

Review of published LCA Studies in a Developing Country: Case of Cameroon



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Abstract

Developed in the sixties, Life Cycle Assessment (LCA) gained attention around the world as environmental impact methods calculation. It's application in Cameroon has received significant attention from both industry and research communities since the mid-2010s. This paper, aims to assess the current status of LCA published research conducted in Cameroon. The methodology was conducted using Scientific research websites and scientific journals databases with keywords such as "Life Cycle Assessment", "LCA", "Cameroon", "Life cycle analysis"; then, Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) method was followed for the selection and analysis of the found papers. 16 LCA related studies with applications in Cameroon were found between 2010 and 2023. These studies focused on various sectors: construction (18.8%), bio - energy (18.8%), electricity (12.5%), waste management (6.3%), agriculture (18.8%), forest management (12.5%), Energy (6.3%) and other sectors (6.3%). The majority of these studies were conducted at the Yaounde I University, involving researchers from the National Advanced School of Engineering. Furthermore, none of the studies addressed economic/social life cycle assessment or life cycle costing. These aspects of LCA, which examine economic and social dimensions, are essential for gaining a comprehensive understanding of sustainability, particularly in developing countries like Cameroon.

Keywords: Cameroon; LCA database; LCA; PRISMA; Energy efficiency

Abbreviations: LCA: Life Cycle Assessment; PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analysis; LCI: Life Cycle Inventory

Introduction

Life Cycle Assessment (LCA) is a standardized method for evaluating the environmental impacts of products and services throughout their entire life cycle, from design to disposal as defined by a set of ISO norms [1-7]. It enables the calculation of the environmental footprint of products and services considering various stages such as manufacturing, transportation, use and end-of-life [5,8-10]. In the past two decades, the utilization of LCA has been steadily increasing in developing countries [11,12]. This adoption has the potential to enhance the attractiveness of products and services from these countries in the global market [5]. While financial support, technology, and technical assistance are important factors in implementing LCA in industrial activities, developing countries have recognized its pivotal role in their industrial practices [13,14]. Cameroon, known as the breadbasket

of Central Africa, faces various management challenges. Additionally, Cameroon aims to become an economic leader in the subregion. In line with this objective, the country has been actively engaged in Life Cycle Assessment (LCA) research and application since 2010 [15]. The objective of this article is to review the research conducted in the field of LCA in Cameroon. It seeks to highlight the most studied areas and track the evolving interest in the application of this method by the scientific community. This analysis will allow us to identify gaps and potential areas where LCA studies can provide substantial added value to the country's economy.

Materials and Methods

To conduct this work, that was mainly about collection, screening and analyzing selected documents found, we relied on

Scientific research websites such as google scholar and scientific journals databases such as the Science Direct and Scopus for data collection. Specific search queries were used such as “life cycle assessment,” “life-cycle assessment,” “LCA,” and “Cameroon” to retrieve relevant documents. We also employed variations of these search terms, including “Life cycle assessment” OR LCA OR “Life cycle analysis” “in Cameroon” “of Cameroon.” The time frame for our search spanned 23 years, from 2000 to 2023.

To screen the gathered documents, we followed the Preferred Reporting Items for Systematic Review and Meta-Analysis

(PRISMA) method. PRISMA is an evidence-based minimum set of items aimed at helping scientific authors to improve the reporting of systematic reviews and meta-analyses [16]. Thus, non-peer-reviewed journal papers, conference papers, PhD and master’s thesis were systemically excluded as illustrated in the PRISMA flowchart presented in figure 1. Our study focused on case studies conducted in Cameroon, either by Cameroonian researchers or researchers from other countries, as indicated in the publications. These methods allowed us to collect, screen, and analyse relevant documents to conduct our research effectively (Figure 1).

