EJED 2(1) 2019: 1 - 20
Ethiopian Journal of Environment and Development
http://www.du.edu.et/duj

The Role of Moisture Schemes in Regional Climate Modeling of Precipitation over the Horn of Africa

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Received: 11 April, 2019 /Accepted: 8 July, 2019

Abstract

This study aims to evaluate the performance of the latest Regional Climate Model version 4 (RegCM4) to simulate the precipitation over the Horn of Africa. Although there are several aspects in which the model can be improved, the focus of this study is to tackle the problem of its moisture scheme. RegCM4 moisture scheme has fourteen moisture scheme parameters, which can be tuned within the allowed physical limits. Each of the fourteen moisture parameters have been varied around the current default setting and over 80 model runs have been performed for a domain defined by 60km resolution, 18 vertical levels covering spatially the whole Africa and the major circulation patterns that derive climate over the region. We have found physical sound set of moisture scheme parameters to be used in the fourteen moisture scheme parameters that have significantly reduced bias in RegCM4 precipitation; improved correlation of RegCM4 precipitation with respect GPCP and CMAP; and captured seasonal and interannual variations over most of the 12 delineated homogeneous regions of Horn of Africa.

Key words: Moisture, scheme, RegCM4, Model, Precipitation

1. Introduction

The Horn of Africa (HOA) has distinct climate characteristics compared to the rest of the continent (Vojtesak et al. 1990). The HOA is replete with complex terrain comprising of some of the known tropical high mountains and the Great Rift Valley System (GRVS).

The complex HOA terrain presents enabling environment where local and large scale climate systems frequently interact to create highly variable climate in both space and time. At the same time, inter-annual variability of the HOA climate is linked to perturbations in the global SSTs, especially over the equatorial Pacific and Indian Ocean basins, and to some extent, the Atlantic Ocean (Ogallo 1988; Nicholson 1997 and Mutai et al. 2000). These three global oceans, all at the same time or each at different times, intriguingly influence the interannual variability of the HOA climate.

Interactions and feedbacks among these multiple climate drivers over the region present challenges in quantitative understanding of regional climate variability and changes based on typical empirical techniques (Ogallo et al. 1988; Ogallo 1989)). Therefore, there is a need to employ physically-based, regional climate models (RCM) that can offer scope and capability to unveil cause-effect relationships between regional climate variability and individual or combination of processes. However, representation of the multiple sources of forcing to the HOA climate also poses a great challenge to RCM as well.

For hydrological cycle, the presence of clouds and resulting precipitation is the primary control on the cycles (pal et al. 2000). The ERA-Intrim reanalysis corrects some of the errors of the ERA-40 reanalysis particularly in the hydrological cycles variables over the tropics. It is also important to accurately represent cloud processes in many modeling application.

Clouds are often poorly represented in both regional and global climate models (RCMs and GCMs) respectively (pal et al. 2000).

In this research we considered SUBEX (subgrid explicit moisture) parameters processes of bottom model level with no clouds (ncld), autoconversion rate for the land and ocean (qland and qoce), autoconversion threshold (Qthc) for the land and ocean (guland, guloce), minimum relative humidity over the land and ocean (rhland, rhoce), maximum relative humidity (rhmax), maximum cloud cover (fcmax), effect of temperature (tc0) on SUBEX, rain drop evaporation rate coefficient (Cevap), Cloud liquid water content for convective precipitation (cllwcv), Max cloud fractional cover for convective precipitation (clfrcvmax) and rain drop accretion rate (Caccr) are varied within the allowed physical limits such that the default settings are enclosed within the variations for the normal year of summer 2000.

This study aims to evaluate the performance of the Regional Climate Model version 4 (RegCM4) to simulate the precipitation over the Horn of Africa of the delineated region. It evaluates the ability of regional climate model (RegCM4) to reproduce the observed rainfall amounts and distribution over the topographically varied region of the HOA.

2. Method and Materials

2.1 Description of study Area

Geographically, the western half of the HOA is dominated by the Great Rift Mountain system which runs nearly the entire length of east Africa and extending into the Arabian Peninsula in the extreme north (Vojtesak et al.1990). The topography of HOA extends from -182 to 5780m above sea levels. The peak of mountain is found in the north western and central parts of Ethiopia as depicted on figure 2.1. Highlands regions encompass mostly in Ethiopia than other countries of HOA.

The mountains have a marked influence on climate and weather in the HOA, presenting a major natural barrier between modified maritime and continental tropical air masses to the west, and Indian Ocean (IO) maritime tropical air to the east (Vojtesak et al.1990). Large-scale tropospheric circulation features influencing the HOA are largely controlled by the Asian monsoon, a seasonal reversal of winds caused by hemispheric-scale, continent-ocean temperature gradients (Ramage et al. 1971; Slingo et al. 2003).

The terrain slopes upward from east to west, transitioning from lowlands at the shorelines, then to rolling hills and plateau, until meeting the Great Rift mountain chain (Figure 2.1).

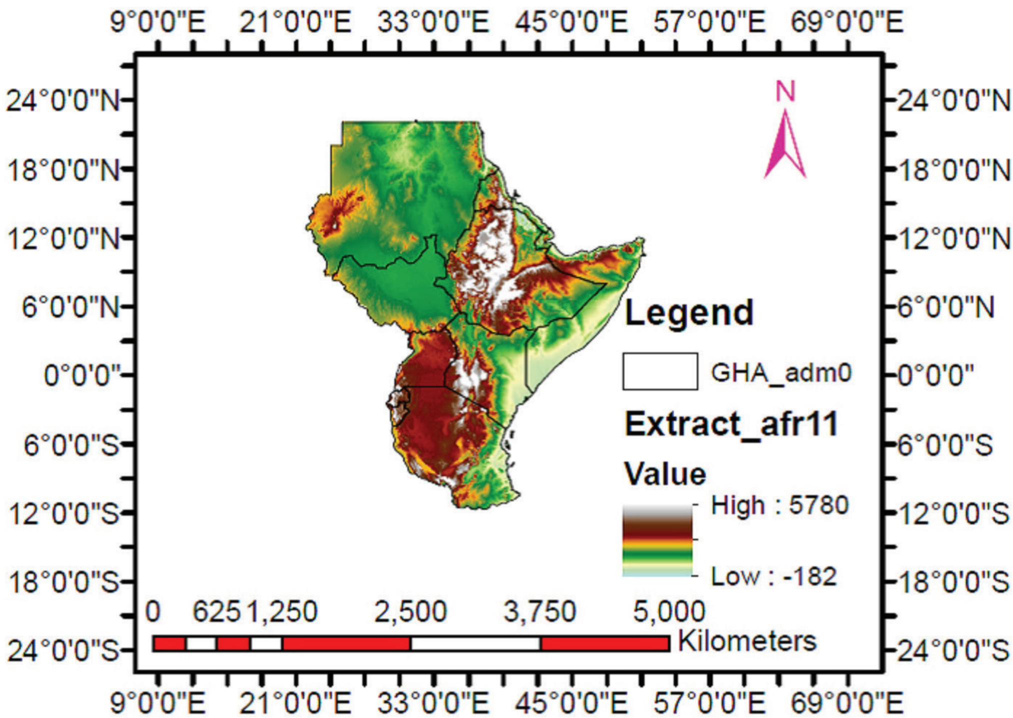

Figure 2.1. *The topography of Horn of Africa Region (study area)*

3. Method

3.1 Boundary conditions

3.1.1 Surface boundary conditions

Orography is incorporated in the model as the lower boundary condition in a terrain following vertical coordinate system (Giorgi et al. 1993). Pressure has been widely used as a vertical coordinate in modeling and theoretical studies. However, there were deficiencies of the sigma treatment of orography. This scheme may not handle sharp terrain gradients effectively (Indeje et al. 2001).

The orography data used in this study were taken from the global 2.5° horizontal resolution orography file archived at International Research Institute (IRI). These data were interpolated to the model horizontal grid resolution of 60 km using the linear interpolation scheme. The land-use data adopted in the model were interpolated from 2.5° resolution data archived at National Centers for Atmospheric Research (NCAR). The time dependent SST was interpolated from 1°X1° grid of the monthly mean observed data. The surface pressure, air temperature, humidity are some of surface boundary condition variables (Giorgi et al. 1993).

3.1.1 Lateral boundary and initial conditions

This scheme consists of Newtonian and diffusion terms that gradually drive the model solution of wind components, temperature, water vapor mixing ratio, and surface pressure toward specified large scale values inside the lateral buffer zone. The lateral boundary condition variables are:

- . Wind
- . Temperature
- . Water vapor; and
- . Surface pressure.

As the size of the horizontal domain decreases, the specification of the velocity components and temperature along the boundaries affects the mean values of these quantities over the entire domain to an ever increasing degree (Giorgi et al. 1993). Thus, on a domain of 224 x 96, a set of boundary conditions may be computationally stable and produce smooth results, but even small errors in the treatment of precipitation, temperature or velocity may profoundly affect the mean kinetic and internal energy budgets over the domain.

Initial conditions in a numerical simulation represent the mean space time characteristics of the atmosphere at the beginning of the numerical experiment. The fields for both lateral and initial conditions are obtained ECMWF reanalysis. After completion of ERA-40, effort was devoted to development of a new reanalysis system derived from the latest version of the operational European Center for Medium Range Weather Forecast (ECMWF) system. In 2006 a new reanalysis was started from January 1989, to produce an interim reanalysis (ERA-Interim) for the data rich 1990s and 2000s, to be continued as ECMWF Climate Data Assimilation System (ECDAS) until superseded by a new extended reanalysis.

The main advances of the ERA-Interim data assimilation over the ERA-40 system are: 12 hour 4D Var, T255 horizontal resolution, better formulation of background error constraint, new humidity analysis, improved model physics, quality control of data drawing on experience from ERA-40 and variation bias correction of satellite radiance data, improvements in radiosonde temperature and surface pressure bias handling, more extensive use of radiances, improved fast radiative transfer model and assimilation of rain affected Sea Surface Model (SSM) radiances through 1D-Var.

ERA-Interim uses mostly the observations prepared for ERA-40 supplemented by data for later years from ECMWFs operational archive. Boundary forcing fields are taken from ERA-40 until 2002, and from ECMWF operations for later dates. However, a few new dataset have been acquired. The ERA-INTERIM is a reanalysis of the global atmosphere covering the data rich period since 1989 and continuing in real time. As ERA-Interim continues forward in time, updates of the Archive will take place on a monthly basis.

The ERA-INTERIM project was initiated in 2006 to provide a bridge between ECMWFs previous reanalysis, ERA-40 (1957-2002), and the next generation extended reanalysis envisaged at ECMWF. The main objectives of the project were to improve on certain key aspects of ERA-40, such as the representation of the hydrological cycle, the quality of the stratospheric circulation, and the handling of biases and changes in the observing system. These objectives have been largely achieved as a result of a combination of factors, including many model improvements, the use of 4-dimensional variational analysis, a revised humidity analysis, the use of variational bias correction for satellite data and other improvements in data handling.

The atmospheric model is coupled to an ocean-wave model resolving 30 wave frequencies and 24 wave directions at the nodes of its reduced one-degree latitude/longitude grid.

The main characteristics of the ERA-Interim system and many aspects of its performance are described in ECMWF.

The sensitivity of models runs of five up to eight sets of experiments for each individual SUBEX parameters of the subgrid explicit moisture processes are done.

ERA-Interim data set is used for initial conditions (ICs) and exponential lateral boundary conditions (LBCs) during sensitivity runs of each of the fourteen parameters as well as long year runs using default and new set of parameters. Sea surface temperature from optical interpolation weekly (OI-WK) are used as surface boundary conditions. For the ICs and LBCs quantities each reanalysis dataset is interpolated to the grid of the RegCM4 and the first set of interpolation fields is used as ICs for the simulation. The physics of convective precipitation scheme used in this experiment is a Grell Arakawa-Schubert (Grell AS) scheme. The RegCM4 was run with the same horizontal resolution of 60km and 18 vertical levels. The domain is 39.9°to west and 80.44° degree in the East direction and from 24.6° to south and 25.1° North direction as shown in Fig 2.2.

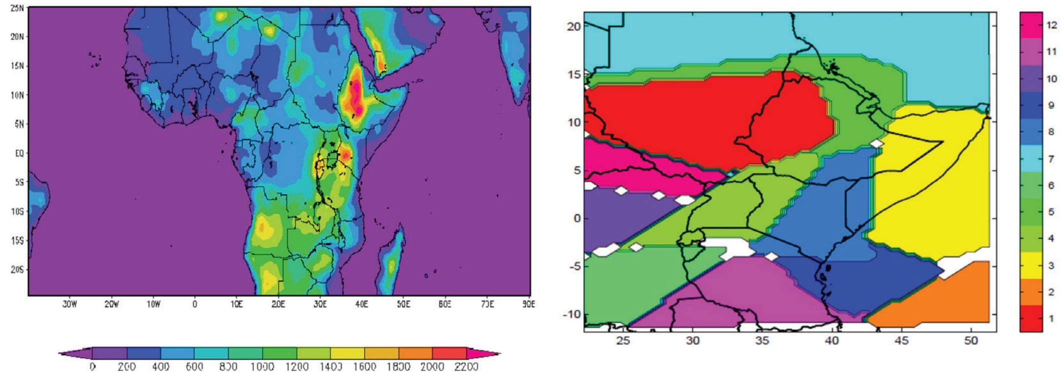

Figure 2.2: RegCM4 Simulation Domain and Delineated regions of Horn of Africa

3.1.1 Validation Data Set: CMAP and GPCP Precipitation

In this study, RegCM4 Precipitation is compared with Global Precipitation Climatology Project (GPCP) and CPC Merged Analysis of precipitation (CMAP). Rain-gauge measurement is the traditional and oldest method for monitoring rainfall. However, because of practical observational limitations it suffers from numerous gaps in space and time, often making its use in climate diagnostic studies is less reliable. On the other hand, rainfall estimates based on satellites is spatially and temporally comprehensive when calibrated using rain-gauge measurements (Xie and Arkin 1998). Xie and Arkin (1998) produced a global precipitation data set called CMAP to assist in problems encountered when relying just on rain-gauge observations. CMAP is a global precipitation data set that uses a global 2.5° X 2.5° grid resolution, temporally distributed monthly/pentad from January 1979 - present. The Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis is globally complete, monthly analysis of surface precipitation grids at 2.5° X 2.5° resolution is available from January 1979 to the present. It is a merged analysis that incorporates precipitation estimates from low orbit satellite microwave data, geosynchronous orbit satellite infrared data, and surface rain gauge observations (Adler et al. 2003). The merging approach utilizes the higher accuracy of the low orbit microwave observations to calibrate, or adjust, the more frequent geosynchronous infrared observations. The dataset is extended back into the premicrowave era (before mid-1987) by using infrared-only observations calibrated to the microwave based analysis of the later years. The combined satellite based product is adjusted by the rain gauge analysis. The dataset archive also contains the individual input fields, a combined satellite estimate and error estimates for each field.

This monthly analysis is the foundation for the GPCP suite of products, including those at finer temporal resolution. The 23-yr GPCP climatology is characterized along with time and space variations of precipitation.

3.1.1 Analysis of Bias, RMSE and Correlation

The performance of the four options of convective schemes in RegCM4 is evaluated quantitatively by analyzing the bias, root mean square error and correlation of the simulations relative to the observation datasets using the methods found in (Wang et al. 2003; Diro et al. 2008).

The primary measure of simulation skill is the model bias (a time average of the error), defined as

$$bias = \frac{1}{N}\left[\sum_{i}\sum_{j}\left(a_{i,j}^{M} - a_{i,j}^{O}\right)\right] \quad (2.1)$$

where N is the total number of grid points within a given region; subscripts **i**, **j** are the horizontal grid point indices in the zonal and meridional directions, respectively; **a** can be any meteorological parameters either daily mean or monthly mean; superscripts **O** and **M** refer to the observed and model simulated quantities, respectively.

The root mean square error (RMSE) is defined as

$$\mathrm{RMSE} = \sqrt{\frac{1}{\mathrm{N}}\sum_{\mathrm{i}}\sum_{\mathrm{j}}\left(a_{i,j}^{M} - a_{i,j}^{O}\right)^{2}} \quad (2.2)$$

A correlation coefficient measures the strength and direction of a linear association between two variables. The correlation coefficient between simulated and observed quantity is defined as where the over bar denotes spatial mean.

$$Corrcoef = \frac{\left[\sum_{i}\sum_{j}\left(a_{i,j}^{M} - a_{i,j}^{\overline{M}}\right)\left(a_{i,j}^{O} - a_{i,j}^{\overline{O}}\right)\right]}{\sqrt{\left[\sum_{i}\sum_{j}\left(a_{i,j}^{M} - a_{i,j}^{\overline{M}}\right)^{2}\left(a_{i,j}^{M} - a_{i,j}^{\overline{O}}\right)^{2}\right]}} \quad (2.3)$$

4. Results

A total of eighty four model runs during sensitivity model runs and two additional model experiments for long period to assess the improvement in simulation of precipitation based on new set of SUBEX parameters versus the default setting were performed. In the following section, we consider both sensitivity studies and long year run.

4.1 Sensitivity Studies for Moisture Scheme Parameters

In this study sensitivity runs were performed for fourteen moisture scheme parameters resulting in total eighty four runs and each individual SUBEX parameters of the subgrid explicit moisture processes experiments were done. These experiments were done from moisture scheme of bottom model level with no clouds (ncld) to maximum cloud fractional cover for convective precipitation (clfrcvmax) which is varied within the allowed physical limits such that the default settings are enclosed within the variations for the normal year of summer 2000.

Table 3.1 shows sensitivity studies accomplished for 14 SUBEX variables. The second row shows the model runs which include the default and additional runs of up to seven experiments while the first column shows the SUBEX variables. The improvement in precipitation prediction based on the new values of the parameters was evaluated using correlation, RMSE and bias of RegCM4 with corresponding CMAP and GPCP values.

Table 3.1: Sensitivity experiments based on JJAS runs of the normal year of 2000.

Subex Param.	**default**	**run1**	**Run2**	**Run3**	**Run4**	**Run5**	**Run6**	**Run7**
Ncld	1	0	2	3	4			
Fc_{max}	0.80	0.50	0.60	0.70	0.90	1.00		
Qland	0.25exp-3	0.5exp-4	0.15exp-3	0.5exp-3	0.75exp-3	0.1exp-2	0.5exp-2	0.1exp-1
Qoce	0.25exp-3	0.5exp-4	0.15exp-3	0.5exp-3	0.75exp-3	0.1exp-2	0.5exp-2	0.1exp-1
Guland	0.4	0.3	0.5	0.6	0.7	0.8		
Guloce	0.4	0.3	0.35	0.45	0.5	0.55		
Rh_{max}	1.01	0.80	0.85	0.90	0.95	1.00	1.03	1.05
Rhland	0.80	0.65	0.70	0.75	0.85	0.95		
Rhoce	0.90	0.70	0.75	0.85	0.90	0.95		
tc0	238.0	230	234	242	246	250	260	270
C_{accr}	3	1	2	4	5	6		
C_{evap}	0.10exp-2	0.35exp-2	0.50exp-2	0.60exp-2	0.75exp-2	0.85exp-2		
Cllwcv	0.3exp-3	0.1exp-3	0.2exp-3	0.4exp-3	0.5 exp-3	0.6exp-3		
$Clfrcv_{max}$	0.25	0.15	0.20	0.35	0.40	0.45		

4.2 Long Years Runs (1989 - 2008) with new set of SUBEX Parameters

The extent of improvement to precipitation simulation with respect to old and new parameter values were described in detail (Table 3.2).

The new parameters the subgrid explicit moisture scheme (SUBEX) improves the agreement between simulated and observed precipitation for the seasons of the years except that of summer which has high roots mean square error (RMSE) than the default SUBEX parameters and Grell AS convective scheme (Fig. 3.1). Furthermore, evaluation of RegCM4 simulation for 1989-2008 showed that the modified moisture scheme (SUBEX) does not only reproduce the 19 years average rainfall realistically but also captures interannual variability adequately over the Horn of Africa.

In RegCM4, both the convective and SUBEX schemes work on subgrid scales; however, their approaches are different. The convective schemes try to diagnose if convection will occur in portions of the grid and allow emulating updrafts in the atmosphere and form precipitation through updrafts. However, the large scale precipitation scheme SUBEX does not emulate up drafts, but instead processes the moisture that is already aloft in the atmosphere. In this process it forms clouds and precipitation if critical thresholds of moisture are surpassed.

In RegCM4, the convective scheme is called before the SUBEX scheme. This implies that some SUBEX precipitation could be generated by moisture moved aloft by the convection that moves moisture aloft but that the convective scheme itself does not rain out.

Separation of convective and stratiform rain was dependent on which scheme generated the rainfall.

Table 3.2: New SUBEX parameter values selected based on best performance in capturing CMAP and GPCP precipitation

subex parameter	Perivious values	accepted values from CMAP	Accepted Values from GPCP
Ncld	1	2	2
Fc_{max}	0.80	0.50	0.50
Qland	0.25 exp-3	0.1 exp-1	0.1 exp-1
Qoce	0.25 exp-3	0.15 exp-3	0.15 exp-3
Guland	0.4	0.3	0.3
Guloce	0.4	0.55	0.55
Rh_{max}	1.01	1.01	1.01
Rhland	0.80	0.90	0.90
Rhoce	0.90	0.95	0.95
tc0	238	246	246
C_{evap}	0.100 exp-2	0.75 exp-2	0.75 exp-2
C_{accr}	3.0	3.0	3.0
Cllwcv	0.3 exp-3	0.3 exp-3	0.3 exp-3
$Clfrcv_{max}$	0.25	0.20	0.20

Fig. 3.1 shows correlation of RegCM4 precipitation reproduced using new SUBEX parameters (marked as new) and default (marked as Grell-AS) values with CMAP(left panel) and GPCP (right panel). There is substantial improvement in reproducing observed precipitation patterns using the new set of SUBEX parameters over nearly all clusters.

