frontiers | Frontiers in Sustainable Food Systems

TYPE Review
PUBLISHED 21 December 2023
DOI 10.3389/fsufs.2023.1289431

OPEN ACCESS

EDITED BY
Ágoston Temesi,
Hungarian University of Agricultural and Life Sciences, Hungary

REVIEWED BY
Michael Pashkevich,
University of Cambridge, United Kingdom
Mihály Soós,
University of Debrecen, Hungary

*CORRESPONDENCE
Lacour M. Ayompe
✉ mlacour@uci.edu

RECEIVED 05 September 2023
ACCEPTED 30 November 2023
PUBLISHED 21 December 2023

CITATION
Acobta AN, Ayompe LM and Egoh BN (2023) Impacts of palm oil trade on ecosystem services: Cameroon as a case study. *Front. Sustain. Food Syst.* 7:1289431. doi: 10.3389/fsufs.2023.1289431

Impacts of palm oil trade on ecosystem services: Cameroon as a case study

Ada N. Acobta, Lacour M. Ayompe* and Benis N. Egoh

Department of Earth System Science, University of California Irvine, Irvine, CA, United States

Palm oil (PO) producing countries are expanding oil palm cultivated areas to meet growing demands at the expense of tropical forests and the ecosystem services (ES) they provide. Current responses to the growing call for sustainable PO trade are based on environmental impacts such as deforestation, partly because most social impacts have not been studied. These responses are based on information from Asia and South America since little has been done in Africa. This study fills these gaps by synthesizing the impacts of PO trade on ES from peer-reviewed and gray literature. Our case study is Cameroon, which harbors part of the Congo basin forest and experiences fast deforestation rates. Fifty-three sources of literature were used for this study (53% peer-reviewed and 47% gray literature). We found that oil palm cultivation was reported to negatively affect 15 ecosystem services in 147 instances (85%) and positively affect seven ecosystem services in 25 instances (15%). The majority of negative impacts were on carbon sequestration and climate regulation (20%), habitat quality (13%) and genetic diversity (13%). The most positive impact was on food provision (8%). These results highlight the trade-offs between food provision and other ES. While current policy responses have focused on environmental impacts, many negative social impacts are associated with PO trade that should be addressed within new policy tools.

KEYWORDS

carbon sequestration, climate regulation, conservation, commodity trade, deforestation, ecosystem services, palm oil, sustainability

Introduction

Palm oil (PO) is one of the most widely used and traded vegetable oils, accounting for nearly 40% of global vegetable oil production (IUCN, 2020). This PO is produced by extraction from the fruits of the oil palm (*Elaeis guineensis*) tree. Palm oil's chemical composition makes it versatile, and so is found in a variety of products like detergents, cosmetics, toothpaste, snacks, and biofuels (Ruggeri and Samoggia, 2018; Mutsaers, 2019; Ayompe et al., 2021). Over the past few years, the global demand for PO has significantly increased compared to other less accessible and more expensive vegetable oils, such as soy (Hoyle and Levang, 2012). For example, between 2012 and 2021, global crude PO production increased from less than 56 million metric tons to 76 million metric tons, representing an average annual growth rate of about 3.2% (Statista, 2022). The countries contributing the most to global PO production are Southeast Asian countries: Indonesia, Malaysia, and Thailand which produced about 63 million tons in 2018. A significant amount is produced by South American countries such as Colombia, Guatemala, Ecuador (3 million tons), while Africa is the least producing continent with the bulk of PO produced mostly by Nigeria, Ghana, and Cameroon (1.6 million tons) (CIFOR, 2021; Ritchie and Roser, 2021). It is speculated that PO might account for 65% of all vegetable oils produced

globally by 2050, as the 51 million tons of global production in 2015 is expected to increase to between 120 and 156 million tons by 2050 (RSPO-EU Roundtable, 2015). However, achieving such a growth rate without implementing sustainable palm oil strategies may come at a cost, especially for biodiversity, and ecosystem services (ES), i.e., the varied benefits humans get from the natural environments (Daily, 1997; Millennium Ecosystem Assessment (Program), 2005). ES such as climate regulation and carbon sequestration as well as water purification, habitat, and provision of food and raw materials among many others support human wellbeing. These ES are depleted by rampant land use and land cover changes to accommodate the expansion of oil palm cultivation globally (Ayompe et al., 2021).

The expansion of oil palm cultivation poses a huge threat to ES in one of the most diverse biomes in the world, the tropical rainforests. Oil palm is native to West and Central Africa and has over the years been nursed and grown in other parts of the world (Murphy et al., 2021). It is today cultivated in countries along the equatorial belt. Countries in this region have the favorable hot and humid climate necessary for the growth of the oil palm crop. The tropical rainforests. Harbors about half of the world's biodiversity, with about 62% of global terrestrial vertebrate species (Pillay et al., 2022). Also, tropical rainforests contain some of the largest depositories of above-ground biomass carbon stores in the world. This carbon stock is amassed by CO_2 removal from the atmosphere through photosynthesis. CO_2 can also be lost back into the atmosphere due to forest disturbances such as deforestation, consequently impacting the global carbon budget (Goïta et al., 2017). The rich biodiversity of the tropical rainforests supports the ecosystem functions that provide ES (e.g., climate regulation and carbon sequestration, provision of timber and medicinal plants) to its communities and the world. Many communities in PO producing countries such as Cameroon, Guatemala, and Indonesia depend on numerous ES for sustenance (Lhoest et al., 2019; Sharma et al., 2019; Castellanos-Navarrete et al., 2021). Usually, forests are cut down and burned to prepare the land for oil palm cultivation, resulting in habitat destruction which is the largest threat to biodiversity and associated ecosystem functions and services. With oil palm cultivation happening in the tropics, deforestation for oil palm poses a threat to its rich biodiversity and their habitat. When natural forest habitat is destroyed, the carbon that has been sequestered for decades or even centuries is released back into the atmosphere (Smith et al., 2013). The land is exposed, leaving it prone to erosion and leaching. Ayompe et al. (2021) for example highlight that the establishment of oil palm plantations next to water bodies causes eutrophication and siltation, impacting local water purification and supply services. If oil palm expansion and the associated deforestation of primary forests are not effectively managed, the negative impacts on ES would contribute to an array of social problems and negatively impact livelihoods.

A lot of research has been carried out on the impacts of PO on biodiversity and the environment and not much literature is available on the impacts on ES. Also, the more general peer-reviewed literature on PO production has focused on South-East Asian countries (Dislich et al., 2017; Reiss-Woolever et al., 2021). This has left a gap in the literature in other PO producing regions of the world like Africa and South America with fast-growing PO sectors. Investors are taking advantage of the fact that the forest that seems available is usually owned by local communities, but the land is easily sold to investors due to weak land tenure systems. Many African governments are seeing the sector as an opportunity to increase GDP and alleviate poverty, therefore putting in place incentives to expand their PO production. The rapid expansion of oil palm plantations in Cameroon, which is a biodiversity hotspot and part of the Congo Basin, poses a threat to the habitat and rich biodiversity present. This includes 7,500 plant species, 968 bird species and 300 species of mammals (MINEPDED, 2012; MINADER, 2015). The rapid deforestation for oil palm can be seen in Figure 1, where a single agro-industrial company allocated an oil palm concession of about 70,000 ha, has deforested about 5,500 ha in 2 years. Although a few studies have researched oil palm cultivation in Africa in general, and Cameroon in particular, there is a lack of knowledge of its impacts, particularly on ES. However, some of these impacts have been documented in various gray literature in the form of news articles, documentaries, NGO reports, and unpublished research theses. This study seeks to improve our understanding of the impact of PO trade on ES using Cameroon as a case study. We intentionally use peer-reviewed literature and the abundant gray literature to extract unpublished knowledge usually hidden in gray literature that documents the impacts of PO trade on ES. We specifically undertake a literature review focused on Cameroon to explore the recorded negative and positive impacts of PO on ES, identify key players in the PO sector, and assess existing research and documentation of these impacts. This study sought to answer three main questions: (1) What are the positive and negative impacts of PO trade on ecosystem services. (2) To what extent are these impacts documented in both peer-reviewed and gray literature. (3) How are these impacts distributed among smallholders and large corporations?

