Application of Different Land Evaluation Methods for Faba Bean (*Vicia Faba*) Production Suitability Assessment for Central Tigray, Ethiopia

Micheal Yemane<sup>a,b</sup>, Fassil Kebede<sup>b,*</sup>, Wolde Mekuria<sup>b,c</sup>


Production of beans has a long history in Atsbi-Womberta district, Tigray, Ethiopia, but the yield is not promising. Thus, this study was undertaken with the objective of evaluating whether Atsbi-Womberta district continues to be suitable for bean production. A watershed within the study site was selected and stratified into six land units based on their slope. A profile was opened in each land unit. And 23 composite soil samples were collected and analyzed for selected physical and chemical properties. Data on climate and landscape characteristics were also collected. FAO land suitability assessment of the watershed for bean production is S<sub>3c</sub>, which is marginally suitable. This study also identified low precipitation during the growing cycle, low organic carbon, sandy loam texture and low sum of basic cations as major limiting factors for bean production. Thus, an integrated approach should be considered if bean would remain a major crop. Possible interventions may include use of stress resistant bean cultivars; increase the level of soil organic matter, addition of mineral fertilizers to raise the level of sum of the basic cations and supplementing the rain water with irrigation water.

Key words: climate; evaluation, faba beans; organic carbon; sum of basic cations; suitability; texture

*World Vision Ethiopia, P.O.Box 3330, Addis Ababa, Ethiopia.

<sup>b</sup>Department of Land Resources Management and Environmental Protection, Mekelle University, P.O. Box 231, Mekelle, Ethiopia

<sup>c</sup>Institute of Soil Science and Forest Nutrition, University of Goettingen, Bu’sgenweg 2, D-37077 Gottingen, Germany

*Author for corresponding: Fassil Kebede, Department of Land Resource Management and Environmental Protection, Mekelle University; P.O.B-231, Mekelle, Ethiopia; E-mail: fyimamu@gmail.com

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Introduction

Land degradation, which includes degradation of vegetation cover and soil, is a major ecological and economic problem in Ethiopia (Haileslassie et al., 2005). Forest areas of the country have been reduced from 40% half a century ago to an estimated less than 3% today. The current rate of deforestation is estimated to be 200,000 to 200,000 ha yr<sup>-1</sup>. It is estimated that fertile top soil is lost at a rate of one billion cubic meters per year, resulting in massive environmental degradation and constituting a serious threat to sustainable agriculture and forestry (Girma, 2001; Dereje et al., 2002; Sonneveld and Keyzer, 2002; Kahsay, 2004; Nyssen et al., 2004).

Soil degradation in Ethiopia can be seen as a direct result of inappropriate agricultural practices on the highlands (Mulugeta et al., 2005). Besides, the dissected terrain, the extensive areas with slopes above 16%, and the high intensity of rainfall lead to accelerated soil erosion once deforestation occurs. The loss of soil and the deterioration in fertility, moisture storage capacity, and the structure, all reduce the country’s agricultural productivity (Mulugeta et al. 2005). The average annual rate of soil loss at national level has been estimated at 12 ton per hectare with an estimated loss from arable lands averaging 42 ton per hectare. The result is a reduction of soil depth by 4 mm per year and decline in the productivity of the soil by 1-2% (Hurni, 1990).

At present, land degradation is the major threat to the sustainability of agriculture in Tigray. A fact that becomes more relevant recognizing that 90% of the population depends on agriculture for their livelihood. Even in good years, farmers cannot produce enough to cover their subsistence needs, with an average household producing only 40% of their annual minimal food requirements (Nyssen et al., 2002; REST five years plan 2001-2006). Diminishing rainfall is another cause for the present environmental situation (Hulme et al., 2000). Sometimes the rains stop in August instead of September. The prevailing cropping systems, to be effective require evenly distributed rain from early June to mid September.

Even though, climate and soil conditions are dynamic in nature, farmers in the area do not adjust their cropping systems in line with the changing growth factors. Farmers are following traditional cropping systems, which led to yield reduction. Besides, fertility of the land varies in the area but fertility class of the land is not known. This leads to over or under-utilization of the land. Mostly it is used over or beyond the capacity of the land, which leads to severe land degradation and yield reduction.

