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An Overview of the Role of Smallholders in Oil Palm Production Systems in Changing Climate

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ABSTRACT

Oil palm production contributes tremendously to the economies of tropical countries, a location where cultivation takes place. The cultivation of oil palm is usually dominated by smallholders and produces about 40% of global palm oil demand. Therefore, in this study, we aim to investigate the role of smallholder oil palm growers in ensuring palm oil production in a changing climate. This study was based on a conventional literature review. Relevant articles were retrieved using search terms such as “climate change” or “oil palm” or “climate change and oil palm” OR “oil palm smallholders” OR “oil palm growers”. The documents were selected by (i) examining the title of the document, (ii) the abstract (iii) and the content of the document sequentially. Only documents that meet the inclusion criteria were selected for the review. The results of this study demonstrated that global climatic changes have a greater negative effect on oil palm production in the tropics. Rising temperatures result in water stress to the palms, as does variability in rainfall, which reduces productivity, declining floral abortion, increase in pests and diseases infestation, and yield loss. Oil palm smallholder growers contribute immensely to global food security. Smallholders are estimated to manage approximately 40% of the global oil palm planted area, producing 40% of the global palm oil demand. In Africa, smallholders produced more than 60% of palm oil demand, 33% in Papua New Guinea, and 40% in Malaysia. In Latin America, where 87% of oil palm growers are smallholders, they produce over 60% of the demand for palm oil. Oil palm production creates jobs and poverty alleviation, provides the most efficient oil, provides vitamins for body-building, and provides nutritious and healthy food. This study recommends long-term and short-term policies on climate change and oil palm, improved regional academic leadership, with a focus on collaboration with scientists in consumer countries, improved institutional research, and collaboration in research between producer and major consumer countries.

INTRODUCTION

One of the fastest-growing crops in Southeast Asia is oil palm (Food and Agriculture Organization 2009, Sheil et al. 2009, Paterson et al. 2018, Paterson 2019, Ahmed et al. 2021). In addition to being used in food all over the world, palm oil and palm kernel can be found in cosmetics, detergents, plastics, chemicals, and pharmaceuticals (Paterson et al. 2013, 2018). Furthermore, biodiesel from palm oil helps Malaysia meet its fuel needs (Paterson et al. 2009, 2013). By 2015, oil palm had surpassed all other edible oils as the most widely consumed globally (Boyce 2017).

About 72% of palm oil production is consumed by the processed foods industry, while the personal care and cleaning products industry consumes 18%, and the biofuels industry consumes 10% (Voora et al. 2019). Asia consumes almost 70% of all palm oil production in the world; China, India, and Indonesia consume 40% of all palm oil produced as food-grade. When the demand for palm oil is broken down by region, Asia is by far the biggest and fastest-growing consumer (Tullis 2019, Jadhav 2019). The European Union and the United States of America account for 14% of global palm oil consumption (Voora et al. 2019). Global vegetable oil and fat production primarily use oil palm as a source, which makes the plant a highly utilized one (Paterson et al. 2013). Globally, 3 billion people use palm oil as their primary energy and vitamin source (d’Enghien 2016). Among the top ten producers of oil palm are Indonesia, Malaysia, Thailand, Nigeria, Colombia, the Ivory Coast, Brazil, Costa Rica, and the Democratic Republic of Congo (Corley & Tinker 2003, Maluin et al. 2020). Oil palm production, for example, is a significant industry in Guatemala, accounting for approximately 1% of the country’s GDP and 4.01% of export volume in 2018 (Guillaume & Soledad 2010). The top ten countries for palm oil exports include China, India, the Netherlands, Pakistan, the Philippines, Turkey, the United States, Kenya, South Korea, and Italy (MPOC 2021).

In the late 19th century Africa began exporting palm oil and kernel and experienced rapid growth, although Malaysia and Indonesia were the first to establish commercial plantations. In the 1920s, plantations were established in the DRC Congo, as well as in some parts of West Africa. The plant is currently grown at latitudes of 19°N (Dominican Republic) and 15°S (Brazil) (Carr 2011). In 2017, Indonesia (USD 18.7 billion), Malaysia (USD 9.8 billion), and the Netherlands (reexport) (USD 1.2 billion) were the top three exporters of crude palm oil and its fractions (refined and unrefined). India (USD 6.5 billion), China (USD 3.5 billion), and Pakistan (USD 2.2 billion) were the biggest buyers (Brack et al. 2016, Workman 2019, Voora et al. 2019). According to the 2016 export figures, palm oil (crude) and palm kernel (refined) were valued at USD 28.2 and USD 3.7 billion, respectively. In 2016, the sector's (retail) market value was at least USD 65 billion, and it contributed significantly to the global economy: global GDP and tax revenues were boosted by USD 39 billion and USD 4.3 billion, respectively (Voora et al. 2019). According to Voora et al. (2019) "In 2013/2014, the sector provided 2.9 million downstream jobs, with people employed in industries that use palm oil derivatives to make food ingredients, pastries, margarine, animal feed, and personal care products".

Oil palm cultivation, both large and small-scale, has made a huge change to regions in the tropics, the lives of people, and the profit margins of palm oil companies. Oil palm has a high production rate and is easy to establish, which in addition to its low cost of operation makes it highly profitable; the crop is also highly efficient economically, and does not use much land, pesticides, and fertilizer (Dislich et al. 2017, Paterson et al. 2018). Palm oil is produced mainly by Malaysia and Indonesia, which together produce 85–90% of overall global palm oil production (Voora et al. 2019). Almost 2/3 (60%) of the global production of palm oil comes from plantations owned by corporations or states, while the rest comes from 3 million smallholder growers (Voora et al. 2019). Recognizing the importance of palm oil in global food security, food sources such as oil palm must be managed carefully in the face of changing climate (Paterson et al. 2013). A significant negative effect will be imposed by changing climate on the cultivation of oil palm, particularly by 2100 (Paterson et al. 2015, 2017). Plantations will expand in the event of climatic changes and variability, as new areas become available - assuming biodiversity issues are overcome - and oil palm growers will need to adjust their methods to the changing climate (Rival 2017, Paterson et al. 2018).

The capability of oil palm growers to produce nutritious palm oil and allied products in sufficient quantities to meet local needs while meeting growing global demand is critical to the development of global food security (Nesadurai 2013, Khatun et al. 2020). Millions of households in developing countries face the globally critical threat of food security, which is an issue that must be solved by ramping up the processes of food production while overcoming the issues of advancing climate change and damage to the environment (FAO 2010). Palm oil is widely acknowledged to be the most efficient plant-derived oil, with the potential to feed the progressively increasing universal population (Meijaard et al. 2018, Weckx et al. 2019, Maluin et al. 2020). Due to such benefits to rural Malaysians and Indonesians, palm oil has now become a remarkable factor in lessening poverty, etc. (Santika et al. 2019), inevitably raising the standard of living of these households and allowing them to have access to improved healthcare and education (Qaim et al. 2020). In addition to meeting the universal demand for non-renewable resources and meeting food security challenges, palm oil is an optimal key solution for food crises and insecurity (Nesadurai 2013, MPOC 2019).

