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Extensive Utilization of Inorganic Fertilizers in Ethiopian Agriculture and Its Possible Consequences on Soil Quality

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Abstract: Ethiopia is the second populous nation in Africa next to Nigeria and is among the fastest growing economy in the world. Staple food production has not yet kept up with its rapid population growth. Addressing interwoven productivity problems and substantial increase in food production from the existing cultivated land is desirable to meet the demand of rapidly increasing Ethiopian population. Most crop lands have been under continuous cultivation for thousands of years without soil replenishment programs. It is obvious that an application of fertilizer enhances production, but simultaneously brought adverse impact on soil quality. The present chemical fertilizer-based intensive production in Ethiopia is believed to have physically deteriorated and biologically deactivated the soil. There is misperception among crop production experts, researchers and particularly political leaders on issue of fertilizer consumption and crop productivity. They do believe that inorganic fertilizer alone can increase yields and promotes its unwarranted utilization for alleviation of poverty. This argument is so powerful that negative impact of fertilizers on soil and climate is often treated as external costs which simply have to be accepted. Due to marginalization of grazing lands in Ethiopia, all forms of crop residues are removed for livestock feed and ameliorating soil fertility through chemical means to boost up productivity. Agricultural use of chemical fertilizers causes soil acidification, depletion of organic matter, emission of green house gases, eutrophication and major contributors of climate change. In the near future food production will apparently remain highly phosphorus-dependent due to the finite nature of rocks deposits. Food security situations of countries will soon be threatened with scarcity of phosphorus. Without sustainable replacement of soil carbon lost via decomposition, the quality of soil is gradually depleted and become unfavorable for soil habitats. Hence, it is advisable to take precaution measures before we completely lose soil biodiversity and follow a very sustainable approach in utilization of chemical inputs in a farm. Ministry of agriculture, universities and research institutions should promote strategies that enhance use of green manure, crop rotation and intercropping as fertilizer to fully exploit existing potential in most part of the country. Promoting researchers to conduct and generate local based technologies in sustainable approach with allocating adequate budget is also mandatory from government.

Key words: Adaptation · Biodiversity · Fertilizer · Food security · Ecological stability · Risk reduction

INTRODUCTION

Ethiopia is still among the poorest countries in the world with the second populous nation in Africa next to Nigeria; and is one of the fastest growth economies in the world [1, 2]. Besides, it is one of the most biological and cultural diverse country in sub-Saharan Africa. Despite being one of the poorest countries with a per capita income of USD 454 (significantly lower than regional average) [3], Ethiopian economy has registered remarkable economic and development performance with an average growth of 10.9% per year from 2000-2010 [4, 5]. This is double growth compared to sub-Saharan African countries and triples the average growth rate of the world over this period and has led to the country being rated as one of the fastest growing economies in the world.

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Staple food production in Ethiopia has not yet kept up with its rapid population growth [6]. Among the major factors that aggravate this problem were undulating geographical area, very fragmented plots of land, poor soil fertility, small scale holding, limited mechanization, insufficient supply of improved seeds, poor knowledge of farmers and improper cultural practices [7, 8]. This together with over-exploitation due to the high population density in the highlands makes the land vulnerable to degradation and restricts the availability of suitable land for farming [9]. The Ethiopian highlands are situated (>2000 masl), which cover 37% of the total geographical area and are inhabited by about 77% of the population with very sparse in lowlands [10]. This uneven human population distribution situation has been exacerbated by the cultivation on very steep slopes and over grazing leading to severe degradation of natural resources [11, 12]. Because of the above facts, very low soil fertility remains a problem in most production areas but particularly those with poor traditional land management practices [13].

To feed this ever increasing population, agricultural production has to be boosted up via improving the agricultural productivity per unit area of the most degraded cropping land that were under cultivation for centuries. The nature of Ethiopia agriculture by itself is challenging, since it is characterized by smallholder based with very small fragment plots of less than two hectare and requires a lot of endeavors to boost up productivity [14]. It is a very tough task to the people and government of Ethiopia to bring significant change on status of crop production since the country is a victim of both natural and manmade hazards for subsequent years. It was also more likely aggravated by poor infrastructure, lack of access to capital, inputs and extension to the farming households.

Addressing of the interwoven productivity problems and improving the livelihood of the rural poor were the core agendas of Ethiopian government for the last two decades [15]. Ethiopia put agriculture at the heart of its economic development by launching its Agriculture Development Led Industrialization (ADLI) strategy two decades ago in 1991 to utilize labour extensively and land intensively [16]. This strategy puts agriculture at the forefront of Ethiopia's development process. The government designed different phases of programs and right policy formulations based on realizing proper image of the country. The implemented policies and programs so far to brought dramatic changes in the sector of agriculture were ADLI, Plan for Accelerated and Sustained Development to End Poverty (PASDEP) and more recently, the growth transformation plan (GTP) [17, 18, 19]. These plans were very comprehensive to foster economic development on the basis of agricultural transformation for increased productivity, production, product qualities and marketability.

Integrated and participatory completion of policies and programs would bring drastic changes in taking peoples out of abject poverty and raising their incomes. The country started to score a very rapid double digit economic growth for the last decades and the livelihood of the nation started to improve and per capita income skyrocketed [4]. The recorded overall economic growth indicated that Ethiopia holds the right track to uproot poverty once and forever. Even though, the Ethiopian economy is diversified, it is heavily reliant on agriculture as the main source of employment, income and food security for a vast majority of its population. It is source of employment to 83% of the population. It also contributes 45% of the GDP and 90% of the foreign exchange earnings besides being a means of ensuring food security in the nation [20]. The sector of agriculture is expected to produce and provide adequate food to fellow citizens, produce and provide adequate raw material to domestic booming industries, produce and provide surplus capitals to be invested on other sectors and produced and provides exportable commodities to meet the hard currency demand of the nation [15].