Thus, to cope with the prevailing ecological fragility at least to some degree, and turn into more robust and compatible livelihood systems, crops, cropping systems, technologies and socio-cultural...
patterns have to be adapted to the prevailing bio-physical environment. Therefore, the present study evaluated whether the currently practiced cropping system of the area is profitable or not to the local community with the current land resource available for bean production.

Materials and Methods

Study Site:
The study was conducted at Atsbi Womberta district, Eastern Tigray, Northern Ethiopia. Atsbi Womberta (13°50' N latitude and 39°45' S longitude) located at a distance of 880 km from Addis Ababa, capital of Ethiopia, and 80 km from Mekele, capital of the Region (Figure 1). The total population of the district is 112,373 (51 % female), having 41,398 households in 16 kebeles and two rural towns.

Mixed crop-livestock production is the major farming system practiced in Atsbi-Womberta district. Farmers practice traditional agriculture using family labor, hand tools and animal power. The average mean annual rainfall is 552 mm having uni-modal pattern of rainfall. Rainfall is erratic and highly variable both temporally and spatially. The altitude of the study site is between 2600 and 2700 m.a.s.l. Rugged and steep chain of mountains dominates the landscape of Atsbi-Womberta with poor vegetation cover. The sparse vegetation has become the main cause for severe soil erosion problem in the area. Soils in Atsbi-Womberta woreda, specifically at Adi-Gesa watershed are classified as typic ustipsamments developed from Enticho sandstones and it is predominantly sandy loam texture.

Experimental Design:
Within Atsbi Womberta district, Adigesa watershed was selected for evaluation as a major bean production area in the Region. The watershed covers 30 km², incorporating two villages called Barka and Mesanu. The watershed was stratified into three slope positions: upper slope (US), middle slope (MS) and foot slope (FS) which is referred to as land units. The upper slope was > 30 %, middle slope was 8-30 % and foot slope is < 2 %. Six profiles were opened (one for each land unit) to study the soil characteristics of Adigesa watershed at one-kilometer interval (Figure 2a and b). To determine the productivity assessment, climatic, landscape and soil requirements for faba bean production (Tables 1 & 2) were assessed. For land evaluation purposes mean ten years climatic data for Atsbi-Womberta district was procured from National Meteorology Station (Table 3).

Soil Sampling and Laboratory Analyses:
In each profile, 3 to 4 horizons were identified and samples were collected from the four sides of horizons. The samples were mixed thoroughly in a large bucket to form a composite soil sample, which was transported to the laboratory for further processing. Plant roots and shoots were handpicked and discarded. Soil samples were air-dried; ground and passed through a 2mm sieve before analysis. Standard analytical procedures of the Ethiopian National Soil Science Laboratory were used for all chemical and physical analyses. Organic matter was determined using Walkley–Black method.
Ammonium and sodium acetate extracts were used to determine exchangeable cations and cation exchange capacity (CEC), respectively (Thomas, 1982). Calcium and magnesium concentrations were determined using atomic absorption spectrophotometer and potassium and sodium were determined by flame photometer. pH and EC were determined using a suspension of 1:5 soil:water ratios. Particle size analyses were determined using the Hydrometer method (Gee and Bauder, 1982). Bulk density was determined by core method (Blake and Hartge, 1986). A total of 23 samples were collected and analyzed representing the six profiles.

Growing Period and Productivity Analysis:
FAO method was utilized to determine length of growing period, start of growing period, end of rain and end of growing period (Sys et al., 1991). Additionally, maximum yield of a crop ($Y_m$) is primarily determined using FAO approach (FAO, 1983).

$$Y = (0.36 ((1 - \frac{n}{N}) \times b_o + (1 - (\frac{n}{N}) \times b_c)) \times \frac{KLA}{(1/L + 0.25 \alpha)} \times HI)$$

Where $Y$ is yield:
- $n$ is actual hours of bright sunshine
- $N$ is astronomically possible hours of bright sunshine, or day length
- $b_o$ is maximum gross biomass production on overcast days
- $b_c$ is maximum gross biomass production on clear days
- $KLA$ is constant leaf area index
- $L$ is days to maturity
- $Hi$ is harvest index

Figure 2a. The Barka sub-district, with examples of profile positions (P1: profile 1; P2: profile 2; P3: profile 3).

