EFFECTS OF GREEN LEGUME BIOMASS ON SELECTED SOIL PROPERTIES AND YIELD OF CEREAL CROP IN JIMMA ZONE, SOUTHWESTERN ETHIOPIA

MSc. THESIS

BY

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Effects of Green Legume Biomass on Selected Soil Properties and Yield of Cereal Crop in Jimma Zone, Southwestern Ethiopia

By

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BIOGRAPHICAL SKETCH

The author, Tsegaye W/yohanis Bekele, was born on April 4, 1986 E.C. in Nada town, Omo Nada district, Jimma Zone, Oromia National Regional State, Ethiopia. He attended Nada Primary School from 1989 to 1997 and Asendabo Secondary School from 1998 to 2000. In 2001, he was enrolled at Alage Agricultural, Technical, Vocational, and Training College, graduating with a Diploma in Natural Resources Management in July 2003. After graduation, he worked as a development agent at the Omo Nada district Agricultural and Rural Development Office. In 2011, he joined Jimma University, where he earned a B.Sc. in Natural Resources Management in 2016. Following his B.Sc. degree, he served as a Natural Resources Management expert at the Omo Nada district Agricultural and Rural Development Office from 2017 to 2021. In September 2022, he began his M.Sc. studies in Natural Resource Management with a specialization in Watershed Management at JUCAVM.

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LIST OF ABBREVIATIONS

AS	Atomic Absorption Spector photometer
BD	Bulk Density
CEC	Cation Exchange Capacity
GM	Green manure
NF	Natural Fallow
RFP	Recommended Fertilizer Practices
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSA	Sub-Saharan Africa
TN	Total Nitrogen
EC	Electrical Conductivity
DM	Dry Matter
WHC	Water Holding Capacity

ABSTRACT

Soil degradation is one of the most pressing environmental challenges the world faces today. It involves the decline in soil quality and productivity due to factors such as erosion, nutrient depletion, and pollution. This degradation compromises the soil's ability to support plant life, affecting food security and biodiversity. This study investigates the impact of green manure from lablab and lupin legumes on the physicochemical properties of soil and wheat yield in Omo Nada district, Ethiopia. The experimental sites were selected based on the ongoing survey results on abandoned crop lands and farmers' feedback on yield responsiveness to chemical fertilizer application. The fallow crops were established using legumes such as lablab and lupin on a gross plot size of 4m × 4m.Initial soil analysis revealed clay-dominant, moderately to strongly acidic soils (pH 5.4-5.9). Post-application of lablab green manure showed no significant changes in most soil chemical properties, though soil pH ranged from 4.8 to 5.45 and total nitrogen from 0.15 to 0.19 mg kg^{-1}. Lablab treatments resulted in higher nutrient values, with promising soil organic carbon buildup. Conversely, lupin green manure significantly ($p<0.05$) affected soil pH and sulfur content, with pH ranging from 5.02 to 5.82 and sulfur from 7.59 to 14.9 mg/kg. Lupin outperformed lablab in modifying soil pH. Soil fertility parameters such as soil organic carbon, total nitrogen, available phosphorus, and C: N ratio improved significantly with lablab green manure. In contrast, nutrients like calcium, magnesium, potassium, and sulfur showed decreased concentrations. Lupin green manure also led to significant increases in available P, Ca, and K, but OC and TN concentrations decreased. Both green manures enhanced soil P levels compared to inorganic fertilizer treatments. Wheat yield and harvest index significantly benefited from green manure treatments, particularly lablab, which showed grain yield increases of 30-105% over recommended fertilizer. Lablab treatments whole biomass, below ground, Above Ground, and AG+50%RIF showed the highest yield advantages. The findings indicate that short-term fallow of lablab can improve soil fertility and subsequent wheat productivity, reducing fertilizer costs. Overall, incorporating green manures can enhance soil nutrient levels and wheat yield, promoting sustainable agricultural practices. Further research is recommended to explore the long-term benefits and economic viability of these green manure practices.

Keywords: Lablab, Lupin, wheat yield, soil pH, organic matter

1. INTRODUCTION

1.1. Background and Justification

Soil deterioration is one of the world's most pressing environmental challenges right now (Fanish, 2017). Inappropriate technological usage has led the quality of the soil to degrade, leading in the loss of organic matter and the degradation of the soil's structure, which has an influence on the movement of nutrients, air, and water and, eventually, on plant development (Ayub et al., 2020). Because of this, adding organic matter to the soil, including green manure, has grown to be a popular and significant agricultural practice that benefits the environment by restoring soil quality, preserving soil organic matter, reclaiming degraded soils, and providing nutrients to plants (Chimouriya *et al.,* 2018). Globally, there are several types of green manure crops that support soil nutrient dynamics and promote soil health (Fanish, 2017).

Green manuring is the process of turning green plants into the soil either by raising them in the same field or plants grown elsewhere at the green stage before flowering and being incorporated into the soil (Das *et al*., 2020). Since it can increase cropping system sustainability by reducing soil erosion and improving soil physical properties, soil organic matter and fertility levels, nutrient retention (Dinnes *et al*., 2002), and lowering the global warming potential (Robertson *et al*., 2000).

The use of organic fertilizers, such as green manure crops, has increased dramatically in recent years due to concerns about the environment and the need to reduce input costs (Iderawumi and Kamal, 2022). Because they think it's more economical and environmentally beneficial than using inorganic mineral fertilizers (Wang *et al.,* 2018). The global community would maintain soil fertility and biodiversity in order to balance food supply, population growth, and environmental safety. To attain this aim, several governments have adopted various initiatives to conserve and sustainably exploit biological variety (Leonard, 2021). Planting crops that will decompose in the soil is a method used to replenish nutrients and enhance organic matter. In order to prevent soil erosion and serve as winter cover crops or to increase the productivity of depleted land, green manure crops are typically grown in between the main crops (Abdulraheem and Lawal, 2021). In developing and populated nations, restoring the soil fertility of agricultural land is a major task. Ethiopia's present trend of decreased agricultural output or stagnant crop yields is the consequence of a number of soil-related constraints. The acceptance of ineffective soil management approaches, widespread burning of crop residues, rash adoption of agronomic procedures, and asymmetric nutrient management are all evidence of low crop yields (Florentin *et al.*, 2011). Furthermore, declining agricultural output per unit of land area is also possible due to declining soil organic matter, sparse application of bio- and organic fertilizers, and inadequate management (Reddy *et al.*, 2022). The principal causes of low crop productivity are increasing agricultural techniques that deplete soil organic matter, which might be viewed as a serious danger to crop production sustainability.

Many farmers have decided to use green manures in order to improve soil fertility and demonstrate their commitment to long-term agricultural sustainability. However, not all farmers now employ green manure to replenish depleted soils. Reducing the amount of organic nutrients in the soil weakens the soil’s ability to hold water, bargain with organic absorption, and lower cation exchange capacity (Abdulraheem *et al*., 2012). All of these ultimately contribute to nutrition absorption via the mineralization of organic material (Bonini and Alves, 2010).

An effective tool for the crop’s optimum growth is green manuring. By incorporating nutrients like nitrogen into the soil, it aids in preserving soil fertility and the soil’s overall condition. (Iderawumi and Kamal, 2022). Green manuring, according to Pandey *et al*. (2008), improved the physical and biochemical structure of the soil, decreased nutrient losses through leaching, and increased water holding capacity. A few obstacles need to be removed for this method to work properly, such as providing farmers with high-quality manure seeds and conducting more studies on green manure crops to understand their potential.

Green manuring has been widely practiced, but in recent years, interest in it has declined due to increased pressure for food production, the presence of other competitive and profitable crops, and the accessibility of both cheap and expensive artificial fertilizers. Green manures have recently regained importance for both organic growers and low-input farms using conventional agronomic methods due to access to soil issues, depletion of soil fertility, and public concern about abuse and energy conservation (Kumar *et al*., 2014). The best green manure crops are those that have fast growth and early canopy cover, high N_2-fixing capacity. This is because they are efficient in capturing and recycling nutrients, and decompose easily. Green manure legume species such as lupin and lablab were selected and grown on selected degraded cropland. These legumes have previously been demonstrated to have quick growth, favorable impacts on restoring soil physicochemical qualities of degraded farmland, and considerable residual effects on following cereal crops such as wheat (Amede et al., 2021). However, the efficacy of green manuring by partitioning the biomass for improving the soil fertility of degraded lands and crop yield in Ethiopia, particularly in the study area (Omo Nada) has not yet been thoroughly investigated.

1.2. Statement of Problems

A significant barrier to plant growth and higher production is soil deterioration in developing countries. The loss of organic matter, the buildup of pollutants in the soil, the decline in crop production, and the loss of soil fertility are all examples of how the quality of the soil has deteriorated. The future of agriculture is unfavorable due to excessive tillage, continuous cropping, and heavy pesticide use. We need to employ green manure, vermi compost, compost, bio-fertilizers, amrit jal, vermin wash, etc. to stop the trend of soil degradation and to achieve sustainable agriculture (Fudzagbo and Abdulraheem, 2020; Abdulraheem and Onifade, 2021). One of the best options to enhance soil health and provide for the nutritional needs of future crops is green manuring. Inter seeding legumes between main crops as green manure could be an alternative to succession or rotational cropping. Furthermore, determining the optimal timing for turning around green manure legumes would be important in reducing their competitive influence on major crops. Nevertheless, scientific studies are limited with respect to green manure legumes incorporation in tropical conditions as mechanisms of soil fertility restoration and sustainable crop production. As a result, the current experiment was designed to determine if the integration of green biomass from legumes enhances the physicochemical qualities and response of wheat.