Methods

This study used a combination of peer-reviewed and gray literature to assess the impacts of PO trade on ES in Cameroon. The decision to use a combination of sources was based on the limited peer-reviewed articles available on the topic for Cameroon and to make use of unpublished knowledge in gray literature not necessarily captured in peer-reviews. The ES mentioned or described in the review material were recorded, and whether the impacts were positive or negative. Figure 1 summarizes the review process used in the study.

Study area

Cameroon is chosen as the case study based on: (1) Its rapid deforestation of primary forests for commodities such as palm oil (Vijay et al., 2016; Ordway et al., 2019). For example, the Government of Cameroon has increasingly been expanding PO production to reduce poverty and increase the country's Gross Domestic Product (GDP). In 2019, Cameroon was ranked the seventh largest global oil palm fruit producer, with an annual production of about 1 million tons (FAOSTAT, 2019) after expanding the cultivation area by 120,000 ha between 2000 and 2017 (Nkongho et al., 2015). (2) It is part of the Congo basin forest area, with few regulations regarding oil palm expansion and PO production, and (3) It is the largest PO producer in the Central Africa sub-region, but extremely limited research has been done on Cameroon's PO sector.

Cameroon is located 414.6 mi (667.2 km) north of the equator, with a hot and humid tropical climate and rainfall exceeding

FIGURE 1
Deforestation in an oil palm concession in Cameroon over 2 years (5,500 ha cleared) (source: Palmoil.io Newsletter – March 2023).

3,000 mm, making it favorable for the growth of OP. Some part of the Congo basin forest is found in Cameroon, with a primary forest extent of about 16 million hectares with about 100 thousand hectares lost in 2020 (Mongabay, 2020). It is a biodiversity hotspot, ranking fourth in flora richness and fifth in fauna diversity in Africa (MINEPDED, 2012). Cameroon has a rich fauna of about 300 species of mammals, 285 species of reptiles, 199 species of amphibians, 613 species of fish and 968 species of birds (MINADER, 2015). More than 33 identified important bird areas (IBA) have been designated, harboring rare and threatened bird species (Ngute et al., 2019). The rich volcanic soils account for rich vegetation which harbors flora and fauna and encourages considerable agricultural, forestry, and fishing activities, that draw international interest and also benefit the wellbeing of local people (GEF, 2018).

Cameroonian communities not only depend on the many ES for livelihoods, but also for aesthetics and recreation (Cuni-Sanchez et al., 2019; Lhoest et al., 2019). The rich biodiversity also serves as a recreational attraction for people from around the world and has for many years contributed to the Nation's GDP. Among the many attractions is the rich avian diversity which is a unique attraction for bird watchers from around the world who trek the lowlands and mountain forests visiting the many birding areas in Cameroon. Non-timber forest products such as spices (e.g., *njangsa*), vegetables (e.g., eru), fruits, and seeds (*bush mango and ogbono*) are delicacies and have become vital sources of livelihood with some individuals depending entirely on this ES for sustenance (Awono et al., 2016; Njoh and Wanie, 2018; Gallois et al., 2020). The available biodiversity and ES that benefit the wellbeing of local communities are now being threatened by the rapid expansion of the PO sector in Cameroon.

In Cameroon, oil palm is cultivated in the North West (Expert Knowledge), South West, Littoral, South, and Center regions. The cultivation and transformation process of oil palm to PO is carried out both on large and small scales by industries and individual smallholder PO producers. This classification was made following Ayompe et al. (2021), with smallholders being planters with oil palm planted areas of 50 ha or less and not considered agro-industries or explicitly mentioned as smallholders in the documents. Some of the large companies as of 2012 are the French group Bolloré with companies including - Société Camerounaise de Palmeraies (SOCAPALM) (28,027 ha), Société Africaine Forestière et Agricole du Cameroun (SAFACAM) (4,870 ha), and the Swiss Farm (3,793 ha); two State-owned companies: Cameroon Development Corporation (CDC) (12,670 ha) and Pamol Plantations (9,500 ha) (Hoyle and Levang, 2012): and privately owned oil palm plantations by companies such as Sithe Global Sustainable Oils Cameroon (SGSOC) (23,000 ha), Camvert (68,000 ha), and Green Valley (134 ha) (Greenvalley Plc).

Peer-reviewed literature

Peer-review literature relevant to this study was gathered from "Google Scholar," "Proquest," "Scopus" and "Web of Science" (Google Scholar, Proquest, Scopus & Web of Science) searches. Several searches were conducted on Google Scholar with various combinations of the keywords. First, a search was done in 2021 using the key words (Palm + Oil + Cameroon) to identify studies on PO production in Cameroon. This yielded about 37,200 articles that were too broad on the subject matter based on their titles. The following combination of keywords were further used for more specific results: (Palm + oil + Cameroon + Impact + ES) or (ecosystem + services + oil + palm + Cameroon) or (palm + oil + deforestation + Cameroon) or (palm + oil + impacts + Cameroonian + communities). These searches yielded about 15,000 results. The abstracts of all articles on the first five google pages were read and sorted by relevance. For the following google pages, only abstracts were read for article titles with a focus on PO in Cameroon. Between the 10th and 15th page, no more relevant articles were identified, and therefore the search was stopped. A second search on Google Scholar was done in February 2023 with the search terms (palm + oil + Cameroon) yielding 42,083 results. The same search terms and processes used for the first search was replicated for the second search. It generated 164 hits on "Scopus," 43 hits (title as filter) and 116 hits (abstract as filter) for "Web of Science." "Proquest" yielded 2,772 hits for full articles from scholarly Journals. Given that Cameroon is bilingual country, a search was also made using the French terms (huile + de + palme + Cameroun) generating two hits on "Scopus," 72 hits on "Proquest," no hits from "Web of Science" and 35 results from "Google Scholar." Other articles were identified through references cited in read articles. Articles were first sorted based on their titles and abstracts, after which a total of 69 articles were downloaded from all sources after checking for repeated articles (Figure 2). We read the articles, looking for any records of activities in the oil palm cultivation or the PO production process affecting

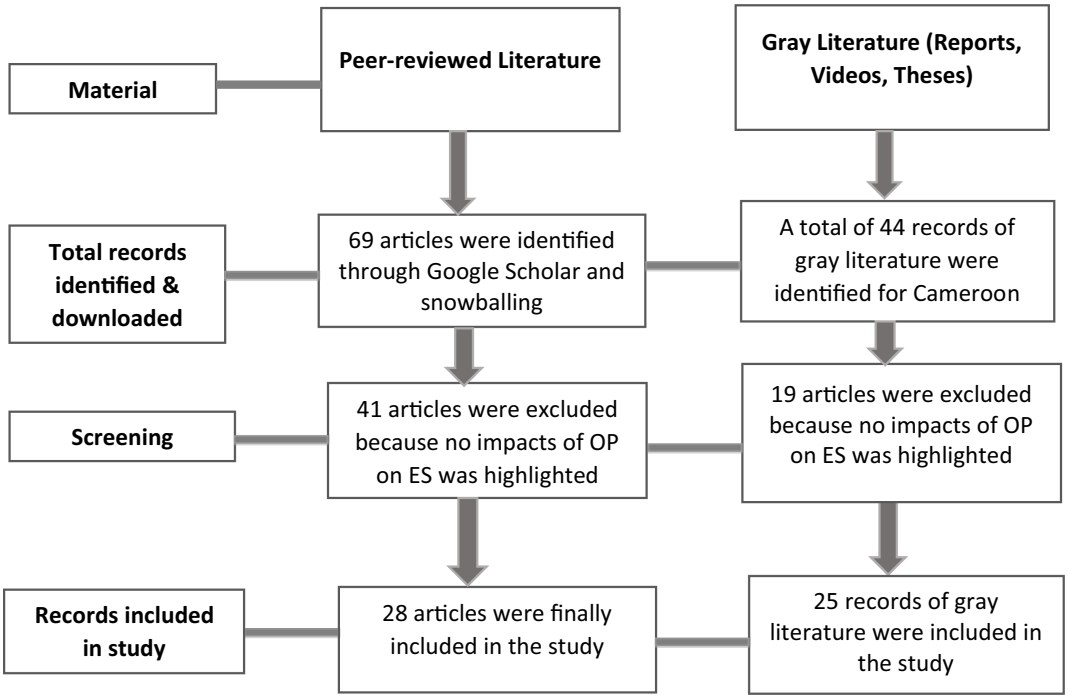

FIGURE 2
Schematic of the selection and exclusion methodology.

recorded ES. A total of 28 pieces of peer-reviewed literature which identified listed ES impacted by oil palm expansion or PO production in Cameroon were used for the study. The articles found on Google Scholar with relevant information ranged between the years 1984 to 2021.

