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SCHOOL OF GRADUATE STUDIES

ENVIRONMENTAL ENGINEERING STREAM

COMPARISON OF ENVIRONMETNAL PERFORMANCE AND ECONOMIC BENEFIT OF MUNICIPAL SOLID WASTE COMPOST AND CHEMICAL FERTILIZER

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A thesis submitted to the School Of Graduate Studies of Addis Ababa University in partial fulfillment of the Degree of Master of Science in Environmental Engineering

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ACRONYM

ASS	Atomic absorption spectroscopy
BOD	Biochemical oxygen demand
C:N	Carbon to Nitrogen ratio
CO_2-e	Carbon dioxide emission
CO_2-eq	Carbon dioxide equivalent
DTPA	Diethylene Triamine Penta Acitic acid
$gpot^{-1}$	Gram per pot
IPCC	Internationl Panel for Climate Change
ISWM	Integrated Solid Waste Management
$Kgha^{-1}$	Kilogram per hectar
$KgNha^{-1}$	Kilo gram nitrogen per hetar
$Lton^{-1}$compost	Litre per ton compost
MSW	Municipal Solid Waste
MWRNMA	Ministry of Water Resource and National Metrological Agency
T	Ton
UNFCCC	United nation frame work conventaio on climate change

ABSTRACT

With the increasing rate of urbanization and industrialization, the current method of municipal solid waste (MSW) management cannot be effective and efficient to handle thousand tons of waste generated daily in big cities like Addis Ababa. The objectives of the present study were therefore, to (i) demonstrate the positive environmental effect of municipal solid waste composting and the negative impact of nitrogen (N) fertilizer (ii) compare the environmental performance of municipal solid waste compost and nitrogen fertilizer (iii) compare economic benefit of MSW compost and N- fertilizer from agricultural and environmental point of views. A series of experiments such as scenario analysis, incubation, leachate and effects of municipal solid waste compost on yield and yield components of wheat were conducted to achieve the stated objectives. The scenario analysis compared either disposing MSW in landfill or compositing for soil amendment to improve crop production. The results of the scenario analysis revealed that composting resulted in greenhouse gas reduction due to avoidance of methane emission from landfill. The addition of MSW compost significantly increased the soil total nitrogen (Nt), organic C, available P, pH and other microelements. Similarly, the leachate experiment revealed that the application of both MSW compost and N-fertilizer produced higher concentrations of NO_3*-N fluxes in the collected leachate that clearly showed fertilization during establishment poses serious threat to water quality in the absence of growing plants. Moreover, the application of both MSW compost and N-fertilizer had positively responded in improving wheat yield and yield component. The partial budget analysis with minimum acceptable rate of return 100% revealed that the highest net benefit (7038.35 Eth. Birr) was recorded with combined application of (20-kg N+3.33-t com)* ha^{-1}*, however; the highest marginal rate of return (1024%) was registered for sole application of 5-t compost* ha^{-1}*. The results of the present study revealed that using MSW as soil amendment along with appropriate composting techniques and soil management not only improve soil fertility and reduce investment on chemical fertilizers but also can alleviate the contribution of MSW to environmental pollution.*

Key words: MSW compost, incubation, leachate, economic analysis and urea

1. INTRODUCTION

1.2. Background

Urbanization and industrialization result in increasing volumes and varieties of both solid and liquid wastes. For instance, 60% of the produced municipal solid wastes (MSW) are identified to be biodegradable in Ethiopia (Getachew *et al.*, 2010). With the increasing rate of urbanization and industrialization, the current method of municipal solid waste management could not be effective and efficient to handle thousand tons of MSW generated daily in big cities like Addis Ababa. This calls for the integrated municipal solid waste management (ISWM). Otherwise wastes generated from industries and cities continue to challenge the life and livelihood of millions of people, and ecosystems functions and services by polluting air, water, soils and releasing hazardous greenhouse gases to the atmosphere. However, due to unawareness of inherent value of waste as an exploitable resources and methods of available for waste processing, solid waste is discarded for sanitary reason rather than extracting valuable resources.

The amount of municipal solid waste that goes daily to the final disposal sites for Addis Ababa and other cities has reached about 400 and 1600 t day^{-1},respectively. If such waste has not well handled and processed, it can emit the potent greenhouse gas, methane, where 62% was released from MSW and the CH_4 emission was about 18% from open-dump of MSW of Addis Ababa city (MWRNMA, 2007).

The MSW can be used for agricultural soils amendment through composting; the energy content of MSW can be recovered either biologically or thermally. The biological energy recovery is by methane production through anaerobic digestion, whereas the thermal recovery is by combustion to produce heat. The organic content of MSW can be hydrolyzed either chemically or enzymatically to produce a sugar. The sugar can be used as a substrate for ethanol fermentation or for single-cell protein production. Of the three uses of MSW, using for soil amendment can be economically feasible and environmentally sound under Ethiopian conditions where soil degradation is severe and low external input agriculture is common practice because of socio-economic situations of the smallholder farmers. Furthermore, developing nations are concerned, with rare exception; adequate economic resources would preclude processes such as hydrolysis and perhaps large-scale anaerobic digestion in a reactor. These processes depend upon relatively expensive sophisticated equipment. On the other hand, composting can range from the composting carried out by individual homeowners to that undertaken by municipalities and equipment for composting need not to be sophisticated.

The use of MSW compost as soil amendment is a feasible option for increasing the soil organic matter contents and one of the sustainable waste management strategies. Moreover, MSW compost increases soil organic carbon and this in turn increases carbon sequestrations capacity of the soil (Timothy *et al.*, 2005). Therefore, MSW composting can serve as one of the mitigation potential of climate change by reducing greenhouse gas emissions from non-engineered sanitary landfills due to increment of soil carbon content when used as soil amendments.

The nutrients present in MSW compost gradually releases for plant growth which is the expected advantage of the use of MSW compost as agricultural soil amendments. Even though integrated municipal solid waste management is neglected in most cities, compost production for soil amendment has got considerable attention in Ethiopia. This is encouraging since sudden increase in fertilizer prices and deterioration of soil quality along with the current devaluation of domestic currency are hindering to achieve food security and sustainable agricultural development in the country.

To effectively utilize for processing MSW into compost, standard compost application methods, chemical characterization and its fertilizers potential has to be investigated. Furthermore, agronomic benefits and safe use of compost application must be demonstrated and cost benefit analysis has to be developed. Compost has also good quality in improving soil physical, chemical and biological properties for plant growth and development.

Fertilizer production consumes approximately 1.2% of the world’s energy and is responsible for approximately 1.2% of the total greenhouse gas emissions (Wood, S, Cowie, and A. 2004). As such, fertilizer production comprises an important component of agricultural life cycle assessments where system boundaries are wide enough to include indirect emissions from agricultural inputs. Life cycle analysis of agricultural inputs (chemical fertilizer and compost) determines GHG emissions and absorptions in chemical fertilizer and MSW compost production, transportation and storage, as well as during application and crop growth, i.e. throughout every stage of the life of a fertilizer .This allows a better understanding of what can and shall be done to improve the overall carbon balance. To identify and solve the key challenges related to the management of the nexus issues (Agriculture, Environment and sustainable development), Composting as best option of solid waste management in Ethiopia and sources of plant nutrient has been compared with chemical fertilizer from carbon footprint perspective. To make different GHG comparable, they are converted into CO_2_equevalents (CO_2-eq). For example 1kg N_2O corresponds to 310 kg CO_2-eq, as it has 310 times stronger effect on climate than CO_2 (www, yara.com, 2010).

Although a number of studies have been conducted to examine the economic impacts of chemical fertilizer, improved seeds, and physical conservations structures, to the best of my knowledge study has not been conducted on environmental performance of municipal solid compost and chemical fertilizer under Ethiopian condition.

1.2. Statement of the problem

The cost of solid waste management is increasing with increasing population and urbanization which is becoming a difficult task for the governance of the city. The growing concern of health and environmental risks in the land fill areas are now becoming more serious at Addis Ababa. By any standards of waste disposal system, it is not acceptable to use the Repi site (waste disposal site of Addis Ababa) for disposals purposes. Incompatible land use activities such as settlement and other public assembly areas are located within unacceptable distance from the site. Since there is no appropriate cover means, the bad smells are carried as far as 2 km away by prevailing winds.

Different researches conducted on municipal solid waste of developing counties, indicate that almost 60% of the municipal solid waste is organic that; can be recycled into compost, which can serve as alternative source of plant nutrient, although this has not been clearly addressed and well practiced in context of our country to the bests of my knowledge. On the other hand, soil productivity is a great challenge for the resource poor farmers, and chemical fertilizer remains the main crops yield augmenting technology despite its adoption rate remains minimal (Menale *et al.,* 2008).

In addition to low application rates, there is significance evidence suggesting a pull back from using fertilizer. Escalating prices and production and consumption risks have been cited as one of the factors limiting the use of inorganic fertilizers in Ethiopia (Menale *et al.,* 2008). Thus, given the aforementioned challenges to inorganic fertilizer adoption, a key policy intervention for sustainable agriculture is to encourage adoption of agricultural technologies that rely on a great extent, on renewable local or farm resource organic farming practices such as compost among such technologies has to be well addressed and practiced.

1.3. Objective

1.3.1. General objective

To compare the economic benefit and environmental performance of municipal solid waste compost and chemical fertilizer

1.3.2. Specific objective

- To demonstrate the positive environmental effect of municipal solid waste composting and the negative impact of chemical fertilizer
- To compare the environmental performance of municipal solid waste compost and nitrogen fertilizer
- To compare economic benefit of MSW compost and N-fertilizer from agricultural and environmental point of views

1.4. Scope of the study

The study was intended to cover environmental performance and economic benefit of municipal solid waste compost relative to chemical fertilizer. Due to time constraint and financial limitation pot study had been conducted under greenhouse condition which is really stressed condition compared to actual field study on the farmland.

2. LITRATURE REVIEW

Different mechanisms are developed for the management of municipal solid waste and resource utilization, but it is difficult to use all these methods in integration as some of the mechanisms require sophisticated equipments and skilled expertise, which are not economically acceptable for developing countries. In this chapter different findings done on composting as option of integrated solid waste management and its importance with respect to environment and soil amendments were summarized.

2.1. Characteristics and management of municipal solid waste

2.1.1. Characteristics of municipal solid waste

MSW is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources. Urban wastes can be subdivided into two major components: organic and inorganic. The primary difference between wastes generated in developing nations and those generated in industrialized countries is the higher organic content characteristic of the former. Ideally, solid waste should not contain faecal matter or urine, and the mixing of these materials with household waste should be prohibited by law. However, enforcement difficulties, combined with variations in way of life, necessitate some tolerance in this matter. Solid waste collection in a manner satisfactory with respect to environmental health is made difficult when human excretory wastes are mixed with household wastes. Handling of pathological wastes, abattoir wastes, industrial wastes, and similar materials, in association with household wastes, also should not be permitted. Nevertheless, it is important to keep in mind that despite all precautions, some pathogens and chemical residues inevitably will be present in the waste (UNEP, 2009).

