Crop Residues as Animal Feed
Vs
Conservation Agriculture
in the
Central Highlands of Ethiopia

Angaw Tsigie
Getachew Agegnehu
Agajie Tesfaye

Research Report 95

Ethiopian Institute of Agricultural Research
Crop Residues as Animal Feed Vs Conservation Agriculture in the Central Highlands of Ethiopia

Efficient use of Crop Residues: Animal Feed Vs Conservation Agriculture Research Project

©EiAR, 2011
λ.
Website: http://www.eiar.gov.et
Tel: +251-11-6462633
Fax: +251-11-6461294
P.O.Box: 2003
Addis Ababa, Ethiopia

ISBN: 978-99944-53-76-4

Copyediting and design: Abebe Kirub
Printing: Abesolom Kassa
Binding and collation: Abesolom Kassa, Miftah Argeta, and Wudnesh Mamo
Distribution: Solomon Tsega, Bogalech Abebe, and Meseret Kebede
## Contents

Acknowledgements i

1. Introduction 1

2. Materials and Methods 4
   2.1 The project area 4
   2.2 Treatments, design, and data collection 5
   2.3 Statistical analysis 6

3. Results and Discussion 7
   3.1 Soil analysis 7
   3.2 Crop residue production 10
   3.3 Yield and yield components 11
   3.4 Additional outputs of the project 17

4. Conclusion 20

5. Recommendations 22

6. References 25
Acknowledgments

The project team would like to extend its deepest gratitude to Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) for its financial support of the project entitled “Efficient Use of Crop Residues: Animal Feed versus Conservation Agriculture”. The project was financed under ASARECA CGS stream A. The support of ASARECA in providing close supervision, technical backstopping, capacity building and monitoring of the project along the way from inception to completion phases is also duly acknowledged. It is also our pleasure to appreciate the colleagues from Kenya, Uganda and Tanzania, who are members of the same project in their respective countries in sharing their experiences and reading materials related to the project.

The team would also duly acknowledge the supports given by Ethiopian Institute of Agricultural Research (EIAR) during implementation of the project. We are also indebted to North Shewa Zone of Oromiya Region and Office of Agriculture and Rural Development of Degem District for the closer supports rendered during implementation of the project on farmers’ field and for providing relevant information. The team also appreciates the farmers of Degem District who hosted the experiments of the project for their active participation in managing, monitoring, and evaluating the experiments. We would also like to thank the farmers of Degem who provided the required information.
1. Introduction

Land degradation and associated soil fertility depletion are considered the major biophysical root causes of the declining per-capita food production and natural resource conservation in sub-Saharan Africa (Sanchez et al., 1997; Farouque and Tekeya, 2008; Vanlawe et al., 2010). Declining soil fertility has also increased concerns about the possibility of feeding the growing population (Gruhn et al., 2000). In Ethiopia, century long low input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation; this has also prompted the expansion of farming to marginal, non-cultivable lands including steep landscapes and rangelands.

Agricultural system involving a combination of sustainable production practices has the following major attributes: it conserves resources; it is environmentally non-degrading, technically appropriate, and economically and socially acceptable (FAO, 2008). In practice, sustainable agriculture uses less external inputs (e.g., fertilizers) and employs locally available natural resources more efficiently (Lee, 2005). Conservation agriculture seeks to achieve sustainable agriculture through minimal soil disturbance (minimum tillage), permanent soil cover, and crop rotations (Lee, 2005). Conservation agriculture conserves and enhances soil organic matter. This makes it possible for fields to act as a sink for carbon dioxide, increases the soil’s water retention capacity and reduces soil erosion.

Though conservation agriculture was earlier suggested as an alternative system by the Ethiopian Highlands Reclamation Study (FAO, 1986), the practice of minimum tillage is less developed in Ethiopia. In addition, no research was attempted to evaluate its application to the Ethiopian setting; but Sasakawa Global 2000 (SG-2000) initiated a conservation agriculture project in 1998 to demonstrate its merits in selected maize growing areas of the country by using improved varieties of maize and optimum levels of fertilizer. The results of several years of observations in the demonstration plots revealed increased crop yields and better income from the conservation agriculture plot compared to the conventional one (SG-2000, 2007). At the same time conservation tillage and compost has been included as part of extension packages to reverse extensive land degradation in Ethiopia (Edwards et al., 2007). There exists ample evidence to show that compost and conservation tillage can result in higher and/or similar yields compared to chemical fertilizer (SG-2000, 2004). This implies that these two organic farming techniques can create a win-win situation, where farmers are able to reduce production costs, provide
Crop residues as animal feed vs conservation agriculture

environmental benefits, and at the same time increase their yields. In spite of such encouraging results, adoption of conservation agriculture is very limited even in areas that received significant extension and experimental demonstrations. The major reasons are the need for non-selective pre-planting herbicide for weed control which is less available and unaffordable; lack of appropriate minimum tillage implements to facilitate seed-soil contact; and free range grazing of animals following crop harvest that impinges upon practicing conservation agriculture. Furthermore, from conventional agriculture and environmental management practices to non-conventional ones represent one of the great challenges in terms of changing habit and mind sets.

Organic amendments such as animal dung and crop residues are largely used for competing uses especially for household energy source instead of being recycled to maintain soil fertility. Burning of dung cake and crop residues is common in Ethiopia due to serious shortage of fuel wood. Bojo and Cassels (1995) reported that the use of dung cake accounts for about 50% of the total fuel supply of households especially in the highland cereal zones of the north and central Ethiopian highlands. The practice denies the soils of important sources of organic matter and nutrients. The use of dung as fuel instead of fertilizer is estimated to reduce Ethiopia’s agricultural GDP by 7% (Zenebe, 2007) meaning the lack of alternative fuel sources is a significant constraint. In addition, supply of animal manure is scarce to begin with: the average smallholder typically owns 2 or fewer cattle of the local breeds that produce very little dung. In addition, manure is also used as a source of cash income in the rural areas of the country. On the other hand, if the availability of manure is not a constraint its application for soil fertility restoration, particularly for fields far from the homestead, is limited by its bulkiness for transport and labour source.

There are only few studies that assessed the role of crop residue management on soil properties, crop growth and yield under field conditions in Ethiopia. Recently, a comprehensive work on crop residue management for wheat production was carried out at Kulumsa Agricultural Research Centre. According to Asefa et al. (2004) stubble burning tended to increase the grain yields of wheat and decrease the severity of the grass weed Bromus pectinatus infestation in contrast to partial removal and complete retention of stubble. Full stubble retention increased the incidence of the root disease eyespot and the severity of broad leaf and grass weed infestation (Asefa, 2001). In contrast, research results from long-term field experiments in West African agroecosystems showed that the use of mineral fertilizers without recycling of organic materials resulted in higher yields, but this increase was not sustainable (Bationo et al., 1993). As a result of the higher organic carbon, Bationo et al. (1993) reported a large positive and additive effect of crop residue and mineral fertilizer application on pearl millet yield. Over the duration of the study, grain yield in control plots (no fertilizer, no crop residue) were low and steadily
declined. This showed that the potential for continuous millet production on these soils is very limited in the absence of soil amendments. In general, efficient management and utilization of crop residues may contribute to the sustainability of the integrated farming system.