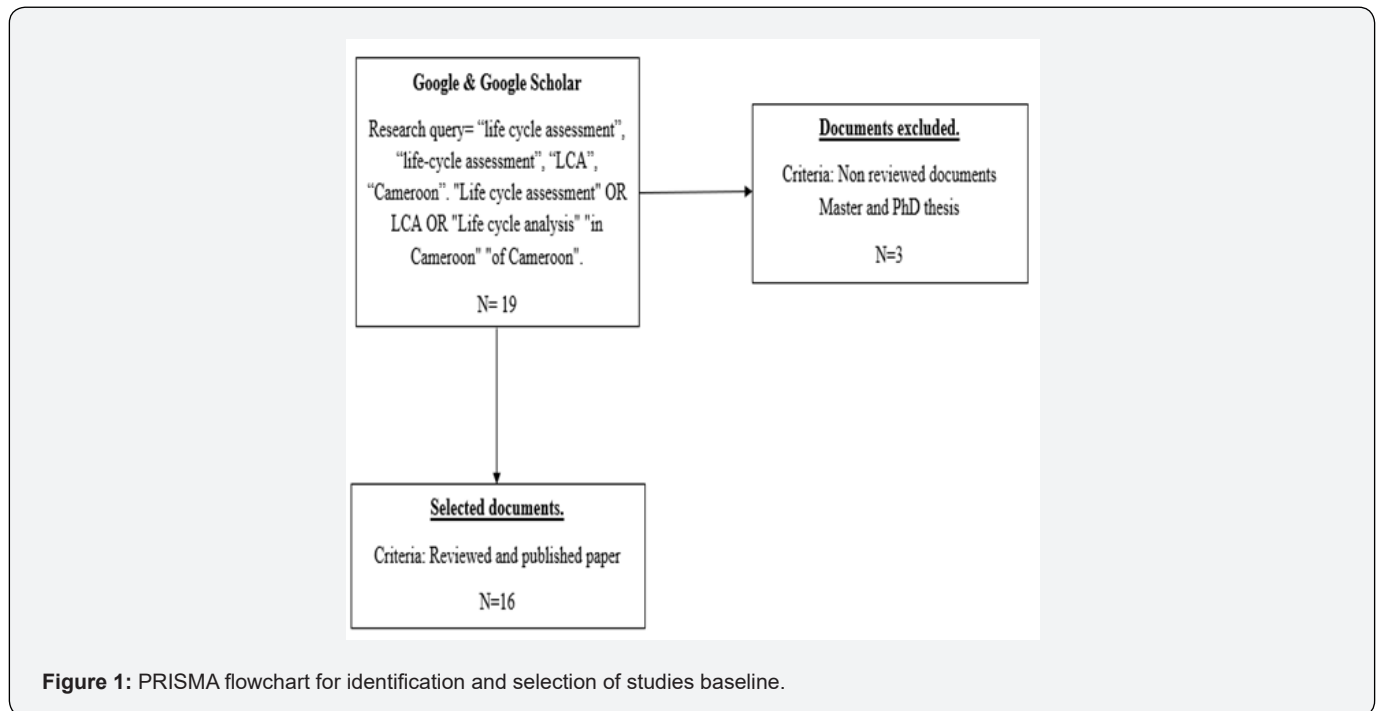


Figure 1: PRISMA flowchart for identification and selection of studies baseline.

Results

As highlighted above, a total of 16 reviewed and published research articles related to LCA studies done in Cameroon were found. Table 1 shows the total of those articles with the years of publication, the subject or the topic of each article, the related field or domain of each study, the LCA database used, the LCIA method used the university or institution of the scientific who conducted each study. Figure 2 represents a summary of the number of published articles per year from 2010 to 2023, illustrating the trend in LCA research in Cameroon over the years (Figure 2).

Based on our study, the analysis of LCA studies conducted in Cameroon reveals that the University of Yaounde 1 has been actively involved, with researchers from the university contributing to the publication of nine research articles. Following closely is the University of Dschang, with researchers from the institution participating in five research articles (Figure 3). This indicates the significant involvement of these universities in LCA

research within Cameroon.

