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EFFECT OF CRUDE OIL EXPLORATION ON GLOBAL FOOD SECURITY: A REVIEW

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Abstract: Crude oil exploration activities have impacted the land, air, and water negatively in places where such activities are taking place. These impacts generally imply low soil fertility, which in turn implies low agricultural productivity and a reduced source of livelihood in affected areas. Its effect also includes the loss of major soil nutrients that are necessary for food and fiber production. Several research papers were reviewed on the effects of crude oil exploration on global food production and efforts being made to alleviate this negative impact. The reviewed literatures includes places where crude oil exploration activities have been carried out. Several works of literatures reviewed indicated that there is a downward decline in food production due to the severe nature of damage to the environment as a result of crude oil spill on the environment. Consequently, there have been significant advances in regulation for protecting the environment in developed and developing countries, including the development of remediation frameworks and guidelines. On the other hand, studies have rarely reported on the risks and health effects of contaminants in developing regions and there is scarce information regarding contaminated land assessment and environmental remediation. Coordinated efforts are needed to increase the production of food but to remediate the impact on the environment to a level that will not hinder food production and threat to well-being of the inhabitants of these places where exploration is taking place.
Keywords: food security, crude-oil, agriculture, contamination, food production

1. INTRODUCTION

Crude oil exploration modifies the local environment causing substantial damage under certain circumstances. Soil contamination, salination, loss of biodiversity, depletion of groundwater aquifers, and pollution of watercourses are all possible consequences of crude oil exploration. The results are losses to society as a whole and rising costs of farm production. Crude oil contamination of the environment associated with exploration and production operations is a common feature in oil-producing nations around the world (Kuch *et al.,* 2019). This has resulted in significant contamination of the total environment (air, soil, water, and biota) and negatively impacted food security across the globe. The Discovery and utilization of plants with high adaptation to crude oil pollution are currently deemed a safer and cost-effective panacea to food security and environmental challenges arising from contamination due to oil spillage in oil-producing economies. Research has also revealed that there exists a link between loss/decrease in livelihood in agriculture due to disruptions of the ecosystem and weakening rural economy. There is empirical evidence of a link between livelihood in agriculture on one hand and food security (Dercon, 1999; Pender *et al*., 2001). Awojobi *et al*. (2014) report a similar trend between declining agricultural production and deteriorating rural economy in the oil-producing areas of Nigeria. Research shows that 80 percent of those who are involved in agricultural production in the environmentally degraded areas in Latin America are poor, 60 percent in Asia, and 81 percent in Africa (Bifani, 1995; Iglesias and Quiroga, 2007). There also exists an established coincidence of poverty with areas seriously affected by mineral resource exploitation (Ajakaiye and Adeyeye, 2001; Binswanger and Landell-Mills, 1995; Langton and Mazel, 2008). Pender *et al*. (2001); Vosti and Reardon (1997) argued that agricultural production cannot sustain people's livelihood while at the same time the natural resources that agricultural production depends on are destroyed or polluted. The world population grew from 2.5 billion in 1950 to 6.1 billion in the year 2000. By the year 2050, the world population is estimated to reach 9.1 billion Figure 1. Currently, the world population is growing at an annual rate of 1.2%, i.e. 77 million people per year. Six countries

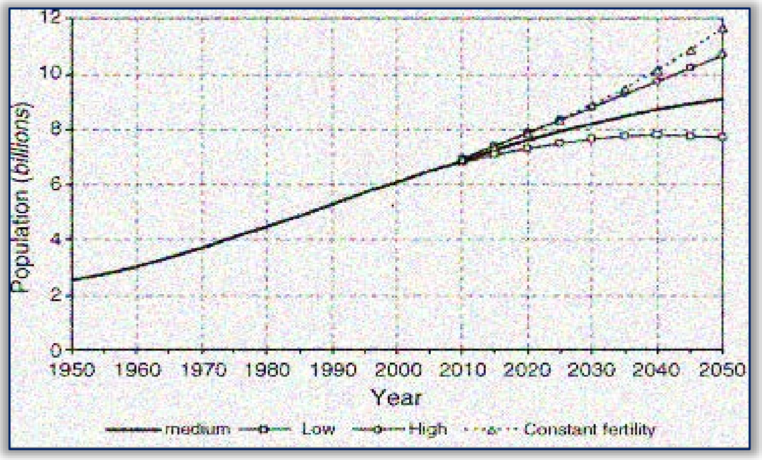

Figure 1: Estimates of the world population growth with projections till 2050.
Source: Gerland *et al.* (2014)