To Ethiopia, increasing total production and productivity is not an option rather it is mandatory and given first priorities previously in formulation of its agriculture related policies, strategies and programs. Production and productivity can be basically enhanced through implementing the following two alternatives ways. The first alternative is boosting up productivity through extensive utilization of inputs and or improvement of technologies with applying limited level of inputs. The second option is enhancing efficiency of production and productivity of farming households with utilization of few levels of inputs and technologies. Ethiopia was implementing the first option so far and this paper is mainly focused on the fraction of this option i.e. extensive utilization of inputs mainly chemical fertilizers in transforming its agriculture and its possible consequences on farm biodiversity.

Substantial increase in food production from the existing cultivated land is desirable to meet the demand of rapidly increasing Ethiopian population and contribute to poverty alleviation. Increasing yields involves higher demand of plant nutrient that cannot be fully supplied from natural sources alone. The production capacity of a soil is determined largely by its chemical and physical

properties and soil moisture content, which help in the full utilization of the essential elements in the soil by plant roots [21]. Natural plant nutrients come from the weathering and breakdown of geological parent materials and the subsequent release of their chemical components which can be taken by growing crops [22]. All soils do not contain adequate quantity of the nutrients required for crop growth. Most soils are deficient in one or more of the essential elements that supports crops to complete their life cycle. Fertilizers are used to provide nutrients that are not present in soil in amounts necessary to meet the needs of the growing crop [23].

It is obvious that applications of fertilizers promotes crop growth, development and enhances quality of production. The addition of essential elements is needed to improve the natural soil nutrient reserve and to compensate for the elements exploited from the root zone through harvesting, leaching, volatilization and erosion [24]. Fertilizers are directly applied to the field for two main purposes. The first aim is to replenish the macronutrients depleted in frequent cultivation and for immediate uptake by growing crops. The second is aimed at modification of the soil physical, chemical and biological properties to enhance water holding capacity, organic matter, soil tilth and aeration.

Today fertilizer has become essential to modern agriculture to feed the growing population but continuous chemical amendments adversely impacts soil environment [24]. Uses of fertilizers, especially, the chemical one have brought in blessings on humanity, which helped to avert wider spread starvation and deter death across the globe [25, 26]. Soil is an important ecological niche for different microbial communities in the crop rhizosphere. Soil quality is the capacity of a certain type of soil to normally function within natural or managed biodiversity boundaries, to maintain plant and animal productivity, preserve or enhance water and air quality and support human health and habitation [27]. The excessive and continuous use of chemical fertilizers on agricultural lands not only affects the soil health and soil physicochemical properties but also pollutes the biodiversity in addition to the depleting resources and high cost.

The main body of the article considers the importance of fertilizers, the concept of soil health and the positive and negative effects of fertilizers application on soil health, with a focus on indirect effects on soil acidity, soil erosion, soil microbial populations, fertilizers in relation to soil organic matter maintenance and integrated nutrient use, followed by perceived research needs in relation to soil health.

The Approach of Ethiopian Government in Enhancing Productivity: Historically Ethiopia was under authoritarian regime for centuries those who were mainly relying on exploitation of the asset of the farming households than engaging in alleviation of the socio-economic bottleneck of the country [18, 28]. This system caused the food security situations of the country to gradually deteriorate and consequently caused death for hundreds of thousands of countrymen from hunger and famine. Most part of the economy was highly dependent on subsistence form of agriculture that was profoundly penalized with surplus production due to reprehensible system of cultivation [29]. Agriculture has been failed to provide adequate staple food for many who have founded their livelihood in this sector and caused almost half of the Ethiopian population forced to live under the mercy of international food aid [15]. One of the major underlying causes of this situation was persistence of improper polices and strategies for extended period of time [30]. As a result, the country apparently remains at low level of social and economic development. To resolve, century's accumulated intermingled problems of Ethiopia, needs comprehensive policies and strategies to address the most pressing problem of the nation. Thus, the Ethiopian government has set its goals primarily for alleviation of poverty [31]. It is also recognized that designing of development strategies that addresses this issue are inevitable and must focus on facilitation of poverty reduction in the utmost effective ways. The previous agricultural development strategies were formulated in concurrence with this goal to bring the profound anticipated effects.

Any kind of economic development requires capital, labor, land and effective management to expand the economics of the nation rapidly and sustainably. Ethiopian government had identified existing potentials and constraints for formulation of right policies to foster broad based rapid economic growth that can bolster and benefit majority of the population. It has identified that capital was major constraint for investment but it acknowledge the availability and easy access of the most precious resources of labor and land. The government has decided to ignite economic development with utmost utilization of the existing resources i.e. land and labor [17].

Fortunately, these resources are profoundly found in rural area of Ethiopia. Since, the livelihood of most Ethiopian is rural based, the policy frameworks for development must require to have comprehensive rural and agricultural center visions to realize it. In 2003, the Ethiopian government ratified rural development policies

and strategies [32]. It is obvious that agriculture has a dominant role in Ethiopian economy and any rural development endeavors must directly link with agricultural development. The development in agriculture has not remained confined in the sector but overwhelmingly intensifies to realize the country development objectives *via* generation of additional incomes to be invested in other sectors [33, 34, 35]. It stimulates the country economy *via* promoting expansion of industrialization, job creation and trade in urban areas.

The policy emphasizes that economic development can be drowned *via* enhancing capital formation and utilization of modern technologies that boosts productivity and should be carried out at the farm level. The strategies were focused on increasing of agricultural output and productivity through irrigation, application of chemical fertilizer; improve access to farm implements, exploitation of improved seeds and diversification of production system [17, 18, 19]. The agricultural knowledge of farmers was also projected to enhance through agricultural extension and advisory service at Kebelle level. Following subsequent implementation of policies, strategies and programs aligned with agriculture, Ethiopia designed growth and transformation plan which was mainly focus on scale up of productivity of labor and land with different approaches for varied agro ecological zones, focus on specialization, diversification and strengthening of agricultural market system [19]. It was projected to achieve the growth target of agricultural through adoption of improved technologies with proper agronomic management practices that augments production and therefore increase household incomes for small holder farmers compared to previous levels. The plan also anticipated 1.2 million metric tons of chemical fertilizer consumption as needed to meet the target yields of GTP [19]. Policy wise, it is very impressive and plans to radically transform the country from low productivity and low wage activity to high productivity as well as high wage activity.