Furthermore, our findings demonstrate that foreign researchers and universities have also played a role in LCA studies conducted in Cameroon. Collaborations between local and foreign researchers were observed in several publications. Notable examples include the School of Environment of Beijing Normal University (China), Parthenope University of Napoli (Italy), and the University of Agricultural Science and Veterinary Medicine, King Michael I of Romania. It is worth noting that most studies conducted by foreign universities in Cameroon involved the participation of local researchers.

However, there was one study on palm oil conducted by Achten et al. [17] that did not involve local researchers. The distribution of LCA studies among the universities/institutions involved - as presented in Figure 3- provides insights into the collaborative efforts and contributions made by various academic institutions, both local and foreign, in advancing LCA research in Cameroon.

Table 1: Summary of all selected LCA studies done in Cameroon.

| Year | Subject/topic | Area | Database used | Method used | University / Institutions | Type of document |
|------|---|---------------------|---|-------------------|--|------------------|
| 2010 | Life cycle assessment of the overall Bio - energy consumption of a road construction project and its management in Cameroon | Construction | Primary data/Existing literature | Empirical / other | National advanced school of engineering, University of Yaoundé I | Research article |
| 2010 | Life Cycle Assessment of a Palm Oil System with Simultaneous Production of Biodiesel and Cooking Oil in Cameroon | Bio - energy | Primary data/Existing literature | other | Katholieke Universiteit Leuven Belgium Universidade Nova de Lisboa Portugal | Research article |
| 2011 | Environmental impacts of farms integrating aquaculture and agriculture in Cameroon | Agriculture | Eco invent database | CML 2001 | University of Dschang, CIRAD, Montpellier, France INRA, Sol Agro et hydrosystème Spatialisation, Rennes Agrocampus Ouest, Rennes, France | Research article |
| 2012 | Social impact assessment in LCA using the Preston pathway: The case of banana industry in Cameroon | Agriculture | Primary data/Existing literature | Empirical / other | Université Montpellier 1 | Research article |
| 2016 | Life Cycle Assessment of Domestic Wastewater in a Neighbourhood with Spontaneous Housing - a Case Study of Bonamoussadi, Cameroon | Waste - management | Primary data/Existing literature | Empirical / other | National advanced school of engineering, University of Yaoundé I | Research article |
| 2016 | Paper Consumption and Environmental Impact in an Emerging Economy | Forest - management | Primary data/Existing literature | Empirical / other | Department of Civil Engineering and Urban Planning, National Advanced School of Engineering, | Research article |
| 2017 | Environmental Profile of CBA (Copper-Boron-Azole)-Treated Wooden Utility Poles: A Developing Country Case | Electricity | Primary data/Existing literature | Empirical / other | National advanced school of engineering, University of Yaoundé I | Research article |
| 2017 | Life Cycle Assessment of Power Utility Poles – A Review | Electricity | / | / | National advanced school of engineering, University of Yaoundé I | Research article |
| 2018 | Energy and environmental sustainability of Jatropha-Biofuels Chain from nontoxic accessions in Cameroon | Bio - energy | Primary data/ Existing literature/ Eco invent V2 | other | Société de Développement et d'Exploitation des Productions Animales, University of Udine, Via delle Scienze Italy | Research article |
| 2018 | Applying the Life Cycle Analysis in the Construction of Social Housing in Cameroon: The Case of Single-Store Houses at the Sic Residential Area in Olembe (Yaounde) | Construction | 2008 HNPS database, ECOINVENT data base | Other | National advanced school of engineering, University of Yaoundé I | Research article |