1.3. Objectives

1.3.1. General objectives

- To examine the potential effects of green legume biomass on selected soil properties and yield of cereal crop

1.3.2. Specific objective

- To evaluate the effect of green manure biomass incorporation on soil physicochemical properties.
- To determine the growth and yield response of wheat to green manure incorporation.

1.4. Research Questions

- Do legume green manures have positive effects on selected soil physicochemical properties of degraded crop land?
- Is there any significant yield response of a cereal crop wheat grown after the incorporation of green manures on degraded crop land

2. LITERATURE REVIEW

2.1. Green Manuring

Growing green manure as part of a crop rotation is an essential a part of organic farming systems. Green manures are plant life grown to build up nutrients for the principle crop. When they have constructed up most biomass (whilst green, or soon after flowering (Dubey *et al.,* 2015) green manure plants are dug into the soil and at this factor, they release nutrients and become fully decomposed within a short period of time (Eyhorn *et al*., 2004)

The green manure should be prepared to be incorporated earlier than the next crop is sown. There must no longer be a long gap between digging within the green manure and planting the following crop. This is to prevent nutrients from the green manure from leaching out of the soil before being taken up with the aid of the next crop (Puig *et al.,* 2013). The time gap should no longer than 2 to 3 weeks and green manure should not be ploughed deeply into the soil but only worked into the surface soil (Cherr *et al.,* 2006).

Legumes applied as green manure continue to be a critical supply of nitrogen in lots of crop production systems (Meena *et al.,* 2018). One truth to be considered is that the benefits of green manures occur over a long time and aren't usually visible right away (Eyhorn *et al*., 2004). They not only serve as a direct source of plant-available nitrogen but also have a great potential for increasing the availability of soil nitrogen to subsequent crop plants, conserving nitrogen, and enhancing long-term soil fertility (Ashraf *et al.,* 2004). Legumes also are recognized to be successful in the mineralization of soil local nitrogen which might be a crucial mechanism through which green manures enhance soil productivity (Yuvaraj *et al.,* 2020).

Caporali *et al*., (2004) suggested that the quantity of nitrogen contributed via the green manure depended upon the species and the weather trend that determined the energy and length of the green manure increase cycle. He said that the non-leguminous green manure had a bit effect on next maize yield and grain and straw nitrogen accumulation, compared to green manuring by leguminous. Weed growth in maize was also affected by cover crop green manuring, and their aboveground biomass and density were lower with the selected cover crops than the control treatment. These results suggest that legume green manuring can allow good yield of maize besides helping a successful weed control (McCauley, 2011).

Vetch (Vicia sativa) and faba bean (Viciafaba) have been examined as green manures in natural cotton production in clay loam soil (Athens, Greece) in 2005 and 2006. In both years, root formation turned into promoted as root dry matter, root duration density, root diameter, and root floor place in plots in which vetch become incorporated. Results show no significant effect of green manuring on yield (Abera and Gerkabo, 2021).

2.2. Green Manure in Sustainable Agriculture

Utilizing green manure as an additional to artificial fertilizers is crucial to sustainable agriculture. A market gardener, a home gardener, or a major agricultural initiative can all benefit from green manure, a stimulating element of sustainable agriculture. Market gardeners need to make the most of the soil while improving the health of the ground because they frequently try to maximize production on a short amount of land. Small-scale market gardeners are not the only ones that employ green manure, though. On large farms, it can also be utilized to improve soil health and production. Sustainable production methods are part of organic agriculture and help to restore the natural equilibrium that has been disturbed by incorrect farming practices. It is a different type of agriculture that allows for soil fertility to be achieved through green manuring and crop rotation as an alternative to synthetic chemical pesticides and fertilizers, which are environmentally dangerous agricultural production inputs **(**Girma, 2017**).**

Green manuring and organic fertilization are of importance to scientists in terms of soil sustainability and crop productivity (Fageria, 2007), who discovered interesting facts like the benefits of green manuring in crop yields should be evaluated both in combination with chemical fertilizers and in isolation. GM is preferred over other organic fertilizers because they are created immediately in the field and are easier to absorb during plowing or regular weeding efforts (Tamiru, 2013). The usage of green manure in combination with fertilizers is required due to existing growing challenges. Green manuring is a sustainable alternative to summer fallowing in agricultural systems. There are several advantages to using green manure. GM adds a significant amount of humus to the soil, which is critical for crop growth.

One of the most important benefits of green manure is that it provides a substantial amount of nitrogen and organic matter to the soil. Some green manure crops have a deep root system that can aid in lifting nutrients from deeper levels of the soil and release them in the top layer, where the next crop can easily access them. Soil structure and aggregates are the basic units of soil structure and aggregates, and organic matter plays a vital role in aggregate and structure stability (Annabi *et al*., 2007). We need to employ green manure, vermi compost, compost, bio-fertilizers, amrit jal, vermiwash, etc. to stop the trend of soil degradation and to achieve sustainable agriculture (Fudzagbo and Abdulraheem, 2020; Abdulraheem and Onifade, 2021), among other things. One of the best options to enhance soil health and provide for the nutritional needs of future crops is green manuring.

2.3. Green Manure towards Improvement of Soil Fertility Enhancement

One of the most crucial challenges in organic agriculture is the management of soil fertility. In this agricultural method, fertilization with organic and natural materials is required. In a study on cabbage, Moyin-Jesu (2015) came to the conclusion that using poultry manure can enhance soil fertility, assure environmental sustainability, and generate large economic benefits. There are two primary sources of nutrients, namely the breakdown of soil minerals and the decomposition of organic matter (Meena *et al.,* 2018). According to the type of mineral source, the release of nutrients from soil mineral breakdown is much slower, and may take centuries for a reasonable amount of nutrients to be released. In contrast, the release of nutrients from organic materials can start within a few days to many years and last for centuries (Lambers *et al.*, 2019).

Additionally, the ability to recycle nutrients was increased through the use of green manures between crop cycles. Higher agricultural yields are a result of the improved soil characteristics of the available land (Iderawumi and Kamal, 2022). One method to enhance soil structure, stop soil erosion, maintain soil moisture, and increase the amount of organic matter in the soil is to use “green manure”. Additionally, green manuring stops soil erosion, ensuring that the nutrients essential for plant nourishment stay in the soil (Meena *et al*., 2018).

2.3.1 Effect of Green Manure on Soil Physical Properties

Soil microbial biomass is recommended as an ecological factor to evaluate changes in soil usage and management characteristics since it is a significant biological property (Santos *et al.,* 2012). Additionally, soil microbial biomass contains enzymes that are crucial to soil activities such the atomization of organic materials. Due to its influence on microbiological advancement, soil agitator action ability is to be used as a measure of soil quality (Maitra *et al.,* 2018). A clear measure of soil health, soil microbial biomass reacts to changes in soil management. Crops grown with green manure aid in boosting soil organic matter, water retention ability, microbial biomass, and nutrient uptake efficiency... Additionally, it results in a decrease in soil erosion nutrients (Iderawumi and Kamal, 2022). We can deliver the nutrients to the plant more effectively by applying high-quality green manure crops like legumes that have low lignin content and low carbon-to-nitrogen ratios because the nutrition is supplied to the plant more quickly. Legumes are usually utilized as green manure crops as they fix atmospheric nitrogen in the root nodules through symbiotic fixation with a bacterium (*Rhizobium*) and leave part of it for utilization of the companion or succeeding crop (Kebede, 2021).

Soil bulk density (BD)

Soil bulk density (BD) is defined as the mass of oven-dried solids divided by the bulk volume of the solids plus pore space at specified soil water content, usually the moisture content at sampling (Mohan and Prasadini, 2019). It is an indirect measure of the total pore space which is also affected by texture and structure. The BD of fine textured mineral soils usually ranges from about 1.0 to 1.5 g/cm^3, and that of sandy soils from 1.3 to 1.7 g/cm^3, whereas, the BD of organic soils is usually much less than that of mineral soils and may be as low as 0.4 g/cm^3 (Estefan *et al*.,2013). White (2006) ranged the values of BD from <1 g cm^3 for soils high in OM, 1.0 to 1.4 g cm^3 for well- aggregated loamy soils, and 1.2 to 1.8 g cm^3 for sands and compacted horizons in the clay soils. The ideal BD for plant growth is <1.60 and <1.40 g cm^3 for loam/clay loam and clay soils, respectively **(**Schroeder *et al*., 2022).

