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Review

Status of Life Cycle Assessment (LCA) in Africa

Selim Karkour [1,*], Safa Rachid [2], Mariem Maaoui [3], Chia-Chun Lin [4] and Norihiro Itsubo [1]

[1] Graduate School of Environmental Studies, Tokyo City University, Tokyo 158-0087, Japan; itsubo-n@tcu.ac.jp
[2] Department of Health Sciences, Université Privée de Marrakech, Marrakech 42312, Morocco; safarachid97@gmail.com
[3] Higher Institute of the Sciences and Techniques of Water of Gabes, University of Gabès, Gabes 6029, Tunisia; meriem.maaoui@gmail.com
[4] Graduate Institute of Environmental Engineering, National Taiwan University, Taipei City 106032, Taiwan; d03541009@ntu.edu.tw
* Correspondence: g1893103@tcu.ac.jp

Abstract: Life cycle assessment (LCA) has received attention as a tool to evaluate the environmental impacts of products and services. In the last 20 years, research on the topic has increased, and now more than 25,000 articles are related to LCA in scientific journals databases such as the Scopus database; however, the concept is relatively new in Africa, where the number of networks has been highlighted to be very low when compared to the other regions. This paper focuses on a review of life cycle assessments conducted in Africa over the last 20 years. It aims at highlighting the current research gap for African LCA. A total of 199 papers were found for the whole continent; this number is lower than that for both Japan and Germany (more than 400 articles each) and nearly equal to developing countries such as Thailand. Agriculture is the sector which received the most attention, representing 53 articles, followed by electricity and energy (60 articles for the two sectors). South Africa (43), Egypt (23), and Tunisia (19) were the countries where most of the research was conducted. Even if the number of articles related to LCA have increased in recent years, many steps still remain. For example, establishing a specific life cycle inventory (LCI) database for African countries or a targeted ideal life cycle impact assessment (LCIA) method. Several African key sectors could also be assessed further.

Keywords: life cycle assessment; LCA; Africa; review

Citation: Karkour, S.; Rachid, S.; Maaoui, M.; Lin, C.-C.; Itsubo, N. Status of Life Cycle Assessment (LCA) in Africa. *Environments* **2021**, *8*, 10. https://doi.org/10.3390/environments8020010

Academic Editor: Spyros Foteinis
Received: 31 December 2020
Accepted: 31 January 2021
Published: 5 February 2021

1. Introduction

According to United Nations (UN) projections, the African population, which is composed of more than 1.2 billion people at present, is expected to double by 2050 [1]. By this time, Nigeria, South Africa, and Egypt might also enter the list of the top 30 global economies by 2050 [2]. The high population and economic growth may have an impact on environmental problems in Africa. According to an Africa Environmental Outlook (AEO3) [3] report, several environmental problems already exist in Africa, including air pollution (more than one million people die every year in Africa due to air pollution [4]), water scarcity, and toxicity due to the heavy use of chemicals.

The economies of the 54 countries of Africa are mainly based on raw products [5,6] such as oil (Angola, Algeria, and Nigeria), metals (Egypt, Ghana, and South Africa), agrcultural products (cocoa beans in Cote d'Ivoire and Ghana), oilseeds (Ethiopia and Togo), or coffee (Ethiopia and Uganda).

As highlighted by Bjorn et al. (2013) [7], little has been done concerning life cycle assessment (LCA) in Africa, where networks/research groups are notably limited. LCA is a useful technique to assess the environmental impacts of a product or service throughout its entire life cycle, i.e., from the extraction of raw material through to processing, transport, use, and finally recycling/disposal [8]. By considering several different impacts over the entire life cycle, it is possible to identify potential tradeoffs from transitioning one stage

to another or from one environmental problem to another. These are major differences with other assessment methods, such as the carbon/water footprint (focusing only on one environmental aspect) or the methods focusing only on the direct emissions of products during operation. Several global life cycle inventory databases [9] and life cycle impact assessment methods [10] exist that include African information, although the impact resolutions or data are limited.

Several country reviews have been conducted in recent years, such as in Austria [11], Brazil [12], Ghana, Ivory Coast, and Nigeria [13], Indonesia [14], Portugal [15], South Arica [16], and Sweden [17]. When focusing on the reviews published for African countries, it was found that several existing studies have been omitted, and several of the reported studies were not peer-reviewed and were sometimes ordered by private sector information. Additionally, key information has not been extracted (for example, the results or type of LCI database and the data used for the assessments). The existing research gaps for African countries are similar and it would be interesting to produce a clear overview of the situation for the whole continent.

Given this situation, we decided to focus on the current pub-lished studies in Africa while focusing on life cycle assessment in order to highlight what has been done so far, but also to identify possible research gaps. This review does not apply to African LCA researchers alone, but also to anyone who has a possible interest in conducting LCA rsearch in Africa.

2. Materials and Methods

This review was conducted with "Google Scholar" and "Scopus", research articles published between 2000 and 2020. Keywords for this review were "life cycle assessment", "life-cycle assessment", "LCA", and the name of each African country (e.g., "life cycle assessment" and "Morocco"). A total of 25,000 research articles were found when only using the keyword "life cycle assessment", while around 400 were found for African countries. As the focus was on environmental impacts, research based on other types of life cycle assessments such as life cycle costing (LCC) or social life cycle assessment (SCLA) were excluded. Research that was not peer-reviewed was also withdrawn to preserve the neutrality of the review. As the results found in the research articles were mainly based on life cycle inventory databases based on situations in developed countries (e.g., Ecoinent v2 [9]) or European life cycle assessment methods (e.g., CML-IA [18]), similar to previous reviews, we chose to not directly compare data from one region with data from another (i.e., Asia, Europe, or America). The LCIA results that were extracted from research articles are included in the Supplementary Materials.

3. Results

3.1. Overview

A total of 199 research articles related to African LCA were found.

Table A1 shows the Gross Domestic Product (GDP; Purchasing power parity (PPP), 2017 data) for each African country, as well as the main economic sector in each country and the number of published LCA studies. From Table A1 and Figure A1, it can be observed that the research published so far has not followed the economic situation in each country.

Africa's top economies (Egypt, Nigeria, South Africa, Algeria, and Morocco) are among the most active countries concerning LCA research. On the other hand, the least developed economies (Guinea-Bissau, Central African Republic, and Djibouti) do not even have a single research article focused on LCA. Surprisingly, some advanced African economies, such as Angola or Sudan, do not have a single research article either, despite the potential interesting research topics (oil and agricultural products for example). Mauritius's situation is singular, where, as a very active country with a relatively small GDP, Mauritius shows a good example for other African countries as the key drivers of the economy. Overall, North Africa has been the most active region, whereas many countries in Central Africa have not received any attention. South Africa is the leading country on the continent,

with more than 40 LCA studies focused on the country. South Africa has the longest history with LCA research, starting from the beginning of the 2000s. Further recommendations concerning potential research topics in the future are provided in Section 4.3.

The number of research articles published from 2010 increased when compared with 2000–2010 (Figure 1), proving that LCA received more attention; however, it can be observed that publications in recent years (2017–2020), have not followed a constant pace. Therefore, the concept is still under development for the African continent, especially when considering that the number of LCA studies conducted by African research institutes/universities is still limited (The first author was based in Africa for 121 research articles).

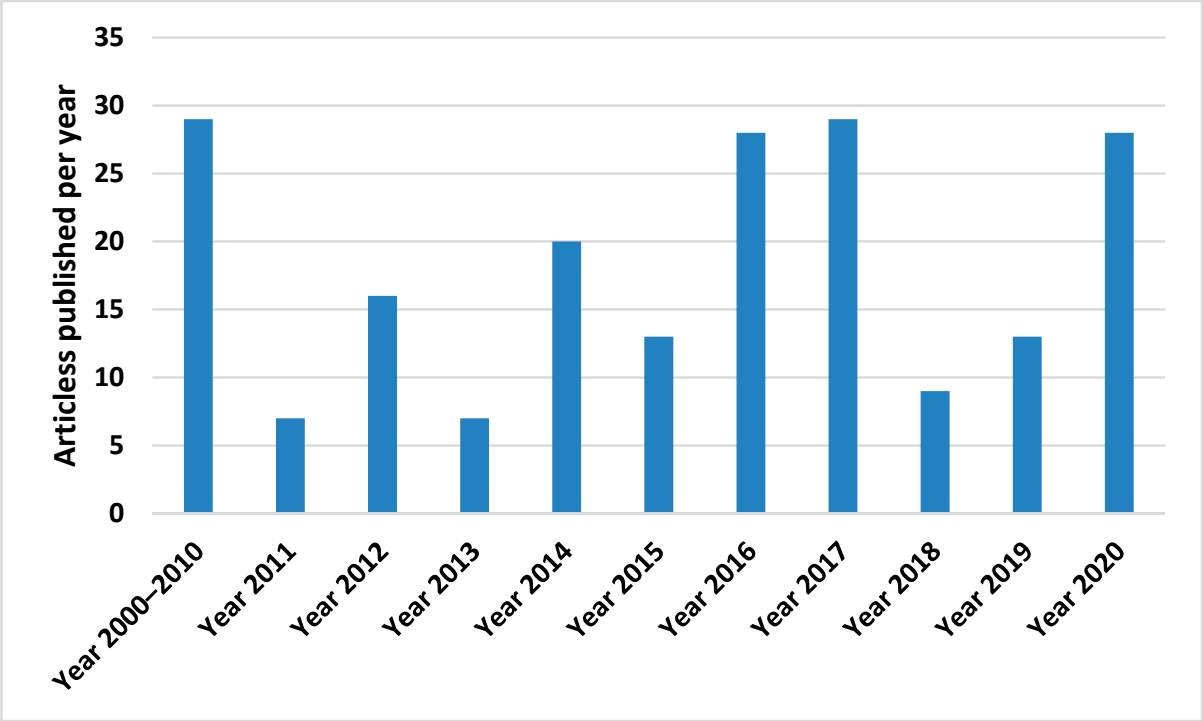

Figure 1. Research articles published by year.

When looking at which types of product/services have been studied the most (Figure 2), two topics received the most attention, namely, agriculture (53 articles) and energy/electricity (a total of 60 articles). This can be well understood, as many African countries rely on the agricultural sector for revenue (both from domestic consumption and overseas demand). For the electricity and energy sector, several problems exist in Africa due to solid fuel consumption in households, causing severe indoor air pollution [3]. The total electricity generation of Africa was around 800 TWh in 2020 [19] (which is nearly equal to the production of a developed country such as South Korea).

A description of each study is provided in Table 1. The main details of each research article are provided, such as the year of publication, country, product, functional unit, LCI database, and LCIA method used. In addition, Table A2 presents information such as the allocation, system boundaries, and institution of the first author for each study.

Concerning the life cycle inventory (LCI) database chosen, almost half of the research articles (100) used Ecoinvent as their LCI database, including 35 studies that used Ecoinvent v2 (mainly containing processes based on the situations in developed countries).

Concerning the Life-Cycle Impact Assessment (LCIA) method, CML was the most widely chosen (45) followed by ReCiPe (39), and EcoIndicator (24). It has to be noted that only nine studies chose ReCiPe2016 [10], one of the latest global LCIA methods, that contains characterization factors specific to African countries.

A map of the research articles published per country is provided Figure 3. Additionally, a bar graph is presented in Figure 4, with the number of articles for the top eight most studied countries. It can be observed that these eight countries account for two thirds of the total number of African LCA publications. This highlights the fact that currently only 15% of Africa has been more or less covered whereas the environmental impacts of products or services in the 85% remaining countries remain mostly undetermined. It also shows the importance of the South African LCA community compared with most of the African countries.

When looking at the institution of the first author in each article, it was found that outside Africa, France (17), Spain (10), and the UK (10) were the three countries the most linked to the African LCA research. The information for each research article is presented in Table A2.

Figure 2. Research articles published by product type.

Table 1. Summary of available life-cycle assessment (LCA) studies in Africa.