| | | | | | | |
|------|--|--|------------------------------------|-----------------------|--|------------------|
| 2020 | Approach for Evaluation of Cost and Environmental Impacts of Buildings Using BIM Objects | Construction | Primary data/Existing literature | Other | National advanced school of engineering, University of Yaoundé I | Research article |
| 2021 | Production of activated carbon from cocoa pods: Investigating benefits and environmental impacts through analytical chemistry techniques and life cycle assessment | Other | Primary data/Existing literature | other | University of Dschang Parthenope University of Napoli, Italy National Higher Polytechnic School of Douala, University of Douala University of Agricultural Science and Veterinary Medicine, King Michael I of Romania School of Environment, Beijing Normal University | Research article |
| 2021 | Forest Operations for Power Poles under Cradle-to-Gate Life Cycle Assessment Perspective | Forest - management | Primary data / Existing literature | Empirical / other | University of Yaounde I ENSET of Ebolowa - Cameroon University of Dschang IUT of Fotso Victor De Bandjoun | Research Article |
| 2022 | Environmental impact of second-generation biofuels production from agricultural residues in Cameroon: A life-cycle assessment study | Bio - energy | Ecoinvent database version 3.6 | ReCipe Mid-poid v1.04 | University of Yaoundé I University of Dschang University of Douala Parthenope University of Napoli, Italy University of Agricultural Science and Veterinary Medicine, King Michael I of Romania School of Environment, Beijing Normal University, Beijing, | Research article |
| 2023 | Analysis of environmental sustainability of Cameroon tea production: an LCA study | Agriculture | Ecoinvent database version 3.5 | ReCipe Mid-poid v1.03 | University of Yaounde I University of Dschang | Research article |
| 2023 | Assessment of Green House Gas Emissions from Thermal Technologies for Electricity Generation in Cameroon Using Life Cycle Analysis Method | Energy, Environment and Sustainability | Primary data/Existing literature | Other | University of Douala University of Ebolowa | Research article |

Moreover, we found that the domains where LCA study have been carried out in Cameroon are mostly:

i. Construction with three studies focused on road construction project [18] and social housing construction [19,20].

ii. Bio - energy with three studies focused mostly on production of biofuel from agricultural residues [21] from non-toxic accessions [22] and from palm oil [17].

iii. Electricity with three studies focused on power pole [23], wooden utility pole [24] and power utility poles [25].

iv. Waste management with one study focused domestic waste management of social housing [26].

v. Agriculture with three studies focused on banana industry [27], tea production [28] and environment impact of agriculture farms in Cameroon [29].

vi. one Field study focused on the activated carbon from cocoa pods [30].

vii. And one studies for both Energy, Environment and Sustainability [12].

Figure 4 shows those different domains of LCA study.

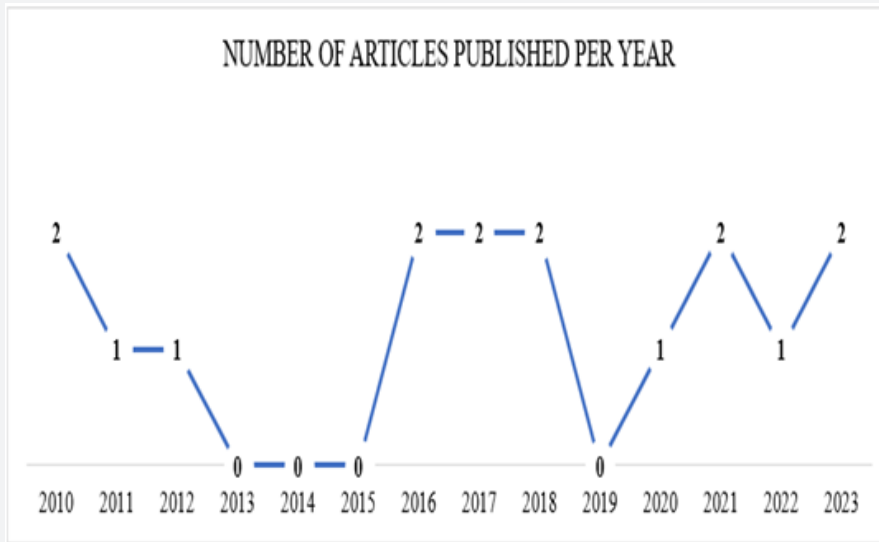


Figure 2: Number of LCA studies in Cameroon published from 2010 to 2023.

