employed, mostly for forecasting physical qualities, evaluating mechanical stability, and monitoring CO_2 plume migration and leakage during storage (Yao et al., 2023).

Our study applies the different previous studies and UAVs as well as remote sensing techniques studies-based methods to find out a solution for carbon capturing. Different figures and diagrams support the ideas for the study and methods include the analysis of sensors and remote sensing systems, drone, UAV's applied feasibility to determine the efforts these system can make for carbon capture process in atmosphere.

Methodology

The methodology deals with studying previous works and summarizing the procedures into the methods that can be later be applicated in order to capture carbon CO_2 from atmosphere. The drone as well as remote sensing based implementations on previous works are studied and pointed out in order 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 the mitigations strategies to solve such global issue of carbon emission related hazards.

According to article published in moretrees.eco site he issue is that carbon dioxide is throwing the greenhouse effect out of balance. Prior to the 1700s, the Earth was successfully controlling the greenhouse effect, collecting solar energy while generating greenhouse gases at a consistent rate. 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 major hazards can be:

- Melting ice caps and warming oceans will cause sea levels to rise.
- Extreme weather events, such as 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.

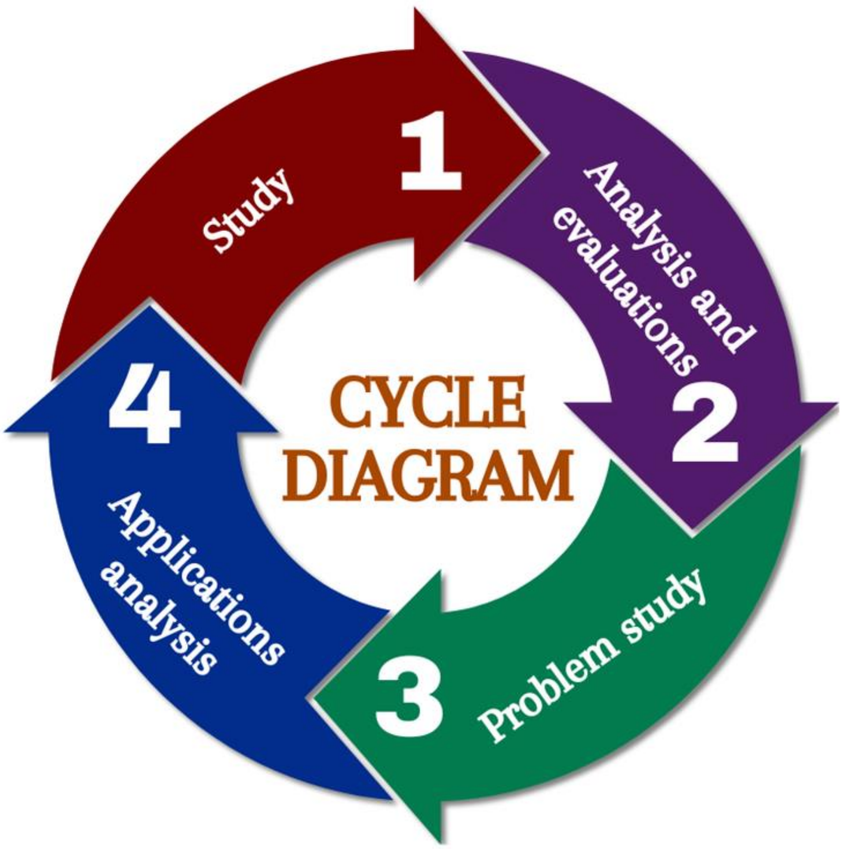

Figure 2. Proposed strategy for research

The methodology can be further be elaborated with the cyclic diagram as given in Figure 2. We carry out the global world carbon capturing problem [11] which is very rapid and shall be applied mitigations and strategies to halt or eradicate them. The analysis is carried out studying works as in (Dziejarski et al., 2023; Liu et al. 2023; Ko et al., 2020) that utilized Machine learning models to sensors 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 the remote sensing has a greater application in the carbon capture with the applications of sensors and image processing as well as different methods integrations (Ko et al., 2020).

Results and Discussions

The results has shown that there are various applications of carbon capturing utilizing the methods such as UAV and remote sensing as well as artificial intelligence based techniques. The systematic studies show that the availability of the various harmful effect can be minimized utilizing such technologies for carbon capturing (Liu et al., 2023).

