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AN OVERVIEW USE AND IMPACT OF ORGANIC AND SYNTHETIC FARM INPUTS IN DEVELOPED AND DEVELOPING COUNTRIES

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ABSTRACT

This review assesses the general view of conventional and organic farming. Many studies have revealed that the continuous use of synthetic farm inputs has a negative effect on the soil, producers, products and the ecosystem. The lack of knowledge, capital and information has affected farmers' actions and decisions regarding synthetic and organic farm inputs. In developed countries, farmers have been selective in applying only limited amounts of synthetic fertilizer and pesticides to reduce the concentrations of heavy metal and harmful chemicals in the farming environment. Literature shows that soil samples taken after cultivation had higher concentrations of Lead, Cadmium and Arsenic, when compared to the concentrations of these heavy metals in soil before cultivation. There is a clear evidence that undesirable levels of heavy metals develops in soils subjected to different farm inputs. This indicates that farm input can have adverse effects on soil ecosystem. The pesticides use in Africa generally increased by about 6% from 2002 to 2014. Therefore, there is a need to create awareness on the use of synthetic farm inputs. In developing countries, farmers are exposed to banned and harmful farm inputs, which could affect human health and the ecosystem. Intensified knowledge, access to correct information and alternative organic farm inputs are required to transform the existing conventional farming to organic farming practices. Developing countries should extend their knowledge and information of the farming system to decrease the impact of synthetic farming inputs on the environment, the soil ecosystem and public health. Governmental organizations (GOs) and non-governmental organizations (NGOs) should develop a willingness to take the proper measures to facilitate and implement proper mechanisms; to intensify alternative natural farm inputs to obtain relevant knowledge and capital to sustain organic farming practices and to contribute to the security of the food supply, human health and the environment.

Key words: Organic agriculture, conventional agriculture, environment, harmful farm inputs, heavy metals

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INTRODUCTION

Organic farming is a reliable means of ensuring sustainable ecosystem management and food security [1, 2, 3, 4]. An agricultural production activities that take in to account the environmental, social and economical factors that positively contributes towards sustainable production are recognized as organic agriculture**.** Many countries experience significant soil fertility deterioration due to the application of intensive Conventional farm inputs in the soil and environment [1, 2, 3, 4]. Indeed, agriculture started along with human civilization. At inception, farming was totally dependent on the processes of nature. However, advancements in science and technology, have resulted in innovative farming practices. Syntetic farming is a farming system that uses technology inputs such as pesticides, chemicals and synthetic tools in the production of agricultural food or industrial products. Synthetic fertilizers, herbicides and pesticides were introduced and implemented in developed and developing countries since 1850 and 1965, respectively [5, 6].

The prolonged application of farm inputs has degraded the environment and diminished soil fertility. The rise of conventional farm inputs prices, deterioration of the environment, coupled with the increasing population, suggest the probable emergence of an "agricultural crisis", the reversal of which will require dramatic action [7, 8]. Environmental protection and eco-balance is a crucial means of preventing environmental deterioration and promoting sustaining human existence on the planet earth [9].

Literature sources report that many developed and developing countries use synthetic farm inputs to increase food production [4, 10]. The use of synthetic farm inputs neglects the possible long-term effects of chemical residue on the environment and on human health [11, 12]. Indeed, synthetic farm inputs help produce enough food to meet the growing food demand. Nonetheless, the increased use of chemical fertilizers and pesticides has long-lasting effects on the soils, the ecosystem, ground water and human health [13].

Developing countries rely heavily on rain-fed agriculture. The global climatic change and increasing population requires water resources to produce healthy and sufficient foods [14]. Environmentally-sustainable agricultural practices make use of environmentally friendly farm inputs, irrigation practices and farming system that are relevant to the farming situation.

Environmentally-sustainable agricultural practices excludes the use of synthetic farm inputs. The main objective of an organic farming system is to create a sustainable environment and safely maximize food production and the economy without affecting environmental and human health. Its purpose is to replenish soil fertility, to enhance biodiversity, to improve the nutritional quality of food, to create rural income and to provide environmental protection [1, 4, 15].

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This review explores synthetic and organic farming in developed and developing countries, as well as their effects on the environment, and it provides an overview of the available alternative natural farming methods.

RESEARCH AIM AND QUESTIONS

The aim of this study was to review the impact of synthetic and organic farm inputs and to summarise possible solutions, based on literature, as well as to improve recommendations on how the current environmental degradation can be reversed. This review outlines the general outlook on the application of synthetic farm inputs and its effects in both developed and developing countries. This will provide valuable information to policy makers, researchers and relevant organizations to develop and implement different programs, which could play a major role in the protection of the environment and human health. This review assesses relevant scientific findings to identify some possible directions for the key aspects of key environmental issues that require rehabilitation, in order to support the food production system. The key questions of this study are further presented as follows:

- What are the general views on the existing synthetic farm input crises and organic farming benefits in developed and developing countries?
- What are the potential solutions to reverse the existing environmental degradation arising from the use of synthetic agricultural inputs and promotion of organic farming?

EFFECTS OF SYNTETIC FARMING IN DEVELOPED AND DEVELOPING COUNTRIES

Conventional agriculture uses mono cropping, tilling, pesticides and fertilizers. Conventional agriculture contributes to yield productivity at the expense of the farming environment, human health and the soil ecosystem [16, 17, 18]. Global trends and estimated future demand highlight the reasons behind continual increase in the application of conventional farm inputs in the different farming systems [5]. Synthetic fertilizer, herbicides and pesticides are the common synthetic farm inputs. Data from FAO indicate a slight increase in pesticide use, as shown in Figure 1.