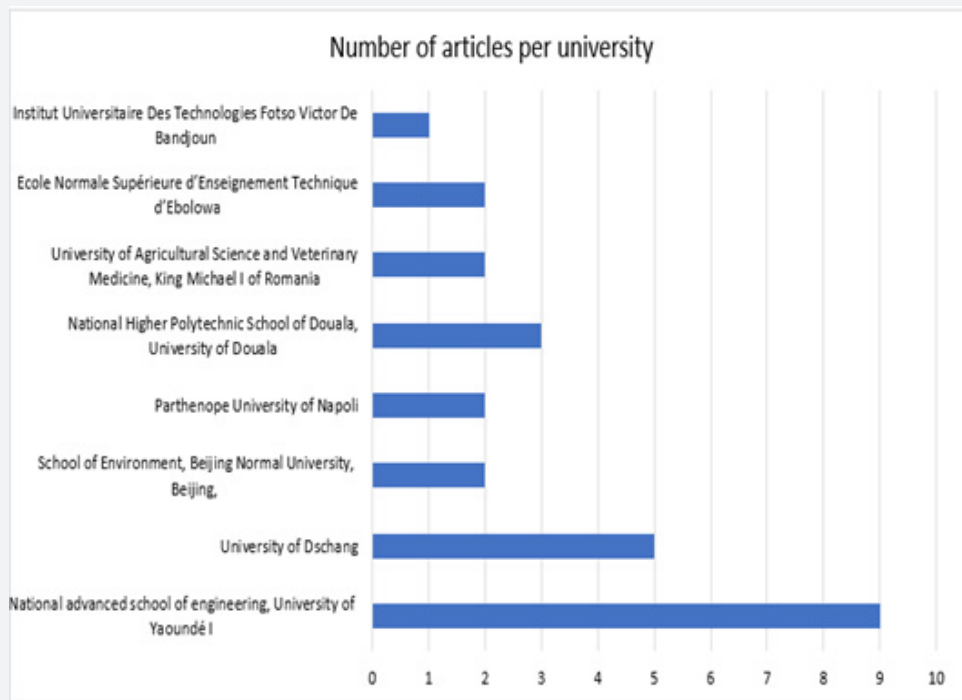


Figure 3: Different University of published articles.