Soil moisture content (SMC)

Soil microbial biomass is recommended as an ecological factor to evaluate changes in soil usage and management characteristics since it is a significant biological property (Singh and

Gupta, 2018). Additionally, according to Silva *et al.* (2012) soil microbial biomass contains enzymes that are crucial to soil activities such as the atomization of organic materials. Due to its influence on microbiological advancement, soil agitator action ability is to be used as a measure of soil quality and handle moisture for a long time (Iderawumi and Kamal, 2022). A clear measure of soil health, soil microbial biomass reacts to changes in soil management. Crops grown with green manure aid in boosting soil organic matter, water retention ability, microbial biomass, and nutrient uptake efficiency (Meena *et al*., 2018).

2.3.2. Effect of Green Manure on Soil Chemical Properties

Green manuring is a technique or method that can be used to improve the soil's qualities, which will finally result in good production. As leguminous crops are utilized, which fix atmospheric nitrogen in the root nodules by developing symbiotic relationships with rhizobium bacteria, nitrogen is the main nutrient that is added by the practice of green manure. Organic matter is also additional to the soil via green manuring (Iderawumi and Kamal, 2022). Recently, it has been assumed that green manures' primary effects on soil quality enhancement are related to an increase in soil organic matter (SOM) levels, nutrient availability and cation exchange capacity (CEC), organic acid formation, a decrease in Al^{3+} levels, and the recycling and mobilization of nutrients from deeper soil layers. The addition and balancing of SOM are crucial for the recovery of damaged soils in tropical contexts because biological activity, such as root action, macro- and microbiological activity, and organic material decomposition, is the only way to restore and sustain soil physical conditions (Abdulraheem and Tobe, 2022).

Soil organic matter (SOM)

Soil organic matter, which depends on biomass amount to offset mineralization, has a specific impact on soil fertility. N is the most studied nutrient, but P and K levels are also significant. Higher biomass return to the soil can improve soil organic carbon and soil total N. Farms and particularly biologic farming, depend heavily on the soil organic matter (SOM). By being incorporated into the soil, green manure helps to improve its physical and chemical characteristics and plant growth (Ding *et al*., 2021; Seminchenko and Sukhareva, 2022). Then, in cropping systems, green manure legumes supply nutrients to crops based on their capacity to fix biological nitrogen (Edmilson *et al*., 2013). Millions of microorganisms reside in the organic matter of the soil, which is broken down by bacteria and makes nitrogen available to plants (Zhouet *et al.,* 2021).

Carbon, nitrogen, zinc, and other plant nutrients from organic inputs are retained depending on the microbial population in the nearby environment (Costerousse *et al.,* 2021) and biochars (Kassio *et al.,* 2017). Utilizing green manure, soil microorganism change nitrogenous and carbon molecules into nutrients that plants may receive (Leonard, 2021). In the plants, the roots absorbed a higher concentration of nutrients than the shoots (Zandvakili *et al*., 2017). When compared to controlled fields, the allowed use of green manuring produced significant levels of organic matter reserves that improved the physical and chemical qualities of the soil. Additionally, the ability to recycle nutrients was increased through the use of green manures between crop cycles. Higher agricultural yields are a result of the improved soil characteristics of the available land (Iderawumi and Kamal, 2022)

Soil organic carbon (SOC)

The SOC is a greater suitable index for crop production in arid and semiarid regions, because it has high-quality consequences on the WHC. The penetration of green manure roots, particularly dhaincha and sun hemp in soil, holds it in place and prevents soil erosion (Tanveer and Ikram, 2019). Green gram and sesbania green manuring decreased the soil *pb* to the extent of 0.03–0.07 Mg m^3 and enhanced the mean weight diameter of soil aggregates in the upper layer of soil when compared to fallow soils during the growth of rice and wheat (Meena *et al*., 2018). In sandy soils, green manure helps to hold more water by reducing drainage rate through improvement in soil physical properties (Selvi and Kalpana, 2009; Yadav *et al.,* 2017).

Total nitrogen (TN)

Green manure crops help in the fixation of atmospheric nitrogen by forming a mutual correlation with the legumes. Rhizobium species have the capacity to fix the nitrogen into the soil according to the nutrient demand of the plant. They fix the nitrogen in the roots by the formation of root nodules which provide ground to the Rhizobium present in the rhizosphere. The binding material present in the soil comes from the carbonic acid which is released from carbon dioxide after decomposition (Kumar *et al.,* 2018; Kumar and Hemantaranjan, 2017); Dwivedi and Prasann, 2016). Meena *et al*. (2018) reported that legumes could contribute to

40% of total N fixation in the world as a result of their symbiotic relationship with *Rhizobium* bacteria, and can meet 50-80% of plant N requirement with biological nitrogen fixation.

Available phosphorus (AVP)

Some legumes can change the unavailable form of phosphorus (P) to the available form by releasing some organic acids an enzymes by the roots, resulting in an increase of P availability in the soil and bringing P increase abundance in a cropping system (Gogoi *et al.*, 2018; Sumiahadi *et al.,* 2018). The use of legumes in rotations may enhance P availability and yields of the subsequent cereal crop. P-efficient legumes such as white lupin (*Lupinus albus*) and pigeon pea (*Cajanus Cajan*) are characterized by rhizosphere processes (acidification of the rhizosphere and/or excretion of organic acids) that allow these species to mobilize P from sparingly soluble P pools (Gaind, 2017). The P is taken up by the legume and partly returns to the soil through the residues as a high-quality organic P source for the subsequent cereal crop (Mitran *et al*., 2018).

Cation exchange capacity (CEC)

As leguminous crops are utilized, which fix atmospheric nitrogen in the root nodules by developing symbiotic relationships with rhizobium bacteria, nitrogen is the main nutrient that is added by the process of green manure. Organic matter is also added to the soil via green manuring (Meena *et al*., 2018). Recently, it has been expected that green manures' primary effects on soil quality improvement are related to an increase in soil organic matter (SOM) levels, nutrient availability and cation exchange capacity (CEC), organic acid formation, a decrease in Al_3^+ levels, and the recycling and mobilization of nutrients from deeper soil layers. The addition and balancing of SOM are critical for the recovery of damaged soils in tropical environments because biological activity, such as root action, macro- and microbiological activity, and organic material decomposition, is the only way to restore and sustain soil physical conditions (Abdulraheem and Tobe, 2022).

2.4. Effect of Green Manures on Crop Yield

In cropping systems, green manure legumes supply nutrients to crops based on their capability to restore organic nitrogen (Edmilson *et al*., 2013). Millions of microorganisms reside in the organic matter of the soil, which is broken down by bacteria and makes nitrogen available to plants (Zhou *et al*., 2021). Technically, applying organic, inorganic, or a combination of both fertilizers can maintain or enhance soil fertility (Abdulraheem *et al.,* 2022a).

Organic additions are better for developing a sustainable agriculture system than inorganic fertilizers (Abdulraheem *et al.,* 2022b). Although the application of organic fertilizer has not always met the requirement for nutrients since it depends on a variety of variables, such as the pace of decomposition and the release of nutrients, it can also provide physical and biological changes in the soil (Hayat *et al*., 2010; Egbe *et al*., 2012).

Crops grown with green manure are used for improving soil organic matter, water retention ability, microbial biomass, and nutrient uptake efficiency. Additionally, it results in a decrease in soil erosion nutrients (Iderawumi and Kamal, 2022). We can deliver the nutrients to the plant more effectively by applying high-quality green manure crops like legumes that have low lignin content and low carbon-to-nitrogen ratios because the nutrition is supplied to the plant more quickly. Legumes are usually utilized as green manure crops as they fix atmospheric nitrogen in the root nodules through symbiotic fixation with a bacterium (*Rhizobium*) and leave part of it for utilization of the companion or succeeding crop (Kebede, 2021).

According to past studies, applying green manures to soil sparked soil microbial growth, which led to the subsequent mineralization of plant nutrients and increased soil quantity and quality (Chimouriya *et al.,* 2018). In light of the microbiological activity of the soil, it is possible to remark that green admixture supplies nutrients abundant in organic carbon for the microbial biomass, which transforms bare nutrients in bulb leftovers into accessible for the crops and improves the variety of soil microorganisms (Iderawumi and Kamal, 2022). Utilizing green manures has several advantages, one of which is the release of nutrients from plant biomass. The nitrogen (N) nutrient, which has been one of the most limiting in productive systems, has recently drawn increasing attention due to its increased mobility in the soil (Robertson and Vitousek, 2009). Because they can fix nitrogen, members from the Fabaceae family should specifically be used as green manure. This trait greatly reduces the use of conventional chemical fertilizers while also greatly increasing the economic return of the primary activity.

3. MATERIAL AND METHODS

3.1. Description of The Study Area

3.1.1. Location

The study was conducted in Omo Nada district, Jimma zone, Southwestern Ethiopia. Omo Nada district, one of 20 districts of Jimma zone, is located about 72 km away from Jimma town, and 294 km Southwest of Addis Ababa. Its specific location lies between 7^0 36' 00.87'' - 7^0 41' 05.72'N latitude and 37^0 16' 55.88''- 37^0 14' 40.73'' E longitude with an area of 80,508.666 ha. The district is bordered by Omo Beyam district to the South, by Mancho and Dedo to the West, by Kersa to the North West, Tiro Afeta to the North, by Sokoru to the North East, and by the Omo River to the East which separates it from the SNNPRS (ONDANRO, 2021 *unpublished*).