Gray literature

To identify gray literature on PO production and ES in Cameroon, we carried out a Google search using the same search terms used in the peer-reviewed literature. The Google "video" and "news" filters were then used to search for video documentaries as well as news reports. Twenty-one news reports were identified with relevant information on the subject being widely discussed. These news articles were excluded from the review material for scientific purposes. Fourteen out of 21 videos that were reviewed were included in the study (Figure 2). A list of PO companies in Cameroon was compiled from peer-reviewed literature and searches made using Google search engine with keywords (Cameroon + palm + oil + Company name). A Google search for individual PO companies in Cameroon including "Herakles farms," "SOCAPALM," and "PAMOL" was done to pull out any literature available about their activities.

A list of national and international NGOs doing work related to agriculture and the environment in Cameroon was compiled from recommendations by scientists who had carried out PO related work in Cameroon, Google searches and mentions in other articles. Search terms included (Agricultural + organizations + in + Cameroon), (Environmental + organizations + in + Cameroon), (palm + oil + in + Cameroon). Links that mentioned NGO names were further explored as well as those that yielded information about palm oil, to identify mentions of any NGOs. NGOs that were not on the previously compiled list from recommendations and personal knowledge were explored further to find out if they implemented PO related work. We went through each of the organizations' websites and searched (palm + oil) or (oil + palm) as keywords to view any reports that had been written concerning oil palm or PO in Cameroon. A Google search was also done with the keywords (oil + palm + Cameroon + "Name of NGO"). Other reports were generated from the "Google Scholar" and "Proquest" searches. Ten NGO reports related to PO in Cameroon were included in this study. Additionally, four theses on PO in Cameroon were retrieved during the search process out of which two were found to be relevant and included in the analysis. A search was also made on the Environmental Justice Atlas (EJAtlas | Mapping Environmental Justice) with key search words (oil + palm + Cameroon). The Environmental Justice Atlas is a platform that documents global environmental injustices especially those associated with resource exploitation. Three search results were obtained with the desired information. However, given that the search results focused on PO companies in areas already included in other parts of the review, these three articles were excluded from the analysis to avoid repetition.

Data extraction and analysis

Data was extracted from a total of 28 peer-reviewed and 25 gray literature and recorded in Supplementary Table S1. Some of the information extracted and recorded were material type, source, publication year, region of the country, type of PO production (smallholder, industrial, or both), and PO company. The ES were classified into four categories based on the Millennium Assessment

classifications (Millennium Ecosystem Assessment (Program), 2005): Provisioning Services (food, raw material, medicinal resources, fresh water, cropland), Regulating Services (climate regulation and carbon sequestration, water purification, erosion control, disease regulation, flood prevention, pollination), Cultural Services (spiritual and religious experience, sense of place, recreation and ecotourism, mental health, aesthetic appreciation, inspiration, and cultural heritage), and Supporting Services (habitat, genetic diversity, soil formation, and nutrient cycling). This list of ES was used to screen each of the articles and listened for in the videos to have been impacted by oil palm cultivation or PO production. We worked with indicators for other ecosystem services such as assuming the cultural ES "spiritual and religious experience" was negatively impacted whenever articles mentioned land grabbing and destruction of sacred shrines by foreign oil palm companies. This would also impact food provisioning ES for the farmers in terms of losing land that would have been used for cultivation or harvesting Non-timber forest products (NTFPs). Each of these services identified in the studies was recorded with either a positive impact, negative impact or both when reported. The frequency of occurrence in each article and the percentage frequencies were calculated and recorded.

Results

Sixteen ESs were found to be impacted by oil palm cultivation. Both positive and negative impacts are documented in peer-reviewed literature and in gray literature like news reports, NGO reports, video documentaries, and thesis dissertations. Fifty-three records were used for this study, out of which 28 (53%) were peer-reviewed literature and 25 (47%) gray literature. The records used were published between the years 1984 to 2021 (Figure 3A). Reports and videos made up most of the records for gray literature. Figure 3B shows the frequency distribution of the sources of literature used in the study.

The ES considered in this study are grouped into Provisioning, Regulating, Cultural Services and Supporting Services. A total 172 entries were made, with an overwhelming 147 (85%) negative impacts and only 25 (15%) positive impacts. Forty-one percent of negative impacts were recorded in peer-reviewed literature while 59% of those impacts were recorded in gray literature. The most negative impacts identified from all sources were on carbon sequestration and climate regulation with 35 entries (24%) followed by habitat quality with 22 entries (15%) and genetic diversity with 20 entries (14%) (Figure 4). The least reported negative impacts were on soil formation with one entry (1%), followed by disease regulation, water purification and aesthetic values with three entries each (2%). Palm oil production was seen to have positive impacts on seven ES. Peer-reviewed literature recorded 18 entries (72%) while gray literature recorded 7 entries (28%). The most positive impacts recorded were on food provisioning services with 13 entries (52%) while the least were on pest regulation and habitat quality with one entry each (4%) (Figure 4). Other ecosystem services recorded to be impacted positively were raw material provision, genetic diversity, medicinal resource provision, and cultural heritage. Ecosystem services with no recorded impacts in gray nor peer-reviewed literature were recreation, air purification, pollination, and flood prevention, although the removal of forests destroys habitat for pollinators especially closer to agricultural land. In addition, the removal of forests reduces water infiltration and may result in flooding. Fifty-seven percent of the negative impacts on ES was recorded by studies with focus on agro-industrial PO production (Figure 5). Studies focused on smallholder PO production recorded 18% percent of the negative impacts on ES. Twenty-five percent of negative impacts were recorded by studies that included both smallholder and agro-industrial PO production. On the other hand, studies that focused on smallholder PO production recorded the most positive impacts on ES with 29%, compared to agro-industrial companies which recorded 17% of the positive impacts. Fifty-four percent was recorded by studies which considered both agro-industrial and smallholder PO production. Generally, agro-industrial companies received most attention from both gray and peer-reviewed literature recording 51% of all impacts and smallholders recording 20%.

The literature focused on PO producing areas in Cameroon which are South West, North West, Littoral, Centre, and South regions. Some of the literature sources looked at PO at a national level. It was found that most of the records (38%), focused on PO production in the South West region of Cameroon, with 19% gray and 19% peer-reviewed literature. The frequency of studies in the other regions were 10% for Littoral (4% gray, 6% peer-reviewed), 2% for South (all gray literature), 2% for North West (all peer-reviewed literature) and 6% Center (2% gray, 4% peer-reviewed). About 32% of the records were national studies (17% peer-reviewed,15% gray literature). These results are shown in Figure 6.

In these regions, actors in PO production are both individual smallholder farmers and agro-industrial companies. Some major agro-industrial companies highlighted in the literature sources are SPFS, SOCAPALM, CDC, PAMOL, SGSOC, SAFACAM, and CAMVERT, which were identified in both gray and peer-reviewed literature. The most highlighted PO company in all the records was SGSOC, highlighted 36% of the time in all material. The least highlighted companies were SAFACAM (5%) PAMOL (5%), and SPFS (5%).