account for half of the annual increment: India, China, Pakistan, Nigeria, Bangladesh, and Indonesia. According to the United Nations (UN) estimates, the population of the more developed regions (1.2) will change little during the next 50 years. The projections in population mean an increase in the demand for food. Whatever the development plan adopted, agricultural production needs to be increased in various regions of the world currently afflicted with hunger and malnutrition. Various tools have been suggested and be called upon, such as the prevention of crude oil contamination of the environment during exploration and post exploration processes (Apata, 2010).

2. EFFECT OF CRUDE OIL EXPLORATION ON SEED GERMINATION

Seed germination seems to be affected by oil at least in two ways. At the high level of crude oil pollution, seed germination is prevented probably by oil soaking through the outer integument of the seeds. At the low level of crude oil pollution, seed germination is retarded by the presence of oil (Ndubuisi et al., 2013; Udo and Oputa, 1984). The effect of crude oil on a plant is one of great concern as it causes damage to different parts of the plant that are vital for its well-being and survival and hence obstructs development and growth (Udo and Oputa, 1984). Udo and Fayemi (1975) showed that the leaves of plants affected by crude oil pollution tend to dehydrate and show a general sign of chlorosis, indicating water deficiency. The reduction of leaf area may be due to dehydration. Adipah (2018) observed that a reduction in photosynthetic rate resulted in a decreased rate of growth, which led to the reduction of leave sizes. Osuji and Nwoye (2007) observed that the volatile fraction of oil had a high wetting capacity and penetrating power and when in contact with the seed, the oil would enter the seed coat and kill the embryo readily, which will, in turn, cause a reduction in percentage germination. Udo and Oputa (1984) found that the significant reduction in final germination percentage of all the species maize may be due to toxic effects of crude oil on the seed and poor aeration of the soil. Table 1 shows the result from various researchers on the effect of crude oil spillage on crop production.

Table 1: Observed effects of crude oil spillage on crop production by different researchers

S/No.	Effects of crude oil spillage on crop production	Reference(s)
1.	Inhibition of seed germination	Turrell (1947)
2.	Delayed germination by inducing stress, which prolongs lag phase	(Arancon *et al.* 2004; Ginsburg, 1931; Udo and Oputa, 1984)
3.	Inhibit the uptake of water and nutrients by the root of the plant, hence causing deficiency to other parts of the plants	Udo and Fayemi (1975)
4.	Affects the regeneration of stumps and anatomical features of leaves	Hopkins (1999)
5.	Causes cellular and stomata abnormalities, disruption of the plant water balance, which indirectly influences plant metabolism	(Crafts and Reiber, 1948; Currier, 1951; Singh *et al.*, 2005)
6.	Causes root stress, which reduces leaf growth via stomata conductance and causes chlorosis of leaves	Currier (1951)
7.	Enlargement of cells in various tissues due to oxygen starvation.	(Currier, 1951; Osuji and Nwoye, 2007)

3. EFFECT OF CRUDE OIL EXPLORATION ON AGRICULTURAL SOILS

Plants germinate, develop and grow in a soil medium where water, air, and nutrient resources supply plants for healthy growth for productive and profitable agriculture that will ensure food security. Frequent crude oil spillage on agricultural soils, and the consequent fouling effect on all forms of life, render the soil (especially the biologically active topsoil) toxic and unproductive (Osuji and Nwoye, 2007). The crude oil reduces the soil's fertility such that most of the essential nutrients are no longer available for plant growth and crop utilization (Abii and Nwosu, 2009). The enormity of toxicity by oil spillage on crop performance is exemplified in mangrove vegetation, which has been dying off in recent times (Henry *et al*., 1996). Spilled crude oil which is denser than water, reduces and restricts permeability; organic hydrocarbons which fill the soil pores expel water and air, thus depriving the plants' roots of the much-needed water and air (Mosier, 1998). Soil properties involved in the soil-plant-water relationship are degraded and this includes texture, infiltration, hydraulic conductivity, moisture content, and density, which affect root and leaf development, plant growth, and yield (Michael, 2009; Odugwu and Onianwa, 1987). Oil spillage has affected crop yield and farm income, and by extension, the social and economic livelihood of farming communities which have plunged the world into food insecurity in most oil exploring communities (Odugwu and Onianwa, 1987).