UAVs in Carbon Capturing

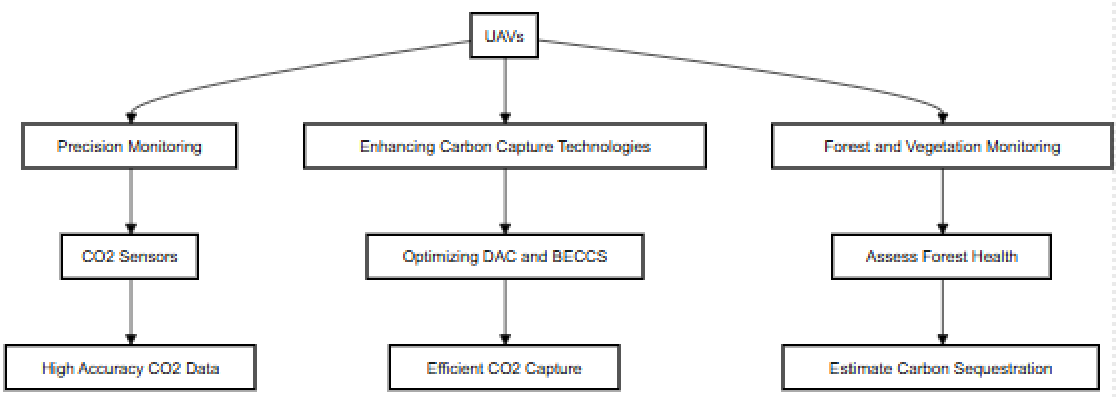

Figure 3. UAV in carbon capturing

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 CO_2 sensors used to monitor CCS facilities are often costly and require professional maintenance. In this study, we created a portable, low-cost colorimetric CO_2 sensor with high soil CO_2 detection efficiency for CCS sites. The sensor is made up of 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 the deployment and monitoring of 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).

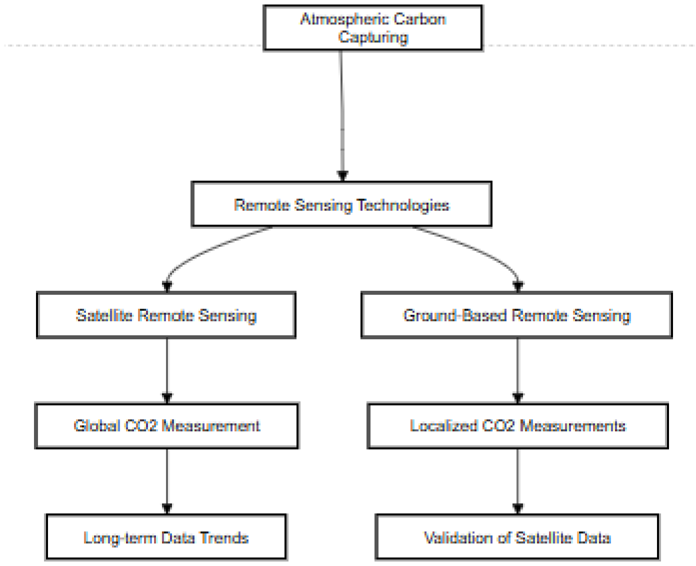

Figure 4. Atmospheric carbon capturing phenomenon

Forest and Vegetation Monitoring

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

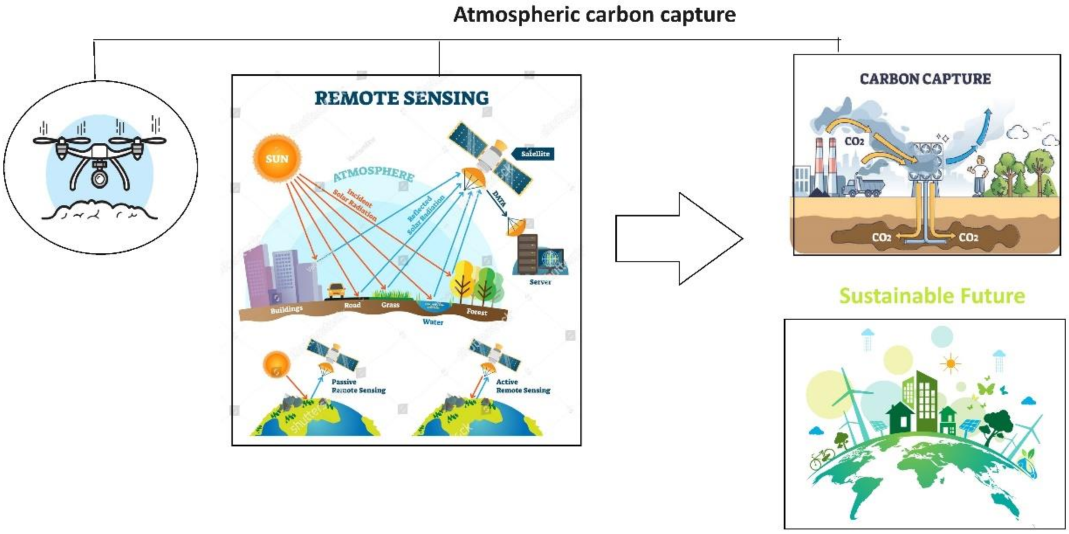

Figure 5. Illustration highlighting Carbon capturing using UAV and remote sensing

Remote Sensing Technologies

i. 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, which is critical for understanding patterns and the global carbon cycle (Ko et al., 2020).

ii. 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

The integration of 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).