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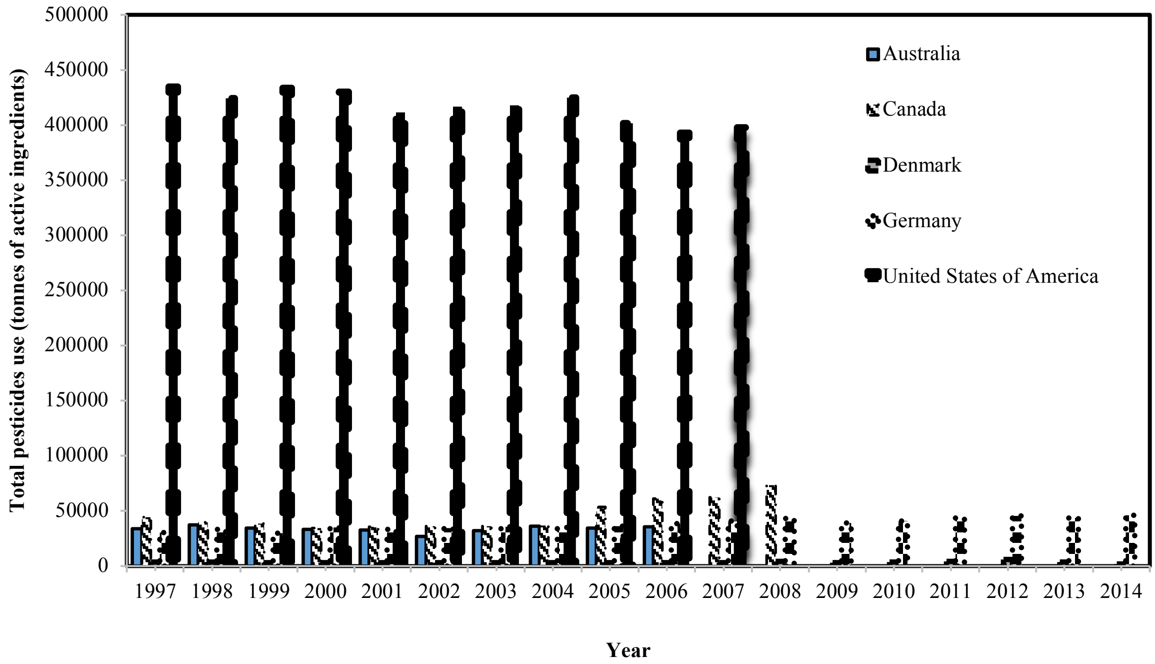

Figure 1: Pesticides usage in developed countries (Source: [19])

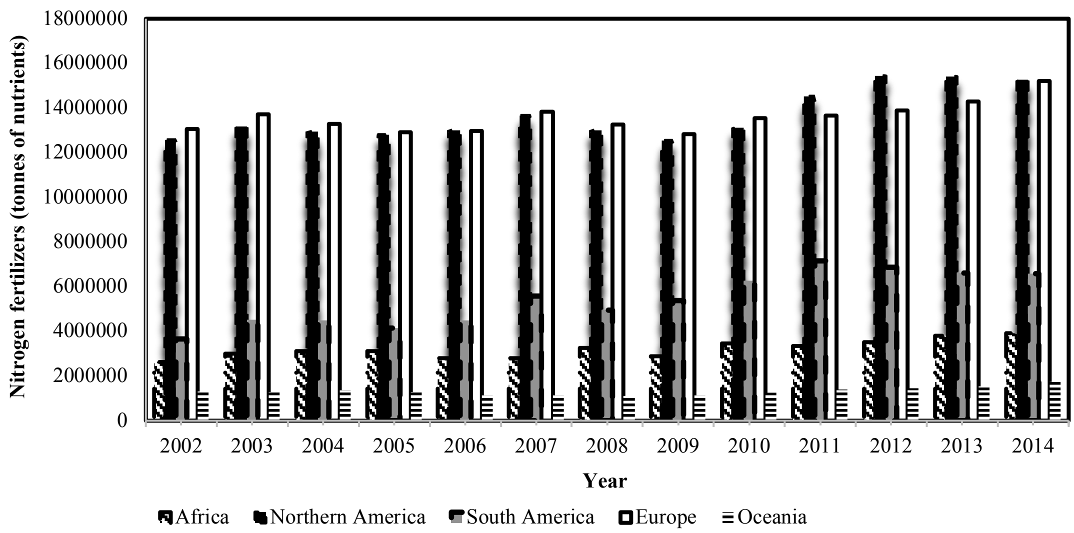

Figure 2: Nitrogen Fertilizer usage in developed and developing counties (Source of data: [19])

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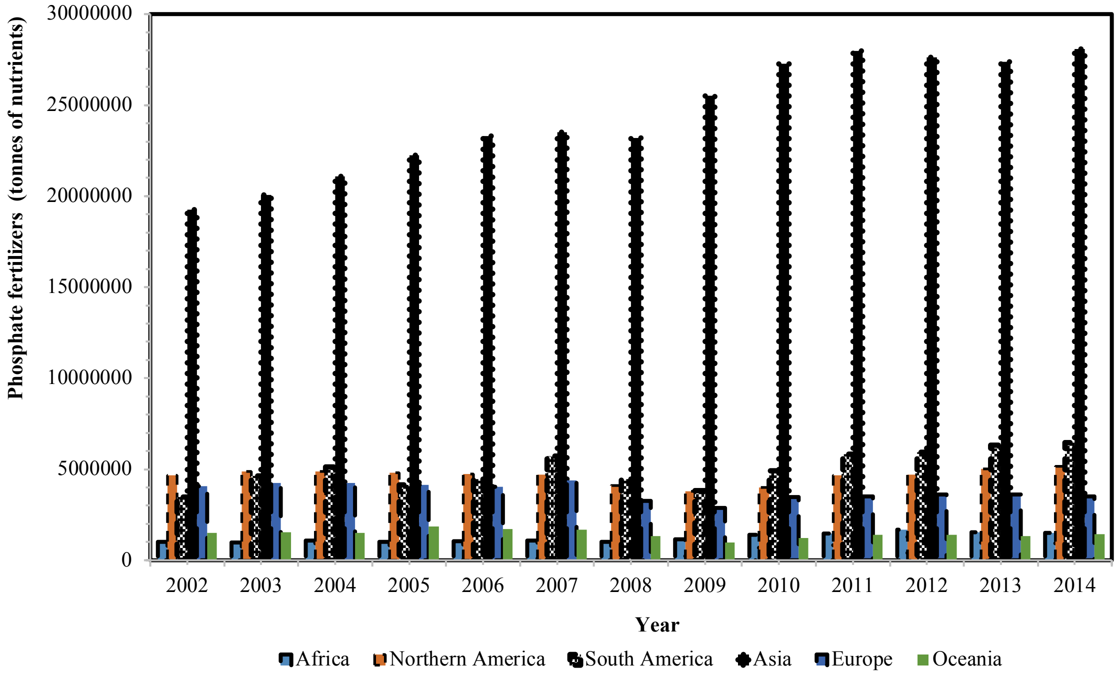