Fertilizer Use and Crop Production in Ethiopia: There are two general foreseeable options for increasing agricultural output to hasten economic development. The first is increasing net cropped area by clearing uncultivated lands while the second is increasing productivity per unit area through intensive utilization of inputs and effective management of plots under cultivation. The feasibility of the first option to boost up production is not compromised due to shortsightedness in term of long term benefit and its likely consequences on ecological disruption and political unrest. Giving the current federal system of administrative where regions are autonomous in administration of their own lands across their geographical location and most of the bare land that may be brought into cultivation is also only found in low land plain of few regional states. Therefore, it is not easy to exploit this alternative for resettlement of small holders from high to sparsely populated regional states due to environmental, ecological and ownership reasons. Hence, the second option is economically and ecologically more feasible, if it is carried out under economically viable and environmentally sustainable manner.

Consumption of fertilizer is one of the vital inputs in crop production. Without utilization of fertilizer, world food production could be reduced from 40-60% annually [36]. No one region in the world has increased crop production and adequately deal with food insecurity without enhancing fertilizer use [37]. Expanding of fertilizer use is very critical not only for meeting of the food demand of the globe but also for sustaining soil fertility and ensure profitability of the farming system. Growers who utilize fertilizer are capable of producing surplus foods that are crucial to go beyond subsistence through increased production and productivity of cereals and animals per hectare, meat and milk per animal and leading to more food outputs per person [38]. However, majority of the chronically hungry are small farmers in developing countries who produce much of what they eat, are often too poor to purchase inputs and are marginalized from product markets. The recent advances in aggregate productivity have therefore not brought reductions in the incidence of hunger for all [39]. The conventional wisdom is that, in order to double food supply, efforts need to be redoubled to modernize agriculture in terms of utilization. Such strategy has been successful in the past but there are doubts about the capacity of such systems to reduce food poverty in future.

Most of the agricultural land of Ethiopia were/are under continuous cultivation for thousands of years without proper soil replenishment programs. To sustain and increase productivity of such type of soils, intensification of crop based agriculture in association with a sharp increase in the use of chemical fertilizers is inevitable [40]. To meet the agricultural growth target of Ethiopia, there is no doubt that fertilizer use must support doubling production, poverty reduction, job creation and industrialization for achieving environmental sustainability objectives. To feed the ever increasing population, there is need of first feeding the soil to support crop growth and enhance productivity. No

country in the world has been able to increase agricultural productivity without expanding the use of mineral fertilizers but the question is to what extent fertilizer becomes an option. Meeting the different nutritional demand of human beings as vitamins, carbohydrates and proteins; the growing plants should nourished with minerals for vigorous and healthy growth.

Many types of fertilizers are consumed in the world, among them Urea $[CO(NH_2)]_2$ and diammonium phosphate (DAP) are the two main types consumed in Ethiopian agriculture principally for grain crops [41]. Urea has the highest nitrogen content compared to all solid nitrogen containing fertilizers commonly used in agriculture [42]. The agriculture dominant economy of Ethiopia is depends on intermediate inputs like fertilizer. Recently, quantity of chemical fertilizer consumption has been enormously increased compared to previous times. The total amount of imported fertilizers in 2008 increased by over 400, 000 tons; and was mostly utilized for cereals [43]. In the last 10 years, importing of fertilizer in Ethiopia increased by more than 50%, from less than 370, 000 metric tons which was in 2002 to almost 570, 000 metric tons in 2011, with a spike of 627, 000 metric tons in 2009 [44]. During this time, sales, distribution and consumption of fertilizer that is predominated by urea than DAP, have increased by more than 100% with an average growth rate of 6% per year.

According to CSA [45], nearly 90% of the total consumed fertilizers in Ethiopia are used on strategic (cereal) crops, 4.7% on pulses and 1.8% on oil seeds but only 3% of fertilizer is accounted for non-grain crops. The increase fertilizer use in Ethiopia has been very remarkably increasing since inception in 1960. In more than five decades following the introduction of fertilizer under the *Freedom from Hunger* program in the late 1960s, fertilizer use grew from 3, 500 tons in the early 1970s to only about 34, 000 tons in 1985. In contrast, it grew from 140, 000 tons in the early 1990s to about 650, 000 tons in 2012 [41]. The amount of fertilizer applied was 550, 500 metric ton for the period of 2010/2011 which was increased by 30% compared to the estimated application of 426, 700 metric tons throughout 2009/2010.

According to CSA [45], among major strategic cereal crops, maize has received a higher average application rate of 175 kg ha^{-1}, while the lowest rate was applied for sorghum with 97 kg ha^{-1}. Fertilized areas in Ethiopia are more than doubled from 1.12 million ha in 2003/04 to 2.31 million ha in 2010 [41]. The growth in fertilizer use was triggered by the market liberalization programs in the 1990s following topple of the Derg regime. Since then fertilizer promotion has been involved with several policy

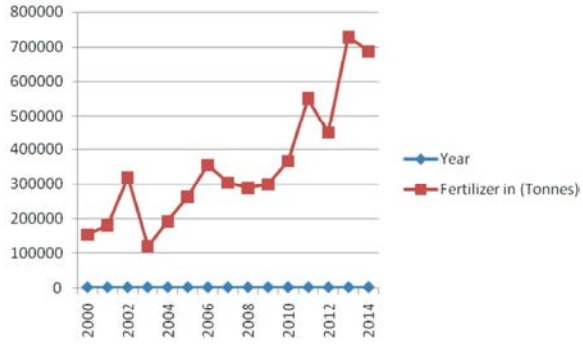

Fig. 1: Trends of chemical fertilizer utilization in Ethiopia (tones)