Figure 2b. The Mesanu sub-district, with examples of profile positions (P1: profile 1; P2: profile 2; P3: profile 3).
### Table 1. Climatic Requirement of Faba Beans

<table>
<thead>
<tr>
<th>Climate characteristics</th>
<th>Class, degree of limitation and rating scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S1</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Precipitation during growing cycle (mm)</td>
<td>400-500</td>
</tr>
<tr>
<td>Mean temperature of the growing cycle (°C)</td>
<td>15-20</td>
</tr>
<tr>
<td>Mean minimum temp. of the growing cycle (°C)</td>
<td>10-15</td>
</tr>
<tr>
<td>Relative humidity of development stage (%)</td>
<td>60-50</td>
</tr>
<tr>
<td>Relative humidity of maturation stage (%)</td>
<td>50-30</td>
</tr>
<tr>
<td>n/N development stage</td>
<td>0.6-0.5</td>
</tr>
<tr>
<td>n/N maturation stage</td>
<td>&gt; 0.7</td>
</tr>
</tbody>
</table>

Source: F (Sys et al., 1991). Where S1 is no to slight limitation or 0-1, S2 moderate limitation or 2, S3 severe limitation or 3 and S4 very severe limitation or 4.

### Table 2. Landscape and Soil Requirements for Beans

<table>
<thead>
<tr>
<th>Land characteristics</th>
<th>Class, degree of limitation and rating scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S1</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Topography (t)</td>
<td></td>
</tr>
<tr>
<td>Wetness (%)</td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
</tr>
<tr>
<td>Physical soil characteristics (s)</td>
<td></td>
</tr>
<tr>
<td>Texture / structure</td>
<td></td>
</tr>
<tr>
<td>Coarse fragment (Vol %)</td>
<td></td>
</tr>
<tr>
<td>Soil depth (cm)</td>
<td></td>
</tr>
<tr>
<td>CaCO3 (%)</td>
<td></td>
</tr>
<tr>
<td>Soil fertility characteristics (f)</td>
<td></td>
</tr>
<tr>
<td>Apparent CEC (cmol (+)/kg clay)</td>
<td>&gt; 24</td>
</tr>
<tr>
<td>Base saturation (%)</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Sum of basic cations (cmol (+)/kg soil)</td>
<td>&gt; 7</td>
</tr>
<tr>
<td>pH H2O</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>&gt; 0</td>
</tr>
<tr>
<td>Salinity and Alkalinity (n)</td>
<td></td>
</tr>
<tr>
<td>ECe (dS/m)</td>
<td></td>
</tr>
<tr>
<td>ESP (%)</td>
<td></td>
</tr>
</tbody>
</table>

Source: (Sys et al., 1991)
Land suitability evaluation:
The crop requirements with respect to climate, landscape and soil were summarized in the separate tables according to Sys et al. (1993). With the help of these tables, the qualitative land suitability evaluation was done for faba beans (*Vicia faba*) by comparing the actual soil characteristics and qualities with crop requirements. The lands were classified using the Simple Limitation Method (SLM), the Limitation method regarding Number and Intensity (LMNI) and two Parametric Methods (PM), namely the square-root and the Storie methods (Sys et al. 1991).

The SLM implies that the crop requirement tables are made for each utilization type. For each characteristic, the tables define the class-level criteria. The methodology suggests that, in the first place, an evaluation of the climatic characteristics is made, with an aim to determine a climate class level to be used in the following evaluation. The climate class level was determined by the lowest class level among those found for particular climatic characteristics. Then, similarly, the land class was determined by the lowest class level among those found for particular landscape-soil characteristics.

The LMNI evaluates in the first place the climatic characteristics, regrouped according to radiation, temperature, rainfall and humidity. For each climatic characteristic group, the most severe limitation determines the climatic suitability class, which was then used as the corresponding limitation level for the total evaluation.

The PM consists in numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum (normalized as 100%) and the minimum value. Finally, the climatic index, as well as the land index, was calculated from individual ratings using the Storie method (Storie, 1976) square root method (Khiddir, 1986).