2.1.2. Importance of municipal solid waste management

In an attempt to accelerate the pace of its industrial development, an economically developing nation may fail to pay adequate attention to solid waste management. Such a failure incurs a severe penalty at a later time in the form of resources needlessly lost and a staggering adverse impact on the environment and on public health and safety. The penalty is neither avoided nor lessened by a resolve to do something about the waste at a later time, when the country may be in a better position to take appropriate measures. The rate of waste generation generally increases in direct proportion to that of a nation's development. Nor is the penalty lessened by the faulty rationalization that advances in developmental status has higher priority than maintenance of a liveable environment. The greater the degradation of the environment, the greater is the effort required to restore its good quality. In summary, the effort to preserve or enhance environmental quality should at least be commensurate with that afforded to the attainment of advance in development (Forbes *et al.,* 2003).

The organic fraction of MSW is an important component, not only because it constitutes a sizable fraction of the solid waste stream in a developing country, but also because of its potentially adverse impact upon public health and environmental quality. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter. Impact on environmental quality takes the form of foul odors and unsightliness. These impacts are not confined merely to the disposal site. On the contrary, they pervade the area surrounding the site and wherever the wastes are generated, spread, or accumulated. Unless an organic waste is appropriately managed, its adverse impact will continue until it has fully decomposed or otherwise stabilized. Uncontrolled or poorly managed intermediate decomposition products can contaminate air, water, and soil resources (UNEP, 2005).

For several reasons, resource recovery is a major element in solid waste management in developing nations. Reclaimable inorganic components (metals, glass, plastic, textiles, and others) traditionally have been recovered mostly by way of unregulated manual scavenging by private individuals (typically known as the “informal” sector). In recent years, the trend is to formalize and mechanize scavenging through the establishment of material recovery facilities. Reuse and recovery of the inorganic components of the waste stream is an important aspect of waste management. Special attention is given to organic (biodegradable) residues since, in the majority of developing countries, these residues constitute at least 50% of the waste (by weight). The resource recovery aspect regarding the organic component is threefold（i） the component can be used in agriculture as a soil amendment through composting (ii) Its energy content can be recovered either biologically or thermally. Biological energy recovery is by way of methane production through anaerobic digestion. Thermal recovery is by way of combustion to produce heat (iii) the organic content can be hydrolyzed either chemically or enzymatically to produce a sugar. The sugar can be used as a substrate for ethanol fermentation or for single-cell protein production（UNEP, 2005).

Of the three applications, use in agriculture is the most practical. Although dating back many years, methane production (“biogasification”) has only recently begun to receive serious attention as a potential alternative source of energy. Many hurdles, primarily economic in nature, must be surmounted before either single-celled protein production or ethanol fermentation become a practical reality. An accurate knowledge of the quantity and composition of the waste input is essential to the success of a resource recovery undertaking. The composition and constancy of the amount of the input must be assured. Obviously, it would be sheer foolishness to attempt an operation of any practical size without having an assured supply of raw material. Not only must the constancy of the supply be assured, it must always be available at a reasonable cost. Additional requirements are adequate economic and qualified human resources. As far as economically developing nations are concerned, with rare exception, adequate economic resources would preclude processes such as hydrolysis and perhaps large-scale anaerobic digestion in a reactor. These processes depend upon relatively expensive sophisticated equipment. On the other hand, composting can range from the composting carried out by individual homeowners to that undertaken by municipalities. Equipment for composting need not be sophisticated（UNEP, 2005).

2.2. Composting of municipal solid waste

In economically developing countries, constraints related to economics, technology, and qualified personnel have narrowed the choice of acceptable solid waste management, treatment, and disposal options. Viable options include minimization, recycling, composting, incineration, and sanitary landfilling. Composting is the option that, with few exceptions, best fits within the limited resources available in developing countries. A characteristic that renders composting especially suitable is its adaptability to a broad range of situations, due in part to the flexibility of its requirements. As a result, there is a composting system for nearly every situation; i.e., simple systems for early stages of industrial development to relatively complex, mechanized systems for advanced industrial development. The compost option affords the many advantages of biological systems: lower equipment and operating costs; in harmony with the environment; and results in a useful product. On the other hand, composting is sometimes attributed with disadvantages often associated with biological systems namely, a slow reaction rate and some unpredictability. Regarding the attributed disadvantages, slow reaction rate may be justified, in that retention times are in terms of weeks and months. However, the attribution of unpredictability is not justified. If all conditions are known, applied, and maintained, the course of a given process will be predictable (Duz *et al.*, 1985).

Among the major prerequisites for successful composting are a satisfactory understanding and application of the basic principles of the process. Without this understanding, inadequacies of design and operation are practically inevitable. An understanding of the biology rests upon knowledge of the basic principles of the process. Such knowledge enables a rational evaluation of individual compost technologies and utilization of those technologies. An obvious benefit of the knowledge is the ability to select the system most suited to an intended undertaking. An accompanying benefit is the ability to critically evaluate claims made on behalf of candidate systems (Hoornweg *et al.*, 2000).

“Composting is the biological decomposition of biodegradable solid waste under controlled predominantly aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture”. The terms and phrases that collectively differentiate composting from other decomposition processes are: “biological decomposition”, “biodegradable”, “under controlled predominantly aerobic conditions”, “sufficiently stable”, and “matured”. The phrase “biological decomposition” implies that the decomposition is accomplished by living organisms. “Biodegradable” refers to the substrate and it requires that the substance be susceptible to decomposition attack by certain living organisms, e.g., bacteria and fungi. Such substances are organic compounds formed either by living organisms or by way of chemical synthesis (e.g., halogenated hydrocarbons) (Bertoldi, M *et al*, 1983).

2.3. Fundamental principles of composting process

No matter what technological approach is chosen, every successful composting process is governed by the same fundamental principles. Clear understandings of these principles can help facility operators manage their site successfully and generate a high quality product. The actual break down of organic materials is accomplished by a wide variety of microorganisms. Managing the composting process for peak effectiveness can be seen as making sure that this vast workforce of tiny laborers is provided with everything that they need. These needs include, a favorable C: N ratio, sufficient moisture, adequate oxygen.(On farm composting,1999).

C: N ratio: all organic materials contain carbon and many contain varying amounts of nitrogen as well. In the composting process, the microbes require nitrogen in order to break down the materials that are high in carbon. The balance, or ratio, between these two elements in the mixture is important. The farther the ratio between carbon and nitrogen in actively composting mixture is from the ideal, the more the process will be negatively affected. High carbon, little nitrogen [i.e., C: N too high] _without adequate nitrogen, microbes lack the tools required to break down carbon sources. The process proceeds very slowly. High nitrogen, low carbon [i.e., C:N too low] _ nitrogen in excess of what the microbes need to break down the available nitrogen can easily lost to the atmosphere as ammonia gas. In order to both keep your process working well and avoid losing valuable nitrogen, your organic mixture will have to provide the microbes with correct balance of carbon and nitrogen. Carbon to nitrogen ratio, or C: N ratios are reported as the number of units of carbon per unit of nitrogen. The ideal ratio for a composting mixture is accepted to be 30 or thirty units of carbon for every units of nitrogen. Knowing the C: N ratio of each of your feedstock will allow you to calculate the C: N ratio of the final “recipe”. Table of average C: N ratios are available in reference books on composting and these numbers can be very helpful for quick calculations using common feedstock. C: N ratios can also be obtained through laboratory analysis. Once you know the characteristics of your ingredients, determining the proportions need to produce an acceptable C: N ratio in your final mixture can be done manually or using computer program. Depending on your feedstock stream, the C: N ratio of your incoming materials may change seasonally. For example, grass clippings, which are rich in nitrogen, can contribute to a lower C:N ratio during the summer month, while the extra paper waste and dry Christmas tree in January’s feedstock stream will produce a much higher C:N ratio. To maintain an optimum process, recipes must be adjusted to account for these fluctuations (*http://www.cfe.cornell.edu/compost/calc/cn ratio.html).*

Moisture: moisture is essential for living organisms. Most microorganisms are very sensitive to this factor in their environment. When an actively composting mixture’s moisture content falls between 35% and 40% (where water makes up 35-40% of the total weight), decomposition rates slow significantly as microbes are less able to carry out their metabolic activities; below 30% moisture they essentially stop (this is why a dry compost cannot be considered finished simply because it is no longer reheating; if reheating behavior is being used to establish maturity, the material must be at a moisture content favorable for microbial activity).On the other hand, too much moisture can quickly lead anaerobic conditions as water fills in all of the tiny spaces in the mixture. This leaves no room for air, a conditions that is not favorable for microorganisms that require oxygen (called aerobic microorganisms), and can result in the production of offensive odors. The upper limit of a moisture content providing the needed conditions for effective composting varies with different feedstock materials. This difference is based on the size and structure of the materials, since this affects the porosity, the ability to trap and retain water. For most common mixtures, 55 to 60% is the recommended upper limit for starting moisture content. Compost recipes are usually started containing this higher amount of moisture, since the materials tend to dry as composting proceeds: heat generated by the microbes’ actively cause the water to evaporate. To calculate the starting moisture content of your recipe it is essential to know the moisture content of each of your feedstock. This can be measured by weighing a known amount of the material before and after drying. It is essential when sampling to make sure that the material you are testing is representative of the whole batch take samples from the inside of the pile, rather than the outside, where the material is subjected to drying ,or sample immediately after the material has been mixed. Material being collected for moisture analysis should also be protected from drying until it can be properly weighed; carrying plastic bags to transport the sample once it is removed from the pile can help ensure that the tests are accurate. The moisture content of your incoming feedstock determines the proportion of materials that will result in an acceptable mixture. Balancing the moisture content and C: N ratio of your mixture helps you ensure that your material degrades successfully (Guide to compost use, 1996).

Oxygen: when aerobic microorganisms have access to enough oxygen to meet their requirements, is the preferred method of composting. When there is insufficient oxygen, conditions favor anaerobic microorganisms-this result in a less efficient process and the production of undesirable odors. In this way, moisture content and oxygen availability are linked while microbes require moisture; materials that are too wet and heavy will not have room between the particles for air to diffuse into it. Depending on the processing method you have chosen, a variety of practices can be followed to ensure that the microbes in your composting Piles or windrows which are turned during composting can be constructed to maximize air flow through the material, using either passive or active forms of aeration. Physically turning composting materials re-fluffs the mass, allowing air to flow into the pile more easily. *(http://www.recycle.com/compost/compost.htm).*

Temperature: in tracking their process, many operators choose to monitor temperature instead of oxygen. The rise in temperature in composting mass is the result of heat given off by the microorganisms as they break down the material. This makes temperature of the process is going: if temperature fails to rise, the mixture may not have sufficient oxygen or moisture, while a very high temperature (above 65^0c) indicates a process so active that the microbes can quickly run out of both oxygen and moisture .Temperature is simple to measure and the equipment is relatively inexpensive-though it does not give specific information on which factors may be out of balance(C:N ratio, moisture, or oxygen),it provides a quick check on how active the composting process is *(http://www.recycle.com/compost/temprature.html).*

Particle size: once you have determined the proportion of feedstock to create a recipe with acceptable C: N ratio and moisture levels, one of the most practical ways to ensure that the microbes in your mixture continue to receive adequate moisture and oxygen throughout the decomposition process is to regulate the particle size. Most materials are composed of a variety of different sized pieces or particles. The average size, however, is important, since an average size that is too large or too fine is likely to cause difficulties. Particle too large: e.g. tree limbs, large chunks of manure or other solid material have good air flow through the channel of these particles, but likely dries out quickly, decomposes slowly since only the outside surfaces of the large pieces are exposed to microbial activity. Particles too small: e.g. saw dust, grass clippings, sledges Can have good moisture retention, but is likely to become anaerobic, as air cannot easily infiltrate the pile. Operators and researchers have found that, in general, a particle size range of 1.5-5cm provides the best balance of moisture retention and oxygen diffusion for effective composting. Particle size can often be regulated during preprocessing of feedstock before they are added to the compost mixture. Most grinders and shredders are adjustable, and screens or classifiers can be used if necessary to remove large pieces of solid materials. Particle size is particularly important in static systems, where the materials will not be turned during composting. In these systems the material itself needs to maintain enough porosity so that the air can infiltrate the pile throughout the process *(http://www.recycle.com/compost/compost.htm)*.