This study employed a conventional literature review to provide a current overview of the effect of changing climate on oil palm production and the role of oil palm smallholders in palm oil production. Several search engines were used to find articles relevant to this study, including Web of Science, Scopus, Elsevier, ProQuest, ResearchGate, and Google Scholar. Documents were found using suitable and appropriate search terms, such as "climate change" OR "oil palm" "climate change and oil palm" OR "oil palm smallholders" OR "oil palm growers" and so on. At this stage, the title and abstracts of the searched documents were thoroughly reviewed to categorize them into various themes and associations. Duplicate documents were removed, and the relevant documents were saved for future reference. Documents and articles that were not published in English, as well as articles that predated the year 2000, were excluded. The objective of this study is to investigate the role of smallholder oil palm growers in oil palm production in a changing climate. Oil palm's international importance as a vegetable oil source is a comparatively new phenomenon, boosted mainly by the initiative of Malaysian businesses and government over the past 3 to 4 decades, which established the crop and developed the industry through constant research support (Carr 2011). The findings of this study have the potential to benefit policymakers/stakeholders and the palm oil industry by providing mechanisms to adapt to the effect of climatic changes as well as enhancing the capacity of smallholders to improve oil palm production for global food security.

MATERIALS AND METHODS

Phase 1: Searching and Identification of Documents

Documents and articles pertinent to this review were obtained from reliable database systems such as Google Scholar, Scopus, ProQuest, Elsevier, and Web of Science. Documents and related articles were obtained from search engines via relevant search terms such as "climate change" OR "oil palm" or "climate change and oil palm" OR "oil palm smallholders" OR "oil palm growers" etc. Initial search 1,500 documents were returned from the search engines.

Phase 2: Screening and Selection of Relevant Documents

In this stage, the title, abstracts, and content of the searched documents were comprehensively reviewed and evaluated for categorization into various themes, topics, and associations. Duplicate documents were sorted out and the relevant original documents were retained for further review. Documents that were not written in English were excluded, as well as articles that pre-dates the year 2000 (Table 1).

Phase 3: Inclusion and Exclusion Criteria (Table 1)

Phase 4: Reviewing of Included Articles

Documents included in this review were selected from articles that specifically indicated in their titles or abstracts commitments to oil palm smallholder and food security directly or indirectly. Also included were full-text reviews and assessments of documents that reported the role of oil palm in feeding the world and the economies of oil palm smallholders. Papers that reported difficulties faced by smallholders in changing climate and the effect of changing temperature and rainfall on oil palm were also included.

Oil Palm

A native of West Africa, the oil palm (Elaeis guineensis), is normally found between Angola and The Gambia (Dislich et al. 2017, Nambiappan et al. 2018). The oil palm range in West African forests, where semi-wild palm trees have long grown around farmsteads and supported village economies (Carr 2011). The species is widely utilized in palm oil production (Corley & Tinker, 2003, Dislich et al. 2017, Nambiappan et al. 2018). Palm plantations have been established widely in many tropical countries where the climate is favorable. Oil palm is widely regarded as a highly efficient and profitable oil crop globally, which is easy to set up and establish, requires minimal capital, and has high-yielding productivity (Wahid et al. 2005). Oil palm is now farmed in the lowlands of tropical-humid countries (about 18.1 million hectares spread over 43 nations); production, 7.1 million hectares in Indonesia, and 4.6 million hectares in Malaysia, together make up approximately 85% of global palm oil production output (Dislich et al. 2017). Oil palm can be grown on various soil types, even on soils not favored by most other crops, within a pH range of 4-8 if sufficiently moist (Corley & Tinker 2003, Paterson et al. 2013).

Water is essential for oil palm growth, flowering, and fruit development. The range, distribution, and parameters relating to rainfall must be taken into consideration when selecting suitable plantation areas. A suitable amount of rainfall for oil palm trees is between 2,000 and 3,000 millimeters per year, or more than 200 rainy days annually (Carr 2011, Unjan et al. 2017). At temperatures below 15°C, growth may cease. Maximum and minimum temperatures range from 30-32°C and 21-24°C, respectively. (Paterson 2013, Ahmed et al. 2021, Abubakar et al. 2021). Oil palms are sensitive to high temperatures, with photochemical efficiency declining to above 35°C (Paterson et al. 2013). Palms require a relative

Table 1: Criteria for including and excluding retrieved articles.

Inclusion	Exclusion
Documents published in English	Documents not published in English
Google Scholar, Scopus, ProQuest, Elsevier, and Web of Science	Articles, textbooks on purchase or request
Documents indexed in Web of Science, Scopus, Elsevier, ProQuest, ResearchGate, and Google Scholar from 2000 to 2021	Pre-2000 documents that are not available through Web of Science, Scopus, Elsevier, ProQuest, Research Gate, or Google Scholar
Reviews, conferences, and articles	Magazine articles, patents, films, television broadcasts, generic documents, and statutes
Phase 2: title, abstract and full-text review	
Oil palm	Another crop rather than oil palm
Oil palm smallholders	Non-smallholders
Climate change and adaptation	Mitigation, the vulnerability only
Smallholders and food security	Large scale growers
Role of palm oil	Other vegetable oils

humidity between 75 and 80% and solar radiation should be not less than 16 or 17MJ m^{-1} d^{-1} (Unjan et al. 2017, Oettli et al. 2018); it also does not grow in areas subjected to continuous flooding (Carr 2011, Paterson et al. 2013). Palm oil production costs are minimal compared to other plants as it requires a comparatively low input of fertilizer (Dislich et al. 2017). The production capacity of oil palm trees reaches its maximum at age 9-18 years (USDA FAS 2012, Dislich et al. 2017). The palm tree normally reaches a height of approximately 10 m and is productive for 25-30 years before needing to be replanted (Corley & Tinker 2003, Abubakar et al. 2021).

Climate Change Impact on Oil Palm Production

In most parts of the world, weather and climate are the most important factors influencing oil palm productivity (Zhai & Zhuang 2009). Agricultural regions have seen a rapid evolution of climate change in the past few decades with a broad increase in atmospheric carbon dioxide (CO_2) throughout the world (Lobell & Gourdji 2012). The essential confidence that climatic changes and CO_2 will persist in the long term tends to raise several concerns on the security of food supply and agricultural production, a key question is how climatic variations would then affect global crop production (Lobell & Gourdji 2012). The Intergovernmental Panel on Climate Change has outlined the Low Emission Scenario (B1) and the High Emission Scenario (A1FI) as a means of determining global temperatures which predict to rise by 1.8°C to 4.0°C, which will negatively impact oil palm and other crop production (IPCC 2007a). Several factors contribute to the effect of climate change on oil palm, including changes in pests and diseases, site conditions, and climatic conditions (Fleiss et al. 2017, Paterson 2021). When growing conditions are unfavorable for oil palm, for example, temperatures that are higher or water deficiencies, the trees may be more susceptible to pests and diseases, resulting in lower yield. The pollination of oil palm may also be negatively declined as a result of changing climate, which results in lower yield (Fleiss et al. 2017). In most cases, climatic factors such as temperature and rainfall, as well as abiotic factors such as diseases, pests, and pollinators, will have a negative effect on the cultivation of palms (Rival 2017, Paterson 2020). Rising temperatures, deviations in rainfall records, droughts, floods, and persistent extreme weather are all evidence of climate change (Tang 2019). The quality, quantity, and price of palm oil produced per palm depend on the weather conditions and variabilities (Shanmuganathan & Narayanan 2012).