Source: Author's calculation based on various Central Statistical Agency (CSA, 2000-2014) publications [109].

changes, ranging from liberalization, with both public and private-sector participation, to government monopoly control over imports with exclusive marketing through farmers' cooperatives in 2008. The recent momentum of increasing fertilizer use has been largely driven by the Growth and Transformation plan, which sets annual cereal production targets for each region. Increasing the distribution of chemical fertilizer and improved seed has been the key move for achieving these targets. A clear manifestation of this strategy is the sharp increase in fertilizer imports, which jumped from 440, 000 tons in 2008 to 890, 000 tons in 2012. However, fertilizer availability (import plus change in stocks) far exceeded total use, resulting in large carry-over stocks reaching almost half a million tons in 2012 [41]. Ethiopian agriculture uses a relatively high rate of artificial fertilizer as opposed to animal manure. All fertilizer is imported by the Government of Ethiopia. The majority is distributed to smallholders through cooperatives on a credit basis, with a small balance being sold to commercial and state farms. The quantity of fertilizer utilization is enormously increased for last decade as have been seen in Fig. 1.

The future of fertilizers utilization in Ethiopia is very inefficient in terms of proper quantity importation and carries over stock distribution to beneficiaries. National blanket recommendation of fertilizer to both moisture deficit and adequate agro-ecologies zones with equal doses is also another uncompromising fact. Farmers in drought prone areas of the country are still not willing to adopt fertilizer due to burning effects resulted with moisture deficit but they are forced to adopt it with pressure exerted from political leaders, Development agents and woreda offices of agriculture. Many farmers located in drought prone areas of the country are not

using to apply chemical fertilizers in to their plot rather either disposed it in to bare land and/or sale it for illegal collectors with cheap price. Generally, poor management and application significantly affects potential productivity of the farm and drive bankruptcy of national budget.

Soil Life and Chemical Fertilizer Use: Soil quality refers to the ecological equilibrium and functionality of a soil as vital living system and its capacity to maintain a well balanced biodiversity with high biodiversity above and below surface to keep human, animal and plant health [46]. Soils have fundamental roles in sustaining of life on planet earth and are bases of agricultural development and ecological sustainability [47]. It constitutes the largest pool of organic carbon which is vital for climate change adaptation and mitigation [48]. Our soils are responsible for buffering, filtering and moderating the water cycle and for regulating the carbon, oxygen and plant nutrient cycles [48]. In the time of water scarcity, soils are fundamental for appropriate water storage and distribution [49]. The soil rhizosphere also plays an imperative role in hosting for a quarter of the planet's biodiversity [50]. These precious resources must be sustainably utilized on long term basis for crop productivity with minimizing the adverse impact on the ecology, which will only be reached with the maintenance or recovery of the soil health alone [51].

Availability of higher microbial biomass diversity has the ability to keep the ecological balance after interruption of soil biodiversity [52]. This ability of the soil is defined as resilience which means a biological buffering against interruption in biodiversity [53]. Similar to microbial diversity and biomass, biochemical reactions like enzymes are also vital indicators of soil health. Like enzymes found in animals and plants to carry out life sustaining chemical reaction, there are also enzymes found in the soil that plays crucial roles in maintaining soil ecology [54]. These enzymatic activities have direct relation with level of microbial population in the soil and are mainly microbial origin [55]. A unique balance of chemical, physical and biological (including microbial especially enzyme activities) components contribute to maintaining soil health [55].

The metabolic processes in the soil which determine by enzymes are influenced by physical, chemical, microbiological and biochemical properties [56, 57]. The enzyme levels in soil systems vary in amount primarily due to the fact that each soil type has different amounts of organic matter content, composition and activity of its living organisms and intensity of biological processes [55]. When soils are exposed to different management practices like fertilizer, microbial community is also affected which results into drastic change in enzymatic activities [58]. Acidification as well as neutralization of the soil may be very harmful to microbes, which often depend on a sole enzyme and enzymes are active only in a very specific pH. Changes in pH slow down enzyme reaction and microbes have to enter into rest, encysting, or die from hunger [51]. This change of enzymatic activities in the soil negatively affects physical, chemical and biological nature of soils. It is estimated that acidic soils are covering more than 40% of cultivated lands in Ethiopia [59]. Finally, decomposition, transformation plant and animal residues and nutrient recycling actions are hampering. Therefore, mineralization and access of nutrients to growing crop roots gets deficient and hence productivity is diminished.

The present chemical fertilizer based intensive production in Ethiopia is believed to be physically deteriorated and biologically deactivated the soil. There is misperception among extension agents, crop production experts, researchers and particularly political leaders on issue of chemical fertilizer consumption and crop productivity. They do believe that application of inorganic fertilizers alone can increase yields and promotes its unwarranted utilization for alleviation of abject poverty in the country. This argument is so powerful than the negative impact of fertilizers on the soils, environment and climate are often suppressed or treated as external costs which simply have to be accepted. Temporarily, it may be a solution to aggressively compensate the available food, fiber and oil crop demand gaps that a country requires urgently. However, crop productivity did not depend on the extensive utilization of chemical inputs only but it also greatly depends on organic substance that sustains soil life and crop productivity such as crop residue, compost, dead roots, root secretion and farm yard manures [53]. These organic residues are responsible for formation of organic matter, supporting soil life, improving soil structure and plant metabolism and crop production.

Due to marginalization of grazing lands in Ethiopia, all form of crop residues are not incorporated in to soil rather it is completely removed for livestock feed since antiquity [60]. This together with conventional tillage results in decreasing soil organic matter content due to sustainable oxidation rate [61]. Without periodic replacement of organic matter, soils subjected to intensive inorganic fertilizer will become exhausted of their active humus content, leading to the degradation of soil biological,

physical and chemical properties [46]. Soil organic matter is the energy sources of many microorganisms function beneath in the soil particularly root zone. Soils with low or exhausted soil organic matter cannot support large populations or a great diversity of soil microbes, which are responsible for the liberation of plant nutrients, disease suppression and the development and maintenance of certain physical properties of the soil [46].