2.3.1. Compost maturity and stability

Compost is considered mature when the energy and nutrient –containing materials have been combined into stable organic mass. The composting process results in a dark brown material in which the initial constituents are no longer recognizable and further degradation is not noticeable. The length of the time needed to achieve finished compost will vary with many factors and can take anywhere from couple of weeks to over a year. Stability describes compost’s resistance to further biological breakdown. Immature composts can contain phytotoxic organic acids. Stability and maturity are critical for compost used in greenhouse potting mixes and bagged products, but less critical for application to farmland, especially when several weeks elapse between application and planting. Making sure that compost is matured before adding it to the soil is very important. Application of immature, carbonaceous compost could affect plant growth adversely, since the compost may have its own demand for nutrients as the breakdown to maturity continues in the soil. In addition, immature composts made from nitrogen rich feedstock are often high in ammonium which can be toxic to plant growth (Frank *et al*., 1996).

Table 1. Chemical properties of municipal solid waste compost

Analysis	Why important	Unit	best	comments
C:N ratio	Ratio of carbon to nitrogen .stable soil organic matter has C:N of 12-15	None	12 to 15	Compost with high C: N will reduce N availability to plants. This affects compost use for farmland application.
Electrical conductivity (EC)	a measure of soluble salts high salts may injure plants	ds/m	0 to 4	EC is critical for greenhouse potting mixes, less critical for farmland application especially in humid areas.
pH	Acidity or alkalinity	none	Most plants6-7	Below 5 or greater than 8 may injure plants
Ammonium nitrogen(NH_4-N	Ammonium nitrogen is plant available nitrogen form ,but high values injure plants	ppm or mg/kg dry weight	Less than 500	Ammonium is most critical in greenhouse potting mixes and high in PH environments.
Nitrate nitrogen(NO_3-N	Nitrate nitrogen is plant available form	ppm or mg/kg Dry weight	200 to 500	Low values indicate lack of plant available nitrogen
Moisture content	Tells how much water and organic matter is present	Percent as is weight	40 to 60	Compost with >60% moisture may be clumpy and hard to spread. High moisture also means more water and less organic matter per hectare applied. Low moisture materials (<40%) may be dusty.
Organic mater	Tells percent of dry amendment that is organic matter	Percent dry weight	40 to 60	Low values (<30%) usually indicate the organic matter has been mixed with sand or soil. High values(>60%) indicate fresh, uncomposted material

Source: Bary *et al.*, 2002

2.4. Environmental and economic benefit of compost

The emission of landfill gases (LGs) produced by the anaerobic and aerobic decomposition of organic matter is a major source of Greenhouse gases (GHG) which are responsible for global warming and ozone depletion. There is significant variation in the amount of carbon present in different municipal solid waste streams. However, it is reasonable to assume that one million tons (t) of unsorted MSW contain approximately 0.3 Mt of carbon in various forms. Experimental research and process modeling demonstrate that about 0.2 Mt would be converted to landfill gases (LGs) consisting of 0.09 Mt carbon dioxide and 0.09 Mt methane, and other trace constituents. LG emissions from landfills account for nearly half of the world's total anthropogenic sources of methane. Furthermore, methane is between 19 and 21 times more potent as a GHG than is carbon dioxide. It is therefore not surprising that eliminating methane emissions from MSW can substantially lower the world's overall GHG emissions. Although beneficial, recovering methane from landfills has proven to be only partially successful since up to 60% of the methane generated escapes through leakage. It is clearly much better to prevent landfilling of organic waste in the first place. Composting is one of the simplest ways to prevent emissions of methane because the organic fraction of the waste stream is diverted from landfill. While composting does release carbon dioxide, it is currently considered to be a neutral process since the removal of carbon dioxide from the atmosphere by photosynthesis to produce organic matter is also not considered (Hoornweg *et al.*, 2000).

Landfill leachate is created when water percolates through the waste and biological and chemical constituents from the waste are brought into solution. Depending on the landfill design and prevailing weather conditions, composting may not significantly reduce the quantity of landfill leachate, but it will improve the quality of the leachate. This is achieved by reducing the concentrations of biochemical oxygen demand (BOD) and phenols produced as a byproduct from the decomposition of leaves and metals mobilized by the formation of carbonic acid from the decomposing organics. Composting may also produce leachate, potentially high in BOD and phenols, which should not be discharged into water bodies. Collecting and re-circulating the leachate into active compost piles will mitigate any environmental impacts while at the same time enhance the compost process (the composting process is usually a net-water user). In developing countries, organic matter constitutes a significant portion of municipal solid waste. Diversion of organic materials from landfilling extends the life of the landfill by reducing the amount of waste to be disposed (Hoornweg *et al.*, 2000).

Composting rarely generates profits on its own. However, when viewed as a component of an integrated solid waste management program, composting can provide economic benefits on a much larger scale. The costs of composting includes raw materials, production, marketing, and hidden environmental costs; whereas the benefits involve the market value of the compost, savings from avoided waste disposal costs, as well as various positive environmental impacts . When considering the large quantities of organic matter generated in developing countries, governments can save money by reducing the amount of waste requiring collection, transport, and disposal. The extent of these savings are dependent on how the waste management system incorporates composting initiatives, including the elimination of temporary dumping sites, rerouting of collection vehicles, and the redirection of labor . Traditional cost accounting systems usually do not include the hidden costs and benefits of environmental and social externalities since they are difficult to quantify. The following table presents some of the environmental costs and benefits of composting which are rarely accounted for (Economist, 1998).

Table 2. Environmental costs and benefits of composting

Costs	Benefits
Potential odor emissions	Reduced land fill spaces
Improper disposal of rejects	Reduced surface and ground water contamination
	More flexible over all management system
	Reduced transportation costs
	Enhances recycling of materials such as glass and metal
	Reduce erosion and improves efficiency of fertilizer
	Reduce air pollution from burning wastes

Source: Economist, 1998.

There are other benefits which may not directly impact the operation of the composting facility but do affect the overall health and well being of society. Water contamination can occur from leachate infiltration or from disposing of waste into open water bodies. Poor water quality has been linked to various human infections and diseases. Each year, about 900 million people experience diarrhea or contact diseases such as typhoid and cholera spread by contaminated water. Providing alternative waste treatment options, such as composting, will reduce the quantities of waste blocking rivers, canals and drains, and stagnant water where mosquitoes prefer to breed and potentially transmit diseases, such as malaria and Dengue fever (Albrecht, R., 1989).

2.4. 1. Impact on soil physical properties

Generally, the application of compost to soil improves soil structure and tilth. In addition, compost can reduce soil bulk density and soil strength, providing opportunities for deeper root penetration. Soil aggregate stability is highly dependent upon soil humus content, which can be increased with addition of compost. However, high rates of addition may be required to significantly increase aggregate stability. When incorporated, compost generally increases the cation exchange capacity of soils. Use of compost can increase total soil porosity. Significant increase in elongated pores involved both transmission pores (50-500µ) and pores greater than 500µm. Elongated pores greater than 500µm are essential for growth of principal roots, for drainage, and for soil aeration (especially in fine textured soils). This increases air movement into the root zone, water infiltration into the soil, soil water-holding capacity, and plant available water in the root zone (Giusquiani *et al.,* 1995).

2.4. 2. Impacts on soil biological properties

Many bacteria and fungi have been identified as biocontrol agents in compost-amended substrates. Generally, these biocontrolagents suppress plant pathogens in two different ways, through either “general” or “specific” suppression. The mechanisms involved are based on competitions for resources (air, water, and nutrients), production of antibiotics, hyperparasitisim, and the induction of systemic acquired resistance in the host plant (in effect, inoculating the plant against the disease) (Hoitik *et al*., 1997).

2.4.3. Municipal solid waste compost and plant nutrition

Since mature compost has undergone extensive microbial degradation and stabilization, little mineralization of remaining organic N is likely occurs in the cropping year of application. Consequently, if compost application rates are based on total N in the compost, (which necessarily includes recalcitrant organic N).Crops may experience N deficiency and yields may be poor. Thus, the agronomic rate, of application of compost is usually dictated by the "plant available" N (PAN) content of the compost, which is a fraction of total compost N. Organic N in compost, is not immediately available to crops because mineralization of organic matter is a microbial process that requires time. The C: N ratio of the organic material influences microbial activity. The greater the ratio, the more limiting nitrogen becomes for microbial decomposition of organic matter. When composts with C:N ratios greater than 20:1 are added to soils, both mineral N and any subsequently mineralized, organic N can become "appropriated" by microbes (immobilized in microbial biomass), leaving plants N deficient. Thus, the C: N ratio of compost is an important factor in calculation of plant available N. Soil temperature and moisture influence plant availability of organic N. Cool and/or wet weather slows microbial activity and thus inhibits mineralization process. Consequently, may not correspond to the time when crop demand is greatest. For example, compost may not able to supply nutrients needed at crop emergence in a wet cool spring (Dick and McCoy, 1993).

Availability coefficients are used to calculate plant available N; that is, they are used to predict mineralization in the field. In theory, if the C: N ratio of a matured compost is high (e.g.>30) and compost is very resistance to microbial decomposition, immobilization of compost N can be expected, and availability coefficient could be nil. Matured compost with C: N ratios above 20 will probably have very low mineralization potential in the first cropping season; therefore, availability coefficients will be very low. At a very low C: N ratios (e.g.8 to 10) N availability coefficient may increase to approximately 0.5.While initial immobilization of N in soil-incorporated composts is not uncommon, the, C: N ratio of matured compost is commonly in the range of 8 to 14. Some compost N will become available after application for a crop. Predicting how much and when nutrients will be mineralized can be difficult albeit critical to crop performance. Rough guide lines for availability coefficients at various C: N ratios are in the following table.