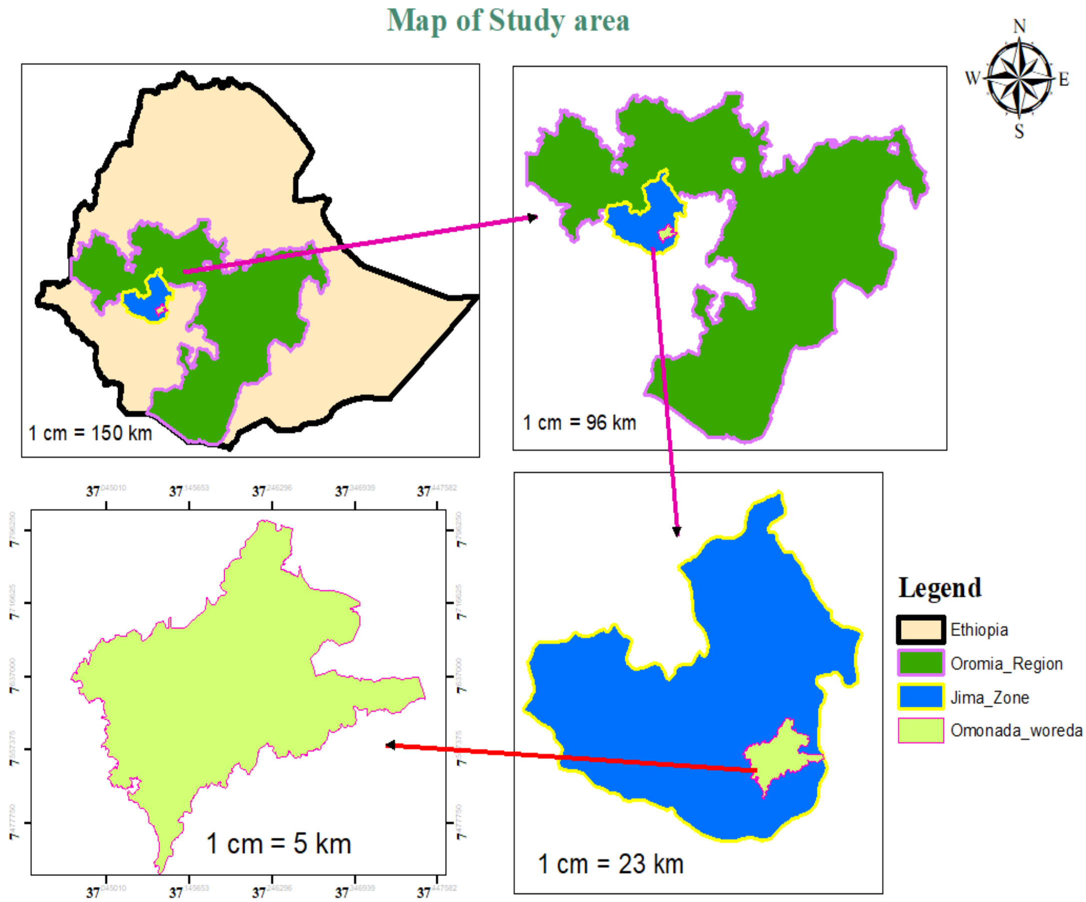

Figure 1: Location map of the study area

3.1.2 Climate of the study area

The agro-ecological zone of district 62.7% covers *Woina Dega* (midland), 23.9% *Dega* (highland), and 13.58 *Kola* (lowland) areas. The climatic condition is generally wet *Woina Dega*, the mean annual rainfall ranges between 1280-1600 mm and the annual temperature varies within the range of a maximum of 25-30^{0}C and minimum of 12.4-15^{0}C. The rainfall pattern generally is uni-modal, with over 70 percent falling between April and August while the main rainy season (*kiremt*) ranges from July - September, and the dry season in the area is mostly from October to February (ONDANRO, 2021 *unpublished data*).

3.1.3 Topography and soil of the study area

The area is characterized by gentle, flat, and undulating topography with altitudes ranging from 1017–2952 m.a.s.l. The large number of soils in the study area is dominated by Dystric Fluvisols followed by Cromic Vertisols and Dystric Nitosols some Orthic Acrisols and Eutric Fluvisols (Alemayehu *et al*., 2014).

3.1.4 Population of the study area

The district has 24 rural kebeles and four urban centers which are divided into 7 kebeles. The total population of the district is 198,618 which is the aggregate of 99,508 male populations and 99,110 female populations. The total households in the district are 22,681 which is the aggregate of 21,451 male and 1,230 female. From the total population, the number of the population living in rural areas and urban centers were 175,321 and 23,297 respectively. The district has also a total livestock population of 527,667, poultry 192,979, and beehives 32467 (ONDANRO, 2021 *unpublished data*).

3.1.5 Vegetation cover of the study area

The vegetation cover has been removed and replaced by cultivation fields grazing land and plantation of exotic species such as: eucalyptus species mainly *Eucalyptus globules* and *camandulensis and Geravillia robusta.* Remnants of the indigenous vegetation such as *Cordia africana, Ficusvaita, Croton mycrostachyus, Acacia abysinica, Olea africana Juniperus procera, Podocarpusgracilor,* and other indigenous species are found scattered here and there. Thus, like other parts of the country, the natural vegetation of the area has been victim of the influence of man and its domestic animals. For instance, the grazing land, natural forest, and fallow lands are decreasing from time to time while cultivated and residential lands are increasing. Accordingly, from the total area of the district (80,508.666 ha) cultivated land (the lands covered by annual and perennial crops) accounts for about 45,430.768 ha, vegetation covered (forest, woodland, bush, and shrub) accounts for about 4,747.1971 ha, and grazing land accounts about 17,743 ha, construction 4,638.428 ha, the land which is unusable for cultivation is 1,150.1802 ha, as well other lands accounts about 6,799.0927 ha. Cereal (86.7 percent), pulses (12.5%), and oil seeds (0.8 percent) .whereas maize accounts for 63.3 percent of total cultivated land. (ONDANRO, 2021 *unpublished data*).

3.1.6 The farming system of the study area

The major crops growing in the district are Maize (*Zea mays*), Teff (*Eragrostis tef*), Sorghum (*Sorghum bicolor*), Wheat (*Tiriticum vulgare*), Barley (*Hordeum vulgare*), and other pulse crops. The farming system is generally characterized by mixed subsistence farming which includes crop production and livestock raring and in some areas cash crop production like Pepper. It has wide potential for crop production regardless of low rainfall, high diversification of crops, so as to cope with adverse weather as well as high-level utilization of modern agricultural packages (extension) such as improved seeds, fertilizers, and other related inputs, high opportunities of off-farm employment are distinct characteristics of the study area. Most of the land is flat to gently sloping and is very conducive even for mechanization. There are some small-scale irrigation practices near Nada, Beyam, Qawa, and Dima River using motor pumps and also Lake Gibe (Dam-I) for hydropower and fishing (ONDANRO, 2021 *unpublished data*).

3.1.7 Profile of Selected Watersheds in the study area

Elfeta and Gola watersheds are located in Doyo Yaya and Goro Sedan kebeles of Omo Nada district Jimma zone of Oromia Regional State respectively. These watersheds are identified during the year 2012 and cover 27 villages. The watershed has 455 land-holding families. The farming system in the watersheds is mixed farming, with crop husbandry being the most essential component of the farmers' livelihood. Crop husbandry is characterized by the cultivation of annual crops such as cereals and some vegetables. The largest number of the land is cultivated by cereals like maize, "teff', and wheat (Omo Nada Agricultural Bureau (2021).

3.2. Types and source of data

In order to attain the main goal of the research, both primary and secondary data were collected and used. The primary data were collected from lab results and field observations. To get the primary data, the study employed a two-stage sampling techniques. First Doyo Yaya and Goro Sedan kebele were purposively selected from 24 kebeles of Omo nada district due to their high potential and more experience in natural resource management. To get a general overview and identify the study site, a reconnaissance survey was conducted. According to the information supported by district experts, DAs, and local people, the whole area of the study site was fully covered with natural forest that had been degraded gradually due to the lack of proper management. As a result of significant deterioration, local residents are vulnerable to low production, erosion, and floods. Secondary data were gathered from all available written records, published and unpublished journals, and electronic resources. .

3.2 Experimental Layout and Treatments

The experimental sites were selected based on the ongoing survey results on abandoned croplands and farmers' feedback on yield responsiveness to chemical fertilizer application. Two sets of sequential experiments were established: 1) growing the legume fallow crops, and 2) growing cereals following the incorporation of the legume biomass as green manure. The fallow crops were established using legumes such as **lablab and lupin** on a gross plot size of **4m × 4m**. There were three levels of green manure plant parts incorporated into the soil: shoot biomass only (SB or above ground (AG)), root (below ground) only (BG), and whole plant biomass (WPB) of lablab and lupine.