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2011	Algeria [20]	Drilling mud	1 well drilled 4100 m deep	Primary data/Existing literature/SimaPro	IMPACT 2002+
2012	Algeria [21]	Recycled water	5 L of recycled water intended to be used for irrigation	Primary data/Existing literature/Ecoinvent	Eco-Indicator 95
2013	Algeria [22]	Potable water	1 L of potable water	Primary data/SimaPro	Eco-Indicator 99
2015	Algeria [23]	Cement	1 ton of cement	Primary data/SimaPro 7.1	IMPACT 2000+
2015	Algeria [24]	Ammonia	1 ton of anhydrous ammonia with 99.9% purity	Primary data/GEMIS	Other
2016	Algeria [25]	Drilling mud	Drilling mud treatment scenario	SimaPro 7	Eco-Indicator 99
2017	Algeria [26]	Mussels	1 ton of fresh Mediterranean mussels	Primary data/Existing literature/Ecoinvent v3	CML
2017	Algeria [27]	Hotel building	impact/occupant/m^2	Primary data/Ecoinvent	Other
2017	Algeria [28]	Biodiesel	1 ton of biodiesel	Primary data/Existing literature/Ecoinvent v3.1	IMPACT 2002+
2020	Algeria [29]	PV Energy	1 year of utilization	Primary data	Other
2014	Benin [30]	Tomatoes	1 hectare	Primary data	ILCD
2017	Benin [31]	Tomatoes	1 kg of product	Primary data/Existing literature/Ecoinvent v2.2	ReCiPe2008
2016	Burkina Faso [32]	Energy sources for a water purification plant	One year	Ecoinvent v3	ReCiPe
2018	Burkina Faso [33]	Jatropha biofuel	hectare.year/gigajoule of *J. curcas* SVO or JME	Primary data/Existing literature	ReCiPe
2018	Burkina Faso [34]	PV	1 L of oil	Ecoinvent	ReCiPe World E/A
2010	Cameroon [35]	Palm Oil	1 MJ in a car engine	Primary data/Existing literature/LCA database	Other
2010	Cameroon [36]	Road	Number of vehicles moving on that road for a period of fifty years	Primary data/Existing literature	Other

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2012	Cameroon [37]	Farms	1 ton of fresh fish (both tilapia and African catfish) at the farm exit gate	Existing literature/Ecoinvent	CML2001
2016	Cameroon [38]	Waste Water	1 life-cycle	Primary data/Existing literature	Other
2019	Cameroon [39]	Jatropha	1 MJ of JVO obtained	Primary data/Existing literature/Ecoinvent v2	Other
2010	Egypt [40]	Wastewater	Treatment of 1 m^3 of wastewater	Primary data/Existing literature	Eco-Indicator 99
2012	Egypt [41]	Wastewater	Treatment of 1 m^3 of wastewater	Existing literature	Eco-Indicator 99
2014	Egypt [42]	Building materials (Method)	-	-	-
2014	Egypt [43]	Residential building	1 usable floor space (m^2)	Primary data/Existing literature/Ecoinvent V3	IMPACT 2002+
2014	Egypt [44]	Building database	-	-	-
2014	Egypt [45]	Cotton	1 kg of dyed cotton yarn	Primary data/Ecoinvent v2	Eco-Indicator 99
2015	Egypt [46]	Diesel fuel, solar pump	Irrigation of 1 feddan of rice	Primary data	IMPACT 2002+
2015	Egypt [47]	Jatropha Biodiesel	1 ton of Jatropha Biodiesel	Primary data	IMPACT 2002+
2016	Egypt [48]	Dredged Material	1 trip per day	Primary data/SimaPro 8	IMPACT 2002+
2016	Egypt [49]	Energy system	The operation of the power supply system for a calendar year	Existing literature/ecoinvent	Eco-Indicator 99
2016	Egypt [50]	Aquaculture	1 ton of live tilapia at the farm gate	Primary data/Existing literature/Ecoinvent v2.2	Other
2016	Egypt [51]	LCA tool	-	-	-
2016	Egypt [52]	Transport vehicles	Total Vehicle Kilometers Travelled (VKT) in Egypt	Primary data?/Existing literature	IMPACT 2002+
2016	Egypt [53]	Tilapia	1 ton of Tilapia	Primary data/Existing literature/Ecoinvent v2	CML baseline 2000
2016	Egypt [54]	Acrylic fiber	1 kg production of acrylic fiber.	Primary data/Existing literature/Ecoinvent v2.2	Eco-Indicator 99

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2016	Egypt [55]	Cement	1 kg of cement	Primary data/Ecoinvent v3	IMPACT 2002+
2016	Egypt [56]	Acrylic fiber	1000 kg production of acrylic fiber.	Primary data/Ecoinvent v2	Eco-Indicator 99
2017	Egypt [57]	Bricks	1 kg of brick products	Primary data/Existing literature/IDEA	LIME2
2017	Egypt [58]	Lubrication oil	1000 kg lubrication used oil	Existing literature/Ecoinvent v2	Eco-Indicator 99
2019	Egypt [59]	Waste water	1 m^3 of treated wastewater	Primary data/Existing literature/Ecoinvent v2	CML2000
2020	Egypt [60]	Waste	1 ton of waste	Primary data	Other
2020	Egypt [61]	Wastewater	1 m^3 of treated wastewater	Primary data/Gabi	ReCiPe
2020	Egypt [62]	Bioethanol	1 ton of bioethanol	Primary data/Existing literature/Ecoinvent v3	CML-IA
2012	Ethiopia [63]	Rose cultivation	1 bunch of roses consisting of 20 stems	Ecoinvent v2	CML 2 baseline 2000
2017	Ethiopia [64]	Biogas, dung	Amount of primary energy needed to provide energy carriers	Primary data/Existing literature/ecoinvent v2.2	CML2001
2017	Ethiopia [65]	Milk	1 adult cattle unit (cu)/1 kg of milk produced by a cow	Primary data/Existing literature/Ecoinvent v2.2	Other
2020	Ethiopia [66]	Electricity from a wind farm	The generation of 1 kWh of average electricity	Primary data/Existing literature/Ecoinvent v3	ReCiPe 2008
2012	Ghana [67]	Cooking fuels	1 MJ of energy delivered to the cooking pot	Primary data/Ecoinvent/Gabi 4	CML2001
2020	Ghana [68]	Building	180.50 m^2 gross floor area (GFA) for a lifespan of 50 years	Primary data/ICE	Other
2020	Ghana [69]	Food products	1 kg of product/1 kcal unit	Existing literature/Ecoinvent v3.5	CML2001/ReCiPe2008
2011	Ghana [70]	Timber	1 kg/1 euro/1 m^3 of product produced	Existing literature	CML2000
2011	Ghana [71]	Biogas	Production of 1 MJ of useful energy	Primary data/Ecoinvent/Gabi 4	CML2001
2011	Ghana [72]	Cyanide containers	1 package	Primary data/Existing literature	Eco-Indicator 99

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2010	Ghana [73]	Timber	1 m^3/1 kg/1 euro	Primary data	Other
2008	Ghana [74]	Cocoa	1 kg of cocoa beans processed	Primary data/Ecoinvent/Gabi 4	CML2001
2009	Ivory Coast [75]	Biofuel	1 MJ of JME	Primary data/Ecoinvent	Other
2007	Kenya [76]	Food products	1 ton of grade 1 product	Existing literature/Ecoinvent	CML baseline 2000
2016	Kenya [77]	Biowaste	1 kg of wet biowaste	Primary data/Existing literature/Ecoinvent v3.3	ReCiPe 2016
2017	Kenya [78]	Solar photovoltaic microgrid system	1 kWh of electricity consumed by the community	Ecoinvent v2.2/Gabi 6	ReCiPe 2008
2020	Kenya [79]	Food products	1 kg of edible boneless weight	Existing literature	IPCC/AWARE
2020	Kenya [80]	Bioenergy	Different scenarios	Existing literature/Ecoinvent v3.1/Agrifootprint	ReCiPe2016
2014	Libya [81]	Crude oil	Ultimately presented in terms of the functional unit (km)	Primary data/Ecoinvent	Eco-Indicator 99
2015	Libya [82]	Wind farm	1 kWh of electricity produced	Primary data	Other
2014	Madagascar [83]	Solar cooker	1 meal	Primary data	Other
2017	Madagascar [84]	Electricity generation	1 year	Primary data/GEMIS	Other
2016	Malawi [85]	Tea	1 kg of tea	Primary data/Existing literature	CML2002
2016	Malawi [86]	Building materials	1 m^2 wall	Primary data/Existing literature	Other
2019	Malawi [87]	Mining products	1 kg of rare earth oxide (REO)	Primary data/Existing literature/Ecoinvent v3/Gabi	TRACI
2004	Mali [88]	Thermosyphon solar water	1 complete solar hot water system	Primary data/Existing literature	Other
2014	Mali [89]	Jatropha-based bioenergy	1 MJ of electricity.	Primary data/Ecoinvent v2.2	ReCiPe
2017	Mali [90]	Insect-based feed production	1 kg whole dried larvae with a residual water content of less than 10%	Existing literature/Ecoinvent v3.0	Other
2017	Mali [91]	Shea butter	1 kg of shea butter	Primary data/Existing literature	CML 2001
2020	Mali [92]	Cotton	1 t and 1 ha of seed cotton at the farm gate and 1 t and 1 ha equivalent of baled cotton fiber and cottonseed at the ginning plant gate	Primary data/Ecoinvent v3/World Food LCA Database	ILCD

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2012	Mauritania [93]	Octopus	24 kg carton of frozen common octopus up to the point of import in the year 2009.	Primary data/Ecoinvent/LCA Food Database	CML baseline 2000
2014	Mauritania [94]	Building materials	Structure and envelope of a classroom block consisting of eight modules in Nouakchott for a period of 30 years	Ecoinvent v2.2	Other
2004	Mauritius [95]	Sugarcane	1 ton of raw cane sugar exported	Primary data/Existing literature	CML
2005	Mauritius [96]	Biodegradable waste	Treatment of 1 kg of biodegradable wastes by composting and Anaerobic Digestion (AD)	Primary data	Other
2008	Mauritius [97]	Electricity generation bagasse	1 GWh of electricity exported to the national electricity grid	Primary data/Existing literature/BUWAL 2000	Eco-Indicator 99/CML World 92
2008	Mauritius [98]	polyethylene terephthalate (PET) bottle	Use and disposal of 1000 packs of 1.5 LPET bottles, used for the packaging of 9000 liters of beverage	Primary data/BUWAL 2000	Eco-Indicator 99
2011	Mauritius [99]	Waste	The disposal of 300,000 tons of Municipal Solid Waste (MSW) in one year	Primary data	IMPACT 2002+
2012	Mauritius [100]	PET bottle	1 ton of used PET bottles supplied to the respective disposal facilities	Primary data	Eco-Indicator 99
2012	Mauritius [101]	PET bottle	1 ton of used PET bottles	Primary data/Existing literature/SimaPro 7.1	Eco-Indicator 99
2012	Mauritius [102]	PET bottle	1 ton of used PET bottles	Primary data/Existing literature/Ecoinvent	Eco-Indicator 99
2015	Mauritius [103]	Electricity generation	1 MWh of electricity delivered to the consumer	Primary data/Ecoinvent v2	CML 2 Baseline 2001
2017	Mauritius [104]	Waste	The management of 427,687 t of MSW generated in the year 2010	Existing literature/Ecoinvent v2.0	CML-IA
2014	Morocco [105]	Tomatoes	1 kg of fresh bulk tomatoes delivered at the Saint-Charles International Market entry gateway	Primary data/Ecoinvent v2.2	ReCiPe