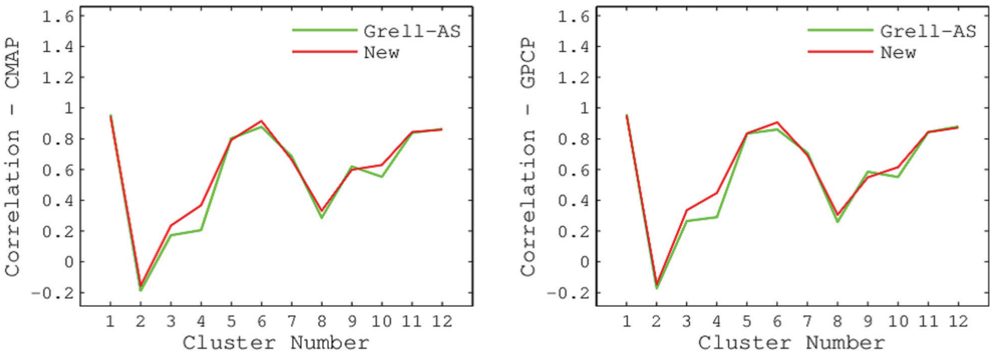

Figure 3.1: Correlation simulated precipitation based on new and old SUBEX with CMAP (left panel) and GPCP (right) for the long year model run.

Figure 3.2 shows the simulated precipitation based on new and old SUBEX parameters with CMAP and GPCP for the long years model run is evaluated by using statistical methods to visualize its accuracy with the old model (Grell-As) for different year intervals. The root mean squared error (RMSE) and bias are implemented statistics for evaluating the overall quality of the simulated precipitation. The Root Mean Squared Error (RMSE) is the square root of the average squared distance of data point. RMSE (upper panels) and bias (lower panels) as depicted in (Fig.3.2). There is a slight rise in the RMSE over some regions in cluster 6, and 10 – 12.

However there is significant improvement in the bias for clusters in the region, especially over the region in cluster 4, 6, 8, 10 - 12.

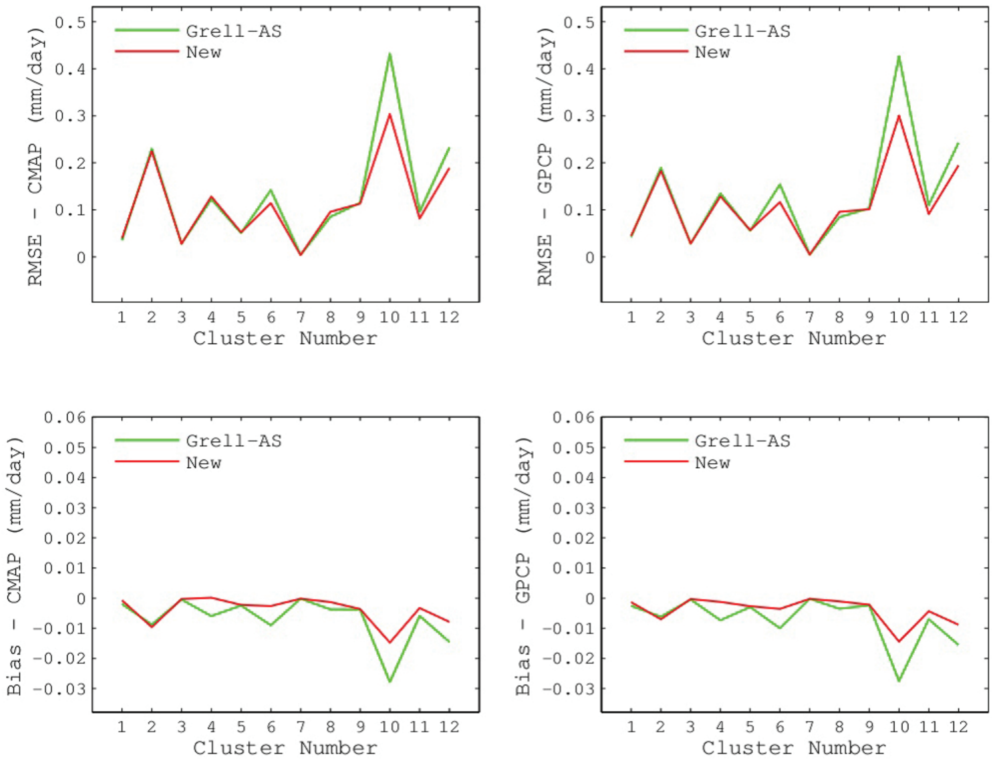

Figure 3.2: RMSE (top) and Bias (bottom) of simulated precipitation based on new and old SUBEX parameters with CMAP (left panel) and GPCP (right) for the long years model run

Fig.3.3 shows the seasonal mean RMSE (top panels) and Bias (bottom panels) of simulated precipitation based on new parameters (red) and old (green) with CMAP (left) and GPCP (right) for the whole Horn of Africa regions. The correlation of the simulated precipitation using new parameters with the observational data set had declined during the JJAS period, which is a wet season for most of northern part of the horn of Africa.

From our previous result of cluster analysis in this study, this is probably an artifact introduced due to averaging over the whole domain which is characterized by different seasons. It is considered imperative that RCMs be tested concerning the ability to reproduce historical observations of both mean climate and temporal variability for more extended periods.

Therefore, we evaluated the ability of the new SUBEX parameters to reproduce the 1990 – 2008 (19 years) time series for the all the clusters in the region and inter-annual variability within each delineated regions.

The degree of similarity between modeled and observed inter-annual rainfall variability is a valuable model diagnostic that measures the sensitivity moisture schemes over Horn of Africa precipitation.

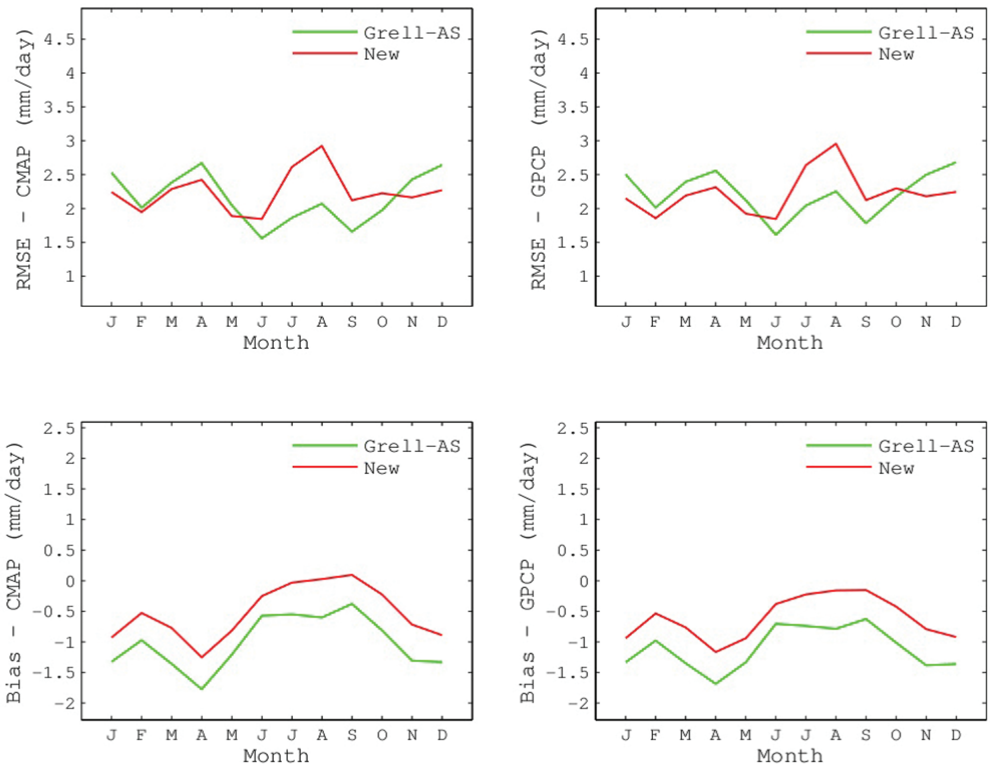

Figure 3.3: RMSE and Bias of simulated precipitation based on new and old SUBEX parameters with CMAP (left panel) and GPCP (right) for the long year model

Fig. 3.4 (top panel) shows remarkable improvement in both magnitude and pattern of precipitation produced using the new parameters. There are several instances at which there is improvement in magnitude which exceeds 2mm/day in contrast to simulation on the basis of default values.

Fig. 3.4 (middle panel) shows the time series for cluster 2 which is over Indian Ocean. Both old and new set of parameters have bad performance in capturing the observed pattern as well as magnitudes over the whole simulation period. There is either small or significant over clusters 3, 4, 7, 8, and 9 as shown in Figs. 3.4 (bottom panel), 3.5 (top panel), 3.6. The clusters include regions characterized by low lands, deserts, and semi arid climate. Most of these regions lie in east, northeast, south parts of Horn of

Africa, mostly along and towards south and eastern side of the great rift valley. This signals that our choice particularly regarding rain drop evaporation is not optimal. On the other hand, the new simulation has captured observed inter-annual rainfall variability over clusters 1, 6, 11, 12 remarkably and partly over clusters 5 and 10 as shown in Figs. 3.4 (top panel), 3.5 (bottom panel), and 3.7 (middle and bottom panels). These regions are either on north-western side of Great Rift Valley or south of equator. The north part of Ethiopian main rift valley region is part of the region with moderate improvement.

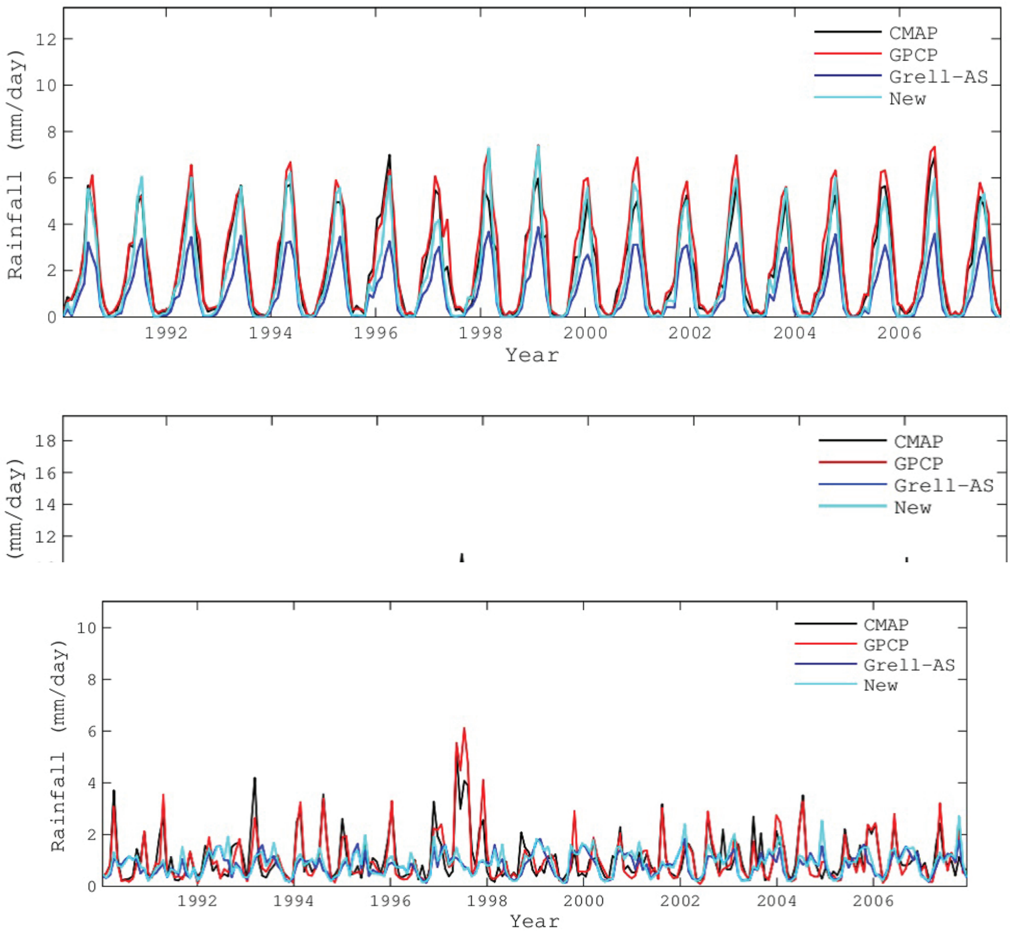

Figure 3.4: Rainfall time series: CMAP (black); GPCP (red); Old SUBEX parameter (marked as Grell-AS, blue); and New parameters (light green) for cluster number-1 (top), 2 (middle) 3 (bottom).

The clusters 4, 5 and 6 are depicted in Fig.3.5 with two observational data (GPCP and CMAP) by considering Old and New SUBEX parameters. Over the three cluster (cluster-4, 5 and 6) the New SUBEX parameter performed better than the Old SUBEX (Grell-AS) parameters. Temporally it showed better results simulated rain fall in capturing precipitation over these clusters locations.

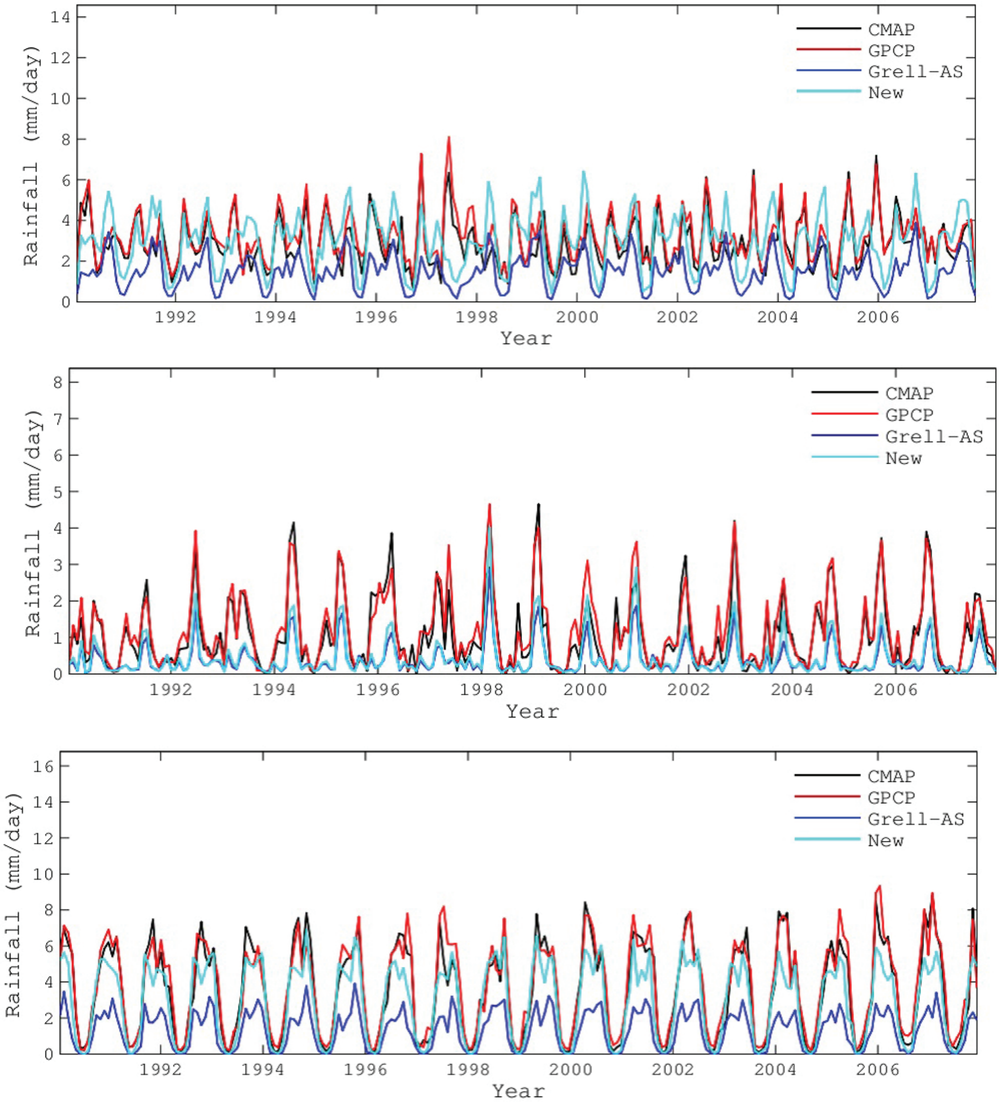

Figure 3.5: Rainfall time series: CMAP (black); GPCP (red); Old SUBEX parameter (marked as Grell-AS, blue); and New parameters (light green) for cluster number-4 (top), 5(middle), 6 (bottom).

In comparison to cluster 4-6, the New and Old SUBEX parameter over clusters 7 and 9, poor capturing ability were observed by New and Old SUBEX parameters (Fig 3.6). However, over cluster 8, simulated New SUBEX parameters showed better performance than the Old SUBEX parameters (Grell-AS).

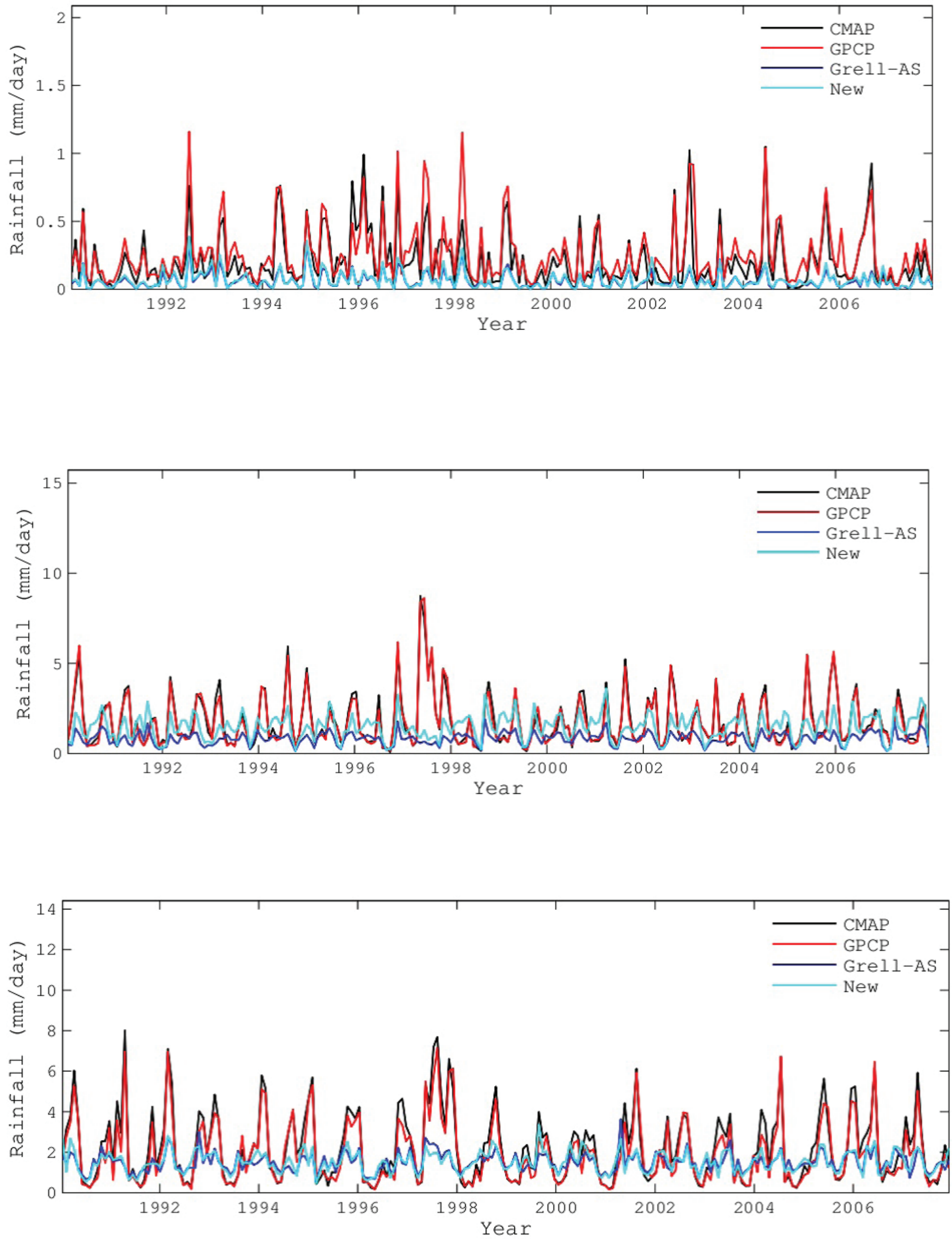

Figure 3.6: Rainfall time series: CMAP (black); GPCP (red); Old SUBEX parameter (marked as Grell-AS, blue); and New parameters (light green) for cluster number-7 (top), 8(middle) and 9 (bottom).

Over cluster 10-12 of delineated regions of parts of Horn of Africa, New SUBEX parameters performance is observed. This simulated scheme showed strong potential capturing precipitation over these three clusters (10, 11 and 12). Such strong comparison was not observed by Old SUBEX parameters with observational values. Therefore, higher capturing ability was observed by New simulated model in comparison with the observational values (GPCP and CMAP).