### Table 3. Climatic data for Atsbi-Womberta district

<table>
<thead>
<tr>
<th>Months</th>
<th>Rainfall (mm)</th>
<th>Temp (min)</th>
<th>Temp (max)</th>
<th>RH (%)</th>
<th>Sunshine (h)</th>
<th>Solar Radiation (Jule/m2/day)</th>
<th>ETo (mm/day)</th>
<th>Wind Speed (km/day)</th>
<th>td (°C)</th>
<th>tn (°C)</th>
<th>N</th>
<th>n/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>6</td>
<td>4.9</td>
<td>24.1</td>
<td>56</td>
<td>10.6</td>
<td>21.6</td>
<td>3.8</td>
<td>130</td>
<td>19.16</td>
<td>10.31</td>
<td>11.36</td>
<td>0.93</td>
</tr>
<tr>
<td>February</td>
<td>5</td>
<td>6.6</td>
<td>24.6</td>
<td>57</td>
<td>9.8</td>
<td>22.2</td>
<td>4.2</td>
<td>138</td>
<td>19.83</td>
<td>11.62</td>
<td>11.64</td>
<td>0.84</td>
</tr>
<tr>
<td>March</td>
<td>42</td>
<td>7.3</td>
<td>26</td>
<td>51</td>
<td>10.5</td>
<td>24.6</td>
<td>4.9</td>
<td>147</td>
<td>20.87</td>
<td>12.43</td>
<td>12</td>
<td>0.88</td>
</tr>
<tr>
<td>April</td>
<td>54</td>
<td>10.6</td>
<td>27</td>
<td>48</td>
<td>10.9</td>
<td>26.4</td>
<td>5.4</td>
<td>156</td>
<td>22.31</td>
<td>15.01</td>
<td>12.46</td>
<td>0.87</td>
</tr>
<tr>
<td>May</td>
<td>42</td>
<td>9.4</td>
<td>25.8</td>
<td>57</td>
<td>12.2</td>
<td>28.1</td>
<td>5.5</td>
<td>173</td>
<td>21</td>
<td>13.74</td>
<td>12.76</td>
<td>0.96</td>
</tr>
<tr>
<td>June</td>
<td>38</td>
<td>9.2</td>
<td>26.9</td>
<td>38</td>
<td>10.9</td>
<td>25.7</td>
<td>5.5</td>
<td>164</td>
<td>21.65</td>
<td>13.84</td>
<td>12.94</td>
<td>0.84</td>
</tr>
<tr>
<td>July</td>
<td>139</td>
<td>10.7</td>
<td>23.3</td>
<td>54</td>
<td>8.2</td>
<td>21.8</td>
<td>4.5</td>
<td>156</td>
<td>19.59</td>
<td>14.02</td>
<td>12.84</td>
<td>0.64</td>
</tr>
<tr>
<td>August</td>
<td>154</td>
<td>9.8</td>
<td>22.8</td>
<td>72</td>
<td>8</td>
<td>20.7</td>
<td>4.1</td>
<td>156</td>
<td>19.05</td>
<td>13.28</td>
<td>12.56</td>
<td>0.64</td>
</tr>
<tr>
<td>September</td>
<td>18</td>
<td>8.1</td>
<td>23.6</td>
<td>67</td>
<td>10.1</td>
<td>24.5</td>
<td>4.5</td>
<td>147</td>
<td>19.27</td>
<td>12.32</td>
<td>12.18</td>
<td>0.83</td>
</tr>
<tr>
<td>October</td>
<td>14</td>
<td>7.3</td>
<td>22.3</td>
<td>72</td>
<td>10.9</td>
<td>24.2</td>
<td>4.2</td>
<td>181</td>
<td>18.26</td>
<td>11.45</td>
<td>11.8</td>
<td>0.92</td>
</tr>
<tr>
<td>November</td>
<td>31</td>
<td>5.7</td>
<td>22.1</td>
<td>75</td>
<td>10.2</td>
<td>21.3</td>
<td>3.5</td>
<td>121</td>
<td>17.84</td>
<td>10.31</td>
<td>11.44</td>
<td>0.89</td>
</tr>
<tr>
<td>December</td>
<td>10</td>
<td>3.6</td>
<td>22</td>
<td>76</td>
<td>10.6</td>
<td>20.9</td>
<td>3.2</td>
<td>112</td>
<td>17.32</td>
<td>8.81</td>
<td>11.26</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Source: Ethiopian National Meteorological Station. (ETo is evapo-transpiration, td is day time temperature, tn is night time temperature, n is actual hours of bright sunshine, N is astronomically possible hours of bright sunshine, or day length.

### The Storie method:
The index was taken as a product of individual ratings:

\[ I = A \times \frac{B}{100} \times \frac{C}{100} \times \ldots \]

Where I is and index and A, B, C are climatic or landscape ratings for each characteristics.