Reduced tillage and maintenance of ground cover with crop residues may increase water availability to the crop and increase grain and straw yields in semi-arid areas of Ethiopia. According to Tewodrose et al. (2005) the application of 3 t ha\(^{-1}\) of tef straw increased grain yield of sorghum by 70% in conventional tillage and by 46% in zero tillage treatments in the central rift valley of Ethiopia. Mulching has to do with reducing unproductive water loss. Mean soil water throughout the season was 16% more with 3 t ha\(^{-1}\) application of straw compared to without straw application. Tewodrose et al. (2005) concluded that ground cover with crop residues is necessary to achieve acceptable yield with zero tillage in low moisture stress areas of the country.

Alternative uses of crop residues as feed, roof thatching, fuel, fencing and other purposes are also major constraints in addition to the low biomass productivity of crops in the area that contributed to continuous nutrient depletion. In order to assess and evaluate the existing and potential of crop residues production in the country and its applicability in soil fertility and natural resource management a crop residue project was initiated by Ethiopia, Kenya, Tanzania and Uganda sponsored by Association for Strengthening Agricultural Research in East and Central Africa. The objective of this study was to investigate the effect of crop residue management as a component of a system with other integrated soil fertility and plant nutrient management practices on soil fertility and crop productivity in the highlands of Ethiopia.
2. Materials and Methods

2.1 The project area

Field trials were conducted for two years (2009 - 2010) on Nitisol of Degem District of North Shewa in the Central Highlands of Ethiopia. The rainfall is bimodal in which the long-term average annual rainfall 1150mm is received from June to September and the short rainy season is from January to May. The average minimum and maximum air temperatures are 10.24°C and 22.09°C, respectively. Three sites were selected from three farmers situated at different distances from each other. The latitude, longitude, and altitude of each of the experimental sites are presented in Table 1. Experimental fields were ploughed using ox-drawn local implement.

Table 1. Geo references of experimental sites

<table>
<thead>
<tr>
<th>Experimental sites</th>
<th>Latitude (North)</th>
<th>Longitude (East)</th>
<th>Altitude (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elamoferso</td>
<td>09°048.786'</td>
<td>03°036.514'</td>
<td>3102</td>
</tr>
<tr>
<td>Anno Kerre</td>
<td>09°048.377'</td>
<td>03°039.849'</td>
<td>3096</td>
</tr>
<tr>
<td>Gende-Sheno</td>
<td>09°048.729'</td>
<td>03°033.658'</td>
<td>3101</td>
</tr>
</tbody>
</table>

The soil type of the experimental fields is reddish-brown (Nitisol), which were ploughed using oxen-drawn local implement.

Figure 1. Map of the project area
Soil chemical properties of the experimental fields were determined for samples taken before planting (Table 1) and after harvesting barley in the Soil and Plant Analysis Laboratory of Holetta Agricultural Research Center. Land was leveled and the organic nutrient sources including well decomposed compost and farmyard manure were applied and incorporated into the soil before planting using oxen-drawn local implement to be ready for nutrient release for the crop after germination.

2.2 Treatments, design and data collection

The treatment options were selected combinations of nitrogen and phosphorus fertilizers either alone or with compost or manure and mixed cropping of barley with faba bean or vetch. The experiment included the following eight treatment options:

- Control: with no input and crop residue;
- Retention of 50% barley straw + 50% recommended NP fertilizer (25 kg urea and 50 kg DAP/ha);
- Organic source: 100% conventional compost (6 t/ha);
- 50% conventional compost (3 t/ha) + 50% recommended NP fertilizer (25 kg urea and 50 kg DAP/ha);
- Retention of 30% straw + 50% recommended NP fertilizer (25 kg urea and 50 kg DAP/ha) + mixed intercropping of faba bean with barley;
- Retention of 50% straw + 50% recommended NP fertilizer (25 kg urea and 50 kg DAP/ha) + under-sowing of vetch;
- 50% compost (3 t/ha) treated by effective microorganism (EM) + 50% recommended NP fertilizer (25 kg urea and 50 kg DAP/ha);
- 100% recommended NP fertilizer (50 kg urea and 100 kg DAP/ha).

The compost was prepared in pits from two to three months using a mixture of crop residues and animal manure; its measurement is on dry weight basis. Samples collected from well-decomposed compost were analyzed for N (1.1%), P (0.32%), K (1.06%), Ca (2.03%) and Mg (0.79%) using the same analytical procedures that were used for soil. Normally, the frequency of tillage for barley production in the highlands of Ethiopia is 3-4 times before planting and the last pass for seed covering during planting. In contrast, in this trial the first tillage was carried out during the application of the decomposed compost before planting to mix thoroughly in the upper 15-20 cm soil depth using ox-drawn local implement to be ready for nutrient release for the crop after germination; the second pass was done to cover the seed during planting, which was lower in terms of frequency of tillage compared to farmers' practice. Barley was seeded at the recommended rate of 125 kg/ha. In a treatment with intercropping 37.5% of the normal seed rate of faba bean (75 kg/ha) was mixed intercropped with barley. The varieties used were HB-42 for barley and CS-20-
DK for faba bean. The experimental design employed was randomised complete block with three replications. A plot size of 5 m by 8 m (40 m²) was used. The experiment was planted in May and harvested in November in both seasons.

Crops of the mixed cultures were harvested separately from the whole plot. Grain yield, above ground biomass, thousand seed weight, number of productive tillers, plant height (average of 10 plants) and spike length were recorded. Seeds were weighed and adjusted to constant moisture levels of 12% and 10% for barley and faba bean, respectively. Then grain yield of faba bean from the intercropped plot was converted to barley equivalent yield of mixed cropping system using the average price of year 2010 for both crops as follows:

\[
EY_{fb} = Y_{fb} \times P_1 / P_2
\]

\[
EY = Y_b + EY_{fb}
\]

Where \( EY_{fb} \) is barley equivalent yield of faba bean (kg ha⁻¹), \( Y_{fb} \) is yield of faba bean (kg ha⁻¹), \( P_1 \) is price of faba bean (ETB 7.16 kg⁻¹), \( P_2 \) is price of barley (ETB 3.95 kg⁻¹), \( EY_i \) is barley equivalent yield of mixed cropping system (kg ha⁻¹) and \( Y_b \) is barley grain yield (kg ha⁻¹).