Table 3. Nitrogen availability coefficient guideline for compost

C:N	Incorporated	Broadcast
<10	0.5	0.38
10 to 15	0.25	0.19
16 to 20	0.1	0.08
21 to 25	0.05	0.03
>25	0.00	0.00

Source: Wander *et al.*, 1994

The availability of residual compost N to crop plants in the second year after addition is not well documented. As a general rule, 10% of the remaining organic N (after cropping season) is available for the next crop. It may take years before microbial system support cycling efficiencies that effectively support uptake of significant quantities of nutrients from composts, in the second and subsequent season. However, consistent, annual applications of organic matter increase available soil N over time as microbial mediated N cycling dynamics improved. The concentration of available N in finished compost is generally lower than in manures. As a consequence, application rates are generally higher, allowing for greater organic matter additions to soil. Thus, use of compost as nutrient source instead of manure provides a greater opportunity to make improvements in soil physical properties (Wander *et al.*, 1994; Gunapala and Scow, 1997; Wander and Traina, 1996).

The calculation of an application rate for compost to meet crop nutrient requirements is similar to the calculation of an application rate for manure. After settling an appropriate availability coefficient, obtaining a chemical analysis of the compost that includes total N, P, K, and determining realistic crop N, P, and K requirements (based on realistic yield expectations for a particular soil or field), a grower can calculate a compost rate. The rate can be based on N, P, or K as the critical or priority nutrient. The amount of compost to apply is calculated from the recommended rate of the priority nutrient and the plant available nutrient content of the compost.

That is, the amount of compost to apply equals the recommended amount of priority nutrient divided by the plant available priority nutrient (the total priority nutrient concentration of the compost multiplied by the availability coefficient) For example, if compost contains 60kg.total N ton^{-1} (wet basis) and the availability coefficient is 0.25(for incorporated material), then the plant available N is 56×0.25=14 kg ton^{-1}. If the priority nutrient is nitrogen and the recommended amount of N for the crop is 140 kg ha^{-1},then the appropriate application rate is 140 (recommended amount) divided by 14 (plant available N) equaling 10 tons of compost per hectar compost (Hodges, 1998).

As a general rule, availability of P and K in compost manure is somewhat higher than N.The availability coefficient for both P and Kin manure is 0.8. Crop nutrient requirements for P and K vary considerably, so when manure application rate is based on PAN, P and K may be over or under-supplied. With vegetable crops, P requirements are somewhat lower than N requirements (on kg ha^{-1} basis) and K requirements are somewhat higher. Thus, P generally tends to be over applied and K under applied (Sanders, 1999).

2.4.4. Limitations of municipal solid waste compost

Public health hazards arise when the product is composted human excrement or is composted industrial wastewater solids (i.e., sludge). Wastes from diseased animals could be ranked with human excrement as a hazard to public health, but perhaps to a lesser degree. Only those pathogens not exterminated during or after composting pose a hazard to public health. It is important to keep in mind that passage through the compost process is not of itself a guarantee that all viable pathogens have been killed, and hence that the product is entirely free of viable pathogens. The reality is that the intervention of some factor may have prevented exposure of all pathogens to the bacterial conditions associated with the compost process. Pathogens that escape these conditions can subsequently re-contaminate “steriled” material. A single kilogram of insufficiently exposed infested or contaminated material can re-contaminate an entire pile of compost. Failure to expose all material in a composting pile to temperatures lethal to pathogens can result in pockets of contaminated material. Subsequent turning or other redistribution of material can lead to a recontamination of the entire composting mass. In systems that involve no turning, and in which sufficiently elevated temperatures seemingly should prevail throughout the composting mass, pockets of low temperatures might nevertheless exist (Gilbert E J, 1998). A factor that amplifies the effects of high temperature and may even compensate for incomplete exposure to high temperature is the collection of inhibitory phenomena that begin in the composting mass at the time compost conditions are imposed and end when the process is terminated. Because the phenomena are time-dependent, loosely speaking it might be said that passage of time more or less compensates for shortcomings in exposure to high temperature. Thus, passage of time allows: (i) destruction of pathogens,(ii) competition with non-pathogenic microorganisms, (iii) antibiosis, and (iv) the development of a less than favorable environment. An important factor regarding pathogen survival and multiplication is the fact that the normal habitat of pathogens is the human body. Because of this, nutrient sources useful to pathogens are compounds usually found only in the human body. Therefore, only a relatively few compounds in a composting mass can be used as nutrient sources by pathogens. These compounds are rapidly destroyed under composting conditions. Because they are adapted to the protective environment provided by their host, pathogens are at a disadvantage when competing with microbes indigenous to the habitat constituted by the composting material. Moreover, the presence of some antibiotics is ensured by the proliferation of *a*ctinomycetes and fungi normally characteristic of composting. For example, species of Streptomyces (actinomycete) and Aspergillus (fungus) appear in substantial numbers during composting. Therefore, all things considered, a year of storage should be ample for rendering a product safe for most uses (Ragen, N, 1997).

The bulky nature and low density of the dry compost product are responsible for most of the difficulties that pertain to transport and mechanics of applying the product. Because the volume to-weight ratio is higher, a low-density product is more expensive to transport than is one of a high density. In as much as compost generally is an uncompacted low-density product, the volumetric capacity of the transport vehicle is reached long before its weight capacity. The bulkiness and low density of compost necessitate the use of bulky equipment to spread it on the field. As previously indicated, a manure spreader can be used or adapted to apply compost to the field. With regard to manual application, more trips per unit mass of material are needed (Waksman *et al.,* 1952).

Emissions during composting; during the composting process, small amounts of methane (CH_4) and nitrous oxide (N_2O) are released by microorganisms. N_2O is released during denitrification of nitrite and nitrate. Methane is released during anaerobe circumstances when organic compounds are used by microorganisms. The level of N_2O and CH_4 emissions are related with the types of organic materials that are composted, the type of composting, the amount of material and the processing circumstances (moisture, temperature and structure). Especially aeration significantly influences methane emissions. Apart from that there are different measuring methods (continue versus momentous measuring) which may affect the emissions which are measured. (Heres *et al.*, 2007). Studies on windrow composting gave very different results for the emission of CH_4 and N_2O (Andersen *et al.*, 2010).This implies that there is no golden rule to quantify the amount of gaseous (CH_4, N_2O) emissions during composting. As a result, the highest, values of different studies conducted on compost were considered. These values have been chosen, as it was stated that the compost was actively turned and properly managed.

Table 4. Emissions of CH_4 and N_2O due to composting

type of gas	minimum measured (kg/t waste)	maximum measured (kg/t waste)	minimum (in kgCO_2-eq/t waste)	Maximum (kgCO_2-eq/t waste)	minimum (in kgCO_2-eq/t compost)	maximum (in kgCO_2-eq/t compost)
Methane(CH_4)	0.08	0.3	2.00	7.5	4.74	17.79
Nitrous oxide (N_2O)	0.04	0.1	11.92	29.80	28.27	70.68
Total						88.47

Source :(Heras *et al.* , 2007)

Emissions during compost application: nitrogen can be released into the air in the form of N_2O with the application of fertilizer and compost, and activities of soil microorganisms. Application of compost emitted less nitrous oxide than of chemical fertilizer where 0.7% instead of 1% (Luske, 2010).

2.5. Effects of nitrogen fertilizers on environment

Emissions during production of urea: considerable amount of CO_2 is emitted during the production of urea and much of the CO_2 emission is associated with ammonia synthesis, modern urea factories emit 3.1 kg CO_2-eq $kg^{-1}N$ (Wood and Cowie, 2004). **Emissions during transportation**: the emission due to transportation does not directly related to urea synthesis but other factors such as truck or ship used for transportation and amount of fuel consumed per km during transportation of the product, European average 0.1 kg CO_2-eq kg^{-1} N (www.yara.com, 2010). **Emissions during application:** due to application of urea fertilizer nitrogen is emitted as N_2O-N which is deemed as highly "effective" greenhouse gas with a global warming potential of 310 times stronger than CO_2 (IPCC, 1996a). The default emissions factor for direct N_2O emission (N_2O-N) is 1% of the applied nitrogen, plus another 0.325% due to indirect emission, occurring elsewhere from nitrogen that has been leached or emitted, thus 0.01325 kg of applied nitrogen is emitted as N_2O-N (Edi *et al.*, 2003). This is equivalent to 6.45 kgCO_2-eq kg^{-1}N, with the conversion factor of N_2O-N to N_2O, 44/28 (IPCC, 2006).

Only a small fraction (about 2.5%) of earth's water is fresh and suitable for human consumption. The rest (more than 97%) is in oceans and seas. Of the less than 2.5% of fresh water approximately 13% is groundwater; an important source of drinking water for many people worldwide. For example, more than 50% of the world's population depends on groundwater for drinking water. For many rural and small communities, groundwater is the only source of drinking water (Mahvi *et al.*, 2005).

Application of fertilizers to farmland soils is a necessity to produce food and fiber. However, elevated concentration of NO_3^- in ground water from intensive agriculture has raised concern over possible contamination of drinking water supplies. The effect of excessive nitrate in drinking water is linked to methemoglobinemia (or blue baby syndrome) which affects the fetus and young children and non-Hodgkin's lymphoma. Often nitrate concentrations in agricultural areas are associated with pesticide and microbial contaminations. Nitrogen fertilizers or manure applied to farmlands can be considered as non-point sources of nitrate. Nitrogen compounds in these sources are oxidized in aerated soils to soluble nitrate. With sufficient surface-water infiltration, soluble nitrate can leach below the root zone to underlying groundwater. Unconfined aquifers with shallow water tables overlain by permeable soils are especially vulnerable to agricultural contaminations. To maintain yield increase and minimize nitrate pollution of the ground waters, "best management practices" for N-fertilizer should be disseminated and an excessive fertilizer application prevented. The practices include soil conservation, balanced fertilization, more frequent N-top dressings at smaller rates during the rainy season, use of slow-release fertilizers, improving nutrient capture from soil by the genetic manipulation of crop plants, feed lot runoff collection and abatement, and use of wetlands (Mahvi *et al.*, 2005).

Schematic representations of the nitrogen cycle often make it look as if the nitrogen undergoes simple chemical reactions to change from one form to another. However, while many chemical reactions do take place in the soil, the nitrogen conversion occurs primarily through the action of soil organisms. The most common form of nitrogen is ammonium (NH_4^+), and is found in the excretions of larger organisms. This quickly consumed by plants, fungi and special bacteria (nitrifying bacteria). Their excrement contains nitrogen first in the form of nitrite (NO_2^-), which is then consumed by other bacteria that excrete nitrogen in the form of nitrate (NO_3^-). This is the preferred form of nitrogen for grasses and most row crops. It is not surprising then the most grassland soils are dominated by bacteria. Most of our agricultural crops are grasses (grains, forage grasses) and grassland plants. These plants are accustomed to, and will be healthiest in soil high in humus. Because the metabolic activity in the soil is highest during the most active growth period of plants (highest temperature), the nitrogen will become available to plants just as it is required ,so supply and demand are in perfect balance.