### Square-root method

\[ I = R_{\text{min}} \sqrt{\frac{A}{100} \times \frac{B}{100} \times \frac{C}{100}} \]

Where:

I=index, Rmin- minimum rating and A, B, C etc. remaining ratings.
Results and Discussion
Growing period and faba bean requirement
The length of growing period (LGP) in the Atsbi-Womberta district is found to be 90 days. It begins from 29th June and ends on 26th September (Fig 3), but farmers used varieties of beans that require 100 days. This makes the LGP of the study area unsuitable to the varieties that farmers are currently using. The area receives 552 mm rainfall per annum on average (Table 3). The length of humid period extends from second decade of July to third decade of August, for fifty days.

Estimated and actual yield of beans
The estimated yield of a high yielding bean hybrid in the study area is 3.2-ton/ha, provided all growth conditions are optimal. But farmers are currently producing only 0.3 ton/ha, instead of 3.2 t/ha! This indicates the production is by far lower than the predicted yield. The likely reasons for the lower yield are poor soil management and inadequate precipitation during the growing cycle.

Climatic, Landscape and Soil Suitability
The climatic data of Atsbi-Womberta district was compared with the specific climatic requirements for bean production and the suitability assessed subsequently (Table 4). After analyzing the data using simple/maximum limitation method, precipitations of growing cycle, relative humidity and radiation (n/N) at development stage were found to be limiting factors with the class of moderately suitable (S2), for better bean production in the study area. The climatic rating implies yield reduction of 40 % from the estimated theoretical yield.

Results after applying limitation method regarding number and intensity of limitations shows climatic suitability of Atsbi-Womberta woreda has four slight limitations and two moderate limitations. The suitability class for climate using this method becomes S2. The climatic index is found to be 35.5 using parametric method. This shows the climate of the study area has severe limitation level (S3) to grow beans successfully.

Soils in Atsbi-Womberta district, specifically at Adi-Gesa watershed are classified as Typic Ustipsamments developed from Enticho sand stones. The study revealed that sites at the upper slopes have low CEC, low clay content and low organic carbon content. However, the sites found at the lower slopes have relatively higher organic carbon, electrical conductivity, calcium carbonate and base saturation (Table 5; Table 6a and b). The suitability of the study area determined by the most limiting land characteristic with landscape and soil factors showed that most of the specific sites had moderate to severe limitations (Table 7, Figure 4).

Table 4. Results of Climatic Evaluation for Growing Beans

<table>
<thead>
<tr>
<th>Parameters to be considered for rating</th>
<th>Data</th>
<th>Rating</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation of growing cycle (mm)</td>
<td>311.2</td>
<td>65.5</td>
<td>S2</td>
</tr>
<tr>
<td>Mean temperature of growing cycle (°C)</td>
<td>16.45</td>
<td>97.4</td>
<td>S1</td>
</tr>
<tr>
<td>Mean minimum temperature of growing cycle (°C)</td>
<td>9.6</td>
<td>93.7</td>
<td>S1</td>
</tr>
<tr>
<td>Relative humidity of development stage (%)</td>
<td>38</td>
<td>68</td>
<td>S2</td>
</tr>
<tr>
<td>Relative humidity of maturation stage (%)</td>
<td>67</td>
<td>88.2</td>
<td>S1</td>
</tr>
<tr>
<td>n/N development stage</td>
<td>0.84</td>
<td>85</td>
<td>S2</td>
</tr>
<tr>
<td>n/N maturation stage</td>
<td>0.83</td>
<td>100</td>
<td>S1</td>
</tr>
</tbody>
</table>

Figure 3 The growing period of Atsbi-Womberta district
Table 5. Soil physical properties and organic matter content of the study site