It is obvious that organic matter is reservoir of all essential plant nutrients and significantly contributes the cation exchange capacity of the soil [62]. Loss of soil organic matter and degradation of soil structure results with loss of soil pore space and reduce of soil's ability to passively exchange gases with the atmosphere [53]. Degradation of soil structure reduces drainage of excess moisture and overall reduction and weakening of soil aggregates and reduces soil's ability to hold together as a cohesive mass. Soils with few or unstable aggregates are not as resistant to the erosive forces of irrigation or rainwater and easily detach and travel with moving surface water [53]. Soils with depicted problems obviously declines soil health and increased crop susceptibility to insect pests and pathogens [46]. Therefore, sustainable agriculture must aim at meeting required demanded of the present population without compromising productivity potential of next generation.

Nutrients, amount and availability are the most important factors to be maintained, to keep the soil healthy. Nitrogen, phosphorus and potassium are very important to plant health. These nutrients are cycled through a natural biodiversity by producers (plants), consumers (animals) and decomposers. Recycle of these nutrients on farm in Ethiopia is quite difficult due to complete removal of residues during time of harvest for purpose of livestock feed. Soils capacity in releasing of adequate nutrients to crops eventually run out and cannot support plant growth [63, 64, 65, 66, 67].

Impact of Chemical Fertilizer Applied in the Form of Urea: Nitrogen improves the health and quality of growing crops relative to other essential elements particularly the grass family [68]. Physiologically nitrogen plays pivotal roles in plants life by surrounding magnesium atom in their green organ of chlorophyll (major photosynthetic pigment), which captures radiant energy and permits the formation of sugar from the combination of two inorganic compounds called CO_2 and H_2O [27]. Thus, biological processes are essential for keeping the soil capacity for recycling carbon to the atmosphere and assure the prolongation of photosynthesis, alongside with nutrient mineralization for plant and microbial nutrition. Nitrogen is usually founds in the soil both in organic and inorganic forms but there is wider variation in the types of organic compounds that contain nitrogen. Organic compounds can be small and easily degraded by microorganisms like amino acids, or large complex molecules that are quite resistant to microbial decay. The most resistant of these soil organic materials are typically referred to as humus. Inorganic forms of nitrogen are nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+) and ammonia (NH_3). Nitrate and ammonium are readily taken up by plants and beneficial for plant growth whereas nitrite and ammonia are toxic to plants.

Nitrogen is one of the macronutrients which are required in massive quantity compared to the rest of major essential elements and found in different chemical forms with very vibrant behavior [69, 70]. Nitrogen is also an integral component of amino acids that make up the protein and enzymes in all living organisms. Urea [$CO(NH_2)_2$] is the most commonly used nitrogen (N) fertilizer and has high N content per unit material (46%), lower cost, ease of storage, along with solid and liquid formulation options make it a popular choice for farmers [71].

Agricultural use of Synthetic nitrogen fertilizers causes soil acidification, organic matter depletion, green house gas emission and major contributors of climate change [72]. Fertilizer affects the life of microorganisms in soil biodiversity either directly in making contact with the fertilizer or indirectly through changing the chemical in the environment and food sources of the organism. The direct effect of fertilizers on soil living organisms are either short term immediately after application or long term after recurring application in a given cropping season. The indirect effects are resulted from over prolonged period of application due to drastic changes in soil pH, plant productivity, residue inputs and soil organic matter levels [73]. These effects significantly affect nutrient availability to crops and consequently brought changes in productivity.

As the study indicated by Angus *et al*. [74], band application of urea and ammonia fertilizers significantly reduces total microbial activity in proximity areas of treated for a period of five weeks and then returns to normal. However, rate of recovery time were not the same for all microorganisms and some group of organisms shows very slower return after five weeks. These researchers were come across with solid conclusion of most group of microorganisms were not adversely affected by one season application but they did not

drown any conclusions about the long term effects on soil living organisms. Hati *et al*. [75] and Schuman *et al*. [76], showed that adding of chemical fertilizers resulted in enhancing organic matter accumulation and biological activities because of increasing biological yield in the form of decaying roots, litters and crop residues but it is not true in Ethiopian condition giving the complete removal nature of residues from the soil.

The fertilizer applied in the form of urea is not in most usable forms for uptake by plants but it needs further conversion by microorganisms in soil into ammonium and/or nitrate [77]. Plants also capable in directly absorption of urea but not actively involved as nutrition until it is hydrolyzed into ammonium by urease enzyme produced by soil microorganisms [78, 79]. Immediately where urea is making in contact with soil or plants with available moisture, urease enzyme quickly starts breaking down of urea into ammonium bicarbonate during hydrolyzed process. The initial reaction of urea with water raises the level of alkalinity of the solution to pH> 9 due to the formation of ammonium carbonate [77]. Nevertheless, succeeding conversions of first product ammonium bicarbonate in to nitrate is an acid forming process. Therefore, application of urea in the soil ultimately aggravates acidification. Similarly, the activity of microorganisms is greatly impaired and reduces overall productivity of the soil.

It is advisable to farmers not to apply urea in an area where there is moisture deficit since hydrolyze process of urea is ceased. The application of chemical fertilizers to soil reduces pH and increases its electrical conductivity (EC) [80]. Moreover, soil water content had a significant impact on electrical conductivity of chemical fertilizer amended soils, where electrical conductivity decreases under dry conditions. Inorganic nitrogen concentration increases with inorganic treatment [80]. This increase was especially pronounced in inorganic fertilizer treated soils due to repeated mineral fertilizer addition. Water de?cit led to an accumulation of NH_4^+-N in this treatment, whereas for NO_3^--N concentration was higher under well-watered conditions. This result enhancing soil salinity level that take place during moisture deficit in soil and has also decreases the rate of both urea hydrolysis and the subsequent nitrification.

