Hindawi
Applied and Environmental Soil Science
Volume 2022, Article ID 4738416, 14 pages
https://doi.org/10.1155/2022/4738416

Review Article

Growing Use and Impacts of Chemical Fertilizers and Assessing Alternative Organic Fertilizer Sources in Ethiopia

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Received 12 November 2021; Accepted 28 January 2022; Published 20 March 2022

Academic Editor: Kalpana Bhatt

This paper reviews relevant facts and statistics about the benefits and impacts of the growing use of chemical fertilizer with a focus on soil fertility, crop productivity, and alternative sources of biofertilizers. Agriculture in Ethiopia is the main source of the economy, and it is the key contributor of the export value and provider of raw materials to processing industries. However, Ethiopian agronomical production is characterized by low output, lack of infrastructure, and low level of technology and is enormously dependent on rainfall availability. In Ethiopia, soil fertility reduction is evolving as a serious contest causing low crop yields, and research findings reported that, at the country level, nutrient balance indicated a depletion rate of 122 kg N ha^{-1} yr^{-1}, 13 kg P ha^{-1} yr^{-1}, and 82 kg K ha^{-1} yr^{-1}. To control soil fertility depletion, primarily fertilizers are used as the source of essential plant nutrients. In Ethiopia, the use of chemical fertilizers to increase crop production was low relative to other developing countries; however, now, it is steadily increasing. Urea and diammonium phosphate are common practices for maintaining soil fertility. Chemical fertilizer consumption increased from 12 kg/ha in 1996 to 36.2 kg/ha in 2018. The main cereals' production increased from 16.5 quintal/ha in 2009 to 23.94 quintal/ha in 2018.

1. Introduction

With the worldwide human population continuously growing, increasing crop production without experiencing a distractive impact on the environment is the main contest that agriculture is currently facing [1–4]. Agriculture plays a significant role for developing nations that have agricultural land. The rapid rise of the human population determines a growing demand for food and water, which results in higher energy usage and, therefore, the use of nonrenewable resources [3, 5, 6]. In Ethiopia, agriculture is the primary source of human welfare and economic growth [7, 8] and the main contributor to the economy. It accounts for about 37% of the gross domestic product of the country and is a source of living for over 70% of the country's population [7, 9], and exports are dominated by agricultural products [10]. However, the production is categorized by low productivity, survival orientation, low level of technology, low level of inputs (fertilizer and pesticide), lack of road and market institutions, and extreme susceptibility to rain inconsistency [11].

2. Food Security Challenge in Ethiopia

Food security remains challenging for most developing countries in Africa, including Ethiopia [4, 12, 13]. On average, agricultural productivity in Africa is lower than that in other regions [14]. For food self-sufficiency, crop productivity growth is vital for stimulating growth in other parts of the economy [3, 4, 15]. Subsequently, agriculture is the key source of raw materials to food processing, beverage, and textile industries [16]. Increasing area farming land is no longer a feasible strategy to feed the growing population [17]. Hence, intensification strategies to increase crop productivity while protecting the environment have become essential to attaining agricultural growth, food needs, and nutrition security [3, 17, 18]. Furthermore, many constraints hamper agricultural productivity in Ethiopia; among the key factors, soil fertility depletion is one [16]. To increase crop production needs cumulative effort to use endorsed fertilizers, enhanced crop variety, and control of crop pest diseases [18]. However, agriculture largely depends on the increasing use of chemical fertilizers [19]. Fertilizer's consumption growth is dependent on the expansion of the human population [20].

Soil has been subjected to severe nutrient deficiency triggered by natural and man-made factors [16, 21]. Therefore increasing agricultural productivity requires a range of measures, including appropriate use of fertilizer, crop protection innovations, and improved seeds [16, 22]. Largely cereal-based mixed crop-livestock systems dominate Ethiopian rain-fed agriculture [9]. The major cereal crops, teff, wheat, maize, barley, and sorghum, represent about 96% of total cereal production [21]. Additionally, vegetables and fruits are also one of the rapidly expanding agricultural markets in Ethiopia [23].

2.1. Agricultural Productivity and Soil Depletion. Soil fertility reduction is the main contest that causes serious food insecurity and poverty [24]. Increasing crop productivity remains the most feasible pathway for achieving the great challenge of feeding 9.8 billion people by 2050 [25]. Nowadays, effective soil fertility amendment strategies are one of the most essential needs for increasing soil fertility [24, 26] because soil nutrient deficiency is one of the major limiting factors for cereal crop yield reduction [21]. Soil infertility is evolving as a serious problem causing low crop yields and food insecurity in the country [7, 21, 24, 27, 28]. Ethiopia faces the highest rates of nutrient depletion in sub-Saharan Africa [21, 28]. At the state level, findings on nutrient balance indicated a depletion rate of $122\,kg\,N\,ha^{-1}\,yr^{-1}$, $13\,kg\,P\,ha^{-1}\,yr^{-1}$, and $82\,kg\,K\,ha^{-1}\,yr^{-1}$ [29], which were rated twofold as high as the average nutrient reduction rate for sub-Saharan African [27]. The reduction of soil fertility has led to reduced crop productivity in most African countries, including Ethiopia [30,31]. Poor soil fertility management and continuous cropping increase soil nutrient depletion and reduction of organic matter [9]. Management of soil fertility has been a great problem for farmers for thousands of years [32].