— The linkage between Energy and Food Security in Selected Asian Nations

Mendelsohn (2014) reported that Asian agriculture contributes to around two-thirds of global agriculture GDP. This can be said that Asian nations have the most favorable agricultural conditions in the world. Figure 1 shows the share of land area that is arable in selected Asian economies. It can be seen that over 60 percent of the land in Bangladesh and India is agricultural land (Figure 2). Achieving food security is of huge importance for human development and peace in any nation. However, food insecurity still prevails in many developing countries in Asia. Barrett (2010) reported that the number of chronically undernourished people in Asia's developing countries was still high as 512 million (globally, 780 million chronically undernourished people are living in developing countries. While environmental degradation due to oil exploration activities in Africa is the major cause of food insecurity, global energy prices significantly affect food security in Asia countries. Fossil fuels (oil, gasoline, diesel, natural gas, etc) are widely used in the primary production of agricultural productions. Ambitions to increase global food supplies in Asia through increased productivity of crops, animals, and fish resources may be partly constrained by the limited future availability of cheap and accessible fossil fuels. Sims *et al*. (2015) reported that small-scale agricultural and fishery production systems in low-income countries in Asia may not be able to emulate the past efforts of high-income countries in achieving desirable productivity increase if to do so will depend on increased reliance on fossil fuels. Energy is widely consumed not only in primary production, but also in secondary production, such as in drying, cooling and storage, and transport and distribution. The modernization of food supply chains has been associated with GHG emissions from fertilizers, transportations, processing, and retailing. Sims *et al*. (2015) reported that there is a positive correlation between oil price and food price after using a panel-VAR model on selected eight Asian economies, namely Bangladesh, the People's Republic of China, Indonesia, India, Japan, Sri Lanka, Thailand, and Viet Nam.

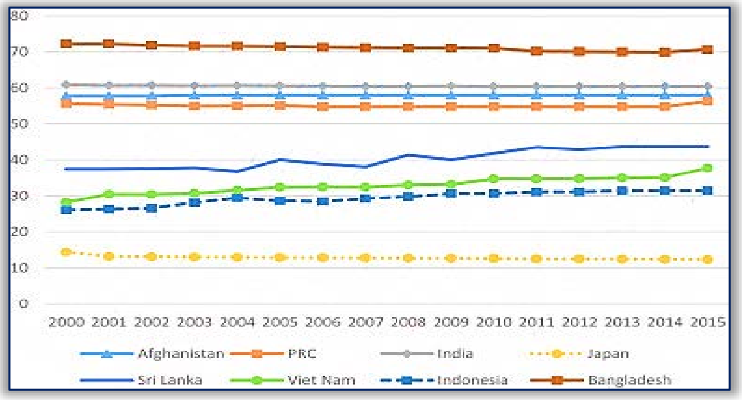

Figure 2: Agricultural land (%) in selected Asian economies
Source: World Bank data (2017)