In the process of denitrification, applied urea reacts with water in soil and rapidly converts into ammonium carbonate by urease enzyme. The ammonia gas (NH_3) produced in the process is major concern of agriculturalists because it exacerbates to exceed 50% of the loss of applied nitrogen [81]. Additionally, the loss of ammonia gas may brought unconstructive ecological impact on the quality of environment and grounded with soil acidification [82]. Over application of urea fertilizer causes accumulation of (NH_4^+) which directs to varied tribulations like killing germination seedlings, nitrite toxicity and urea nitrogen loss in the form of ammonia [83, 84, 85].

Many research outputs involved in the atmosphere indicates the increase rate of reaction in the stratosphere that may cause eminent threat in distruction of ozone layer. The stratosphere ozone shields the biosphere from the harmful ultraviolet radiation and also influences the earth's temperature [86]. Nitrogen loss to the atmosphere through denitrification may contribute to "greenhouse gases" in the atmosphere thereby exacerbating the problems of the breaking down of ozone layer. Nitrogen losses can be particularly high from intensively cultivated and fertilized land [87].

In an area where urea fertilizer is applied frequently, it increases the acidity level and results with limitation of availability of nutrients particularly phosphorus and get higher the concentration of toxic metals in soil solution. The supply and effectiveness of phosphorus fertilizer is affected by soil acidification due to fixation and make it an accessible to plants. Urea application reduces the effective use of this inadequate and costly nutrient. Research output in this regard indicates that yield was reduced from 30-50% due to acidification problem induced from inorganic nitrogen application on long term basis [88]. The study also emphasis the problem was drowns by increasing dose of nitrogen application since 1980 in china.

The availability and mount of humus in agricultural soil is key parameter for soil fertility and sustainable production [53]. Humus depends on the supply of organic matter derived from farmyard manure and crop residues. It is produced by some living organisms whereas decomposed by others. Maintaining fertility of cultivated soils is reliant on the balance between humus accumulated, decomposition, supply and consumption [53]. Soils enriched with humus content are very effective in chemical fertilizer utilization. It is expected to increase biological yields in areas where fields are treated with high dose of fertilizers. This is resulted from enhancement of temporarily storage of applied chemical fertilizers in organic matter produced due to previous high dose treatment whereas the reverse is true with low humus content.

There is an argument that role of fertilizer application is not just to increase the production but also o produce an adequate biomass left in the fields to feed the soil as organic matter. The perception is extensive application of fertilizer could supplies adequate nutrients and results in mount of biomass production in the form of straw, residue, bubbles and root exudates that enrich soil humus. This perception seems true, where chemical fertilizers stand for a long term investment in sustaining and preservation of cultivated soils. However, researches carried out for many years concludes that chemical fertilization indicates the opposite of organic matter fertilization rather it shows humus content depletion in the long run regardless of providing significant amount of residues [89, 90].

It is proved that higher rate of nitrogen application for boosting up productivity also interrelated with rapid decomposition of humus [89]. Another research was conducted for a century half from 1955-2005 with NPK fertilizer in USA. This fertilization was significantly adds larger amount of residues that feds the soil but soil humus content was fell subsequently and significantly. The research also indicated lower layer of the soil located 15-30cm and 30-46cm were most vulnerable and affected by this fertilization [90]. As indicated by different researchers larger rate of nitrogen application hastens decomposition rate of humus by stimulating the activity of microorganisms. Larger amount of nitrogen is produced globally but its utilization efficiency is diminished significantly based on confirmation of 40 years research output [91]. Worldwide estimation of nitrogen use efficiency indicated 33-36% only [92, 93]. The aforementioned research results indicated that unwise management and inefficient utilization of fertilizer that relies on actual plant demands rather it was to achieve higher economic yield.

Scientists are estimated that 12% of greenhouse gas emission is contributed from the sector of agriculture [48, 94]. It is placed in forefront among most important emitters and originator of climate change [95]. The depicted figure is not involving the emissions coming from chemical fertilizer production industries. Industrial nitrogen fertilizer fixation process is also one of the largest consumption of energy and generated high quantity of CO_2 during the process [96]. At the same time, high quantity of nitrous oxide (N_2O) is also escaped to the atmosphere in production process of nitric acid which is crucial for synthetic nitrogen formation.

Impact of Chemical Fertilizer Applied in the form of DAP: Phosphorus is a naturally occurring element mainly founds on earth crust, water and all living organisms [97]. It is very crucial plant nutrient to all living organisms due to its involvement in biochemical and physiological process [98]. In every component of cells of all living organisms, phosphorus is vital and not replaced by other nutrients. It is used in the process of photosynthesis during which harvesting of radiation energy emitted from the sun is converted into carbohydrate. Phosphorus is not found separately in nature but usually founds in combined with other elements to form phosphates [99]. This complex form of phosphorus is found in soil, water, plant, animal and human beings [98]. In the near future food production will apparently remain highly phosphorus dependent due to the finite nature of rocks deposits, from which phosphorus fertilizer is originated [100]. Food security situations of countries will soon threatened with scarcity of phosphorus and it also a raise geopolitical problem because of phosphorus reserve is only found in very few countries since phosphorus could not be manufactured synthetically and there is no means of substitution for it in farming [101, 102].

The phosphorus compounds found in the soil are not readily soluble and then amount of plant available form is very less compared to plant demand particularly at pick growth stages. Mixed farming systems followed in high populated areas of developing countries are also abandons the phosphorus to be available in the soil because of overgrazing of crop residues [101]. Grazing animals are met up their phosphorus requirement from plants in range and/or fields but plants obtained their phosphorus in the parent material available in growth media from which soil is formed. Application of supplementary phosphorus is required in replenishment of soil solution to support crop growth and productivity [97]. Therefore, application of phosphorus for crop fertilization greatly increases in today's agriculture. It is often an adverse factor in biological productivity of aquatic biodiversity where it is found in smaller no concentration at all naturally.