To increase soil fertility, fertilizers (organic, inorganic, or their integration) are used as the source of plant nutrients [7]. Increasing soil fertility through fertilizer application is the common way of modern agricultural practice [33]. Fertilizers are substances applied to the soil to supply essential nutrients to the plant tissue to increase the growth and yield the plants [30, 32, 34]. Furthermore, it could be organic or inorganic and natural or synthetic that supplies plants with the necessary nutrients for plant growth and optimum yield [35]. The use of chemical fertilizers like urea (46% N) and diammonium phosphate (DAP: 18% N, 46% P_2O_5) is the common practice in Ethiopia [28].

3. Essential Plant Nutrients

Researchers all over the world have dedicated substantial devotion to the science of plant nutrition [36]. Plant nutrient sources are the most important controlling factor for growth and productivity [36]. Plants mainly need about 17 nutrients for optimal growth and productivity [25] and are mainly made up of four main elements (hydrogen, oxygen, carbon, and nitrogen) [32]. Plant nutrients can be categorized into macronutrients and micronutrients (Table 1).

Many fertilizer producers provide plant macronutrients individually or in mixtures with the soil, and the application of macronutrient fertilizers commonly affects nutrient accessibility to plants [37]. Nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur are essential plant macronutrients [32, 37]. NPK-containing fertilizers are the three primary macronutrients [32, 38]. Macronutrients are needed in large amounts, and they are limiting plant growth and development in soil systems.

The type of fertilizer depends on the available nutrient content specified in terms of fractions of nitrogen (N), phosphorus pentoxide (P_2O5), and potash (K_2O). The shortage of important nutrients, specifically nitrogen (N) and phosphorous (P), is the most significant factor limiting crop yield [39].

3.1. Nitrogen. Nitrogen is a building block of proteins and genetic material, and it is the nutrient that is necessary for the proper growth and development of living organisms [5]. Nitrogen (N) is the most used nutrient, and N fertilizer has long been a critical component of agriculture, currently accounting for over 50% of the world's food production [25, 30, 40]. Though plentiful nitrogen gas (N_2) exists in the ambient air, crops can only take either ammonia (NH_3) or nitrogen oxides (NO_x) such as nitrate NO_3^- and nitrite NO_2^-, which are the major components of nitrogen fertilizers [41]. Nitrogen fertilizers are substantial for worldwide food self-reliance, primarily for Africa, where the nitrogen input is low [42]. Nitrogen and phosphorus are essential nutrients for plant growth, and subsequently, the use of these nutrients as chemical fertilizers has been growing since the green revolution in the 1960s and controls crop yield [43]. The supply of N is presently limitless because of the production of urea by the Haber Bosch process [44]. World plant nutrients production increases within the proportion of urea in world N production that the production is about 40% of all N fertilizers produced [45]. The comparison of increasing use of nitrogen fertilizer for different regions is given in Figure 1.

3.2. Phosphorus. Phosphorus is indispensable for plant growth, is often a key limiting nutrient in agriculture, and has no substitute in food production [46, 47]. Securing sufficient P will be critical for future food security [46]. Phosphorus is a vital element required in relatively large quantities for the development of plants, which are usually

Table 1: Essential plant nutrient classification.

Nutrients supplied by water and air	Nutrients supplied by the soil			
Nonmineral	Primary macronutrient	Secondary macronutrient	Micronutrients	
Carbon (C)	Nitrogen (N)	Calcium (Ca)	Zink (Zn)	Iron (Fe)
Hydrogen (H)	Phosphorus (P)	Magnesium (Mg)	Chlorine (Cl)	Manganese (Mg)
Oxygen (O)	Potassium (K)	Sulfur (S)	Boron (B)	Cobalt (Co)
			Molybdenum (Mo)	Nickel (Ni)

Source: [32].

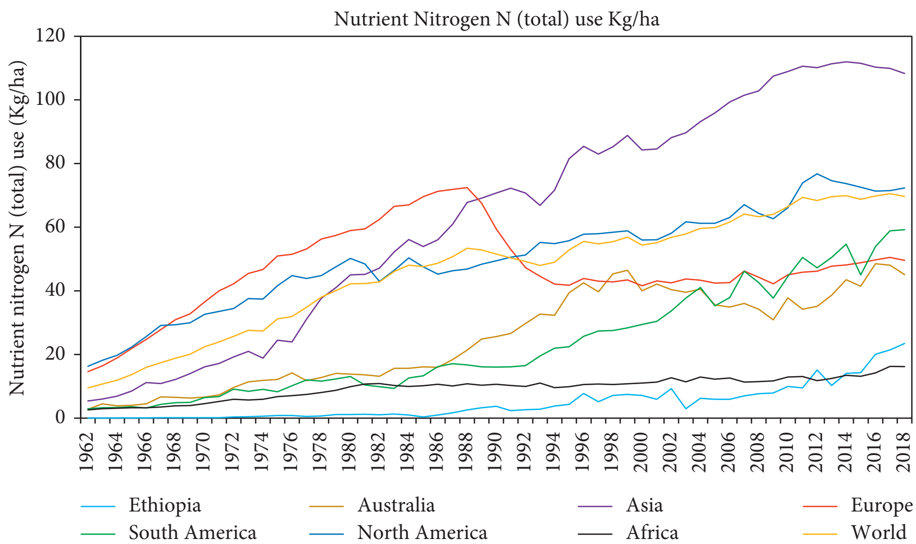

Figure 1: Use of nutrient nitrogen N (total) growth (Kg/ha) of the continents (1962–2018). Source: author's compilation from the FAOSTAT database.

derived from a nonrenewable phosphate rock resource [48–51]. Globally, about 50–60% of the phosphorus-based fertilizer need is attained by mineral fertilizer [52]. Phosphate rock deposits are limited, and there is a serious concern about the accessibility and cost of phosphate rock in the future [44]. The demand for phosphorus resources other than nonrenewable P rock has driven the development of several phosphorus recovery technologies [48]. For instance, the recovery of phosphate from waste material has been getting ample attention these days [53]. The comparison of increasing use phosphorus containing fertilizers for different regions is given in Figure 2. The common commercial phosphorus fertilizers are monoammonium phosphate (MAP), diammonium phosphate (DAP), and triple superphosphate (TSP) [45, 48].