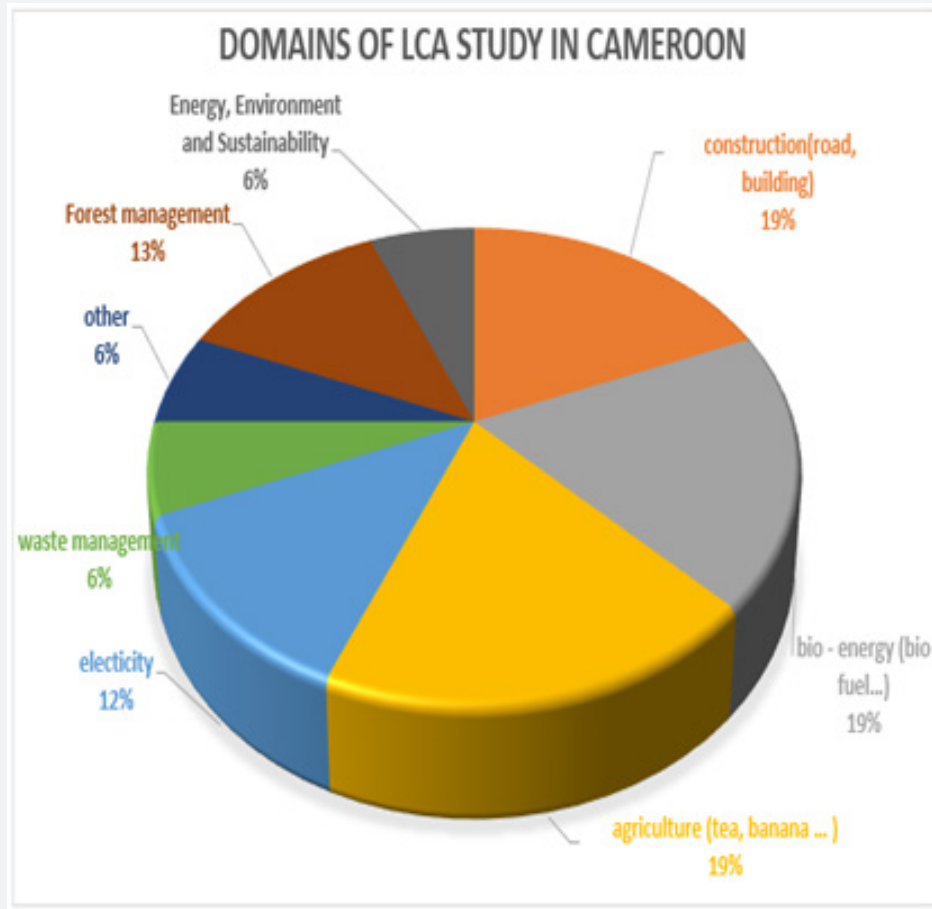


Figure 4: LCA studies in Cameroon domain allocation.

Discussion

The Need for Improvement of Interest (Government, Researchers, and Industries)

Over the past few decades, many developed countries have witnessed their governments introducing stricter regulations with a focus on sustainability aspects [31]. As a result, the demand for sustainability professionals who can guide institutions, organizations, and companies in providing sustainable services or products has increased in these countries. To promote thinking and research in sustainability through Life Cycle Assessment (LCA) in developing countries, the government has a crucial role to play by defining regulations that aim to steer the country towards sustainability.

African universities and their researchers also have an important role to play, similar to their counterparts in developed countries who have responded to these growing societal needs by developing comprehensive sustainability programs or incorporating sustainability aspects into existing curricula

[32]. As Viere et al. [33] mentioned, it is necessary to encourage and support higher educational institutions in implementing a minimum level of “life cycle literacy” into students’ curricula across various domains by increasing the availability, visibility, and quality of teaching on life cycle thinking and LCA. Tolppanen et al. [34] went further and proposed that LCA should be taught starting from lower secondary school to demonstrate the importance of sustainability to young individuals and develop their vocational interests. In this regard, the National Advanced School of Engineering of Yaounde 1 has made improvements to the engineering program by including LCA as a topic, but there is still a long way to go.

Furthermore, concerning national industries, it is important for them to understand that LCA is, in principle, a suitable tool to use in technical research and development (R&D) processes for environmental assessment of emerging technologies or preliminary product designs [35]. By incorporating LCA early in their R&D projects, industries can improve their environmental performance and create future career aspirations. Overall, it is

essential for governments, educational institutions, and industries to collaborate in promoting and integrating LCA and sustainability principles into policies, curricula, and practices. This concerted effort will contribute to the development of a sustainable future for both developing and developed countries.

The Need for Cameroonian LCI Databases and LCIA Methods

An important point was raised, regarding the reliance on European databases or existing literature-based databases for conducting Life Cycle Assessment (LCA) studies in Cameroon. It is true that primary data, which are collected specifically for a particular context or region, tends to be more precise. However, secondary databases like Eco invent have the advantage of being evaluated and accepted by a large community of LCA specialists and researchers. The availability of developed country databases is primarily due to their economic, demographic, and environmental contexts [36]. Therefore, using these databases to assess conditions in Cameroon introduces significant uncertainties. To address this issue, it is crucial for Cameroonian researchers to focus on developing their own Life Cycle Inventory (LCI) databases that take into consideration the current situation of the country.