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2014	Morocco [106]	Perennial crops	1 kg of fresh fruits	Primary data/Ecoinvent v2.2	ReCiPe 2008
2016	Morocco [107]	Clementines	1 kg raw fruit at the farm gate	Ecoinvent v2.2	ReCiPe
2016	Morocco [108]	Photovoltaic power plant	1 MWh	Ecoinvent v3	ReCiPe
2016	Morocco [109]	Photovoltaic power plant	1 MW	Ecoinvent v2.2	Other
2016	Morocco [110]	Fresh fruit	1 kg of fresh fruits	Primary data/Ecoinvent v2.2	ReCiPe 2008
2018	Morocco [111]	Electric energy	1 kWh of produced electric energy	Primary data/Gabi/Ecoinvent v3.1	CML2001
2019	Morocco [112]	Automotive headrest	1 headrest for automotive seating	Primary data/Ecoinvent	IMPACT 2002+
2020	Morocco [113]	hybrid solar/biomass micro-cogeneration	1 kWh of electricity	Primary data/WIOD/EORA	ILCD
2020	Morocco [114]	Solar water heater	Utilization during one year	Primary data	Other
2020	Morocco [115]	Waste Water	Treat effluent of one population equivalent for one day	Primary data	ReCiPe midpoint 2014
2013	Mozambique [116]	Jatropha oil	1 MJ of energy in the form of jatropha oil or fossil diesel	Primary data/Existing literature	Other
2016	Mozambique [117]	Biomass power plant	1-GJ pellets delivered to a combined heat and power (CHP) plant	Primary data/Existing literature	Other
2010	Nigeria [118]	Future electricity scenarios	56,160 TJ/yr for 2003; 346,000 TJ/yr for 2010; 551,000 TJ/yr for 2020; 764,000 TJ/yr for 2030	Primary data/Existing literature/GEMIS 4.3/SimaPro	Other
2014	Nigeria [119]	Biodigesters	One meal	x	Other
2015	Nigeria [120]	Residential building	One life-cycle	Primary data	Other
2015	Nigeria [121]	Municipal solid waste management	Waste Management scenarios	Primary data/Ecoinvent	Other
2015	Nigeria [122]	Jatropha biofuel	1 MJ of fuel used in a typical biodiesel-fired power plant/Jatropha plantation of 1 hectare (ha) over a 20-year period	Literature review/Agrifootprint/Ecoinvent	ReCiPe
2016	Nigeria [123]	Shea butter	1 kg of shea butter	Primary data/Ecoinvent	TRACI

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2019	Nigeria [124]	Electricity	1 kWh of electricity generation	Existing literature/Gabi	CML 2001
2020	Nigeria [125]	Electricity	1 MWh of net electricity produced	Primary data/Ecoinvent	CML 2001
2020	Nigeria [126]	Cowpeas	1 ton of grain	Primary data/Gabi 8.7	CML
2020	Nigeria [127]	Cassava	1 ha land area	Primary data/Existing literature	Other
2020	Nigeria [128]	Sweet Oranges	1 ha	Primary data	Other
2013	Nigeria [129]	Passenger transport	467 billion people/km in 2003/721 billion people/km in 2020/942 billion people/.km in 2030	Existing literature/GEMIS4.3	CML 2001
2013	Nigeria [130]	Biodiesel	The functional unit was defined as one kilogram of soybean	Primary data/Existing literature	Other
2017	Nigeria, Ghana, ivory coast [13]	Review	-	-	-
2019	Rwanda [131]	Tomatoes	1 kg of tomatoes at farm-gate	Existing literature/Ecoinvent v2.2	ILCD
2011	Senegal [132]	Shrimp products	1 kg of shrimp and the accompanying packaging material at the point of import to Europe	Primary data/Existing literature/Ecoinvent v2	CML 2002
2019	Somalia [133]	Treated water	1 L of treated water	Existing literature/Ecoinvent v3.4	ReCiPe 2008
2002	South Africa [134]	Review	-	-	Review
2002	South Africa [135]	Wool	1 kg of dyed two-fold wool yarn	Primary data/Existing literature	Method
2002	South Africa [136]	Potable water	1 kL of potable water	Primary data/Gabi 3	ReCiPe
2003	South Africa [137]	Method	-	-	-
2006	South Africa [138]	Water supply	1 Mℓ/d of potable water supplied at Rosslyn	Primary data	special African
2009	South Africa [139]	Urban water	1 kL of water	Primary data/Existing literature/Gabi 3	CML
2010	South Africa [140]	Sugar	1 ton of raw sugar	Primary data/Ecoinvent	Eco-Indicator 99
2012	South Africa [141]	Photovoltaic/Wind Radio	One radio base station utilization during 10 years	Primary data	ReCiPe2008
2014	South Africa [142]	Container glass waste	1 ton of container glass waste	Primary data/Ecoinvent v2	Other

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2014	South Africa [143]	Clay brick Walling	1 standard brick equivalent (SBE)	Primary data/Ecoinvent v2.2	IMPACT 2002+
2014	South Africa [144]	Polymer bag	1 m^2 of plastic film	Primary data/Ecoinvent v2.2	IMPACT 2002+
2015	South Africa [145]	Biofuel	1 km traveled	Aspen simulation/Existing literature/Ecoinvent v2.2/Greet 2.7	Other
2016	South Africa [146]	Agriculture	1 metric ton of extractable sucrose delivered at the mill gate in the form of sugarcane stems or billets.	Primary data/Existing literature/Greet	Other
2016	South Africa [147]	Method for constructing LCAs	-	-	-
2016	South Africa [148]	Books	The reading of 21 books by a single user in two hours per day over a four-year period	Ecoinvent v3	ReCiPe2008
2016	South Africa [149]	Lignocellulosic lactic acid	1 ton of Lactic Acid (LA) produced	Aspen/Ecoinvent	ReCiPe
2017	South Africa [150]	Timber	Quantity of materials required to construct the roof truss system of a house	AUSLCI/Ecoinvent v3.1	ReCiPe
2017	South Africa [151]	Maize	one kilogram of maize in silo storage	Primary data/Existing literature/Ecoinvent v3.3	ILCD
2017	South Africa [152]	Meat	1 kg of LW meat/1kg of CW meat	Primary data/Ecoinvent	CML IA
2017	South Africa [153]	Biorefineries	a biorefinery with a processing capacity of 65 (tDM/h) tons bagasse and trash per hour	Primary data/Existing literature	Eco-Indicator 99
2017	South Africa [154]	Biorefineries	1 MWh electricity produced	Aspen simulation/Existing literature/Ecoinvent v3	CML-IA baseline 3.02
2017	South Africa [155]	Biorefineries	1 MWh electricity produced	Aspen simulation/Existing literature/Ecoinvent	CML-IA baseline 3.02
2017	South Africa [156]	Biorefineries	1 ton BD produced/1 MWh electricity produced	Aspen simulation/Existing literature/Ecoinvent v3	CML-IA baseline 3.02
2017	South Africa [157]	Zinc oxide	ZnO surface area (1 m^2/g)	Primary data/Existing literature	ReCiPe
2017	South Africa [158]	Domestic Biogas Digester	1 MJ	Primary data	Other

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2018	South Africa [159]	Sandstone	1 t of sandstone	Primary data/Existing literature	IMPACT 2002+
2018	South Africa [160]	Acid mine drainage (AMD) treatment	1 m^3 of effluent generated by an AMD reactor	Primary data/Existing literature/Ecoinvent v3	ReCiPe2016
2018	South Africa [161]	Sanitation system	The provision of a sanitation service for the daily defecation of a 10-adult occupant household in South Africa	Primary data/Ecoinvent v3.0	ReCiPe2016
2018	South Africa [162]	Soybean Biodiesel	1 L of Biodiesel	Existing literature	Other
2018	South Africa [163]	Sugarcane Ethanol (Inventory)	-	-	-
2019	South Africa [164]	Seawater desalination	1 kL of potable water	Primary data/Existing literature/Ecoinvent v3	ReCiPe
2019	South Africa [165]	Method for the Construction industry	-	-	-
2019	South Africa [166]	Coal power plant	712-MW power-generating unit	Primary data/Ecoinvent	Eco-Indicator 99
2020	South Africa [167]	Straw	Annual straw consumption per capita	Primary data/Existing literature/Ecoinvent v3.5	ReCiPe
2020	South Africa [16]	Review	-	-	-
2020	South Africa [168]	Wastewater	1 L of real wastewater	Primary data/Existing literature/Ecoinvent v3.6	ReCiPe2016
2015	South Africa [169]	Sugarcane	1 ton of extractable sucrose produced leaving the farm gate	Primary data	Other
2012	South Africa [170]	Pork	1 kg of pork (carcass weight)	Existing literature/Gabi 2006	CML2001
2012	South Africa [171]	Saline wastewater	A daily production of 40 ton of dehydrated sodium sulphate by each process and another 960 ton/day of "ice + liquid water" mixture in the amounts obtained by EFC.	Existing literature/Ecoinvent v2.2	IMPACT 2002+
2012	South Africa [172]	Water treatment	1000 m^3 of boiler feed water (BFW)	Existing literature/Ecoinvent	CML 2 baseline 2000 V2.04
2010	South Africa [173]	Biodiesel	1 ton of biodiesel	Primary data/Existing literature	Other
2010	South Africa [174]	Biofuel	A unit of product, over a one-year production period	Primary data/Existing literature	-

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2002	South Africa [175]	Water recycling plant	1 kL of water as supplied to industry	Primary data/Gabi3	CML
2007	Tanzania [176]	Production of biofuels from pyrolysis of wood	One year	Primary data	Other
2012	Tanzania [177]	Electricity	The functional unit for this study is 1 MW h net electricity at the power plant.	Ecoinvent v2.2/USLCI 1.6.0	CML(IA)
2013	Tanzania [178]	Bioethanol produced from sugarcane molasses	1 ton of combusted jatropha biodiesel.	Primary data/Existing literature/Ecoinvent	CML (IA)
2014	Tanzania [179]	Electricity	1 MWh gross electricity generated at the power plant.	Ecoinvent v2.2/USLCI 1.6.0	CML (IA)
2014	Tanzania [180]	Maize	One ton of Maize	Primary data/Existing literature/Gabi 4	Other
2016	Tanzania [181]	Review	-	-	-
2020	Tanzania [182]	PV Electricity	1 m^2 of PV module	Primary data	Other
2007	Tunisia [183]	Coastal area	1 L of water sample	Primary data	Other
2011	Tunisia [184]	Sea bass	1 ton of live fish weight produced.	Primary data/ecoinvent	CML 2 Baseline 2000
2012	Tunisia [185]	Jatropha biodiesel	1 hectare of Jatropha	Primary data/Existing literature	Other
2013	Tunisia [186]	Olive-waste cake	1 kg of AC from by-product olive-waste cakes	Primary data/Existing literature/Ecoinvent v2.2	CML 2 Baseline 2000
2014	Tunisia [187]	Groundwater pumping system	1 m^3 pumped at a 35 m depth, 2 bars of pressure, and 0.9 bars of friction losses in pipes	Ecoinvent v2.2	ReCiPe
2015	Tunisia [188]	Shale gas	1 MJ of shale gas	Primary data	ReCiPe v1.06
2017	Tunisia [189]	Sheep/chicken meat	1 kg of carcass	Primary data/Existing literature	Other
2017	Tunisia [190]	Sea cages	1 ton of live fish	Primary data/Ecoinvent v3	Other
2017	Tunisia [191]	Seabass	1 ton of fish at the fish farm gate	Primary data/Ecoinvent v3	CML2 baseline 2000
2017	Tunisia [192]	Sulfuric acid production system	1 ton of sulfuric acid	Primary data/Ecoinvent v3	ILCD
2017	Tunisia [193]	tomatoes	1 ton of soilless geothermal greenhouse cherry tomatoes	Primary data/Ecoinvent v3.3	ILCD