Natural Fallow (NF) and growing cereals with three fertilizer levels of 0, 50%, and 100% of the recommended inorganic fertilizer (RIF) were also included in the treatments on the same plot size. The treatments were arranged in a randomized complete block design laid out in two degraded croplands.

The legume fallow crops were sown at the seed rate of 60 kg ha^{-1}, following the onset of small rains at the beginning of May (the belg season in Ethiopia). Two legume crops were selected lablab and lupin. During planting, 100 kg NPS-B ha^{-1} was applied for all the legume crops to ensure adequate plant growth and biomass production. Harvesting of the legume fallow crops was done at the flowering stage of each legume and incorporated into targeted plots as per the experimental design just three weeks before planting the cereal. Each treatment was assigned in the same plot:

(i) The shoot biomass-only treatment is a non-treated plot, which received biomass transferred from the harvest of green manures grown in another plot;

(ii) The root-only treatment is the source, from where the shoot was harvested and transferred to other non-treated plot and

(iii) The whole biomass plot is where the green manure was incorporated into the same plot where the legume was grown.

Wheat was sown during the main rainy season following the incorporation of the legume biomass with three fertilizer levels of 0, 50%, and 100% of the recommended inorganic fertilizer (RIF). Crop phenology, grain yield and its components, and grain quality were recorded for the cereal. The experiment included seven treatments with three replications and (2 legumes crops*7 treatments * 3 replications) 42 number of observations.

Table 1. Treatments of the study

Treatment Code	Legume Type	Green Manure Type	Fertilizer Level	Description	Sites
T1	-	-	100% RIF	Natural fallow, 100% recommended fertilizer	Site1 (Doyo Yaya
T2	Lablab	Above ground (AG)	0% RIF	Shoot biomass only, no additional fertilizer	
T3	Lablab	Above ground (AG)	50% RIF	Shoot biomass only, 50% recommended fertilizer	
T4	Lablab	Below Ground (BG)	0% RIF	Root biomass only, no additional fertilizer	
T5	Lablab	Below Ground (BG)	50% RIF	Root biomass only, 50% recommended fertilizer	
T6	-	-	0% RIF	Natural fallow, no additional fertilizer	
T7	Lablab	Whole Biomass (WH)	0% RIF	Whole plant biomass, no additional fertilizer	
T1	-	-	100% RIF	Natural fallow, 100% recommended fertilizer	Site 2 (Goro Sedan
T2	Lupin	Above ground (AG)	0% RIF	Shoot biomass only, no additional fertilizer	
T3	Lupin	Above ground (AG)	50% RIF	Shoot biomass only, 50% recommended fertilizer	
T4	Lupin	Below Ground (BG)	0% RIF	Root biomass only, no additional fertilizer	
T5	Lupin	Below Ground (BG)	50% RIF	Root biomass only, 50% recommended fertilizer	
T6	-	-	0% RIF	Natural fallow, no additional fertilizer	
T7	Lupin	Whole Biomass (WH)	0% RIF	Whole plant biomass, no additional fertilizer	

3.2.1 Soil sampling and analysis

Initial soil samples were collected randomly from the permanent plots of Omo Nada site at a depth of 0–20 cm before and after the experiment using an auger and core sampler. The soil samples were thoroughly mixed to form a composite soil sample and used for the determination of the soil's physical and chemical properties. The collected soil samples were air-dried, crushed by using a mortar and pestle then passed through a 2-mm sieve and oven-dried for bulk density and moisture contents.

The pH and EC of the soil samples were determined and measured at 1:2.5 water to-solid ratio after shaking for 30 min with distilled/deionized water (Rayment and Higginson, 1992). Soil texture was determined by using the Hydrometer method (Sternberg and Creager, 1961). The CEC of the soils and samples were measured by using 1 M ammonium acetate (CH_3COONH_4) (at pH 7) (Rayment and Higginson, 1992). Potassium (K) and sodium (Na) were analyzed by using a flame photometer. Organic carbon was determined by the Walkley-Black oxidation method and total nitrogen (TN) by the Kjeldahl method (Van Reeuwijk, 1992). Soil exchangeable acidity (H^+ and Al^{3+}) was determined by extracting with 1 M potassium chloride (KCl), and then titrating with 0.1 N sodium hydroxide (NaOH) and 0.1 N hydrochloric acid (HCl) (Sims, 1996). Ca and Mg concentrations were measured by using Atomic Absorption Spectrophotometer (AAS) after the digestion of samples using standard methods. Soil, samples were digested with concentrated nitric acid ($HNO_{3)}$ (Friel *et al.*, 1990, Zheljazkov and Nielson, 1996). The wet-digested samples were diluted with distilled water. Free Iron, Aluminum, and Manganese concentrations were determined by using AAS at their respective wavelengths of 248.3nm, 309.3nm, and 279.5nm respectively after extraction by dithionite-citrate solution (Mehra and Jackson, 1960).

3.2.2. Plant tissue and green manure analysis

The whole plant and green manure parts were collected from each plot and the collected samples were washed with distilled water and air-dried. The air-dried tissues were then ground into 0.25 mm size, and subjected to wet digestion. The digest was then analyzed for NPK analysis.

3.2.3. Yield and biomass

Dry Matter (DM) yield at each harvest the entire plot was cut to 5 cm above ground level using a sickle and a sub-sample of the mown material was taken and dried at 70 °C for 24h to determine DM yield.

3.2.4. Statistical analysis

The acquired data were statistically analyzed using R software. A one-way analysis of variance (ANOVA) was done using the R software to examine the influence of treatments (green manure) on physicochemical characteristics and crop production (Steel and Torries, 1980, Hinds and Milliken, 1987). The GLM model was used to separate means when treatments were substantially different ($p<0.05$).

4. RESULT AND DISCUSSION

4.1 Effect of green manure on soil chemical properties

4.1.1 Effect of lablab

The initial experimental sites had a clay-dominant soil texture, moderately acidic for the lablab site (pH=5.9) and strongly acidic for the lupin site (pH=5.4). Soil analysis after lablab green manure application showed no significant ($p > 0.05$) differences among treatments in the tested soil chemical properties (Table 2). However, soil pH ranged between 4.8 (BG+50%RIF) to 5.45 (100%RIF). Total Nitrogen content appears to be similar across all treatments, ranging from 0.15 mg kg^{-1} (100%RIF) to 0.19 mg kg^{-1} (AG and AG+50%RIF). Whereas, available phosphorus content has ranged from the largest 100%RIF (36.9) to the lowest NF (10.09). Potassium on the other hand showed very little variability between the treatment where the 100%RIF resulted in 469.9 mg kg^{-1} and BG in 396.8 mg kg^{-1}.It appears that the treatment 100%RIF generally resulted in relatively higher values of most of the nutrients compared to other treatments. Although not significant, OC ranged between 1.8-2.13%. This OC build-up seems promising for the future fast soil organic carbon build-up due to green manure incorporation. The present results are in disagreement with Amede *et al.* (2021) who reported that the incorporation of green manure legume crops of different species resulted in differences in soil chemical properties. Amede *et al*. (2021) used quite a wide range of green manure legume crops compared to the present study which was narrow and that could be a difference observed between the results of this study with that if Amede *et al*. (2021).

Table 2. Effect of lablab green manure incorporation on soil physicochemical properties

Treatment	**pH H2O**	**Ca mg/kg**	**K mg/kg**	**Mg mg/kg**	**Na mg/kg**	**AvP mg/kg**	**S mg/kg**	**TN%**	**OC%**	**Om%**	**Cn Ratio**
100%RIF	5.45± 0.6^{a}	185.3±39 1.2^{a}	469.9± 96.7^{a}	247.6± 62.7^{a}	20.4± 3.5^{a}	36.9± 20.5^{a}	12.6±2. 9^{a}	0.15± 0.01^{a}	1.80± 0.3^{a}	3.3± 0.5^{a}	12.02±0 .9^{a}
AG	5.1.2± 0.03^{a}	1430.9 ± 74.2^{a}	458.08 ±22.9^{a}	209.4± 18.8^{a}	22.9± 5.1^{a}	13.9± 2.4^{a}	14.07±1 .02^{a}	0.19± 0.03^{a}	2.04± 0.01^{a}	3.53± 0.01^{a}	11.± 1.84^{a}
AG+50%RIF	5.01± NA^{a}	1357.8 ± NA^{a}	461.8± NA^{a}	165.8± NA^{a}	18.77 ± NA^{a}	10.92 ± NA^{a}	15.62± NA$_{a}$	0.19± NA^{a}	2.04± NA^{a}	3.57± NA^{a}	12.0± NA^{a}
BG	4.95± 0.12^{a}	1378.4 ± 32.3^{a}	396.8± 27.63^{a}	204.10 ±7.29^{a}	23.37 ± 5.8^{a}	23.50 ± 9.8^{a}	17.45±4 .14^{a}	0.17± 0.005^{a}	2.06± 0.02^{a}	3.57± 0.04^{a}	12.± 0.34^{a}
BG+50%RIF	4.8± NA^{a}	1354.6 ± NA^{a}	405.17 ± NA^{a}	192.90 ±NA^{a}	23.9± NA^{a}	18.48 ± NA^{a}	15.32± NA^{a}	0.16± NA^{a}	2.06± NA^{a}	3.56± NA^{a}	12.1± NA^{a}
NF	5.2± 0.14^{a}	147.9± 145.3^{a}	455.3± 6.95^{a}	217.11 ±40.8^{a}	22.61 ± 5.4^{a}	10.09 ± 3.8^{a}	11.14±2 .9^{a}	0.17± 0.01^{a}	2.13± 0.17^{a}	3.67± 0.29^{a}	12.± 1.25^{a}
WH	5.0± 0.03^{a}	1406.6± 81.^{a}	434.05 ± 37.2^{a}	199.42 ±8.62^{a}	20.40 ± 3.7^{a}	17.3± 8.62^{a}	14.40±2 .22^{a}	0.16± 0.005^{a}	1.59± 0.42^{a}	2.75± 0.73^{a}	9.7 ± 2.1^{a}
CV (%)	0.51	11.6	10.7	12.3	22.7	52	19.3	9	11.4	11.7	13.03
p-value	0.477	0.151	0.66	0.310	0.97	0.252	0.174	1.066	0.365	0.365	0.549