As a result of climate change and its indirect effects, palm production in Malaysia has decreased (Zainal et al. 2012). Malaysian CPO production fell by 3.3% in 2009 (MPOB 2010). In Western Malaysia, the average FFB fell by 7.5%, 4.7% in Sabah, and 2.6% in Sarawak (See Fig. 1 for global oil palm FFB production in 2018) (MPOB 2010). A higher number of abortions, elongated inflorescences, reduced productivity, rotten fruit bunches, water stress, and colonization of lance leaves (fronds) are other impacts of climate change on oil palm production (Ahmed et al. 2021). These significantly decreased productivity in oil palm globally. Climate change reduces male and female flowering, dehydrates tissue and cells, and reduces nutrient uptake (Abubakar et al. 2021). Other impacts include; general metabolism disruption and negative effects on photosynthesis; rising temperatures cause pests and diseases pandemics by changing the fertility and life-cycle of the pests, as well as influencing the pollination process and changing the mode of operation of pollinating insects such as *Elaeidobius kamerunicus* (Ahmed et al. 2021).

The Effect of Changing Temperatures on Oil Palm Production

The impact of changing temperatures on oil palm production is wide-ranging. When temperatures rise by 1-4°C, there will be a 10-40% decrease in palm oil production (Sarkar et al. 2020). Changes in temperature that results in drought conditions would cause approximately 208,000 ha of the present cultivated areas to become marginal and unsuitable for oil palm production in Malaysia (Zainal et al. 2012). A rise of 2°C in temperature could lower oil palm yields by 30% (MNRE 2010, Paterson et al. 2018, Abubakar et al. 2020). A warmer environment results in the quicker evaporation of soil water, causing water stress on the palms and a more intense effect of dry periods (Oettli et al. 2018). These result in loss of FFB yield, disruption in photosynthesis and respiration, and general metabolism of the palms (Fleiss et al. 2017). Although warming alone is unlikely to have severe impacts, projections indicate that oil palm cultivation in Southeast Asia will become challenging in 2100 as global temperatures are projected to rise (Corley & Tinker 2015, Paterson et al. 2015). For example, Zainal et al. (2012) reported that for every 1°C rise in temperature, oil palm revenue is expected to decline by RM 44.52 (USD 10.63), RM 45.60 (USD 10.89), and RM 37.70 (USD 9.01) for Peninsular Malaysia, Sabah, and Sarawak. The future projection indicates that on average, oil palm losses will be (RM/hectare) RM 341.29 (USD 81.52) by the year 2029, RM 127.43 (USD 30.44) by the year 2059, and RM 51.80 (USD 12.37) by the year 2099 for Peninsular Malaysia, Sabah and Sarawak respectively (Zainal et al. 2012).

The Effect of Changing Rainfall on Oil Palm Production

Rainfall has a marginal effect of reducing net revenue per hectare by RM 4.59 (USD 1.10) and RM 1.60 (USD 0.38) for Sabah and Sarawak, respectively (Zainal et al. 2012). A water deficit of 100 mm in an oil palm plantation during the phase of sex determination reduces yield by 6% (Ambar Suharyanti et al. 2020). In contrast, the decline in productivity during the floral abortion phase is more signed up to 7% and has a greater effect on bunch quantity as opposed to bunch weight (Ambar Suharyanti et al. 2020). A study by Carr (2011) indicates that increasing the water deficit by 100 mm in a single year can result in an 8-10% reduction in production the following year, and a 3-4% reduction the following year. Similarly, Corley & Tinker (2015) gave a more detailed explanation concerning water deficit; in the flowering phase of the plant, a 100 mm water deficit can adversely affect the following three components: 1) floral initiation (1-3% yield loss per 100 mm water deficit); 2) sex determination (3-4% yield loss per 100 mm loss); 3) floral abortion (8-10% yield loss per 100 mm loss).

A study conducted on the influence of water and nutrient management on oil palm yield trends on a large-scale plantation in Ghana indicates that as the water deficit increases, oil palm production decreases in tandem, the results of the research can be summarised as follows: A yearly water deficit of 150 mm yields 22-25 tonnes/ha FFB, a yearly water deficit of 250 mm yields 16-18 tonnes/ha FFB, and a yearly water deficit of 400 mm yields 6-7 tonnes/ha FFB (Rhebergen et al. 2019). Similarly, Carr (2011) reported that each 100 mm rise in soil water deficit results in a loss of approximately 10% in productivity. Moisture shortages in oil palm plantations can be the reason for lower nutrient uptake in oil palm trees (Teh 2016, Shafiq 2017), which impacts flower development and causes a rise in abortion, lowered productivity, and extended inflorescences that last about 8-9 months (Shafiq 2017, Woittiez et al. 2017). Two months consecutively or longer of reduced rainfall will result in a depressed oil extraction rate about 11 months later (Muhamad Rizal & Tsan 2008). Higher rainfall, which caused flooding, reduced crude palm oil (CPO) production and quality, with the events being attributed to influencing the ripening process of the FFB and reflecting on the yield in later months (Shanmuganathan et al. 2014).

Climate Change Adaptation for Oil Palm Sustainability

Adaptation to climate change involves "adjustment in natural or human systems in response to actual or anticipated climatic stimuli or their effects, which mitigates harm or capitalizes on beneficial opportunities" (IPCC TAR 2001). Oil palm growers specialized in adapting to climate change. Recent techniques for adaptation were employed to address the effect of climatic changes and variability in plantations. These adaptation options include; the use of improved variety, soil, and water conservation practices, mulching, silt pit, agroecological practices, such as sustainable use of recommended fertilizer, integrated pest management, frond management, land clearing without slash burning, intercropping, patronizing extension services, access to government subsidies and incentives, livelihood diversification, loan and or credit, buying of crop insurance, etc (Nabara & Norsida 2018, Abubakar et al. 2021)

Oil Palm and Global Food Security

Food security is a general concern globally, with the FAO reporting that over 815 million people are chronically malnourished (FAO 2020). Essentially palm oil had an important role to play in feeding and nourishing the world, both directly and indirectly, and will go on to play a vital part in addressing this issue head- on (Nesadurai 2013, Vel et al. 2016, Sibhatu 2019, Ayompe et al. 2021). At the 1996 World Food Summit, food security was defined as "existing when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2008). Food security "is determined by availability (having an adequate supply of suitable food), access (having enough income or other resources to access food), and utilization/consumption (having adequate dietary intake and the ability to absorb and use nutrients in the body)" (Molotoks et al. 2021). The role of palm oil in food security has not been fully explained as a topic in literature (Hervas 2021). The development of oil palm has some success in alleviating poverty, improving food security, and contributing to employment and economic development, especially in Malaysia and Indonesia (Hervas 2021, Ajonina & Okanyene 2021). Ajonina & Okanyene (2021) reported that oil palm production has increased food security in Cameroon.

Global Oil Palm Production

Many countries grow a small amount of oil palm, but only two dominate the global market: Indonesia and Malaysia (Abubakar et al. 2021). In terms of oil palm planted area, Indonesia has (7.1 million ha) (Dislich et al. 2017), Malaysia (has 5.9 million ha), Thailand (has 2.3 million ha), Colombia (524 thousand ha), Guatemala (has 190,000 ha), Ecuador (290,000 ha), and Cameroon (250,000 ha) in 2019 (Ordway et al. 2017, MPOC 2021, Statista 2021a). The expansion of oil palm plantations occupies 24% (4.5 Mha) hectares globally (Ordway et al. 2017). There were 16 million hectares of oil