Discussion

Oil palm cultivation is expanding globally, which has caused many negative impacts on biodiversity and human wellbeing. However, most of the impacts reported are generally related to biodiversity and the environment and mostly in Asia and South America. To our knowledge, few studies have looked at the impacts on ES (Ayompe et al., 2021), and even fewer studies focus on African countries. This has left a wide research gap in the PO sector of producing countries in Africa like Cameroon, even though they are hotspots for commercial oil palm plantation establishment in recent years. In this study, we set out to assess the negative impacts of PO trade on ES focusing on Cameroon. Studies have shown that oil palm cultivation can contribute to changes in ecosystem functions due to land use and land cover change, pollution, fires, and the introduction of alien invasive species that drive ecosystem changes (Moreno-Peñaranda et al., 2018). These changes usually cause negative impacts on ES, especially with the deforestation of primary forests (Meijaard et al., 2020).

We found overwhelming negative impacts on ES in the PO producing regions of Cameroon. According to this review, the three most reported ES impacted negatively were climate regulation and

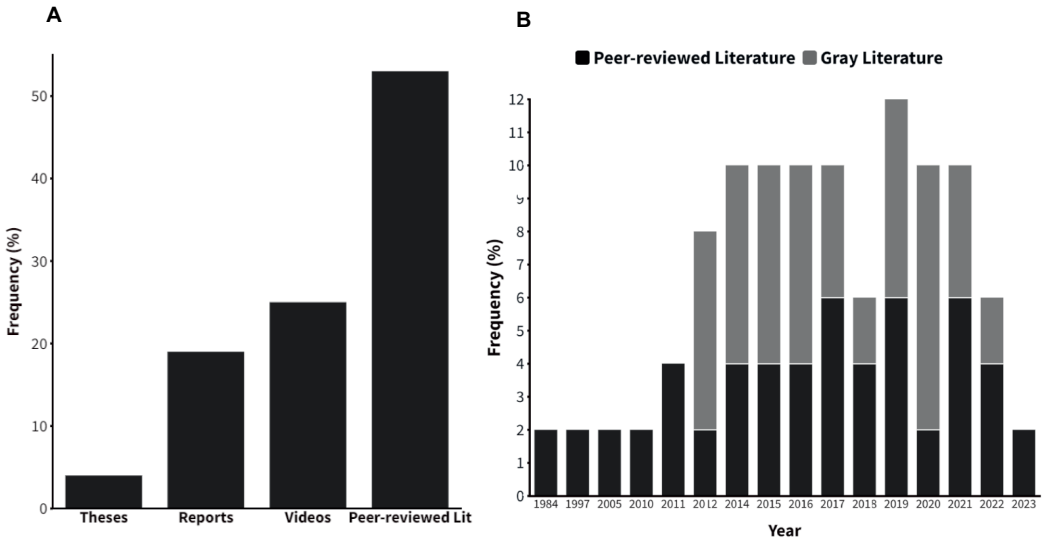

FIGURE 3
(A) Frequency of gray and peer-reviewed literature by year. **(B)** Sources of literature used in the study.

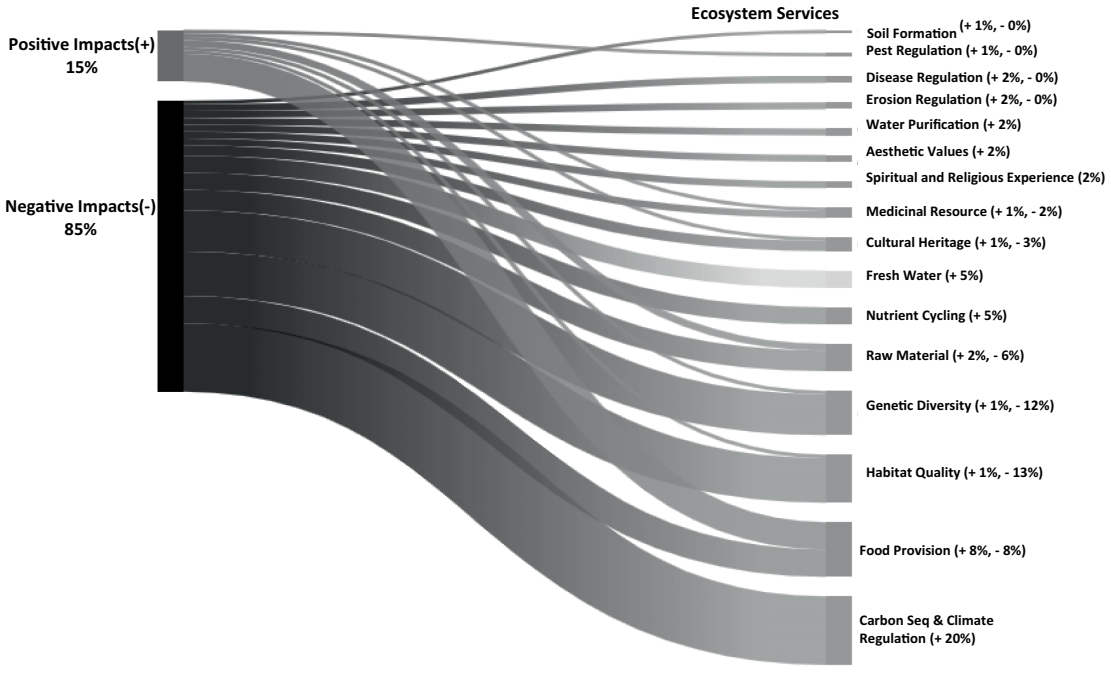

FIGURE 4
Positive and negative impacts of palm oil on ecosystem services identified in the literature review.

carbon sequestration, habitat quality, and genetic diversity. This finding is in line with other studies like Dislich et al. (2017) that reported carbon regulation, and habitat functions as some of the most negatively impacted ES in their global review of ecosystem functions of oil palm plantations. It is a widespread practice for industrial oil palm growers to deforest vast land for oil palm plantations (Carlson et al., 2018; Qaim et al., 2020). The deforestation then results in habitat loss for wildlife, loss of plant and animal species, loss of potential for air purification, and loss of terrestrial biomass with stored carbon (Nobre et al., 2016). Some ES are linked to the availability of other ES and livelihoods. For example, habitat quality, which was identified as one of the most negatively impacted ES is linked to provisioning services. The loss of habitat leads to the loss of animal species that inhabit that area. These animals often serve as a source of food and income for local community members through hunting. The *Warneckea ngutiensis*, a rainforest shrub described as from near Nguti

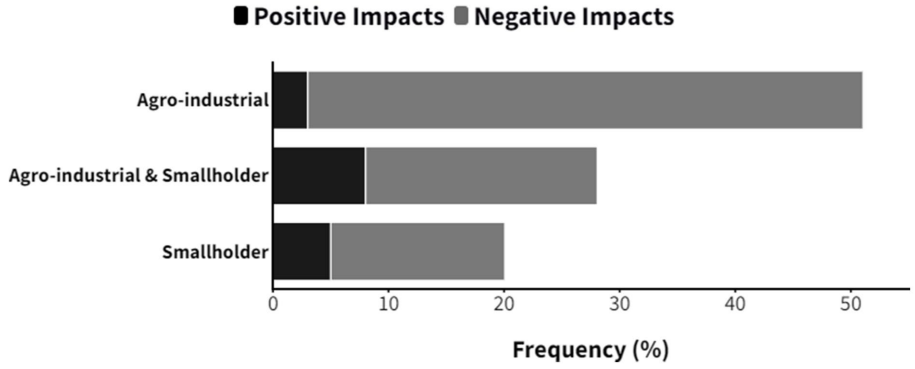

FIGURE 5
Impacts of different actors in Cameroon's palm oil sector as identified in the literature review.