3.3. Potassium. Potassium (K) plays multifunctional activities in plants, related to enzyme activation, osmotic adjustment, turgor generation, cell expansion, and regulation of membrane electric potential [54]. Plants uptake K as the cation (K+), and various sources of K are available in soils or provided as fertilizers, including potassium chloride (KCl), potassium nitrate (KNO_3), potassium sulfate (K_2SO_4), and potassium carbonate (K_2CO_3) [54, 55]. The quality or grade of potassium fertilizers is expressed as a percentage of potassium oxide (K_2O) equivalent.

3.4. Micronutrients. Micronutrients are required in lesser quantities, in parts-per-million (ppm) [32], and are usually present in adequate amounts in most soils, but their availability may be limited due to a variety of circumstances, and most micronutrients are more available when the soil pH is below 7 [37]. The shortage of micronutrients in the human diet is a global problem and could be caused by soil-related constraints, excessive tillage, and other harmful agricultural management practices [56].

4. Crop Production and Chemical Fertilizer Consumption

4.1. The Growing Use of Chemical Fertilizer. Fertilizers can be classified as chemical/mineral and organic. Chemical fertilizers are produced by the fertilizer industry, are mainly nitrogen, phosphate, and potash [57], and have significantly sustained the increasing population of the world [58]. Chemical fertilizers are widely considered a major option for addressing the crisis of nutrient depletion and sustaining food production [7]. However, these fertilizers are expensive due to the cost of production (cost of raw materials and the cost of capital) [59]. They are extensively used to enhance crop yield [60]; in several agricultural systems, numerous macronutrients dissolve quickly in the soil and supply the nutrients to the plants in large amounts [58]. Currently,

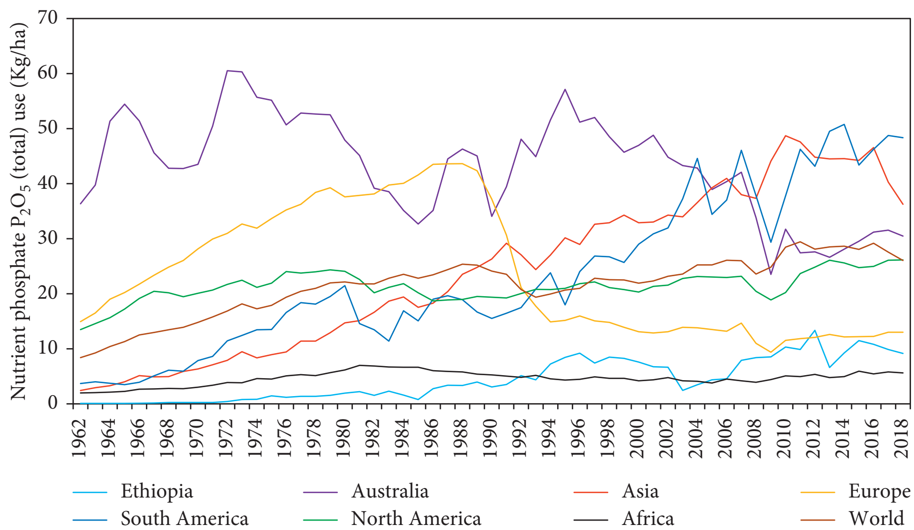

FIGURE 2: Use of nutrient phosphate P_2O_5 (total) growth (Kg/ha) of the continent's average (1962–2018). Source: author's compilation from the FAOSTAT database.

there is an increase in the consumption of chemical-based fertilizers to meet the demand of high deficiency of nutrients in the soil [34]. Optimal use of synthetic fertilizer is vital for improving ecosystem services of any food production system while avoiding potential negative environmental impacts [61]. Worldwide mineral fertilizer consumption is steadily increasing in response to the growing population and increased demand for food crops and nonfood crops [62]. The application of synthetic fertilizers in Ethiopia is still very low [61]. However, the use of chemical fertilizers is increasing steadily. The major source of fertilizer sales in Ethiopia has been urea and DAP since the 1960s, and there has been no change in the composition of the use of fertilizers in Ethiopian agriculture until 2014/15 cropping season [16]. Due to the unbalanced use of fertilizer, the loss in soil fertility is also significant in Ethiopia. Diammonium nitrate (DAP) has been gradually substituted by NPS in the past two years to meet the sulfur demand of most of the Ethiopian soils [16]. The import quantity of fertilizer is increasing; main diammonium nitrate, urea, and NPS (nitrogen-phosphate fertilizer with sulfur) are imported in Ethiopia.