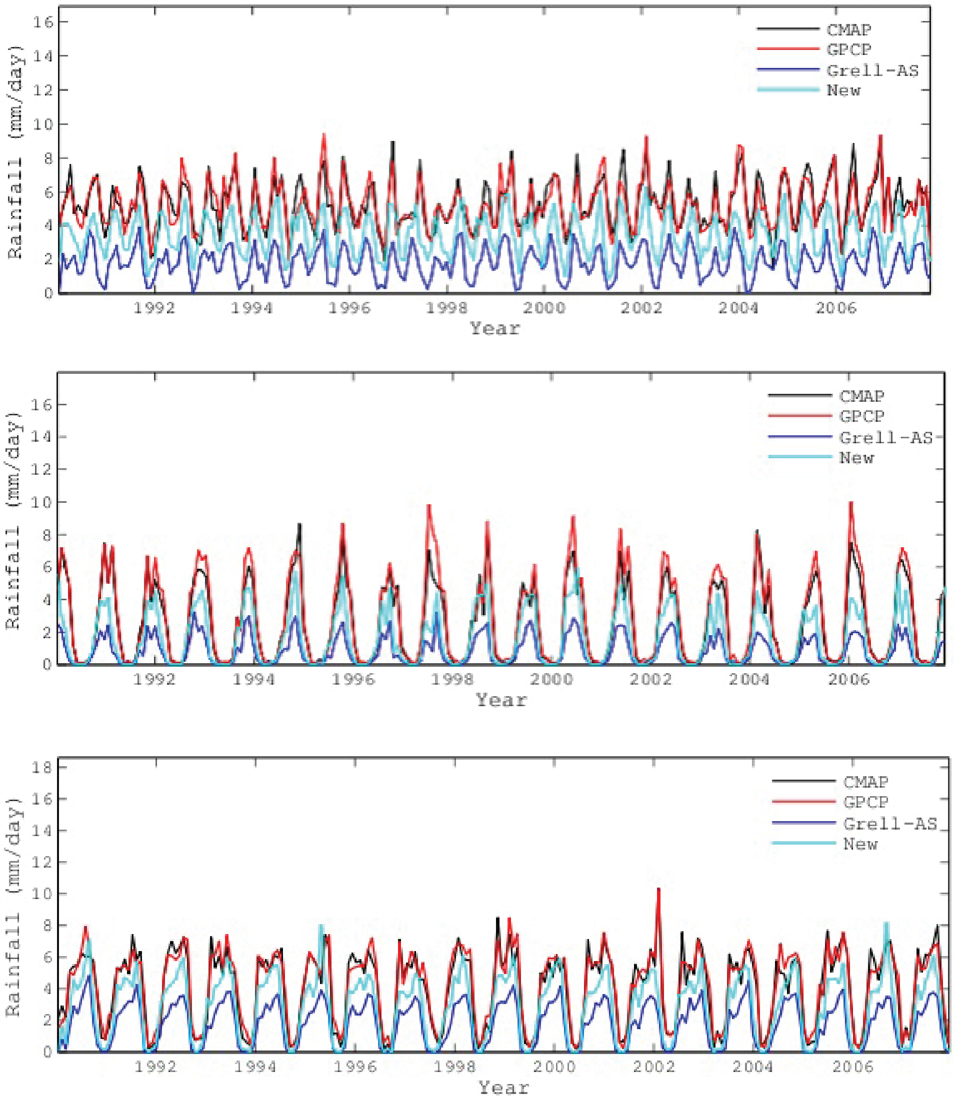

Figure 3.7: Rainfall time series: CMAP (black); GPCP (red); Old SUBEX parameter (marked as Grell-AS, blue); and New parameters (light green) for cluster number-10 (top), 11 (middle) and 12 (bottom).

Conclusion

The nonconvective precipitation, which is parameterized through subgrid explicit moisture scheme (SUBEX) in RegCM4 and its predecessors, is improved through optimal set of parameters for the horn of Africa region. The optimal set of SUBEX parameters are selected such that there is a large and significant correlation of simulated precipitation with observed precipitation of CMAP and GPCP; there is small RMSE and Bias in RegCM4 precipitation compared to these data set.

We have found optimal set of moisture scheme parameters which has significantly reduced the existing discrepancy between observation and simulated rainfall by RegCM4. The comparison of the two long years runs have shown significant difference between the simulations (New and Old SUBEX parameter). To assess either the new parameters have altered the simulated precipitation in the direction which agrees with observation, we have compared both simulations with CMAP and GPCP. The result of the comparison has shown that there are significant improvements for some of the clusters located in north-western part of horn of Africa which includes western Ethiopia highlands and low lands as well as part of Sudan. There are also some clusters with significant improvement on south-western of the region. However, low lying regions in south-easter which includes south-eastern part of Ethiopia, Somalia, part of Kenya and adjoining Indean Ocean have shown little or no change in capturing the observed precipitation pattern and inter annual variations. This is probably an indication that further improvements are needed in particular with respect to rain drop evaporation rate. In summary, we have found better set of parameters that can replace the old parameters for further climate studies over the western and south-western and north-western part of the horn of Africa.

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EJED 2(1) 2019: 21 – 45

Ethiopian Journal of Environment and Development

http://www.du.edu.et/duj

EJED

Effects of scattered Faidherbia albida (Del. A. Chev) tree on yield and yield components of three Cereal crops in Central Ethiopia

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Received: 13 April, 2019 /Accepted: 8 July, 2019

Abstract

Understanding tree-crop interaction is a key aspect in determining approprate tree-crop combination and managements. However, little is known about the influence of tree crop interaction and tree management on crop productivity. The study was conducted with the aim of investigating the effects of Faidherbia albida on yield and yield components of three cereal crops: wheat (Triticum aestivum L.), maize (Zea mays L.) and teff (Eragrostis tef (Zucc.) Trotter) in Central Ethiopian farmers field at Silti District.Three independent experiments were conducted using randomized complete block design with five replications for each experiment. The treatments consist of five radial distances at: 1.5m, 3.5m, 5.5m and 12.5m and contorl (25 m far from tree trunk). The yield and yield components data were collected from four directions and then the average was taken for analysis using one way ANOVA and mean separation was done using LSD at 5% significance level. Results showed that yield and yield component of wheat and maize were higher under and near the tree canopies than far from canopies. In contrast teff yield and yield component increased with increasing distance from tree trunk. Plant height, number of tiller per plant, spike length, total aboveground biomass and grain yield were all significantly higher (P < 0.05) for maize and wheat associated with F. albida compared to outside the canopy. Whereas, results from teff showed lower yield and above ground biomass close to the tree trunk compared to outside the canopy. The tree also used for fencing, fuelwood, fodder, construction and income generation. Therefore, the present study clearly showed that compatibility of maize and wheat under F. albida land use system are better tree crop combination design not only to enhance cereal productivity but also other tree benefits to farmers, while teff is incompatible to grow under F. albida land use system. Further study is required for the detailed species physiological response of the studied crops to shade.

Keywords: *Agroforestry, F. albida, cereal crops, crop productivity, Ethiopia*

1. Introduction

The smallholder agricultural sector in East Africa, including Ethiopia is the dominant economic and social activity for millions of households who are often resource-poor, food-insecure and most vulnerable to climate change (Affholder et al. 2013). However, agriculture is predominantly subsistence and rain-fed based with low input farming and hence characterized by low yield. Consequently, poor agricultural productivity has led to food shortages and these problems are likely intensified, as the human population is growing faster in these regions (Alain, 2018). Soil degradation and soil nutrients depletion is the most serious environmental constraint to crop production in Sub-Saharan Africa (Lal, 1988). The wide spread loss of soil carbon, Nitrogen and other nutrients from agricultural landscapes are severely reduce agricultural production in the region (Syers, 1997; Lal, 2001; Tadesse, 2001).In Ethiopia, the qualities of most agricultural soils have dramatically declined due to successive high rate of soil erosion and associated loss of soil organic carbon and nutrient contents (Hurni, 1993; Lemenih, 2004). Soil degradation is further worsened due to nutrient depletion arising from long years of land cultivation, and inadequate nutrient inputs, absence of appropriate cropping practices, lack of nutrient saving and recycling technologies (Stoorvogel & Smaling, 1993).

High population pressure and corresponding shortage of agricultural land led to shorter fallow periods, use of crop residues for forage and fuel wood instead of soil fertility maintenance, and expansion of farming system to marginal land causing severe decline in soil productivity (Haileslassie et al. 2006). Ethiopia has made extensive efforts to boost the production and productivity of major cereal crops like maize, wheat, teff, and sorghum through wider adoption and dissemination of inorganic fertilizers, improved seed variety, soil conservation practices and technologies (Gebresilassie, 2015). However, the downward spiral of soil fertility and the corresponding declining of crop productivity and production are still unabated (Getahun et al. 2014). Consequently, the gap between demand and supply of food is still large (Getahun et al. 2014 &Tesfaye, 2018). Agroforestry has a considerable potential for improving biodiversity, soil fertility and crop yield and provide other multi-purpose benefits for farmers (Nair, 1993; Young, 1997). Hence, promoting green agricultural growth through integrating agroforestry tree with cereal crops in smallholder farmers would be one possible strategy for boosting cereal productivity while protecting the environment. Additionally, it can improve the microclimate beneath the canopies and mitigate climate changes through sequestering carbon (Shiferaw et al. 2014). Traditional *F. albida*-crop integration is one of such a strategy (ICRAF, 2000; Garrity et al. 2010; ECRGE, 2011) and has been widely practiced for many generations by smallholder farmers in central rift valley of Ethiopia (e.g. Poschen, 1986; Kamara & Haque, 1992; ICRAF, 2000).

F. albida is an indigenous nitrogen fixing tree with a unique 'reverse phenology' − i.e., shedding leaves during the crop growing season, which permits penetration of enough radiation for the understory crops, has been understood to be one of the main reasons for its positive interaction with crops and it is well adapted and growing in different habitats, soil types and agro-ecologies with various cereals (Rao et al. 1998). Due to its nitrogen fixation ability and deep rooted nature, the tree can enhance soil fertility by adding nutrient and organic carbon into soil system through litter fall decomposition and nutrient pumping (Kamara & Haque, 1992; Roupsard, 1999; Kho et al. 2001; Payne et al. 1998). Beside these, internal nutrient inputs, soil under the canopies of the tree could also receive external nutrient through manuring from livestock and bird and other animal dropping (IIRR & NAPC, 2016).

Studies in Ethiopia have shown that *F. albida* improves soil fertility mainly nitrogen and organic carbon, which is assumed to be convert into higher crop yield under its canopy than away from it (Poschen, 1986; Manjur et al. 2014). Similarly, studies conducted in Malawi (Saka et al. 1994) and Niger (Kho et al. 2001) showed high soil fertility and crop yield beneath the canopies of *F. albida* tree compared to open area. However, in some cases such positive synergies were not observed (Poschen, 1986).

Therefore, the effects of on farm scattered trees including that of *F. albida* on cereal crop yield is inconsistent and depends on several factors such as crop type, tree management applied, difference in tree morphology and age, tree density, and climatic and soil conditions (Poschen, 1986; Bayala et al. 2015). For examples, Jiru (1997) reported increased grain yield for sorghum, wheat and maize when they grow under lopped *F. albida* than far from canopies while the same authors found yield loss for teff when it was intercropped with lopped *F. albida* trees close to tree trunk than open area in central Ethiopia. The existence of such deferential tree crop interactions among different crop species signal the need for more site and crop specific studies in order to design best tree crop combination and this study was designed to fill this research gap. Moreover, improperly selected and managed trees in agroforestry strongly compete with crops for light, resources, shade, and water and thus can have a devastating effect on crop yields. Therefore, understanding *F. albida* crop interaction is essential for formulating appropriate tree crop combination and tree management strategies. Thus, there is a need to know what difference exist in tree crop interaction with increasing distance from *F. albida* tree trunk in order to design the best tree crop combination. Therefore, this article aims to: (1) investigate the effect of scattered *F. albida* tree on cereal production and productivity by measuring yield and yield components with increasing distance from tree trunk, and (2) identify compatible and incompatible cereal crops to integrate with *F. albida* tree in Silte Zone, SNNPRS of Ethiopia.

2. Materials and Methods

2.1 Study site description

The study was carried out in Silti district located approximately between 7°38' to 8°07' N latitude and from 38°12' to 38°30' E longitude in Siltie Zone of Southern Nations, Nationalities and Peoples Regional State (SNNPRS) of Ethiopia (Fig. 1). According to Silti wereda agriculture and natural resource office the district has an altitude ranging from 1650 to 3100 masl and the dominant soil types included eutric Cambisols, chromic Luvisols, chromic Vertisols, eutric Fluvisols, Leptosols and pellic Vertisols. The district is dominantly Weyna Dega (mid altitude) in agroclimatic condition in which *F. albida* growth lies between 1700 to 2000 masl.The climate is also characterized by bimodal rainfall distribution with a total of 875 – 1,213 mm, and the mean annual temperature of 12°C - 25°C (average data from nearest meteorological stations). The dominant and important scattered trees on farm land in the district are *Acacia* species particularly *F. albida*, *Eucalyptus spp., Cordia africana*, and *Corotonmacrostachy*.The dominant annual crops intercropped with *F. albida* trees are Zea mays (maize), Triticum aestivum L(wheat), Eragrostis tef (teff), Sorghum bicolor L (sorghum), Hordeum vulgare L(barely) and vegetables such as green paper.

A typical cereal crop (Wheat, Maize, and Teff) production practices in the study area commenced for maize in March and for teff in April to June. However, production practice for wheat is commenced after rain softens the soil, and fields can be ploughed multiple times (average of three times). Sowing was occurred around the end of March for maize and between late June and early July for teff and wheat. Manual row seeding was used for maize, wheat, and teff. Pollarding, lopping, pruning, tinning and total removal of trees in their farming plots of tree management practice were applied in the study area.

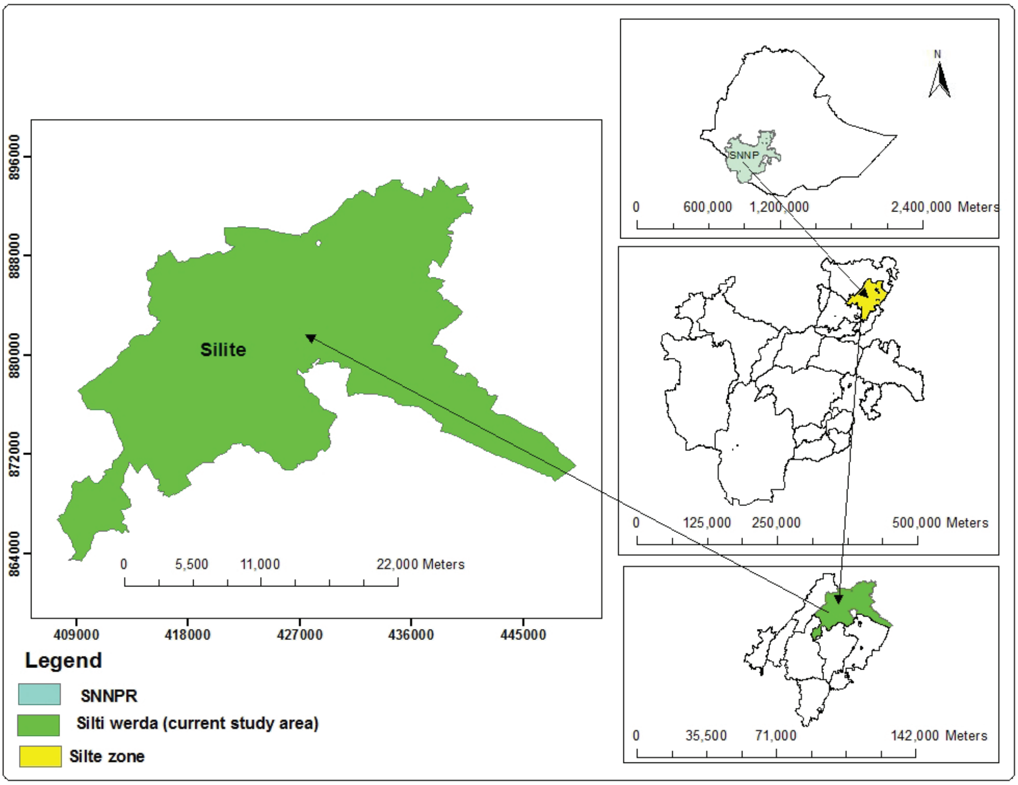

Figure1 *Location map of the study area*

2.1 Experimental design

Three independent experiments were conducted using randomized complete block design (RCBD) to evaluate performance of three cereal crops (wheat, maize and teff) grown beneath the pollarded *F. albida* tree. For each experiment, 5 mature isolated and a total of 15 on farm *F. albida* trees which have about similar size, shape and age and uniform soil, topography and crop husbandry were selected. To investigate each experiment, a total of 15 farmers were selected (5 farmers per experiment who owned and managed the tree on maize, wheat and teff fields). Farm fields used for experimental data collection were selected mainly using the following criterion: (1) the tree species of interest was grown within the selected crop fields, (2) the selected tree was located in the selected crop fields isolated from other on-farm trees at least by 50 m, and (3) open field and under canopy plots had similar characteristics, except for the presence of the tree. Each of these three independent experiments were replicated up to five times under five experimental units totaling to 75 experimental units, and five radial distance from tree trunk 1.5m, 3.5m, 5.5m, 12.5m and 25 m (control) were considered as treatments. Each quadrant (1m*1m) dimension was used for experimental unit and data were collected under the units. Manjur et al. (2014) experimental design was modified for this research work by using two additional experimental units (Fig. 2).

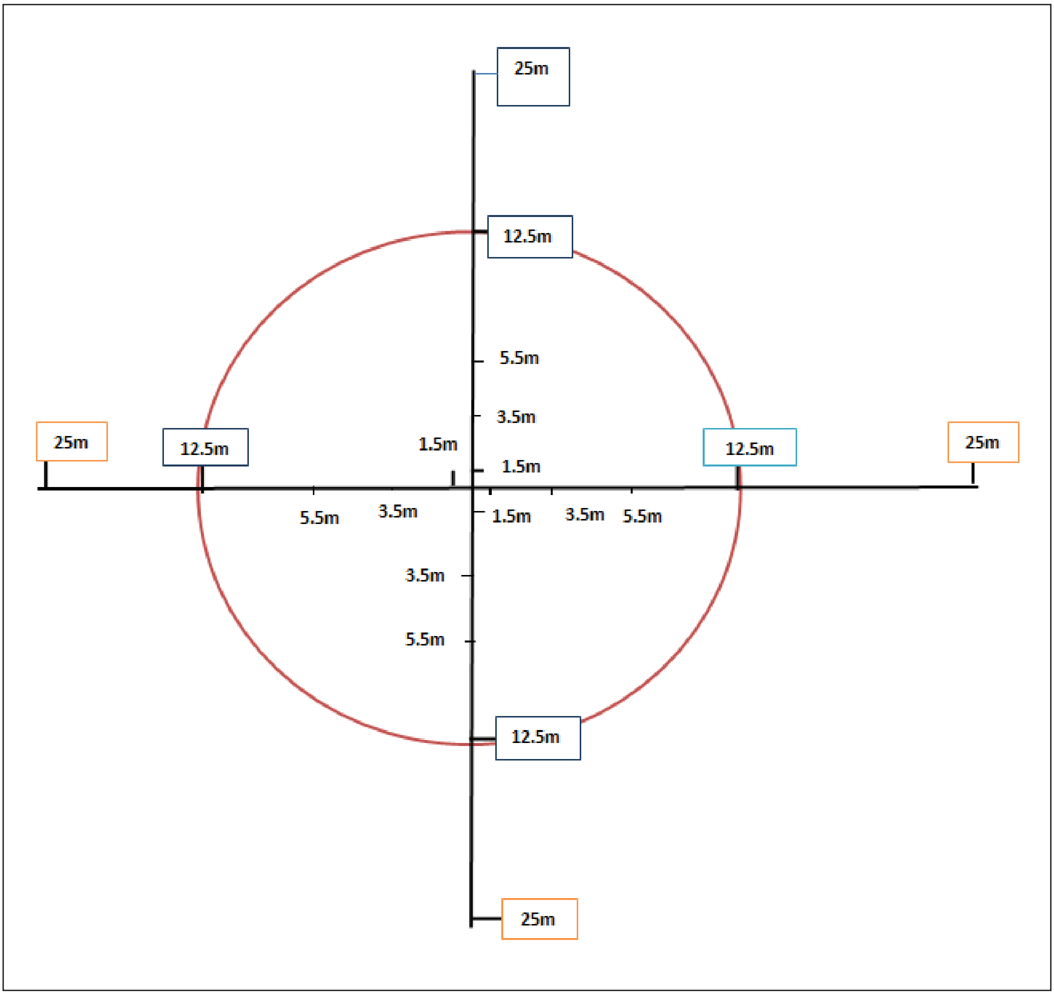

Figure 2 *Experimental design modified (adapted from:Manjur et al., 2014)*

Where:

1) The center of the circle represents a single F. albida tree;

2) The circle represents the area covered by the canopy of the tree;

3) The area covered by the canopy is divided into four radial transects (fully labeled here);

4) Five plots (1m * 1m each) were established on each radial transect at distances of 1.5 m, 3.5 m, 5.5 m

12.5 m, and at 25 m away from the tree trunk all directions and a total of twenty fiveplots were considered in single experiment.

5) The five plots for a similar distance on each of the four radial transects were considered as a single treatment, e.g. the plots at a distance of 1.5 m on each of the four radial transects.

Note that the figure is not drawn to scale and, of course, the area covered by the canopy is not a perfect circle.

2.1 Methods

Prior to crop planting, the canopy of each tree was properly managed through pollarding to minimize the competition of tree for growth mainly for light against crops. The study was carried out under on farm condition where the experiments for the three crops were set up on nearby farmlands on similar soil types, climate, tree management, cropping history and landscape conditions. Average canopy radius of 12.5 m was used as a bench mark of maximum of radius from the base of the tree trunk which was measured data using GPS in the area (Table 1). In order to minimize residual effects from prior land management, cropping history of the farm plots was checked with the owners. Hence, plots that were consistently cropped with cereals for five years were considered. Trees with relatively similar age, diameter, height and canopy cover were selected (Fig. 3).

Figure 3 *GPS coordinate data collection and tree management practice*

Tree height was estimated using graduated poles and diameter at breast height was measured with a Caliper. Canopy width and length was measured with measuring tape by stretching it from point judged to be directly below the edge of the canopy to tree trunk. Compass and meter tape used to determine sampling direction and radial distance (1.5m, 3.5m, 5.5m and 12.5m and 25 m) along the sample transects. GPS was used to identify the exact location of the trees. Data were collected from four directions (east, west, north and south), and the average of the four directions per radial distance was used in data analysis.

