

REGULATING ANTHROPOGENIC EMISSION OF GREENHOUSE GAS IN THE AFOLU SECTOR BY REDUCING EMISSION FROM DEFORESTATION AND FOREST DEGRADATION

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ABSTRACT

The Agriculture, Forestry, and other Land Use (AFOLU) sector is responsible for a significant amount of global greenhouse gas (GHG) emissions. Ensuring that the global mean temperature should be less than 2°C by 2030 above pre-industrial level is being advocated by the United Nation Framework Convention on Climate Change (UNFCCC). This has led to the emergence of 'Reducing Emission from Deforestation and forest Degradation plus forest carbon conservation, sustainable forest management, and enhancement of forest carbon stocks (REDD+)'. The UNFCCC instituted the REDD+ as a global payment system to discourage GHG emission from the forest sector. The aim of this study is to review articles on the United Nations' REDD+ initiative to control human-induced GHG emissions in the AFOLU sector. The study was started with a literature search of papers that were published between 2015 and 2024. A total of 2,735 papers was retrieved of which only 38 satisfied the inclusion requirements for the review. The included papers were thoroughly read, analysed, and discussed in detail. Particularly, the author reviewed AFOLU; REDD+; Monitoring, Reporting, and Verification (MRV), Remote Sensing and Geographic Information Systems (GIS) for MRV; as well as the economic significance of REDD+. Summarily, it was concluded that the REDD+ has significant positive implication for many countries, reduction of GHG emissions, and climate change mitigation.

Keywords: Carbon emission, carbon market, forest biomass, LULC, REDD+

INTRODUCTION

The major topical scientific debates have predominantly focused on the causes and effects of global warming and climate change as they are severe ecological problems due to their profound global impacts. Climate change results

from excessive emission of GHGs into the atmosphere (Sarfraz, 2024), which have made the concentrations of the gases in the atmosphere to increase significantly in the 20th century. The main gases that form part of the GHGs comprise carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) (Zheng et al., 2019; Sparrevik & Utstøl, 2020). The rising emissions of GHGs have been linked to many factors, especially, agriculture and deforestation. Thus, the Agriculture, Forestry, and Other Land Use (AFOLU) sector attracts important considerations in climate change policies. Some of the major factors of GHGs emission in the AFOLU sector are management of agricultural lands, forests, wetlands, land use and land cover change (LULCC).

The LULCC comprise afforestation and the transformation of forest and grassland to cropland and pasture. The AFOLU-related events can give rise to both sources and sinks of CO₂ usually from forestry and changes in land use (Tubiello et al., 2013). This is coupled with non-CO₂ agro-based emissions including CH₄ from livestock and rice cultivation, N₂O from manure storage, agricultural soils, and burning of biomass. In the future, the AFOLU-based emission is expected to increase in developing nations as food production and land conversions will certainly increase (Pradhan et al., 2019). Of course, this certainly calls for urgent attention or action.

The REDD+ mechanism is a collaborative tool used to ensure low emissions of carbon dioxide through reducing deforestation and forest degradation. In this case, financial incentive is used to encourage the avoidance of deforestation and forest degradation in developing nations. With this, the emission of GHG is reduced in many countries through independent or collaborative efforts; which in turn, reduces the damaging effects of climate change. Such international actions greatly depend on the assessment of carbon stocks and forest biomass, especially in the AFOLU sector. Of course, GHG emissions can be reduced with the AFOLU sector by 0.4 to 5.8 Gt CO₂-eq year⁻¹ through reduced deforestation and forest degradation (Intergovernmental Panel on Climate Change [IPCC], 2019).

MATERIALS AND METHODS

The main purpose of this paper was to review the literature on reducing emissions from deforestation and forest degradation towards limiting anthropogenic Greenhouse gas emissions in the AFOLU sector. A systematic review normally involves certain stages (Muka et al., 2020) to reduce bias, and generate robust as well as dependable conclusions. Therefore, four progressive phases of the systematic method were used to retrieve relevant document including identification, screening, eligibility determination, and exclusion/inclusion of papers (Page et al., 2021). This approach is significant as it is transparent and allows for replication of the study.