100%RIF=100% recommended fertilizer, AG=Above Ground, AG+50%RIF=Above Ground +50% recommended fertilizer BG=Below Ground BG+50%RIF= Below Ground +50% recommended fertilizer, WH=Whole biomass, NF=Natural fallow

4.1.2. Effect of lupin

Soil analysis after lupin green manure application showed significant ($p < 0.05$) differences among treatments only for soil pH and available S (Table 3). Compared to 100%RIF, soil pH values were significantly higher for treatments AG, NF, BG and WB though these treatments were statistically at par. Significantly higher values of pH were recorded for treatments AG (5.82), NF (5.82), and WB (5.72). A significantly lower value of pH was recorded for the 100%RIF (5.02) which was statistically at par with BG + 50%RIF. On the other hand, significantly higher values of S were recorded for 100%RIF (14.9 mg/kg) followed by AG+50%RIF (12.4 mg/kg) and BG+50%RIF (10.02 mg/kg). The higher S content in the RIF (either 100% or 50%) treated plots could be associated with the type of fertilizer that was applied in the form of NPS which contains about 7% S. The effect of lupin biomass partitioning was better than lablab in modifying soil pH.

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Table. 3. Effect of lupine green manure on soil chemical properties

Treatment	**pH H2O**	**Ca mg/kg**	**K mg/kg**	**Mg mg/kg**	**Na mg/kg**	**AvP mg/kg**	**S mg/kg**	**TN%**	**OC%**	**Om%**	**Cn Ratio**
100%RIF	5.02 ±0.36b	1485.9±195.08a	426.98±62.87a	211.77±45.56a	20.95±1.25a	25.34±11.83a	14.9±2.21a	0.15±0.005a	1.94±0.29a	3.36±0.50a	12.40±1.45a
AG	5.82±0.06a	1818.79±7.49 a	527.89±33.28a	250.43±14.29a	19.79±1.46a	29.56±9.85a	7.80±2.01a	0.13±0.01a	1.52±0.1a	2.60±0.17a	11.63±0.41a
AG+50%RIF	5.64±NAab	1893.93±NA a	576.41 ±NA a	250.87±NA a	21.62±NAa	41.76±NAa	9.34±NAab	0.13±NAa	1.33±NAa	2.29±NAa	10.23±NAa
BG	5.73±0.36a	1854.71±245.9a	469.35 ± 10.9 a	249.14 ± 8.40a	19.86±5.15a	30.14±19.17a	7.9±1.40a	0.15±0.01a	1.65±0.26a	2.84±0.44a	10.98±0.57a
BG+50%RIF	5.56± NAab	1772.55 ± NAa	506.96 ± NAa	251.24± NA a	15.89±NAa	32.64±NAa	9.54±NAab	0.14±NAa	1.55±NAa	2.64±NAa	11.92±NAa
NF	5.82±0.09a	1895.29 ± 45.64a	488.82±35.89a	245.69±11.30a	20.30±2.38a	38.91±14.48a	7.59±1.57a	0.15±0.00a	1.73±0.08a	2.99±0.14a	11.59±0.57a
WH	5.72±0.10a	1824.4±71.84a	485..43±53.89a	251.34±28.39a	21.73±4.37a	31.05±18.78a	8.58±2.14a	0.14±0.01a	1.66±0.28a	2.86±0.49a	11.28±1.38a
CV(%)	3.15	7.39	7.62	10.9	14	40	19	6.9	14.4	14.4	8.8
p-value	0.0156	0.1398	0.08545	0.8270	0.6488	0.8789	0.026	2.1736	0.413	0.413	0.5772

100%RIF=100% recommended fertilizer, AG=Above Ground, AG+50%RIF=Above Ground +50% recommended fertilizer BG=Below Ground BG+50%RIF= Below Ground +50% recommended fertilizer. WH=Whole biomass, NF=Natural fallow

4.2 Comparison of soil chemical properties before and after green manure amendment

Figures 2 and 3 shows the changes in soil chemical properties after the harvest of wheat. Soil pH increased significantly regardless of the legume species when compared with the initial soil pH. Soil pH at the T1 plots decreased compared to the initial pH level on both lablab and lupin fields. Other soil fertility parameters such as soil OC (except T7), TN, available P, and C:N (except T7) significantly changed positively due to lablab green manure incorporation (t-test, $p < 0.01$). On the other hand, nutrient concentrations of the experimental soil amended by lablab green manures showed a decrease (t-test, $p > 0.05$) in nutrients like Ca (except T1), Mg, K and S available P (except T1) (Figures 2). This might indicate that the turnover of soil organic matter in green manures is short-lived unless crop fields are alternately covered by green manure crops every two or three years.

Similarly, green manure amendment with lupin showed variable responses in soil chemical properties (Figure 3). Accordingly, available P, Ca (except T1), and K (except T1) significantly changed positively due to lupin green manuring (t-test, $p < 0.01$). However, OC (except T1) and nutrients such as TN, Mg, and S decreased in their concentrations (t-test, $p > 0.05$) compared to the initial respective values. Short-term application of lablab or lupin biomass (whole, below-ground, or above-ground parts with or without inorganic fertilizer) contributed to the observed increased concentrations of several nutrients in the soil. For instance, available soil P levels increased in both legume green manures than the inorganic fertilizer treatment alone (100%RIF) or the natural fallow (NF) plots. This soil P improvement could be due to the addition of P through the green manure resources used in this study. Previous studies (Astier *et al.*, 2006; Partey *et al*., 2014; Carvalho *et al*. 2015) have also shown that the incorporation of green manure in the short-term increased the content of some chemical elements in the soil.

On the other hand, the present result showed that soil organic C, TN, Mg, and S, did not change significantly in the short-term with the addition of lupin green manure (either whole, above or below-ground biomass). Also, Ca, K, S, and Mg did not change with the addition of lablab green manure. These indicate that the nutrients are not sensitive to short-term changes of soil quality with different soil or green manure management practices (Liu *et al*., 2013).