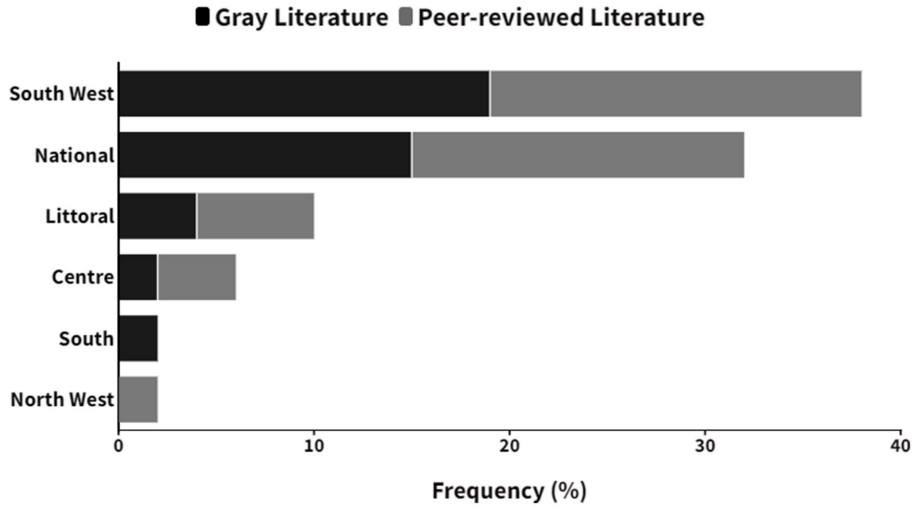

FIGURE 6
Palm oil producing regions in Cameroon identified in gray and peer-reviewed literature.

in the South West Region of Cameroon, unique in having only a vestigial staminal oil gland is reported to be Critically Endangered due to an oil palm plantation project (Stone and Cheek, 2018). Other provisioning ES like raw materials, non-timber forest products, and even medicinal plants are also negatively impacted by habitat loss, and so do the livelihoods of community members who depend on the exploitation of these services.

The most reported ES to be impacted was climate regulation and carbon sequestration. Climate regulation and carbon sequestration are provided largely by the availability of trees, therefore cutting down trees impacts their ability to remove and store carbon. Lack of trees will also lead to a loss in air purification potential even if not reported, which leaves communities prone to air pollution-related illnesses. Various sources of air pollution would impact human health in diverse ways such as eye and skin irritation, respiratory inflammation, cardiovascular issues, psychological effects, and even death (Finlay et al., 2012; Nchanji et al., 2016; Petrenko et al., 2016). These illnesses take away productivity hours and the cost of healthcare places a financial burden on those impacted. It is even more worrisome given that those impacted by air pollution-related illnesses are usually the rural poor with limited access to proper healthcare. If oil palm plantations were established on secondary, selectively logged forests or previous cropland, there might be fewer negative impacts on these ES (Meijaard et al., 2020). The most reported ES to be impacted negatively are linked to disturbances like forest cover loss which makes the impacts more easily identified. The said ES are charismatic, gaining the most attention nowadays, e.g., carbon loss from deforestation contributing to the global carbon budget and causing increasing global temperatures is talked about largely. Habitat loss and loss of genetic diversity are at the forefront of discussions among conservationists. As a result, negative impacts on these ES easily gain attention from researchers and NGOs and are recorded more frequently.

ES that were reported with the least negative impacts (disease regulation, soil formation, erosion control and recreation) do not necessarily mean they are the least important. These ES have been

identified by other studies to be impacted negatively by PO production as well; for example, a recent study by Morand and Lajaunie (2021) found trends of increasing vector-borne disease and deforestation attributed to oil palm establishment. When forests are cut down, the ecosystem of that area is modified and might become inhabitable for species that prevent the presence of hosts or vectors and in turn favor the prevalence of vectors that carry and spread diseases. The soil surface is exposed for the first few years before OPs mature as a result of deforestation, accentuating erosion and leaching. Soil texture and its biological characteristics are also modified during oil palm cultivation, which is often partly responsible for the degradation of plant diversity in oil palm plantations (Mesmin et al., 2021). Negative cultural impacts were recorded on cultural heritage and spiritual and religious services. Reviewed materials reported instances where community ancestral burial grounds were destroyed, community ancestral lands were seized pushing them to relocate, disturbing their place identity and sense of belonging. Some communities often have ancestral shrines in the forest where they often go to pour libations among other cultural practices to connect with their ancestors. These are spiritual and religious services that are lost when these areas are seized and converted to oil palm plantations. These impacts were identified especially in situations of land grabbing from communities by large PO corporations. Most negative impacts on cultural ES affect local communities more directly and would be picked up and talked about earlier by local people and non-governmental organizations.

One of the most frequently occurring natural disasters in Cameroon is flooding. Studies elsewhere and in Cameroon have shown that deforestation of natural forests for oil palm plantations increases runoff during rainfall (Meijaard et al., 2020). The runoff often collects in the lowlands leading to flash floods. Some of the flood-prone regions in Cameroon also happen to be major PO producing regions of the country (Ndille and Belle, 2014; Yengoh et al., 2016; Zogning et al., 2016). Some studies carried out in other PO producing countries identified unsustainable PO cultivation practices specific to the said areas like peatland draining and forest burning, which were also not identified in this review for Cameroon (Sumarga and Hein, 2014; Sharma et al., 2019).

The most positive impact was recorded on food provisioning, as the oil palm fruits are usually eaten as a snack, and PO is used as an ingredient in a wide variety of dishes locally. In addition, palm wine is extracted from old oil palm trees and consumed widely by local people while the palm fronds are used as local raw materials for roofing (Hollier, 1984; Cheyns and Rafflegeau, 2005; Mesmin et al., 2021). Takoumbe et al. (2023) in their recent study found the pseudo trunk of the tenera variety with the potential to be used in the implementation of insulating materials, reinforcement of composite materials, and in furnishing as wood. Smallholder oil palm plantations with agroforestry were observed to improve habitat suitability for the Congo Grey Parrot near the Korup National Park, possibly because of its palm fruits for feeding (Dueker et al., 2020). These findings are in line with the study conducted by Dislich et al. (2017), who found food and material production to increase with the establishment of oil palm plantations. Ejidike et al. (2004) mentioned noticing abundance in the Giant West African snail (*Archachatina marginata*) which is a delicacy and a source of income for many local communities. The low rate of reporting impacts on some of these ES could be due to a lack of published research that take into consideration inhabitants' perspectives, more attention on compelling ES, little necessity of some ES to the community/country, or the negative impacts might have just not been experienced.

A reasonable percentage of the recorded impacts were found in gray literature (reports, video documentaries, and thesis dissertations). Including information from gray literature in this review was a conscious decision to complement data availability issues in the data-poor countries in Africa. Since the goal was to understand which ES were impacted and not necessarily the extent of the impacts, gray literature happened to be a rich data pool of information that is otherwise not captured in peer-reviewed literature. Even peer-reviewed literature is limited to major PO producing countries in Southeast Asia. In the literature search, the available literature discussed the general environmental impacts of PO in Cameroon. No peer-reviewed literature was found that quantified the impact of PO production on the availability of ES. However, some peer-reviewed literature such as Mesmin et al. (2021) qualitatively looked at the environmental impact of oil palm in Cameroon. They carried out some soil and water analysis around oil palm plantations and discovered that groundwater was under the influence of a major source of pollution (from oil palm plantations and PO mills), making them unfit for human consumption without prior treatment.

Studies have shown that smallholders deforest primary forests for oil palm cultivation even more than agro-industrial companies in Cameroon (Ordway et al., 2019; CIFOR, 2021). In this study, negative impacts on ES such as habitat quality, genetic diversity, climate regulation and carbon sequestration were recorded more from agro-industrial companies than from smallholder farmers. This contradictory result might be the case because agro-industrial companies are more visible. It is easier to isolate large scale deforestation by agro-industrial companies compared to smallholder farmers with individual lands scattered around the regions. Agro-industrial companies deforest vast areas of land over a noticeably short period (Verité, 2013) and so attract media attention that document the resulting impacts. On the other hand, numerous individual smallholder farmers deforest small patches of forest and only expand over a prolonged period of time going barely noticed (Ravikumar et al., 2017; Benami et al., 2018). Agro-industrial companies thus happen to be targets for many NGOs. The SGSOC subsidiary, Herakles Farms, was the most mentioned in literature to have negative impacts on ES. This is because this company was taken into court by Greenpeace International for rapid deforestation of high value forests in Cameroon. It was talked about in NGO reports, peer-reviewed articles, and documentary videos. It attracted so much attention because it was the most ambitious PO project yet in Cameroon. It was supposed to cover about 73,000 hectares of land, serving as an environmental corridor for five protected areas (Korup National Park, Bakossi National Park, Banyang-Mbo Wildlife Sanctuary, Nta Ali Forest Reserve, and Rumpi Hills Forest Reserve) and a biodiversity hotspot (Kupsch et al., 2014). This project met quite some resistance from local people, NGOs, and the media (France 24, 2012; Mongabay, 2013; Al Jazeera, 2015). In 2013, the government of Cameroon reduced the lease term from 99 years to a three-year probationary lease for about 23,000 hectares. Experiences as such among other reasons have contributed to the international pressures for PO producers to be certified.