Figure 3: Phosphate Fertilizer usage in developed and developing countries (Source of data: [19])

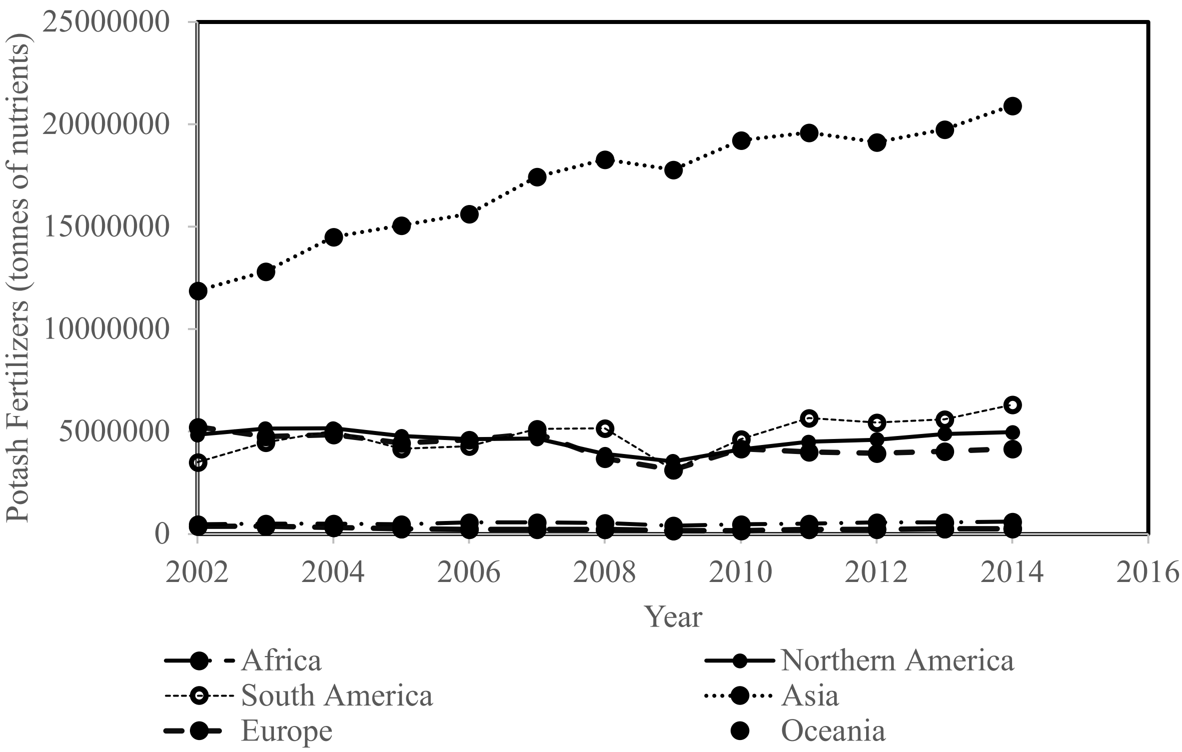

Figure 4: Potash Fertilizer usage in developed and developing counties (Source: [19])

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The data presented in Figures 2, 3 and 4 show increasing usage of nitrogen, phosphate and potash fertilizers in different regions of the world. The perpetual increase in the use of conventional farm inputs, particularly the quantity of fertilizers applied, has its own residual (heavy metal concentrations) effect on the cultivated soil and the farming environment [18, 19]. The application of pesticide causes high contamination beyond the targeted area, resulting in soil and ecosystem imbalance.

Developed countries have consistently applied fertilizer and pesticides in their production systems for more than a century. The effect of fertilizers and pesticides was initially restricted to the areas in which the specific treatment had been implemented. Around the middle of the nineteenth century, the use of modern spraying appliances such as aeroplanes, helicopters, and ground operated power sprayers prompted the spread of the effects of pesticide beyond the targeted environment [20]. These effects have been observed throughout the entire ecosystem [13]. The application of harmful farm inputs, such as Calcium and Arsenate, has changed the nature of the soil, and made it unproductive for some years [21, 22]. Ultimately, unsafe chemical usage such as the application of different pesticides has resulted in noticeable damage to both humans and the entire environment [21].

Heavy metals, such as lead (Pb), cadmium (Cd), mercury (Hg), Arsenic (As), Copper (Cu), Nickel (Ni), Zinc (Zn), and chromium (Cr), lead to serious health problems in animal and human metabolism [37 - 38, 40 - 45]. Research findings suggest that repetitive fertilizer application is the possible cause of heavy metal accumulation in cultivated soil [11, 19, 23]. The application of rock phosphate fertilizer treatments and synthetic farm inputs has resulted in the increasing residue of heavy metal contents in cultivated soil [23]. Some European countries have proposed regulations on fertilizer type, content and application rate to reduce the content of heavy metal and other harmful chemicals in the cultivated soil [23, 24].

In Europe, the quality of phosphorus fertilizers varies from region to region [19]. Analysed samples from different European countries indicate a decrease in the chemical concentration of synthetic farm inputs present in the farming soil [19, 25]. Scandinavian countries, in particular, exhibit lower levels of heavy metal concentration, compared to other European countries.

Heavy metal concentrations above the regulatory limit in a 137,000 km^2 of sample of agricultural land in the European Union was observed [26]. It is noted that Western and Mediterranean regions have a high concentration of at least one kind of the heavy metals, while North-Eastern and East-Central Europe are less affected by heavy metal residue in the soil [26]. A study conducted in Western and Eastern European countries highlighted the negative outcome of application of insecticides and fungicides on biodiversity and natural pest control of the farming system [18, 27, 28]. Another study conducted in Germany, France and Australia (southern Victoria) shows that 42% of Animal or Plant group losses have a natural relation to the recorded taxonomic pools [30].