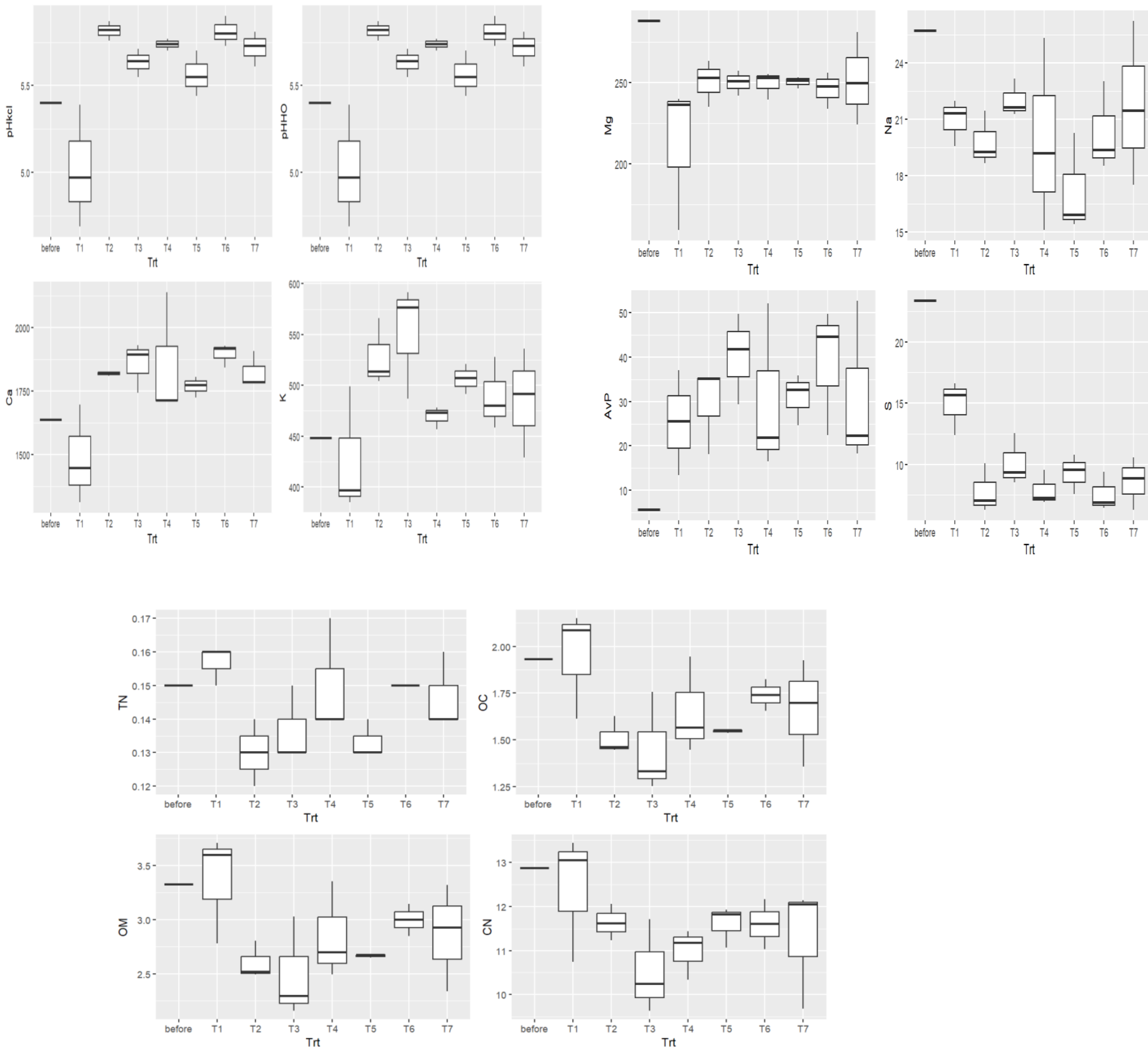
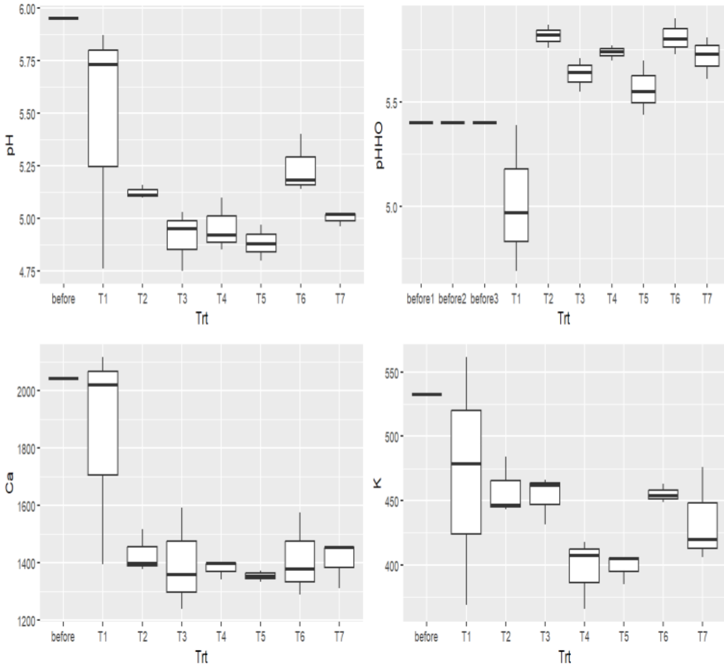


Figure 2: Comparison between the initial and after harvest soil chemical properties in response to lablab green manure treatments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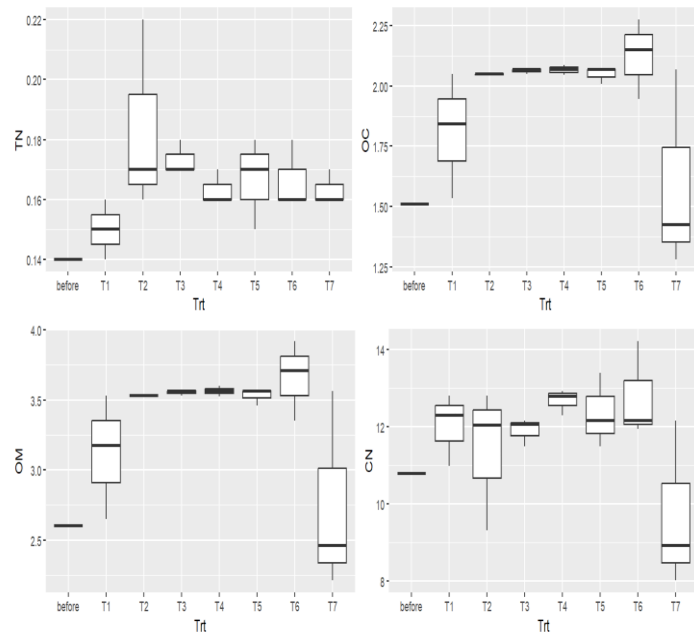
TN
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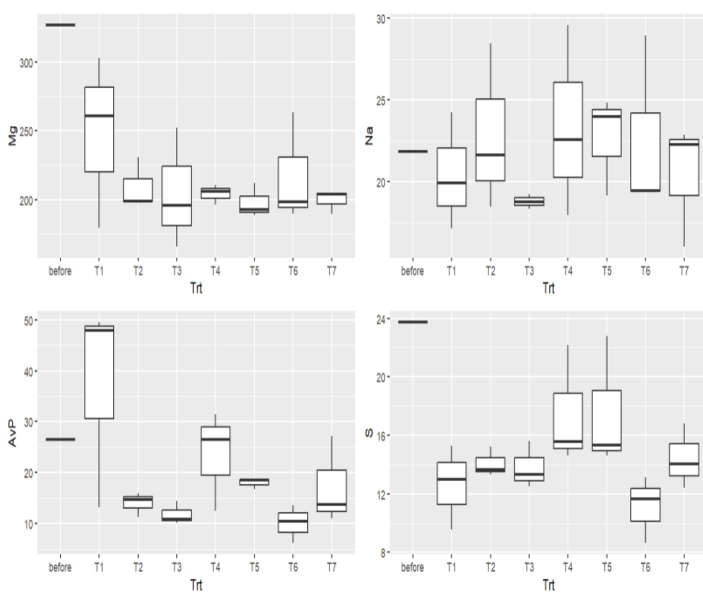
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before
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T5
T6
T7

Figure 3: Comparison between the initial and after harvest soil chemical properties in response to lupin green manure treatments

4.3. Effect of green manure of lablab on growth and yield components of wheat

The analysis of variance showed that growth and yield components were not significantly influenced by the incorporation of lablab green manure. Thousand seed weight was however significantly influenced ($p<0.05$) (Table 5). Generally, plant height ranged from 76.13 cm (BG+50%RIF) to the least 60.53cm (NF). The tiller number ranged from the lowest in BG (3.00) to the highest in WH (4.00). The same was true for the leaf area where treatments did not differ in their effect on the leaf area and it ranged between 14.8 cm^2 (NF) to 22.6 cm^2 (AG+50%RIF).

Thousand seed weight was significantly higher for BG (24.73 g) and NF (24.60) while BG and NF were statistically similar with 100%RIF, AG, AG+50%RIF, and BG+50%RIF.

Previous studies have also shown that either green manure alone or combined with inorganic fertilizer can stimulate the subsequent crop growth, yield, and soil nutrient levels (Yang *et al*., 2018; Amde *et al*., 2021) as was demonstrated with wheat following green manuring with red and white clover (Wivstad, 1998).

Table 4. Effect of green manuring on wheat yield under lablab treatment

Treatment	Grain yield (kg ha−1)	Biomass yield	Pht	Tiller	Fertile tiller	LA	Thousand SW	HI
100%RIF	2586.00± 652.60 bc	6562.50± 1653.59 bc	65.33± 8.73 a	3.66± 1.15 a	2.66± 0.57 a	16.07± 4.55 a	23.73± 0.98 ab	41.74± 17.02 a
AG	4484.33± 137.17 ab	8333.33± 902.10 ab	68.86± 5.74 a	3.66± 1.15 a	3.00± 1.00 a	20.38± 2.25 a	23.66± 0.66 ab	54.31± 6.98 a
AG+50%RIF	3373.66± 1319.45 abc	10625.00± 1653.59 a	73.60± 7.63 a	3.66± 1.15 a	3.33± 1.15 a	22.63± 2.22 a	22.96± 0.76 ab	31.98± 13.28 a
BG	4800.50± 550.92 a	8333.33± 1301.04 ab	72.73± 8.60 a	3.00± 1.00 a	2.33± 0.57a	15.62± 5.70 a	24.73± 0.15 a	57.96± 4.60 a
BG+50%RIF	2601.66± 480.63 bc	7083.33± 1572.88abc	76.13± 6.13 a	3.66± 1.52 a	3.33± 1.15 a	19.72± 8.42 a	22.90± 0.65 ab	37.28± 6.51 a
NF	1475.00± 342.68 c	4166.66± 902.10 c	60.53± 9.14 a	3.66± 0.57 a	1.66± 0.57 a	14.81± 1.31 a	24.60± 0.80 a	36.38± 9.87 a
WH	5312.00 ±764.99 a	8645.83± 1183.10ab	74.66± 3.34 a	4.00± 1.00a	3.33± 0.27 a	22.23± 3.52 a	22.63± 0.65 b	62.42± 14.32 a
CV (%)	20.48	17.87	10.56	30.83	28.29	21.33	2.77	23.79
p-value	0.0001676***	0.002423 **	0.1884	0.9647	0.9647	0.1442	0.02494*	0.02494*

100%RIF=100% recommended fertilizer, AG=Above Ground, AG+50%RIF=Above Ground +50% recommended fertilizer BG=Below Ground BG+50%RIF= Below Ground +50% recommended fertilizer, WH=Whole biomass ,NF=Natural fallow

4.5. Effect of green manure of lupin on growth and yield components of wheat

Similar to the effect of lablab, green manure of lupin did not show significant effects on the growth and yield components of wheat (Table 6). But thousand seed weight was affected by the lupin green manure treatment. The measured values of these parameters fall within the range of the values recorded for the field of lablab.