Planting date was 16 April and harvested on October 11 for maize (Shone variety) and it was 08 July for wheat (Shorima variety) and harvested on October 31 and planting date was 28 July for teff (quncho variety), and harvested on November 11 all in 2018. Maize plots were fertilized with 73 kg ha^{-1} Dap, 56 kg ha^{-1} Urea (split applied 50% at sowing and the remaining side dressed at the age of 3-4 leaf). Wheat plots were fertilized with 80 kg ha^{-1} Dap, 60 kg ha^{-1} Urea (split applied 50% at sowing and the remaining side dressed at the age of 25-30 days), and teff plots were fertilized with 66 kg ha^{-1} Dap, 52 kg ha^{-1} Urea (split applied 50% at sowing and the remaining side dressed at the age of 30-34 days). Seed was drilled at a spacing of 30 cm between rows and plants, 25 kg ha^{-1} for maize and drilled at a spacing of 25 cm between rows at the rate of 110 kg ha^{-1} for wheat. Teff was drilled at a spacing of 20 cm between rows at the rate of 16 kg ha^{-1} (Fig 4). Field cultivation and site preparation involved the traditional "Maresha" plowing with a pair of oxen. Weeding was carried out using hoeing for maize, and combination of herbicide (2,4D) and hand weeding were used for wheat and teff.

Figure 4 *shows site preparation, sowing, and seedling crops.*

2.1 Experimental data collection

Measured variables for maize includes: average plant height, number of plant per m^2, number of ear per plant, Length of ear, grain yield and above ground biomass, and for that of wheat and teff: average plant height, tillers/m^2, tillers/plant, spike length, grain yield and above ground biomass. Grain was separated from the straw by threshing manually. Grain yield was quantified in quintals ha^{-1} and above ground biomass was in ton ha^{-1}.

Yield gain/loss of wheat, maize and teff, under the influence of tree were computed using the following equation.

$$\text{Yield } gain/loss = \frac{YUIT-YOIT}{YUIT} * 100\text{-----------}1$$

Where YUIT is yield under the influence of tree, YOIT is yield outside the influence of tree.

Table 1 *F. albida tree characteristics data, mean of their height, DbH, canopy size and (GPS) coordinates*

No	Sample Acacia *albida* tree for	Average height in meter	DbH in centimeter	Canopy size in meter	X,Y (GPS) coordinate (in meter)	
					X coordinate	Y coordinate
1	Maize	13	95.5	15	887474	429966
2	Maize	14	89.2	16	887663	429972
3	Maize	16	79.9	16	887570	429846
4	Maize	12	79.6	16	887454	429902
5	Maize	15	89.2	14	887103	430790
6	Wheat	10	90.7	14	868922	432592
7	Wheat	8	63.7	12	868902	432528
8	Wheat	11	70	10	868505	433583
9	Wheat	12	66.9	12	868506	433925
10	Wheat	14	73.9	13	868560	433978
11	Teff	17	64	10	887886	430023
12	Teff	15	76.4	12	887383	430232
13	Teff	14	73.2	13	887347	430287
14	Teff	12	82.8	11.5	887475	430394
15	Teff	13	70	12	887121	430861

2.1 Data analysis

The data of crop yields and yield component in response to distance from tree trunk were tested with one-way-ANOVA. Then, the mean for treatments that showed significant differences by F-test were separated by least significant difference (LSD) test and significance was declared at 0.05 significant levels, which is the most widely used multiple comparison procedure (Zar,1996). All statistical analyses were conducted in R Core Team (2015) software.

3. Results and Discussion

3.1 Effects of F. albida on Maize yield and yield component

The analysis of variance of the study revealed that the grain yield and yield components of maize were significantly ($P \leq 0.05$) affected due to the presence of *F. albida* tree. The grain yield of maize decreased significantly with increasing distance from the tree trunk. Considerably higher maize yield ($P \leq 0.05$) was found close to tree trunk (i.e., at 1.5 m) than far from the tree trunk at 25m. As compared to the control (25m), there were a significant maize grain gain of 30.1% and 26.1% close to tree trunk and at the edge of the canopies (3.5m), respectively. Similarly, above ground biomass of maize showed statistically significant (p=0.05) difference among radial distance from *F. albida* tree trunk (Table 2).

Table 2 *The effects of F. albida on maize yield and yield components*

parameters	Radial distance (m)									
	1.5	3.5	5.5	12.5	25	Cv	LSD	F value	(Pr > F)	LS
Height in m	2.692^{a}	2.664^{a}	2.548^{b}	2.534^{b}	2.428^{c}	1.80	0.062	26.4	7.1e-07	***
Number of stem per m^2	6^{a}	5.8^{ab}	5.4^{bc}	5.0^{c}	4.0^{d}	7.75	0.544	19.1	6.3e-06	***
Number of ears per stem	1.2	1.2	1.0	1.0	1.0	22.7	NS	1.0	0.436	.
Ear length	27.4^{a}	28.0^{a}	28.4^{a}	26.0^{b}	21.4^{c}	3.75	1.282	44.5	1.8e-08	***
yield in quintal per ha	60.88^{a}	57.64^{ab}	54.06^{b}	49.38^{c}	42.58^{d}	6.41	4.549	22.4	2.2e-06	***
Agb in ton ha^{-1}	23.4^{a}	21.52^{a}	18.66^{b}	17.78^{b}	15.56^{c}	7.97	2.073	20.7	4.5e-06	***
Yield gain	**30.1%**	**26.1%**	**21.2%**	**13.8%**						

***= (*P<0.001*), ‘ . ’= (*P<0.1*), CV= coefficient of variation, LS= Level of significance, LSD= List Significant Difference, Agb = Above ground biomass

3.1 Effects of F. albida on Wheat yield and yield components

Wheat yield was significantly affected by distance from the center of *F. albida* tree trunk. Likewise, above ground biomass was strongly affected by distance from the tree trunk. Significantly higher above ground biomass ($p<0.05$) was recorded at 1.5 m and it was lower as it gets far from the tree trunk (Table 3).

Table 3 *The effects of F. albida on wheat yield and yield component*

Parameters	Radial distance (m)									
	1.5	3.5	5.5	12.5	25	Cv	LSD	F value	(Pr > F)	LS
Height in cm	85.6^{a}	81.7^{b}	80.1^{b}	74.9^{c}	69.3^{d}	2.9	0.3	31.8	2.4e-09	***
Number of tillers per plant	5.6^{a}	5.4^{a}	4.4^{b}	3.8^{b}	3.8^{b}	10.9	0.7	14.8	3.1e-05	***
Number of tillers per m^{2}	639.2^{a}	634.4^{a}	577.4^{a}	471.4^{b}	455.6^{b}	12.2	91	8.4	0.00077	***
Spike length in cm	8.5^{a}	7.8^{b}	7.6^{b}	6.98^{c}	6.6^{d}	2.9	0.3	58.5	2.4e-09	***
yield in quintal per ha	49.2^{a}	48.5^{a}	43.5^{b}	38.5^{c}	37.2^{c}	6.5	3.8	19.2	5.9e-06	***
agb in ton ha^{-1}	18.3^{a}	18.1^{a}	15.6^{b}	15.4^{b}	13.9^{c}	5.1	1.1	25.1	1.0e-06	***
Yield gain	**24.3%**	**23.2%**	**14.5%**	**3.4%**						

***= (*P<0.001*), CV= coefficient of variation, LS= Level of significance, LSD= list significant difference, Agb = above ground biomass

3.1 Effects of F. albida on Teff yield and yield components

Teff yield and yield components were significantly affected by distance from the center of *F. albida* tree trunk. In contrast to maize and wheat, teff yield and yield components showed an increasing trend with increasing distance from tree trunk. Statistically higher teff yields ($p<0.05$) of 25.46 quintal ha^{-1} was recorded at 25m while very low teff yield of 14.3 quintal ha^{-1} was measured very close to the tree trunk at 1.5 m. Likewise above ground biomass showed increased trend with increasing distance from the tree trunk (Table 4).

Table 4 *the effects of F. albida on teff yield and yield components*

Parameters	Radial Distance (m)									
	1.5	3.5	5.5	12.5	25	Cv	LSD	F value	(Pr > F)	LS
Height in m	1.22[c]	1.39[ab]	1.38[ab]	1.41[a]	1.34[b]	3.4	0.06	14.2	3.9e-05	***
Number of tillers per plant	9.8[a]	10.2[a]	9.6[a]	8.0[b]	6.4[b]	6.9	0.82	27.3	1.4e-07	***
Number of tillers per m^2	840.0[b]	992.2[b]	1170.2[a]	969..2[b]	923.2[b]	5.3	69.8	33.3	5.6e-07	***
Spike length in cm	48.05[b]	53.1[a]	51.9[a]	52.7[a]	48.06[b]	7.7	3.71	4.1	0.0177	*
yield in quintal per ha	14.30[c]	17.24[bc]	14.88[c]	20.04[b]	25.46[a]	20.7	5.11	7.2	0.0017	**
Agb in ton ha^{-1}	8.40[c]	8.78[b]	9.20[a]	9.20[a]	9.32[a]	1.4	0.16	49.9	7.7e-09	***
Yield loss	**-78.1%**	**-47.7%**	**-71.1%**	**-27.1%**						

*=(*P<0.05*), **= (*P<0.01*), ***= (*P<0.001*), CV= coefficient of variation, LS= Level of significance, LSD= list significant difference, Agb = above ground biomass

3.1 Effects of F. albida on grain yield and yield components of Maize and Wheat

Study results demonstrated, unlike that of teff whereby competitive interaction observed, *F. albida* has facilitative effect when intercropped with wheat and maize. The yield benefits of cereal crops when grown under parkland management such as *F. albida* have been extensively documented by other researchers ranged from slight decreases to doubling of yields (Nyamadzawo, 2015). Results of the present study revealed that presence of *F. albida* significantly improved yield and yield components of maize. Maize crop had longer height, more stem per m^2 and longer ear length, higher grain yield and higher straw yield under the tree canopy than far from it. The study results goes well with finding of Saka et al. (1994) who found 100% grain gain of maize beneath the tree trunk than the open area in Malawi. Our results are also comparable with similar studies by Poschen (1986); who found 76% maize grain gain in Eastern Ethiopia. Results of this study is in agreement with the finding of Jiru (1997) who found higher maize yield gain of 67% than far from the tree trunk when maize was inter-cropped with lopped *F. albida*in Central Ethiopia. Our study showed that 30.1% yield increment of maize (Shone Varity) at 1.5 m, and 11.2% at 12.5 m, compared to the control. Maize above ground biomass also showed an increment of

33.5% at 1.5 m, and 12.5% at 12.5 m, compared to the control (25 m).

At harvest, the wheat crop had taller height, longer spike, more tillers per m^2 and per plant, higher grain yield and higher straw yield under the tree canopy (1.5m) than far from it (25m). Results of the present study showed that yield increment for wheat (Shorima Varity) was increased by 24.3% at 1.5 m, and 3.4% at 12.5m compared to the control. Also higher wheat aboveground biomass was recorded which was increased by 23.8% at 1.5 m, and 9.7% at 12.5 m (Table 2). Results in this study complement and support the findings of other researchers in Ethiopia (Jiru, 1997; Gosaye, 2010; Shiferaw et al. 2014; Tesfaye, 2017). For instance, Jiru (1997) found higher wheat yield of 40% under canopy than as compared to outside the canopy in central Ethiopia when wheat grown under lopped *F. albida*, Shiferaw et al. (2014) also found higher wheat yield of 23% in rift valley of Ethiopia. Similar study by Gosaye (2010) also found higher wheat yield of 244.11% at 0.5m, and 100% at 10m from tree trunk than the sole cropping. These results also agree with similar study by Tesfaye (2017) who found significantly higher ($P < 0.001$) plant height, total aboveground biomass, and wheat grain yield, when wheat was intercropped with *F. albida* compared with sole wheat in Ethiopian central rift Valley. Moreover, study conducted by Hadgu et al. (2009) found higher barely yield of 49% in Northern Ethiopia.

There has been extensive scientific documentation on scientific literature that has extensively documented the remarkable positive effect of trees on efficiency of nutrient recycling due to their deeper root system and nitrogen fixing ability. For instance, its deeper root system improved its complementarity in resource use as it can take up subsoil nutrients that are beyond the reach of crops and recycle them to the surface through litter-fall (Komicha, 2018). The combined effects of improved soil fertility, soil water and microclimate modification such as reduction of air and soil temperature have been documented by Shiferaw et al. (2014). Tesfaye (2017) and ICRAF (1989) also observed that yield and yield components improvement of cereals could be associated with soil fertility improvement through different tree soil interaction process of nitrogen fixation, nutrient recycling, accumulated soil organic matter. The tree can also ameliorate microclimate and thereby improve water availability through different ecological processes such as hydraulic redistribution and improve water use efficiency of understory crops (Bayala et al. 2015). The yield improvement could also resulted due to the applied tree management practices of pollarding, consequent reduction of tree competition for growth resources mainly for light, water and nutrient. Study by Kho et al. (2001) noted that the lower temperature under the canopy of *F. albida* could play an important role for enhancing cereal productivity especially in dry land.

3.1 Effects of F. albida on grain yield and yield components of Teff

On contrast to maize and wheat, teff yield and above ground biomass showed an increasing trend with increasing distance form tree trunk. At harvesting time, the teff crop had lower grain and straw yield under the tree canopy than far from the canopies. Our result agree with finding of Jiru (1997) who found yield loss for teff when it was intercropped with lopped *F. albida* trees close to tree trunk than open area in central Ethiopia. Results of the present study showed that teff yield was decreased by 78.04% at 1.5 m, and 27.1% at 12.5 m compared to outside of the canopy. Likewise low above ground biomass of 11% at 1.5m, 6.2% at 3.5m, and 1.3% at 5.5m and 12.5m were measured compared to open area. The reduction of teff yield and yield components with decreasing distance from open area may indicate incompatibility of teff to integrate with *F. albida*. Our field observation revealed, overtopping of teff was occurred under the tree than open area before maturity age due to tinny and weaker teff stem close to tree than outside. As a result, teff stem close to the tree could not support upright the plant. This overtopping caused interruption of air flow and cross pollination for seed preparation and finally massy teff tiller was unproductive and weightless. As a result, yield and yield component of teff were lower at the base of the tree compared to outside the canopy.

4. Conclusion

The findings from the three experiments clearly showed that yield and yield components of wheat and maize decreased with increasing distance from tree trunk. Whilst, teff yield and yield components decreased with decreasing distance from control to tree trunk. Plant height, number of tiller per plant, spike length, total aboveground biomass and grain yield were all significantly higher ($P < 0.05$) for maize and wheat associated with *F. albida* compared to outside the canopy. Whereas, results from teff showed lower yield and above ground biomass close to the tree trunk compared to outside the canopy. Hence, response of cereal crops for presence of pollarded *F. albida* tree may be dependent on crops types and their resources use efficiency and availability of resources like, light, nutrients and water. It could also be inferred that the observed increment in yield of wheat and maize are associated with improved soil properties and microclimate under and near the canopy, characteristics of crop and applied tree management (pollarding). However, reduction of teff yield and yield components with decreasing distance from open area to tree trunk may be associated with the presence of *F. albida* and consequent overtopping of crop before maturity age.

In general, based on the present results, large seeded cereal crops like maize is the first alternative crop suitable for cultivation with pollarded *F. albida*. The second alternative crop with potential for cultivation under *F. albida* is wheat. The combination of small seeded crops like teff with *F. albida* is incompatible as it was confirmed by the observed low crop yield and yield components beneath canopies of *F. albida* compared to the control.

5. Acknowledgments

The authors gratefully thank Dilla University for the immense support provided to carry out this task. Special thanks also go to Silti zone and Silti woreda administrators, development agents, agricultural research center Worabe branch and Silti Wereda farmers for their imaginative opinions and cooperation during the field work and provision of various office facilities. We are also thankful to Silte Zone for the financial support.

Conflict of interest

The author(s) declare that they have no competing interests

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Appendixes

Appendix Table A. Tables presented in this appendix provide Result of Analysis of variance for data on maize yield under experimental tree recorded in the study area.

Sources	DF	Sum Sq.	Mean Sq.	F-value	Pr > F	LS
REP	4	76.9	19.23	1.67	0.206	-
TRT	4	1031.9	257.98	22.41	2.16e-06	***
Residuals	16	184.2	11.51			

REP= Replication, TRT=Treatments, LS= Level of significance, *** (*P<0.001*)

Appendix Table B. Tables presented in this appendix provide Result of Analysis of variance for data on maize above ground biomass under experimental tree found in the study area.

Sources	DF	Sum Sq.	Mean Sq.	F-value	Pr > F	LS
REP	4	19.57	4.89	2.046	0.136	-
TRT	4	192.05	48.01	20.075	4.45e-06	***
Residuals	16	38.27	2.39			

REP= Replication, TRT=Treatments, LS= Level of significance, *** (*P<0.001*)

Appendix Table C. The effects of *F.*albida on under-story maize yield in quintal ha−1.

No	Number of treatments	Mean grain yield in quintal ha−1 (average of five replication)	Yield difference from the mean	Yield incre-ments in % over the control	STD
1	T1 (1.5 m)	60.88[a]	+7.972	42.98%	1.92
2	T2 (3.5 m)	57.64[ab]	+4.732	35.37%	1.19
3	T3 (5.5 m)	54.06[b]	+1.152	26.96%	5.82
4	T4 (12.5 m)	49.38[c]	-3.528	15.96%	5.06
5	T5 (25 m)	42.58[d]	-10.328	-	0.81

STD = standard deviationSTD

```
Statistics
MeanCVMS errorLSD    alpha   test               treat.Pr(>F)
  52.908 6.412782 11.5116 4.548983    0.05 Fisher-LSD2.16e-06 ***
```

Appendix Table D. The effects of *F.*albida on understory maize above ground biomass (abg) in toneha−1.

No	Number of treatments	Mean abg in toneha−1 (average of five replication)	abg difference from the mean	abgincrements in % over the control	STD
1	T1 (1.5 m)	23.40[a]	+4.016	50.39%	1.92
2	T2 (3.5 m)	21.52[a]	+2.136	38.30%	1.19
3	T3 (5.5 m)	18.66[b]	-0.724	19.92%	5.82
4	T4 (12.5 m)	17.78[b]	-1.604	14.27%	5.06
5	T5 (25 m)	15.56[c]	-3.824	-	0.81

STD = standard deviationSTD

```
Statistics
MeanCVMS errorLSD    alpha   test               treat.Pr (>F)
  19.384 7.978209 2.39165 2.073458    0.05 Fisher-LSD4.45e-06 ***
```

Appendix Table E. The effects of *F.*albida on understory maize height in meter.

No	Number of treatments	Mean maize height in meter (average of five replication)	Height difference from mean	height increments in % over the control	STD
1	T1 (1.5 m)	2.692[a]	+0.1188	10.87%	0.037
2	T2 (3.5 m)	2.664[a]	+0.0908	9.72%	0.059
3	T3 (5.5 m)	2.548[b]	-0.0252	4.94%	0.054
4	T4 (12.5 m)	2.534[b]	-0.0392	4.36%	0.091
5	T5 (25 m)	2.428[c]	-0.1452	-	0.0712

STD = standard deviation

```
Statistics
```

```
MeanCVMS errorLSD       alpha    test        treat.Pr (>F)
2.57321.8044750.0021560.062254510.05 Fisher-LSD7.057e-07 ***
```

Appendix Table F. The effects of *F.*albida on understory maize ear length in centimeter.

No	Number of treatments	Mean maize ear length in centimeter (average of five replication)	Ear length difference from mean	ear length increments in % over the control	STD
1	T1 (1.5 m)	27.4[a]	+1.16	28.04%	1.14
2	T2 (3.5 m)	28.0[a]	+1.76	30.84%	0.70
3	T3 (5.5 m)	28.4[a]	+2.16	32.71%	0.54
4	T4 (12.5 m)	26.0[b]	-0.24	21.49%	1.22
5	T5 (25 m)	21.4[c]	-4.84	-	2.07

STD = standard deviation

```
Statistics
MeanCVMS errorLSD      alpha    test     treat.Pr (>F)
  26.24 3.645413 0.915 1.2824990.05 Fisher-LSD1.778e-08 ***
3.92e-05 ***
```

Appendix Table G. Tables presented in this appendix provide Result of Analysis of variance for data on wheat yield under experimental tree found in the study area.

Sources	DF	Sum Sq.	Mean Sq.	F-value	Pr > F	LS
REP	4	50.3	12.57	1.599	0.223	-
TRT	4	604.0	151.00	19.219	5.91e-06	***
Residuals	16	125.7	7.86			

REP= Replication, TRT=Treatments, LS= Level of significance, *** (*P<0.001*)

Appendix Table H. Tables presented in this appendix provide Result of Analysis of variance for data on wheat above ground biomass under experimental tree found in the study area.

Sources	DF	Sum Sq.	Mean Sq.	F-value	Pr > F	LS
REP	4	4.07	1.017	1.466	0.259	-
TRT	4	69.47	17.369	25.050	1.02e-06	***
Residuals	16	11.09	0.693			

REP= Replication, TRT=Treatments, LS= Level of significance, *** (*P<0.001*)

Appendix Table I. Tables presented in this appendix provide Result of Analysis of variance for data on teff yield under experimental tree found in the study area.

Sources	DF	Sum Sq.	Mean Sq.	F-value	Pr > F	LS
REP	4	27.3	6.82	0.471	0.75653	-
TRT	4	415.4	103.85	7.163	0.00167	**
Residuals	16	232.0	14.50			

REP= Replication, TRT=Treatments, LS= Level of significance, ** (*P<0.01*)

Appendix Table J. The effects of *A.albida* on under-story wheat yield in quintal ha−1.

No	Number of treat-ments	Mean grain yield in quintal ha−1 (average of five replication)	Grain yield differ-ence from mean	Yield incre-ments in % over the control	STD
1	T1 (1.5 m)	49.18[a]	+5.784	32.06%	3.51
2	T2 (3.5 m)	48.48[a]	+5.084	30.18%	3.36
3	T3 (5.5 m)	43.54[b]	+0.144	16.92%	3.69
4	T4 (12.5 m)	38.54[c]	-4.856	3.57%	1.65
5	T5 (25 m)	37.24[c]	-6.156	-	1.99

STD = standard deviation

Statistics

```
MeanCVMS errorLSD    alpha   test            treat.Pr (>F)
43.396 6.459158  7.8569 3.758132      0.05 Fisher-LSD5.91e-06***
```

Appendix Table K. The effects of F.*albida* on understory wheat above ground biomass (agb) in toneha−1.