Soils that are low in oxygen (due to water logging, compaction,etc) contain a large number of (facultative) anaerobic bacteria (those that can exist without oxygen =denitrifying bacteria). These will take much of the excess nitrate (NO_3^-) convert it to form of nitrogen (N_2 or N_2O) and oxygen. This supplies the soil with badly needed oxygen, and supplies the nitrogen fixing bacteria in this air –starved environment with nitrogen (N_2). Any excess returns to the air as nitrogen gas (N_2O). Of course in all situations some of the nitrogen will be leached to deeper levels of the soil and into the waterways, where it feeds other organisms (Hermary, 2007).

So we can see that here, too, nature creates balance. In natural systems, nitrogen is never “lost”. However, with the application of chemical nitrogen fertilizers, which are either applied as nitrates, or converted to nitrates through the bacterial activity in the soil, this delicate system is disrupted. Nitrates (NO_3^-) are anions, that is, they are not held on cation exchange sites. So anything that is not immediately taken up by plants is quickly leached out, and dissipates into the air as gas, as these fertilizers must be applied with large amounts of water to prevent salinization of the soil. Thus the soil environment deals with the artificially created excess nitrogen in the way the system works naturally. Of course these leads to the pollution of our ground water and rivers, and all the health problems associated with that. However, an excess of nitrate also creates other problems. Nitrates are salts, dehydrating their surroundings. They are also very strong oxidizers, literally burning up the organic matter in the soil. These attributes not a problem in natural ecosystems where nitrates are made available only as quickly as they can be consumed, but become a serious detriment when excess nitrates are applied. To slow down this expensive loss of synthetic nitrogen, various form of nitrogen are then coated, or combined with, various substances, creating so-called “slow release” fertilizers. Supposedly these various coatings make nitrogen available at a rate plants can absorb. What all these advertisements don’t tell us is that these products undergo chemical reactions in the soil, with serious “side effects” on the soil and soil life. Here are just some examples of the most common nitrogen fertilizers (Casiday R and Frey R, 1998).

Urea (NH_2CONH_2) is consumed by bacteria which convert it to (excrete) anhydrous ammonia (which is a gas) and carbon dioxide ($2(NH_3) + CO_2$). Anhydrous ammonia is highly toxic and kills organisms. If urea is applied to the soil surface, the gases quickly dissipate. However, in the presence of high air humidity anhydrous ammonia gas vapors formed. These are heavier than air and can accumulate in low lying areas. If urea is incorporated into the soil, the ammonia gas reacts with water (H_2O) to produce ammonium hydroxide (NH_4OH). Which has a pH of 11.6; it is highly caustic and causes severe burns. This creates a toxic zone in the immediate vicinity of the applied urea that kills the seeds, seedlings and soil dwelling organisms. Within a few days further chemical reactions in the soil release the ammonium ion $NH4^+$, which then follows the same path as naturally occurring, ammonium, with any excess nitrate crated in this way leached into the environment (Hermary, 2007).

Triple super phosphate is produced by treating phosphate rock with either sulfuric acid or phosphoric acid, making it extremely acidifying. When applied to the soil it reacts with calcium to form tri-calcium phosphate, which is water insoluble, i.e. requiring microbial action for breakdown. Even in soil with health microbial activity only about 15-20% this phosphorous is easily available to plants, considerably less in soil which does not have good microbial diversity. The production of each ton of phosphoric acid is accompanied by production of 4.5 tons of calcium sulphate, also called phosphogypsum. This is a highly radioactive and also contains heavy metals and other impurities. Depending on the production process, radioactive substances and heavy metals can be execrated into the fertilizer. These are just some examples of the potentially highly determinant effects of some common fertilizers. It is important to know that any substance used to excess will unbalance the soil, even naturally occurring substances such as dolomite lime (Casiday R and Frey R, 1998).

3. MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted at Debre Zeit Agricultural Research Center that located about 50 km Southeast of Addis Ababa at 38°58´E, 08°44´N and 1900 masl with 850 mm and 17 ^{o}C mean annual rainfall and 17°C average temperature, respectively, (Teklu *et al.*, 2010).

3.2. Sampling and analysis of soils and municipal solid waste compost

Two soil types were collected from Debre Zeit and Holetta Agicultural research farmlands where ten subsamples were collected for each soil type to get a composite sample. The soil types were Andosol and Nitisol; the former sample was collected from farmlands of Debre Zeit Agricultural Research Center, while the later from Holetta Research Center. However, the municipal solid compost was taken from Gerji composting site of environmental protection authority of Addis Ababa, Ethiopia. The selected chemical properties of soil samples and compost were analyzed with procedure described by James and Wells (1990). Accordingly, the pH was measured potentiometrically in supernatant suspension of a 1:2.5 soil: liquid ratio using a pH meter. The exchangeable bases (Na, K, Ca, and Mg) were determined with 1 N ammonium acetate at neutral pH and exchangeable Ca and Mg in the ammonium acetate leachate were measured by atomic absorption spectroscopy (AAS), whereas the exchangeable K and Na by flame photometer. The organic carbon was determined with the procedure described by Walkley and Black (1934) while total nitrogen with Kjeldhal procedure (Bremner and Mulvancy, 1982). The available P was determined by Olsen method, whereas the available micronutrients (Cu, Fe, Mn, and Zn) were extracted with DTPA as and measured by AAS at 248.5, 279.5, 324.7 and 213.9 nm wavelengths for Fe, Mn, Cu and Zn, respectively.

3.3. Experimental set ups

Four sets of experiments were conducted to achieve the stated objectives where the experimental procedures were elaborated in details in the next sections.

3.3.1. Experiment 1: scenario analysis

Carbon footprint of MSW compost and chemical fertilizer were calculated to demonstrate the positive environmental effect of municipal solid waste composting and the negative impact of chemical fertilizer. The calculation was made based on intergovernmental panel on climate change (IPCC, 2006) guidelines for greenhouse gas inventories and the approach used by united nations frame work convention on climate change (UNFCCC,2008) for the determination of emission reduction. To illustrate the beneficial effect of composting and the impact of chemical fertilizer on climate, the greenhouse gas of two different situations were compared (i) a baseline scenario where different organic waste was land filled and agriculture used chemical nitrogen fertilizer (ii) the second scenario where different organic waste materials were processed into compost to use for soil amendment. In the baseline scenario, organic waste was transported to a landfill, or illegally damped, whereas the agricultural fields were fertilized with urea. In the second scenario, waste materials were used for composting for soil amendment. In the comparison, the compost and urea fertilizer were used on assumed wheat farm located to south east of Addis Ababa at around 30 km. In both scenarios, the organic waste fractions were taken into consideration. In the baseline scenario, anaerobic fermentation took place and methane was emitted, whereas in the second scenario, organic waste was composted in windrow composting in the controlled microbial composting method. Emissions of greenhouse gases (N_2O and CO_2) due to production, transportation of compost and urea, methane emission during anaerobic fermentation, direct and indirect emissions due to fertilizer and compost applications and soil carbon sequestration were all taken into account.