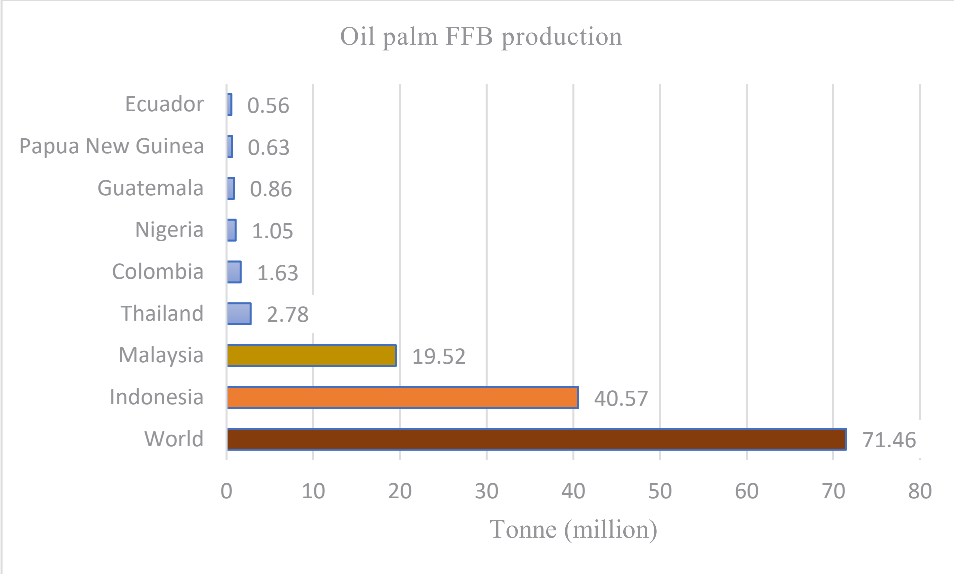

Fig. 1: Oil palm FFB production in 2018.
Source: Oil World (2021)

palm planted globally between 1990 and 2010, accounting for approximately 10% of the global land under permanent crops (Pirker et al. 2016). The planting areas in Malaysia and Indonesia increased by 150% and 40%, respectively, as a result of this dynamic development (Pirker et al. 2016, Killeen et al. 2013).

In the past half-century, the production of palm oil has increased dramatically (Abubakar et al. 2021). Total global output in 1970 was only 2 million tonnes, and this has more than tripled: global output in 2018 was 72 million tonnes (See Fig. 2 for global palm oil production) (Hannah & Max 2021). Indonesia produced 57% of this (41 million tonnes),

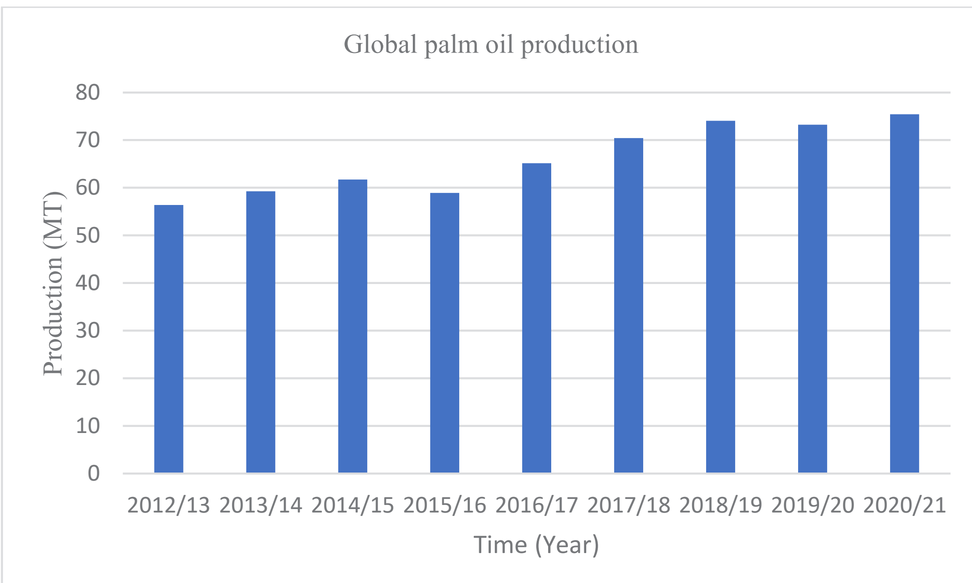

Fig. 2: Global trend of palm oil production (Statista 2021).

Table 2: Palm oil production by country in 2020.

Country	Productions (tonnes/million)
Indonesia	48.3
Malaysia	19.7
Thailand	3.1
Colombia	1.6
Nigeria	1.28
Philippines	0.90
Guatemala	0.88
Sierra Leone	0.75
Benin Republic	0.75
Honduras	0.60
Papua New Guinea	0.56
Angola	0.55
Côte d'Ivoire	0.51
Cameroon	0.46
Ghana	0.36
Cost Rica	0.27
Mexico	0.23
Peru	0.20

Statista (2021) and United States Department of Agriculture (2021).

with Malaysia producing 27% (20 million tonnes). Table 2 presents palm oil production by country in 2020.

Global Palm Oil Consumption

Global consumption of palm oil had surpassed 73 million metric tonnes by 2019/2020, with that figure expected to rise to roughly 75.45 million metric tonnes in the subsequent year (Statista 2021a). In Germany, the food sector consumption of palm oil and palm kernel oil was 246,500 tonnes and 30,100 tonnes respectively in 2017 (Meo Carbon Solutions 2018). In 2017, the feed sector consumed approximately 148,250 tonnes of palm oil in Germany, while pharmaceuticals and other chemical industries consumed approximately 120,000 tonnes of palm oil and 15,000 tonnes of palm kernel oil (Meo Carbon Solutions 2018). Oil palm domestic consumption by country in 2021 showed that Indonesia consumed about (15,225MT), India (8,550MT), China (7,170MT), EU-27 (6,765MT), Pakistan (3,495MT), Malaysia (3,450MT), Thailand (2,677MT), Nigeria (1,740MT), Bangladesh (1,630MT), and USA (1,470MT) (USDA 2021a, 2021b). Palm oil consumption in Colombia was estimated to be more than one million metric tonnes in 2019, while consumption in Brazil was estimated to be (750,000 MT). In contrast, the consumption of palm oil in Venezuela was estimated to be only (58,000 MT) that year (Statista 2021a). In 2019, about 500,000 MT of palm oil was consumed domestically in Cameroon (Statista 2021a). In the year 2019, Latin America accounts for 1.1 million MT of palm oil consumption (Statista 2021a). Global palm oil consumption is shown in Fig. 3.

The Role of Palm Oil in Feeding the World

Alleviating Poverty

Following years of decline, the trend of global hunger has increased since 2014 (FAO et al. 2018). Overall, the global percentage share of people who are malnourished rose to 10.6 % in 2015, and then declined to 11 % in 2016 (United Nations 2018, Molotoks et al. 2021). In 2017, the global undernourished population was estimated to be 821 million, or roughly one in every nine people (FAO et al. 2018). This increase in food insecurity represents a momentous risk of being unable to meet the Sustainable Development Goal (SDG) target of which by 2030, hunger

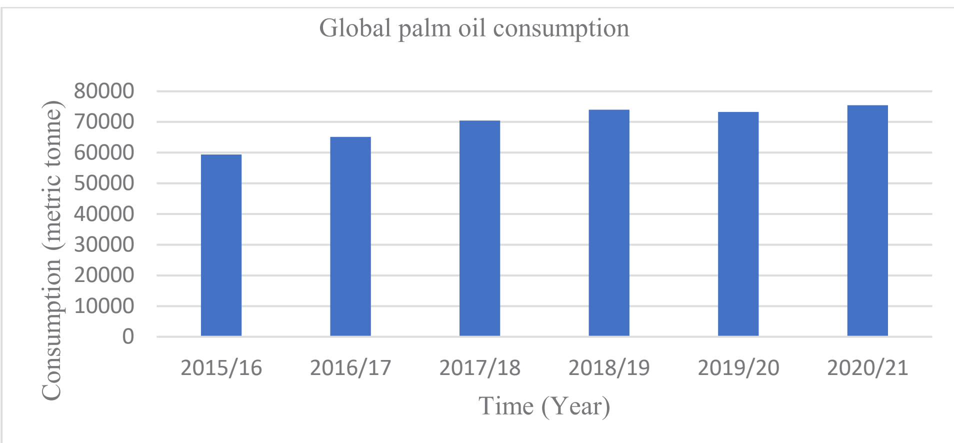

Fig. 3: Global palm oil consumption (Statista 2021).

will be eradicated (FAO et al. 2018, Molotoks et al. 2021).