No	Number of treatments	Mean above ground biomass (Agb) in toneha−1 (average of five replication)	Agb Difference from mean	agb increments in % over the control	STD
1	T1 (1.5 m)	18.34[a]	+2.072	31.19%	1.20
2	T2 (3.5 m)	18.04[a]	+1.772	29.04%	1.33
3	T3 (5.5 m)	15.58[b]	-0.688	11.44%	0.30
4	T4 (12.5 m)	15.40[b]	-0.868	10.16%	0.51
5	T5 (25 m)	13.98[c]	-2.288	-	0.44

STD = standard deviation

```
Statistics
MeanCVMS errorLSD    alpha   test                treat.Pr (>F)
16.268 5.118493 0.69335    1.1164070.05 Fisher-LSD1.021e-06 ***
```

Appendix Table L. The effects of *F.albida* on understory wheat height in centimeter.

No	Number of treatments	Mean wheat height in centimeter (average of five replication)	height difference from mean	height increments in % over the control	STD
1	T1 (1.5 m)	85.62[a]	+7.296	23.48%	1.60
2	T2 (3.5 m)	81.68[b]	+3.356	17.79%	3.50
3	T3 (5.5 m)	80.08[b]	+1.756	14.49%	4.17
4	T4 (12.5 m)	74.90[c]	-3.424	8.02%	5.21
5	T5 (25 m)	69.34[d]	-8.984	-	4.35

STD = standard deviation

```
Statistics
MeanCVMS errorLSD       alpha     test         treat.Pr (>F)
78.324 3.19905 6.27815      3.3594050.05 Fisher-LSD1.943e-07 ***
```

Appendix Table M. The effects of *F.albida* on understory wheat spike length (SL) in centimeter.

No	Number of treatments	Mean wheat spike length in centimeter (average of five replication)	SL difference from mean	SL increments in % over the control	STD
1	T1 (1.5 m)	8.54[a]	+1.06	30.18%	0.59
2	T2 (3.5 m)	7.76[b]	+0.28	18.29%	0.71
3	T3 (5.5 m)	7.56[b]	+0.08	15.24%	0.80
4	T4 (12.5 m)	6.98[c]	-0.5	0.64%	0.83
5	T5 (25 m)	6.56[d]	-0.92	-	0.82

STD = standard deviation

```
Statistics
MeanCVMS errorLSD      alpha    test     treat.Pr (>F)
7.48 2.966891 0.04925 0.29754290.05 Fisher-LSD2.39e-09 ***
```

Appendix Table N. The effects of F.*albida* on understory wheat numbers of tillers ¯1m².

No	Number of treatments	Mean wheat numbers of tillers ¯1m² (average of five replication)	Tillers difference from mean	tiller increments in % over the control	STD
1	T1 (1.5 m)	634.4	+78.8	39.24%	0.54
2	T2 (3.5 m)	639.2	+83.6	40.23%	0.54
3	T3 (5.5 m)	577.4	+21.8	26.73%	0.54
4	T4 (12.5 m)	471.4	-84.2	3.47%	0.83
5	T5 (25 m)	455.6	-100	-	0.44

STD = standard deviation

```
Statistics
MeanCVMS errorLSD      alpha    test     treat.Pr (>F)
555.6 12.20058    4595 90.884370.05 Fisher-LSD0.000767 ***
```

Appendix Table O. Tables presented in this appendix provide Result of Analysis of variance for data on teff above ground biomass under experimental tree found in the study area.

Sources	DF	Sum Sq.	Mean Sq.	F-value	Pr > F	LS
REP	4	0.060	0.0150	1.017	0.428	-
TRT	4	2.944	0.7360	49.898	7.74e-09	***
Residuals	16	0.236	0.0148			

REP= Replication, TRT=Treatments, LS= Level of significance, *** (*P<0.001*)

Appendix Table P. The effects of *A.albida* on understory teff yield in quintal ha−1.

No	Number of treatments	Mean grain yield in quintal ha−1 (average of five replication)	Grain yield difference from mean	Yield increments in % over the control	STD
1	T5 (25 m)	25.46	+7.076	78.04%	0.91
2	T4 (12.5 m)	20.04	+1.656	40.14%	5.32
3	T2 (3.5 m)	17.24	-1.144	29.4%	1.44
4	T3 (5.5 m)	14.88	-3.504	4.06%	5.70
5	T1 (1.5 m)	14.30	-4.084	-	1.00

STD = standard deviation

```
Statistics
MeanCVMS errorLSD      alpha  test      treat.Pr (>F)
18.384 20.71155 14.4979    5.1050380.05 Fisher-LSD0.00167**
```

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http://www.du.edu.et/duj

Mass flowering and death of *Arundinaria alpina* (highland bamboo) impact on livelihood of rural community: the case of Gedeo Zone, Southern Ethiopia.

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Received: 18 April, 2019 /Accepted: 8 July, 2019

Abstract

Ethiopia owns the largest coverage of bamboos in Africa that sums up to more than 1 million hectares. This constitutes about 67% of the total area of bamboo in Africa. Bamboo plays a crucial role in the livelihood of the local people of Gedeo zone, south Ethiopia. However, the mass flowering and mass death currently hit the bamboo forest of the zone and affected both the people livelihood and the ecosystem of the area. Thus, this paper tries to highlight the consequences of mass flowering of bamboo forest on the livelihood of rural community of the zone. Two districts were purposively selected and 120 sample households were chosen randomly for data collection. Both primary and secondary data were deployed to answer the stipulated objectives. Extensive field observation, questionnaires, and group discussions were held to gather the primary data. Additionally, documents and other available materials were also used as a secondary data source. Descriptive statistics was conducted to analyze quantitative socio-economic data. Qualitative data were summarized by condensing the collected information. The result of the study indicated that, the local people have experiences of bamboo production using their indigenous knowledge. Lack of awareness about the time of mass flowering and death exacerbated the incident. There was no management plan prepared and used in the bamboo forest area. The flowering interval was estimated and the coming time of flowering and death is expected to be after 75-80 years. Massive socio-economic and ecological problems were also observed after mass flowering and subsequent seed setting. Hence, now it is time to search for different strategies to stop or to reduce the influences of mass flowering and death of bamboo in the area.

Key words: Bamboo, Arundinaria alpina, impacts of mass flowering, Ethiopia

1. Introduction

Bamboo is recognized as “poor man’s timber” as it is directly related with human life from cradle to eternal voyage (Chuaby, 2013). It is the fastest growing plant in this planet one can almost watch it grow and is wonderful replacement for the slow growing forest with its short growth cycle (Kigomo, 2007; Groum, 2008). Bamboo belongs to the grass family *Gramineae* (also called Poaceae), the fifth largest flowering plant family, under the sub-family *bambusoideae* (Nadgauda, 2002). It is multipurpose non-timber forest resources that maintain the ecology, generate income and provide employment for alleviation of poverty (Abebe et al. 2009).

Due to its excellent flexibility and high tensile strength, straightness, woody nature, light weight, workability and suitable fiber characteristics, bamboo has been made into a wide variety of products. Thus it has been being used in our daily lives ranging from domestic household products to industrial applications. It has commonly been used for furniture, building, flooring, bio-energy, food, forage and medicine (Kassahun, 2000). Baboo also plays a vital role in environmental amelioration, biodiversity preservation, soil water conservation, waste purification potential; adaptability to low quality sites and it has also the capacity to redress most of the deforestation related problems (Woldemichael, 1980; Kassahun, 2000).

Despite the ever increasing global bamboo utilization, mass flowering and subsequent seed setting, bamboo is affecting the ecosystem and users livelihood. Many bamboo species only flower from 65 to 120 years intervals. This physiological cycle (the period between two consecutive flowerings) is the same for specific area and specific species (Chaubey, 2013). Once a particular species reaches its life expectancy, it will start to flower and die in some kind of a “mass suicide” (LUSO, 1997; Nadgauda, 2002). Dying after flowering is a characteristic phenomenon of monocarpic flowering, which shares as a member of the grass family (Nadgauda, 2002). Mass flowering isn’t triggered by environmental aspects, rather it is as some sort of genetic alarm clock in each bamboo cell that signals the diversion of all energy to flower production and the cessation of vegetative growth. That means, it is the age of the seed which decides flowering time, not its shoot (Schroder, 2011).

According to many literatures, there are two most probable reasons why bamboo dies after flowering. The first is that the death of bamboo is due to resource exhaustion, as it would be more effective for parent plants to devote all resources to create a large seed crop than to hold back energy for their own regeneration. A second explanation is that the mother plant is creating an optimal environment for its seedlings to survive. When the mother plant dies, the bamboo seedlings will have full access to water, nutrients and sunlight that would otherwise be used by the mother plant (Schroder, 2011; Wang, 2016), which is a Mechanism to create disturbance in the habitat to provide the seedlings and saplings a gap in which they grow. As bamboos are aggressive at their early ages, the seedlings would be able to outstrip other plants and take over the space left by their parents. Thus, fruiting at the same time increases the survival rate of their seeds by flooding the area with fruit. Therefore, even if predators eat their fill, seeds will still be left over the area. The total population failure after bamboo death leaves the land bare and takes at least few years for a bamboo to regenerate (Ramanayake, 2006). Subsequently, soil erosion and landslides prevail (Helen, 2008).

Mass flowering is flowering of entire populations of bamboo with all culms. The mass flowering of bamboos and consequential seed setting also have economic and ecological consequences that affect the livelihood of the local people. The huge amount of seeds in forests attracts large populations of rats which consume available food crops and may cause severe spread of diseases and food scarcity in surrounding areas (Schroder, 2011). Bamboo flowering and fruiting is something of calamity, since the culms and root stocking are no longer available quickly for the rural and urban population for different uses (Shanmughauel et.al. 1977). It may also cause soil erosion as the roots of the bamboo that binds the soil together dried up and loosen the soil especially in the hilly areas. Die-off events result in the loss of habitat and diversity (Demisew, 2011)

Ethiopia contributes the largest coverage of bamboos in Africa. It covers more than 1 million hectares. If this resource is managed and utilized effectively, Ethiopia can generate over 12 billion Birr every year (Melaku, 2008). Bamboo area of Ethiopia constitutes about 67% of the total area of bamboo in the continent (Kasahun, 2000). The two species of bamboo found in Ethiopia are the highland bamboo, *Arundinaria alpina*, and the lowland bamboo, *Oxytenanthera abyssinica* (Demelash et al. 2015). They are indigenous to Ethiopia and endemic to African (Kassahun, 2000).

The study area is covered with highland bamboo, *Arundinaria alpina*. This species is known in different languages as local names in Ethiopia. According to Woldemichael (1987) and Azene, (2007), it is called Anini (in Agew); Kerkeha (in Amharic); Kias (in Gamu); Shineto /Shinato (in Kefigna); Lemmen, Shimela (in Afan Oromo); Shenbek'wa (in Welayita); lema (in Konso, Kembata, Gedeo, Sodo Gurage and Sidamo); werye /shikaro /Shinato (in Kefa); lewu (in Nuwer).

Despite its current and potential advantages for social, economic development and environmental benefits, bamboo resource of Ethiopia has been given less attention. As a result, only few researches have been done to solve the problems arising at different bamboo potential areas of Southern Region and Zones. Bamboo is one of the major sources of livelihood for Gedeo people. But these days, the loss of bamboo resource because of mass flowering and mass death is being a major concern and pressing issue. The problems are aggravated mainly because of lack of awareness about the causes and the consequences of mass flowering and death of bamboos. Therefore, this study tries to fill this gap through: 1) identifying the experiences of the local community that aggravated mass flowering problems and, 2) investigating the consequences of mass flowering and death of the highland bamboo.

2. Material and methods

2.1 Description of study area

Gedeo zone is found between 5 and 7 degrees North latitude and 38 and 40 degrees East longitude, in the escarpments of the southeastern Ethiopian highlands overlooking the Rift Valley, in the narrow strip of land running from North (Sidama zone) and to South, east and west (Oromiya region) (Tadesse, 2002). The land area of the Zone is estimated to be 1352.4 Km2 (GZAO, 2006). In altitude, the area ranges from 1200 meter above sea level in the vicinity of Lake Abaya to 2993 meter above sea level at Haro Wolabu Pond at Bule district (Tadesse, 2002). Gedeo zone is located 369 kms South of Addis Ababa and 90 kms South of Hawassa along Addis Ababa (Ethiopia) to Moyale (Kenya) international road. The study was carried out in the junction area of the two districts of Gedeo zone, namely Bule and Gedeb districts, which is called Jego community bamboo forest and surrounding individuals' bamboo plantations areas (Fig.1). This area was covered with dried bamboo of 1,156.41 hectares (Birhane and Melesse, 2015).

Gedeo Zone has sub-humid tropical climate which receives annual rainfall that ranges from 1200 to 1800 mm; the mean monthly temperature is 21.5° C with mean monthly maximum and minimum temperature of 25°C and 18°C respectively (Birhane and Melesse, 2015). Gedeo zone is endowed with two rainy seasons, which is from March to May and from July to December. However, the truly dry months are only January and February; others count with intermittent rain showers. The climate is suitable for abundant forest cover (Tadesse, 2002). Based on figures from the CSA (2007), the Gedeo zone had an estimated total population of 975,506 of which 486,996 were males and 488,510 were females with annual growth rate of 2.9%. This zone is one of the most densely populated regions in the country with an estimated population density of 769 people per square kilometer (CSA, 2007).

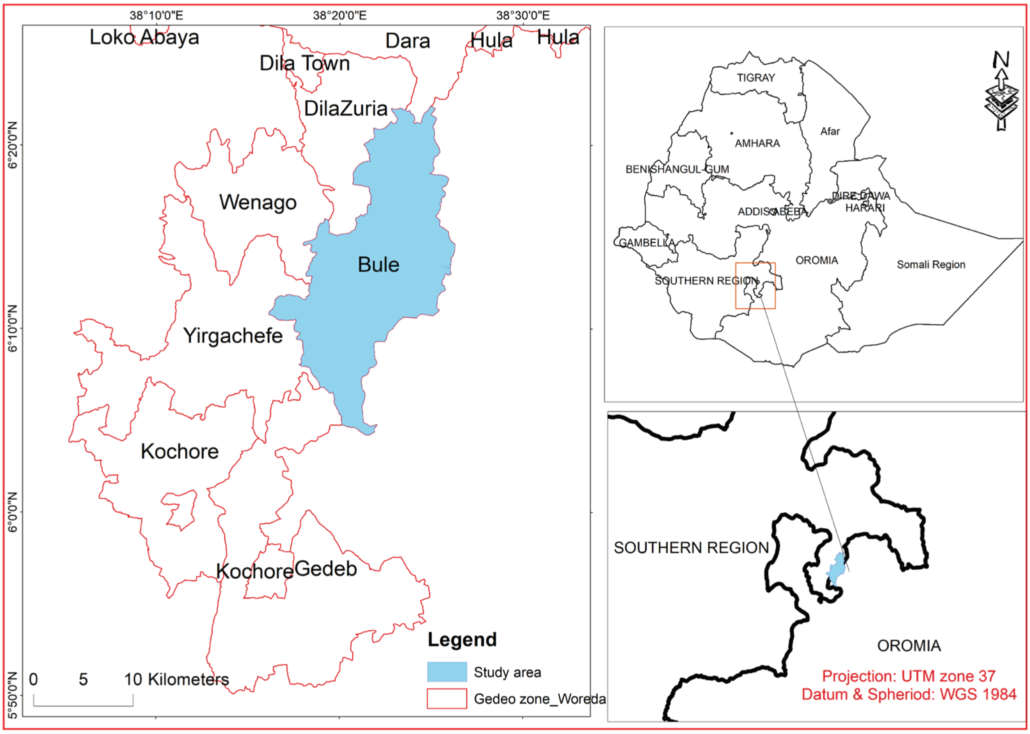

Figure 1 *Map of the study area*

2.2 Data collection

Two Districts of the Gedeo zone, Bule and Gedeb Districts were selected purposively based on the bamboo production potential and the current mass flowering and mass death experiences. A total of 120 households were selected from the two districts from both sexes and various age groups. By the help of district natural resource experts and Kebele committee members, six areas with large bamboo resource were purposefully selected for field and socioeconomic survey. Equal number of sites and farmers were selected from both districts since there are similar conditions in both districts. Therefore, 60 farmers were randomly selected from farmers who have long experiences in bamboo cultivation and utilization in each district. In addition to this, eight focus groups of elders who have long experiences in bamboo cultivation and utilization were purposefully. Natural resource experts of the districts and kebeles adminstrators/officials were also involved as an information source and facilitator. Along with questionnaires, extensive field observation, and group discussions were held to gather the data. Audio-visual tools like camera and tape recorder were also used to facilitate extensive documentation process. Moreover, documents and different materials were also assessed as secondary data source.

2.3 Data analyses

The quantitative data were analyzed by using descriptive statistics such as percentages and graphs. In addition, MS-Excel was used to generate tables and bar graphs to determine the experiences and the impact of flowering on the socio-economic factors that influence the livelihood of the local community (Tesfaye et al. 2011). Qualitative data were summarized by condensing the information and were used to elaborate the results from quantitative analysis (Yin 2009).

3. Result and Discussion

3.1 Experiences on bamboo regeneration, management and utilization

3.1.1 Species distribution

According to the field observation and the information gathered from all the respondents and the district experts, the whole bamboo forest area has been covered by only one bamboo species. This species is *Arundinaria alpina*, highland bamboo and it is one of the two bamboo species found in the country. According to the respondents and researchers' observation, other bamboo species has not been introduced to the study area (Fig 2).

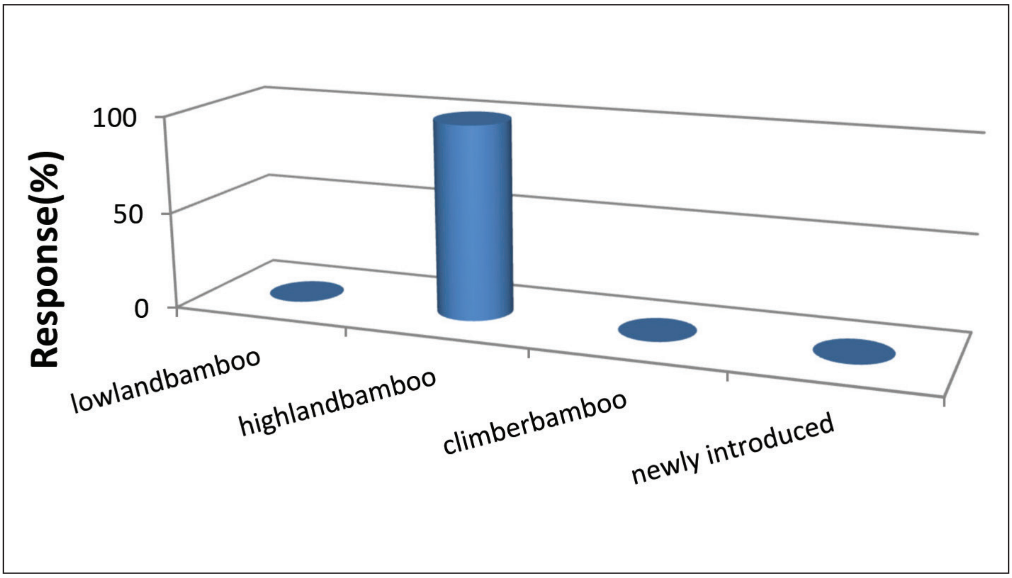

Figure 2 *Types of Bamboo in Gedeo zone*

This study supports that the introduced species in the South Region of Ethiopia are at their testing stage at Sheka and Wondogenet (Yigardu et al.

2016). Since the bamboo forest was drying, it was difficult to notice the morphological nature of the bamboo of the study site. On the other hand, very few bamboos were observed after a very long distance interval that didn't dry, which might indicate the presence of landrace variability under a single species. Though there is no detailed study of land race varieties, during our discussion, the elders call the land race varieties by the name "bamboo having teeth" and "bamboo without teeth".

As stated by all the respondents, there is no mass flowering and death differences observed from district to district and from Kebele to Kebele. In view of the fact that the whole bamboo forest is covered with only one species grown from the same seed year; the whole area is affected when this single species is affected, as a result the same species grown disappear at the same time. The problem is worsen in that, when the current species mass flowering and death happen, either there is no alternative species left or there is no bamboo forest of the same species grown from different seed year in the area for usage.

3.2 Propagation methods

In the study area, there are natural bamboo forest and bamboo plantation. As to the respondents' response, and the observation made, the natural bamboo forests are found around community lands and plantation of bamboo forest are found around homesteads in the study area. The community bamboo forests were originated from natural regeneration from seed regeneration and there is no interference of people on regeneration and management. Moreover, according to all respondents, bamboo plantations were originated from vegetative propagation by man. There is no nursery for the production of planting materials rather all bamboo propagation is done by farmers themselves on their own land. Almost all respondents confirmed that traditional rhizome cuttings were the common propagation method for bamboo plantations (Fig 3). In this method, rhizomes with the accompanying root system are detached from the parent rhizome in sections that are above 1m long culm containing nodes. This study agrees with the study, which says Propagating by means of rhizome with whole culm is traditionally known old age methods for bamboo propagation (Yared et al. 2017). The respondents prove that they all use vegetative propagation from their own bamboo forest rather than bringing it from other area of different seed year bamboos plantation. Furthermore, they strengthen their perception by saying it is the fastest and available method of regeneration for their uses. Though 65% of the respondents heard about the other methods of planting as stem cutting and bamboo seedling production from seed, still they are using this single method.