In developed countries like Western Europe and the USA, fertilizer use intensity is up to 288 kg/ha on average [22]. However, in developing countries like Ethiopia, consumption is very low. According to Sheahan and Barrett [63], findings on six African countries show that synthetic fertilizer use is the highest in Malawi (146 kg/ha), followed by Nigeria (128 kg/ha), Ethiopia (45 kg/ha), Tanzania (16 kg/ha), Niger (2.5 kg/ha), and Uganda (1.2 kg/ha). In general, Ethiopian fertilizer application (kg/ha) is lower than that in most developing countries (Figure 3).

Researchers and policymakers in many developing countries widely recognize the importance of agricultural growth policies and accelerating the growth of food production by increasing the use of chemical fertilizers and chemical pesticides as a means to raise agricultural productivity [64,65]. For instance, the mean total nitrogen input to croplands increased from 19 kg N ha^{-1} yr^{-1} in (1961–1965) to 42 kg N ha^{-1} yr^{-1} in (2010–2017) for SSA [30]. According to Elrys et al. [42], African nitrogen consumption will reach 154 kg N ha^{-1} yr^{-1} in 2050. As shown in Figure 3, the nitrogen fertilizer consumption of Ethiopia is below sub-Saharan Africa. However, it steadily increased from 9.3 in 2002 to 23.5 in 2018 (Figure 4).

In Ethiopia, chemical fertilizer is primarily used in cereal production [38], and about 60% of the farm households use chemical fertilizers, but a huge percentage only use small quantities [38]. The farm households used about 28.2 kg of urea per ha and 36.7 kg of DAP per ha [66], mostly for teff, sorghum, wheat, and maize production, and cereal production may account for 90% of fertilizer use with most of the remaining applied to pulse, oilseed, and nongrain crops [22, 67].

4.2. Major Crop Types Cultivated in Ethiopian. Crop production is a major food production ecosystem in most of Africa [61]. From various crops species (cereals, oilseeds, pulses, vegetables, root crops, and fruits), the production of cereal grains is critical for food security [3]. Cereals are important crops in Ethiopia and cover the largest share of household production [68], and smallholders are responsible for producing a substantial share of the region's crops. Cereals crops such as teff, wheat, maize, sorghum, and barley are the main of Ethiopia's agriculture and food economy, accounting for about three-quarters of the total area cultivated (Figure 5) and consumption activities [68, 70]. The report of the year 2020/21 Meher season crop production survey indicated that a total cropland area of about 12,979,459.91 hectares is covered by grain crops (i.e., cereals, pulses, and oilseeds), from which a total volume of about 341,828,693.39 quintals of grains is obtained, from private peasant holdings [69].

As labeled on Table 2, from the total grain crop area, 81.19% (10,538,341.91 hectares) was under cereals. Teff, maize, sorghum, and wheat took up 22.56% (about 2,928,206.26 ha), 19.46% (about 2,526,212.36 ha), 12.94% (1,

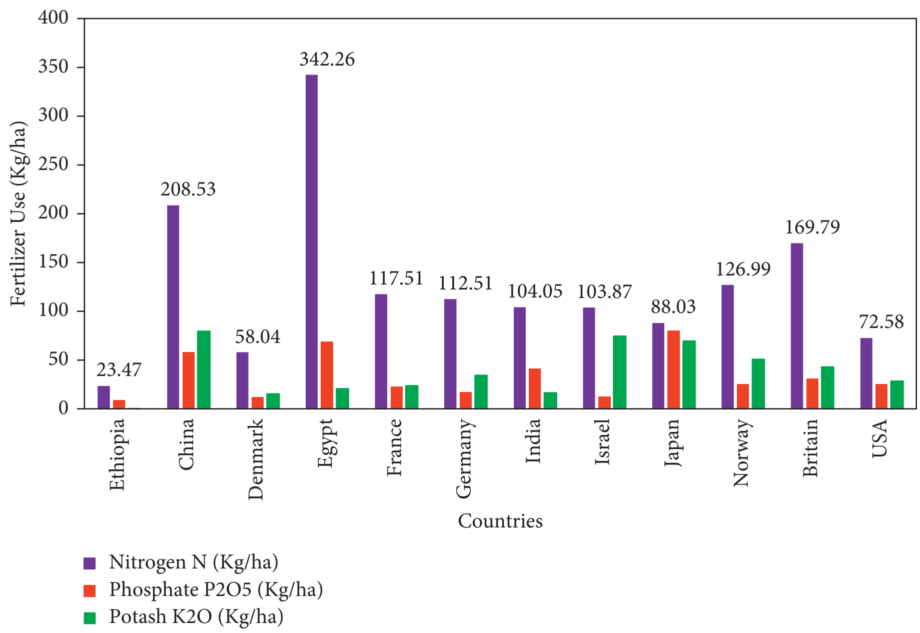

Figure 3: Comparison of fertilizer usage (nitrogen phosphate and potash) of countries in 2018. Source: author's compilation from the FAOSTAT database.