— Negative impacts of Oil Exploration on Food Security in Nigeria

In the past, Nigeria produced sufficient food to feed its people as well as to export. Today, its economy is largely dependent on oil production. The agricultural sector is unable to produce enough food, forcing Nigeria to import food to feed its people. The country's heavy reliance on oil has led Nigeria to civil instability, corruption, economic exploitation, and environmental degradation that has led to a decrease in food production in the Niger Delta area of Nigeria where most of the exploration takes place (Ugochukwu and Ertel, 2008). Loss of soil fertility through loss of soil organic matter, leaching of nutrients, loss of the nutrient-laden topsoil, changes in soil-pH, reduction in cation exchange capacity, salinization, waterlogging, and other forms of soil degradation are major problems associated with agricultural productivity in the oil-producing areas of Nigeria. Abii and Nwosu (2009) reported that soil fertility loss and declining crop yield, among others, were of high priority because these were found to be an indirect source of pressure on natural resources and community structure, especially amongst the poor. Crude oil is known to exert adverse effects on soil properties and plant growth. Crude oil has been reported to be increasingly deleterious to soil biota and crop growth (Amadi *et al*., 1996; Chikere *et al*., 2017; Osuji and Nwoye, 2007). Figure 2 shows the share of poverty across the globe following the collapse of crude oil prices in 2018. This event triggered unpleasant memories of the 2014 and 2015 crash in world oil prices, the Nigerian government found itself in unchartered waters. It continues to struggle to revive the economy amidst dwindling oil revenues compounded by unemployment, poverty, and insurgency. Global poverty projections released by The Brookings Institution in 2018, based on data from the World Poverty Clock, shows that Nigeria has overtaken India as home to the largest population of people living in extreme poverty, with 87 million citizens living on less than $1.90 a day compared to India's 73 million (see Figure 3 and 4).

Table 2: Incidence of Poverty in Nigeria and Ondo State in selected years (1985-2006)

Selected years	1985	1992	1997	2002	2006
Percentage of poor people in total population	43	34	48.5	54.2	54.4
Percentage of extreme poor in total population	28	40	45	52	53
Percentage of poor people in oil-producing States	15.4	16.5	24.8	28.6	30.10
Percentage of poor people in Ondo State	3.85	---	5.94	11.73	12.25
The poverty line for all poor persons (N)	395	395	658	825	846
The poverty line for Extreme poor Persons (N)	253	164	320	523	531

Source: Apata (2010).

Insight into incidences in Nigeria revealed that food insecurity-induced poverty is on the increase in crude-oil producing States in Nigeria. The poverty incidence in Table 2 shows that poverty in Nigeria increases by 11.2% between 1985 and 2002, while about 55% of these incidences occurred in the crude oil-producing zones of

Nigeria (Ebeku, 2000). Analysis of Table 2 indicates that Ondo State (an oil-producing State) has the highest number of poorest in that group. Poverty incidences have been on the increase in the State, as it rose from 5.94% in 1997 to 12.25% in 2006 (Enisan and Oni, 2012; Modupe, 2008).

— Impact of crude oil contamination on agricultural land and crop production in the USA

Oil contamination of Agricultural land is a problem in North Dakota despite a recent decline in oil production activities (*Croat et al*., 2020). Song and Davis-Kollman (2019) reported that over 175 oil spills were reported from June 2018 through June 2019 in North Dakota, amounting to nearly 200 m^3 of oil. Many of the spills were about 10 barrels, and 90 percent of the spill affected agricultural land, including cropland, pastureland, and natural grasslands (Croat *et al*., 2020). Osgood (1974) reported that for over five years there were more than 200 hydrocarbon spills in Pennsylvanians alone. In Mountrail County, North Dakota 21,000 barrels of Bakken crude oil were accidentally released into the environment (Kuch and Bavumiragira, 2019). Figure 5 shows a crude oil-contaminated site undergoing remediation in North Dakota, USA. Total petroleum hydrocarbon has been reported by many researchers to potentially reduce the productivity of agricultural land which has necessitated remediation of contaminants (Eom *et al*., 2007; Issoufi *et al*., 2006; Yi *et al*., 2016). Returning crude oil-contaminated land to production is crucial for food security. Wetland and grassland conversion to provide more acreage for row crop production which is an unhealthy practice could be curtailed or bring to a halt (Wimberly *et al*., 2017). After crude oil contamination, a holistic approach puts into consideration all soil health parameters such as physical, chemical, and biological properties and their interactions that allow the soil to function. Croat *et al*. (2020) reported a decline in the yield of Wheat (*Triticum aestivum* L.) and field pea (*Pisum sativum* L.) cultivated on soil remediated from crude oil contamination. The crop yield was $61 \pm 20\%$ lower in the modified land-farm soils and $52 \pm 25\%$ lower in thermal desorption-treated soils. These results suggest that land contaminated with crude oil may not be able to recover to pre-contamination conditions easily, hence the need for a holistic approach to the remediation of crude oil contaminated land.