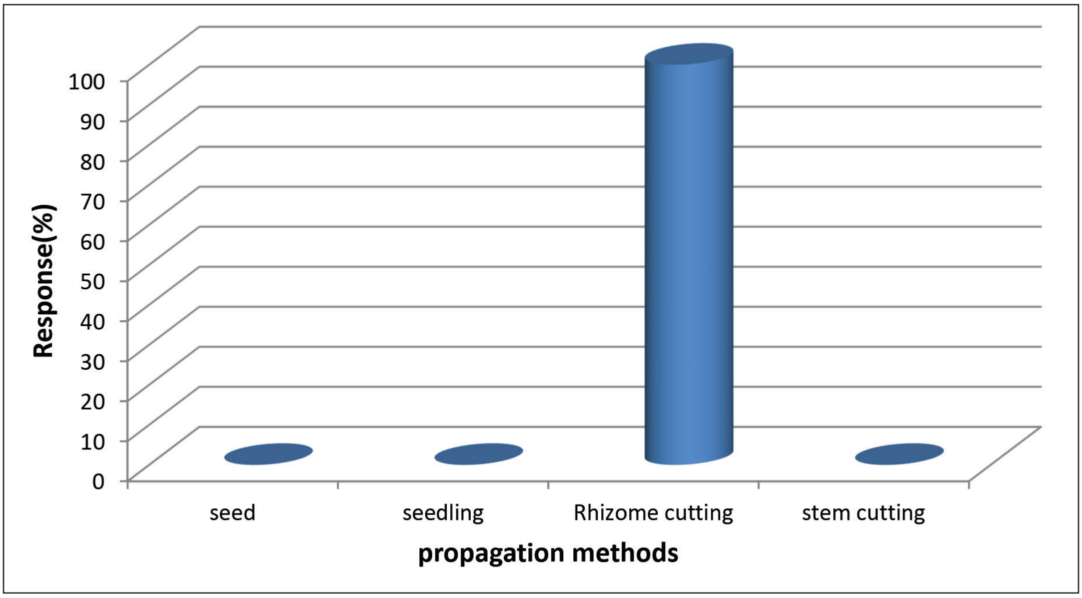

Figure 3 *propagation methods*

3.3 Cultural practices

During field survey, different size areas of bamboo plantations, which are owned by the respondents, were observed. Respondents have no experience of applying any cultural practices in natural bamboo forest to improve its productivity. In the same way, in bamboo plantation, thinning, fertilizing, protecting from diseases and pests are not as such known by local community. Though it is not satisfactory, there were experiences of soil loosening, weeding and partly fencing practices from our discussion with respondents (Fig 4). When they were asked why they were not using cultural practices, they justified their perception by saying bamboo does not need any Cultural practices and some of them have no idea about bamboo cultural practices. In addition, as it is observed, there was no management plan prepared and used in the bamboo forest area. As a matter of this fact, no one guessed the flowering time of the bamboo forest before flowering.

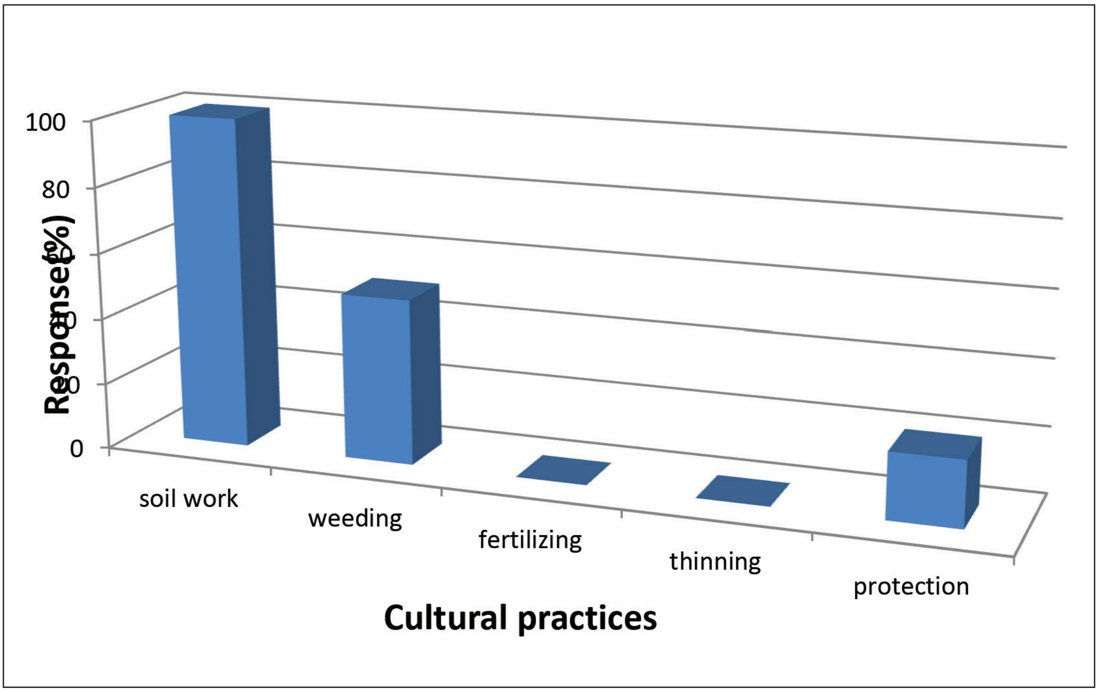

Figure 4 *Cultural practice applied to bamboo production*

3.4 Rural community awareness and perceptions about Mass flowering and death of bamboo

Respondents and experts reported that bamboo flowering is a new phenomena for most of the people especially for young ones. When bamboo starts to die, they assumed it was due to disease and they informed different organizations to treat the bamboo forest. After some information and observations, they noticed that their bamboos were flowering. According to the elders, mass flowering and mass death were experienced in this place around 75-80 years ago. This experience is agreed with study made by Schroder (2011) and Demisew et al. (2011). 69% respondents of elders have information about bamboo flowering. But none of them knows about the interval of mass flowering of bamboo. So, they did not prepare another option for their income source to reduce the challenges they are facing from mass flowering. The response of elders implies that the flowering interval or physiological cycle of mass flowering for this specific area takes 75-80 years since flowering takes place at the same time interval and at the same place.

3.4.1 Uses of bamboo resources

Arundinaria alpina is used extensively by the rural community for different purposes in the study area (Table 1). The present use is mainly limited to traditional uses for construction, fencing, firewood, fodder and also it is being used for making different traditional bamboo crafts. The findings of Zenebe et al (2014) have similar ideas with the respondents of this study. 99.2% of respondents use main part of culm for construction, 96.7% of them use it for fence and 91.2% of them use it for craft making; and still all the respondents 100% and 25% of them confirm that the rest of the bamboo parts left from culm are used for firewood and fodder respectively. Surprisingly, the respondents said that they have no experience of using bamboo for food, charcoal, medicine and erosion control.

Table 1 *Frequency distribution of respondents regarding uses of bamboo*

Uses	Frequency	Percentage
Fire wood	120	100
Feed/fodder	30	25
Construction	119	99.2
Charcoal making	0	0
Crafts	110	91.7
Food	0	0
Erosion control	0	0
Medicine	0	0
Fence	116	96.7

3.5 Local community constraints related to bamboo resources cultivation and utilization

Concerning bamboo resources cultivation and utilization, there were a number of constraints mentioned by the respondents. The constraints include: shortage of planting materials, poor awareness on cultivation and utilization, limitation of budget and land (Fig 5). Of the constraints mentioned by the respondents, two of them are critical: lack of planting materials and poor awareness on cultivation and utilization. In view of the respondents, it is difficult to get large amount of planting materials by using rhizome method. So it is difficult to get planting materials for establishing large plantations. Besides, there are no government or private nurseries that supply planting materials.

From respondents' response, the local people have traditional thinking that bamboo does not need cultural practices. The respondents replied that they did not have any training on bamboo cultivation, craft making, marketing, management and conservation, and utilization of bamboo resources.

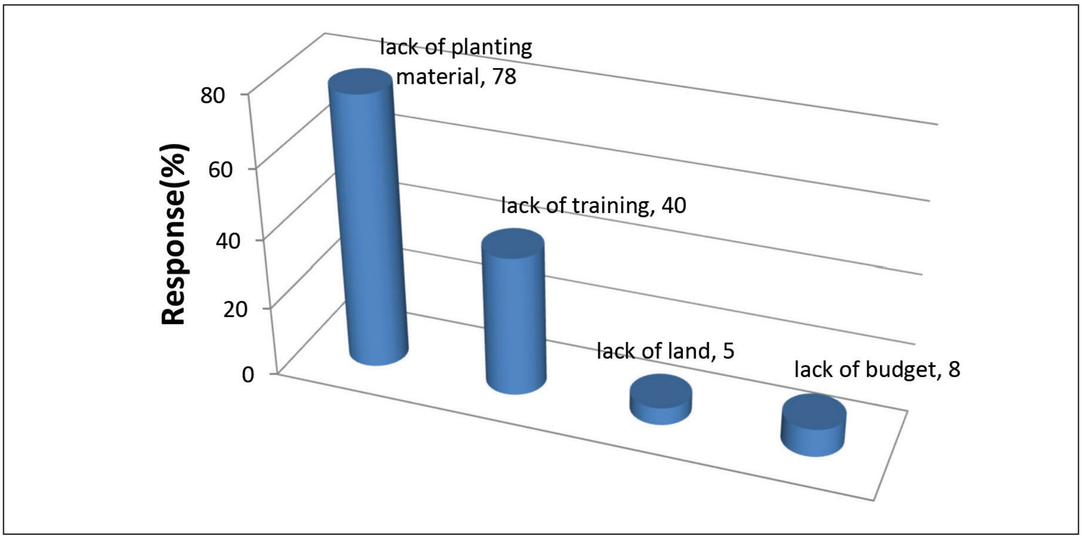

Figure 5 *constraints related to bamboo resource development*

4. Mass flowering impacts

4.1 Socio-Economic impacts of mass flowering of bamboo

4.1.1 Influence on Income generation

As to the respondents and expert's report, bamboo Culm is of owing high strength, light weight and easiness of working, it is suitable for different purposes. All of the respondents rated the influence of mass death of bamboo on income generation as high. When one local farmer explained, "Bamboo is everything for us: it is construction material for our house and fence, for making household furniture, for feeding our animals, for heating and lighting and for cash source, etc. When mass flowering and mass death took place, we felt as if we had lost one of our family members, and now we are almost left bare handed".

According to Melaku's (2008) estimation, it can be easily deduced that 1,156.41 ha of dried bamboo area can lead to a loss of more than 13, 876,920 birr per year for the coming years until the area returns to its full production.

Figure 6 *Part of elders' group discussion*

4.1.2 Impact on job opportunities

Regarding to the perception of respondents, bamboo craft making is one of the main occupation in the study area. Bamboo poles, dissected/splits/ of bamboos and crafts making help to earn cash to fulfill the basic needs of their family and give self employment to the whole families. Most of the respondents engaged in bamboo craft making hand in hand with other agricultural activities. And a few of them use bamboo as the only job for them. Bamboo craft making is their traditional occupation so that they do not learn these skills from outside their locality. Finally they said "we will lose jobs for the coming at least 5-8 years due to death and absence of bamboo raw materials".

4.1.3 Vulnerability for extra cost

From the discussion with community, it is replied that bamboo is one of the most important thing for the people in their daily life. But due to the scarcity of bamboo resources resulted from mass flowering and death, no more bamboo raw materials will be supplied for the coming years. Thus, there is no way of getting low cost bamboo. According to the respondents' explanations, to embark upon this problem, they look for other materials as wood, iron bars; corrugated sheets that needs extra money for making furniture, construction and other uses.

4.2 Ecological consequences of mass flowering of bamboo

4.2.1 Conversion of bamboo forest to other open land use types:

All respondents including experts agree on the increasing rate of conversion of mass flowered and dead community bamboo forest to open agricultural land. During the discussion, one of the respondents said, “Leave alone these open places of mass flowering, some of the farmers were illegally found pushing the intact community bamboo forest”. The respondents also explained that obstruct of bamboo based income could also have a possibility of forcing local community to convert the area into a farm land that can offer short-term returns to fill the income gap. The researcher also observed some indicators such as clearing and fire setting here and there around the boundaries of community bamboo forest that might be the sign of expansion of agricultural farm lands by minimizing the bamboo forest area. Animals were also observed grazing near and around dried bamboo forest. Similar stories were recorded for highland bamboo in Southern Ethiopia, Sheka Zone, Masha district where farmers gave up bamboo after its death and converted lands to ‘Enset’ plantation (Adnew and Statz, 2007). As it was observed, the conversion of land was taking place more in community bamboo forest than individually owned bamboo plantation forest.

4.2.2 Bamboo flowering and outbreak of rat population

Even though there is potential outbreak of rodents in the flowering and mass death area of bamboo forests (Demissew et al. 2011; Schroder, 2011), according to the respondents view in this study there has not been any significant effects of rats observed in the study area. From these contradictory studies results, it can be concluded that there might be other factors that discouraged rat outbreak in the study area.

4.2.3 Threats on regeneration and biodiversity

According to the respondents’ response and experts’ observation and Demissew et al. (2011) findings, bamboo forests were rich in life varieties. A number of Birds and different kinds of wild animals were sheltering and grazing in the bamboo forest. Now, the biodiversity is decreasing as the result of migrations of these animals due to the loss of their habitat, bamboo forest, by mass death.

Mass flowering has brought positive impact on regeneration. Previously reproduction of high land bamboo was done only by vegetative propagation from only single parent. Respondents were also told that mass flowering gave a chance of getting large amount of seed from sexual reproduction that helps to establish bamboo plantation. Unfortunately, as it is a new incident and due to knowledge gap, most of the respondents are not using this opportunity.

5. Conclusion

The local people have experiences of bamboo production using their indigenous knowledge. The whole study area covered with only one species grown from the mother trees flowered at the same time; and they are germinated in similar time or are grown from the same seed year. New bamboo species was not introduced and there was no propagation and plantation of the same species having different seeding year to obtain an additional option of bamboo product. The local people were not using seeds or seedlings from other areas to have diversity. The cultural practices were not properly applied and there was no management plan prepared and used in the bamboo forest area.

Mass flowering and death of bamboo is natural phenomenon. The subsequent effect after death of bamboo was an expected due to lack of knowledge about the time of mass flowering and death as the local people didn't make any preparations for the coming problem. The local people have no idea about the interval of flowering. The flowering time of bamboo was estimated to be 75-80 years. Therefore, for this area, the coming time of flowering will be expected to be after 75-80 years as flowering interval is the same for the same area.

Bamboo is everything for the local people. Bamboo area, which is mass flowered and dead, can lead to a loss of more than 13, 876,920 birr per year. Hence, the local people have lost the income coming from bamboo and they also missed their job related to bamboo and now they are exposed to unnecessary cost due to mass death of bamboo. Besides, mass drying led to conversion of bamboo forest site to other land uses to get quick money. When bamboos disappear from the area, there happen migrations of wildlife to find better habitat. Mass flowering, on the other hand, has brought mass seed for mass regeneration. Generally, now a day, due to these facts, the local people are facing a big challenge. Training provisions and raising awareness on proper cultivation, particularly regeneration and utilization of bamboo should be given to the community to ensure sustainable development and management of the bamboo forest. Moreover, further research on optimization of propagation methods including tissue culture and land race varieties should be conducted.

6. Acknowledgment

The authors gratefully thank Dilla University for the immense support provided and financial support to carry out this task. Special thanks also go to Gedeo zonal officials and Bule District and Gedeb district administrators, development agents, and farmers for their imaginative opinions and cooperation during the field work.

Conflict of interest

The authors declare that they have no competing interests

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EJED 2(1) 2019: 64 – 90

Ethiopian Journal of Environment and Development

http://www.du.edu.et/duj

The Effect of Smallholder Farmers' Managed Wetlands on Plants' Diversity and Soil Properties in Gedeo Zone, Gedeb wereda, Southern Ethiopia.

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Received: 20 April, 2019 /Accepted: 8 July, 2019

Abstract

This study was conducted in southern Ethiopia to assess the impact of smallholder farmers' managed wetlands on plants diversity and soil properties. Vegetation data were collected from 60 plots having (1m x1m) quadrats laid on five transects lines along the altitudinal gradient. Vegetation data were analyzed using, descriptive statistics, Sorenson's similarity, and Shannon-Wiener diversity index and R. 2.14 software. Sixty composite soil samples were collected at depth of 0-15 and 15-30 cm to study soil texture, pH, electrical conductivity, soil organic carbon, total nitrogen and cation exchange capacity at a distance of 1m, 100 m, 200 m and 300 m from the wetland. Moreover, 60 undisturbed soil core samples were collected to examine soil bulk density. Analysis of variance ($P<0.05$) was employed to test the degree of variations. Result showed 65 plant species were identified and grouped in 21 families. Of all families, Poaceae contains 12 species. The Sorenson's similarity showed highest similarity was observed between community one and two 85% and lowest similarity were observed between community one and three 28%. The highest diversity of species was observed in community four while the highest species evenness was observed in community two. A soil bulk density ($p = 0.001$) and EC significantly varied ($p<0.001$, $p = 0.041$ respectively) with distance from wetland. Similarly, variation was observed on silt, clay, soil bulk density and CEC ($p = 0.031$, $p = 0.046$, $p<0.001$ and $p<0.001$ respectively) along with the soil depth. The soil near the wetland has shown improvements relative to the distance treatments. The improvement in the soil properties near the wetland was due to higher soil organic matter (SOM) input and less soil disturbance.

Keywords: Soil properties, Plant diversity, and Smallholder farmers'

1. Introduction

Wetlands are an important resource base actively utilized by rural communities for socio-economic activities (Dube and Chitiga, 2010). The more water content in wetlands allows diverse flora and fauna life to develop and enrich species biodiversity (Berhanu, 2003). A large number of people are believed to be dependent on wetlands for their livelihood. The loss of species from wetlands has led to a decline in productivity, nutrient retention and resistance to invasion by introduced plant species (Naeem et al., 2000). Despite their importance, wetlands are being continuously altered for the agricultural purpose by human (Dube and Chitiga, 2010).

In Ethiopia, wetlands are locally known as *Chefa*, and cover about 1.14 - 2% of the country's land mass (Tariku and Abebayehu, 2003; Karlsson, 2015). Currently, studies estimated that wetland of Ethiopia exceed 2% (22,500 km2) of the country's surface area (Mengistu, 2006). The dispersed distribution of wetland has made them accessible to a high proportion of the rural population (Kassahun *et al*., 2014). The use of wetland as pasture and cultivation area has increased due to the growing rural population and economic pressures (Dioxn and Wood, 2003). As a result, wetlands cultivation is becoming a well-established tradition amongst rural farmers in Ethiopia so that their gardens provide a regular supply of crops which is especially important during drought years (Tuluab, and Destabc, 2015).

In Ethiopia shortage of agricultural land forced the surrounding communities to drain the wetland for crop cultivation, to meet the increasing food demand of household. In this regard Afwork (2001) and Berhanu (2003) reported that small landowner farmers drain wetland to keep their food security. Draining wetland for growing food crops, the appearance of invasive plant species due to mismanagement of the resources, and the introduction of eucalyptus tree into the wetland ecosystem are the major threats that are posing a danger to the country's wetlands (Zerihun and Kumlachew, 2003). Furthermore, Assefa et al. (2015) also reported that poor community plant eucalyptus tree near the wetland to generate income and for farmland expansion. Planting a eucalyptus plant harms wetland-dependent plant and soil fertility (Kassahun *et al*., 2014). Moreover, drainage and cultivation of wetland have major impact on wetland hydrology (Doxon,2002) which determine vegetation composition, diversity and soil properties(Collins, 2005) disposal of industrial waste affecting wetland plants diversity and oil properties (Bahilu and Tadesse, 2017).

The ecological value of wetland in Gedeo zone has been taken for granted because of incorrect public perceptions, poor legislation and conservation strategies that are not backed by adequate scientific research (Bogale, *et al.,* 2015). This makes it difficult to get full information about wetland flora, and soil properties to plan for wetland conservation and to integrate conservation and development goals at local level. Similar problems were observed in the study area (personal observation). In Gedeb wereda wetlands cultivation is increasingly needed due to growing population associated to shortage of agricultural land decline in crop productivity of the uplands. Furthermore, drainage of wetland for micro irrigation and temporary roads construction has impact on wetland hydrology which is one of strongest determinant for wetland vegetation composition, diversity and soil properties. Therefore, there is a need to continue research on wetland plant diversity, and soil properties, especially in view of the growing level of human impacts that are contributing to their destruction. This research is the first of its kind in the study area since there is no research carried out on plants and soil properties before. Thus, this study investigates how the exploitation of Gedeb wetland by smallholders' farmers change vegetation composition, plant diversity and soil properties.

2. Materials and Methods

2.1 Description of the study area

The study was conducted in Gedeb woreda, Gedeo zone, Southern Ethiopia (Figure 1). The wetland is found in Ginda watershed of Gedeb Woreda southern Ethiopia. The wetland is located between 5051′03″ to 5058′33″ latitude and 38012′46″ to 380 15′ 46″ longitudes covering a total area of 38.2 km2. The study was conducted in two kebele (Gedeb Gubeta and Harmufo) purposely selected among five kebeles based on the extent of wetland coverage and wetland uses by smallholder farmers. Accordingly twenty households (HHs) living around wetlands were selected by purposive sampling techniques (i.e. HHs near to the wetland were purposively selected than HHs far away from it). After selecting the respondents, a survey questionnaire was distributed to 120 respondents. Survey questionnaire was prepared in English and later it was translated in to Amharic to collect the benefits of wetland for the local community.