The identification phase involved a literature search based on relevant keywords and search terms (Avenalia et al., 2023), including "Greenhouse gas emissions," "AFOLU," and "REDD+". These search terms were used to find scientific journal articles in the Google Scholar and Scopus databases. Scopus is a global database of peer-reviewed articles that provides thorough and reliable records (Harzing & Alakangas, 2016; Perevochtchikova et al., 2019; Zhu & Liu, 2020). The Google Scholar is similar to Scopus, but it is characterized by a more inclusive and detailed content. However, it is not well characterized by disciplines, document types, countries, and languages (Pranckutė, 2021). Thus, its sophisticated search

engine covers citations that are not covered by other databases (Yang & Meho, 2006). By integrating keywords using the Boolean operator "AND" between the chosen keywords, the articles gathered by these databases were identified.

After locating the assigned manuscript, we used the excel spreadsheet for explicit recording of the title, abstract, keywords, year of publication, journal name, source title, digital object identifier (DOI), and citation. With this approach, a total of 2,735 scholarly articles were generated. The papers passed through a first-level screening by two investigators who are experts in systematic reviews with focus on the titles and abstracts of the publications (Dekkers et al., 2019; Van Elswyk et al., 2022). Also, a third investigator who is an expert in the subject matter was involved independently (Teo et al., 2023). All duplicate papers were removed, then, we chose the appropriate studies carefully to be used for full-text screening based on a cautious review of their abstracts.

Many references that require further screening resulted from the bibliographic searches. Thus, search results were appropriately arranged for eligibility screening (Frampton et al., 2016). To do this, the eligibility requirements that defined the main studies in the searches were outlined (Higgins et al., 2016). In this stage, the articles that were obtained were examined to ensure that they met the requirements. Of course, papers that did not align with the study's primary goal were expunged before further analysis of the papers.

The exclusion/inclusion phase was used to examine the viability of previously published papers. Also, other papers were removed for remarkable reasons including inadequacy of text, duplication of papers, absence of summaries, or lack of relevance. Furthermore, exclusion/inclusion criteria were developed (table 1) to safeguard the researchers from likely biases that can affect the results. Papers that met the inclusion criteria for further analysis and content assessments were selected using these criteria.

Table 1: Selection of literature using inclusion and exclusion criteria

Criteria	Decision
Only papers written in English and published between 2015 and 2024	Included
Papers dealing with GHG emissions, AFOLU, and REDD+	Included
Document that is in harmony with the research aim	Included
Research articles and technical reports	Included
Document available in Scopus, and Google Scholar	Included
Papers that are duplicated within the search documents	Excluded

RESULTS AND DISCUSSION

Search Result

After the literature search, we identified a total of 2,735 records. However, unsuitable documents were removed. These included such as gray literature, extended abstracts, presentations, keynotes, book chapters, non-English language papers, and inaccessible publications. This eventually reduced the number of articles to 1,517. Furthermore, the screening process culminated in reducing the number of filtered articles to 728. The papers were further evaluated, which yield a total of 131 papers that fulfilled the eligibility criteria. Also, duplicated papers and articles that lack clear relevance to the topic being studied (i.e., regulating anthropogenic emission of GHGs in the AFOLU sector by REDD+) were

manually removed during the main body reading. In the end, 38 publications (31 peer-review articles and 7 technical reports) that fulfilled all the inclusion criteria were retained and used in this review. The review procedure is depicted in figure 1.