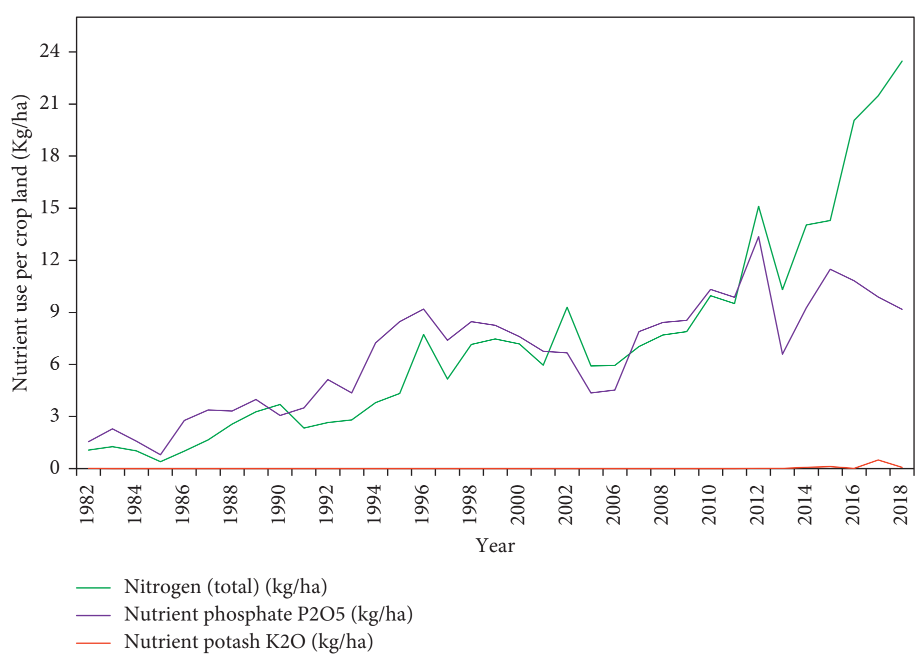

Figure 4: Fertilizers (N, P_2O_5, and K_2O) use growth (kg/ha) of Ethiopia from 1993 to 2018. Source: author's compilation from the FAOSTAT database.

679, 277.06 ha), and 14.62% (1,897,405.05 ha) of the grain crop area, respectively [69].

4.2.1. Fertilizer Use and Crop Yield. Previous to the beginning of the twentieth century, almost all increases in crop manufacturing occurred as a result of increases in the area cultivated, but later to the end of the century, almost all increases were coming from increases in land productivity [64, 71]. Adding chemical fertilizers to the crop plays a major part in the production per hectare and the intensification of the agricultural yield [72]. According to FAO (2013), in the year 2000, the world consumption of fertilizer components, nitrogen (N), phosphorus (P), and potassium (K), was 64.9, 25.9, and 18.2 kg ha¯1, respectively, which increased to 85.8, 33.2, and 20.4 kg ha¯1, respectively, in the year 2014 [45].

Most of the African development strategies include efforts to increase the productivity of smallholder farmers [73]. The intensification of crop-based agriculture has been associated with a sharp increase in the use of chemical

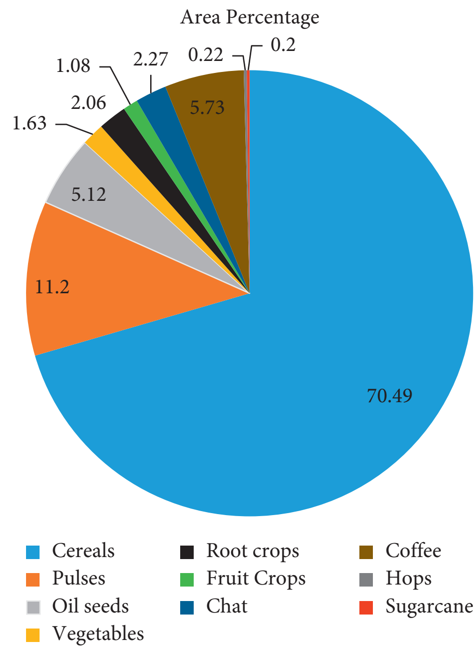

FIGURE 5: Ethiopian land area percentage covered by different crop types, 2020/21 Meher season. Source: [69].

TABLE 2: Estimate of area, production, and yield of crops for 2019/20 and 2020/21 Meher seasons.

Crop type	Area (hectares)		Production (quintals)		Yield	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
Grain crops	12,858,638	12,979,460	335,103,036	341,828,693	26.06	26.34
Cereals	10,474,336	10,538,341	296,630,122	302,054,261	28.32	28.66
Teff	3,101,167	2,928,206	57,357,101.87	55,099,615	18.50	18.82
Barley	950,739	926,107	23,780,050	23,391,099	25.01	25.26
Wheat	1,789,306	1,897,405	53,152,703	57,801,306	29.71	30.46
Maize	2,271,442	2,526,212	96,283,366	105,570,936	42.39	41.79
Sorghum	1,827,244	1,679,277	52,633,478	45,173,502	28.80	26.90
Finger millet	455,580	480,343	11,259,579	12,030,164	24.71	25.04
Oat	21,282	15,502	457,543.61	305,403.43	21.5	19.70
Rice	57,575.72	85,288.87	1,706,301.01	2,682,235.14	29.64	31.45
Pulses	1,563,519.43	1,674,950.34	30,051,568.79	31,999,988.65	19.22	19.10
Oilseeds	820,782.12	766,167.66	8,421,345.36	7,774,444.17	10.26	10.15
Vegetables	238,505.79	243,568.75	8,761,390.18	9,067,870.78	36.17	37.23
Root crops	248,223.82	307,295.80	46,380,932.79	56,216,815.32	186.85	182.94
Fruit crops	115,533.76	161,470.82	8,347,071.22	14,192,409.18	72.25	87.89

Source: [69].

fertilizers [15, 74]. The use of fertilizers remains very low in sub-Saharan Africa [61], though the increased use of fertilizer has huge potential to increase crop yields [22, 36, 61].