<table>
<thead>
<tr>
<th>Location</th>
<th>Barka sub - district</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Mesanu sub - district</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slope class</td>
<td>Horizon depth (cm)</td>
<td>OM (%)</td>
<td>OC (%)</td>
<td>sand</td>
<td>silt</td>
<td>clay</td>
<td>Textural class</td>
<td>Slope class</td>
</tr>
<tr>
<td>US 0-20</td>
<td>1.43</td>
<td>0.71</td>
<td>68</td>
<td>8</td>
<td>24</td>
<td>SCL</td>
<td>US 0-25</td>
<td>1.43</td>
<td>0.71</td>
</tr>
<tr>
<td>20-45</td>
<td>1.93</td>
<td>0.96</td>
<td>66</td>
<td>16</td>
<td>18</td>
<td>SL</td>
<td>25-65</td>
<td>1.43</td>
<td>0.71</td>
</tr>
<tr>
<td>45-90</td>
<td>2.79</td>
<td>1.35</td>
<td>60</td>
<td>14</td>
<td>26</td>
<td>SCL</td>
<td>65-145</td>
<td>1.64</td>
<td>0.82</td>
</tr>
<tr>
<td>90-200</td>
<td>1.29</td>
<td>0.64</td>
<td>72</td>
<td>14</td>
<td>14</td>
<td>LS</td>
<td>145-230</td>
<td>2.43</td>
<td>1.21</td>
</tr>
<tr>
<td>MS 0-20</td>
<td>2.14</td>
<td>1.07</td>
<td>82</td>
<td>8</td>
<td>10</td>
<td>LS</td>
<td>US 0-25</td>
<td>1.43</td>
<td>0.71</td>
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<tr>
<td>20-50</td>
<td>1.86</td>
<td>0.93</td>
<td>82</td>
<td>6</td>
<td>12</td>
<td>LS</td>
<td>25-65</td>
<td>0.86</td>
<td>0.43</td>
</tr>
<tr>
<td>50-135</td>
<td>1.21</td>
<td>0.61</td>
<td>82</td>
<td>6</td>
<td>12</td>
<td>LS</td>
<td>65-165</td>
<td>1.14</td>
<td>0.57</td>
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<tr>
<td>135-205</td>
<td>0.86</td>
<td>0.43</td>
<td>80</td>
<td>4</td>
<td>16</td>
<td>LS</td>
<td>165-210</td>
<td>0.79</td>
<td>0.39</td>
</tr>
<tr>
<td>FS 0-20</td>
<td>2.79</td>
<td>1.39</td>
<td>64</td>
<td>20</td>
<td>16</td>
<td>SL</td>
<td>FS 0-20</td>
<td>3.29</td>
<td>1.64</td>
</tr>
<tr>
<td>20-70</td>
<td>1.21</td>
<td>0.61</td>
<td>66</td>
<td>12</td>
<td>22</td>
<td>SCL</td>
<td>20-75</td>
<td>2.79</td>
<td>1.39</td>
</tr>
<tr>
<td>70-180</td>
<td>1.64</td>
<td>0.82</td>
<td>64</td>
<td>14</td>
<td>22</td>
<td>SL</td>
<td>75-135</td>
<td>1.21</td>
<td>0.61</td>
</tr>
</tbody>
</table>

S = sand; LS = loamy sand; SL = sandy loam; SCL = sandy clay loam; US, MS and FS = upper, middle and foot slope respectively.

Table 6a. Soil chemical properties of the Barka sub – district.

<table>
<thead>
<tr>
<th>SC</th>
<th>Horizon depth (cm)</th>
<th>pH-H₂O</th>
<th>EC μS/cm</th>
<th>CaCO₃ (%)</th>
<th>K cmol(+)/kg</th>
<th>Na cmol(+)/kg</th>
<th>Mg cmol(+)/kg</th>
<th>Ca cmol(+)/kg</th>
<th>SBC cmol(+)/kg</th>
<th>CEC cmol(+)/kg</th>
<th>BS (%)</th>
<th>ESP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 0-20</td>
<td>7.2</td>
<td>16.4</td>
<td>6.6</td>
<td>0.06</td>
<td>0.00</td>
<td>0.88</td>
<td>3.78</td>
<td>4.72</td>
<td>11.6</td>
<td>40.8</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>20-45</td>
<td>7.4</td>
<td>15.6</td>
<td>7.2</td>
<td>0.04</td>
<td>0.15</td>
<td>1.44</td>
<td>5.33</td>
<td>6.81</td>
<td>16.8</td>
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<td>0.01</td>
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</tr>
<tr>
<td>45-90</td>
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<td>22.5</td>
<td>7.8</td>
<td>0.04</td>
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<td>5.33</td>
<td>7.19</td>
<td>19.2</td>
<td>37.4</td>
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<tr>
<td>90-200</td>
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<td>0.00</td>
<td>0.00</td>
<td>1.78</td>
<td>7.55</td>
<td>9.33</td>
<td>12.5</td>
<td>74.9</td>
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<tr>
<td>MS 0-20</td>
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<td>18.6</td>
<td>5.2</td>
<td>0.07</td>
<td>0.15</td>
<td>0.53</td>
<td>2.87</td>
<td>3.47</td>
<td>6.76</td>
<td>51.4</td>
<td>0.01</td>
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<tr>
<td>20-50</td>
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<td>17.2</td>
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<td>0.15</td>
<td>0.53</td>
<td>2.87</td>
<td>3.47</td>
<td>6.76</td>
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<td>0.01</td>
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<td>17.2</td>
<td>5.3</td>
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<td>0.64</td>
<td>2.40</td>
<td>3.11</td>
<td>14.0</td>
<td>22.2</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>FS 0-20</td>
<td>7.1</td>
<td>15.8</td>
<td>8.6</td>
<td>0.04</td>
<td>0.15</td>
<td>1.11</td>
<td>10.1</td>
<td>11.3</td>
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<tr>
<td>20-70</td>
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<td>0.00</td>
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<td>7.48</td>
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<td>18.7</td>
<td>47.7</td>
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<td>70-180</td>
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<td>15.9</td>
<td>8.0</td>
<td>0.02</td>
<td>0.00</td>
<td>1.16</td>
<td>7.88</td>
<td>9.06</td>
<td>19.7</td>
<td>45.9</td>
<td>0.00</td>
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</tr>
</tbody>
</table>