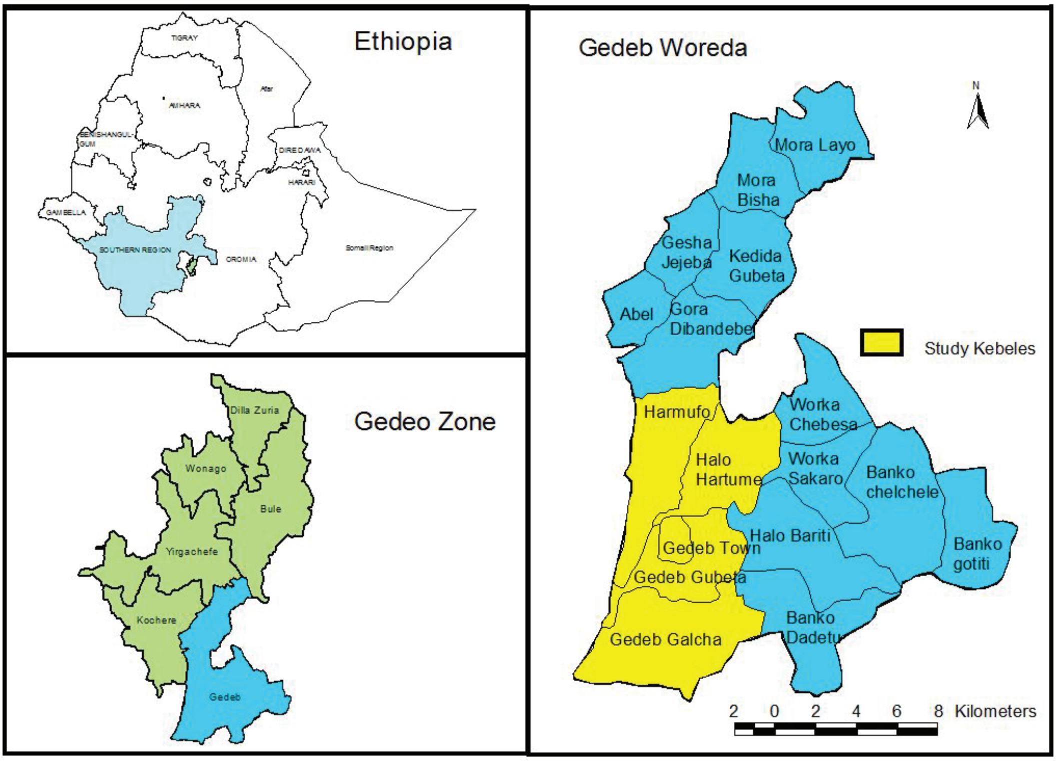

Figure 1: Location map of the study area

According to FAO's soil classification, dominant soil types of Gedeb wereda are Eutric Fluvisols, and Eutric Nitosol (Ethio-GIS, 1994). The average yearly annual rainfall is 1480 mm. the rainfall distribution is bimodal (Figure 2).The maximum and minimum temperature are 22.9^{0}c and 12.3^{0}c respectively (Figure 2). The area is densely populated with 603 persons per sq km in 2014 with high growth rate of about 3.3% per a year. With this growth rate, more agricultural land is demanded in the near future to meet the demand for agriculture production of which wetland are among the potential victims.

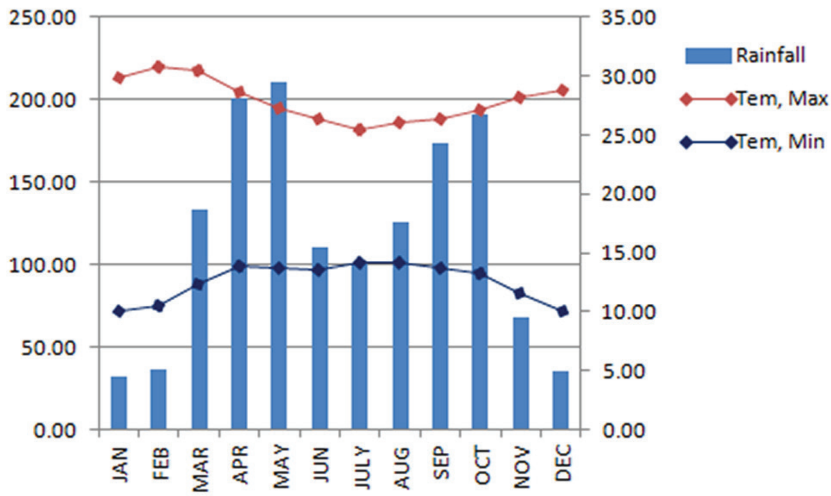

Figure 2: Mean monthly rainfall and temperature of Gedeb Wereda (2000-2009 GC) Source: Ethiopia Meteorological Agency, Hawassa Branch, (2012).

2.2 Plant Sampling and identification

A plant sampling survey was made from June 2016 to mid- September. This period was selected because most species were expected to reach their full growing stage. Five transects lines 400 m long and 2 m wide were laid parallel to each other on the water flow. These transects were laid from the northern direction towards the south 80 m apart.10 quadrates of 100 cm x100 cm were laid systematically along each transect line. Sixty quadrates were sampled on the wetlands. In each quadrate, different plant species were recorded and identified using flora of Edwards (1989), Azene (2007), Edwards and Mesfin (1995), Sebsebe and Edwards (1997).

2.3 Diversity assessment

The Shannon diversity (H ') and evenness (E') indices were calculated as a measure to incorporate both species richness and species evenness (Magurran, 988). The Shannon diversity index (H') 1was calculated using the following formula (Helper and Soetalk, 1998).

$$H' = -\sum_{i=1}^{S} pi \ In \ pi$$

Where:

H′= Shannon-Wiener Diversity Index, S= number of plant species encountered, pi = is the proportion of individuals found in the i^{th} species, Pi = ni/N =, Ni = number of individual species, N= total number of all individual of all species.

The values of Shannon diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran, 1988). The evenness (E) component of H' was computed

$$E = \frac{H'}{\mathrm{Ln(S)}} = \frac{H'}{H'\mathrm{max}}$$

Where: E= Evenness, H`max= Ln (S), S= total number of species in sampled plots. Sorensen's similarity index was used to assess the similarity of plant species in the wetlands using the formula (Kent and Cooker, 1992). Hmax is the maximum level of diversity possible within a given population, which equals ln (number of species). Magurran (1988) explained that *E* ' ranges normally between 0 and 1, where 1 representing a situation in which all the species are equally abundant.

$$S = \frac{2C}{A+B}$$

Where: S is Sørensen‟s similarity index, C= is the number of species common to both sites, A is the number of species present in one of the sites to be compared B is the number of species present in the other site.

2.4 Soil sampling

Soil samples were collected by soil auger measuring 5 cm in diameter and 30 cm in depth. Sixteen soil samples were collected from 60 quadrates at depth of 0-15 cm and 15-30 cm. The samples were placed into self-sealing plastic bags and stored in a cooler until laboratory analysis was carried out. The soil sampling was chosen among the plots used for plant sampling using a simple random method. Soil bulk density was determined by core method using core sampler and drying it to constant weight in an oven at a temperature of 105^{0}c for 24 hours. Soil texture was determined by hydrometer methods (FAO, 2006). Soil organic carbon was determined by Walkley method (Nelson and Sommers, 1982). Soil total nitrogen was analyzed by Kjeldahal method (Bremner and Mulvaney, 1982). Soil pH (1:2.5 soil: water) was measured by using the glasscalomel electrode whereas electric conductivity (EC) was measured by conductivity meter using suspension of 1:2.5 soil water ration. Cation exchange capacity (CEC) was determined at soil pH 7 after displacement by using 1N ammonium acetate method in which it was thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium.

2.5 Data analysis

Descriptive statistics such as frequency and percentage were used to summarize wetland vegetation and soil data collected from the fields. The results of the study were demonstrated in tables, bar graph and figures. Vegetation data were analyzed using Sorensen's similarity index, Shannon-Wiener's diversity index, and Shannon index of evenness. Multivariate analysis was carried out using R- program Version .2.14. Analysis of variance (ANOVA) was employed to test the degree of variations. Turkey's Honest Significance Difference (HSD) test was used when the mean separation showed statistically significant differences ($p < 0.05$).

3. Result and Discussions

3.1 Benefits of wetland for smallholder framers

As it was indicated in Table 1 a large proportion of household farmers were found to be dependent on Gedeb wetland. Thus, the wetland area the local community used for cultivation accounts about 32.33% and for ching grasses 17.41% and for grazing 17.41%. This indicated that wetland is pressurized by the local community. The evidences suggested that wetland in this area serve the needs of the people in individual, family, community, and village levels. The study also revealed that the majority of households' livelihood was directly linked to the wetland. This result suggested that the wetland is the most important resource for livelihoods of the local community and the dependence of the community on wetlands resources are higher. Similarly study by Kassahun *et al*. (2014) reported that 40% of the community used wetland for cultivation while Elias *et al.* (2016) reported that about 50% people used wetlands for cultivation.

Table 1. Wetland resource uses by smallholder farmers

Uses of wetland	Respondents	
	Frequency	Percentage
Ceremonial	15	7.46
Thatching grasses	35	17.41
Dry season grazing	31	15.42
Water for livestock	30	14.92
Cultivation	65	32.33
Micro irrigation during dry season	25	12.43
Total	201	100

3.2 Species composition

A total of 65 wetland plant species representing 55 genera and 21 families were recorded from Gedeb wereda wetland (Appendix 1).The Families with the highest number of species were poaceace with 12 (18%) species followed by Asteraceae with 7(11%) and Cyperaceae with 6 (9%) species and the rest with 1 to 3 (1.5% - 4.5%) species (Table 2). The number of species in each plot varied greatly from 7 species in plot 8 to 18 species in plot 29. These findings are similar with Zerihun and Kumlachew (2003) who reported family poaceae is the dominant in wetland of southwestern Ethiopia.

Table 2. Wetland plant families, genus and species in Gedeb wereda

Family	Genus	%	Species	%	Family	Genus	%	Specieses	%
Acanthaceae	1	1.5	1	1.5	Juncaceae	2	3	2	3
Amranthaceae	2	3	3	4.25	Lamiaceae	3	4.5	3	4.25
Apiaceae	3	4.5	2	3	Nymphaceae	1	1.5	1	1.5
Asteraceae	7	11	7	11	Onagraceae	1	1.5	1	1.5
Commelinaceae	2	3	5	8	Osmundaceae	2	3	2	3
Cyperaceae	6	9	12	18	Polygonaceae	3	4.5	5	8
Dryopteridaceae	1	1	1	1.5	Potamogetonaceae	1	1.5	1	1.5
Eriocaulaceae	1	1.5	1	1.5	Ranunculaceae	2	3	1	3
Fabaceae	1	1.5	1	1.5	Solonaceae	1	1.5	1	1.5
Poaceae	12	18	11	20	Tiliaceae	2	3	1	1.5
Irideaceae	1	1.5	1	1.5	Total	55	83	65	100

There are about 58.46% herb and 41.43% gramminoid in the wetlands. Number and life forms of the species are indicated in appendix 1. In terms of their habitat, (37%) of the species are found in damp or wet habitats. Of the rest, 37 species (57%) grow in both wet and dry habitats. Many of these are weeds or plants of marginal habitats. Sufficient habitat information is not available for the remaining 4 species (6%). This finding is in agreement with Melaku *et al*., (2004); Rebecca (2006) who reported that most of wetland plant species is dominantly found in marshy habitat.

3.3 Sorenson's similarity for the communities

The distribution of plant species in identified plant community showed there is a dissimilarity patterns (Table 2). The overall similarity coefficient ranges from 14%-61% among all the communities. The highest similarity was observed between community one and two (85%), this may be due to the existence of quadrate id adjacent to each other. The lowest similarity was observed between community one and three (28%), and community two and four (14%). The reason is the existence of similar soil chemistry and altitudinal gradients in each habitat. Similar findings by Dube and Chitiga (2011), reported that similar soil physical and chemical properties determine the distribution and abundance of plant species.

Table 3. Sorenson's Similarity coefficient among the four communities

Community	I	II	III	IV
I	1			
II	0.61	1		
III	0.28	0.58	1	
IV	0.35	0.14	0.43	1

3.4 Species richness, diversity and similarity of the communities

The overall Shannon–Wiener diversity and evenness of the wetland were found to be H'max=2.06 and E=0.115 respectively. However, the H'max values of the four communities were different (Table 3). The Shannon–Wiener diversity (H') and Evenness (E) values of the entire wetland were less than H'max values of some communities like community 2 and 4 (Table 3) which implies that each community may show variation with total species richness and diversity indices. Study by Fungai (2006) also reported that the wetland specie's richness varied overexploitation of plant species for different purpose.

Table 4. Species richness, diversity and evenness in each community

Community types	Quadrats included in each community	No of species	H' Max	evenness (E)
Type I	34,3	2	1.9	0.11
Type II	65,62.26,60,59,58,57,56,55,54,52, 50, 49,48,47,46,45,44,43,42,40,39,38,37,33,29,28,10	28	2.25	0.14
Type III	14,9,12,1	3	1.6	0.12
Type IV	3,8,6,11,13,53,25,32,23,16,20,30,7,22,16,24,18,19,17,41,135,27,21,5,4,2, 51,31,36,15,24,63,64	33	2.49	0.09

As shown in table 3, the highest H' max were community type 4 followed by community type 2 and 1.Whereas the lowest H' max' were community type 3 (H'=1.6). Community four also consisted the highest number of species richness followed by community two and the least was at community one. The highest species richness and diversity indices were community 4 and 2. This may be due to less proximity to the residence and exposure to disturbance, like grazing, browsing and others (personal observation). Similar work by Afework 2001; Zerihun and Kumlachew (2003) reported the lowest species diversity and evenness were due to increasing anthropogenic disturbances notable through agriculture, settlement, intensive grazing, expansion of huge infrastructures and brick making. Similarly Mcune and Grace (2002) and Assefa *et al.*(2015) explained in their study that the highest species diversity and evenness were found due to low disturbance intensity while there was a drastic decrease at high disturbance intensity of wetland.

3.5 Plant Communities classification

Cluster analysis was used to identify groups of sampled vegetation that are similar in terms of their species composition. The R- program software was used to perform a hierarchical cluster dendrogram which depicted the vegetation community of wetland species. Thus, four plant community types were identified (figure 3) and the distribution of sample plot in communities were shown in Table 5.

Table 5. Plant community type and their respective species

Community type	Altitudinal ranges (m)	Number of plots	Plots in the community
Type I	2234 -2243	2	34,3
Type II	2234–2403	28	65,62.26,60,59,58,57,56,55,54,52,50,49,48,47,46,45,44,43,42,40,39,38,37,33,29,28 &10
Type III	2309- 2408	4	14,9,12&1
Type IV	2407-2460	32	3,8,6,11,13,53,25,32,23,16,20,30,7,22,16,24,18,19,17,41,135,27,21,5,4,2,51,31,36,15,24,63&64

The four plant communities are:- *Osmunda cinnamomea-Sagitaria graminea, Nymphea odonata-Carex atherodes, Amaranthus hybridus-Andropogon virginicus and Sonchus aspera-Cynodon datylon* and their descriptions are given as follows:

3.5.1 Osmunda cinnamomea-Sagitaria graminea community types

The community type distributed between altitudinal ranges of 2234 and 2243 meter above sea level. In this community, *O. cinnamomea* is the dominant species in the herb layer because of browsing resistance and more frequently found near the river bank (Cayssials, and Rodríguez, 2016) while *S. graminea is* less abundant due to less browsing resistance and most disturbed by human due to versatile uses (Keser *et al*.,2015).

3.5.2 *Nymphea odonata-Carex atherodes* community types

In this community *Nymphea odonata* is the most frequently occurring species followed by *Carex atherodes.*This community is comprised of 15 plots and 25 species and distributed in the altitudinal range of 2234–2403 meter above sea level. *N. odonata and C. atherodes* is the herbaceous layer while *Carex lacustris, Carex michauxiana* and *Carex Vulpinoidea* are the graminoid layer that makes the community.

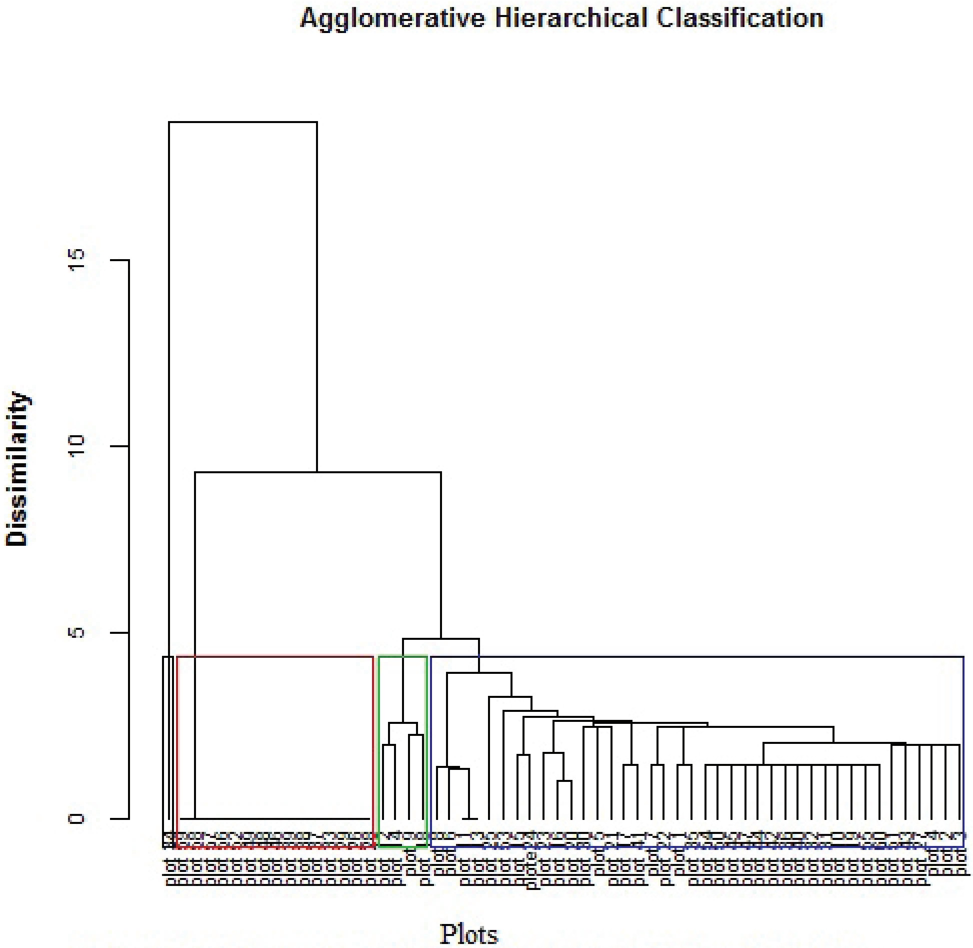

Figure 3 Dendrogram output of the cluster analysis showing the four communities and respective plots

3.5.3 Amaranthus hybridus- Andropogon virginicus community types

This community is found between 2309 and 2408 meter above sea level. They are distributed in 3 plots and comprise 3 species which make the community. In this community *Amaranthus hybridus, and Andropogon virginicus* are the dominant graminoid layer while *Oenanthe* sp. are the herbaceous layer.

3.5.4 Sonchus aspera- Cynodon datylon community types

This community is distributed between the altitudinal ranges of 2407 and 2460 meter above sea level. It comprised 15 plots and 30 species. In this community

S. aspera and C. datylon is the dominant graminod layer while *Eriocaulon abyssinicum*, *Hydrocotyle umbellate* and *Hygrophila* auriculata are the dominant herbaceous layer.

3.6 Soil Physical Properties

3.6.1 Soil Textural Fraction and Bulk Density

Soil textural fractions of sand, silt and clay content of soil samples did not show statistically significant mean difference with distance from the river bank. However, the overall mean values of sand and silt decreased while clay increased from the river bank (Table 7). On the other hand, the overall mean values of silt ($p = 0.031$,) and clay ($p = 0.046$) had shown statistically significant variation with soil depth (Table 6). Higher overall mean value of silt and clay were observed on the top soil (0-15cm, 28.4±1.24) and lower soil depth (15-30cm, 53.87±1.99) respectively. The decreasing sand and silt fractions with respect to horizontal distance from the river bank might be due to long term soil pulverization that converted sand and silt into crumb. On the other hand, the decrease of clay soil fractions near the river bank might be due to selective removal of clay through translocation favoring sand and silt to increase. The tendency of decrease in clay fractions near the wetland could also be related with the high abundance of plant root channels (macrospores) favoring the migration of fine clay fractions into the lower soil layers below 15 cm. This finding is in concurrent with Mosaddeghi *et al*. (2000) and Fenthun (2008) that reported clay fraction decreased due to selective removal from the mass of the soil. Moreover, the concave shape of the local area landscape position also contributed for the removal of clay by leaching.

Table 6. Soil textural fraction (clay, silt and sand), and soil chemistry (pH, EC, SOC (%), TN (%) and CEC).

Source of Variation	df	Soil Parameters																	
		Sand		Silt		Clay		BD		pH		EC		SOC		TN		CEC	
		MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P
DISTA	3	31.8	0.826	8.3	0.836	67.49	0.697	3.3	p<0.001	0.17	0.513	0.007	0.041	0.359	0.637	0.045	0.181	1.883	0.813
SDEP	1	190.2	0.187	142.3	0.031	587.2	0.046	3.51	p<0.001	0.003	0.914	0.011	0.290	1.4	0.141	0.001	0.846	431.9	P<0.001
DISTA*SDEP	3	67.1	0.599	67.4	0.086	60.4	0.732	0.091	0.011	0.125	0.63	0.003	0.353	0.119	0.903	0.044	0.195	0.404	0.977
ERROR	52	106.43		29.03		140.4		0.022		0.215		0.002		0.629		0.027		6.011	
TOTAL	**60**																		

DISTA = Distance, SDEP = Soil depth, MS = Mean square, p = p-value, BD = Soil bulk density, EC = Soil Electrical conductivity, SOC = Soil organic carbon, TN = Total Nitrogen, CEC = Cation exchange capacity.