By developing country-specific LCI databases, researchers can ensure that the data used in LCA studies more accurately reflect the unique characteristics and challenges faced by Cameroon. This will increase the reliability and relevance of LCA results for decision-making processes related to sustainability and environmental assessment in the country. To develop these databases, collaboration between researchers, relevant institutions, and stakeholders is essential. It will involve collecting primary data from various sectors of the economy, considering local production processes, resource use, and waste management practices.

Additionally, efforts should be made to ensure the quality and transparency of the data collected, following internationally recognized LCA guidelines and standards. Investing in the development of country-specific LCI databases will contribute to improving the accuracy and precision of LCA studies in Cameroon, enabling better decision-making, policy development, and sustainable development practices tailored to the country's unique circumstances.

Perspectives for LCA Research

As we noticed, the preferred domains of Cameroonian researchers in the field of Life Cycle Assessment (LCA) currently focus on bio-energy (25%), construction (18.8%), and agriculture (18%). However, it is important to acknowledge that the main industries in Cameroon are food processing, sawmilling, manufacturing of light consumer goods, and textiles. The tertiary sector also plays a significant role in the country's economy.

Given the composition of the industries and the importance of the tertiary sector that represents 52% of the GDP and employs 42% of the active population. Cameroonian researchers in LCA should indeed investigate the optimization and durability of products in these sectors. This presents a wide range of opportunities for intervention and improvement. By focusing on these industries, researchers can contribute to enhancing energy efficiency, resource management, waste reduction, and overall sustainability in these sectors. The construction sector, being a significant driver of economic growth in Cameroon, requires particular attention in terms of energy and resource management. It is encouraging to note that there have been a few studies conducted in this area, but further research and application of LCA principles can significantly contribute to sustainable practices in construction.

As highlighted by S. Karkour et al. [15], Cameroonian researchers have the potential to reduce CO₂ emissions by increasing studies in specific areas such as timber exports, oil production, and road transport. Timber exports, particularly to China (nearly 20% of the exports), have been increasing, and understanding the environmental impacts associated with this trade can help guide sustainable practices. Oil production is a vital sector in Cameroon's economy, but it is also a major contributor to CO₂ emissions (43%). Conducting LCA studies in this area can provide insights into the environmental impacts of oil production and guide strategies for emissions reduction and sustainable practices. Road transport is another significant contributor to CO₂ emissions in Cameroon, nearly 25% of the total. By investigating the environmental impacts of road transport and exploring alternative transportation methods or efficiency measures, researchers can contribute to reducing emissions and promoting sustainable mobility solutions.

In summary, Cameroonian researchers in LCA have the opportunity to make a significant impact by focusing on industries such as food processing, sawmilling, manufacturing of light consumer goods, textiles, and the tertiary sector. Additionally, areas of study including timber exports, oil production, and road transport offer avenues for reducing CO₂ emissions and promoting sustainability.

Conclusion

The research work presented in this article on the review of the various works carried out within the framework of LCA in Cameroon made it possible to highlight main facts. First, despite a gain in interest from 2010 with the publication of the first scientific article in the field of LCA, the need for an increased intensity of interest in sustainable development in the developing countries in general and Cameroon in particular remains a priority. This is because we note that many local products are out of step with the standards of the international market, which is increasingly turning towards sustainability. Moreover, the areas of predilection

for LCA studies remain very minor and not very varied in the country; this more so as the country is in full economic growth and therefore sees more and more factories and service companies emerging every day. This leaves the Cameroonian researchers with a large market for research through the development of databases specific to the country. However, we can also call for a greater implementation of the concept of sustainability via LCA in all universities and engineering schools in the country.

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