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Scientists indicate that the existing soil fertility loss of exhausted cultivated land and environmental as well as biodiversity degradations could limit the future food production capability to feed the growing population [31, 32]. The accumulation of toxic farm input residues causes the degradation of soil fertility and ground water pollution through toxic runoff, which affect the balance of the ecosystem [9, 21, 33]. The frequent over-application of farm inputs, therefore, limits the availability of fertile farmlands, healthy water sources, and balanced ecosystems for future generations [9]. The sharply declining soil health and fertility and the increasing application of synthetic farm inputs, against the growing population trends, might suggest a looming agricultural crisis.

In view of this, integrated organic farming systems could facilitate social, economic and environmental transformation through job creation, reducing production costs and promoting environmental rehabilitation [6, 22, 34]. Therefore, to sustain the social, environmental and economic needs, environmentally-friendly production systems and relevant agricultural and economic policies are necessary. These production systems and these policies should consider the relationships between the environment, production, social justice and health [35].

EFFECTS OF CONVENTIONAL FARMING IN DEVELOPING COUNTRIES

There is an ever-increasing need for synthetic farm inputs in developing countries to meet food production demands and the expanding population, whilst still using the existing production system [5]. The fertilizer usage in developing countries increased dramatically from 2.7 to 121.6 million tonnes, between 1960 and 2020 [5]. The increasing application of synthetic farm inputs has resulted in deteriorating soil health, increased pesticide toxicity, environmental and ecosystem pollution[8, 23, 36].

The application of pesticides beyond the targeted pest area could pollute ground and surface water, as well as the ecosystem [6]. Due to lack of sufficient knowledge and awareness, workers, producers and consumers in developing nations have been exposed to restricted and banned pesticides, such as DDT (dichlorodiphenyltrichloroethane), HCH (Hexachlorocyclohexane) and lindane (gamma-hexachlorocyclohexane) [8, 37]. Resistance developed by pests has resulted in the increased pesticide use, year in year on, with more than the recommended applications and banned chemicals being used. The increased use of pesticides in Africa has led to the presence of active ingredients in agricultural soil (Figure 6).

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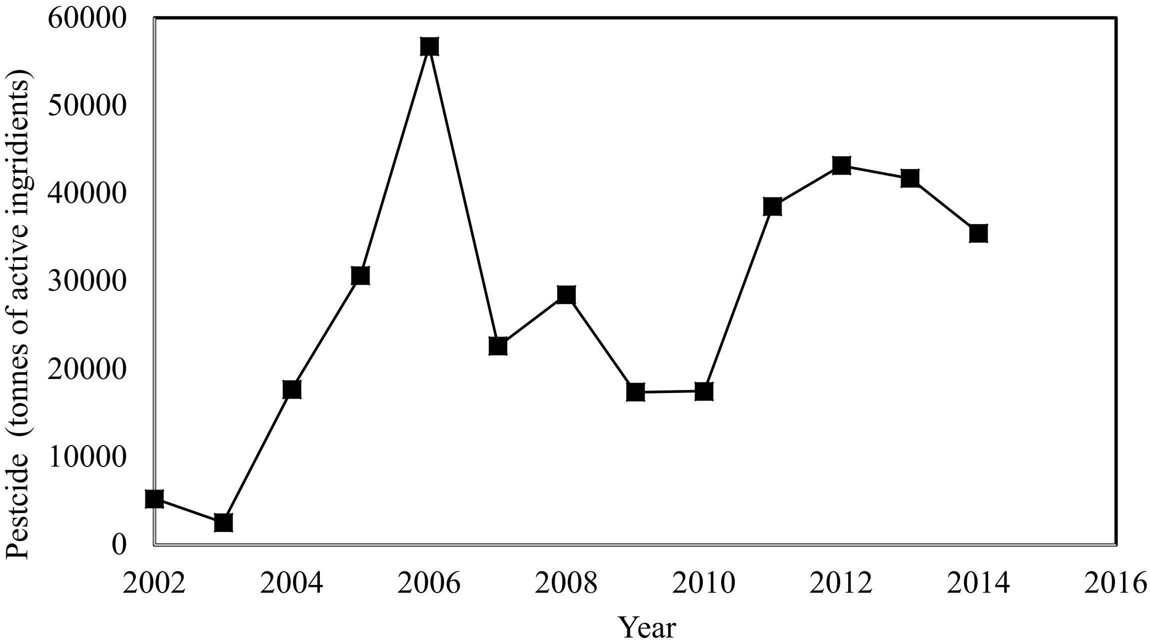

Figure 6: Pesticide usage in Africa (Source: [19])

Unsafe pesticide usage by producers and consumers has led to various chronic health problems such as undesirable neurotoxic diseases, reproductive and dermatologic effects, as well as asthma, allergies, diabetes and cancer [8, 37, 38, 39].

In many developing countries, increasing rural to urban migration is one of the contributing factors to the escalating use of synthetic farm inputs and the high levels of dependency on these methods. Indeed, synthetic farm inputs increase the farmers' agricultural productivity enabling them to feed their families and the urban population in general [20, 40, 41]. However, literature clearly shows that the increased chemical use could have long-lasting and negative effects on the producers and consumers who are directly exposed to synthetic farm inputs and produce [20, 42, 43, 44].

Biodiversity and the balance in nature have been lost due to the increased use of synthetic farm inputs [9, 21]. In developing countries, farmers' limited education, lack of access to detailed instructions, information and technology, has exposed farmers to harmful synthetic farm inputs [20, 42, 41].

Some government organizations (GOs) and non-government organizations (NGOs) have been promoting the use of chemical fertilizers and pesticides through different development projects to achieve higher productivity and pest control. The implementation of these methods has increased productivity and the ability to control pests, but over time, leading to an increase in heavy metal concentrations in the soils. The chemical residues have had harmful effects on the farming environment [20, 41]. The data displayed in Figure 7 shows that fertilizer consumption is increasing in Africa as well as in the world.