Oil palm cultivation is increasingly being promoted by Indonesia and Malaysia as a means of alleviating poverty and promoting development in jungle areas (Majid Cooke 2012, Potter 2012, Santika et al. 2019). Other developing countries taking similar steps are Brazil, Peru, Colombia, Nigeria, Gabon, Ghana, and Rwanda (Villela et al. 2014, Byerlee et al. 2009, 2017, Meijaard et al. 2018). The Malaysian plantation sector employs a large number of people, guaranteeing many rural residents a monthly income and employment, and over 2 million people rely on the palm industry for a living, aside from providing economic benefits to the country and job opportunities (Ahmad et al. 2020). More than 600,000 Malaysians are engaged effectively in the oil palm industries, which includes both skilled and unskilled labor. According to Basiron (2007), "the quality of life of people has improved as a result of their involvement in cultivation or downstream activities". The oil palm industry employs 1.7–2 million people in Indonesia (Wakker 2006, Zen et al. 2006). Agricultural smallholders in Indonesia have an average annual household income of IDR 30,417,441 (USD 2,132), with oil palm farming making up 85.8%, non-oil palm farming at 8%, and farming at 6.2% (Ramadhana et al. 2021). More than 63% of the household income of smallholders comes from oil palm-based activities in Indonesia (Susila 2004). In Malaysia, oil palm accounts for 66.7% of smallholders' income (Dayang Norwana et al. 2011). The proportion of oil palm-related assets in total household assets is also very high, estimated to be around 63-72% in Indonesia (Susila 2004). Oil palm growers in Nigeria earn between N35,000 and N40,000 per month, employing up to 4 million people and providing income to many growers and their families (High Carbon Stock 2015). In Peru, smallholder farmers earn about USD 3,336 annually from oil palm plots, which can go up to 14,500/USD/ha/year when prices are at their highest (Bennett et al. 2019).

There are two types of planters identified in the palm oil sector. The organized companies are in contrast to the smallholders and the independent growers. A variety of businesses are available in the oil palm production and processing channel, counting on producers, milling units, relationships among industries and producers, and intermediary actors (Feintrenie 2013). In comparison to scheme and managed smallholder households, independent small-scale farmers have incomes that are lower monthly from oil palm cultivation (IDR 2.17 million) (USD 189.18) (Lee et al. 2014). The income and consumption of households are adversely affected by these factors (Santika et al. 2019). Palm plantation expansion in some areas has resulted in higher incomes, especially among smallholder and wealthier growers (Shahputra & Zen 2018, Santika et al. 2019). Nevertheless, the economic benefits of oil palm differ significantly between locations that have varying biophysical characteristics and communities with dissimilar starting socioeconomic situations (Shahputra & Zen 2018, Santika et al. 2019). Similarly, Santika et al. (2019) in their study of Kalimantan oil palm farmers, recorded an overall rise in the base indicators of physical and financial well-being between 2000 and 2014. Usually, rural areas where oil palms are grown tend to have lower average rural poverty, such as in North Sumatra, Riau, Central Kalimantan, and Southern Nigeria (Shahputra & Zen 2018). For example, in five years, Riau experienced a decline in rural poverty from 21% to 10% (2009-2013). It is clear that, in terms of gross development disparities, the cultivation of oil palm has lowered the disparity between Java and the outer islands of Indonesia significantly (Shahputra & Zen 2018). Ramadhana et al. (2021) observed several factors like "household income, level of education, family size, family members earning an income, number of children attending school, and amount of credit taken by the household that has a strong and positive effect on the expenditure of oil palm smallholders".

In terms of wide-ranging benefits, according to the industry, the oil palm sector employs nearly 6 million individuals, most of whom are elevated out of economic hardship (Goenadi 2008). The cultivation of oil palm provides a consistent cash inflow from consistent yields and ever-present demand, which has given money to thousands of smallholders to invest in plantations and environmental improvements and to provide an education for their families (Jezeer et al. 2019). Oil palm has also aided in the reduction of disparities between urban and rural populations. It has improved access to healthcare and education for rural populations, ensuring a higher quality of life and standard of living for themselves and their children.

The Most Efficient Vegetable Oil

Approximately 9.1 billion people will live on the planet by 2050, an increase of 34% from the current figure (FAO 2009). Feeding ever-growing and possibly urban populations, food production must increase by 70% (FAO 2009, 2017). The estimated annual quantity of oils and fats to meet this demand will be 150 million additional tonnes of oils and fats (d'Enghien 2016). It is a significant challenge to produce 150 million tonnes of oil (d'Enghien 2016) from the point of edible oil resources and the perspective of which plants can compete with oil palm. Oil palm is the only vegetable oil plant that meets all standards on all environmental measures when compared to sunflower, rapeseed, soybean, and others

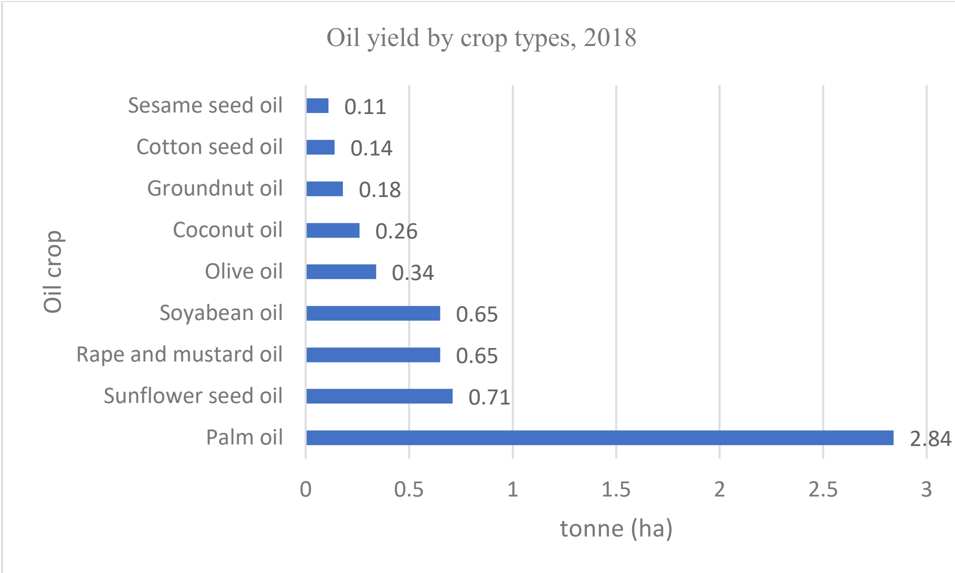

Fig. 4: Oil yield by crop types, 2018.
Source: Oil World 2020.
Note: Global oil yields are measured as the average amount of vegetable oil produced per hectare of land. This is different from the total yield of the crop since only a fraction is available as vegetable oil.