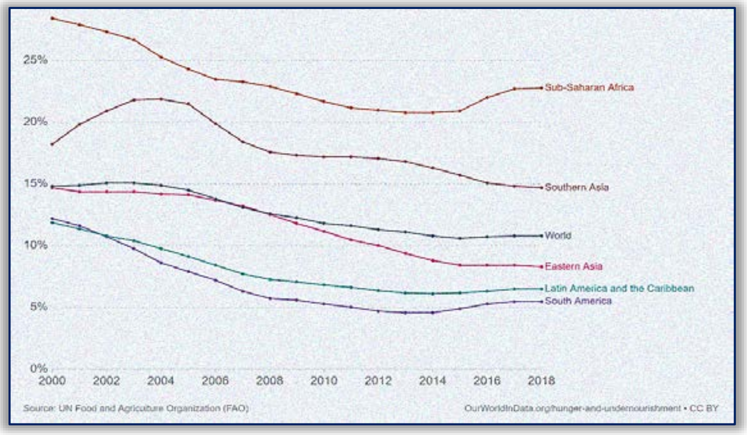

Figure 3: Share of people who are undernourished from 2000 to 2018
Source : Van Lancker and Parolin (2020).

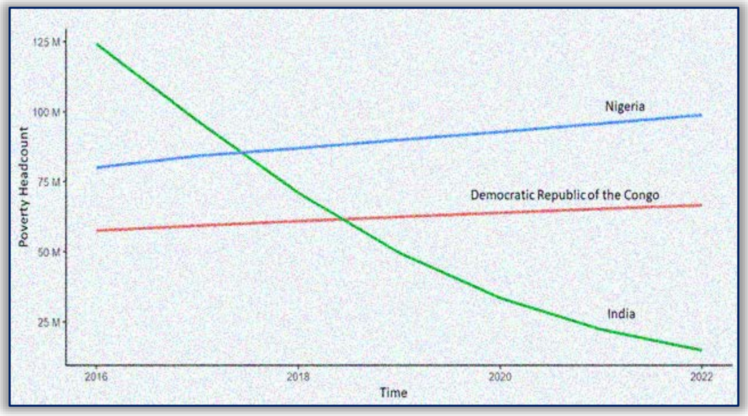

Figure 4: Poverty headcount in Nigeria, Democratic Republic of Congo, and India from 2016 and beyond. Source: Okoi (2019).

Figure 5: Crude oil-contaminated site undergoing remediation in North Dakota, USA.
Source: Cozzarelli *et al.* (2017).

From the report of the various researchers, the following conclusions can be reached:

1. Agricultural land exposed to hydrocarbon contamination requires remediation.
2. Remediated soils produce lower yield and biomass than non-contaminated soils.
3. An increase in soil organic carbon is critical to long-term remediation success.

Fang (1990) reported that the Gulf of Mexico has long been an important location for oil and gas production in the United States, providing a substantial portion of the country's energy requirement. These activities have caused great consequences on the ecosystem such as Fiddler crabs (*Ocypodidae, Uca*). Fiddler crabs are an ecologically important group in the northern Gulf of Mexico's coastal ecosystems and are very active burrowers and bioturbators. Bioturbation is the biological mixing and redistribution of sediments and is one of the major processes influencing physicochemical properties of sediments in coastal ecosystems (Giangrande *et al*., 2002; Meysman *et al*., 2003; Wang *et al*., 2010). Burger *et al*. (1991) reported the effects of oil contamination on the feeding rate and population densities. Consequently, oil spill impacts on fiddler crabs are likely to have a cascade of effects, with negative consequences on many members of coastal ecosystems. At least 820,000 birds perished in the Gulf of Mexico according to a report (Trevors and Saier, 2010). Figure 6 shows a Pelican covered by a crude oil spill in the Gulf of Mexico United States of America.