Activity of human beings affects phosphorus concentration to rise over years in many water bodies of the world due to increase in application of agricultural fields. Phosphorus is the least abundant of major nutrients found in water. Increasing even very low concentration of phosphorus in water bodies hinders aquatic productivity. Of the total phosphorus mined

globally 80-90% is utilized for fertilization of agricultural fields [103]. According to Cordell *et al*. [104] from the total application into the field only 20% is absorbed by crops while the rest is lost due to inefficient steps along the phosphorus cycle. Worldwide, 80% of lost phosphorus is apparently goes into water bodies and cause large scale pollution in rivers, lakes, coastal areas and algae [102]. Critically addressing the water and energy issues will soon become a challenge to rapidly growing world population [104]. Reyes and Michelle [102] reports nearly 70% of water demand of the world is to the sector of agriculture but the need to devise mechanisms to limit availability of phosphorus in water bodies in the future has not been recognized widely still today.

Nitrogen and phosphorus generally are present in aquatic environments at natural levels usually below 0.3 and 0.01 mg/L, respectively. When these nutrients inter into water bodies leaking from agriculture at higher rates, aquatic plant productivity may increase dramatically [105]. This process, referred to as cultural eutrophication that may adversely affect suitability of the water for other uses [106]. Excessive aquatic plant productivity results in the addition to the system of more organic material, which eventually dies and decays. Decomposing of this organic matter by micro-organisms produce unpleasant odors and deplete the oxygen supply available to other aquatic organisms. Depleted oxygen levels, especially in colder bottom waters where dead organic matter tends to accumulate, can reduce the quality of fish habitat and encourage the propagation of fish that are adapted to less oxygen or to warmer surface waters. Anaerobic conditions can also cause the release of additional nutrients from bottom sediments. Highly enriched waters will stimulate algae production, consequently increasing turbidity and color. In addition, certain algae can produce severe taste and odor problems that impair the quality of drinking water sources [107]. Therefore, this is a real challenge to 0.3% of world population directly relied on their livelihood in water bodies though harvesting of fish.

CONCLUSIONS

So far in Ethiopia Urea and DAP fertilizers are imported and distributed to beneficiaries in larger quantity since 1960 [108]. These fertilizers are still applied nationally to all crops with blanket recommendation without determining the chemical nature of the soil and regardless of site specific crop demand and soil supplying power. The recommendation is largely advocated by political leaders and national research institutions as means of increasing production to fill the available food deficit only. The existing modes of recommendation and application have its own drawbacks in terms of nutrient utilization efficiency, green house gas emission, hydrosphere pollution and economic profitability. The major bottlenecks are aroused from the national recommendations that treat both moisture adequate and stress locations with equal doses of chemical fertilizers without considering possible consequences. This system has many challenges that brought socioeconomic constraints in the livelihood of farming households.

Farmers located in moisture deficit areas are still suffering both from production lose and carryover fertilizer credits. As a result, the anticipated hope of reducing poverty with full package of fertilizer use was not as expect in drought prone parts of the country. Farmers in those locations are suffer with asset degradation resulted from fertilizer loan and frequent production arrests due to moisture deficit. In area where drought extends for two or more production years, farmers also adopts improved seeds and dose of fertilizers within these years. Due to loss of production they have nothing to pay and then significant numbers of small holders are forced to cash in good harvest times. Therefore, expending of the farm output for repayment of input credits by selling their products in low price during the mehere season is not uncommon.

The consumption of improved seeds is very limited in Ethiopia due to limitation of development, multiplication, storage and distribution. Thus, the major means for increasing productivity is mostly reliant on chemical fertilizers. One can simply ask a question why the fertilizer demand per hectare is increasing from time to time across the globe including Ethiopia. If the farm is frequently fertilized during growing seasons based on actual requirement of the crop to support growth and productivity, then soil fertility will not be degraded. Thus, where comes this rate of fertilizer application change with time? It is not the demand of the crop that increases but it is fertility level of the soil get decreases regardless of right amount of synthetic fertilizer applied to each specific crops. This is a simple indicator that with increasing application of inorganic fertilizer there is an increasing mineralization and decomposition of stored foods in soil. Therefore, it is the rationale behind for increasing dose of synthetic fertilizer application from time

to time. The different research outputs reviewed above are also confirmed this hard fact. The conclusions also revealed that rapid degradation of soil organic carbon, the prime sources of natural nitrogen is correlated with rate of chemical fertilizer application particularly all nitrogen containing fertilizers.

The application of synthetic fertilizer hastens the formation of plant biomass which is largely constituted from carbon consumption during photosynthesis. Microbial decomposition of plant residues assimilates mineral nitrogen for synthesis of biomass contains organic nitrogen that presents in equilibrium with more stable organic humus. However, the addition of larger biomasses shifts the equilibrium towards assimilation through increasing carbon input relative to nitrogen and towards decomposition by increasing the input of nitrogen relative to carbon. This is carried out in a farming system where higher amount of synthetic nitrogen is applied and residues are left after separation of the grain from the straw to be incorporated into the soil through tillage that served as sources of soil microbial feed and humus after decomposition. Following discovery of artificial fertilizers, human being becomes destructor of the important of plant residue cycling.

But Ethiopian agriculture holds a different history. It took crop residues completely out of the farm for livestock feed since antiquity and at the same time applied chemical fertilizers alone to boost up productivity. The role of soil microorganisms is disregarded and diminished in the repeated tillage farming system that depends on chemical fertilizers with minimum carbon input. There is prevailing outlook that Ethiopian population is increasing significantly and its demand for food and fiber will be triple in the near future. Modernizing of agriculture reliance on adoption of new technology emanating outside and intensive chemical input dominant by synthetic fertilizer will not be a long lasting solution. The addition of inorganic fertilizers only would not maintain soil fertility without addition of residues to sustain soil humus but it may be a temporarily solution to increase farm output. Continuous use of acid forming fertilizers in the absence of organic humus in the soil has caused many serious ecological and sociological problems. Without sustainable replacement of soil carbon that lost *via* decomposition, the quality of soil gradually depleted and become unfavorable for habitats in the rhizosphere. Therefore, a soil without microorganism is a dead soil and will not support growing plants. As a result, the survival of mankind and animals will jeopardize.