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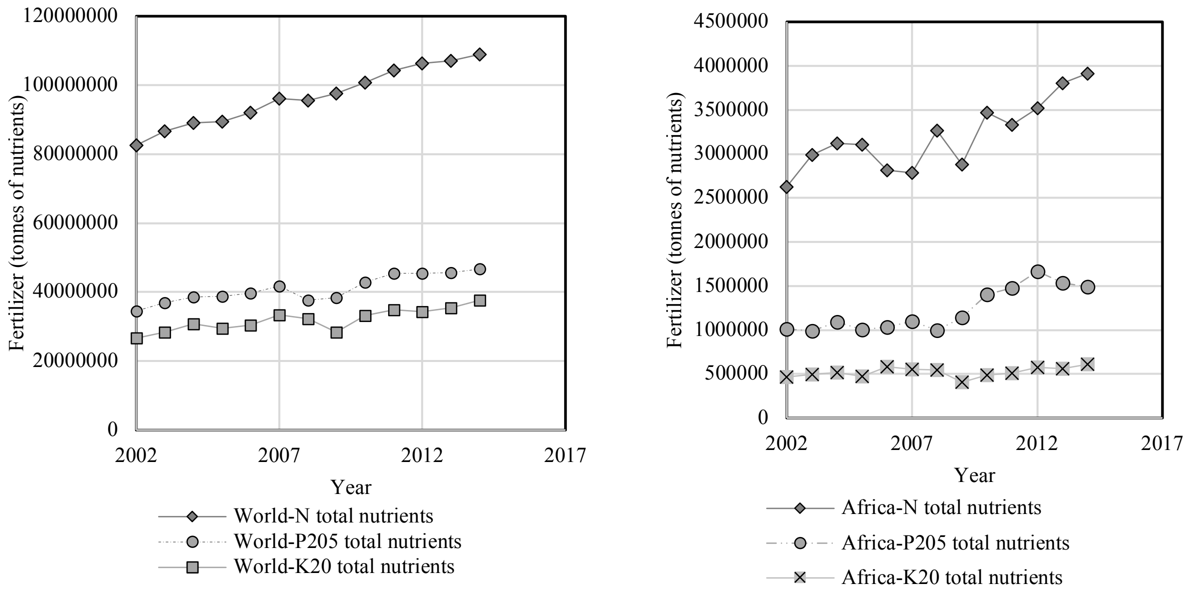
It is obvious that the use of high-breed seeds, fertilizers and pesticides contributes to the increasing food price and the farmers' credit, while at the same time promoting the farmers' dependency on these inputs. Partly replacing conventional farming with organic farming could decrease input dependency and expenditure by using locally available natural resources [15].

To protect the environment and human health, relevant and timely preventive measures and policies are required [39, 45]. Integrated Pest Management is useful to maintain the health of the ecosystem and increase the biodiversity [6]. Similarly, creating an awareness of safety issues during the application of agricultural inputs is critical [37]. Agricultural development should focus on the development of agricultural technologies, knowledge and practice that do not have negative effects on the environment and on human health [6, 22, 34, 35].



World Africa

Figure 7: Fertilizer consumption in nutrients (World and Africa) (Source: [19])

FARM INPUTS AND HEAVY METAL ACCUMULATION IN AGRICULTURAL SOILS

As discussed in the previous section, the increasing application of fertilizers and pesticides in cultivated soil results in increased heavy metals concentration in the soil ecosystem [23, 46]. Heavy metals are poisonous to animal and human health, soil, plants and aquatic life. The application of fertilizer and pesticide beyond the recommended amount lead to a higher content of lead (Pb) and arsenic (As) in the soil, compared to cadmium (Cd) [23]. Atafar *et al.* [23] revealed that phosphate fertilizer has a high level of ZN, Cu and Cd in the soil. However, Andrews *et al.* [46] suggested that the concentration increased due to the impurity of the phosphate rock used for production. High concentration of heavy metal in the soil affects key soil microbial processes and the activity of microorganisms in the soil and water [47, 48].

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The accumulation of heavy metals varies in relation to the type of fertilizer (Table 1). As can be seen from Table 1 there are higher concentrations of Pb, Co and CR in TSP fertilizer than in MAP and DAP fertilizer. The heavy metal concentration is higher in phosphatic fertilizers than in other fertilizers (Table1). Similar findings by Benson *et al.* [49] show that the superphosphate fertilizer is comprised of higher concentrations of copper (Cu), vanadium (V) and zinc (Zn), whereas urea fertilizers, to some extent, contain high concentrations of nickel (Ni), lead (Pb) and cadmium (Cd). The continuous use of P fertilizers containing Cd results in Cd concentrations in the farming soil as well as the risk of heavy metals in the food chain and possible ecosystem pollution [49].

The continuous application of synthetic farm inputs has resulted in the accumulation of chemicals in the cultivated soil, ground water and the environment [23]. The accumulation of heavy metals varies, before and after cultivation (Figure 5). Atafar et al. [23] reported that the cadmium, arsenic and lead content increased by 13%, 92% and 192%, respectively, when heavy metal concentrations in soil samples before harvesting were analysed and compared with those after harvesting (Figure 5). This indicates that the detected heavy metal content in the fertilizers that are applied in the cultivated soil is the source of heavy metal concentrations in the soil as shown in Table 1.

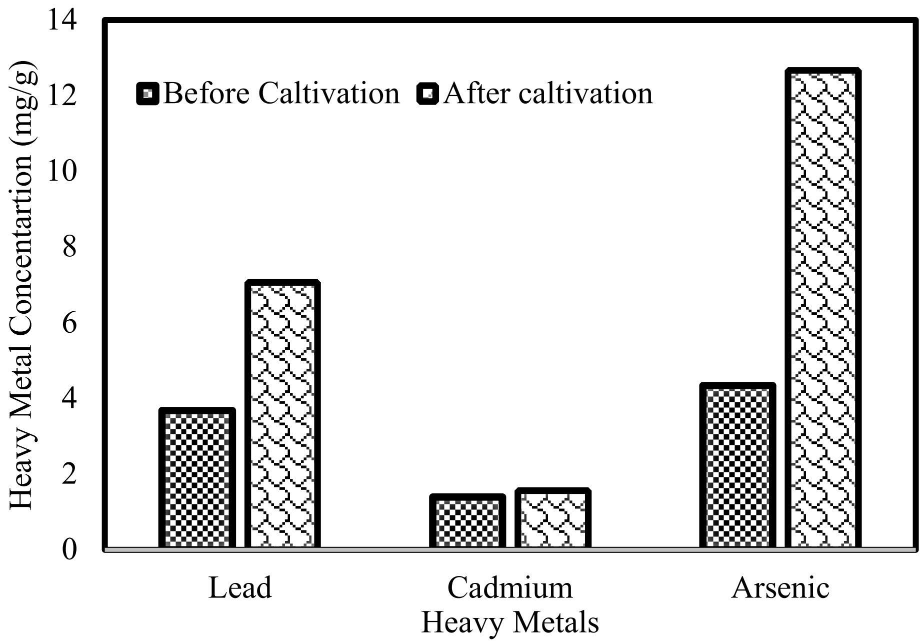

Figure 5: Heavy metal concentrations before and after fertilizer application in Sudan (Source of data: [23])