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2018	Tunisia [194]	fisheries (seafood)	1 ton of landed seafood by demersal trawlers in the Gulf of Gabes	Primary data/Ecoinvent v3	CML baseline 2000
2019	Tunisia [195]	Agricultural practices	1 ha/1 dinar	Primary data/Existing literature/Ecoinvent	ReCiPe2016
2020	Tunisia [196]	Ground water irrigation	Area of land cropped over 1 year	Primary data/Existing literature	ReCiPe 1.07
2020	Tunisia [197]	Tomatoes	1 ton of soilless cherry tomato produced.	Primary data/Ecoinvent v3.3/Agrifootprint 3.0	ILCD
2020	Tunisia [198]	Electricity	1 MWh of electricity generated	Primary data/WIOD/SimaPro	ILCD
2020	Tunisia [199]	Electricity	1 kWh of electricity output	Primary data/Existing literature	ILCD
2020	Tunisia [200]	Olives	1 ton of olives and 1 ha of cultivated olive growing area	Primary data/Ecoinvent v3.2	ILCD
2020	Tunisia [201]	Seafood	1 t of landed seafood	Primary data/Ecoinvent v3	ILCD
2013	Uganda [202]	Sanitary products	Number of sanitary pads needed to provide effective protection from menstruation for one woman over one year.	Ecoinvent v2.2	IMPACT 2002+
2014	Uganda [203]	Waste	The waste production for the base year 2011	Primary data/Existing literature	Other
2014	Uganda [204]	Charcoal	1 kg of charcoal produced and utilized	Primary data/Existing literature	CML2001
2016	Uganda [205]	Water	3.57 L of potable water	Primary data/Existing literature/SimaPro	Eco-Indicator 99
2016	Uganda [206]	Waste	1 ton of impurity-free anima waste treated to produce a quality soil improver/fertilizer.	Primary data/Existing literature	CML
2019	Uganda [207]	Juice, dry fruits	1 L of packaged juice ready for consumption/1 kg of packaged dried fruits including the non-edible parts	Primary data/Existing literature	CML2001
2012	Zambia [208]	Biochar	1 ton of maize	Primary data/Existing literature/Ecoinvent v2.2	ReCiPe (a voir)
2017	Zambia [209]	Biochar production System	Preparation and sequestration of 1 kg biochar	Primary data/Existing literature/Ecoinvent v3.2	ReCiPe

Table 1. *Cont.*

Year	Country [Ref.]	Product	Functional Unit	LCI Database	LCIA Method
2007	Zimbabwe [210]	Plastic carrier bags	1 kg of polyethylene	Primary data/Existing literature/Gabi 3	Other
2007	Zimbabwe [211]	Paper	53 gsm (g/m^2) newsprint paper produced in Zimbabwe from the pulping of pinewood	Primary data	Eco-Indicator 99
2008	Zimbabwe [212]	Vehicle leaf springs	One life-cycle	Primary data	Eco-Indicator 99
2008	Zimbabwe [213]	Cement	1 ton of cement	Primary data	Eco-Indicator 99
2015	Zimbabwe [214]	Steel balls	1 kg of steel	Primary data	Other
2019	Zimbabwe [215]	Municipal solid waste management	Annual generation of MSW	Ecoinvent v3	ReCiPe 2016
2020	Zimbabwe [216]	Waste	Annual biodegradable waste generation for Harare and its dormitory towns	Existing literature/Ecoinvent v3	ReCiPe 2016 v1.02

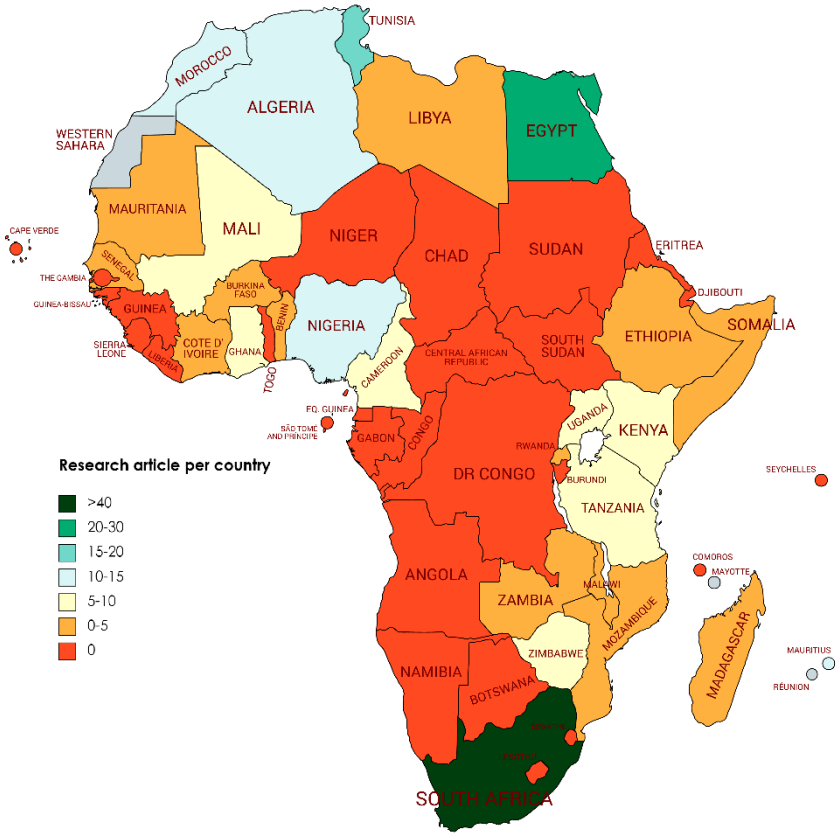

Figure 3. Research articles published per African country.

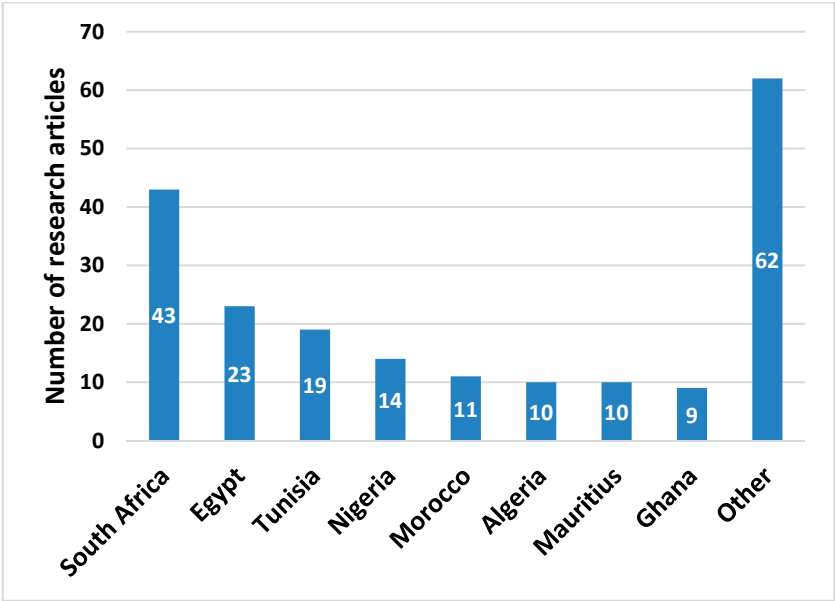

Figure 4. Research articles published for the eight most studied African countries.

3.2. A Focus on LCA for Agricultural Products

Several points can be highlighted regarding the research on agricultural products.

For fisheries, Lourguioui et al. [26] found in Algeria that a reduction of 3150 MJ and 156 kg CO_2eq per ton of fresh mussels could be reached if mussel farming activities would be operated in cooperation, instead of the traditional competitive scheme, as the resulting efficiency would be higher. The authors also highlighted the importance of applying LCA

to the seafood production sector in Algeria. In Egypt [50], the importance of management practices was also highlighted to produce Nile Tilapia, carps, and mullets. By choosing better practices, life cycle impacts could be reduced by 22%. In Tunisia [184,191], it was shown that the production of seabass was an important source of nitrogen and phosphorus releases due to the fish feed. Cascade raceways featured higher impacts than traditional raceways. In sub-Saharan Africa, fish also constitute one of the main sources of animal protein. In Cameroon [37], the eutrophication impact was higher for Cameroon farms than for an intensive trout monoculture (France) or extensive carp polyculture (Brazil) due to poor water and poor manure management. In Senegal [132], F. Ziegler et al. found that artisanal fisheries have far lower inputs and emissions in the fishing phase compared with industrial fisheries. The global warming impacts from artisanal fisheries mainly come from the use of heavy fuel oil and low-quality refrigerants.

For the beef and dairy industries, D. Woldegebriela et al. [65] found out that milk production in Ethiopia had a higher global warming impact (1.75–2.22 kg CO_2eq/kg milk) than other developing countries due to the large amounts of low-quality feeds fed.

For fruit and vegetable products, C. Basset-Mens et al. [107] showed that compared with mangoes from Brazil or peaches/apples from France, it could be observed that except for terrestrial acidification and marine eutrophication, the results were higher for all the other impact categories for clementine production in Morocco. There are several reasons that explain these results: the higher amount of fertilizer used (6 kgN/kg) and the high amount of water needed to grow clementines (8000 m^3/hectare compared with 2.767 for apples grown in France), despite the fact that water is scarce in Morocco and it has to be withdrawn from more than 100 meter deep wells. The energy required to pump this water is also important (22,830 MJ per hectare compared with 2946 for mangoes grown in Brazil). Moreover, the Moroccan electricity mix is composed of more than 50% fossil energy (coal), which explains why the impact of climate change was also high. S. Peyen et al. [105] also showed that tomato cultivation had a higher impact in Morocco than in France (28 vs. 7.5 L H_2Oeq/kg). They highlighted the importance of LCA for other impact categories (e.g., total energy consumption and global warming), which showed higher results in the case of France.

For forestry, in Ghana [73], it was found that the wastage of wood during timber processing contributed considerably to resource depletion, and land use impact was also a major concern, while kiln-dried lumber, plywood, and veneer production lines affected CO_2 emissions considerably. Relatively high energy consumption was also reported due to biomass combustion for drying wood products.

For other types of crops such as cocoa [69], it was revealed that even though fertilizer and pesticide usage was low, the water consumption was higher in Ghana's plantations than in other parts of the world such as Ecuador or Indonesia. For cassava, a major crop cultivated mainly in Western Africa, it was calculated that the higher energy consumption came from planting operations, where the global warming potential (GWP) per one hectare was about 80 kg CO_2eq.

3.3. A Focus on LCA for Energy

The second topic that has received interest is life cycle assessment for energy and electricity systems.

Jatropha is often one of the preferred choices in Africa to replace conventional transport fuel. In Burkina Faso [33], it was found that its production could reduce both GHG emissions and energy consumption by around 80% when compared with diesel fuel. One of the main challenges is the land transformation that implies the quantity of energy output per hectare was limited (less than 10 GJ/ha). Therefore it could become a competitor of food crops. Another type of biodiesel is made using palm oil [35], where the results for Cameroon confirmed this tendency with a reduction of 70% compared with conventional fuel in the range of 60–80 g CO_2/MJ. Proton-exchange membrane fuel cells have also received attention; however, the results found in Morocco [111] were much higher than

those in Norway (4040 g CO_2 vs. 239 g/kWh) due to the electricity generation primarily based on fossil fuels for hydrogen production.

For cooking fuel, biogas is also an option to reduce the impacts of indoor air pollution. J. Lanche et al. [64] showed that 130,542 t CO_2eq could be saved annually in Ethiopia if dung cakes were replaced with biogas. Indoor air pollution could also be avoided as dung combustion contributes to significant Nitrogen Oxide (NOx) and Particulate Matter (PM) emissions.

The use of renewables for electricity has been studied extensively. Several researchers have pointed out the need to develop photovoltaic (PV) systems and biomass power plants. R. Brizmohun et al. [103] pointed out the impacts of African fossil fuel power plant plants by analyzing the emissions of Mauritian plants. The global warming potential of electricity from coal was estimated to be 1444 kg CO_2eq/MWh, which is about six times the minimum value obtained in the literature. The lack of abatement technology for PM2.5, SO_2, and NOx was highlighted, as well as the higher sulphur content of the coal.