Figure 6: An exhausted oil-covered pelican in the Gulf of Mexico, USA.
Source: Landau (2011)

— Impact of crude oil exploration on food production in Gulf Cooperation Council Countries of Kuwait, Bahrain, Oman, Qatar, Saudi Arabia, and United Arab Emirate

The arable land in this region is quite limited, averaging around 4.25% of the total land area available for agriculture (Kotilaine, 2010). This available arable land is further threatened by crude oil contamination from a crude oil spill. Another thing that has hindered agricultural self-sufficiency in the arid regions is the scarcity of freshwater. Scarce freshwater is further threatened by crude oil spills into water sources such as groundwater, surface water, and other sources. Water use for irrigation and livestock represent the biggest share of total water use, 45% in Bahrain, 54% in Kuwait, 88% in Saudi Arabia, 89% in Oman, 59% in Qatar, and 83% in the United Arab Emirate (Eliasson *et al*., 2003). Al-Awadhi *et al*. (2005) reported that food imports are expected to increase in the region to meet the region's growing population. Barrett (2010) reported that that the level of petroleum hydrocarbons in the coastal waters of Kuwait is in the range of 0.1-6.88 µg/L.

The oil industry in Kuwait has a history of pollution from spills and oil well flaring that extensively contaminated soils use for agricultural production. This has also caused contamination of sediments, swampland, and petroleum hydrocarbons affecting groundwater (Asem *et al*., 2016).

In Kuwait, Sawaya *et al*. (1999) found certain fruits to exceed the maximum residue limits for pesticides specified by the monitoring agencies. Abosede (2013) and Emerson (1983) reported that oil spills can contaminated soils and alter Physico-chemical properties to an extent that these soils can no longer be used for agricultural production. Barua *et al*. (2011) concluded that the effect of crude oil spills on soil caused a decrease in soil moisture tension (hydrophobic), porosity, water holding capacity, soil pH extractable phosphorous which are vital for crop growth and development. Marinescu *et al*. (2010) confirmed that oil spills on soil caused variations in chemical properties and at high pollution levels, inhibited the growth of crops. Khamehchiyan *et al*. (2007) indicated that oil contamination on soil caused a decrease in soil strength, permeability, maximum dry density, optimum water content, and Atterberg limits. Figure 7 shows the groundwater contamination in Kuwait.

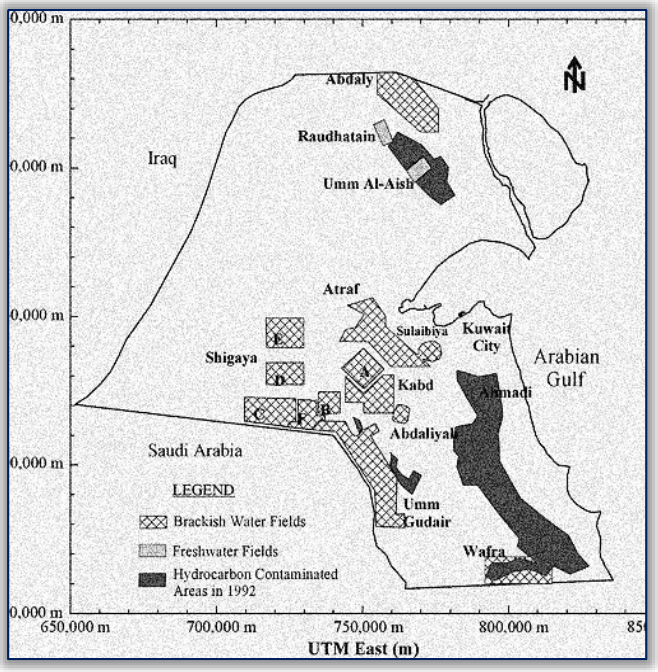

Figure 7: Oil-polluted areas of Kuwait concerning the nearby water fields.
Source: Mukhopadhyay *et al.* (2008)