The availability of water and its usage for irrigation purpose influence human health, household income, soil ecosystem and environment [30]. The use of wastewater and runoff for irrigation has perpetuated the permeation of toxic chemicals, such as heavy metals, into the soil, causing air pollution, soil salinity and soil ecosystem imbalance, as well as the contamination of surface and ground water reserves [12, 50, 51]. About 20 million hectares of agricultural land in the world is irrigated using waste water. However, in Africa and Asia, 50% of urban community gets vegetables produced from artificially irrigated farms [11]. In general, efficient agricultural water management practices remain

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crucial to efficient utilisation of water and improved environmentally friendly agricultural production for economic growth, food security, human health, soil ecosystem, restoring water resources and the ecosystem [52, 53, 54].

Therefore, the idea of sustainable agricultural development should focus on the implementation of developed agricultural technologies, knowledge and practices that have no significant negative effects on the environment and human health [14]. The limited availability of information and knowledge about soil content has resulted in the continuous application of unsuitable fertilizers, leading to an increase in heavy metal concentrations in the soil [55]. Hence, environmentally-friendly production systems and relevant economic policies are necessary.

CAN ORGANIC FARMING FEED THE WORLD?

Several research reports indicate that organic farming could increase the world food supply and eradicate hunger by using integrated farming practices, which could sustain environmental wellbeing, the rural economy and community health [38, 56, 57, 58, 59]. Experiences in both developed and developing countries suggest that organic farming is a potential means for increasing productivity, attaining better nutritional benefits, reducing input expenses and promoting environmental rehabilitation [3, 40, 57, 58, 60, 61]. Research findings indicate the yield differences between organic and conventional production systems [62]. However, natural farming restores the ecosystem, and it promotes economic feasibility and health benefits, compared to conventional agriculture [40].

There are indications that the demand for organic beverages and organic food (in food markets all over the world is increasing) [40, 63, 61, 64]. The data from many developed and developing countries show increasing production from organic farmland and organic retail sales (Figure 8). The latest data indicate that 50.9 million hectares is dedicated to organic farming and is handled by 2.4 million producers [63].

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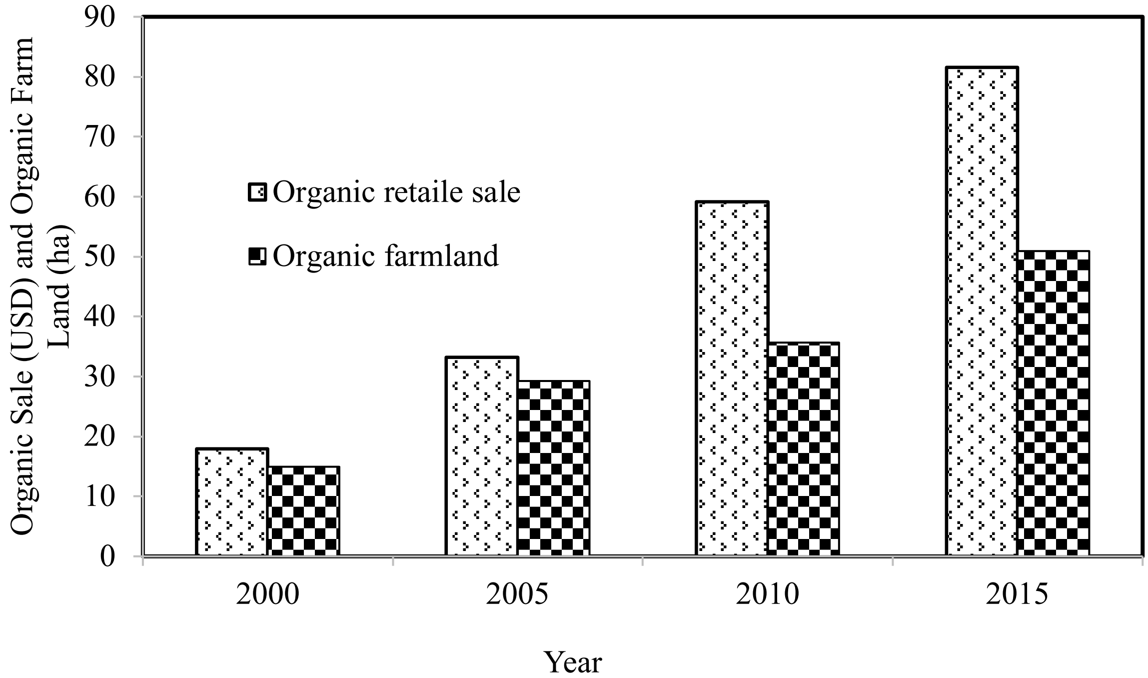

Figure 8: Growth in organic food and drink sales and farmland (world total) (Source: [65])