SC = slope class; BS = base saturation; ESP = exchangeable sodium percentage; SBC = sum of basic cations

Table 6b. Soil chemical properties of the Mesanu sub – district.

<table>
<thead>
<tr>
<th>SC</th>
<th>Horizon depth (cm)</th>
<th>pH-H₂O</th>
<th>EC μS/cm</th>
<th>CaCO₃ (%)</th>
<th>K cmol(+)/kg</th>
<th>Na cmol(+)/kg</th>
<th>Mg cmol(+)/kg</th>
<th>Ca cmol(+)/kg</th>
<th>SBC cmol(+)/kg</th>
<th>CEC cmol(+)/kg</th>
<th>BS (%)</th>
<th>ESP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 0-25</td>
<td>6.5</td>
<td>17.5</td>
<td>5.2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.25</td>
<td>1.51</td>
<td>1.76</td>
<td>6.82</td>
<td>25.7</td>
<td>0.00</td>
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</tr>
<tr>
<td>25-65</td>
<td>6.7</td>
<td>14.7</td>
<td>2.9</td>
<td>0.02</td>
<td>0.00</td>
<td>0.43</td>
<td>2.40</td>
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<td>6.92</td>
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<td>0.00</td>
<td>0.92</td>
<td>4.18</td>
<td>5.12</td>
<td>20.3</td>
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<td>0.00</td>
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<td>145-230</td>
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<td>16.6</td>
<td>7.5</td>
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<td>0.16</td>
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<td>6.82</td>
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<td>5.2</td>
<td>0.04</td>
<td>0.00</td>
<td>0.75</td>
<td>3.31</td>
<td>4.10</td>
<td>13.5</td>
<td>30.3</td>
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<td>0.02</td>
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<td>9.90</td>
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<td>0.00</td>
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<td>165-210</td>
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<td>130</td>
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<tr>
<td>FS 0-20</td>
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<td>0.02</td>
<td>0.15</td>
<td>1.24</td>
<td>13.1</td>
<td>14.4</td>
<td>18.5</td>
<td>77.9</td>
<td>0.01</td>
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<td>135-210</td>
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<td>19.5</td>
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<td>0.15</td>
<td>0.93</td>
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<td>7.72</td>
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<td>55.8</td>
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</tr>
</tbody>
</table>

SC = slope class; BS = base saturation; ESP = exchangeable sodium percentage; SBC = sum of basic cations.
Table 7. Evaluation Results on Landscape and Soil of Study Site for Faba Beans Production