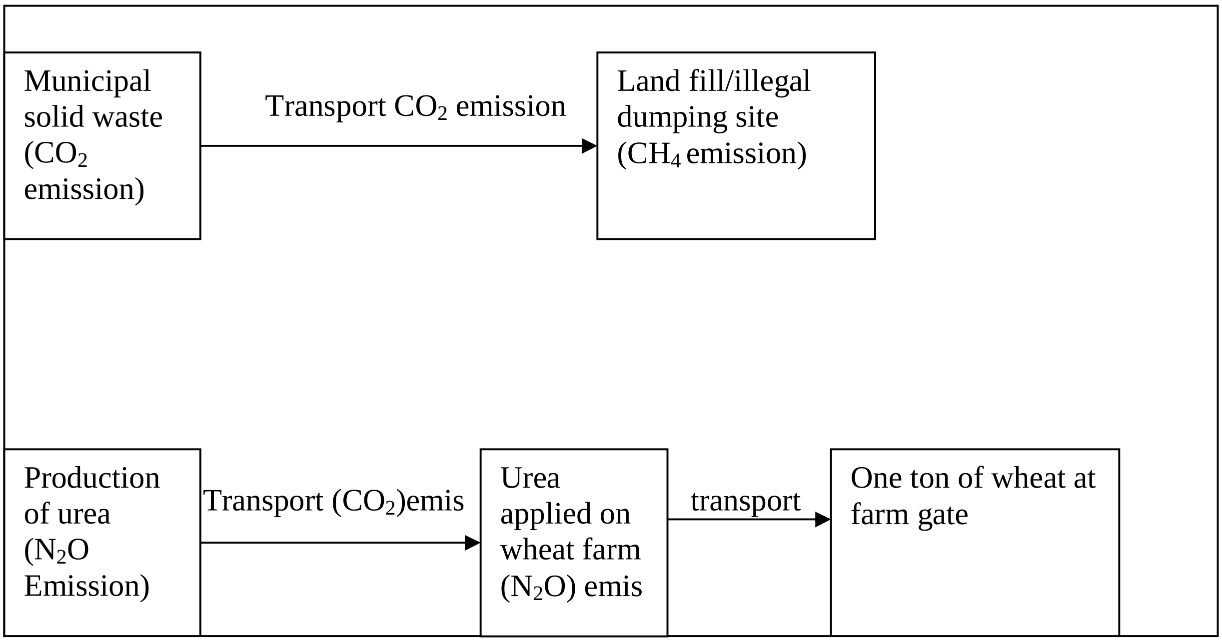

Figure 1. System boundary for the baseline scenario

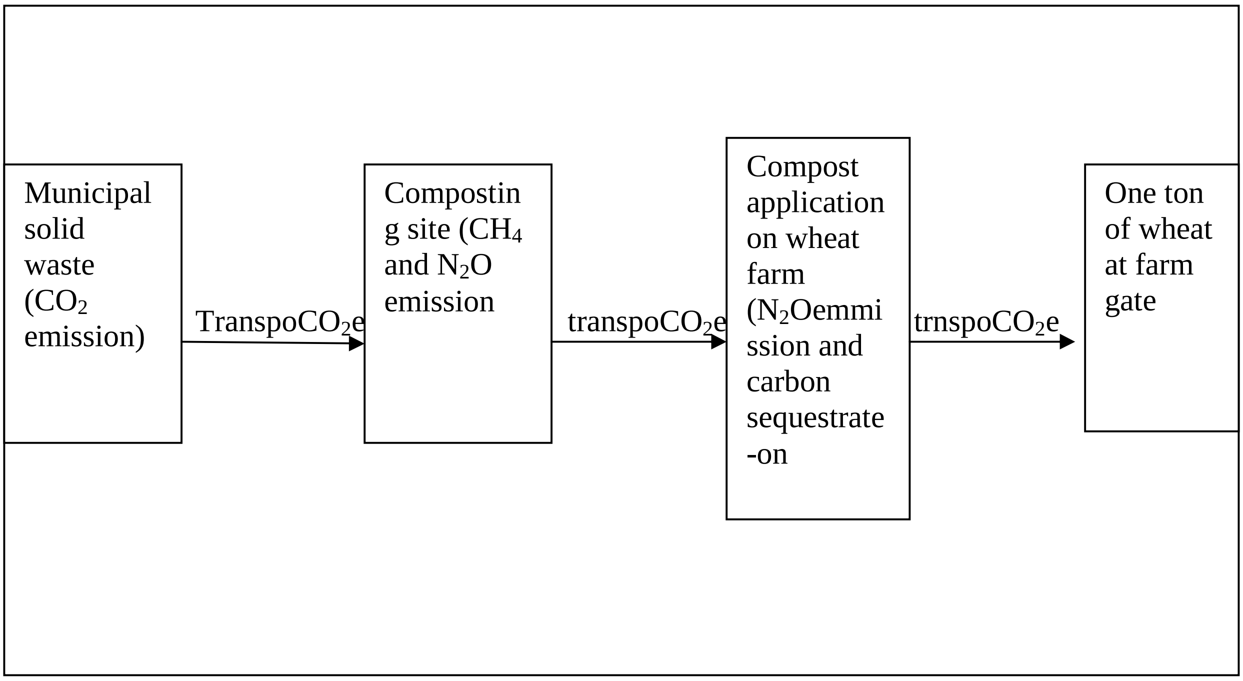

Figure 2. System boundary for composting scenario

The baseline scenario: it was assumed that a part of organic waste materials were not recycled in the baseline scenario in Ethiopia in general and in Addis Ababa in particular. It was also assumed that the waste was transported over 15 km (one way) by truck with a diesel consumption of 0.3 L km^{-1} and a truck load of 15 t MSW. Therefore, the emission of CO_2 due to MSW transportation was $((0.3L/km \times 30km \times 2.68kg/L)/15t)$ =1.6 kg t^{-1} where the emission factor for diesel used is 2.68 kg CO_2 L^{-1} (Anderson *et al.*, 2010). Methane is emitted due to anaerobic decomposition of organic waste that helped to calculate greenhouse gas emissions from disposal waste sites. The calculation methodology differentiates the fraction degradable organic carbon (DOC) for organic waste types (Luske, 2010). The quantity of organic waste disposed into landfill was 75,100 t yr^{-1} (Getachew *et al.*, 2002), whereas the fraction of degradable organic carbon was 34% (MWRNMA, 2007). Therefore, the amount of waste dumped was multiplied with the fraction of degradable carbon (75,100t $yr^{-1}\times0.34$) which was 25, 534 t yr^{-1}. Furthermore it was assumed that 70% of the organic carbon present in the waste was decomposed anaerobically in a landfill of Addis Ababa. The fraction of methane in the emission to air from disposal sites of Addis Ababa was estimated to 62 % (MWRNMA, 2007). The landfills in and around Addis Ababa are relatively shallow that assumed to be much less than 4 m depth where the methane correction factor (MCF) of these types of landfills is 0.4 (IPCC, 2006). Greenhouse gas emission of the baseline scenario was calculated by multiplying the amount of degradable carbon and warming potential 25 for methane (Andersen *et al.*, 2010).

In literature different emission factors of urea have been published and are in between 3.0 to 7.0. kg CO_2-eq kg^{-1}N (Cowie and Wood, 2004). In this research the most conservative value 3.2-kgCO_2-eqkgN^{-1} was used. It was assumed that the production of urea took place at the boarder of Ethiopia (Djibouti port) and was transported by truck over 1000km (one way)with a fuel use of 0.3L diesel per km and a truck load of 20t. Urea consists for 46% out of pure N. the emission factor for diesel amounts to 2.68 kg$CO_2$$L^{-1}$. The emission due to transportation of 1kg of urea to the farm amounts to therefore 0.1kgCO_2-eqkg^{-1}N. The default emissions factor for direct N_2O emission (N_2O-N) is 1% of the applied nitrogen, plus another 0.325% due to indirect emission, occurring elsewhere from nitrogen that has been leached or emitted, thus 0.01325 kg of applied nitrogen is emitted as N_2O-N (Edi *et al.*, 2003). This is equivalent to 6.45 kgCO_2-eq kg^{-1}N, with the conversion factor of N_2O-N to N_2O, 44/28 (IPCC, 2006).

Composting scenario: it was assumed that the composting facility in Addis Ababa composted 75,100 t of organic waste in the period of December 2010 to December 2011. The total amount of compost produced during this period was 31,542t; this means that 42% of the input material was eventually turned into compost. It was also assumed that the input materials which were used (green leaves, dust particles, sawdust etc) were collected manually from household to the transfer stations which were at a different distance from the composting facility. The average distance between the transfer stations and composting facility was assumed to be 20 km; hence the waste was transported over 20 km (one way) by a truck with a diesel consumption of 0.3 L km^{-1} and a truck load of 15t. Therefore, $(((40km \times 0.3L/km)/(15t \times 0.42)) = 2)$ two liter diesel fuel is required to transport a ton of MSW compost. Furthermore, it was also assumed that the end product (compost) was transported to the farm gate which was 30 km (one way) from composting facility with a consumption of 0.3 lit diesel km^{-1} with truck load of 20 t.

Table 5. Diesel used during different phases of composting (based on the above assumptions and discussion)

Activities	L t^{-1} compost
Transport of input materials (MSW)	1.9
Diesel used composting facility (e.g. turning of the compost etc)	1.4
Diesel used for transporting compost to the farm	0.9
Total	4.2

Studies on windrow composting gave very different results for the emission of CH_4 and N_2O (Andersen *et al.*, 2010).This implies that there is no golden rule to quantify the amount of gaseous (CH_4, N_2O) emissions during composting. As a result, the highest, values. (88.47-kgCO_2-eqt^{-1}compst) of different studies conducted on compost were considered (Heres *et a*l., 2007). These values have been chosen, as it was stated that the compost was actively turned and properly managed. Application of compost emitted less nitrous oxide than of chemical fertilizer where 0.7% instead of 1% (Luske, 2010).

In calculating carbon footprint of wheat for baseline and composting scenarios fertilizer application at 70-kgN ha^{-1} and compost application 5-t compha^{-1} with wheat grain yield of

4000kg ha^{-1} for chemical fertilizer and 5% less for sole application of MSW compost was assumed.

3.3.2. Experiment 2: incubation

Incubation experiment was conducted under greenhouse condition to investigate the environmental performance of MSW compost on selected soil properties. The treatments of the experiments were [(i) Control (without any amendments) (ii) 5-t compost (iii) 10-t compost (iv) 15-t compost (v) 20-t compost (vi) 60-kg N (vii) 120-kgN (viii) 180-kg N] ha^{-1}. The treatments were laid out in a complete randomized design with three replications. The amounts of MSW compost and urea fertilizer were calculated based on their total N (Nt) that applied into 100 gm soil for each treatment. The soil moisture was adjusted to 60% field capacity by weighing. The vessels in which the incubation carried out were placed in the greenhouse at an average temperature of 30 $^{O}{}_{C}$ and relative humidity of 60% for 90 days. The 30 gm of incubated soil samples were taken in the first, second and third months of incubation period to detect changes observed due to MSW compost and urea fertilizer. Accordingly, soil, organic carbon, ammonium, nitrate, exchangeable bases and available micronutrients concentrations were determined following the procedures described in section 3.2 above.

3.3.3. Experiment 3: leachate collection

This experiment was designed to compare the concentration of nitrate nitrogen (NO_3-N) in the leachate collected from high application rate of urea and MSW compost to compare the soil amendments either urea or MSW compost contributed nitrate to surface and/or ground water pollution. The five treatments used in this experiment were [(i) control (without any amendment) (ii) 5-t compost (iii) 10-t compost (iv) 15-t compost (v) 200-kg N] ha^{-1}. The treatments were laid out in a complete randomized design with three replications. The amount of soil sample for each treatment of the replications was 250 gm per pot that was thoroughly mixed with the treatments and placed in greenhouse for two months.

The soil sample amended with compost and urea fertilizer was leached with 0.5 L distilled water using graduated plastic jug simulating soil saturation. The leachate was collected every 20 days interval for compost and urea amended soil sample. The collected leachate was measured with graduated cylinder and then used for analysis of nitrate-nitrogen. The nitrate concentration in the leachate was analyzed with Kjeldal procedures as described for total nitrogen in section 3.2.

3.3.4. Experiment 4: effects of compost amendment on wheat yield and yield component

Pot experiment was designed under greenhouse condition to compare the effectiveness of MSW compost and urea fertilizer in improving the growth, yield component and nitrogen uptake of wheat on Andosol. The treatments of the experiment were [(i) control (without amendment) (ii) 2.5 t compost + 30 kgN (iii) 1.667 t +40 kg N (iv) 3.333 t compost + 20-kgN (v) 5 t compost (vi) 60-kgN (vii) 10 t compost (viii) 120-kg N] ha^{-1}. The treatments were laid out in randomized complete design with six replications using wheat as a test crop under green house conditions. The pots were filled with sieved soil (3 kg pot^{-1}). The MSW compost was mixed with the soil sample a week before wheat planting while the urea was applied at the tiller stage. All treatments including the control received the recommended rate of P for wheat production on Andosol in the form of triple super phosphate. The amount MSW compost and urea fertilizer were calculated from the recommended rate of nitrogen. The number of seeds placed in each pot was 20 and thinned to 14 after emergency. Distilled water was used for irrigating wheat throughout the experimental period and yield and yield components such as plant height, biomass and nitrogen uptake were recorded. The three replications were harvested at flowering stage while the remaining three treatments allowed growing until maturity.

3.4. Economic benefit

To demonstrate the economic benefit of MSW compost, partial budget analysis and marginal rate of return for sole and integrated application of urea and municipal solid waste compost in wheat production with 100% minimum acceptable rate and marginal rate of return was made CIMMYT (1987)

3.5. Statistical analysis

Some data subjected to analysis of variance (ANOVA) using SAS version 9 statistical software and mean comparison had been done with least significant difference (LSD) for the significantly differed means among the treatments at 5% probability level.

4. RESULT AND DISCUSSIONS

4.1. Selected chemical properties of soils and MSW compost

The selected chemical properties of the soil types revealed variation (Table 6). Accordingly, Nitisol was strongly acidic, very low concentration of organic matter and total nitrogen. Furthermore, the soil had low concentration of available phosphorus and micronutrients. The concentrations of exchangeable bases were low as compared to other soil types. In general the Nitisol was very poor in fertility status that was confirmed by very poor wheat growth regardless of compost and urea fertilizer applications. While the Andosol was characterized by neutral pH, low organic carbon, total nitrogen content and micro nutrients but far better than Nitisol

Table 6. Selected chemical properties of soils and compost used for series of experiment

Samples	1: 2.5	%		Ppm					Exch. bases, Ech. Acidity (cmol$_c$ kg^{-1})				
	pH-H_2O	OM	TN	AVP	Cu	Fe	Mn	Zn	Ca	Mg	K	Na	CEC
Nitisol	5.25	0.93	0.03	8.15	0.34	0.63	6.73	0.56	7.14	1.66	5.83	0.08	32.9
Andosol	7.4	1.35	0.06	7.00	0.04	0.40	0.14	1.39	32.3	7.56	2.61	2.78	43.0
Compost	6.46	13.8	1.21	13.38	0.03	0.02	0.03	0.08					

The MSW compost was near neutral in pH with higher concentration of available phosphorus, OM, total N than the three soil types used in the present study (Table 6). However, the OM concentration in the compost was low by 20 to 55% of similar materials reported elsewhere (Grigatti *et al.*, 2004; Weber *et al.*, 2007). The low concentration of OM in the MSW compost of Addis Ababa could be attributed to the compost had been mixed with sand and soils (Bary et al, 2002) or the MSW was subjected to decomposition for a long period of time. Nevertheless the MSW compost had total nitrogen that could be used for soil amendment since total N content is an important compost property used to decide amount of compost for land application. The C: N of the compost was within acceptable range (12 to 15 %) that plays a crucial role in nitrogen transformation in soil environment where (Frank *et al*., 1996; Bary *et al.*, 2002).