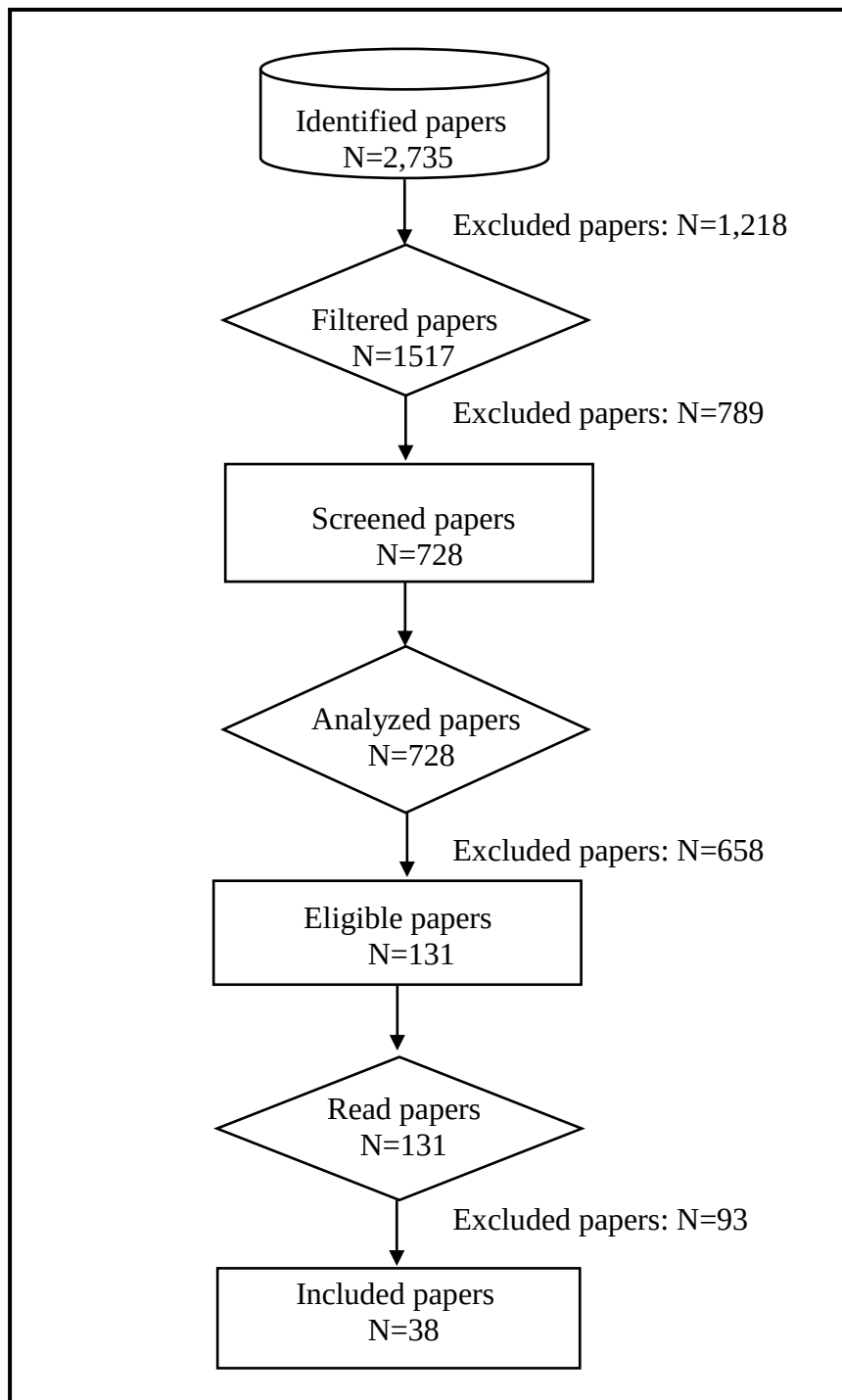


Figure 1: The flow diagram of the review.

It is noteworthy that the articles used for the final review consisted of 1.39% of the original

articles in the databases. Thus, it was concluded that this review employed a larger sample compared to the earlier review by Yang et al. (2018) in which 0.7% of the original articles in the databases were used.

Significance of the AFOLU Sector

Carbon sink can result from biomass sequestration, afforestation, agriculture, forestry, and other land uses. Plants absorb nitrogen (N) from the soil and CO₂ from the environment as they grow. Also, AFOLU activities contribute to CO₂ sources due to many situations such as peatland drainage and deforestation. The AFOLU sector also causes the release of non-CO₂ gases, mostly from agriculture, including CH₄ from cattle rearing and rice, N₂O from storing manure, and N₂O from burning biomass and agricultural soils.