### 2.3 Statistical analysis

Analysis of variance was performed using the SAS statistical package program version 9.0 (SAS Institute Inc., 2002). The total variability for each trait was quantified using pooled analysis of variance over years as per the following model.

\[
P_{ijk} = \mu + Y_i + R_{j(i)} + T_k + TY_{(ik)} + e_{ijk}
\]

Where \( P_{ijk} \) is total observation, \( \mu \) = grand mean, \( Y_i \) = effect of the \( i^{th} \) year, \( R_{j(i)} \) is effect of the \( j^{th} \) replication within the \( i^{th} \) year, \( T_k \) is effect of the \( k^{th} \) treatment, \( TY_{(ik)} \) is the interaction of \( k^{th} \) treatment with \( i^{th} \) year and \( e_{ijk} \) is the random error.

Results were presented as means and LSD at 5% probability level was used to establish differences among means. Correlation coefficients (\( r \)) among agronomic traits were calculated. In order to assess the effects of treatments on barley growth and yield, from eight structurally selected combinations of organic and inorganic fertilizers, seven single degrees of freedom orthogonal contrasts were also performed using the procedure of SAS.
3. Results and Discussion

3.1 Soil analysis

Soil chemical properties of the three sites were determined using appropriate procedures. Representative composite soil samples were collected from each trial site in order to carry out proper soil analysis and interpretation. Each composite sample was made of five sub-samples. Then the samples were taken to the soil and plant analysis laboratory of Holetta Agricultural Research Center for analysis. The soil analysis is important to identify the level of nutrients in the soil and to determine suitable rates of fertilizer to be recommended. Finally the soil analysis data generated were interpreted to illustrate the current position of soil fertility statuses of each trial site.

The soil chemical property of the farm, which is shown in Tables 1, was determined using different appropriate procedures. Soil reaction (pH) was measured in H$_2$O with water to soil ratio of 1:1 (Black, 1965). Organic carbon was determined according to Walkley and Black method (1934). Total nitrogen was determined using Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus was determined following Olsen method. Exchangeable cations and cation exchange capacity were analyzed using ammonium acetate method (Black, 1965).

The average soil pH of the three trial sites is 6.02, which is ideal for the production of most field crops. The soil does not require lime, but it should be closely monitored. Based on the results of soil analysis the average total nitrogen (N) and available phosphorus (P) were found to be above the critical level (Table 1); but not optimal for crop production. The average total N and P values were 0.23% and 25.33 ppm, respectively. Thus, based on the categories of soil characteristics both nutrients are in the medium range (Jones, 2003).

The exchangeable cations (EC) and cation exchange capacity (CEC) of the soil were also determined following the standard extraction methods. The average contents of potassium (K), calcium (Ca) and magnesium (Mg) in the soil were 1.73, 8.22, and 3.22 Meq/100 g soil, respectively (Table 1). According to the soil analytical results, these nutrients were below the optimum range. The average CEC of the soil is also below the critical range which is 18.86 Meq/100 g soil. The CEC of a soil is the reflection of the status of exchangeable cations (ECs) in the soil. Thus, as the status of ECs decreases the CEC of the soil also decreases.
Though the amount of micronutrients required by plants is small compared to macronutrients, they are equally important and limiting productivity of crops as macronutrients do. Accordingly, major micronutrients which have been envisaged to be mainly associated with such soil types were determined using appropriate extraction methods (Table 1). The soil available micronutrients measured were copper (Cu), zinc (Zn), and manganese (Mn). According to Jones (2003), the critical values of Cu, Zn and Mn are 0.2, 0.6, and 2.0 ppm, respectively. In line with this, the average values measured for Cu, Zn and Mn were 40.00, 40.83 and 19.17 ppm, respectively (Table 2), indicating that the status of these nutrients is at optimum level. Similarly, representative soil samples were taken from each plot after harvesting.

Soil pH values, organic carbon (OC), nitrogen and phosphorus measured for samples taken after harvesting were significantly (p<0.01) affected due to the application of different soil fertility management treatments as indicated in Table 2. The highest pH value (5.75) was recorded from 3t/ha of EM-compost and half dose of the recommended rate of NP fertilizer. The average soil pH of the treatments is about 5.62, which requires close supervision for liming to maintain the soil pH at optimum level (Table 3). The lowest soil pH (5.18) was recorded from the control plots. In most cases soils whose pH is less than 5.5 are deficient in Ca, Mg and P (Marschner, 1995; Mengel and Kirby, 1996; Somani, 1996). The exchangeable acidity of this soil needs to be determined to decide whether liming is required or not.

Though the status of total organic carbon is below the critical level, the highest organic carbon was recorded from plots treated with crop residue and organic and inorganic nutrient sources (Table 3). The average organic carbon content of the experimental soil is 2.76%, which is also categorized in low range. In contrast, the total N and available P determined after harvesting have been found to be above the critical range. As noted above for organic carbon, the highest soil nitrogen and phosphorus was recorded were recorded from plots treated with crop residue and organic and inorganic fertilizers (Table 3). The lowest soil N and P contents were obtained from the control plots. In general, the integrated use of organic and inorganic nutrient sources including crop residue could result in significant improvement in soil fertility, indicating that if the best alternative options is adopted in the area the overall condition of the soil and agricultural productivity would be improved in sustainable basis.
Table 2. Soil analytical results of the trial sites at Degem for samples taken before planting

<table>
<thead>
<tr>
<th>Site</th>
<th>PH(1:1) H₂O</th>
<th>OC (%)</th>
<th>N (%)</th>
<th>P (ppm)</th>
<th>Exchangeable cations in meq/100g</th>
<th>Micronutrient (ppm)</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K</td>
<td>Ca</td>
<td>Mg</td>
</tr>
<tr>
<td>Elamoferso</td>
<td>6.01</td>
<td>2.03</td>
<td>0.22</td>
<td>28</td>
<td>2.71</td>
<td>9.71</td>
<td>2.88</td>
</tr>
<tr>
<td>Anno Kerre</td>
<td>5.91</td>
<td>2.10</td>
<td>0.23</td>
<td>20</td>
<td>1.26</td>
<td>5.64</td>
<td>1.89</td>
</tr>
<tr>
<td>GendeSheno</td>
<td>5.75</td>
<td>2.04</td>
<td>0.24</td>
<td>28</td>
<td>1.22</td>
<td>9.31</td>
<td>4.89</td>
</tr>
<tr>
<td>Mean</td>
<td>5.89</td>
<td>2.05</td>
<td>0.23</td>
<td>25.33</td>
<td>1.73</td>
<td>8.22</td>
<td>3.22</td>
</tr>
</tbody>
</table>

Table 3. Soil analytical results of the trial sites at Degem District for samples taken after harvesting, 2009-2010