Assessment of field studies has shown that fertilizer use is critical to growing crop productivity [4]. Fertilizer consumption (kg/ha of arable land) is increased from 12 kg/ha in 1996 to 36.2 kg/ha in 2018 (Figure 6), and agricultural association sources revealed that cereal yield recorded significant growth in Ethiopia for the last decades [68]. Primary cereals yield increased from a level of 10.3 quintals/ha in 1999 to 16.5 quintals/ha in 2009, the growth has been found [68], and 23.94 quintal/ha was reported in 2018 (Figure 7).

Chemical fertilizers are relatively inexpensive, have high nutrient contents, and are rapidly taken up by plants [75]. However, the use of excess fertilizer can result in several problems, such as soil nutrient loss, surface water and groundwater pollution, soil acidification or basification, and reductions in useful microbes [75, 76].

Modern agricultural practices have emphasized the large use of fertilizer, and this strategy has truly improved grain yields in many nations in the last three decades. However, repeated and excessive use of chemical fertilizers additionally led to a decline in crop yields and soil fertility [77]. Hence, the current agricultural trends emphasize finding alternatives to nonrenewable chemical fertilizers due to huge procurement costs and environmental contamination [76]. The search for an effective process for the formulation of an eco-friendly, low-cost, and competent organic fertilizer is hence in-demand [26].

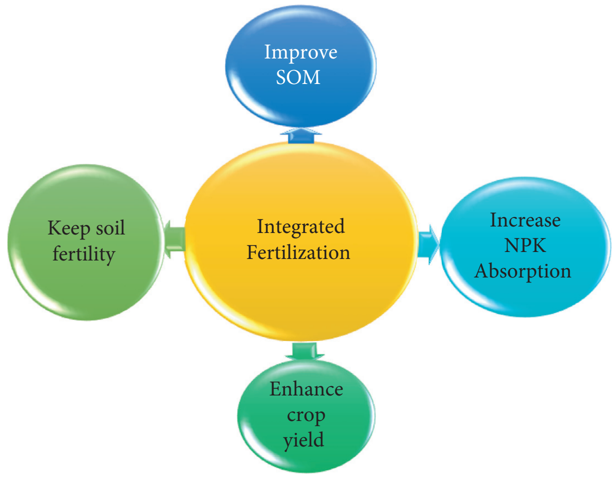

FIGURE 6: Diagrammatic presentation of integrated fertilization.

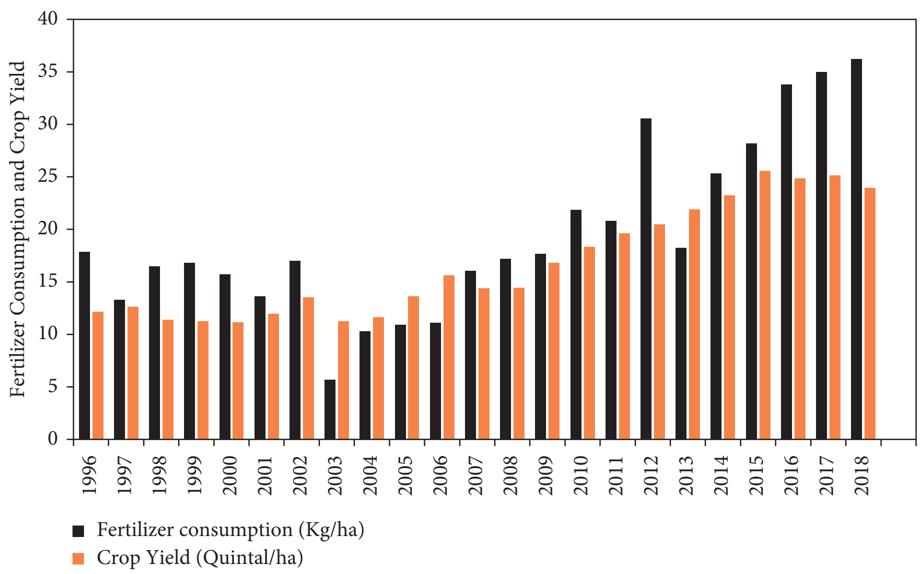

FIGURE 7: Fertilizer consumption (kg/ha) and crop yield growth in Ethiopia (1995–2018). Source: author's compilation from the World Bank.

5. Organic Fertilizer Sources

Organic fertilizers are naturally existing sources that are recycled plant or animal-derived matter that contains a reasonable amount of plant nutrients [32, 57, 78, 79]. Organic fertilizers can improve the soil microbial community and soil preservation capacity and increase nitrogen utilization efficiency, soil fertility, and, ultimately, the quality of agricultural products [76, 80]. The use of solid organic manure for the formulation of eco-friendly compost could be an effective alternative to improve soil fertility [26,81]. Alternative nutrient-rich organic sources that are available to farmers are not widely promoted [7]. Organic fertilizers are low-cost, renewable sources of plant nutrients that support chemical fertilizers [75, 76].

Scholars recommend that organic farming is becoming more and more popular [81], and it is the fastest-growing sector in the agriculture inputs, although only about 1% of the world's agricultural area is covered by organic farming [82]. The application of organic fertilizer is beneficial to improving the quality of cultivated land [83]. Organic agriculture has appeared as a substantial area worldwide because of the rising demand for safe and healthy food and long-term sustainability and concerns on environmental pollution related to unselective use of agrochemicals [84]. Some of the benefits of organic fertilizers are soil preservation, conservation of soil fertility, reduction of water pollution (groundwater, rivers, and lakes), minimizing utilization of nonrenewable external inputs, and improving product yield and quality [79]. Nutrient cycles are closed with the aid of composting, mulching, green manuring, and crop rotation [85].