Wind power also received attention in Ethiopia [66]. Similar to studies conducted in developed countries, the CO_2 emissions per kWh output were low, around 35 g CO_2/kWh.

Electricity demand in the Middle East and North African (MENA) region has increased at a rate of 6–8% in recent years. To limit the impacts of this increase, a hybrid solar and biomass power plant was evaluated in Tunisia [199]; the GWP impact was found to be 22 kg CO_2eq/MWh, with the boiler system and field having the greatest impact. Resource depletion and human toxicity were not negligible due to the solar field. Similar results were obtained in Morocco [113]. One of the solutions to promote renewables would be to retrofit existing dams to generate electricity from hydro power. This option was studied in Nigeria [125], finding corresponding values between 1.6 and 5.5 kg CO_2eq/MWh. It was highlighted that there were advantages in terms of saving on economic investments as well in that case.

Finally, the extraction of raw materials such as coal, oil or natural gas has not received as much attention, as further highlighted by A. Irhoma et al. [82] in Libya. The study showed that crude oil production and distillation had significant impacts. The impact of respiratory inorganics was also highlighted. The authors pushed for a reduction in fossil resources at refineries but also raised concerns for flaring and venting issues.

4. Discussion

4.1. The Need for an African LCI Database

As observed in several studies [26,74,87,179] and highlighted furthermore in Table 1, many of the LCA results obtained in the different studies were based on data from European-based LCI databases, namely, Ecoinvent or Gabi. Even though there has been progress in globalizing inventory processes from Ecoinvent v2 to Ecoinvent v3 [217], most of the processes are based on the situations in developed countries. Therefore, several important uncertainties may exist when using these data to evaluate African conditions, especially for the least developed African economies. To solve these limitations, the Life-Cycle Initiative has promoted the "Global LCA Data Access network" (GLAD) to encourage the compatibility between the LCI databases and share information between different countries [218]. Several datasets can be found for African countries and future research could focus on improving these datasets.

4.2. The Need for an African LCIA Method

A second comment can be made when looking at the life cycle impact assessment (LCIA) methods used in the different studies. Many of the models have been developed based on the situation in developed countries (i.e., in terms of the population, population density, meteorological conditions, etc.). This point has also been raised by M. Ghazi et al [20]. Only a few studies in our review used a global life cycle impact assessment method, namely, ReCiPe2016 [10], Impact World+ [219] or LIME3 [220]. These methods provide characterization factors for each impact that is specific to the global region

or country. The accuracy of the damage assessment can be greatly improved; however, limitations still exist, for example, models for air pollution damage in these methods divided Africa into only a limited number of regions. Some improvements could be made to further take into account the specific socio-economic disparities between African countries in these methods.

4.3. Future Possible Topics of LCA Research

In this section, some potential research topics are raised from economic and environmental points of view. Environmental data were mainly collected from global popular databases used in LCA such as EDGARv5.0 [221] or FAOSTAT [6], economic information from OEC [5], and the world factbook from CIA [222].

A remark concerning all African countries can be raised, even though several reports from the UNEP [223] have highlighted the potential impacts of second-hand vehicles in African countries (imported mainly from Europe and the USA), there is no research paper that has focused on second-hand vehicles in Africa, despite the fact that the global LCA community has focused extensively on transport. The impact of tourism could be also studied furthermore, as the concern for sustainable tourism has been raised in recent years [224].

A description for each African country is provided in Table 2, regarding each aforementioned topic.

Table 2. Potential future topics of research. (x: no discussion topic).

Country	Agriculture	Energy	Other
Algeria	*- Wheat, one of the major crops there, was found to have a green water footprint (WF) higher than global average (3290 vs. 1277 m^3/ton)* [225]	*- Attention could be paid to petroleum and natural gas extraction as it contributes considerably to the country's GDP. These two sectors represent 15% of the total CO_2 emissions* [221]. *-Electricity is almost only produced from natural gas* [19], *where it represents 25% of the total CO_2 emissions* [221]	*- Road transport represents 25% of CO_2 emissions* [221]
Angola	*- Cassava is a major source of revenue for agriculture, where its green WF was found to be higher than the global average (819 vs. 550 m^3/ton)* [225] *- The burning of savanna represents more than 70% of the CO_2 emissions from the agricultural sector* [6]	*- Oil-related extraction contributes to about 50% of the GDP* [222] *and about 20% of the country's CO_2 emissions* [221]	*- Road transport is the top sector for CO_2 emissions, representing nearly 25%* [221]
Benin	*- Attention has already been paid to tomatoes as one of the major sources of agricultural revenue. A focus on cassava and yam production could be interesting, as together they represent more than 50% of the country's agricultural revenue* [6]	*- More than 50% of the country's total energy supply is from biofuel and waste products* [19]	*- Road transport is the top sector for CO_2 emissions, accounting for nearly 75%* [221]
Botswana	*-The country's agriculture is not well developed. Roots and tubers account for most of the production* [6]	*- Nearly 100% of the electricity is produced from coal* [19], *where the sector represents more than 50% of the CO_2 emissions* [221]	*- Mining activities represent up to 25% of the country's GDP* [222], *and this could be a potential research topic*
Burkina Faso	*- Sorghum and maize represent about 30% of crop revenue* [6]. *Their green WF was found to be two and three times higher, respectively, when compared with the global average* [225]	*- More than 95% of the households use solid fuels for cooking* [226]	*- Almost 50% of the country's total CO_2 emissions are due to road transport* [221] *- Gold mining represents a major source of revenue for exports (more than 75%)* [5]
Burundi	*- Bananas and cassava together represent about 50% of the revenue from agriculture* [6]. *Their green water footprint was found to be higher than the global average* [225]	*- More than 95% of the households use solid fuels for cooking* [226]	*- One third of the country's CO_2 emissions are from road transport* [221]
Cameroon	*- Exports of timber (especially to China) have been increasing in recent years (nearly 20% of the exports)* [5]	*- Oil production is a solid pillar of the economy* [5] *and it is also the highest contributor to CO_2 emissions (43%)* [221]	*- Road transport is the 2nd highest CO_2 emitter, accounting for nearly 25% of the total* [221]

Table 2. *Cont.*

Country	Agriculture	Energy	Other
Cabo Verde	*x*	*x*	*- The tourism industry mainly contributes to the economy* [222]
Central African Republic	*x*	*x*	*- Gold and diamond mining significantly contribute to the economy* [5]
Chad	*- The agricultural sector is reported to have the 4th highest CO_2 emissions in Africa, especially due to savanna burning* [6]	*- Oil is a major source of revenue (85% of the exports)* [5], *where the sector represents more than more than one third of country's CO_2 emissions* [221]	*- Road transport accounts for more than one fifth of CO_2 emissions* [221]
Comoros	*- Coconuts are a major crop product; their green water footprint was found to be twice that of the global average* [225]	*x*	*- Road transport contributes to nearly 50% of the emissions* [221]
Congo DR	*- Cassava is the major crop produced, resulting in significant land burning before plantation. The burning of savanna represents more than 80% of the CO_2 emissions from the agricultural sector* [6]	*- Nearly 100% of the total energy supply is from biofuel and waste products* [19]	*- Mining products represent an important source of revenue, especially copper and cobalt* [5]
Djibouti	*x*	*x*	*- Important transportation infrastructure (e.g., Addis Ababa–Djibouti railway) has been under development recently* [222].
Egypt	*- The use of synthetic fertilizers contributes to about one third of CO_2 emissions from the agricultural sector* [6]	*- Electricity is mainly produced from fossil fuels (natural gas)* [19], *where the sector represents almost 40% of CO_2 emissions* [221]	*- Road transport represents 20% of the CO_2 emissions* [221]
Equatorial Guinea	*- Sweet potatoes and cassava are two major crops produced in the country, where their green WF was found to be four times higher than the global average* [225]	*- The oil industry represents an importance source of revenue (more than 80% of exports* [5]*) and it represents 30% of CO_2 emissions* [221]	*- The chemical industry represents a source of revenue for exports* [5], *where the sector represents 30% of country CO_2 emissions* [221]
Eritrea	*- Sorghum is the main crop produced, where its green WF was found with a water footprint more than twice that of the global average* [225]	*- Almost 100% of the electricity is produced from oil* [19], *where the sector accounts for more than one half of the CO_2 emissions* [221]	*- Road transport accounts for more than 20% of CO_2 emissions* [221]
Eswatini	*- Sugarcane is the major crop produced in the country* [6]	*- About one half of the country's CO_2 emissions are due to the electricity sector* [221]	*- Road transport accounts for about one third of CO_2 emissions* [221]
Ethiopia	*- Emissions due to agriculture are reported to be the highest in Africa, especially due to manure management* [6]	*-About 90% of the country's energy supply is from biofuel and waste products* [226]	*- Road transport accounts for about one third of CO_2 emissions* [221]

Table 2. *Cont.*

Country	Agriculture	Energy	Other
Gabon	*- Cassava is one of the main crops produced [6], where its green WF was found to be higher than the global average (847 vs. 550 m^3/ton) [225]*	*- The oil and natural gas sectors are the main sources of revenue for the country, representing about 50% of CO_2 emissions [221]*	*x*
Gambia	*- Groundnuts bring important revenue to agriculture; their green WF was found to be higher than the global average (3657 vs. 2469) [225]*	*- More than 95% of the households use solid fuels for cooking [226]*	*- Road transport accounts for about 50% of the CO_2 emissions [221]*
Ghana	*- The burning of savanna contributes to more than 40% of the CO_2 emissions from the agricultural sector [6]*	*- Oil is an important source of revenue for exports [5], where the sector accounts for about 20% of the CO_2 emissions [221]*	*- Road transport accounts for about 40% of the CO_2 emissions [221]*
Guinea	*- Agriculture relies on rice production [6], where its green WF was found to be about four times higher than the global average (4004 vs. 1146 m^3/ton) [225]*	*- The electricity sector is responsible for about 20% of the CO_2 emissions [221]*	*- Road transport accounts for about 40% of the CO_2 emissions [221]* *- The country's growth relies on mining products, especially as has the highest bauxite reserve in the world [222]*
Guinea-Bissau	*- Agriculture relies extensively on rice production [6], where its green WF was found to be about three times higher than the global average (3291 vs. 1146 m^3/ton) [225]*	*- The electricity sector is responsible for about 20% of the CO_2 emissions [221]*	*- Road transport accounts for about 50% of the CO_2 emissions [221]*
Cote d'Ivoire	*- Cocoa represents a major source of revenue [5], where the LCA results could be compared with its neighbors such as Ghana*	*- More than 50% of the country's electricity is produced from fossil fuels (natural gas) [19], where the sector accounts for about one third of the CO_2 emissions [221]*	*- Road transport accounts for about one third of the CO_2 emissions [221]*
Kenya	*- Agriculture represents one third of the GDP [222]. Tea production was assessed, and maize, potatoes, or sugarcane could be also studied*	*- More than 80% of households use solid fuels for cooking [226]*	*- Kenya is the second largest market for African vehicles [227], where the sector contributes to 50% of the total CO_2 emissions [221]*
Lesotho	*- Potatoes and maize are the two major crops [6]*	*- The electricity sector accounts for about one fifth of the CO_2 emissions [221]*	*- Road transport accounts for about 50% of the CO_2 emissions [221]*
Liberia	*- Cassava is the main crop produced [6], where its green WF was about three times higher than the global average [225]*	*- Almost 100% of households use solid fuels for cooking [226]*	*- Road transport accounts for about 40% of the CO_2 emissions [221]*
Libya	*x*	*- The main economic resource, oil, has already received attention [82]. Apart from that, the electricity sector accounts for 40% of CO_2 emissions [221]*	*- Road transport accounts for about 50% of the CO_2 emissions [221]*
Madagascar	*- Rice, sugarcane, and cassava are the main agricultural products [6] and could receive more attention*	*- The electricity sector accounts for about 50% of the CO_2 emissions [221]*	*- Road transport accounts for about 25% of the CO_2 emissions [221]*