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>% OC</th>
<th>% N</th>
<th>P (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control: no input</td>
<td>5.18c</td>
<td>2.45d</td>
<td>0.22c</td>
<td>18.60c</td>
</tr>
<tr>
<td>50% Straw + 50% NP</td>
<td>5.64ab</td>
<td>2.80b</td>
<td>0.26b</td>
<td>23.13b</td>
</tr>
<tr>
<td>100% Compost (6 t/ha)</td>
<td>5.68a</td>
<td>2.81b</td>
<td>0.26b</td>
<td>23.80b</td>
</tr>
<tr>
<td>50% compost + 50% NP</td>
<td>5.72a</td>
<td>2.93a</td>
<td>0.26b</td>
<td>25.20ab</td>
</tr>
<tr>
<td>30% Straw + 50% NP + faba bean</td>
<td>5.71a</td>
<td>2.84ab</td>
<td>0.26a</td>
<td>25.80ab</td>
</tr>
<tr>
<td>50% Straw + 50% NP + Vetch</td>
<td>5.71a</td>
<td>2.82ab</td>
<td>0.27ab</td>
<td>27.40a</td>
</tr>
<tr>
<td>50% EM-compost + 50% NP</td>
<td>5.75a</td>
<td>2.85ab</td>
<td>0.27ab</td>
<td>27.73a</td>
</tr>
<tr>
<td>100% recommended NP</td>
<td>5.58b</td>
<td>2.62c</td>
<td>0.24c</td>
<td>25.53ab</td>
</tr>
<tr>
<td>Mean</td>
<td>5.62</td>
<td>2.76</td>
<td>0.26</td>
<td>24.65</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.11</td>
<td>0.12</td>
<td>0.02</td>
<td>2.82</td>
</tr>
</tbody>
</table>

Means in a column with different letters are significantly different at p < 0.05.
Major causes of nutrient depletion are farming without replenishing nutrients over time, and/or chemical imbalance issues such as acidity and salinity leading to fixation—often driven by continuous cropping of cereals, removal of crop residues, leaching, low levels of fertilizer usage and unbalanced application of nutrients. In addition, inadequate runoff management can lead to leaching especially for N and K.

3.2 Crop residue production

Based on the production of crops, the amount of crop residue to be produced from each crop was estimated in the study areas (Table 4). Crop residue production is a function of biomass production and translocation. Crop biomass production is determined by the biophysical environment and the genetic make-up of the crop (Nordbloom, 1988). More than one-half of all dry matter in the global harvest is in the form of crop residues, and in most developing countries the amounts of nutrients in crop residues are higher than the quantities applied as fertilizers (IAEA, 2001).

However, crop residues are limited given low yields overall, and for some crops this is exacerbated by off-farm processing (leaves and stems are removed at central processing facility rather than on-farm). Estimates on availability of crop residues usually depend on harvest indices under research condition assuming certain field losses (Nordbloom, 1988); it is the product of the total grain production of each crop by its corresponding conversion factor. In Ethiopia, the current annual production of crop residues has increased from 6.3 million tons in 1980 to about 31 million tons due to the expansion of cultivated land and increased crop productivity (CSA, 2008). Nordbloom (1988) suggested conversion factor for each crop for East Africa.

Crop residue is used for different purposes in the country. For instance, Zinash and Seyoum (1989) reported that 63, 20, 10, and 7% of cereal straws are used for feed, fuel, construction, and bedding purposes, respectively.
Table 4. National estimate of crop residues produced per annum (based on grain yield of 2007/08)

<table>
<thead>
<tr>
<th>Residue</th>
<th>Grain production (10^4ton)</th>
<th>Conversion factor</th>
<th>Crop residue produced (10^6ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tef</td>
<td>3.0</td>
<td>3.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Maize</td>
<td>3.75</td>
<td>2.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Wheat</td>
<td>2.38</td>
<td>0.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Barley</td>
<td>1.36</td>
<td>1.2</td>
<td>1.63</td>
</tr>
<tr>
<td>Sorghum</td>
<td>2.67</td>
<td>3.0</td>
<td>8</td>
</tr>
<tr>
<td>Millet</td>
<td>0.54</td>
<td>3.0</td>
<td>1.61</td>
</tr>
<tr>
<td>Oats</td>
<td>0.04</td>
<td>1.2</td>
<td>0.043</td>
</tr>
<tr>
<td>Rice</td>
<td>0.07</td>
<td>0.8</td>
<td>0.057</td>
</tr>
<tr>
<td>Pulse</td>
<td>1.78</td>
<td>1.0</td>
<td>1.78</td>
</tr>
<tr>
<td>Total</td>
<td>15.59</td>
<td></td>
<td>31.52</td>
</tr>
</tbody>
</table>


3.3 Yield and yield components

Results showed that yield and yield components of barley were significantly affected by the application of integrated soil fertility management practices. Barley grain yield, total biomass and harvest index responded highly significantly (p < 0.001) due to the application of different soil fertility management practices (Table 4). Plant height (average of ten plants), number of productive tillers (NPT) and spike length (SL) significantly (p < 0.001) differed as a result of different soil fertility management treatments (Table 5). Thousand grain weight was the only parameter which was not affected by the treatments.

Table 5. Analysis of variance for barley grain yield and other agronomic traits, 2009-2010

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F-Probability</th>
<th>Root-MSE</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>0.0003</td>
<td>3.97</td>
<td>88.8</td>
</tr>
<tr>
<td>Number of productive tillers (NPT)</td>
<td>0.0001</td>
<td>0.44</td>
<td>4.8</td>
</tr>
<tr>
<td>Spike length (SL)</td>
<td>0.0001</td>
<td>0.31</td>
<td>6.1</td>
</tr>
<tr>
<td>Total biomass</td>
<td>0.0001</td>
<td>454.73</td>
<td>4263</td>
</tr>
<tr>
<td>Grain yield</td>
<td>0.0001</td>
<td>138.86</td>
<td>2134</td>
</tr>
<tr>
<td>Harvest index</td>
<td>0.0004</td>
<td>3.96</td>
<td>50.7</td>
</tr>
<tr>
<td>1000 seed weight</td>
<td>0.6660</td>
<td>1.57</td>
<td>47.0</td>
</tr>
</tbody>
</table>

The highest grain (2575 kg/ha) and biomass (5185 kg/ha) yields of barley were obtained from the applications of the recommended NP fertilizer rate followed by 2353 and 5148 kg/ha for grain yield and total biomass, respectively due to the applications of 3 t/ha EM-compost and half dose of the recommended rate of NP fertilizer (Table 6). The grain yield of barley consistently increased as
the total biomass increased. Though, the highest yields were achieved from the recommended NP fertilizer rate, the other integrated soil fertility management options have also resulted in significant yield advantages compared to the control. On the other hand, the highest harvest index (HI) was recorded from the control plot (Table 6).