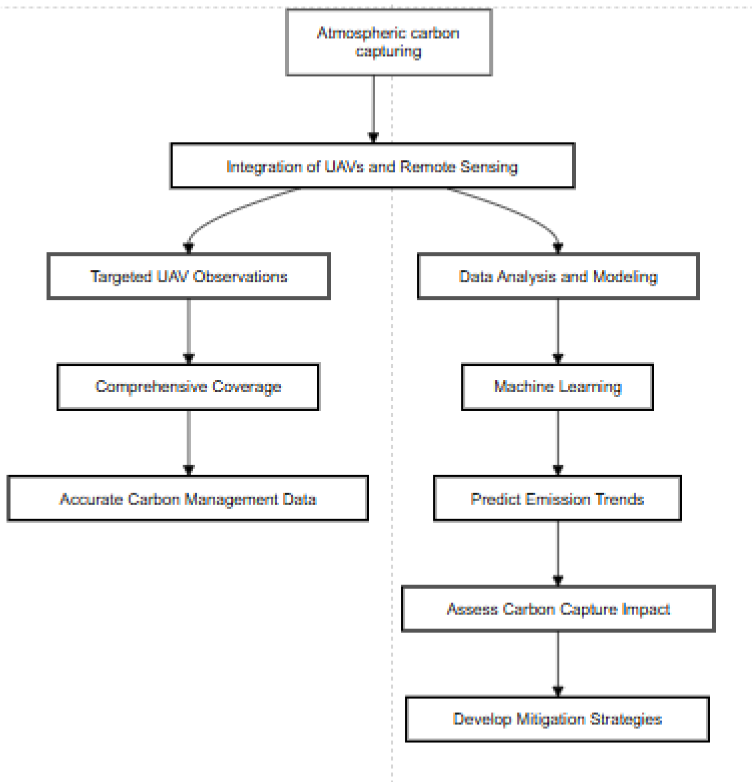

Figure 6. Carbon capturing using remote sensing

Besides, image processing and machine learning implementation along with sensors allows the development of precise monitoring procedures for atmospheric carbon capturing. This can be utilized for the purpose of the precise.

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 the atmospheric conditions similarly, 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 CO_2 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 a number of hurdles. These include technical limits, legislative barriers, and the requirement for major infrastructure and research expenditure. 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 on precise detection of atmospheric CO2 release (Zhang et al., 2021).

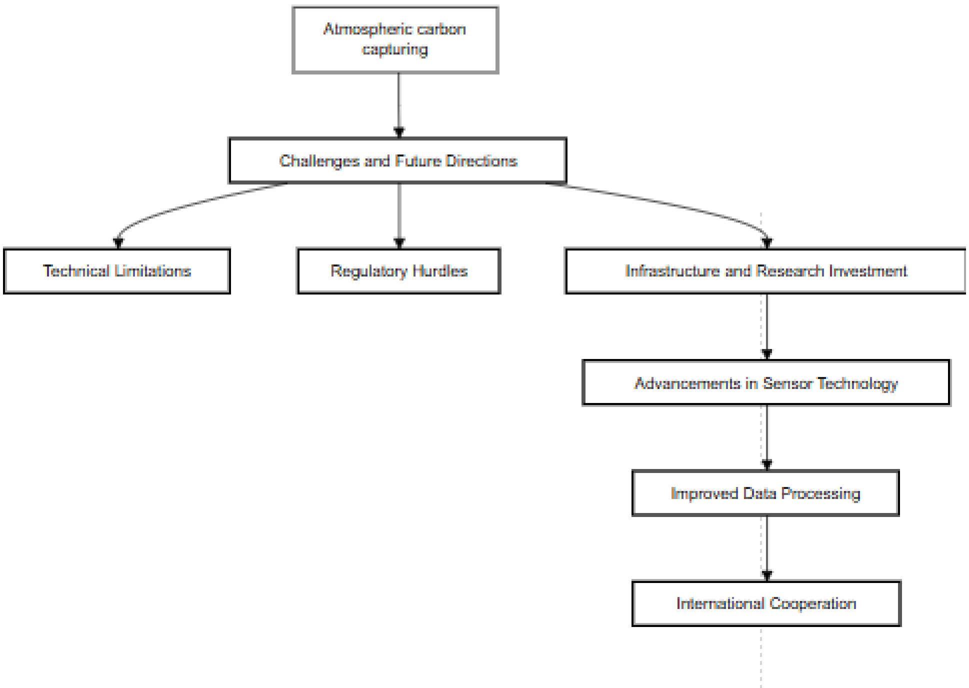

Figure 7. Challenges and future directions representation in diagram

Conclusions

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.

Remote sensing technologies, both satellite and ground-based, 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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