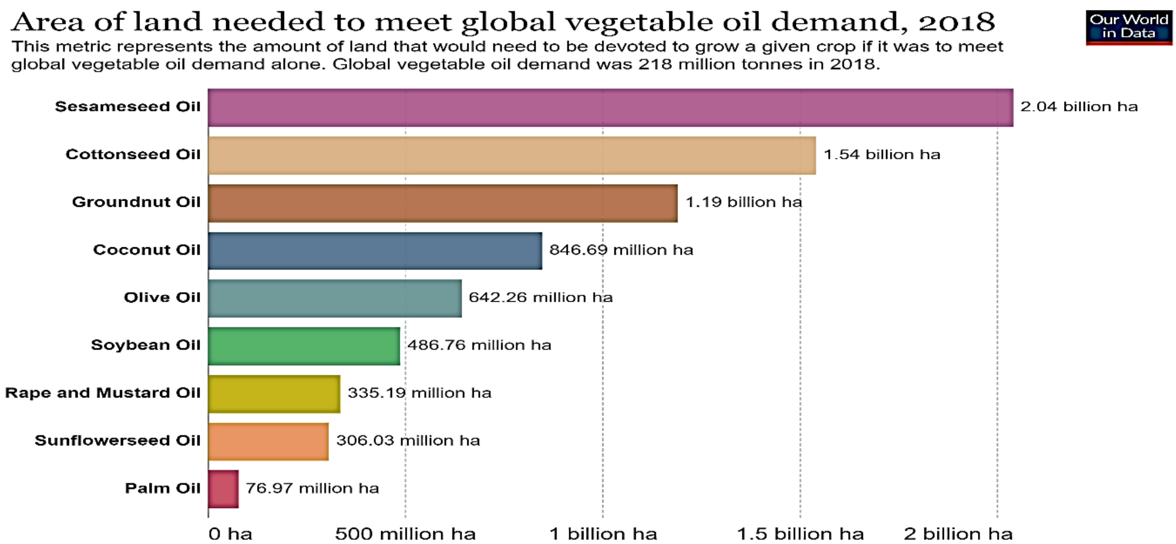

Fig. 5: The amount of land required to meet global vegetable oil demand.
Source: Calculated by Our World in Data based on data from the UN Food and Agriculture Organization (FAO)
OurWorldInData.org/palm-oil CC BY

(Basiron & Chan 2004, Tang & Al Qahtani 2020). Fig. 4 presents oil yield by crop types, 2018.

For example, soybean will necessitate 400 million ha of farmland, 187 million ha of rapeseed, and 250 ha of sunflower (d'Enghien 2016). Palm oil, on the other hand, will require only 38 million ha of farmland (d'Enghien 2016). It is ultimately the most versatile and efficient vegetable oil crop on earth, which produce more oil per hectare as compared to other plants that produce vegetable oil (Murphy 2014). When compared to many oil-bearing plants, oil palm produced 4-10 times the amount of oil per unit area (Roundtable on Sustainable Palm Oil 2017). The push to replace oil palm would then necessitate the use of more land, as well as the use of more fertilizer and pesticides (d'Enghien 2016). The issue of food security, in contrast, is critical for the developing world and future generations (Pawlak & Kołodziejczak 2020). Palm oil is an existing lifeblood of the developing world with about 3 billion people worldwide currently using palm oil for its high energy and vitamin content, including India, Sub-Saharan Africa, and South-East Asia (d'Enghien 2016). As the struggle for available land grows, the potential for oil palm to produce a higher quantity of food from a lower acreage will be even more critical (Varsha et al. 2016, d'Enghien 2016, Khatiwada et al. 2021). Fig. 5 presents the amount of land required to meet global vegetable oil demand.

Vitamin Supplementation

The World Health Organization (WHO) estimates that approximately 190 million children of preschool age in developing nations, particularly in Africa and Southeast Asia, lack vitamin A in their diets (WHO 2011, Loganathan et al. 2017). These result in liver disorder, impaired immunity, stunted growth, and hematopoiesis, and cause rashes and other distinctive ocular effects (e.g., xerophthalmia, night blindness) (Sommer 2008, Akhtar et al. 2013, Stevens et al. 2015). There is widespread use of palm oil in the food and nutrition industries due to its versatility and balanced fatty acid content (~50% saturated, ~50% unsaturated) (Daud et al. 2012). Furthermore, pro-vitamin A and vitamin E are also found abundantly in crude palm oil (Daud et al. 2012). There are a high number of carotenoids (500-700 ppm) and vitamin E (600-1000 ppm) in crude palm oil (Daud et al. 2012). CPO has the potential effectiveness in overcoming deficiencies of vitamin A in children and pregnant women, improving vitamin A deficiency that results in ocular problems, as protection against ischemic heart disease, promoting normal reproductive potential in males and females, aid in diabetes management, ameliorate harmful effects of chemotherapy, and aiding in the management of hypobaric conditions (Loganathan et al. 2017). Palm oil contains a variety of trace components that benefit humans, which include tocotrienols, tocopherols, and carotenoids. Tocotrienols and tocopherols are vitamin E family members that possess well-publicized health benefits, including having antioxidant, anti-inflammatory, anticancer, neuroprotective, and skin protection actions. They also benefit cognition, bone health, and longevity, as well as reducing plasma cholesterol levels (Cestaro et al. 2017). Several studies conducted in Europe, South Africa, India, Burkina Faso, Tanzania, and Nigeria found that intake of palm oil improved Vitamin A status in children, adults, and pregnant and lactating women (van Stuijvenberg et al. 2020, Lietz et al. 2001, 2006, Olmedilla et al. 2002, Ajose et al. 2004, Zeba et al. 2006, Daud et al. 2012). The use of CPO in edible cooking could solve the problem of vitamin deficiency, particularly vitamin A deficiency, in countries where deficiency is a public health issue (Daud et al. 2012).

Producing Nutritious and Healthier Food

Palm oil has a distinct composition that prevents it from containing trans fats. Trans fat is unhealthy, and many health authorities, including the WHO, now advise against it because it has been clinically proven to increase the risk of cardiovascular disease (Ismail et al. 2018). Aside from being a source of fatty acids, and various vital fat-soluble micronutrients, it also has a high calorific content, which provides us with the energy we need to perform our daily activities (MPOC 2021). According to Singh (2014), "Palm oil supplies fatty acids as well as important fat-soluble micronutrients like carotenoids (including pro-vitamin A), vitamins D, E and K". In relation to other vegetable oils, unrefined palm oil is a naturally rich source of carotenoids – 15 times higher than carrots and 30 times higher than tomatoes (MPOC 2021). The cells in the human body need fatty acids as raw materials to build their membranes, including in our bones, nervous system, and brain. The human body also needs these micronutrients to maintain its cells and their daily functions (MPOC 2021). Palm oil has a high calorific content. Palm oil contains 9 Kcal of energy per gram, twice the amount of protein (4 Kcal) or carbohydrates (4 Kcal) in 1 gram (MPOC 2021). All food groups must be included as sources of energy, not least fats, and oils. Expert estimates of the average adult energy requirements are 1,800 to 2,000 Kcal daily, with fats and oils accounting for up to 30% of that total (MPOC 2021).