Table 2. *Cont.*

Country	Agriculture	Energy	Other
Malawi	*- The economy relies on tobacco for exports*	*- The electricity sector accounts for one third of the CO_2 emissions* [221]	*- Road transport accounts for one third of the CO_2 emissions* [221]
Mali	*- Rice and maize, the two main crops produced* [6], *were found to have a green WF twice that of the global average* [225]	*-Almost all households use solid fuels for cooking* [226]	*- Road transport and cement production each account for one third of the CO_2 emissions* [221]
Mauritania	*-Rice is the major crop produced* [6]	*- The electricity sector accounts for about 20% of CO_2 emissions* [221]	*- Road transport accounts for 40% of the CO_2 emissions* [221]
Mauritius	*x*	*- Fossil fuels represent 50% of electricity production* [19], *accounting for more than 60% of CO_2 emissions* [221]	*- Road transport accounts for 25% of the CO_2 emissions* [221]
Morocco	*- The total energy consumption for agriculture is the third highest in Africa (more than 50,000 terajoules* [6]*)*	*- The electricity sector accounts for more than one third of the CO_2 emissions* [221], *especially due to coal power plants* [19]	*- Morocco was also the first destination in Africa for tourism (2018 data* [228]*), and the impact of the tourism sector could receive attention*
Mozambique	*- Cassava is the major crop produced, where its green WF was found to be twice that of the global average (1077 vs. 500 m^3/ton)* [225]	*- More than 95% of households use solid fuels for cooking* [226]	*- The country relies on mineral fuels (coal) and aluminum for exports* [5], *and extraction processes could be further analyzed*
Namibia	*- More than 50% of the CO_2 emissions related to agricultural sector are due to the burning of savanna* [6]	*x*	*- The country relies on mineral extraction, such as diamond and uranium extraction.*
Niger	*- Millet is the main crop produced* [6], *where its green WF was found to be two times higher than the global average (10,330 vs. 4306 m^3/ton)* [225]	*- Nearly 100% of the electricity is produced from fossil fuels (coal and oil)* [19], *where the sector accounts for more than 20% of the country's CO_2 emissions* [221]	*- Road transport accounts for 50% of the CO_2 emissions* [221]
Nigeria	*- Agriculture represents the second highest CO_2 emissions in Africa* [221]*. Cassava has received attention, and in addition, yams and maize could be examined as other major crops* [6]	*- Oil is a major source of revenue for the country* [5], *where it represents 20% of the country's CO_2 emissions* [221]	*- Road transport accounts for about one third of the CO_2 emissions* [221]
Republic of Congo	*- Cassava and sugarcane are the two main crops* [6]	*- Oil a major source of revenue for exports* [5], *where the sector is responsible for 50% of the CO_2 emissions* [221]	*- Road transport accounts for about one third of the CO_2 emissions* [221]
Rwanda	*- The country mainly relies on agriculture, especially bananas and cassava* [6]	*- Almost all households use solid fuels for cooking* [226]	*- Road transport accounts for about 40% of the CO_2 emissions* [221]
Sao tome & Principe	*- Cocoa beans are a major source of revenue for exports* [5]	*x*	*x*
Senegal	*- Rice and groundnuts are the two main crops* [6]	*- Most of the electricity is produced from oil, where the sector contributes to about one quarter of the CO_2 emissions* [221]	*- Gold and phosphoric mining-related revenues have been increasing in recent years* [5] *and could lead to an increase in environmental impacts*

Table 2. *Cont.*

Country	Agriculture	Energy	Other
Seychelles	*x*	*- Electricity accounts for about one quarter of CO_2 emissions* [221]	*- Similar to Cabo Verde, the economy is mostly driven by tourism, and this could be relevant for study*
Sierra Leone	*- Rice is the major crop produced in the country* [6]	*- Nearly 100% of the households use solid fuels for cooking* [226]	*- Mining products (titanium and aluminum) drive exports* [5]
Somalia	*- Revenues are mainly from livestock* [6] *(sheep and goats)*	*- Nearly 100% of the households use solid fuels for cooking* [226]	*- Road transport accounts for about 50% of the CO_2 emissions* [221]
South Africa	*- The most produced crops (maize and sugarcane) have already been paid attention*	*- Electricity, mostly produced from coal [I1], contributes to 50% of the CO_2 emissions* [221]	*- Road transport accounts for about 10% of the CO_2 emissions* [221]
South Sudan	*x*	*- Oil production is a major driver of the economy* [5]	*x*
Sudan	*- The agricultural sector is the 3rd largest for CO_2 emissions in Africa, with sugarcane, sorghum, and millet as major crops.* *- Sudan is also the largest exporter of Arabic gum* [222]	*- About half of the electricity is produced from oil [I1], where the sector accounts for about 20% of the CO_2 emissions* [221]	*- Road transport accounts for about 50% of the CO_2 emissions* [221]
Tanzania	*- Maize is the main crop produced* [6]*, where its green WF was found to be double the global average*	*- More than 95% of the households use solid fuels for cooking* [226]	*- Road transport accounts for about 50% of the CO_2 emissions* [221]
Togo	*- The economy relies on agriculture (yams, cassava, maize, sorghum)* [6]	*- The country has been increasing its production of oil for exports* [5]	*- Road transport accounts for more than 50% of the CO_2 emissions* [221]
Tunisia	*- The agricultural sector has already received attention, where its energy usage was found to be the fourth highest in Africa* [6]	*- Electricity is mostly produced from natural gas* [19]*, where the sector accounts for about one third of CO_2 emissions* [221]	*- Road transport account for about one fifth of the CO_2 emissions* [221]
Uganda	*- The economy mostly relies on agriculture, especially coffee* [5]	*- More than 95% of the households use solid fuels for cooking* [226]	*- Gold mining operations have been increasing in recent years* [5]
Zambia	*- Maize and cassava are the two main crops produced, where their green WFs were higher than global averages* [225]	*- More than 80% of the households use solid fuels for cooking* [226]	*- The mining industry (mostly copper) brings significant revenues* [5]
Zimbabwe	*- Sugarcane, Maize, and Cassava are the major crops* [6] *and tobacco also brings important revenue from exports* [5]	*- About 40% of the electricity is produced from coal [I1], where the sector is responsible for more than one half of the CO_2 emissions* [221]	*- The economy depends on mining (especially gold)* [5]

5. Conclusions

A total of 199 peer-reviewed LCA articles were found for Africa. The interest in LCA for the continent has been growing in the last ten years, but it remains far less than in other countries, including developing countries, located in Asia such as Thailand. The most active African countries are South Africa (43), Egypt (23), and Tunisia (19). It was observed that several countries (especially those in central Africa) were not paid attention. For example, a country such as the DR Congo, whose population may exceed 200 million in 2050, has not yet been the subject of research. With the predicted economic and population growth, the already existing environmental impacts might increase in Africa in the near future. The number of LCA researchers based in Africa is still limited, and it appears important to prioritize education and training of the life cycle thinking for the continent.

African LCA has mainly focused on agricultural products and energy, representing almost half of the research topics. Fisheries, fruits, and vegetables have received considerable attention as well as biofuel. However, several key products of the African economy were not paid attention such as second-hand vehicles or natural resources (oil, natural gas, mining products, etc.). With the African Continental Free Trade Area (AfCFTA) commencing as of 1 January 2021, trade between African countries might intensify, and the need for sustainable production could become very important.

As shown in Table 1, one of this review's key messages is that research has been mainly conducted with LCI databases that are not specific to African countries. The usage of global LCIA methods also remains scarce. Several key economic sectors for African countries have not yet been assessed.

This lack of tools specific to African countries to conduct LCA could lead to uncertainties in consequent results. Future research could probably focus on developing an LCI database that is specific to the African continent and on improving the resolution of impact assessment models to include a higher number of African regions.

Supplementary Materials: The following are available online at https://www.mdpi.com/2076-3298/8/2/10/s1.

Author Contributions: Conceptualization, S.K. and N.I.; methodology, S.K.; formal analysis, S.K. and S.R.; investigation, S.K., S.R., M.M., C.-C.L.; writing—original draft preparation, S.K.; supervision, N.I.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data is available in this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Gross domestic product (GDP) [224] of African countries and articles per sector (the sum of the different columns is not necessarily always equal to the sum of the last column, as, for example, "reviews" cannot be inserted into any sector).

Country	Total GDP (PPP, Million USD)	Share of GDP, Agriculture (%) [Nb of Articles]	Share of GDP, Industry (%) [Nb of Articles]	Share of GDP, Services (%) [Nb of Articles]	Total Number of Research Articles
Algeria	630,000	13.3 [1]	39.3 [4]	47.4 [0]	16
Angola	193,600	10.2 [0]	61.4 [0]	28.4 [0]	0
Benin	25,390	26.1 [2]	22.8 [0]	51.1 [0]	1
Botswana	39,010	1.8 [0]	27.5 [0]	70.6 [0]	0
Burkina Faso	35,850	31 [0]	23.9 [4]	44.9 [0]	4
Burundi	8007	39.5 [0]	16.4 [0]	44.2 [0]	0
Cameroon	89,540	16.7 [1]	26.5 [3]	56.8 [1]	5
Cape Verde	3777	8.9 [0]	17.5 [0]	73.7 [0]	0
Central African Republic	3390	43.2 [0]	16 [0]	40.8 [0]	0
Chad	28,620	52.3 [0]	14.7 [0]	33.1 [0]	0
Comoros	1319	47.7 [0]	11.8 [0]	40.5 [0]	0
Democratic Republic of the Congo	68,600	19.7 [0]	43.6 [0]	36.7 [0]	0
Djibouti	3640	2.4 [0]	17.3 [0]	80.2 [0]	0
Egypt	1,204,000	11.7 [4]	34.3	54	13
Equatorial Guinea	31,520	2.5 [0]	54.6 [0]	42.9 [0]	0
Eritrea	9402	11.7 [0]	29.6 [0]	58.7 [0]	0
Eswatini	11,600	6.5 [0]	45 [0]	48.6 [0]	0
Ethiopia	200,600	34.8 [2]	21.6 [2]	43.6	4
Gabon	36,660	5 [0]	44.7 [0]	50.4 [0]	0
Gambia	5556	20.4 [0]	14.2 [0]	65.4 [0]	0
Ghana	134,000	18.3 [4]	24.5 [4]	57.2 [0]	8
Guinea	27,970	19.8 [0]	32.1 [0]	48.1 [0]	0
Guinea-Bissau	3171	50 [0]	13.1 [0]	36.9 [0]	0
Ivory Coast	97,160	20.1 [0]	26.6 [1]	53.3 [0]	1
Kenya	163,700	34.5	17.8	47.5	7
Lesotho	6656	5.8 [0]	39.2 [0]	54.9 [1]	1
Liberia	6112	34 [0]	13.8 [0]	52.2 [0]	0
Libya	61,970	1.3 [0]	52.3 [2]	46.4 [0]	2
Madagascar	39,850	24 [0]	19.5 [1]	56.4 [0]	2
Malawi	22,420	28.6 [1]	15.4 [2]	56 [0]	3
Mali	41,220	41.8 [3]	18.1 [1]	40.5 [0]	6
Mauritania	17,280	27.8 [1]	29.3 [1]	42.9 [0]	2
Mauritius	28,270	4 [2]	21.8 [2]	74.1 [9]	13
Morocco	298,600	14 [4]	29.5 [6]	56.5 [1]	11
Mozambique	37,090	23.9 [0]	19.3 [2]	56.8 [0]	2