4.2. Carbon footprint in the baseline and compost scenario

Based on the assumptions and methods described in section 3.3.1 greenhouse gas emission of the baseline scenario was calculated (Table 7).

Table 7. Degradable carbon in organic waste and methane emission due to land filling in the baseline scenario

DOC in All waste Types	Fraction DOC which can decompose (DOCf)	Fraction of methane in the gas	Correction factor	Global warming potential of methane	Methane correction factor shallow unmanaged land fill	Emission ton CO_2-eq
25,534 t	0.7	0.62	16/12	25	0.4	147,756

Accordingly, the baseline scenario revealed that if 1000 kg of waste was illegally dumped and/or fermented at landfills, the emission would have been (147,756t CO_2-eq/75100t waste)= 1967 kg CO_2-eq t^{-1}waste.

Based on calculation methodologies and assumptions made on section 3.3.1 carbon footprint of MSW compost is summarized in table 8.The production of 1000 kg compost emitted 99.71 kg CO_2-eq (table 8), although amount of greenhouse gas emission depends on the type of municipal solid waste, composting mechanism and other environmental and soil factors.

Table 8. Carbon footprint of compost before application

Emission source	Emission
Transport of organic waste (kg-CO_2 t^{-1})	5.09
Diesel used composting facility kg-CO_2 t^{-1})	3.75
Methane and nitrous oxide emission during composting(kg-CO_2 t^{-1})	88.47
Transport to the field(kg-CO_2 t^{-1})	2.4
Total(kg-CO_2 t^{-1})	99.71
Total nitrogen in compost (kg-N t^{-1}) compost	12.00
Kg-CO_2-eq kg^{-1} N	10.00

Depending on the assumptions, and methods described in section 3.3.1 the carbon footprint of wheat was calculated for both scenarios. Wheat fertilized with MSW compost had carbon footprint of $((5t\ compost/ha \times 99.71kgCO_2 - eq/tcompost)/(3800kg\ wheat/ha)$) = 0.14 kg CO_2-eq kg^{-1} wheat. While wheat fertilized with urea had carbon footprint of $((9.65kgCO_2 - eq/kgN \times 70kgN/ha)/(4000kg\ wheat/ha))$ = 0.17 $kgCO_2$-eq kg^{-1}wheat. The emission due to fermentation of waste had the largest impact (shares much in emitting greenhouse gas), but even if these were excluded, the carbon footprint from the compost scenario remains lower. Based on application rate, soil management, temperature, moisture level and crop types 0 to 22% of the applied carbon in the compost can be sequestered (Lusak, 2010). And hence carbon footprint of wheat fertilized with compost is expected to be lower than this for the next two years of farming seasons due to high sequestration capacity of compost.

4.3. Effects of compost amendment on soil properties

The soil samples amended with MSW compost and urea responded in a similar fashion in the three consecutive months of the incubation period (Table 9). However, the effects of compost amendment were more revealed after three months of incubation. Both MSW compost and urea application positively affected the total N content, although the differences were not as high as the rate of compost and urea applied to the soil samples. An increment of 14.3% and 54% of total N was observed with the application of 5 and 20 t compost ha^{-1}, respectively, over the control (Table 9). The present study was in agreement with other works that suggested elevated doses of MSW compost increased total nitrogen and also supply nutrients during the initial growing season and could meet subsequent plant demand (Iglesias- Jimenez and Avarez, 1993; Mylayarapu and Zinati, 2009). It should also be considered that a lower application rate could affect nutrient availability, plant development and soil restoration. The increment of total nitrogen was higher with the application of urea than with MSW compost application over the control. For instance, the application of urea at the rate of 60 kg Nha^{-1} increased total nitrogen by 50% over the control which was slightly less than the increment of total N with the application of 20 t compost ha^{-1} where the total N was increased by 54% (Table 9). However, available nitrate nitrogen and ammonium nitrate showed continuous increment with the MSW compost and urea application (Table 9). The highest MSW compost application resulted in higher organic C than all other treatments with the application of 20 t compost ha^{-1} which was increased by 69% over the control. Furthermore, urea application also increased OM as compared to the control treatment. The present finding was in line with that of previous result of study where MSW compost significantly increased soil organic C than NP and NPK chemical fertilizers (Mkhabela, 1998). In general, the present study demonstrated that soil amended with MSW compost increased soil carbon sequestration capacity far better than soil amended with nitrogenous chemical fertilizer. Therefore, using MSW compost not only increase C-sequestering and improving soil fertility, but also one of the safest strategies of MSW disposal methods to reduce their contribution to environmental pollution.

The concentration of available P showed increasing trend along with the rate of MSW compost application (Table 9). However, the application of urea fertilizer slightly increased available P. Similar results were also reported where MSW compost application highly increased available P (Sarwar *et al.,* 2008). This could be attribute to urea fertilizer application could enhance the role of soil microorganism in OM mineralization. The MSW compost application also positively affected the soil pH table (Table 9). In the first thirty days of the incubation period both MSW compost and urea had slightly lowered the soil pH (Table 9).This might be due to inactive stage of microorganisms that have direct effect on activity of dehydrogenase enzymes in the soil until they acclimatize themselves to the environment. However, after two months of the incubation period, there was an increment in soil pH in all treatments of MSW compost application over the control. Compared to each other MSW compost showed equivalent soil pH, although the trend showed a general increase in soil pH with an increase in MSW compost applied. This was in agreement with results obtained by other researchers (Mkhabela, 1998). This indicates MSW compost can be used as soil acidity amendment, however; further long-term researches are required to confirm the present finding.

Table 9. Effects of MSW compost and urea application on selected soil chemical properties after three months of incubation period (average value)

Treatments ha-^{1}	1:2.5	µg-N		%		Ppm	Exchan. cations (cmol$_c$ kg^{-1})				Micronutrients (ppm)			
	pH	NH_4-N	NO_3-N	OC	TN	AVP	Na	K	Ca	Mg	Cu	Fe	Mn	Zn
Control	6.93	16.45	11.75	1.08	0.06	21.8	0.16	0.6	9.9	4.25	0.05	1.34	4.44	0.15
5-t comp.	7.26	23.45	25.55	2.13	0.07	22.2	0.17	0.83	15.4	4.85	0.06	1.14	3.56	1.34
10-t comp.	4.82	32.9	32.7	2.21	0.08	22.4	0.19	1.06	22.1	3.34	0.08	1.32	2.80	2.11
15-t comp.	7.68	35.35	39.00	2.43	0.11	24.0	0.19	1.30	26.05	5.03	0.1	1.37	2.23	3.55
20-t comp.	7.78	24.45	41.7	3.47	0.13	25.0	0.23	1.57	29.45	5.08	0.1	1.50	2.14	4.51
60-kgN	7.57	34.15	17.95	1.31	0.12	22.4	0.12	0.64	9.8	4.58	0.06	1.10	3.32	0.46
120-kgN	7.58	42.35	28.8	1.52	0.14	22.5	0.15	0.62	9.24	4.51	0.06	1.11	3.15	0.39
180-kgN	7.86	59.15	25.55	1.98	0.19	23.1	0.13	0.60	9.33	4.1	0.07	1.25	2.98	0.43

4.4. Nitrate concentration in the leachate

Nitrate (NO_3-N) leaching loads at the end of the first twenty day showed progressive increments with increasing the rate of the applied MSW compost (5 t to 15 t ha^{-1}), whereas urea application accelerated NO_3-N concentration in the leachate particularly with the application of 92 kg N ha^{-1} followed with the application of 15 t compost ha^{-1} (Table 10 and 11). The greatest spikes flow of NO_3-N concentrations were observed during the first twenty day of monitoring where the value ranged from 14% to 92% with the application of MSW compost and urea at the rate of 5 t and 92 kgN ha^{-1}, respectively. However, the concentration of NO_3-N decreased sharply with time. The volume of outflow volume was subjected to the treatment variations where the highest volume of leachate observed with the control treatment, followed by urea application. The present finding also agreed with the previous results that stated the lowest volume of leachate volume was observed MSW compost at the rate of 15 t ha^{-1} (Keshavetah *et al*, 2011).

In general, the present findings showed that over fertilization and irrigation of both chemical fertilizer and MSW compost produced higher NO_3-N concentration in the soil solution that could contribute to surface and groundwater pollution. Moreover, the NO_3-N concentrations in chemical fertilizer applied at medium rate were by far greater than MSW compost applied at highest rate. Some scientists estimate that approximately 20 percent of the nitrogen in fertilizer leached to surface or ground water with extreme levels reaching as high as 80 percent for row crops in sandy soils (Howarth *et al.* 2002). However, there are often buffer zones placed between fertilized land use and surface water where dilution and further remediation would probably occur before runoff with NO_3-N concentration would reach water supplies, nutrients like NO_3-N and NH_4-N are ultimately mobile and could move into ground water (Keshavetah et al, 2011). Thus the levels of nitrate concentration seen in this study could be a problematic for aquatic organisms. For instance, Zachary M *et al.* (2002) stated that NO_3-N levels as low as 0.1mgL^{-1} can cause eutrophication that suggests that the use of aquatic toxicities may be a better indicator of water quality problem than human based maximum contaminant level (Zachary M *et al*., 2002).

Table 10. Effect of MSW compost and urea amendment on nitrate concentration in the leachate of Nitisol

	20 days after amendment					40 days after amendment				
Treatment		dsm^{-1}	ppm		mL		Ds L^{-1}	ppm		mL
ha^{-1}	pH	EC	NO_3-N	K	Outflow	pH	EC	NO_3-N	K	Outflow
Control	6.84	0.11	17.5	0.02	420	5.66	0.16	11.2	0.05	400
5-t compost	6.16	0.10	20.3	0.03	403	5.74	0.10	25.1	0.08	397
10-t compost	6.21	0.11	30.25	0.03	397	5.67	0.25	37.1	0.10	382
15-t compost	5.8	0.11	95.2	0.03	397	6.04	0.13	42.2	0.05	358
200-kg urea	7.35	0.21	245.7	0.04	406	5.54	0.39	111.3	0.16	390

Table 11. Effect of MSW compost and urea amendment on nitrate concentration in leachate of Nitisol (60 days after amendment)

Treatment ha^{-1}	pH	EC ds-^{1}m	NO_3-N ppm	K ppm	Out flow ml
Control	6.7	0.64	12.6	0.077	280
5-t compost	6.32	1.22	14.00	0.131	270
10-t compost	7.01	0.74	15.4	0.171	267
15-t compost	6.82	0.50	15.4	0.071	268
92-kgN	6.21	0.02	52.5	0.280	271

In carrying out the leaching operations, I assumed that soil in this region receive uniform and frequent rainfall causing substantial amount of nutrients leaching during rainy season of the country, Ethiopia.