Palm oil is found in nearly everything, making up almost half of all packaged products found on supermarket shelves, which include pizza, doughnuts, and chocolate (Hannah & Max 2021). Palm oil is also used as an animal feed component in various parts of the world (Ghani 2020). As an edible oil, palm oil is highly versatile and possesses varied properties and functions, which have made it an extremely important and widely used oil. It has a semi-solid form at room temperature, which keeps spreads or spreadable; it resists oxidation, giving products a longer shelf life; it has high stability at elevated temperatures, which gives fried foods their crispy and crunchy texture; and it does not change the taste or smell of food products most common use of palm oil in Asia and Africa is for cooking (Ghani 2020). Because of its high melting point, the oil is in a semi-solid form at room temperature. By substituting other vegetable fats for palm oil, the hydrogenation process is avoided, which results in unhealthy trans fats in products. Palm oil acts as a natural preservative in processed foods. This makes oil palm more useful in the food industry. The global demand for palm oil in 2019 was projected to be 74.6 million tonnes and is anticipated to grow at a volume-based CAGR of 2.3% from 2020 to 2027. The market growth is expected to be driven by higher demand from end-use industries, which is combined with an increase in consumer awareness of the nutritional benefits of palm oil.

Oil Palm Smallholders

Plantations of oil palms are usually large-scale (3000-20000 ha) (Sheil et al. 2009) or smallholder which is defined as 50 hectares, most of which are about 2 hectares and run by local family concerns (Vermeulen & Goad 2006, Dislich et al. 2017). Smallholder oil palm growers are considered the major block in palm oil production. There is some consistency in the definitions of "smallholder" in relation to palm oil production and other commodities. A smallholder, for example, grows a maximum of 2 ha, whereas small-scale growers cultivate plantations sized up to 40 to 50 ha. Nonetheless, these definitions depend on continents or regions. In Colombia, 40 ha would make a farmer a small grower, whereas, in Sierra Leone, a farmer with 40 ha would be considered a large-scale producer (Jezeer et al. 2019). Furthermore, regardless of their land size, smallholders can be differentiated by various factors, for example, their level of organization, whether they have company contracts or otherwise, assets deployed by them, geography, capacities, family or hired labor, and so on. In the discussion of policy and market instruments' impacts on smallholder growers, it is critical to take this diversity into account (Jezeer et al. 2019).

For example, around 400,000 ha are occupied by oil palm plantations in Colombia, 280,000 ha in Ecuador, 103,000 ha in Honduras, 150,000 ha in Brazil, and 2000 ha in Guatemala (Robinson 2013), 117,625 ha in Nigeria (RMRDC 2004). As of 2019, there were estimated to be 6.04 million hectares of oil palm estates in Indonesia. In Malaysia, independent smallholders cultivate 986,331 million ha of land (Rahman 2020). Smallholder plantations account for approximately 40% of oil palm growing land in Indonesia and 13% in Malaysia (MPOC 2021, Azhar et al. 2014; Central Bureau of Statistics Indonesia 2014). Approximately three million smallholders are estimated to be involved in the production of palm oil globally (Rival & Levang 2014), and this number is rising. In Malaysia, there are about 650,000 smallholder growers. In Ecuador, there are about 7,000 smallholder oil palm growers, 7,300 in Honduras, and 1,435 in Brazil (Robinson 2013, Ahmad et al. 2020).

Smallholders can work independently or as part of a team. These smallholders are characterized by being self-financing, involved in managing their plantations, and may have direct dealings with their favorite local operators of palm oil mills; they may even process their palm oil at their own mills or manual presses owned by the local community (Zoological Society London 2015). As a result of the support they receive, smallholders have access to big plantations, receive inputs and training, and receive assistance in establishing their plantations (Sheil et al. 2009). In exchange for the support received, these smallholders agree to sell their harvests at a predetermined price to large-scale companies to be processed at nearby mills, whereas the company deduced any fraction of the loan from the revenue (Dislich et al. 2017).

The Economics of Oil Palm Smallholders

For smallholders looking for a good return from low inputs, oil palm is a rewarding industry (Belcher et al. 2004). According to the 1997 Indonesian Palm Oil Statistics, oil palm smallholders' average annual net income was seven times that of subsistence farmers' (Hartemink 2005). Preparation and planting of land cost NGN 69, 452.70 (USD 169.39) per hectare per year, and land preparation and planting costs NGN 57, 600.00 (USD 140.49) per hectare per year, in Nigeria. Seedlings per hectare were NGN 42, 900.00 (USD 104.63). Cutlass from the 1st to 4th year was NGN 76,800.00 (USD 187.32), and from the 5th year onward was NGN 43,200.00 (USD 105.37) per hectare per year. Pruning (death fronds, epiphytes, etc) up to the 10th year was NGN 4,800.00 (USD 11.71) per hectare per year, and pruning after the 10th year was NGN 3,600.00 (USD 8.78) per hectare per year. The fertilizer application was NGN 4, 800.00 (USD 11.71) per ha per annum (Ukwuteno et al. 2018). Ukwuteno et al. (2018) report that "oil palm plantation maintenance/running cost with cost of materials required for five years and above was found to be NGN 303, 152.70 (USD 739.310) annually, for oil palm plantation in Nigeria". The costs of production vary with the geography and economic strength of a particular country. The cost of oil palm production in other countries may be higher or lower compared to Nigeria. The average yield in Nigeria is 13.56 ($t\ ha^{-1}\ yr^{-1}$), in Malaysia is 15-18 ($t\ ha^{-1}\ yr^{-1}$), in Indonesia is 14.82 ($t\ ha^{-1}\ yr^{-1}$), in Peru, it is 14 ($t\ ha^{-1}\ yr^{-1}$), and 14.6-22.5 ($t\ ha^{-1}\ yr^{-1}$) in Kalimantan (Lee et al. 2014, De Vos et al. 2021). In Peru, an oil palm plantation requires an average investment usually assessed at around USD 3,000–3,500 for each hectare (Bennett et al. 2019). The disparity in yield between countries depends on geography, whereas, higher yields were largely attributed to planting material and harvesting frequency. Strong group organization is another factor that might contribute to pre-certification conditions (De Vos et al. 2021).

Loans, credit, and subsidies are available to smallholder growers. For example, in Brazil, a smallholder is entitled to USD 125,000 for plantation establishment at an interest rate of 5.75% (Brandão & Schoneveld 2015). Smallholders in Malaysia have access to loans of RM 26,600 (equal to about USD 62,001) with a 15-year maturity and a 6.25% interest rate (lower than the market rate) (Bronkhorst et al. 2017). In Peru, USD 2,117,700 has been set aside to assist 160 families in establishing an oil palm plantation (Bennett et al. 2019). Smallholder growers were provided with 700 plants (equivalent to 5 ha) at no charge and needed to get loans from banks to cover the remaining financial cost of establishing their plantations (fertilizer, pesticide, transportation) (Bennett et al. 2019).

The Role of Smallholder Farmers in Food Security

A substantial number of empirical studies contend that smallholders remain critical to nutrition and food security globally (Bennett et al. 2019, Paloma et al. 2020). Smallholder plantations are increasingly being seen as having a positive impact on food security, and nutrition, as well as promoting overall development around the world. Smallholder oil palm production, particularly when it is integrated fully into a diversified rural economy and agrifood value chain, has the potential to contribute even more to inclusive growth and job creation (Paloma et al. 2020).