5.1. Compost. Compost is the product formed by the biodegradation of organic matter (yard waste, animal manure, and food waste) with the help of microorganisms (mainly bacteria, fungi, and actinomycetes) [86–89]. Composting of organic materials is spontaneous biological decomposition, resulting in a stable product and contamination-free for crop cultivation [90, 91]. Usage of biowaste produced from human excretion has been utilized for agriculture since ancient times [92]. Compost contributes an important role in the improvement of the physical, chemical, and microbiological properties of the soil [90]. Manure has many limitations, such as low nutrient content and slow breakdown, and is a means of weeds seed spreading and several nutrient compositions depending on its organic materials, compared to chemical fertilizers. Manure has multiple benefits due to the supply of nutrients, including micronutrients, increased soil nutrient availability due to increased soil microbial activity, the decomposition of harmful elements, soil structure improvements and root development, and increased soil water availability [75]. Application of organic fertilizer sources such as crop residues and manure for smallholder farmers in Ethiopia is limited due to competitive uses for animal fodder and household energy [29].

5.2. Vermicompost. Vermicompost is an emerging technology for fast decomposition and stabilization product of active organic biomass material formed from the interactions between microorganisms and earthworms (red wrigglers, white worms, and earthworms), which is one of the important components of sustainable organic fertilizer and it is quite rich in plant nutrients [87, 89, 93, 94]. Due to the growth of population urban areas, solid left-over production is growing rapidly, making garbage pollution a serious problem [89], and that can be utilized for sustainable land restoration practices by converting into plant nutrients.

5.3. Bone and Blood Meal. Bone and blood meals are the main fertilizers allowed to be used in organic farming [79]. In the processing of animal products, approximately 40–60% of materials are used for food production, and the rest can be utilized for soil amendment [6]. Blood mill and bone meals are good sources of phosphorus, potassium, nitrogen, and calcium source. Bone meal decomposes slowly and releases phosphorus gradually [79]. Bones are the concentrated form of phosphorus captured in the form of animal waste [6]. Dry cattle blood from slaughterhouses can be used as an organic fertilizer because it contains about 10%–13% organic nitrogen [79].

5.4. Biochar. Biochar is produced through the pyrolysis of biomass by thermochemical decomposition of biomass with a temperature of about less than 700°C in the limited supply of oxygen [95], and the main products of pyrolysis are synthetic gas, biooil, and biochar [96–99]. It is a process in which biomass resources such as agricultural residue, food processing waste, solid waste, animal waste, and municipal sludge are thermally decomposed in oxygen-free environmental conditions [100]. Moreover, it is an alternative and relatively safer method for handling organic waste with additional advantages such as extracting useable energy and soil amendment organic fertilizer [98].

Biochar improves the physical properties of soil by enhancing its water-holding capacity, moisture levels, and oxygen content [79, 99, 101]. Furthermore, chemical properties, such as contaminant fixation and carbon sequestration, are also improved [102]. At the same time, biochar leads to changes in soil microbial abundance and diversity [96, 99, 101, 103]. It is currently being assessed as a better soil amendment compared to other organic materials like animal manure to improve soil quality and reduce greenhouse gas emissions [79, 96, 103]. Production and application of biochar are feasible in terms of raw material as it mostly uses waste materials and does not involve any sophisticated process. Therefore, improving phosphate by improved biobased biochar is perceived by the authors as one of the sustainable solutions.

5.5. Sewage Sludge. The amount of industrial waste is increasing and may be considered a potential source of organic matter for soil [104]. Sludge is the solid by-product of sewage sludge generated after wastewater treatment in the sewage treatment plant and is produced worldwide [88, 104–106]. The treatment of domestic and industrial wastes in sewage plants produces large amounts of sludge. Sewage sludge contains high levels of main nutrients and contains organic matter and macro- and micronutrients; this product has been long used in agriculture and horticulture to improve soil fertility [107, 108]. The chemical composition and properties of sewage sludge are highly dependent on the wastewater origin. Sewage sludge ashes can be a good source of fertilizer phosphorus in comprising fertilizer formulations [5]. Moreno et al. [104] reported that sewage sludge showed a potential lower environmental impact in terms of mineral N release and a higher impact in terms of CO_2 emission. Subsequently, it is a capable source of phosphorus [51].

5.6. Biofertilizer. Biofertilizers are produced by living microbial inoculants of bacteria, algae, or fungi alone or in combination, and they enhance the accessibility of nutrients to the plants through their root system [109–111]. Biofertilizer is the use of soil microorganisms to increase the availability and uptake of mineral nutrients for plants [112]. Currently, biofertilizers have emerged as a highly potent alternative to chemical fertilizers due to their eco-friendly, easy to apply, nontoxic, and cost-effective nature. Biofertilizers materials greatly contribute to the success of organic farming improving soil fertility and are valuable for increasing crop productivity [113]. Moreover, biofertilizers are considered as an alternative to chemical fertilizers in modern vegetable production [109, 110]. Biofertilization aims to accelerate the microbial processes, which supplement the availability of nutrients that can be easily assimilated by plants, and to increase the number of useful microorganisms in the soil. Currently, nitrogen-solubilizing biofertilizers represent the biggest part of the global biofertilizer market, followed by phosphate solubilizing biofertilizers [111]. The use of bacteria that solubilize inorganic phosphates is an important method for increasing the utilization efficiency of phosphates [114].