4.5. Wheat response to MSW compost and urea application

The addition of MSW compost alone or in combination with N-fertilizer at different levels increased the height of the wheat over the control treatment (Table 12). The lowest value of wheat height (26.21 cm) was recorded from the control treatment, whereas the highest was 37.22 cm) with application of 60-kg N ha^{-1}, followed by 36.5 cm and 35.22 cm with application of 120-kg N ha^{-1} and 3-t compost ha^{-1} +20-kg N ha^{-1}, respectively. The application of above 60-kg N ha^{-1} on the soil used in the present study did not improve wheat yield and yield component. The application of 10 t compost ha^{-1} provided inferior to all other treatments except the control.

Either the sole application of MSW compost or in combination with N-fertilizer at various levels significantly increased wheat spike length over the control treatment. The highest spike length recorded was (4.77 cm) followed by 4.65 and (4.44) with application of 120-kg N, 1.67-t compost ha^{-1} + 40-kgN ha^{-1}, respectively. The fresh weight plants per pot were also showed significantly affected with the application of various rates of MSW compost and N-fertilizer. Furthermore, the maximum fresh weight (37.76 g pot^{-1}) was recorded with the application of 120-kg N ha^{-1} followed by (29.7 gmpot^{-1}), with application 60-kg N ha^{-1}. Similar results were reported elsewhere where favorable environment results in increasing water and nutrient use efficiency of plants (Sarwar *et al.,* 2008).

Table 12. Effect of MSW compost and urea fertilizer application on growth and yield component of wheat

Treatment (ha^{-1})	Plant height(cm)	Spike length (cm)	Fresh weight (g pot^{-1})	oven dry weight (g pot^{-1})	Grain yield (g pot^{-1})
Control	26.21 b	2.55d	13.93d	3.36 d	1.06b
2.5 t compost + 30 kg N	32.77 ab	4.22ba	22.3 cb	5.33 bcd	2.8 a
1.667 t compost + 40 kg N	30.44 ab	4.44 a	19.96Cbd	5.54 bc	2.83a
3.333 t compost + 20-kg N	35.22 a	4.11 bac	18.7 cbd	5.74 bc	3.2a
5 t compost	32.67 ab	3.33bdc	16.5cd	4.87 cd	2.5ba
60 kg N	37.22 a	4.77 a	25.4 b	6.91 ab	3.16a
10 t compost	30.22 ab	3.22dc	17 cd	4.85 cd	2.3ba
120 kg N	36.56 ab	4,65 a	37.76 a	8.35 a	2.2ba
Cv%	7.88	14.15	19.2	20.58	35.2
LSD $_{5\%}$	6.511	0.9592	6.97	2.0028	1.528

Means followed by the same letters within a column are not significantly different ($p<0.05$) probability level.

Total oven dry biomass of wheat increased significantly over the control with the application of MSW compost and N-fertilizer. The minimum oven dry weight (3.36 g pot^{-1}) was recorded in the control while the maximum oven dry biomass weight recorded was (8.35-g pot^{-1}) with the application of t 120-kg N ha^{-1}. Similar results were also reported by Ibrahim *et al*. (2008) indicating that the soil sample used for this experiment had low N content as revealed by soil total N. The highest wheat grain yield was 1280-kg ha^{-1} followed by 1266.8-kg ha^{-1} with the application of [3.3-t compost+20-kg N] and 60-kg N ha^{-1}, respectively. This resulted in 66% to 62% more grain yield than over the control treatment. The result of the study demonstrated that the application of N-fertilizer in conjunction with MSW compost can give far better result than either with the sole application of N-fertilizer or MSW compost. Similar results were also reported with the integrated N and P -fertilizers either with farmyard manure, and compost on wheat grain yield. In general, the present results clearly indicated that MSW compost is one of the potential fertilizer sources but underutilized in our country. Therefore, soil quality parameters can be improved with the integrated use of MSW compost and chemical fertilizers to sustain agricultural productivity and environmental quality.

4.6. Nutrient uptake of the wheat plant

MSW compost addition alone and in conjunction with urea enhanced the nutrients uptake of plants (Table 13). The concentration of nitrogen in wheat straw was substantially increased with the application of MSW compost alone or in conjunction with N-fertilizer The lowest percentage of total nitrogen (Nt) 0.91% was determined from control (whereas the highest Nt (1.26%) was observed with the application of 120-kg N ha^{-1}. Furthermore, the application of MSW compost at different levels enhanced the phosphorus concentration in wheat straw and combination of chemical fertilizer with MSW compost further improved the phosphorus concentration of the plant. Similar to Nt, the lowest concentration of P was 0.23% for control treatment, whereas the highest P was 0.29 % (T_2) with application of MSW compost at the rate of 2.50-t ha^{-1}+ 30-kg N ha^{-1} . The status of potassium uptake improved in wheat straw with application of either MSW compost in combination with N-fertilizer. The highest potassium concentration (19.52%) was observed with application of 120-kg N ha^{-1}, followed by (16.01%) with application of 60-kg N ha^{-1}. The results of this study realized that MSW compost and N-fertilizer best works for growth and yield attributes of wheat when applied in combination.

Table 13. Effects of MSW compost and urea on plant nutrient status

Treatmentha^{-1}	Nt %	Phosphorus(P) %	Potassium K %
Control	0.91	0.23	9.49
2.5-t compost + 30- kg N	1.16	0.29	14.68
1.667- t compost + 40- kgN	1.14	0.22	9.68
3.333- t compost + 20-kgN	1.17	0.22	11.84
5 -t compost	1.00	0.28	11.54
60- kg N	1.21	0.28	16.01
10 -t compost	1.06	0.19	9.99
120 –kgN	1.26	0.27	19.52

4.7. Economic benefit of municipal solid waste compost

Traditionally cost accounting system for composting does not include the hidden costs and benefits of environmental and social, since they are difficult to quantify. As a result, in the present study only financial analysis was made. Partial budget analysis for municipal solid waste compost and chemical fertilizer in wheat production

Table 14. Partial budget analysis for MSW compost and N fertilizer application for wheat product

Treatments	Average yield	Adjusted yield	Gross benefit	Cost of Comp.pre-paration	Cost of urea	Cost of Dap	Cost of comp applic	Cost of urea and dap app	Total cost that vary	Net benefit
(kg N ^{1}+ t com)ha^{-1}	Kg h a^{-1}		7 birr kg-1	50 birr t^{-1}	10birr/kg	10.6birr/kg	20birr/ton	0.1birr/kg	Ethi.birr	Eth.birr
0+0	426.68	418.14	2926.98	0	0	1060	0	10	1070	1856.96
30+2.5	1120	1097.6	7683.2	125	652	1060	50	16.52	1903.52	5779.68
40+1.667	1133.2	1110.54	7773.78	83.35	869.6	1060	33.34	18.69	2064.98	5708.8
20+3.333	1280	1254.4	8780.8	166.65	434.8	1060	66.66	14.34	1742.45	7038.35
0+5	1000	980	6860	250	0	1060	100	10	1420	5440
60+0	1266.8	1241.46	8690.22	0	1304.34	1060	0	23.04	2387.38	6302.84
0+10	920	901.6	6311.2	500	0	1060	200	10	1770	4541.2
120+0	880	862.4	6036.8	0	2608.69	1060	0	46.08	3714.77	2322.03

Table 15. The marginal rate of return for municipal solid waste compost and N fertilizer in wheat production

treatments kgNha-^{1}+comp,tha^{-1}	Cost that vary Eth .birr	Marginal cost Eth.birr	Net benefit Eth.birr	Marginal net benefit Eth .birr	Marginal rate of return%
0+0	1070	-	1856.96	-	-
0+5	1420	350	5440	3583.04	1024
20+3.333	1742.45	322.45	7038.35	1598.35	496
30+2.5	1903.52	133.52	5779.68	1238.48	927
60+0	2387.38	322.4	6302.84	594.04	184

The partial budget analysis revealed that the highest net benefit (7038.35 Eth. Birr ha^{-1}) was recorded for the combined application of MSW compost and 20-kg N ha^{-1} + 3.333-t ha^{-1} fertilizers followed by sole application of 60-kg N ha^{-1} (6302.84 Eth. Birr) (Table 13). However, the highest marginal rate of return (1024%) was obtained with the sole application of 5-t compost ha^{-1} which provided net benefit of (5440 Eth.Birr) compared to other treatments that provided less marginal rate of return. The study revealed that the combined application of MSW compost and N-fertilizer were more economical than sole application of either N-fertilizer or compost. However, further study needs to be conducted under field condition.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Municipal solid waste composing and use reduced emission of greenhouse gas compared with landfilling method of solid waste management. The reduction was mainly reached due to avoiding methane emission from landfills or illegally damping of the organic wastes. Moreover, the addition of MSW compost at different levels to Nitosol significantly increased the Nt organic C, available P, pH and other microelements. The organic C of the soil increased specially in the treatments where higher MSW compost was applied. This has important implication because all things being equal, soil with higher organic carbon become more productive than those with lower organic carbon. The addition of MSW compost had also positively responded on yield and yield component of wheat (*Triticum Aestivum L.).*The study demonstrated that the integrated use of MSW compost at 2.5-t compost ha^{-1} with 30-kg N ha^{-1} or 3.33-t compost with 20-kg N ha^{-1} appeared to be economical. The finding of the research also realized that high dose of N-fertilizer or MSW compost applications were not economically feasible and environmentally sound.

In general, the present study revealed that the application of both MSW compost and N-fertilizer increased the concentrations of NO_3-N fluxes in the collected leachate that clearly indicated fertilization during establishment poses serious threat to water quality in the absence of plant growth and appropriate soil management. The situation was further aggravated in with the highest dose of N regardless of the source of fertilizer. The concentration of NO_3-N from the control was only slightly less than treatments where medium application of MSW compost was made, Therefore, optimum application of either organic and/or chemical fertilizer can improve water holding capacity of the soil and reduces the contamination of surface and ground water by NO_3-N. Furthermore, composting should be considered as part of integrated solid waste management strategy with appropriate processing technologies selected based on market opportunities, economic feasibility, and social acceptance.

5.2 Recommendation

To enhance MSW composting integration with agricultural and horticultural activities and more focus on implementation and day –to –day operations are important research area in Ethiopia.

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Declaration

I, the undersigned, declare that this thesis entitled “Comparison of Environmental Performance and Economic benefit of Municipal Solid Waste Compost and Chemical fertilizer” is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and that all resources of materials used for this thesis have been duly acknowledged.

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This thesis has been submitted to the University with my approval as the University Advisor.

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