Table 5. Effect of lupin green manuring on growth and yield components of wheat

Treatment	Grain yield (kg ha−1)	Biomass yield	Pht	Tiller	Fertile tiller	Leaf area	Thousand SW	HI
100%RIF	2339.34± 416.3 [a]	67.8±4.08 [a]	3.00 ±1.00[a]	2.67±0.57 [a]	20.48± 0.98 [a]	24.5 ±0.36 [a]	24.50 ±0.36 [a]	32.55±5.79 [a]
AG	2216.0± 313.7 [ab]	7291.67± 1443.3 [ab]	64.26± 4.04 [a]	2.66± 1.15 [a]	1.67± 0.57 [a]	22.9± 3.8 [a]	23.76± 0.65 [a]	31.14±6.65 [ab]
AG+50%RIF	3055.34± 300 [abc]	7916.8± 1443.3 [abc]	71.40± 4.27 [a]	3.66± 1.15 [a]	2.34± 0.57 [a]	21.67± 1.04 [a]	22.37± 0.41 [ab]	39.58±8.83 [b]
BG	2531.34± 206.3 [bc]	9375±0. [bc]	76.87± 6.42 [a]	4.33± 1.15 [a]	3.34± 1.15 [a]	22.57± 5.10 [a]	24.27± 0.66 [abc]	27.89±2.20 [b]
BG+50%RIF	2783.34± 328.8 [bc]	8541.67± 360.8 [bc]	71.80± 6.91 [a]	4.66± 0.57 [a]	2.67± 1.15 [a]	25.73± 1.94 [a]	23.13± 0.61 [bcd]	32.67±4.40 [b]
NF	1510.0± 8.88[cd]	6041.67± 360.8 [bc]	68.34± 3.34 [a]	4.00± 1.00 [a]	3.00± 1.00 [a]	19.57± 3.00 [a]	24.63± 0.76 [cd]	25.05± 1.40[b]
WH	3477.4 ±154.4 [d]	6873.67± 1084.[c]	63.34± 6.53 [a]	2.33± 0.57 [a]	2.00 ±0.0[a]	18.17± 2.85 [a]	46.48± 0.70 [d]	51.50 ±8.93[b]
CV (%)	11.23	9.29	7.91	28.03	33.6	13.7	1.96	15.5
p-value	1.71e-05 ***	0.00882 **	0.0858	0.0799	0.256	0.126	0.00148**	0.002 **

100%RIF=100% recommended fertilizer, AG=Above Ground, AG+50%RIF=Above Ground +50% recommended fertilizer BG=Below Ground BG+50%RIF= Below Ground +50% recommended fertilizer, WH=Whole biomass, NF=Natural fallow

4.5. Effect of Biomass Partitioning of Lablab and Lupin on Wheat Yield and Harvest Index

The results showed that significant ($p < 0.01$) differences were observed in wheat yield and harvest index among the different biomass partitioning treatments of lablab and lupin (Table 4). Results revealed that compared to 100%RIF, the incorporation of lablab green manure parts resulted in grain yield advantages of 105, 86, 73 and 30% respectively for the treatments of whole biomass (WB), below ground (BG), above ground (AG) and AG+50%RIF. The highest grain yield advantage from the biomass partitioning effect of lupin was only 49 and 31% for WH and AG+50%RIF.

Table 6. Effect of biomass partitioning of lablab and lupin on wheat yield and harvest index of wheat in Omo nada district

Treatment	Biomass yield (kg/ha)		Grain yield (kg/ha)		HI (%)		Grain yield advantage (%) over the 100%RIF	
	Lablab	Lupin	Lablab	Lupin	Lablab	Lupin	Lablab	Lupin
100%RIF	6562.5bc	7187.5bcd	2586.0cd	2339.3cd	41.7bcd	32.5bc	-	-
AG	8333.3ab	7291.6bcd	4484.3ab	2216.0	54.3abc	31.1bc	73.4	-5.3
AG+50%RIF	10625.0a	7916.6abc	3373.6bc	3055.3ab	31.9d	39.5b	30.5	30.6
BG	8333.3ab	9375.0a	4800.5a	2531.3cd	57.9ab	27.0c	85.6	8.2
BG+50%RIF	7083.3b	8541.6ab	2601.6cd	2783.3bc	37.2cd	32.6bc	0.6	19.0
NF	4166.7c	6041.6d	1475.0d	1510.0e	36.3cd	25.0c	-43.0	-35.5
WH	8645.8ab	6873.7cd	5312.0a	3477.3a	62.4a	51.5a	105.4	48.6

100%RIF=100% recommended fertilizer, AG=Above Ground, AG+50%RIF=Above Ground +50 recommended fertilizer, BG=Below Ground, BG+50%RIF= Below Ground +50% recommended fertilizer, WH=Whole biomass, NF=Natural fallow

The present result agrees with Amde *et al*. (2021) who showed that green manure treatments produced significantly higher total biomass and grain yield of wheat compared to the application of mineral fertilizer with grain yield increments of 6–53 % for various legume green manure crops. In general, it was visible that the incorporation of green manure biomass treatments surpassed the effect of fertilizer treatments on the total biomass and grain yield of wheat in the present study. The preliminary findings highlighted that short-term fallow of lablab would improve soil fertility and productivity of subsequent wheat while reducing fertilizer costs.

The result was also similar to the study by Gummadi *et al*., (2018), in East Africa, where the short rains became unreliable for crop production it would be advisable to introduce fast-growing green manures as short-term fallows in between main growing seasons. This would not only improve crop productivity but also enhance sustainability by reducing erosion effects, improving carbon sequestration, and increasing biomass for multiple uses.

5. CONCLUSION AND RECOMMENDATION

The study explored the effects of green manures from lablab and lupin on soil chemical properties, wheat yield, and yield components. It found that incorporating lablab green manure did not significantly change soil chemical properties ($p > 0.05$), whereas lupin green manure significantly affected soil pH and available sulfur ($p < 0.05$). Both green manures increased soil pH compared to initial levels, indicating they can reduce soil acidity. Although lablab and lupin treatments raised soil organic carbon (OC) and total nitrogen (TN) levels, these changes were not significant. Lablab green manure showed potential for long-term soil organic carbon buildup. Both green manures improved short-term soil nutrient concentrations, especially available phosphorus. Wheat yield and harvest index were significantly higher with green manure treatments, with lablab outperforming lupin. The highest grain yields were achieved with whole biomass (WB) incorporation for both legumes, with lablab yielding more than lupin. Growth and yield components of wheat, such as plant height, tiller number, and leaf area, were not significantly affected by the green manures. However, the thousand seed weight was significantly higher in some treatments, indicating potential grain quality benefits. Therefore, it’s recommended that

1. **Fertilizer Combination:** Treatments like AG+50%RIF and BG+50%RIF showed promising results for nutrient availability and wheat yield, potentially reducing fertilizer costs and environmental impact. Therefore combining green manure with reduced inorganic fertilizer (e.g., 50% of the recommended rate) is beneficial.

2. **Soil Acidity Management:** Given the significant increase in soil pH with green manure treatments, particularly lupin, farmers in acidic soil regions should consider using green manures to ameliorate soil acidity sustainably.

3. **Adoption and Training:** Farmers should be trained on the benefits and management practices of green manures. Extension services can play a crucial role in promoting the adoption of green manure crops like lablab and lupin to enhance soil fertility and crop yields sustainably. By integrating green manures into cropping systems, farmers can improve soil health, reduce dependency on chemical fertilizers, and enhance the sustainability of agricultural practices.

4. **Further Research:** Additional studies should investigate the long-term effects of green manures on soil chemical properties and crop productivity, focusing on the mechanisms through which green manures influence nutrient cycling and soil microbial activity.

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7. APPENDIXES

Figures of Appendixes