Bahrain is another country whose agricultural activities have been threatened by crude oil contamination. Incidences of food contamination have become increasingly frequent in recent years raising questions about their human health and economic consequences in Bahrain (Musaiger *et al*., 2008). Widespread contamination of soil by chemicals and industrial pollutants means that the crops that are grown and the animals use for food are often exposed to toxic substances (de Mora *et al*., 2010). Several investigations have been carried out in the Middle East countries to study the contamination of coastal waters. In the coastal areas of Iraq in the Northwest region of the Gulf, the concentration of petroleum hydrocarbons ranged from 2.3 to 69.9 μg/L (Al-Imarah *et al*., 2007). A concentration of petroleum hydrocarbons capable of inhibiting crop germination such as water sources is used for irrigation of agricultural land. The levels in Omani coastal waters in 1991 ranged from 0.09 to 66.0 μg/L (Badawy and Al-Harthy, 1991). The Arabian Gulf, in particular, has been subject to inputs of petroleum hydrocarbons from a variety of sources, and it has been estimated that oil pollution in the Gulf represents 4.7% of the total oil pollution in the world (National Research Council, 1985). In 1989 about 239 metric tonnes of oil were accidentally spilled worldwide (Department, 2000; Tolba, 1992). Land-based industrial and urban sources also contribute to the overall pollution in the coastal areas. Refineries and other industries discharge their liquid wastes into shallow coastal areas, and sometimes are untreated or partially treated. Figure 8 shows the Bahrain oil pipeline blaze that was eventually brought under control.

Figure 8: Bahrain Oil Pipeline Blaze Brought Under Control
Source: Musaiger *et al.* (2008)

— Effect of crude oil exploration on agricultural production in South American Countries

Colombia occupies fourth place in Latin America for crude oil production and despite the economic incentives, these activities have caused several environmental problems (Espana *et al*., 2018). The contaminants have affected human health, land, air, and water resources. The affected environment includes 6000 hectares of land for potential agricultural use, 2600 kilometers of rivers and valleys, and 1600 hectares of wetlands (Romero-Ruiz *et al*., 2012). Several studies have indicated the presence of petroleum hydrocarbons in different matrices across Colombia. Oliveira *et al*. (2021) reported high petroleum hydrocarbon concentrations in sediments in the north of Cartagena Bay in Colombia with concentrations above 100 μg/g with a maximum of 1415 μg/g. Petroleum hydrocarbons were detected in nearby ecosystems estimated to be between 8-30 μg/g for bivalves, and 10-40 μg/g for fish. The mountainous character of much of Colombia's territory, along with the attendant climatic variations of the different vertical zones, allows for the production of an unusually wide range of both tropical and temperate-zone crops, from bananas and sugarcane to wheat, barley, and potatoes (Sunderland *et al*., 2013). Due to crude oil contamination, most of this food that was previously produced locally are been imported from various sources to meet demand as shown in Figure 9.

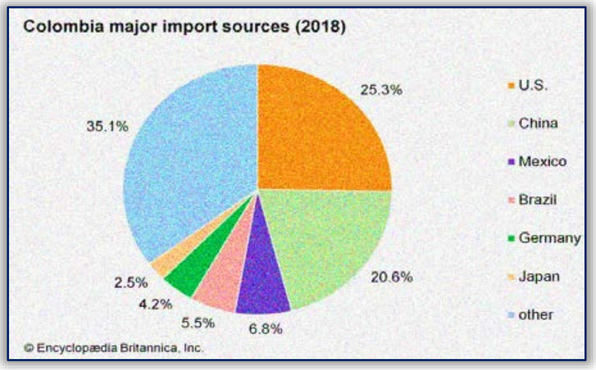

Figure 9: Imports sources of food from different countries
Source: WHO. (2018)

4. CONCLUSIONS AND RECOMMENDATIONS

Crude oil contamination of the environment associated with exploration and production operations is a common feature in oil-producing nations around the world, especially in developing countries. The contamination that occurs during crude oil production and exploration has impacted the environment negatively. The negative impact includes a reduction in major soil nutrients, and in effect, decline in soil ecosystem service. The result is a decline in food and fiber production globally. The increase of food production per capita could be obtained by one of several means, or a combination of them, such as increasing the area of agricultural land, enhancing the yield of crops through the use of organic fertilizers, biological controls, and improved soil and water management. Application of increased concentrations of nutrients can lead to greater rates of biodegradation of petroleum-polluted agricultural soils in crude oil exploring areas. Clean-up funding should be made available to support further development and implementation of a more effective contaminated land management framework that will improve food production globally.

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