Yields from the applications of half the recommended rate of NP fertilizer plus 3 t/ha conventional compost; retention of 30% straw plus 50% of the recommended NP fertilizer rate and intercropping of faba bean; retention of 50% of crop residue plus 50% of the recommended rate of NP fertilizer and under-sowing of vetch; and 3 t/ha EM-compost plus 50% of the recommended rate of NP fertilizer were almost similar. In terms of sustainability, these treatments would have long-term positive and significant impact on soil and agricultural productivity and economic benefits compared to application of only inorganic NP fertilizer. Likewise, research findings indicate that the integrated application of organic and inorganic fertilizer significantly increased maize yield (Nzabi et al. 1998) and improved soil fertility status (Palm et al., 1997; Prasad and Power, 1997). A study conducted by Mubarak et al. (2003) also indicated that application of half dose of the recommended rate of inorganic fertilizer with crop residues combined with chicken manure doubled yield of maize compared to application of only inorganic fertilizer on a maize-groundnut sequence in the humid tropics. Intercropping of pulses with cereals is among the multiple cropping systems used for improving land use efficiency and agricultural productivity. Getachew et al. (2006a) reported that greater land use efficiency, grain and biomass yield advantages were obtained from mixed intercropping of barley with faba bean compared to sole crop of either barley or faba bean.

The findings of Bationo et al. (1993) in West African agro-ecosystem denoted that a large positive and additive effect of crop residue and mineral fertilizer application was noted on millet yield as a result of higher organic carbon. Over the duration of the study, grain yield in control plots (no fertilizer, no crop residue) were low and steadily declined. This showed that the potential for continuous millet production on these soils is very limited in the absence of soil amendments. In contrast, Asefa et al. (2004) reported that stubble burning tended to increase the grain yields of wheat and decrease the severity of the grass weed Bromus pectinatus infestation at Kulumsa agricultural research centre, Ethiopia compared to partial removal and complete retention of stubble.
Table 6. Effect of integrated soil fertility management on yield and yield components of barley in Degem District of North Shewa, 2009-2010

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain yield (kg/ha)</th>
<th>Total biomass (kg/ha)</th>
<th>Harvest index (%)</th>
<th>1000 grain weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control: no input</td>
<td>1497e</td>
<td>2654e</td>
<td>56.7a</td>
<td>47.0</td>
</tr>
<tr>
<td>50% Straw + 50% NP</td>
<td>1834d</td>
<td>3518d</td>
<td>52.3ab</td>
<td>47.3</td>
</tr>
<tr>
<td>100% Compost (6 t/ha)</td>
<td>2036c</td>
<td>3997cd</td>
<td>50.7bc</td>
<td>46.7</td>
</tr>
<tr>
<td>50% compost + 50% NP</td>
<td>2335b</td>
<td>4444bc</td>
<td>54.0ab</td>
<td>47.0</td>
</tr>
<tr>
<td>30% Straw + 50% NP + faba bean</td>
<td>2337b</td>
<td>4755ab</td>
<td>45.7d</td>
<td>46.0</td>
</tr>
<tr>
<td>50% Straw + 50% NP + Vetch</td>
<td>2208b</td>
<td>4407bc</td>
<td>50.3bc</td>
<td>46.7</td>
</tr>
<tr>
<td>50% EM-compost + 50% NP</td>
<td>2353b</td>
<td>5148a</td>
<td>46.3cd</td>
<td>47.0</td>
</tr>
<tr>
<td>100% recommended NP fertilizer</td>
<td>2575a</td>
<td>5185a</td>
<td>50.0bc</td>
<td>48.0</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>162.3</td>
<td>531.55</td>
<td>4.63</td>
<td>NS</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.50</td>
<td>10.67</td>
<td>7.8</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Means in a column with different letters are significantly different at p < 0.05

In general, inorganic fertilizer has immediate benefit, but from the natural resource management and environmental protection point of view efficient management and utilization of crop residues with other organic nutrient sources and the required inorganic fertilizers with correct balance may contribute to the sustainability of agricultural productivity and integrated farming system in the highlands of the country, where soil erosion is serious and the resultant soil fertility depletion is high.

The mean tallest plant height (96.3 cm) was recorded (Table 7) from the application of 30% barley straw, half dose of the recommended NP fertilizer rate and mixed intercropping of 37.5% of the full seed rate (75 kg/ha) of faba bean with full seed rate of barley, indicating that the competition between barley and faba bean in the mixture tended to increase barley plant height. Similarly, the findings of Getachew et al. (2006b) indicated that tef plant height and lodging tended to increase in the mixed culture of tef and faba bean compared to sole crop of each species. The second largest plant height (92 cm) was recorded with the application of recommended NP fertilizer rate; while the shortest plant height (85 cm) was recorded from the control plots.

Number of productive tillers is one of the important agronomic parameters to be considered for enhancing productivity. Experimental results showed that significant number of tillers was produced with the application of recommended NP fertilizer rate followed by half dose of EM-compost (3 t/ha) plus half dose of the recommended NP fertilizer rate. The maximum productive tillers (6) were produced with the application of the recommended NP fertilizer rate followed by 5.6 produced from the application of 3 t/ha EM-compost and half of the recommended NP fertilizer rate. The lowest productive tillers (4.1) were recorded from the control plots (Table 7).
Spike length is among the major parameters affecting the productivity of barley. The largest spike length (6.7 cm) was obtained with the applications of 3 t/ha EM-compost plus half dose of the recommended NP fertilizer rate. The second largest spike length (6.5 cm) was recorded from the applications of 3 t/ha compost plus 50% of the recommended NP fertilizer rate, and retention of 30% barley straw plus half of the recommended rate of NP fertilizer including intercropping of faba bean with barley. The smallest spike length (4.9 cm) was recorded from the control plot.