Table A1. *Cont.*

Country	Total GDP (PPP, Million USD)	Share of GDP, Agriculture (%) [Nb of Articles]	Share of GDP, Industry (%) [Nb of Articles]	Share of GDP, Services (%) [Nb of Articles]	Total Number of Research Articles
Namibia	26,600	6.7 [0]	26.3 [0]	67 [0]	0
Niger	21,860	41.6 [0]	19.5 [0]	38.7 [0]	0
Nigeria	1,121,000	21.1	22.5	56.4	19
Republic of the Congo	29,390	9.3 [0]	51 [0]	39.7 [0]	0
Rwanda	24,680	30.9 [1]	17.6 [0]	51.5 [0]	1
São Tomé and Príncipe	686	11.8 [0]	14.8 [0]	73.4 [0]	0
Senegal	54,800	16.9 [1]	24.3 [0]	58.8 [0]	1
Seychelles	2750	2.5 [0]	13.8 [0]	83.7 [0]	0
Sierra Leone	11,550	60.7 [0]	6.5 [0]	32.9 [0]	0
Somalia	20,440	60.2 [0]	7.4 [0]	32.5 [1]	1
South Africa	767,200	2.8	29.7	67.5	21
South Sudan		- [0]	- [0]	- [0]	0
Sudan	177,400	39.6 [0]	2.6 [0]	57.8 [0]	0
Tanzania	162,500	23.4 [1]	28.6 [6]	47.6 [0]	7
Togo	12,970	28.8 [0]	21.8 [0]	49.8 [0]	0
Tunisia	137,700	10.1 [12]	26.2 [5]	63.8 [1]	19
Uganda	89,190	28.2 [1]	21.1 [1]	50.7 [4]	7
Zambia	68,930	7.5 [1]	35.3 [1]	57 [0]	2
Zimbabwe	34,270	12 [0]	22.2 [5]	65.8 [2]	7

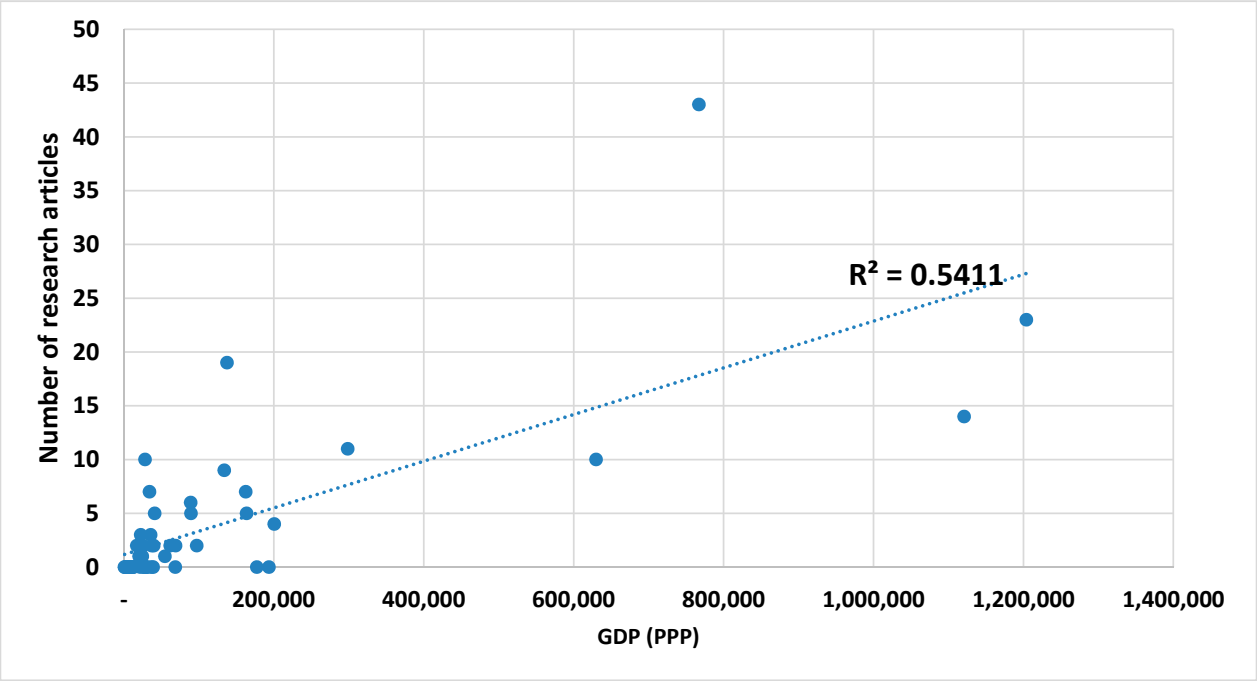

Figure A1. Correlation between the GDP (PPP) with the number of LCA research articles concerning each African country.

Table A2. Summary of available life-cycle assessment (LCA) studies in Africa (Annex to Table 1).

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Algeria [20]	Cradle to grave	No indication/no allocation	EOST	France
Algeria [21]	Cradle to gate	No indication/no allocation	Boumerdes University	Algeria
Algeria [22]	Cradle to grave	No indication/no allocation	Boumerdes University	Algeria
Algeria [23]	Cradle to grave	No indication/no allocation	University of Boumerdes	Algeria
Algeria [24]	Cradle to gate	No indication/no allocation	BADJI Mokhtar University	Algeria
Algeria [25]	Cradle to grave	No indication/no allocation	University of Boumerdes	Algeria
Algeria [26]	Cradle to gate	No indication/no allocation	ENSSMAL	Algeria
Algeria [27]	Cradle to grave	No indication/no allocation	University Saad Dahlab	Algeria
Algeria [28]	Well-to-Tank	No indication/no allocation	Ecole Nationale Polytechnique	Algeria
Algeria [29]	Cradle to grave	No indication/no allocation	Bougara University	Algeria
Benin [30]	Cradle to gate	No indication/no allocation	CIRAD	France
Benin [31]	Cradle to gate	No indication/no allocation	CIRAD	France
Burkina Faso [32]	Cradle to grave	No indication/no allocation	Escola Tècnica Superior d'Enginyeries Industrial	Spain
Burkina Faso [33]	Well-to-Tank	energy allocation	Boumerdes University	Germany
Burkina Faso [34]	Cradle to site	No indication/no allocation	Universitat Politècnica de Catalunya (UPC)	Spain
Cameroon [35]	Well-to-Wheel	No indication/no allocation	KU Leuven	Belgium
Cameroon [36]	Cradle to grave	No indication/no allocation	University of Yaoundé	Cameroon
Cameroon [37]	Cradle to gate	Economic allocation	INRA	France
Cameroon [38]	end-of-life	No indication/no allocation	University of Yaoundé	Cameroon
Cameroon [39]	Well-to-Tank	energy allocation	University of Udine	Italy
Egypt [40]	Cradle to site/end-of-life	No indication/no allocation	Environment and Climate Research Institute, Egypt	Egypt
Egypt [41]	end-of-life	No indication/no allocation	National Water Research Center, Egypt	Egypt
Egypt [42]	Not applicable	No indication/no allocation	E-JUST	Egypt
Egypt [43]	Cradle to grave	No indication/no allocation	E-JUST	Egypt
Egypt [44]	Not applicable	No indication/no allocation	E-JUST	Egypt

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Egypt [45]	Cradle to gate	Economic allocation	Universita Politecnica delle Marche	Italy
Egypt [46]	Not applicable	No indication/no allocation	E-JUST	Egypt
Egypt [47]	Cradle to grave	No indication/no allocation	Riga Technical University	Latvia
Egypt [48]	end-of-life	No indication/no allocation	E-JUST	Egypt
Egypt [49]	Cradle to grave	No indication/no allocation	Parthenope University of Naples	Italy
Egypt [50]	Cradle to gate	Mass and economic allocation	WorldFish	Malaysia
Egypt [51]	Not applicable	No indication/no allocation	Menoufia University	Egypt
Egypt [52]	Not applicable	No indication/no allocation	E-JUST	Egypt
Egypt [53]	Cradle to gate	Mass and energy allocation	E-JUST	Egypt
Egypt [54]	Cradle to gate	No indication/no allocation	Alexandria University	Egypt
Egypt [55]	Cradle to gate	No indication/no allocation	E-JUST	Egypt
Egypt [56]	end-of-life	No indication/no allocation	Alexandria University	Egypt
Egypt [57]	Cradle to gate	No indication/no allocation	E-JUST	Egypt
Egypt [58]	Cradle to grave	No indication/no allocation	Ministry of Petroleum and Mineral Resources, Alexandria, Egypt	Egypt
Egypt [59]	end-of-life	No indication/no allocation	Mansoura University	Egypt
Egypt [60]	end-of-life	No indication/no allocation	Mansoura University	Egypt
Egypt [61]	Cradle to gate	No indication/no allocation	Cairo University	Egypt
Egypt [62]	Cradle to gate	No indication/no allocation	University of Siena	Italy
Ethiopia [63]	Cradle to gate	No indication/no allocation	Wageningen University	Netherlands
Ethiopia [64]	Cradle to grave	No indication/no allocation	Universitat Hohenheim	Germany
Ethiopia [65]	Cradle to gate	Economic allocation	Wageningen University	Netherlands
Ethiopia [66]	Cradle to grave	Ecoinvent 3-allocation, default unit	Addis Ababa University	Ethiopia
Ghana [67]	Cradle to grave	No indication/no allocation	University of Ghana	Ghana
Ghana [68]	Cradle to gate	No indication/no allocation	The Hong Kong Polytechnic University	Hong Kong
Ghana [69]	Cradle to grave	Mass and energy allocation	University of Genoa	Italy
Ghana [70]	Cradle to gate	No indication/no allocation	Wageningen University	Netherlands
Ghana [71]	Cradle to grave	No indication/no allocation	University of Ghana	Ghana

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Ghana [72]	Cradle to grave	No indication/no allocation	Curtin University	Australia
Ghana [73]	Cradle to gate	Physical and economical allocation	Wageningen University	Netherlands
Ghana [74]	Cradle to gate	No indication/no allocation	Kwame Nkrumah University of Science & Technology	Ghana
Ivory Coast [75]	Well-to-Tank	energy allocation	Universite de Toulouse	France
Kenya [76]	Cradle to gate	No indication/no allocation	Marks and Spencer	UK
Kenya [77]	Cradle to grave	No indication/no allocation	Technical University of Denmark	Denmark
Kenya [78]	Cradle to grave	No indication/no allocation	University of California	USA
Kenya [79]	Cradle to gate	No indication/no allocation	University of Michigan	USA
Kenya [80]	Gate to grave	No indication/no allocation	Umeå University	Sweden
Libya [81]	Cradle to grave	No indication/no allocation	Nottingham Trent University	UK
Libya [82]	Cradle to grave	No indication/no allocation	The Higher Institute of Polytechnic Professions	Libya
Madagascar [83]	Cradle to grave?	No indication/no allocation	University of Antananarivo	Madagascar
Madagascar [84]	Cradle to gate	No indication/no allocation	Université de la Réunion	France
Malawi [85]	Gate to gate	No indication/no allocation	Stellenbosch University	South Africa
Malawi [86]	Cradle to site	No indication/no allocation	Edinburgh Napier University	UK
Malawi [87]	Cradle to gate	Economic and mass allocation	University of Exeter	UK
Mali [88]	Cradle to grave	No indication/no allocation	Higher Technical Institute, Cyprus	Cyprus
Mali [89]	Cradle to gate	No indication/no allocation	KU Leuven	Belgium
Mali [90]	Cradle to gate	No indication/no allocation	KU Leuven	Belgium
Mali [91]	Cradle to gate	No indication/no allocation	University of South Florida	USA
Mali [92]	Cradle to gate	Economic allocation	CIRAD	France
Mauritania [93]	Cradle to gate	Mass allocation	University of Santiago de Compostela	Spain
Mauritania [94]	Cradle to gate	No indication/no allocation	Instituto Eduardo Torroja de ciencias de la construcción	Spain
Mauritius [99]	end-of-life	No indication/no allocation	University of Mauritius	Mauritius
Mauritius [100]	Cradle to grave	Economic allocation	University of Mauritius	Mauritius
Mauritius [101]	Cradle to grave	No indication/no allocation	University of Mauritius	Mauritius