By and large, the AFOLU sector is a significant part of human-induced GHG emissions. It is reported by Kreibiehl (2022) to be responsible for 20% to 25% of net global GHG emissions. Thus, it is important in the process of achieving the 2 °C or 1.5 °C global temperature targets set by the Paris Agreement. Of course, the AFOLU will lessen the emission of GHG by 8.3 to 9.1 GtCO₂-eq year⁻¹ in 2050 (Roe et al., 2019; Henderson et al., 2021). It is a unique sector as it can decarbonize beyond the mitigation of emission sources. This can be attained by increasing carbon sink and replacing fossil fuel with bioenergy (IPCC, 2015). The AFOLU sector is the only sector that has the capacity of bulk negative emissions (IPCC, et al., 2018). According to Rogeji (2018), producing negative emissions in most scenarios at 1.5 °C requires more than 1% of Earth's land surface for supporting Carbon Dioxide Removal (CDR) technologies. Yet, this alternative to CDR often overestimates their potential for negative emissions (Heck et al., 2018) and is expensive (Smith, et al., 2016). Conserving existing carbon sinks by reducing deforestation, forest degradation, and loss in peatlands is another important strategy for carbon sequestration in the AFOLU sector (IPCC, 2019). The reason is that both forests and peatlands are imperative sources of CO₂ emissions (Tubiello et al., 2015). Six categories of AFOLU activities have been reported in the literature as highlighted in Table 2.

Table 2: Different categories of AFOLU activities (Source: Zeleke et al., 2016)

Category	Examples
Agriculture management	Crop and livestock management, climate-smart agriculture, conservation agriculture, agricultural intensification, soil conservation.
Afforestation and reforestation	Agroforestry, tree planting, revegetation, drought-resistant forest species, national reforestation programs, assisted and natural regeneration.
Forest management	Sustainable forest management, fire management, ecosystem resilience activities, land management, reduced logging.
Deforestation and degradation avoidance	Fighting desertification, management of pastoralism, forest protection and conservation, management of protected areas and national parks, dune fixation.
Bio-energy	Energy crops, solid waste, liquid waste, biogas, residues, improve firewood and charcoal stoves.
Wetland restoration and conservation	Protection of river basins, lakes, watersheds, coastal adaptation, mangrove conservation, coastal zone management.

The Role of UN-REDD+ Initiative

Though the energy sector is the largest source of carbon emissions to the atmosphere, it is followed by deforestation and forest degradation (Friedlingstein et al., 2023). Thus, climate change can be reduced by forest establishment and expansion, forest conservation, and sustainable forest management (Kreibiehl, 2022). The REDD+ was created to manage emissions from the forestry sector (Chand et al., 2021), and it has garnered significant support from both developed and developing countries (Streck, 2016). It is concerned with global action plans and sustainable solutions (Kumar et al., 2021) with an emphasis on biodiversity conservation, climate change mitigation, and others (Milbank et al., 2018).

The REDD+ is characterized by apparent gain to both the developed and the developing nations. Of course, the developed nations can reduce the emission of GHG at a low cost through the REDD+ while the developing nations can get financial incentives to reduce emissions from the forest sector. The implementation of REDD+ is a function of multilevel governance and multiple stakeholders (Shin et al., 2022). In other words, at the heart of REDD+ project is the relationship among different actors under the global forest and climate change framework. For instance, recipients get financial and technical assistance from donors (either developed countries or international organizations).

MRV For REDD+ Implementation

As mentioned earlier, the REDD+ offers developing nations incentives to reduce GHGs emissions. Implementing REDD+ requires a verified proof of emissions reduction through Measuring, Reporting, and Verifying (MRV). Thus, the phrase "results-based payment" is also employed (Angelsen et al., 2018). There are guidelines and regulations for REDD+

design and implementation, as well as MRV for GHG emissions and removals (Voigt and Ferreira, 2015). The MRV measures changes in the carbon stocks expressed in tons of CO₂ equivalents. Establishing and empowering MRV framework is of great importance in the forest sector as nations may use internationally transferred mitigation outcomes based on principle of cooperation (Kim et al., 2021). In this regard, international support is imperative for consolidating the MRV capacities of a poor nation for the REDD+ programme. Thus, evaluating MRV competences and comprehending the implementation status for each REDD+ nation will go a long way to ensure successful technical and financial cooperation. A reputable national MRV scheme is essential for assessing the results of REDD+ activity. Such system typically entails the establishment of institutional frameworks for defining the roles and duties of stakeholders. In the majority of developing nations, this calls for:

- i. an understanding of the requirements of MRV system
- ii. an assessment of the existing capacity to implement MRV
- iii. identifying and implementing steps needed to build a sustainable MRV system