Table 7. Effect of integrated soil fertility management on yield components of barley in Degem District of North Shewa, 2009-2010

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>No. of productive tillers</th>
<th>Spike length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control: no input</td>
<td>85.0c</td>
<td>4.1d</td>
<td>4.9d</td>
</tr>
<tr>
<td>50% Straw + 50% NP</td>
<td>87.3c</td>
<td>5.0b</td>
<td>5.9bc</td>
</tr>
<tr>
<td>100% Compost (6 t/ha)</td>
<td>86.3c</td>
<td>4.5cd</td>
<td>6.1b</td>
</tr>
<tr>
<td>50% compost + 50% NP</td>
<td>86.0c</td>
<td>4.3cd</td>
<td>6.5a</td>
</tr>
<tr>
<td>30% Straw + 50% NP + faba bean</td>
<td>96.3a</td>
<td>4.7bc</td>
<td>6.5a</td>
</tr>
<tr>
<td>50% Straw + 50% NP + Vetch</td>
<td>88.7bc</td>
<td>4.7bc</td>
<td>6.0b</td>
</tr>
<tr>
<td>50% EM-compost + 50% NP</td>
<td>89.0bc</td>
<td>5.6a</td>
<td>6.7a</td>
</tr>
<tr>
<td>100% recommended NP fertilizer</td>
<td>92.0ab</td>
<td>6.0a</td>
<td>5.7c</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>4.65</td>
<td>0.52</td>
<td>0.36</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.48</td>
<td>9.0</td>
<td>5.10</td>
</tr>
</tbody>
</table>

Means in a column with different letters are significantly different at p < 0.05

Barley grain yield was significantly positively correlated with total biomass, number of productive tillers, spike size and plant height (Figure 2). Grain yield was most strongly correlated with total biomass ($r = 0.94$), followed by spike length and number of productive tillers ($r = 0.43$) and ($r = 0.43$), respectively. Total biomass was also positively significantly correlated with productive tillers, plant height and spike size. However, grain yield was not significantly correlated with harvest index and thousand-grain weight. From this result, it could be understood that high total biomass, taller plant height, and large spike size are the traits associated with good performance of barley. Similar research findings also indicated that grain yield was correlated positively with total biomass and straw yield, spike length, number of productive tillers and plant heights of barley and wheat (Woldeyesus, 2002; Getachew and Taye, 2005).
Partitioning of treatments into single degrees of freedom orthogonal contrasts revealed that grain yield, total biomass, spike length, productive tillers, and plant height of barley significantly differed due to the application of selected integrated soil fertility management treatments (Table 8). The first contrast (control vs. treat.2-8) had a highly significant ($p < 0.001$) effect on grain yield, total biomass, spike length and plant height of barley. Nevertheless, the contrast had no significant effect on thousand grain weight. The results showed that there was no significant effect between the contrast of half of the recommended rate of inorganic NP fertilizer plus 50% of the recommended dose of conventional compost and the treatments (T5 -T8) compared with treatment 4 on grain yield of barley (Table 8). This indicates clearly that there are no significant differences among treatment 4, 5, 6 and 7 on grain yield of barley as...
Crop residues as animal feed vs conservation agriculture

evidenced in yield data of Table 5. Getachew and Sommer (2000) also reported a similar result on shoot dry matter yield and nutrient uptake of maize due to the application of phosphate fertilizer mixed with neutral compost.

Table 8: Variance ratios and probabilities of variance ratios of single degrees of freedom orthogonal contrasts for different soil fertility management practices

<table>
<thead>
<tr>
<th>Contrasts</th>
<th>GY†</th>
<th>BY</th>
<th>HI</th>
<th>TGW</th>
<th>PHT</th>
<th>NPT</th>
<th>SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control vs. treat 2-8</td>
<td>144.32</td>
<td>85.88</td>
<td>15.27</td>
<td>0.00</td>
<td>6.37</td>
<td>22.49</td>
<td>88.40</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0004</td>
<td>0.9485</td>
<td>0.0159</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>T2 vs. (T3-T8)</td>
<td>41.43</td>
<td>25.75</td>
<td>2.74</td>
<td>0.79</td>
<td>1.18</td>
<td>1.51</td>
<td>9.10</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.1063</td>
<td>0.3796</td>
<td>0.2839</td>
<td>0.2771</td>
<td>0.0045</td>
</tr>
<tr>
<td>T3 vs. (T4-T8)</td>
<td>15.21</td>
<td>11.09</td>
<td>0.77</td>
<td>0.00</td>
<td>4.08</td>
<td>3.38</td>
<td>6.26</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0004</td>
<td>0.0019</td>
<td>0.3872</td>
<td>1.0000</td>
<td>0.0505</td>
<td>0.0739</td>
<td>0.0167</td>
</tr>
<tr>
<td>T4 vs. (T5-T8)</td>
<td>0.02</td>
<td>4.28</td>
<td>10.69</td>
<td>0.01</td>
<td>9.18</td>
<td>25.12</td>
<td>3.20</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0078</td>
<td>0.0457</td>
<td>0.0023</td>
<td>0.9139</td>
<td>0.0044</td>
<td>0.0001</td>
<td>0.0818</td>
</tr>
<tr>
<td>T5 vs. (T6-T8)</td>
<td>4.63</td>
<td>0.54</td>
<td>2.97</td>
<td>2.39</td>
<td>11.81</td>
<td>11.91</td>
<td>5.33</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0378</td>
<td>0.4653</td>
<td>0.0929</td>
<td>0.1303</td>
<td>0.0014</td>
<td>0.0014</td>
<td>0.0265</td>
</tr>
<tr>
<td>T6 vs. (T7-T8)</td>
<td>13.58</td>
<td>11.15</td>
<td>1.19</td>
<td>0.99</td>
<td>0.85</td>
<td>23.82</td>
<td>1.70</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0007</td>
<td>0.0019</td>
<td>0.2814</td>
<td>0.3265</td>
<td>0.3624</td>
<td>0.0001</td>
<td>0.1975</td>
</tr>
<tr>
<td>T7 vs. T8</td>
<td>7.69</td>
<td>0.02</td>
<td>2.57</td>
<td>1.07</td>
<td>1.71</td>
<td>2.51</td>
<td>36.37</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>0.0086</td>
<td>0.8887</td>
<td>0.1175</td>
<td>0.3081</td>
<td>0.1993</td>
<td>0.1212</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

†GY = Grain yield; BY = Biomass yield; HI = Harvest index; TGW = Thousand grain weight; PHT = Plant height; NPT = Number of productive tillers; SL = Spike length

In general, crop performance was not up to expectation as the cropping seasons were variable in terms of onset and cessation of rainfall, which was characterized by the late onset and early termination of rainfall. Nevertheless, the integrated soil fertility management practices proved that they did better in improving barley production in barley based cropping system. Experimental plots treated with barley straw were relatively inferior compared to other integrated soil fertility management treatments, which may be due to immobilization of nutrients. Based on different research findings, use of crop residue has multiple purposes in improving soil and water resources. It enhances not only soil fertility status by the slow release of nutrients but also conserves soil moisture and protect soil from erosion. Thus, the effect of organic nutrient sources such as crop residue is not as quick as inorganic nutrient sources, but their effect is long lasting and sustainable. From the results of this study it can be also realized that application of 3 t/ha of conventional compost or EM-compost with half dose of the recommended rate of NP fertilizer, and retention of 30% of straw plus 50% of recommended NP
fertilizer rate and intercropping of faba bean could be alternative integrated soil fertility management measures in place of only inorganic fertilizers. The results of this experiment can be reproducible to other similar agroecologies and farming systems.