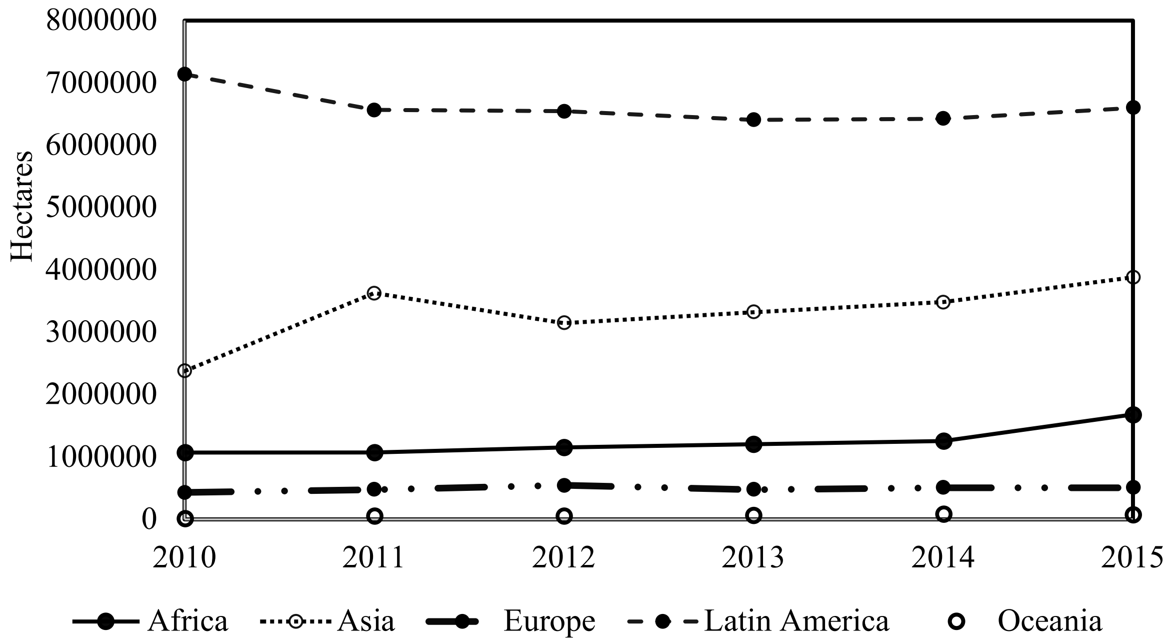

Figure 9: Growth in organic farmland (world total) (Source: [65])

Indigenous knowledge, integrated farming practices, modern scientific innovations, design knowledge and a knowledge of delivery mechanisms could support the sustainable use of natural resources to enhance organic farming practices [3, 56, 66, 67]. Developing countries have a greater potential to increase organic production, when compared to developed countries. The number of registered organic producers and the rate of production keep rising. The increasing trend of organic farm expansion and the sale of organic produce across the word is shown in Figures 8, 9 and 10. The data presented in Figure 9 show that there is an increase in organic agricultural land in Africa and other continents, which is due to the increasing demand for organic products (Figure 6). This clearly demonstrates that there is consumer awareness of organic produce and production systems, that there has been a change in the world's food preferences and production systems, and that there is a preference for environmentally-friendly farming.

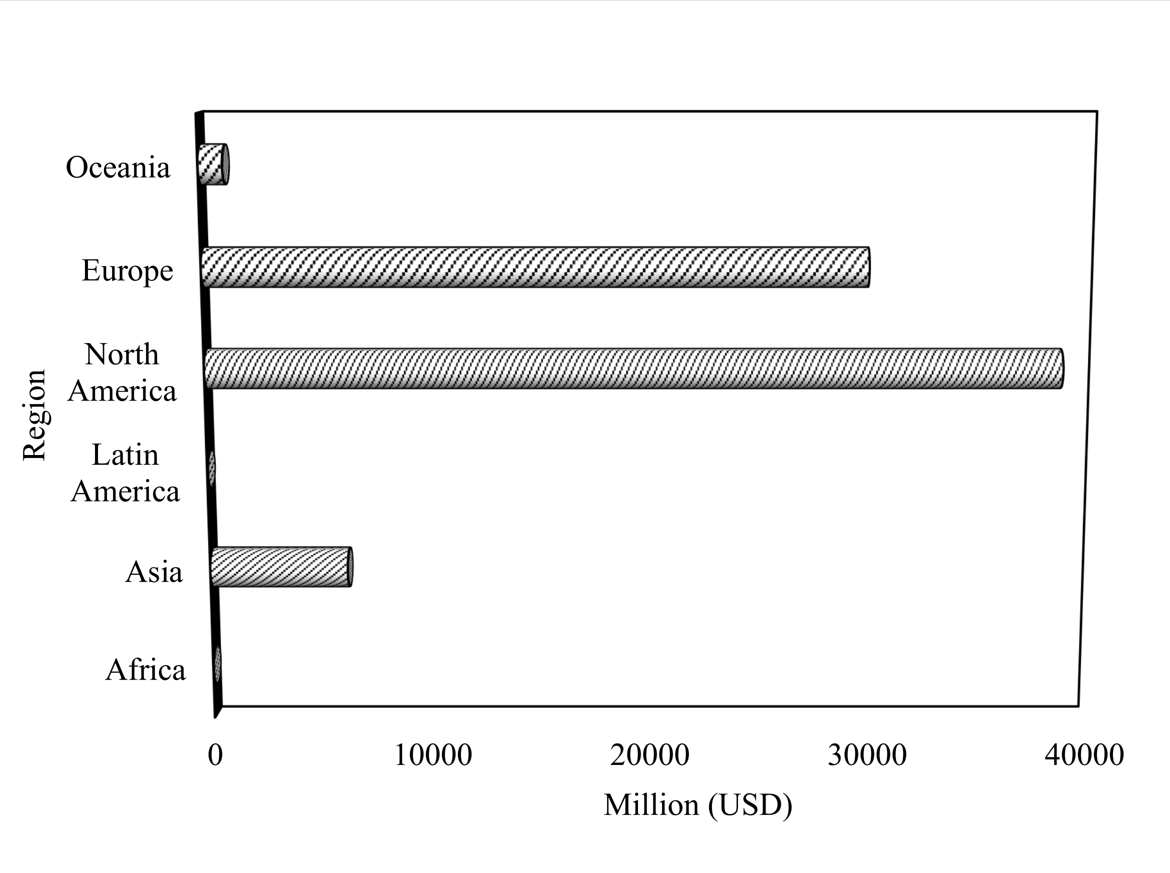

Figure 10: Organic produce retail sale (Source: [66])

The experiences of both developed and developing countries show that there is great potential for organic agriculture to sustain the food supply, as well as healthy environment, economy and community [10, 40, 68, 69]. Hence, organic farming in developing countries is crucial for reducing, environmental degradation, farm input expenses and for increasing the self-reliance of a country [56, 58, 59, 68].