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop</th>
<th>Evaluation method</th>
<th>Limiting characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Simple/maximum</td>
<td>Limitation regarding number and intensity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>limitation</td>
<td>and intensity</td>
</tr>
<tr>
<td>Upper Barka sub-district</td>
<td>Bean</td>
<td>S3</td>
<td>S3</td>
</tr>
<tr>
<td>Middle Barka sub-district</td>
<td>Bean</td>
<td>S2</td>
<td>S2</td>
</tr>
<tr>
<td>Lower Barka sub-district</td>
<td>Bean</td>
<td>S2</td>
<td>S2</td>
</tr>
<tr>
<td>Upper Mesanu sub-district</td>
<td>Bean</td>
<td>S3</td>
<td>S3</td>
</tr>
<tr>
<td>Middle Mesanu sub-district</td>
<td>Bean</td>
<td>S3</td>
<td>S3</td>
</tr>
<tr>
<td>Lower Mesanu sub-district</td>
<td>Bean</td>
<td>S2</td>
<td>S2</td>
</tr>
</tbody>
</table>

c = limitation from climate, f = limitation from soil fertility, s= limitation from soil structure

Discussions
The poor suitability of the upper and middle Barka site for bean production could arise from different factors. Poor fertility status, low organic carbon and low precipitation during growing cycle explained the marginally suitable upper Barka site. Shortage of rain in growing cycle and higher pH of the soil are the main limiting factors at Middle Barka site. On the contrary, lower Barka is moderately suitable for bean production though the low precipitation during the growing cycle and the sandy loam texture has an effect on the growth performance of beans.

The analyses result shows that the upper and middle Mesanu sites are unsuitable for production of beans. This could arise from the low amount of precipitation, low sum of basic cations and low organic carbon content in the upper Mesanu. And low organic carbon content of the soil mainly explains the unsuitability of the middle Mesanu. Like the lower Barka site, lower Mesanu site is found to be moderately suitable for beans production. However, low precipitation of growing cycle and texture of the soil remains as a limiting factor.

Continuous cultivation leads to drastically reduced levels of soil organic matter. Such reductions in the level of soil organic matter have resulted in soil productivity decline (Bationo and Mokwunye, 1991; Kathryn et al., 2000). It is not surprising that soil organic matter (SOM) decline is related with soil fertility decline because both N and P dynamics are closely related to SOM (Wang et al., 2001). This is because of close association total organic carbon has with the proposed soil quality indicator, (Murage et al., 2000). However, the limitation related to soil fertility...
status could be minimized through appropriate land management. For example, the addition of organic materials either in the form of manures or crop residue has beneficial effects on the soils' chemical and physical properties (Batino and Mokwunye, 1991).

A study conducted by Karamanos et al. (1982) revealed that water stress reduced the final leaf size by reducing both the area at unfolding and the mean growth rate. A study conducted by Sangakkara et al. (2004) also revealed that high potassium supply had a positive effect on nitrogen fixation, on shoot and root growth and on water potential. This study indicated that K can apparently alleviate water shortage to a certain extent because K-fed plants maintained higher leaf water potential, turgor potential and relative water content and lower osmotic potential as compared to untreated plants of Vigna radiate (Nabdwal et al., 1998). Besides, the function of stomata is to control water loss from the plant via transpiration. When K+ is deficient, the stomata can’t function properly and water losses from plant may reach damaging levels (Gething, 1990). Therefore, improving the sum of cations and other soil nutrients through the application of organic and inorganic fertilizers could help to alleviate the limiting factors for bean production. Selection of appropriate variety could also help to minimize the effects of some of the causes that resulted in yield decline (Link et al., 1999). It is supposed that the sensitivity of faba beans to high pH in middle Barka site is related to the deficiency of the available forms of N, P and other important nutrients (Schubert et al., 2004).

The limiting characteristic like texture is hard to be improved. However, because of the sandy nature of the soil and low moisture content in general, the study site is not susceptible to structural deformation such as compaction. A study conducted by Veldkamp (1994) also revealed that wet and clayey soils are more susceptible for compaction compared to sandy and dry soils. Besides, to overcome problems that come due to texture, like low water holding capacity and leaching of minerals, construction of conservation structures, water harvesting schemes, application of manure and leaving crop residues in the field is quite important.

Conclusion
The research result revealed that the Atsbi-Womberta woreda is constrained for production of beans. The area is found marginally suitable to produce beans. Farmers are only harvesting 9.4% of estimated yield. Climatic and soil characteristics are the causes for these extremely low productivity of beans. Low and unevenly distributed rain during the growing period has higher contribution for reduced amount of production and low organic carbon is the other limiting factor coming from the soil. Thus, appropriate land management practices such as residue management, application of manures and integrating soil and water conservation structures in the agricultural lands are timely needed.

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References


Hulme, M., Doherty, R., Ngara, T., New, M., Listeri, D