The contribution of smallholders to food security is significantly different across regions (Jezeer et al. 2019). The cultivation of oil palm in Southeast Asia was initially in the form of a monoculture plantation crop driven by government and private companies and reliant on outside labor (Jezeer et al. 2019). Smallholders came into the picture much later as part of mill-related resettlement schemes such as nucleus estate plasma schemes in Indonesia and through the Federal Land Development Authority (FELDA) in Malaysia (Jezeer et al. 2019). Oil palm has always been a smallholder crop in Africa, where it is a native tree, self-planted, self-processed, and is not usually planted in monoculture form. In Latin America, only a small number of corporations and smallholder farmers were involved in biofuels, which were primarily sold in the domestic market (Jezeer et al. 2019). The Nucleus Estate Company in Papua New Guinea uses oil palm fruit from smallholders to operate its mills. Smallholders produce approximately 33% of PNG's palm oil, the majority of which is produced in West New Britain Province (WNBP) (Koczberski et al. 2012). Malaysian crude palm oil production totalled approximately 19.86 million metric tonnes in 2019, of which a total of 40% of the product is produced by small-scale producers, either independently or organized (2020). Around 40% of the global oil palm plantations are under smallholder management and produce almost a third (30%) of the global palm oil output (Saadun et al. 2018). Palm oil and allied products contributed 3.3% to the agricultural GDP in Colombia, 15% in Ecuador, 16% in Honduras, 3.7% in Malaysia, and 1% in Guatemala (Robinson 2013, Department of Statistics 2020, Hervas 2021).

Approximately 25% of Indonesia's oil palm plantations are managed by private smallholders or farmers who operate on a small scale and are not affiliated with companies or mills. This makes up a substantial portion of an industry with an oil output of 31 million tons annually (Thontowi et al. 2018). In both Brazil and Mexico, oil palm smallholder plantations began in the 1940s and 1950s by converting livestock into plantations (Lesage & Feintrenie 2018). Mexico witnessed a tremendous increase in palm oil production from 79, 000 metric tonnes in 2010 to about 140 thousand metric tonnes in 2019 (Statista 2021c). Brazil produced 346 thousand metric tonnes of palm oil in 2016, with production anticipated to exceed half a million metric tonnes in 2018 (Statista 2021b). Smallholder growers contributed immensely to the rise in palm oil production, for example in Honduras smallholder growers produced 620 thousand metric tons in 2016 (Statista 2021a). Similarly, In Ghana, Nigeria, Panama, Nicaragua, Peru, Ecuador (over 87% of all growers are smallholders and contributed 40% of the planted area), and the Dominican Republic more than 60% of FFB and palm oil are produced by smallholder growers (Robinson 2013, Lesage & Feintrenie 2018, Khatun et al. 2020). In Honduras, 7,300 growers with 1-10 ha, control 68% of the planted area and produce more than 60% of the palm oil (Robinson 2013). Up to 2012, the areas under cultivation by smallholder producers in Cameroon made up about 70% of the land area planted with oil palm, an increase of 570% from 1970s figures (Hoyle & Levang 2012, Ordway et al. 2017), and produced 110,000 tonnes of CPO (Nkongho et al. 2014). These account for almost 80% of the demand for edible oil in Cameroon, with smallholders accounting for 30% (Frank et al. 2011, Ordway et al. 2017). Most African oil palm companies promote smallholders to produce more, rather than engage in new plantation development due to the high costs (Nkongho et al. 2015).

Smallholders are expected to increase their production capacity to twice what it is now in the coming decade and are expected to control about 60% of the total oil palm plantation area in Indonesia by 2030 (i et al. 2018). Globally, more than 3 million smallholders rely on palm oil for a living. The smallholders produce around 40% of the world's palm oil, and even though their farms are much smaller than industrial plantations, they contribute immensely to the sustainability of the oil palm industry as well as food security (RSPO 2021, 2012).

Smallholders typically intercrop oil palms with other plant species or fruit trees (Kremen et al. 2012, Fu et al. 2010; Azhar et al. 2017). Depending on the age of the oil palm, the other crops include both annual and perennial plants. Lam et al. (2009) and Azhar et al. (2017) reports that among the annual plants are "pineapple (Ananascomosus), sugarcane (Saccharum officinarum), sweet potato (Ipomoea batatas), capsicum (Capsicum annuum), lemon grass (*Cymbopogon citratus*), banana (*Musa* spp.), pumpkin (*Cucurbita moschata*), and corn (*Zea mays*). Perennial plant examples are papaya (*Carica papaya*), coconut (*Cocos nucifera*), coffee (*Coffea canephora*), kaffir lime (*Citrus hystrix*), and cassava (*Manihot esculenta*). Examples of fruit trees include mango (*Mangifera indica*), breadfruit (*Artocarpus integer*), Cocoa (*Theobroma cacao*), jackfruit (*Artocarpus hetero-phyllus*), key lime (*Citrus aurantifolia*), sukun (*Artocarpus altilis*), and guava (*Psidium guajava*) which are cultivated by independent smallholders in their planted fields". In addition to intercropping, the integration of grazing livestock (e.g. cattle, goats, and sheep) with oil palm planting is practiced by oil palm smallholders to increase protein sources for consumption locally. Tscharntke et al. (2012) put forward that "agriculture practiced under smallholder farmer-dominated landscapes rather than large-scale farming, is the backbone of global food security in developing countries". The availability of secondary crops may serve as an alternative for smallholders to cope with economic uncertainties resulting from crop failures or price drops in the palm oil market (Simien & Penot 2011).

Challenges Faced by Smallholders

Pre-harvest oil palm growers are constrained by numerous socioeconomic, environmental, and political challenges. The major challenges faced by smallholder growers include; land unavailability and lack of ownership, limited credit and loan facilities, availability of better planting materials, training and skills deficiencies, processing facility obstacles, costly agricultural input, lack of technological expertise, pests and diseases, lack of adoption of innovation and technology, lack of knowledge to keep up with advanced agricultural practices, climate change (rising temperatures, rainfall variability, the impact of El-Nino and La-Nina), lack of labor and manpower, social sustainability (problem-solving and thinking outside box) and soil fertility challenges have all had a negative impact on smallholder production globally, Jelsma et al. 2017, Aznie et al. 2018, Junaidi et al. 2020, et al. 2021, Ahmed et al. 2021, Abubakar et al. 2021).

Post-harvest, other challenges include reliance on dealers for selling products, which is vulnerable to highly volatile market prices. Smallholders also faced uncertain market conditions as a result of rising production costs and weak exports, high duties imposed by importing countries, as well as stiff competition from the major players in the industry (Ahmad et al. 2020). Sustainable certification is constrained by the high cost of the certification, lack of standard knowledge and practice, and lack of incentives for certification (Abazue et al. 2019), and the EU supports a resolution to sanction palm oil imports for the biofuel sector, and impose the adoption of a single sustainable certification for palm oil entering the European market. As a result, this scenario is expected to have a significant impact on the income of over 650,000 palm oil smallholders (Brandi et al. 2015, Ahmad et al. 2020, Zakaria et al. 2020).

CONCLUSION

The results suggest that due to climate change, temperature, and rainfall variability, there could be a significant loss of oil palm yield. The contribution of oil palm smallholder growers to the global palm oil demand is immense. Globally, smallholders dominate palm oil production and oil palm cultivation, except for Malaysia and Indonesia. Despite the impacts of climate change, from 1970 to 2020, all palm oil-producing countries recorded a tremendous increase in CPO output per hectare. The global consumption of palm oil had increased dramatically and is projected to reach 75.45 million metric tonnes in 2021. This is attributed to its health benefits and nutrition. Dealing with climate change entails empowering and enhancing the capacity of smallholders. This study suggests the following: improvements in academic integration at the national and regional levels, with a focus on collaboration with researchers in consumer countries, increasing institutional research capacity, enhancing access to finance, embracing best development practices, sustainable market policies that favor smallholders, access to inputs at subsidized prices, integration of smallholders in decision making, adhering to national policies, and it is critical to developing climate-resilient varieties with high-tolerance planting materials and new crop varieties in response to changing climate conditions.

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