### 3.4 Additional outputs of the project

#### 3.4.1 Socio-Economic Assessment of Production and Utilization of Crop Residues in the Central Highlands (Research Report)

After the project approval and agreements made between EIAR and ASARECA to implement the project, conducting socio-economic study was observed to be essential to generate information on the existing farmers' crop residues utilization practices and institutional constraints. Accordingly, the project team conducted a survey and generated several information related to the types of crop residues produced, how they are utilized and any constraints related to it. The report of this study was prepared and published as research report to be used for the project team during subsequent field level experiments and other stakeholders.

#### 3.4.2 Preparation of User Manuals

In addition to identification of best-bet options in the use of crop residues either for soil fertility of animal feed, the project has prepared and published four user manuals and one research report, all of which are the results of project implementation. The project prepared and published the following user manuals:

i. Improving crop residue through urea treatment and multi-nutrient block supplementation

According to the findings of socio-economic survey, 97% of the farmers used crop residues as animal feed. This was mainly because of serious feed shortage problems in the locality and unavailability and un-affordability of other feed resources. However, a large proportion of wastage was observed from crop residues during feeding by animals. It was suggested that if the quality of crop residue can be improved through urea treatment and multi-nutrient block supplementation, the intake rate of crop residue will be increased, the quality of crop residue will be improved, and wastage of crop residue will also be reduced. This ultimately helps to improve livestock productivity through improved feeding and it also releases some quantity of crop residue for improving soil fertility.
ii. Producing and using Alternative Feeds to Crop Residues
Shortage of animal feed is one of the major constraints in livestock production in the project areas. As a result, farmers use a large proportion of crop residues for animal feed by harvesting and taking almost all the crop residues from farmlands. If the farmers are provided with alternative feed resources, the quantity of crop residue used as feed will be reduced and some amount can be released for improving soil fertility either in the form of compost or leaving some proportion in the field and protecting free grazing. Therefore, a users' manual was prepared on production techniques of alternative feed resources to be distributed for development agents and agriculture professionals of the project areas. These development agents are supposed to train the farmers according to the manuals and the farmers will start producing alternative feeds to their animals. This eventually contributes to enhance livestock productivity and release some quantity of crop residues for the soil.

iii. Crop Residues Management for Composting
In addition to leaving some proportion of crop residue in the farm, returning it to the soil through compost preparation is another option. Therefore, the project believed that preparation of a user manual on compost preparation techniques will help development agents and agriculture professionals to train the farmers and promote compost preparation from crop residues.

iv. Communication Tools and Knowledge Sharing Mechanisms for Crop Residues Best-Bet Technologies
In its life period, the project has generated best-bet technological options and other outputs. Unless these technologies are made accessible to the farmers, the expected impact will not be envisaged on agricultural productivity and eventual food security. To ensure dissemination and arrival of the technologies to the farmers, there should be appropriate and culturally acceptable communication methods. In view of this relevance, the project has prepared and published a users' manual on communication tools and knowledge sharing mechanisms to convey the technology from its source to end users. The manual is prepared for development agents and agriculture professionals to disseminate the project technologies are others directly for the farmers using the different options of communication methods revealed in the manual.

3.4.3 Introduction and adaptability testing of alternative roofing materials
According to socio-economic survey results, about 97% of the farmers in the project areas own a house roofed with crop residues. Barley is harvested twice: first for grain and the second for roof thatching purposes. The use of crop residue for roofing is almost as important as using it for animal feed. The use of crop residues for multiple uses creates a condition where almost no crop
residue is left back on farms. Unless the farmers are given with alternative roofing materials, there is no any reason for the farmers to stop using crop residues for roof making. In view of this scenario, the project introduced a better quality roofing grass named as “Sikoy” from other part of the country. This grass was provided to the farmers in the project areas and it was observed to be highly adaptable. The longevity of “Sikoy” grass is higher than that of crop residues and it is also perennial grass for several years. It does not require intensive management and it regenerates every year after harvesting. The farmers felt that such kind of grass is the first of its kind and they were very happy with the introduction. Therefore, as the use of “Sikoy” grass is promoted further, a large proportion of crop residue will be left on farms to improve the fertility of the soil.
4. Conclusion

The poor soil fertility status and widespread soil degradation are currently main constraints to improve crop yields in Ethiopia. Sustainable agricultural production system must adopt an approach that integrate balanced nutrient inputs from various organic and inorganic sources with improved soil and water management, seed systems and improved agronomic practices. Achieving food security for the growing population also means intensifying food production on existing cropland through integrated soil fertility management including enhanced nutrient input and recycling.

Features of nutrient management in large portions of Ethiopia are low nutrient reserves in arable soils, a negative nutrient balance on cropland and with few or no external nutrient inputs. Appropriate technologies and functional institutional arrangements must be developed and implemented to ensure economically viable and ecologically sound nutrient-conserving cropping systems that integrate proper agronomic management, combined use of chemical and organic fertilizers, integration of N-fixing plant species and identification of varieties with higher nutrient use efficiency. Since competition for biomass between different uses and users is the major challenge, there is a need to increase biomass in these systems for soil fertility management and other uses. Thus introducing alternatives for fuel wood and feed production systems in an integrated systems approach will spare crop residues for use as organic fertilizer. Soil ameliorating materials are needed to sustain crop yields.

Approaches for integrating livestock and crop production are needed for more efficient use of manure and crop residues on croplands. The integrated use of chemical fertilizer and locally available soil amendments is the best bet approach for achieving higher fertilizer use efficiency and economic feasibility. Improving the agricultural resource base is hence vital to increase the efficiency of external inputs and make them an attractive option for the farmers. Adoption of ISFM has the potential not only to improve farm productivity and farmers’ welfare but also to bring about environmental benefits.

Crop response to fertilizer and efficiency of chemical fertilizer declines as land is more degraded and nutrient applications are unbalanced. If harvested nutrients are replaced, intensive agricultural systems can be sustained, provided that measures are taken to halt soil erosion and to minimize detrimental changes in soil pH. Soil fertility improvement is fundamental for agricultural intensification based on more sustainable production systems. In this context, holistic soil fertility management programme policies are required to facilitate integration and adoption of these technologies and approaches; including

-20-
provision of fertilizer products for balanced fertilization and improved fertilizer use efficiency, livestock management, manure and crop residue utilization, institutional support in technology dissemination, market incentives to improve adoption and use of external inputs including fertilizers.

The project has also generated best-bet option of technology on efficient use of crop residues. Moreover, different types of manuals related to project outputs have been developed and published. These user manuals help enhance dissemination and sustainability of technology utilization. Moreover, information generated through socio-economic study on farmers’ utilization practices of crop residues has been published in research report. This socio-economic information has helped as benchmark information to plan and implement subsequent experiments.
5. Recommendations

According to the existing utilization practices of crop residues and institutional constraints, the following recommendations are suggested for efficient uses of crop residues to contribute to improvement of agricultural production and productivity.