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Mauritius [102]	Cradle to grave	No indication/no allocation	University of Mauritius	Mauritius
Mauritius [103]	Cradle to site	Economic and mass allocation	University of Mauritius	Mauritius
Mauritius [104]	end-of-life	No indication/no allocation	Sotravic Lte	Mauritius
Mauritius [95]	Cradle to grave	Economic allocation	University of Mauritius	Mauritius
Mauritius [96]	end-of-life	No indication/no allocation	University of Mauritius	Mauritius
Mauritius [97]	Cradle to site	Economic allocation	University of Mauritius	Mauritius
Mauritius [98]	Cradle to grave	No indication/no allocation	University of Mauritius	Mauritius
Morocco [105]	Cradle to gate	Mass allocation	ADEME	France
Morocco [106]	Cradle to gate	No indication/no allocation	CIRAD	France
Morocco [107]	Cradle to gate	Economic allocation	CIRAD	France
Morocco [108]	Cradle to gate	No indication/no allocation	Universidad Politécnica de Madrid	Spain
Morocco [109]	Cradle to grave	No indication/no allocation	INES	France
Morocco [110]	Cradle to gate	No indication/no allocation	CIRAD	France
Morocco [111]	Cradle to grave	No indication/no allocation	University of Ljubljana	Slovenia
Morocco [112]	Cradle to gate	No indication/no allocation	Abdelmalek Essaadi University	Morocco
Morocco [113]	Cradle to grave	Economic allocation	CIEMAT	Spain
Morocco [114]	Cradle to grave?	No indication/no allocation	Mohammed V University	Morocco
Morocco [115]	Cradle to gate	No indication/no allocation	Mohammadia School of Engineering	Morocco
Mozambique [116]	Well-to-Wheel	Mass allocation	Chalmers University of Technology	Sweden
Mozambique [117]	Cradle to site	Mass allocation	Swedish University of Agricultural Sciences	Morocco
Nigeria [118]	Cradle to grave	No indication/no allocation	University of Manchester	UK
Nigeria [119]	Cradle to grave?	No indication/no allocation	Iowa State University	USA
Nigeria [120]	Cradle to gate	No indication/no allocation	Covenant University	Nigeria
Nigeria [121]	end-of-life	No indication/no allocation	National Water Quality Reference Laboratory Minna	Nigeria
Nigeria [122]	Well-to-Wheel	Mass allocation	Cranfield University	UK
Nigeria [123]	Gate to gate	No indication/no allocation	University of Ibadan	Nigeria
Nigeria [124]	Cradle to grave	No indication/no allocation	University of Tlemcen	Algeria

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Nigeria [125]	Cradle to grave	No indication/no allocation	Hohai University	China
Nigeria [126]	Cradle to grave	No indication/no allocation	Nigerian Stored Products Research Institute	Nigeria
Nigeria [127]	Cradle to gate	No indication/no allocation	Landmark University	Nigeria
Nigeria [128]	Cradle to gate	No indication/no allocation	Adeleke University	Nigeria
Nigeria [129]	Cradle to grave	No indication/no allocation	The University of Manchester	UK
Nigeria [130]	Cradle to gate	No indication/no allocation	Ladoke Akintola University of Technology	Nigeria
Nigeria, ghhana, ivory coast [13]	Not applicable	No indication/no allocation	The University of Manchester	South Africa
Rwanda [131]	Cradle to gate	Mass allocation	CIRAD	France
Senegal [132]	Cradle to gate	Economic allocation	The Swedish Institute for Food and Biotechnology	Sweden
Somalia [133]	Cradle to grave	Mass allocation	University of Siena	Italy
South Africa [134]	Not applicable	No indication/no allocation	University of Pretoria	South Africa
South Africa [135]	Cradle to gate	Mass allocation	University of Pretoria	South Africa
South Africa [136]	Cradle to gate	No indication/no allocation	University of Natal	South Africa
South Africa [137]	Not applicable	No indication/no allocation	University of Pretoria	South Africa
South Africa [138]	Cradle to site	No indication/no allocation	University of Pretoria,	South Africa
South Africa [139]	Cradle to grave	No indication/no allocation	University of KwaZulu-Natal	South Africa
South Africa [140]	Cradle to gate	No indication/no allocation	CSIR, South africa	South Africa
South Africa [141]	Cradle to grave	No indication/no allocation	Huawei Technologies CO., Ltd	China
South Africa [142]	end-of-life	Mass allocation	University of Cape Town	South Africa
South Africa [143]	Cradle to gate	No indication/no allocation	University of Pretoria	South Africa
South Africa [144]	Cradle to gate	No indication/no allocation	University of Catania	Italy
South Africa [145]	Well-to-Wheel	Economic allocation	University of Stellenbosch	South Africa
South Africa [146]	Cradle to gate	Mass allocation	University of KwaZulu-Natal	South Africa
South Africa [147]	Not applicable	No indication/no allocation	University of Johannesburg	South Africa
South Africa [148]	Cradle to grave	No indication/no allocation	University of Cape Town	South Africa
South Africa [149]	Cradle to gate	Economic allocation	Stellenbosch University	South Africa
South Africa [150]	Cradle to grave	Physical allocation	Stellenbosch University	South Africa

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
South Africa [151]	Cradle to gate	No indication/no allocation	Zurich University of Applied Sciences	Swiss
South Africa [152]	Cradle to gate	Mass allocation	University of Cape Town	South Africa
South Africa [153]	Cradle to gate	Economic and energy allocation	Stellenbosch University	South Africa
South Africa [154]	Cradle to gate	Economic allocation	University of Stellenbosch	South Africa
South Africa [155]	Cradle to gate	Economic and energy allocation	University of Stellenbosch	South Africa
South Africa [156]	Cradle to gate	Economic allocation	University of Stell+D170:D182enbosch	South Africa
South Africa [157]	Cradle to gate	No indication/no allocation	Institute of Electronic Structure & Laser	Greece
South Africa [158]	Cradle to gate	No indication/no allocation	University of Johannesburg	South Africa
South Africa [16]	Not applicable	No indication/no allocation	University of the Witwatersrand	South Africa
South Africa [159]	Cradle to gate	No indication/no allocation	University of Johannesburg	South Africa
South Africa [160]	Cradle to gate	No indication/no allocation	Council for Scientific and Industrial Research(CSIR)	South Africa
South Africa [161]	Cradle to grave	No indication/no allocation	Cranfield University	UK
South Africa [162]	Well-to-Wheel	Mass allocation	University of Johannesburg	South Africa
South Africa [163]	Well-to-Tank	No indication/no allocation	University of Johannesburg	South Africa
South Africa [164]	Cradle to gate	No indication/no allocation	University of KwaZulu-Natal	South Africa
South Africa [165]	Not applicable	No indication/no allocation	University of Johannesburg	South Africa
South Africa [166]	Cradle to grave	No indication/no allocation	Mount Royal University Calgary	Canada
South Africa [167]	Cradle to grave	Mass allocation	University of Cape Town	South Africa
South Africa [168]	Cradle to gate	No indication/no allocation	Tshwane University of Technology	South Africa
South Africa [169]	Cradle to gate	No indication/no allocation	South African Sugarcane Research Institute	South Africa
South Africa [170]	Cradle to gate	Mass allocation	KU Leuven	Belgium
South Africa [171]	Cradle to gate	No indication/no allocation	University of Cape Town	South Africa
South Africa [172]	Cradle to gate	No indication/no allocation	University of Cape Town	South Africa
South Africa [173]	Well-to-Wheel	Economic allocation	University of Cambridge	UK
South Africa [174]	Cradle to gate	No indication/no allocation	Stellenbosch University	South Africa
South Africa [175]	Cradle to gate	Mass allocation	University of Natal	South Africa

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Tanzania [176]	Cradle to grave	No indication/no allocation	University of Dar es Salaam	Tanzania
Tanzania [177]	Cradle to gate	No indication/no allocation	King Mongkut's University of Technology	Thailand
Tanzania [178]	Well-to-Wheel	energy allocation	University of Dar es Salaam	Tanzania
Tanzania [179]	Cradle to site	No indication/no allocation	Tropical Pesticides Research Institute	Tanzania
Tanzania [180]	Cradle to gate	No indication/no allocation	Yara International	Germany
Tanzania [181]	Not applicable	No indication/no allocation	Tropical Pesticides Research Institute	Tanzania
Tanzania [182]	Cradle to gate	No indication/no allocation	Research Institute of Electric Power Industry, Japan	Japan
Tunisia [183]	Not applicable	No indication/no allocation	CNRS	France
Tunisia [184]	Cradle to gate	No indication/no allocation	Université de Monastir	Tunisia
Tunisia [185]	Cradle to gate	No indication/no allocation	University of Sfax	Tunisia
Tunisia [186]	Cradle to gate	No indication/no allocation	Universitat Autònoma de Barcelona	Spain
Tunisia [187]	Cradle to grave?	No indication/no allocation	IRSTEA	France
Tunisia [188]	Cradle to gate	No indication/no allocation	Institut National des Sciences Appliquée Technologie	Tunisia
Tunisia [189]	Cradle to gate	No indication/no allocation	Université de Carthage	Tunisia
Tunisia [190]	Cradle to gate	No indication/no allocation	Université de Carthage	Tunisia
Tunisia [191]	Cradle to gate	No indication/no allocation	Université de Carthage	Tunisia
Tunisia [192]	Cradle to gate	No indication/no allocation	National School of Engineers of Gabes	Tunisia
Tunisia [193]	Cradle to gate	No indication/no allocation	Gabes University	Tunisia
Tunisia [194]	Cradle to gate	No indication/no allocation	Université de Carthage	Tunisia
Tunisia [195]	Cradle to gate	No indication/no allocation	CIRAD	France
Tunisia [196]	Cradle to grave?	No indication/no allocation	CIRAD	France
Tunisia [197]	Cradle to gate	No indication/no allocation	Université de Gabès	Tunisia
Tunisia [198]	Cradle to grave	No indication/no allocation	CIEMAT	Spain
Tunisia [199]	Cradle to grave	Economic allocation	CIEMAT	Spain
Tunisia [200]	Cradle to gate	No indication/no allocation	(IFAPA)	Spain
Tunisia [201]	Cradle to gate	No indication/no allocation	Cranfield University	UK

Table A2. *Cont.*

Country [Ref.]	System Boundaries	Allocation	Institution of the First Author	Location of the First Author
Uganda [202]	Cradle to grave	No indication/no allocation	Makerere University	Uganda
Uganda [203]	end-of-life	No indication/no allocation	National Water & Sewerage Corporation, Uganda	Uganda
Uganda [204]	Cradle to grave	No indication/no allocation	University of Hohenheim	Germany
Uganda [205]	Cradle to gate	No indication/no allocation	University of South Florida	USA
Uganda [206]	end-of-life	No indication/no allocation	Makerere University	Uganda
Uganda [207]	Gate to gate	No indication/no allocation	Makerere University College of Agricultural & Environmental Sciences	Uganda
Zambia [208]	Cradle-to-gate?	No indication/no allocation	Norwegian Geotechnical Institute (NGI)	Norway
Zambia [209]	Cradle-to-gate?	No indication/no allocation	Norwegian Geotechnical Institute (NGI)	Norway
Zimbabwe [210]	Cradle to gate	Mass allocation	University of Zimbabwe,	Zimbabwe
Zimbabwe [211]	Cradle to gate	No indication/no allocation	University of Johannesburg	South Africa
Zimbabwe [212]	Cradle to grave	No indication/no allocation	University Of Johannesburg	South Africa
Zimbabwe [213]	Cradle to gate	No indication/no allocation	University Of Johannesburg	South Africa
Zimbabwe [214]	Cradle to grave	No indication/no allocation	University of Zimbabwe	Zimbabwe
Zimbabwe [215]	end-of-life	No indication/no allocation	University of Johannesburg	South Africa
Zimbabwe [216]	end-of-life	No indication/no allocation	University of Johannesburg	South Africa

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