Hence, it is advisable to take precaution measures before we completely lose soil biodiversity and follow a very sustainable approach in utilization of chemical inputs in a farm. Reconsider chemical fertilizer approach techniques by giving equal priority to soil organic matter maintenance is inevitable. The urgency to revise the synthetic fertilizer strategies and put into practice organic residue alternatives as fertilizer ingredients has never been more important than it is today. It is also very important to aware that fertilization means feeding the soil to feed the crop not feeding the crop to increase growth, development and productivity. Farming systems that rely on both chemical and organic amendment as nutrient source is crucial to enhance the biological activities to decompose residues and soil ecology maintenance.

Recommendations: There are two types of farming systems in Ethiopia; the mixed farming system in mid and high altitude areas and pastoralist in low land plains. The livestock in mixed farming are not simply utilized for meat, milk and hide purpose but employed in different agricultural activities like draught power, trampling harvest, loading and insurance of livelihoods at times of crop failure during seasons of unreliable rainfall. The dung of animals is major sources of fuel wood for baking and cooking in rural households. Fuel wood accounts more than 80% of household energy consumption today mainly in rural areas. The conventional activity in small holders is completely removal of crop residues for livestock feed. The estimated annual nationwide lose of phosphorus and nitrogen resulting from the use of dung and crop residues for fuel and livestock feed is equivalent to the total amount of commercial fertilizer use (PIP, 2010). Livestock in this farming system plays two important roles i.e. both positive and negative roles on sustainable utilization of agricultural lands. Animals excrete are utilized as farm yard manure (FYM) that positively affect and replaced lost organic matter from the soil through subsequent cropping. The first negative side is crop residues are completely removed for animal feed during the offseason and in doing so, organic matter cycling is penalized. The second is livestock herd pressure is beyond the carrying capacity of the range and cultivated lands. Free grazing of livestock on cultivated lands causes additional depletion of bubbles left after mowing of crops near ground.

Free grazing is very bad cultures which is abundant in Ethiopia and needs immediate action to overcome this menace. It brought destruction on wider biodiversity both

in and outside of the farm. Therefore, harnessing of free grazing in cropping lands following harvest and avoiding consumption of dung for firewood is inevitable. It has been under stood that reliance on fuel wood, crop residue animal waste and charcoal leads to wider spread land degradation, soil erosion, gully formation and siltation. Replacement of this type of energy dependent in rural areas with electric power is advisable for sustainable maintenance of soil ecology. The government of Ethiopia should have an inward look in expansion of rural electrification to uproot grass root energy problems exacerbate in the country than exporting into neighboring countries. In the absence of organic matter recycling in the soil, sustainable fertility maintenance is unthinkable. Application of farm yard manure enhances organic matter, microbial biomass and contains significant amount of calcium that capable to arrest soil acidification. Hence, comprehensive local production and promotion of stoves in affordable price requires priority to conserve biodiversity. It also requires modernizing of the livestock sector to increase productivity with limited environmental impact. Another advantage that can be fully utilized is the expansion of soil water conservation and area closure nationwide. Because it rehabilitates uneconomical degraded lands into grass lands that enable to promote cut and carry system to tackle free grazing. At the same time also provides adequate materials for composting.

Labor productivity in rain based farming system in rural Ethiopia is almost zero. The farmers are usually busy only in one mehere season but in most off times of the year; it is lost without any significant economic contribution. This huge labor must be utilized wisely in productive way to carried out farm output boosting activities. Thus, create awareness on the role of compost to mount productivity and mobilizing of farmers for composing is very vital.

The crop production and extension experts are usually engaged in the dry season in soil water conservation and input demand assessment only. But don't take into account the other available opportunities at their hand that support them to boost soil productivity and improve livelihood of their beloved farmers. Ministry of agriculture and research institutions should come across with strategies that promote green manure, crop rotation and intercropping as fertilizer to exploit existing potential fully in most part of the country. Many part of the country receives bimodal nature of rainfall which is conducive for green manure crop cultivation. Therefore, growing of green manure crops in residual moisture after harvesting of main crops in mehere season and in regions receiving short belg rain to be incorporated into soil for replenishing of organic matter is valuable.

The policies of Ethiopian Government gives priority to adoption of new technologies and improvement of agronomic practices developed abroad than emanating locally to roar agricultural productivity. This was initiated with available budget constraints to finance fundamental researches mainly focus on generation of new technologies and also considering the actual time required for developing a variety locally was not feasible and could not be a solution with the urgent demand of agricultural development. Thereby, the government was reliant on importing of outsourced agricultural technologies both previously and presently. Importing is not a long lasting solution to tackle productivity problem with additional inputs. Today, many federal and regional research institutions are get flourished across the country to conduct both applicable and basic researches and economy of the country is also grow rapidly. Promoting researchers to conduct and generate local based technologies in sustainable manner with allocating adequate budget to basic research is mandatory. At the same time, the government should have to create favorable conditions to conduct fundamental research at higher institution levels to generate new knowledge that bolsters applied research strategies.

Simple utilization of inorganic inputs would not bring long lasting fruitful results without inclusion of organic inputs. Providing equal emphasis to organic fertilization of the soil on today's agriculture is uncompromised. Therefore, policy support and promotion of organic fertilizer utilization comparable with inorganic once is very important and should be conducted unconditionally. Hence, for sustainable utilization of soil resources, combined consumption of organic and inorganic fertilizer is inevitable. Additional introduction and promotion of vermin compost for each household also requires great endeavor to enhance soil fertility biologically. The increased food production should have to occur on existing fragmented plot of lands and this can only be achieved through more intensive production approach. The intensification must be done in an environment friendly manner through ecological intensification. Another potential approach is to adopt cropping systems that may increase the level of plant available phosphorus in soil. Cropping systems that utilize green and animal manures have been demonstrated to have a positive impact on crop yields and reduce dependency on chemical fertilizers.

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