Conventional agricultural practice has resulted in the loss of soil fertility and an in imbalance in the ecosystem. Moreover, literature shows that the cumulative problems arising from the implementation of intensive agricultural practices and cultivation approaches may lead to the conversion of about 30% of the total world agricultural land into unproductive land by 2020 [44].

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Organic farming systems depend on crop rotation, off-farm organic waste, crop residue, animal manure, legumes, green manure and the use of biological pest control, to maintain soil productivity, ecosystem balance and soil fertility. It is the application of natural farm inputs to maximize yield. Organic agriculture has the potential to provide food for the global demand without requiring additional new farmland [10]. Organic farming can enhance soil fertility, the soil micro flora and biodiversity, the nutritional quality of food, economic benefits and sustainable development [15, 44, 70, 71, 72]. For example, an increase in soil organic carbon concentration by 1 Mg ha^{-1} y^{-1} leads to 32 million Mg y^{-1} increase grain production in developing countries [44].

Organic matter affects both the chemical and physical properties of soil [40, 15, 73, 74, 75]. It improves soil porosity and air circulation, which, in turn, creates favourable conditions for the development of useful organisms (i.e. bacteria and fungi inocula). Organic farming enhances the nutrients available to plants by improving nitrogen fixation and the mobilization of key nutrients such as phosphorus, potassium and iron [44]. Therefore, organic farming could provide a solution for environmental pollution and social imbalances, and it could prove beneficial in drought conditions [76, 69]. It must also be noted that organic production requires crop identification on a regional basis and that market assessments need to be undertaken to determine the existing demand for organic products [10, 36].

Transformation of Farming System

It is clear from literature that there should be a radical paradigm shift from conventional farming to organic farming systems [6, 22, 35, 43] Chemical residue from fertilizers and pesticides such as lead, calcium and arsenate have long-lasting effects on the soil ecosystem [20, 44]. Organic farming improves the soil structure and soil micro flora by using locally available natural products [15, 77, 56, 78]. Self-dependent natural farm input production and implementation have a reverse effect on the degrading environment, human health and the increasing food costs. Organic fertilizer usage and methods of application vary in relation to the soil, environment and agro-climatic conditions of the cultivated farm lands [15]. Indeed, the increasing population needs available food products to survive. Using organic fertilizers and natural pest control mechanisms could significantly contribute towards replenishing the deteriorating environment, biodiversity, human health and soil fertility to provide sufficient healthy food for the growing demand [15, 17, 40, 43, 79].

The transformation of a farming system from conventional farming to organic farming could take considerable time. The process requires the step-by-step procedural organic farming system to sustain local and global food and nutritional security. The relevant and procedural research and procedural transformation of organic farming and implementation could provide solutions for the existing environmental rehabilitation, and it could create job opportunities and economic development [10, 36]. The step-by-step implementation of organic farm inputs and farming procedures could enhance soil quality such as the soil water holding capacity, the cation exchange capacity, soil aggregation, and it could reduce susceptibility to crusting and erosion [15, 43, 71, 76, 80].

Organic farming is crucial for decrease in environmental degradation and farm input expense and for improving public health. Therefore, changing the world food production system towards environmental-friendly farming would be a solution in the future.

CONCLUSION

In the modern world, there is an ever-increasing demand for the application of synthetic farm inputs in cultivated soil and the environment to balance the existing food demand and agricultural productivity. Nitrogen was the highest type of fertilizer consumed in the world, as well as in Africa, from 2002 to 2014. The continual application of synthetic fertilizers and pesticides has resulted in human health complications, surface and ground water pollution, and ecosystem imbalances, as well as environmental pollution, declining soil fertility and soil health.

In developing countries, limited basic knowledge about synthetic farm inputs and their application has exposed farmers to harmful and banned farm inputs, without considering the possible negative effects.

At the beginning of creation, natural farming took place for human survival. Organic farming, with the support of science and the advancement of knowledge, could provide solutions for the desired agricultural productivity and pest control. This system has the potential to promote a sustainable healthy life, environment and ecosystem balance.

Organic farmland increased by 242% over a period of 15 years from 2000 to 2015, while organic retail sales increased by 355% during the same period. The highest organic retail sales were in North America, while there were negligible sales observed in Africa and Latin America.

Developing an appropriate agricultural policy and implementation strategy might lead to sustainable agricultural development and provide direction regarding the replenishment of the degraded environment and human health. Therefore, relevant research should be conducted to improve organic farm input production and application. This could help to implement environmentally-friendly organic farming in the existing agricultural production systems.

Governmental Organisations and NGOs should support organic agriculture and production systems and transferring new agricultural knowledge and replacing synthetic farm inputs with organic farm inputs. This could be made possible by encouraging, facilitating and supporting environmentally-friendly thinking and organic farming.

Countries should realise the need for safe and environmental friendly farming technology and agricultural practices that support soil ecosystem, human health and the farming environment. Organising training, facilitating organic farm input production and farm transformation from synthetic to organic fertilizers are crucial for preventing environmental pollution and its outcome on living things.

Relevant government agencies should regularly monitor trace metal impurity levels in imported fertilizers and pesticides.

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Table 1: The heavy metal concentration in different types of fertilizer (MN: multiple nutrient. Source of data: [81])

Fertilizers	Pb (mg.kg-1)	CD (mg.kg-1)	Ni (mg.kg-1)	CO (mg.kg-1)	Cr (mg.kg-1)
Phosphatic fertilizers	11.2-32.4	22.7-36.8	52.8-85.2	5.4-21.2	1999.9-410.0
Liquid fertilizers	4.1-48.5	1.9-27.1	4.6-36.1	30-21.1	0-203.3
Water-soluble MN fertilizers	8.9-17.3	12.0-32.7	3.9-45.5	7.1-15.2	0-236
Solid multiple nutrient fertilizers	11.5-16.7	4.4-28.2	24.2-61.5	5-17.3	40-213.3

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