Palm oil producers worldwide are being pushed to consider adopting sustainable PO strategies with the upsurge of regulatory efforts such as the European Union (EU) due diligence. The most recent is the EU due diligence which requires PO importation to be deforestation-free and should have been produced in accordance with the laws and regulations of the country of production (The Western Producer, 2020; Contexte Environnement, 2021). This means producers would need to be innovative to meet the demand in PO production without deforesting new areas. Success in the due diligence would contribute to a balance, as communities would continue to benefit from forest ES and the livelihood sources they provide, while sustainable PO production creates additional jobs and contributes to the country's GDP. However, traceability may pose a challenge and some conservationists would prefer the money to be used for conservation efforts in PO producing countries. Several other sustainable PO programs have been developed both nationally and internationally. An example is the Roundtable on Sustainable PO (RSPO), an international voluntary PO certification program for PO producers. The RSPO proposes sustainable PO practices such as conserving patches of forests within farmlands which would preserve the biodiversity and ecosystem functions of the area, while continuing to provide opportunities to harvest NTFPs. It also proposes avoiding planting oil palm on steep terrains which are classified as fragile and could exacerbate soil erosion. Proposed actions such as regulation of pesticide use, encourage nutrient cycling by using empty fruit bunches, instituting a water management plan to allow continued availability of water sources and avoid negative impacts on other users in the catchment are essential in maintaining ecosystem functions and resulting services. Some PO producing countries have created guidelines for sustainable PO production such as Brazil, Indonesia, and Malaysia (ISPO, 2013; MPOCC, 2015; Wulandari and Nasution, 2021). African countries are just now developing their sustainable PO programs like the Africa PO Initiative (APOI) (World Economic Forum, 2016). Certification standards like the RSPO are only present in a few African countries. Uptake of certification standards like the RSPO is low in most African countries, with current efforts to improve uptake in countries like Cameroon. Given the rapid expansion in Cameroon's oil palm cultivated area (Ayompe et al., 2021) and the development of a national PO strategy to boost PO production (Feintrenie, 2012; Hoyle and Levang, 2012; OPAL, 2016; Kamto et al., 2019), there is the need for thorough scientific research to critically assess ES threatened by PO expansion in Cameroon. Such research will inform policy development for sustainable strategies that would best preserve these ES.

Conclusion

The results from this study show that in Cameroon, some effort is being invested to document how PO trade impacts the natural environment as 16 ESs were identified to be impacted. The limited number of total records (53) used in this study shows there is room for in-depth field research. Ecosystem services impacted negatively in order of frequency of occurrence were climate regulation and carbon sequestration, followed by habitat quality, genetic diversity, food provisioning, raw materials, nutrient cycling, fresh water, cultural heritage, spiritual and religious experience, water purification, aesthetic values, medical resources, disease regulation, erosion control and soil formation. We found more records of negative impacts of oil palm on ES from agro-industrial companies than smallholder producers.

Despite the numerous negative impacts of PO on ES, there is no doubt that it contributes enormously to income generation, economic growth and possibly enhances some ES if produced sustainably. Major PO producers have attempted to manage the benefits of PO production and mitigate negative impacts by adopting sustainable PO production practices (RSPO, SPOPP, ISPO, MSPO, APOI). Adopting practices that have been found to improve yield while mitigating environmental and ES impacts could enable sustainable production in African oil palm plantations. Such strategies could include planting improved cultivars, optimizing organic fertilizer application, proper timing for oil palm fruit ripeness to improve yield and proper understory vegetation management, managing riparian reserves and conservation of forest fragments within blocks of oil palm to conserve ES benefits. These efforts are a silver lining in that there is the possibility for PO production to be sustainable if decision-makers and PO producers work together. This could be possible following research identifying areas with high-value ES and policies formed taking research findings into consideration. Sustainable strategies need to include both smallholders and agro-industrial corporations, as both sectors are rapidly expanding and impacting ES. Given that the impact on cultural services is mostly caused by large corporations, smallholders and local communities could be protected by policies that protect rights to land, ease access to credit, and technical support (Bennett et al., 2019). Overall, sustainable PO production will go a long way to safeguard the rich tropical biodiversity and the ES they provide. It will open up opportunities to markets such as the European Union, where the European Parliament recently adopted a resolution calling for regulatory action to tackle EU-driven global deforestation. The proposal would impose due diligence obligations on operators placing PO and its derived products on the EU market or exporting them from the EU.

Author contributions

AA: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. LA: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. BE: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing, Supervision.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. We acknowledged funding from the UK Research and Innovation's Global Challenges Research Fund (UKRI GCRF) through the Trade, Development and the Environment Hub project (project number ES/S008160/1). We acknowledged funding from the Swift Foundation.

Acknowledgments

The authors acknowledge funding from the UK Research and Innovation's Global Challenges Research Fund (UKRI GCRF) through the Trade, Development, and the Environment Hub project (project

number ES/S008160/1). The authors acknowledge funding from the Swabb Foundation. BNH was supported by SLAON and HELLMAN foundations as a has been supported by the Conservation Action Research Network (CARN) – (Aspire 2021) grant, the UCI Earth System Science, School of Physical Sciences Diversity and Inclusion fellowship 2021-2022, the UCI Newkirk Center for Science & Society Research Justice Shop fellowship – 2022-2023, and the UCI CLIMATE justice initiative fellowship 2023-2024.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1289431/full#supplementary-material

References

Awono, A., Eba'a Atyi, R., Foundjem-Tita, D., and Levang, P. (2016). Vegetal non-timber forest products in Cameroon, contribution to the national economy. *Int. For. Rev.* 18, 66–77. doi: 10.1505/146554816819683708

Ayompe, L. M., Schaafsma, M., and Egoh, B. N. (2021). Towards sustainable palm oil production: the positive and negative impacts on ecosystem services and human wellbeing. *J. Clean. Prod.* 278:123914. doi: 10.1016/j.jclepro.2020.123914

Benami, E., Curran, L. M., Cochrane, M., Venturieri, A., Franco, R., Kneipp, J., et al. (2018). Oil palm land conversion in Pará, Brazil, from 2006–2014: evaluating the 2010 Brazilian sustainable palm oil production program. *Environ. Res. Lett.* 13:034037. doi: 10.1088/1748-9326/aaa270

Bennett, A., Ravikumar, A., McDermott, C., and Malhi, Y. (2019). Smallholder oil palm production in the Peruvian Amazon: rethinking the promise of associations and partnerships for economically sustainable livelihoods. *Front. For. Glob. Change* 2:14. doi: 10.3389/ffgc.2019.00014

Carlson, K. M., Heilmayr, R., Gibbs, H. K., Noojipady, P., Burns, D. N., Morton, D. C., et al. (2018). Effect of oil palm sustainability certification on deforestation and fire in Indonesia. *Proc. Natl. Acad. Sci. U. S. A.* 115, 121–126. doi: 10.1073/pnas.1704728114

Castellanos-Navarrete, A., de Castro, F., and Pacheco, P. (2021). The impact of oil palm on rural livelihoods and tropical forest landscapes in Latin America. *J. Rural. Stud.* 81, 294–304. doi: 10.1016/j.jrurstud.2020.10.047

Cheyns, E., and Rafflegeau, S. (2005). Family agriculture and the sustainable development issue: possible approaches from the African oil palm sector. The example of Ivory Coast and Cameroon. *Oilseeds Fats Crops Lipids* 12, 111–120. doi: 10.1051/ocl.2005.0111

CIFOR (2021). *On the road to sustainable palm oil production in Cameroon* Center for International Forestry Research Available at: https://forestsnews.cifor.org/71988/on-the-road-to-sustainable-palm-oil-production-in-cameroon?fnl=en.