6. Integrated Fertilization

Soil organic matter (SOM) is central to soil function and quality [115]. Organics, biological, and inorganic fertilizers play a crucial role in improving crop yield and soil properties [116]. As a result, the mixture of chemical fertilizer with organic materials showed great potential for soils with low levels of organic matter [115, 117]. The majority of the researches recommends a combination of inorganic, organic, and biological fertilizers, which constitute an important component of integrated nutrient management and sustainable agriculture [118, 119]. Combined fertilization is an advisable practice to improve nutrient availability and microbial activity, preserve soil fertility, and control soil-borne disease [115, 120, 121]. Expanding combined use of biofertilizer produces the best effects, and organic fertilizers alone cannot withstand the required crop production [75, 78]. Due to low plant absorption (10–30%), phosphate solubilizing bacteria are capable of making P available to plants from both inorganic and organic sources [122]. Integrated application of biochar and nitrogen fertilizers increases plant growth and yield. Biochar may improve the nitrogen use efficiency due to an increase in the cation exchange capacity and giving an increase in water-holding capacity. Sarfraz et al. [123] reported that the maximum value of nitrogen use efficiency (65%) was observed when N at the rate of 50% and biochar at the rate of 1% were applied in the soil.

Comparable plant growth and yield responses have been stated from soil amended with fertilizer blends [124, 125]. The joint application of NPK plus manure enhanced the maximum adsorption capacity of phosphorus [126]. According to Damodar Reddy et al. [120], the combined phosphorus source through fertilizer and manure was greater than their sole application in improving the soil P fertility status. Furthermore, Körschens et al. [127] reported that, on average of 350 yield comparisons, combined mineral and organic fertilization resulted in a 6% yield benefit compared with mineral fertilization alone. The summary of the advantages of integrated fertilizer application is shown in Figure 6.

7. Health and Environmental Effect of Chemical Fertilizers

Synthetic fertilizer plays an important role in increasing soil fertility and crop productivity [128, 129]. However, excessive and continuous use of fertilizers accumulates contaminants in the soil to a level harmful to the environment (air pollution, soil acidification and degradation, and water eutrophication) [129–132]. Among inorganic fertilizers, phosphate fertilizers are the major source of contaminants because phosphate fertilizers are mainly produced from apatite; it usually contains small concentrations of heavy metals, on average 11, 25, 188, 32, 10, and 239 $mg kg^{-1}$ of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), palladium (Pd), and zinc (Zn), respectively [57, 130, 131]. For instance, Morari et al. [57] reported that the acceptable soil concentrations of Cd and Cr are 2 and 100 $mg\,kg^{-1}$, respectively. Continuous use of phosphate fertilizers leads to the accumulation of these and other heavy metals that may cause toxicity to plants and contaminate the food supply [133]. Health problems due to heavy metal contamination are of global concern [134]. Among the heavy metals, lead (Pb) and cadmium (Cd) have serious adverse effects on plant growth and human and animal health when ingested [134]. For instance, cadmium is reported to be carcinogenic and highly toxic to humans and animals [135].

In most regions, about 20–70% of the fertilizer is lost to the environment as dissolved nutrients, greenhouse gases, and other pollutants [136]. The low effectiveness of nutrient assimilation causes serious problems because of environmental protection [137]. Mineral fertilizer compounds migrate from soil to water ecosystems as a result of erosion and rinsing out. It causes accelerated contamination and eutrophication of surface and sea waters [137–139]. From applied nitrogenous fertilizers to the soil, only 50% is used by the plants [140], and more than half of the N-fertilizer produced each year is lost to the broader environment [139]. From this loss, 2%–20% is lost through evaporation, 15%–25% reacts with organic compounds in the soil, and the remaining 2%–10% penetrates surface and groundwater [127]. Subsequently, 50–70% of the environmental pollution with nitrogen compounds comes from agricultural areas' water outflows [137].

8. Conclusion

Modern agricultural practices have emphasized the massive use of chemicals, and this strategy has improved grain yields in several nations within the last decades. However, continual and excessive use of chemical fertilizers additionally led to a decline in crop yields and soil fertility. Therefore, the current agricultural experience concentrates on searching for changes to nonrenewable chemical fertilizers because of immense prices and environmental contamination. The discovery of an efficient method for the formulation of an eco-friendly, low price, and competent organic fertilizer is an essential task for the future agricultural development of the globe. Several types of research suggest that a mixture of inorganic, organic, and biological fertilizers represents a very important part of integrated nutrient management and property agriculture. Developing countries like Ethiopia should concentrate on sustainable sources and ways of soil fertility preservation and amendment in addition to chemical fertilizers. Sustainable soil fertility becomes the means to prove the increasing population's food security and keeping the environment.

Data Availability

The data used to support the findings of this study are statistically valid and available from all authors upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Tilahun Gisila Abebe generated the idea and overall contents of the paper and wrote the final paper by combining each section. Mohan Rao Tamtam and Amare Ayalew Abebe edited the final paper. Kitaw Abraham Abtemmaryam, Tewodros Geremew Shigut, Yared Abate Dejen, and Endayhu Gebeyhu Haile contributed equally to writing draft content.

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