Out of the eight experimental options tested for two seasons, the highest grain yield of barley was obtained from application of full dose (100%) of recommended rate of inorganic fertilizers (50 kg of Urea + 100 kg of DAP per hectare). This was mainly because of easily availability of N and P nutrients to the plant. Even though this option gives the highest grain yield, it is not sustainable option since the cost of inorganic fertilizer is unaffordable for smallholder farmers. Timely availability of these inputs is also another problem faced by the farmers in missing critical planting seasons. Inorganic fertilizers are imported inputs and the country spends a lot of hard currency every year. Moreover, application of inorganic fertilizer to the soil without supplementary application of organic fertilizers degrades soil properties from time to time. Therefore, the use of inorganic fertilizers alone is not a feasible and sustainable option for smallholder farmers. The use of both organic and inorganic fertilizers is believed to be a sustainable option to enhance production and productivity, and also improve soil conditions. In light of this need, the project has identified the sustainable best-bet option as presented in subsequent sections.

During socio-economic surveys, the farmers and district offices of agriculture have revealed that any option that packages both organic and inorganic fertilizers is believed to be a sustainable option both for increased grain yield and soil environment. In light of this expectation, the experiment has been focusing on combinations of both organic and inorganic fertilizers to demonstrate for the farmers and choose the best-bet options. Accordingly, an average of two years’ experimental results have proven that four options of the treatments, both of which are combinations of organic and inorganic fertilizers, have given the second highest grain yields ranging from 2208 – 2353 kg/ha. The yield difference between these treatment options was closely similar and statistically insignificant. Even though the treatments are four, they are considered as one best-bet option offering four options for the farmers to pick one or more depending on their interests and availability of local materials. These treatment options are presented as follows:
Treatment 7: 50% compost (3 t/ha) treated with effective micro-organisms (EM) + 50% recommended NP (RNP) which is 25kg/ha Urea and 100 kg/ha of DAP

In adopting this option, the farmers can obtain 57% more yield from the control treatment. In this treatment option, the farmers are expected to apply half doses of both organic and inorganic fertilizers. Half dose (50%) of compost (3 t/ha) treated with EM was applied together with half dose of recommended NP inorganic fertilizer (25 kg/ha Urea + 50 kg/ha DAP). The compost was prepared from addition of crop residues and other organic materials treated with EM to facilitate decomposition of organic matter. Application of EM has added values, such as it decomposes compost within short period of time (45 days), it avoids pungent smell of compost making preparation and transportation easy, and it also decomposes compost effectively releasing essential plant nutrients easily the soil. In Ethiopia, there is a private enterprise engaged in processing of EM, which ensures availability to the farmers at affordable prices (about USD 5.00 per liter of EM). Application of half dose of compost treated with EM has contributed to use only half dose of inorganic fertilizer. The cost of full dose of Urea (50 kg/ha) and DAP (100kg/ha) was USD 94.00 and then the farmers can spend only USD 47.00 when they apply half dose. In view of these scenarios, treatment 7 has been recommended and selected as one of best-bet options.

Treatment 5: 30% crop residue (CR) +50% RNP+Faba bean intercropped

This treatment gave 56% more yield than the control treatment. In this treatment option, the farmers are expected to leave 30% of crop residue in the farm after harvesting. In addition to this, they are also expected to apply half dose of inorganic fertilizers (Urea+DAP). Intercropping of faba bean with barley has also a valued added advantage since it contributes to improve soil fertility and also ensures additional faba bean yield for the farmers. However, the challenge in this treatment option is free grazing practice as revealed during socio-economic study, which indicated that any crop residue left in the farm is fed away by animals during free grazing practices in the dry season. Free grazing after harvesting of all crops is a common practice in Ethiopia. However, the particular farmer has the right to protect his own farm from being grazed by animals provided that he can afford to stand the whole day protecting the animals. Therefore, this option is suggested to the farmers who can protect their farms from being grazed by animals during free grazing seasons.

Treatment 4: 50% compost + 50% recommended RNP

Treatment has also given 56% more yield from the control treatment. It is basically similar to treatment 7 except that it is not treated with EM. Compost preparation without the use of EM takes relatively long time, 3–4 months to
decay crop residues and plant materials. Therefore, this option is feasible to farmers since compost is prepared from locally available materials. In view of the importance of compost preparation, the project has prepared and published a user’s manual on compost preparation techniques to be distributed for development agents and agriculture professionals of the project area and other similar agro-ecologies. Therefore, this treatment has also been selected and recommended as one of the best-bet options for the smallholder farmers.

**Treatment 6: 50% CR + 50% RNP + Vetch intercropped**

In using this option, the farmers can get 47% more yield from the control practice. It is closely similar to treatment 5 except that it requires leaving 50% of the crop residue in the farm and vetch is intercropped with barley. In addition to yield increment as compared to the control, this treatment option has an added value in that it also generated considerable size of biomass yield from vetch which can be used as animal feed. Vetch also contributed in ameliorating the fertility of the soil. However, the challenge of adopting this treatment option is associated with free grazing practice of animals during dry seasons after harvesting of all crops. Therefore, the farmers who can afford to protect animals from their farms can still adopt this treatment option. This treatment option also as source of animal feed by producing alternative feeds to crop residues for animals. Since almost all (97%) of the farmers use crop residues for animal feed, production of alternative feed types could release some amount of crop residues for the soil. It also contributes to enhance livestock productivity through provision of better quality feed types. In view of this relevance, the project has prepared and published a users’ manual on “producing and using alternative feeds to crop residues” to be distributed to development agents and agriculture professionals of the project areas and other similar agro-ecologies.

It is also recommended that development agents and agriculture professionals of the project areas shall train farmers on various outputs of the project using the user manuals. Farmers need to be trained on compost preparation techniques using crop residues, on production techniques of alternative feed resources, and on techniques of treating crop residues with urea and multi-nutrient block preparation. Moreover, development agents and agriculture professionals shall inform and disseminate project technologies to the beneficiaries using communication tools and knowledge sharing mechanisms suggested in the user manual. EIAR and other relevant stakeholders shall also promote project technologies and enhance crop residues utilization techniques in the subsequent crop seasons through its own resources.
6. References


Black CA. 1965. Determination of exchangeable Ca, Mg, K, Na, Mn, and effective cation exchange capacity in soil. Methods of soil analysis, Agronomy No. 9, part 2, American Society of Agronomy, Madison, Wisconsin.


Crop residues as animal feed vs conservation agriculture


Walkley A and CA Black. 1934. An examination of the Degtjareff methods for determining soil organic matter and proposed modification of the chromic acid titration methods. American Society of Agronomy, Madison, WI.