Contexte Environnement (2021). *Info Contexte - Comment la Commission européenne envisage de freiner la déforestation importee* Contexte Available at: https://www.contexte.com/article/environnement/info-contexte-comment-la-commission-europeenne-envisage-de-freiner-la-deforestation-importee_139115.html.

Cuni-Sanchez, A., Ngute, A. S. K., Sonké, B., Sainge, M. N., Burgess, N. D., Klein, J. A., et al. (2019). The importance of livelihood strategy and ethnicity in forest ecosystem services' perceptions by local communities in North-Western Cameroon. *Ecosyst. Serv.* 40:101000. doi: 10.1016/j.ecoser.2019.101000

Daily, G. C. (1997). "Introduction: what are ecosystem services?" in *Nature's services: societal dependence on natural ecosystems* (Washington, DC: Island Press), 1–10.

Dislich, C., Keyel, A. C., Salecker, J., Kisel, Y., Meyer, K. M., Corre, M. D., et al. (2017). Ecosystem functions of oil palm plantations-a review. *Biol. Rev.* 92, 1539–1569. doi: 10.1111/brv.12295

Dueker, S., Kupsch, D., Bobo, S. K., Heymann, E. W., and Waltert, M. (2020). Congo Grey parrot *Psittacus erithacus* densities in oil palm plantation, agroforestry mosaic and protected forest in Southwest Cameroon. *Bird Conserv. Int.* 30, 156–167. doi: 10.1017/S0959270919000194

Ejidike, B. N., Afolayan, T. A., and Alokan, J. A. (2004). Observations on some climatic variables and dietary influence on the performance of cultivated African giant land snail (Archachatina marginata): notes and records. *Pak. J. Nutr.* 3, 362–364. doi: 10.3923/pjn.2004.362.364

FAOSTAT. (2019). *Food and agriculture organization statistics*. Available at: https://www.fao.org/faostat/en/#home

Feintrenie, L. (2012). *Transfer of the Asian model of oil palm development: from Indonesia to Cameroon* Centre de Coopération Internationale en Recherche Agronomique pour le Développement (Yaoundé: CIRAD).

Finlay, S. E., Moffat, A., Gazzard, R., Baker, D., and Murray, V. (2012). Health impacts of wildfires. *PLoS Curr.* 4:e4f959951cce2c. doi: 10.1371/4f959951cce2c

France 24. (2012). *Cameroon: the rush for palm oil*. Planet hope - France 24 - YouTube. Available at: https://www.youtube.com/watch?v=eA_ja__Bi70

Gallois, S., van Andel, T., Heger, T., Sonké, B., and Henry, A. G. (2020). Comparing apples and pears: the hidden diversity of central African bush mangoes (Irvingiaceae). *Econ. Bot.* 74, 178–194. doi: 10.1007/s12231-020-09497-x

GEF (2018). *International union for the conservation of nature country: supporting landscape restoration and sustainable use of local plant species and tree products (Bambusa ssp., Irvingia spp., etc.) for biodiversity conservation, sustainable livelihoods and emissions reduction in Cameroon* Global Environment Facility Available at: https://www.iucn.org/sites/dev/files/gef_prodoc.

Goïta, K., Mouloungou, J., and Bénié, G. B. (2017). Estimation of aboveground biomass and carbon in a tropical rain forest in Gabon using remote sensing and GPS data. *Geocarto Int.* 34, 243–259. doi: 10.1080/10106049.2017.1386720

Hollier, G. P. (1984). The marketing and distribution of palm oil in north-west province, Cameroon. *Scott. Geogr. Mag.* 100, 171–183. doi: 10.1080/00369228418736597

Hoyle, D., and Levang, P. (2012). *Oil palm development in Cameroon* WWF, IRD and CIFOR, Cameroon Available at: https://www.cifor.org/knowledge/publication/3793/.

ISPO (2013). *Sustainable palm oil in Indonesia* Indonesia Sustainable Palm Oil (ISPO) Certification Program Available at: https://sustainablepalmoilinindonesia.wordpress.com/2013/08/03/indonesia-sustainable-palm-oil-ispo-certification-program/.

IUCN (2020). *Mapping global impacts for all vegetable oils key to sustainability: IUCN study* International Union for Conservation of Nature Available at: https://www.iucn.org/news/science-and-economics/202012/mapping-global-impacts-all-vegetable-oils-key-sustainability-iucn-study.

Al Jazeera. (2015). *Cameroon: from Africa's palms l people and power*. YouTube. Available at: https://www.youtube.com/watch?v=-nHetI7UDv0

Kamto, M., Halleson, D., Ngom, E., Fauvelle, É., Salihovic, A., and Garcia, C. (2019). Using role-play to explore strategies for improving palm oil production and sustainability in Cameroon. *European Tropical Forest Research Network News*, 139–146. Available at: www.etfrn.org/file.php/418/etfrn59-usingrole-play

Kupsch, D., Kadiri, B. S., and Waltert, M. (2014). *Biodiversity, carbon stock and market value assessment for the SGSOC project area, southwest region, Cameroon*. Göttingen: Georg-August-Universität and University of Dschang. Available at: https://www.uni-goettingen.de/de/document/download/0dd3e0ecc8c8d2d7928e7da842ec56ff-en.pdf/SGSOCreport_final.pdf

Lhoest, S., Dufrêne, M., Vermeulen, C., Oszwald, J., Doucet, J. L., and Fayolle, A. (2019). Perceptions of ecosystem services provided by tropical forests to local populations in Cameroon. *Ecosyst. Serv.* 38:100956. doi: 10.1016/j.ecoser.2019.100956

Meijaard, E., Brooks, T. M., Carlson, K. M., Slade, E. M., Garcia-Ulloa, J., Gaveau, D. L., et al. (2020). The environmental impacts of palm oil in context. *Nat. Plants* 6, 1418–1426. doi: 10.1038/s41477-020-00813-w

Mesmin, T., Iii, M., Mboringong, F., Etoga, G., Voundi, E., Pierre, E., et al. (2021). Environmental impacts of the oil palm cultivation in Cameroon. *IntechOpen* 10:5772. doi: 10.5772/intechopen.97862

Millennium Ecosystem Assessment (Program) (2005). *Ecosystems and human well-being: wetlands and water synthesis: a report of the millennium ecosystem assessment*. Washington, DC: Island Press. 5, 563.

MINADER (2015). *The state of Cameroon's biodiversity for food and agriculture report* Ministry of Agriculture and Rural Development ca3431en.pdf (fao.org.

MINEPDED. (2012). *Republic of Cameroon fourth national report to the convention on biological diversity*. Ministry of Environment, Protection of Nature and Sustainable Development. Available at: https://www.cbd.int/doc/world/cm/cm-nr-04-en.pdf

Mongabay, (2013). *Controversial palm oil project approved in Cameroon rainforest* Mongabay News Available at: https://news.mongabay.com/2013/11/controversial-palm-oil-project-approved-in-cameroon-rainforest/.

Mongabay, (2020). The Congo rainforest Mongabay News. Available at: https://rainforests.mongabay.com/congo/

Morand, S., and Lajaunie, C. (2021). Outbreaks of vector-borne and zoonotic diseases are associated with changes in Forest cover and oil palm expansion at global scale. *Front. Vet. Sci.* 8:230. doi: 10.3389/fvets.2021.661063

Moreno-Peñaranda, R., Gasparatos, A., Stromberg, P., Suwa, A., and Puppim de Oliveira, J. A. (2018). "Stakeholder perceptions of the ecosystem services and human well-being impacts of palm oil biofuels in Indonesia and Malaysia" in *Biofuels and sustainability. Science for sustainable societies*. eds. K. Takeuchiet al. (Tokyo: Springer), 133–173.