Remote Sensing and GIS Methods to Support MRV

Forest inventories have been the most accurate source of data for computing the forest above-ground biomass (AGB) and carbon stocks (Clerici et al., 2016). Regrettably, the conventional field-based forest inventories are sometimes subjective, time-consuming, and often too expensive (Ibarrola-Ulzurrun et al., 2019). Thus, remote sensing data can be used to add information to the conventional method as remote sensing provides indicators for various spatiotemporal scales and involves varying temporal revisit frequencies. With remote sensing, it is possible to detect and measure the various biophysical aspects of plant growth (Chong et al., 2017). Many remote sensing systems and specifications are available including passive (e.g., thermal and optical) sensors and active (e.g., LiDAR and Radar) sensors. Optical satellite data from the SOPT and IKONOS can generate stereo view of the forest. Thus, they are used for developing forest canopy height as well as AGB and carbon stocks assessment. Also, thermal data such as those from MODIS and Sentinel satellites (particularly in the Sentinel-3 mission) are commonly used for AGB and carbon stocks assessment. Furthermore, the LiDAR and Radar data have unique advantages in terms of their ability to penetrate tree canopy. They are therefore suitable for measuring tree height, which is a potential indicator for measuring the age of trees and also for estimating forest biomass.

Additionally, Geographic Information Systems (GIS) is used for the analysis and modeling of georeferenced data. It is crucial for spatial planning (Gašparovič & Gašparovič, 2019). Thus, it enables forest management and creation of spatial models of different scenarios. GIS is notable by its capacity to combine various data types (Hiller & Yambaev, 2016). According to Andreev (2020), it aids in the timely collection, visualization, and prediction of ecological data. The integration of remote sensing and GIS models serves as a powerful tool for solving complex and diverse ecological problems. Specifically, it has been used in recent forest biomass inventories to improve the results. Of course, the technique is highly effective for mapping and tracking the distribution of forests on a wide scale as well as measuring their production (Iizuka et al., 2017).

Economic Significance of REDD+ Programme

The creation of REDD+ was with the hope of mitigating the effects of climate change at a relatively modest cost (Golub et al., 2018). The United Nation Framework Convention on Climate Change use global carbon market to support the carbon offset program and thereby discourages deforestation and forest degradation. According to Van der Gaast et al. (2018), internationally transmitted mitigation outcomes qualify forest-related carbon trading. Of course, a country that has evidence of a reduction in greenhouse gas emissions through avoided deforestation and forest degradation can sell the avoided carbon emissions as carbon credits on the international market.

With a well-implemented REDD+, climate change mitigation and additional co-benefits (such as biodiversity protection, poverty reduction, and climate change adaptation) could be attained (Milbank et al., 2018; Morita & Matsumoto, 2017). Utilizing various strategies including results-based finance and voluntary carbon markets to implement REDD+ requires bilateral and multilateral financing, public and private, and local and international efforts. Financing is a crucial component of REDD+ implementation. Unfortunately, little is known about the features of REDD+ finance, its governance, and the complications as well as lessons encountered in creating successful REDD+ finance. Previous research on REDD+ finance has focused on specific funding sources or financing for particular programmes (e.g., Sheng et al., 2016; Recio, 2019; Correa et al., 2019; Schroeder et al., 2020; Ken et al., 2020; Brown & Maclellan, 2020).

Though REDD+ is highly advantageous as a market-based strategy, it is contested (e.g., Boucher, 2015) in the context of the larger debate over the practicality of market-based conservation (Fletcher et al., 2016). Some people criticize the commodification and marketization of standing forests while others' perspective is that market-based finance through carbon markets is an expensive way to reduce emissions.

CONCLUSIONS

This paper reviewed the United Nations' REDD+ strategy for mitigating anthropogenic greenhouse gas emissions in the Agriculture, Forestry, and Other Land Use sector. It is critical to limit the increase in average global temperature to well below 2°C above pre-industrial levels by 2030. To achieve this requires effort to reduce emission of GHGs into the atmosphere. Such efforts can be achieved through the REDD+ mechanism. The REDD+ within the context of the AFOLU sector has been a major contributing factor in the effort to reducing GHG emissions and mitigating climate change. It is also obvious that the REDD+ offers economic benefit, especially, to the developing countries. Finally, the findings in this review are expected to be valuable to scholars, students, and other stakeholders engaged in climate change research and policy.

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