MPOCC (2015). *Malaysian sustainable palm Oil (MSPO)* Malaysian Palm Oil Certification Council Available at: https://www.mpocc.org.my/about-mspo.

Murphy, D. J., Goggin, K., and Paterson, R. R. M. (2021). Oil palm in the 2020s and beyond: challenges and solutions. *CABI Agric. Biosci.* 2, 1–22. doi: 10.1186/s43170-021-00058-3

Mutsaers, H. J. W. (2019). The challenge of the oil palm: using degraded land for its cultivation. *Outlook Agric.* 48, 190–197. doi: 10.1177/0030727019858720

Nchanji, Y. K., Nkongho, R. N., Mala, W. A., and Levang, P. (2016). Efficacy of oil palm intercropping by smallholders. Case study in south-West Cameroon. *Agrofor. Syst.* 90, 509–519. doi: 10.1007/s10457-015-9873-z

Ndille, R., and Belle, J. A. (2014). Managing the Limbe floods: considerations for disaster risk reduction in Cameroon. *Int. J. Disast. Risk Sci.* 5, 147–156. doi: 10.1007/s13753-014-0019-0

Ngute, A. S. K., Hulme, M., Whytock, R. C., Taku, A., and Mayaka, T. B. (2019). The avifauna of mount Mbam, Cameroon. *Bull. Afr. Bird Club* 26, 82–91.

Njoh, G. E., and Wanie, C. M. (2018). Spatial distribution and species abundance area of non-timber Forest products in the Mount Cameroon National Park and adjoining forest zones. *Int. J. Forest Anim. Fish. Res.* 2, 113–122. doi: 10.22161/ijfaf.2.4.1

Nkongho, R. N., Ndjogui, T. E., and Levang, P. (2015). History of partnership between agro-industries and oil palm smallholders in Cameroon. *OCL* 22:A301. doi: 10.1051/ocl/2015005

Nobre, C. A., Sampaio, G., Borma, L. S., Castilla-Rubio, J. C., Silva, J. S., and Cardoso, M. (2016). Land-use and climate change risks in the amazon and the need of a novel sustainable development paradigm. *Proc. Natl. Acad. Sci. U. S. A.* 113, 10759–10768. doi: 10.1073/pnas.1605516113

OPAL (2016). *OPAL in Cameroon* Oil Palm Adaptive Landscape (OPAL) Available at: https://www.opal-project.org/project/opal-in-cameroon/.

Ordway, E. M., Naylor, R. L., Nkongho, R. N., and Lambin, E. F. (2019). Oil palm expansion and deforestation in Southwest Cameroon associated with proliferation of informal mills. *Nat. Commun.* 10:114. doi: 10.1038/s41467-018-07915-2

Palmoil.io Newsletter – March (2023). Available at: https://blog.palmoil.io/palmoil-io-newsletter-march-2023/.

Petrenko, C., Paltseva, J., and Searle, S. (2016). *Ecological impacts of palm oil expansion in Indonesia*. Washington, DC: International Council on Clean Transportation.

Pillay, R., Venter, M., Aragon-Osejo, J., González-del-Pliego, P., Hansen, A. J., Watson, J. E. M., et al. (2022). Tropical forests are home to over half of the world's vertebrate species. *Front. Ecol. Environ.* 20, 10–15. doi: 10.1002/fee.2420

Qaim, M., Sibhatu, K. T., Siregar, H., and Grass, I. (2020). Environmental, economic, and social consequences of the oil palm boom. *Annu. Rev.* 12, 321–344. doi: 10.1146/annurev-resource-110119-024922

Ravikumar, A., Sears, R. R., Cronkleton, P., Menton, M., and Pérez-Ojeda del Arco, M. (2017). Is small-scale agriculture really the main driver of deforestation in the Peruvian Amazon? Moving beyond the prevailing narrative. *Conserv. Lett.* 10, 170–177. doi: 10.1111/conl.12264

Reiss-Woolever, V. J., Luke, S. H., Stone, J., Shackelford, G. E., and Turner, E. C. (2021). Systematic mapping shows the need for increased socio-ecological research on oil palm. *Environ. Res. Lett.* 16:063002. doi: 10.1088/1748-9326/ABFC77

Ritchie, H., and Roser, M. (2021). *Forests and deforestation*. Our World in Data. Available at: https://ourworldindata.org/palm-oil

RSPO-EU Roundtable (2015). *A shared vision 100% sustainable palm oil in Europe: a snapshot of national initiatives* Roundtable on Sustainable Palm Oil Available at: https://www.china.rspo.org/publications/download/2034a4bbb48f0c1.

Ruggeri, A., and Samoggia, A. (2018). Twitter communication of Agri-food chain actors on palm oil environmental, socio-economic, and health sustainability. *J. Consum. Behav.* 17, 75–93. doi: 10.1002/cb.1699

Sharma, S. K., Baral, H., Laumonier, Y., Okarda, B., Komarudin, H., Purnomo, H., et al. (2019). Ecosystem services under future oil palm expansion scenarios in West Kalimantan, Indonesia. *Ecosyst. Serv.* 39:100978. doi: 10.1016/j.ecoser.2019.100978

Smith, P., Haberl, H., Popp, A., Erb, K. H., Lauk, C., Harper, R., et al. (2013). How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals? *Glob. Chang. Biol.* 19, 2285–2302. doi: 10.1111/gcb.12160

Statista. (2022). *Global production volume palm oil 2021/22*. Statista. Available at: https://www.statista.com/statistics/613471/palm-oil-production-volume-worldwide/

Stone, R. D., and Cheek, M. (2018). A revised key to the Warneckea species of Cameroon, and description of Warneckea ngutiensis (Melastomataceae-Olisbeoideae), a new critically endangered rainforest shrub. *Kew Bull.* 73, 1–6. doi: 10.1007/s12225-018-9739-4

Sumarga, E., and Hein, L. (2014). Mapping ecosystem services for land use planning, the case of Central Kalimantan. *Environ. Manag.* 54, 84–97. doi: 10.1007/s00267-014-0282-2

Takoumbe, C., Tiaya, E. M., Ndapeu, D., Mejouyo, P. W. H., Konga Wagang, C. V., Njeugna, E., et al. (2023). Selected physical and mechanical properties of the oil palm pseudo-trunk: case of the Tenera variety from Cameroon. *Resul. Mater.* 17:100354. doi: 10.1016/j.rinma.2022.100354

The Western Producer (2020). *European Union ban on palm oil could be canola boon* The Western Producer Available at: https://www.producer.com/markets/eu-ban-on-palm-oil-could-be-canola-boon/.

Verité. (2013). *Overview of palm oil production in sub-Saharan Africa*. SSA-Verite-Commodity-Report-Palm-Oil.pdf.

Vijay, V., Pimm, S. L., Jenkins, C. N., and Smith, S. J. (2016). The impacts of oil palm on recent deforestation and biodiversity loss. *PLoS One* 11:e0159668. doi: 10.1371/journal.pone.0159668

Wulandari, A., and Nasution, M. A. (2021). Comparison of roundtable on sustainable palm oil (RSPO), Indonesian sustainable palm oil (ISPO) and Malaysian sustainable palm oil (MSPO). *J. Penel. Kelapa Sawit* 29, 35–48. doi: 10.22302/iopri.jur.jpks.v29i1.129

Yengoh, G. T., Fogwe, Z. N., and Armah, F. A. (2016). Floods in the Douala metropolis, Cameroon: attribution to changes in rainfall characteristics or planning failures? *J. Environ. Plan. Manag.* 60, 204–230. doi: 10.1080/09640568.2016.1149048

Zogning, M. O., Tsalefac, M., Ursu, A., and Iatu, C. (2016). Contribution of geographic information Systems for the Mapping of flooding factors in Yaoundé: the case study of Mfoundi upstream watershed. *Present Environ. Sustain. Dev.* 10, 217–234. doi: 10.1515/pesd-2016-0019