Table 7: *Soil textural fractions (Sand, Silt and Clay, %) and Bulk density (g cm-3) in relation to distance from the Wetland (Mean ± SE).*

Soil Param-eters	Soil Depth (cm)	Distance from Wetland				Overall
		1m	100m	200m	300m	
Sand	0-15	24.78±3.37	27.5±4.94	23.29±3.64	21.0±3.79	24.4±1.96[a]
	15-30	22.33±3.62	19.25±3.30	17.57±2.98	23.00±3.79	20.53±1.69[a]
	Overall	23.56±2.41[a]	23.38±3.06[a]	20.43±2.39[a]	22.0±2.58[a]	
Silt	0-15	31.44±2.97	25.0±2.17	29.00±2.23	27.67±1.23	28.4±1.24[a]
	15-30	23.89±1.41	27.00±0.75	24.43±1.84	25.33±1.08	25.13±0.68[b]
	Overall	27.67±1.84[a]	26.00±1.14[a]	26.27±1.52[a]	26.50±0.86[a]	
Clay	0-15	43.78±4.84	47.5±4.45	47.71±4.30	51.33±3.92	47.2±2.21[a]
	15-30	52.22±3.99	53.75±3.73	58.01±4.32	51.67±4.27	53.87±1.99[b]
	Overall	48.0±3.21[a]	50.63±2.91[a]	52.86±3.26[a]	51.5±2.76[a]	
Bulk Density	0-15	0.33±0.03	0.8±0.05	1.02±0.05	1.34±0.11	0.87±0.03[a]
	15-30	0.79±0.05	1.08±0.04	1.6±0.07	1.97±0.01	1.36±0.1[b]
	Overall	0.56±0.02[a]	0.94±0.05[b]	1.31±0.4[c]	1.66±0.11[d]	

Means followed by the same letter(s) across columns and row did not show statistically significant difference along with soil depth and distance from the wetland ($p = 0.05$).

On such a typical hill-slope, the quantity of water stored in the soils increases with proximity to the base of the hill-slope in response to the accumulation of surface and subsurface flow from upslope positions which cause the migration of clay fractions from the surface. Considering soil depth, the overall mean values of sand and silt soil fraction have decreased while clay fraction increases along the soil depth. Soil bulk density showed significant variation with distance from the river bank ($p < 0.001$,) and soil depth ($p < 0.001$) (Table 6). The combined effect of horizontal distance and soil depth had also shown a significant interaction effect on soil bulk density ($p = 0.011$) (Table 6). The overall mean value of bulk density was increased along horizontal distance from wetland and higher value was observed at 300m. This was due to lack of organic matter and higher soil compaction at a distance from the wetland. With respect to soil depth, the presence of less soil aggregation for lower SOC content and the pressure exerted by overlying soil layer caused higher bulk density in the 15–30 cm soil depth Similar results were reported by Mosaddeghi *et al*., 2000; Mulugeta and shemelse 2004).

3.7 Soil Chemical Properties

3.7.1 Soil Organic Carbon (SOC) and Total Nitrogen (TN)

SOC and TN did not vary significantly with horizontal distance and soil depth (Table 7). The interaction effects of horizontal distance from the river bank and soil depth were also not significant on both SOC and TN (Table 7, Figure 4a &4b). The overall mean value of SOC was higher in the first treatment (1m from the river bank) and the value decreased and becomes lower at a distance of 300m. Even though the overall mean values of both SOC (%) and TN (%) didn't show statistical significance along horizontal distance and soil depth, variations were observed between treatments (1m, 100m, 200m and 300m) and soil depth (0-15 cm and 15-30 cm)(Table 7) . With this in mind, the overall mean values of SOC in the first treatment (1m) were higher than treatment two, three and four by 11.32%, 14.56% and 16.26% respectively.

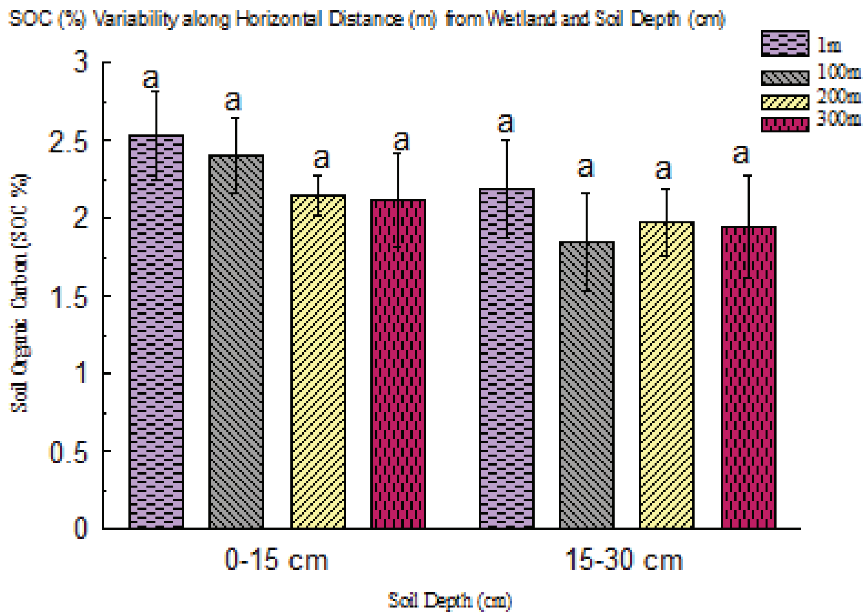

Figure 3a: SOC variation along horizontal distance (m) from the river bank and soil depth (cm).

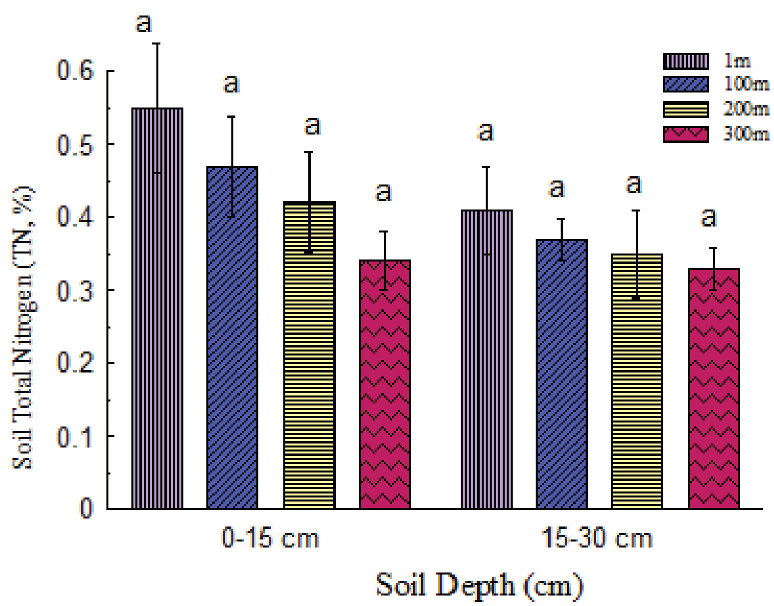

Figure 3b: TN variation along horizontal distance (m) from the river bank and soil depth (cm).

Table 8: Soil pH (1:2.5), EC, SOC (%), SOC (%), TN (%), and CEC in relation to Distance from the river bank and soil depth (Mean ± SE).

Soil Param-eters	Soil Depth (cm)	Distance from the river bank				Overall
		1m	100m	200m	300m	
pH	0-15	4.86±0.1	4.68±0.13	4.81±0.12	5.0±0.29	4.82±0.08[a]
	15-30	4.68±0.24	4.9±0.16	4.71±0.13	5.0±0.06	4.81±0.09[a]
	Overall	4.77±0.13[a]	4.79±0.104[a]	4.76±0.09[a]	5.0±0.14[a]	
EC	0-15	0.11±0.02	0.12±0.02	0.09±0.03	0.061±0.01	0.1±0.01[a]
	15-30	0.103±0.02	0.06±0.01	0.061±0.01	0.05±0.01	0.07±0.01[a]
	Overall	0.11±0.01[a]	0.091±0.013[ab]	0.08±0.014[ab]	0.05±0.01[b]	
SOC	0-15	2.53±0.28	2.4±0.24	2.15±0.13	2.11±0.3	2.29±0.13[a]
	15-30	2.19±0.31	1.84±0.32	1.97±0.21	1.95±0.33	1.99±0.15[a]
	Overall	2.36±0.21[a]	2.12±0.21[a]	2.06±0.12[a]	2.03±0.22[a]	
TN	0-15	0.55±0.09	0.47±0.07	0.42±0.07	0.34±0.04	0.45±0.03[a]
	15-30	0.41±0.06	0.37±0.03	0.35±0.06	0.33±0.03	0.37±0.03[a]
	Overall	0.48±0.06[a]	0.42±0.05[a]	0.39±0.04[a]	0.34±0.02[a]	
CEC	0-15	37.74±0.77	37.58±0.42	36.74±1.03	37.42±0.9	37.4±0.38[a]
	15-30	32.04±0.96	31.86±0.67	31.51±0.96	32.36±1.39	31.93±0.47[b]
	Overall	34.89±0.91[a]	34.72±0.83[a]	34.13±0.99[a]	34.89±1.1[a]	

Means followed by the same letter(s) across columns and row were not significantly different along soil depth and distance from the wetland ($p = 0.05$).

The higher amount of SOC (%) near the river bank (1m treatment) was due to the influence of water availability together with dense vegetation cover (Table 8). These findings concur with (Dube and Chitiga, 2011). Furthermore Taruvinga and Mushunje (2010) also reported that wetland accumulate more organic matters near the river bank. However, at a distant away from the river bank, less SOC was recorded due to the presence of soil disturbance compared to the first treatment. This finding is in agreement with Tekalign (1991) who reported that SOC is higher near to the riverbank due to less oxidation reaction takes place compared to soil far away from the wetland.

Despite the non-significant difference observed between soils layers, SOC (%) appeared to differ slightly within the vertical distribution following the soil depth. Irrespective of distance from the bank, the top surface soils (0–15cm) showed relatively higher SOC content compared to the 15–30 cm depth layer. The decrease in SOC with depth was more at treatment three (200m) and four (300m) as compared to treatment one (1m). Hiederer (2009) reported similar results of a decrease in SOC with soil depth, a result of corresponding decrease of organic matter storage via root biomass and litter decomposition, which are the main pathways of organic carbon inputs.

Similarly, TN (%) didn't show significance variation between treatments and soil depth. Like that of SOC, the first treatment (1m) had higher TN (%) than the rest treatments (Table 8, figure 5). For instance, treatment one (1m) had 14.29%, 23.08% and 41.18% higher TN (%) than treatment two, three and four. The higher amount of TN near the wetland might be due to the presence of higher addition of nitrogen containing organic matters in the area. Wetlands play a vital role in maintaining SOC & TN within it for long period of time. Currently, the wetland that is found in the study area has been suffering from anthropogenic effects and as a result the size of the wetland is shrinking from time to time. As the wetland shrinks, the existing organic matter combine with oxygen and yielded lower amount of SOC & TN at a distant area from the wetland.

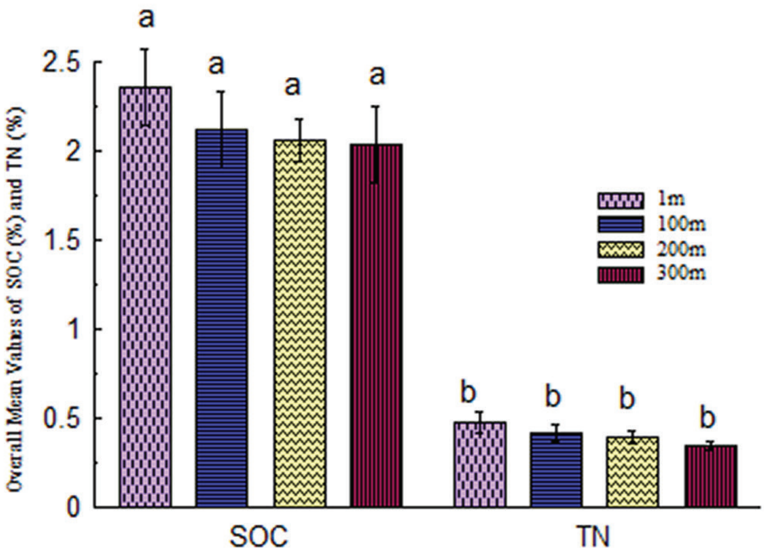

Figure 5: Soil organic carbon and Total Nitrogen content of the soil

Considering the vertical distribution of TN, higher amount was found at the first soil layer (i.e. 0-15 cm). The higher amount was due to higher addition of organic materials near the surface of the soil.

3.7.2 Soil reaction (pH-H_2O, 1:2.5), Electrical Conductivity (EC, ds m^{-1}) and CEC

Soil pH value did not show statistically significant variation among horizontal distance (treatment) from the wetland (Table 6). Relatively higher soil pH values were recorded under treatment four (300m away from the bank)(Table 8). Since the study area is categorized under highland agro-ecology, it is believed that the soil becomes highly susceptible for soil acidity. Even if there was no significant difference between treatments (1m, 100m, 200m and 300m), slight difference in overall mean pH value was seen between treatments. The higher soil pH value under treatment four was probably due to the presence of higher values of soil acidity forming nutrients. Exchangeable bases like Ca2+ and Mg2+ could be accumulated due to animal manures since the area is also used as a grazing land. Misra et al.(1993) reported that animal manure provides considerable amount of Ca2+, Mg2+ and K+ and enhances the pH values of the soil. The lowest value of pH near the bank (treatment one) as compared to treatment four (300m) (4.6% reduced, Table 8) might be due to depletion of basic cations due to leaching either by over saturation of the wetland or by the annual rainfall amount that could allow the precipitation of Al and Fe in the soil.

Soil Electrical Conductivity (EC ds/m) significantly varied along treatments ($p = 0.041$, Table 6). Higher overall mean value of EC was observed near the wetland under treatment one (1m). However, soil EC didn't show any significant difference among soil depths (Table 6). Though soil EC was not significantly affected by soil depth, its distribution was not uniform along soil depth. The overall mean value of EC decreased along the soil depth. Soil electrical conductivity (EC) has generally been associated with determining soil salinity; however, EC also can serve as a measure of soluble nutrients (Smith and Doran, 1996) for both cations and anions and is useful in monitoring the mineralization of organic matter in soil (Deneve *et al.,* 2000). The higher EC on the top soil layer (0-15 cm) near the wetland (treatment one) was attributed from higher nutrients that are emanating from accumulation and decomposition of soil organic matter.

Cation exchange capacity (CEC) has shown a significant variation along the soil depth ($p < 0.001$) and not along the treatment (Table 6). Considering soil depth, relatively higher (17.13%) CEC values (Table 8) was recorded on 0-15 cm soil layer. This is due to the presence of higher addition of soil organic carbon on the top soil surface and the presences of high clay fraction that contributes for the presence of higher CEC in the soil. Similar works by Chapman (1965). Alemayehu and Sheleme (2013) and Tilahun (2007) reported that clay absorb and hold positively charged ions and provides protection against depletion of nutrients through its colloidal particles.

4. Conclusions

The present study revealed that large proportions of household farmers were found to be dependent on wetland since the wetland vegetations have many benefits for the local community. Thus, wetland plant species diversity and evenness were not even because of the wetlands are severely affected by human as well as natural factors. Similarly low similarity index of species composition were observed among the community because of variation of both physical and chemical soil properties. In addition use of wetland for cultivation and drainage of the water have negative impact on soil physical and chemical properties such as soil texture, bulk density, soil organic carbon, electric conductivity, pH, total nitrogen and electric conductivity. The overall mean value of sand and silt particles were not changed as we move away from the river bank while the clay fraction increased due to deposition from upland. Considering soil depth, the overall mean values of sand and silt soil fraction decreased while clay fraction increased along the soil depth due to deposition of clay by translocation process. Soil bulk density showed significant variation with horizontal distance from the bank of the river and soil depth. The overall mean value of SOC and Total nitrogen were higher at 1m from the bank and the value decreased and became lower at a distance of 300m from the bank. Soil pH value did not show statistically significant variation among horizontal distance (treatment) from the wetland of water flow. Soil Electrical Conductivity (EC ds/m) significantly varied along but didn't show any significant difference among soil depths. Therefore proper utilization of wetland resources are urgent agenda to conserve plant diversity and soil physical and chemical properties of the Gedeb wetland.

5. Acknowledgements

We are very happy to acknowledge Dilla University for financing this study. We are also interested to thank land administration and Use office and Gedeb Wereda Agricultural Office for their unreserved support during data collection.

Conflict of interest

The authors declare that there is no conflict of interest.

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6. Appendix 1

List of identified wetland plant species from Gedeb wereda wetland

No	Botanical name	Family	Habit
1	Hygrophila auriculata Schumanch	Achanthaceae	Herb
2	Sagittaria graminea Michx	Alismataceae	Graminoid
3	Amaranthus hybridus L	Amaranthaceae	Herb
4	Oenanthe sp.	Apiaceae	Herb
5	Hydrocotyle umbellate L.	Araliaceae	Herb
6	Bidens frondosa L	Asteraceae	Herb
7	Eclipta prostrate (L.)	Asteraceae	Herb
8	Eupatorium maculatum (L)	Asteraceae	Herb
9	Guizotia scabra Vis.(Chiov.)	Asteraceae	Graminoid
10	Saphaeranthus suaveolens (Forssk) DC	Asteraceae	Herb
11	Sonchus asper (L)	Asteraceae	Herb
12	Sphaeranthus sp.	Astreaceae	Herb
13	Ceratophyllum demersum L.	Ceratophyllaceae	Herb
14	Commelina benghalensis L.	Commelinaceae	Herb
15	Commelina diffusa Burm f	Commelinaceae	Herb
16	Commelina forskalae Vahi	Commelinaceae	Herb
17	Ipomoea fragrans(Bojer	convolvulaceae	Herb
18	Mukia maderaspatana (L) M.J. Roem.	Cucurbitaceae	Climber
19	Carex atherodes Sperng	Cyperacae	Graminoid
20	Carex vulpinoidea Lam	Cyperacae	Graminoid
21	Carex lacustris Willd.	Cyperaceae	Graminoid
22	Carex scoparia Schkuhr ex.wild	cyperaceae	Herb
23	Carex stricata wahlenb	cyperaceae	Herb
24	Cyperus assimilis Steud	Cyperaceae	hHrb

25	Cyperus bipartitus Torr.	cyperaceae	Herb
26	Cyperus esculentus L.	Cyperaceae	Graminoid
27	Cyperus longus Varbadius	cyperaceae	Herb
28	Eleocharis sp.	Cyperaceae	Graminoid
29	Fimbristylis ferruginea (L) Vahl. ssp. Sieberiana	Cyperaceae	Graminoid
30	Juncus roemerians Schele	cyperaceae	Herb
31	Lipocarpha chinensis (Osb.) Kern.	Cyperaceae	Graminoid
32	Rhynchospora subquadrata Cherm.	Cyperaceae	Graminoid
33	Schoenoplectus corymbosus var brachyceras	Cyperaceae	Graminoid
34	Scirpus acutus L.var	Cyperaceae	Graminoid
35	Scirpus americanus (Pers.) Volkart ex	Cyperaceae	Herb
36	Scirpus cyperinus (L.) Kunth	cyperaceae	Herb
37	Scirpus littoralis L.	Cyperaceae	Herb
38	polystichum acrostichoides L	Dryopteridaceae	Herb
39	Eriocaulon abyssinicum Hochst.	Eriocaulaceae	Graminoid
40	Iris missouriensis Nutt	irideaceae	Herb
41	Juncus effuses L	Juncaceae	Herb
42	Juncus spp	Juncaceae	Graminoid
43	Leucas deflexa Hook.f	Lamiaceae	Herb
44	Platostoma rotundifolium (Briq.) A. J. Paton	Lamiaceae	Graminoid
45	Trifolium acaule A.Rich	leguminaceae	Herb
46	Nymphaea odorata Aiton	Nymphaceae	Herb
47	Nephrolepis undulate (Sw.) J. Sm.fern	Oleandraceae	Graminoid
48	Ludwigia repens J.R forst	Onagraceae	Herb
49	Osmunda cinnamomea (L) C. Presl	Osmundaceae	Herb
50	Eleusine indica (L) Gaertn	poacae	Graminoid
51	Agrostis capillaries L.	Poaceae	Graminoide
52	Andropogon virginicus L.	Poaceae	Graminoid

53	Carex michauxiana Doll &Asch	Poaceae	Graminoid
54	Cynodon dactylon (L)	poaceae	Graminoid
55	Digitaria ciliaris (L)	Poaceae	Graminoid
56	Digitaria longiflora Pers	poaceae	Graminoid
57	Leersia hexandra Sw	Poaceae	Herb
58	Panicum anceps Michx	Poaceae	Graminoid
59	Stenotaphrum secundatum (Walter) Kuntze	Poaceae	Graminoid
60	Zinaniopsis miliacea (Michx.) Döll & Asch	Poaceae	Graminoid
61	Pericaria setosula A. Rich	Polygonaceae	Herb
62	Polygonum barbatum L.	polygonaceae	Herb
63	Polygonum hydropiperoides Michx	Polygonaceae	Herb
64	Polygonum senegalense Meisn.	Polygonaceae	Herb
65	Potamogeton natans L.	Potamogetonaceae	Herb

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Ethiopian Journal of Environment and Development

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Talking Plants: Communication and Signaling via Volatiles

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Received: 25 April, 2019 /Accepted: 8 July, 2019

Abstract

There is an urgent need for new sustainable solutions to support plants in facing current environmental challenges. In particular, strengthening of productivity and food security needs sustainable exploitation of natural resources and metabolites. In this review, we fetch the attention to the agronomic potential of volatile organic compounds (VOCs) emitted from plants, as a natural and eco-friendly solution to defend from stresses and to enhance crop production. Plants defense by emitting volatile organic compounds communicate with herbivore-attacked neighbors to activate defenses before being attacked. Many volatile compounds especially, transcriptome and signal cascade analyses of VOC-exposed plants indicates that plants snoop to prime direct and indirect defenses and to hone competitive abilities. A diversity of emission responses have been observed from stressed plants. Although, the similarities have been seen in bearing environmental stress, it is also established fact that an emission of VOCs can be induced at any time from leaves of all plant species following abiotic and abiotic stress.The present challenges regarding changing environment which may hamper the use of VOCs in open field are analyzed by several scientist and solutions for a better exploitation of VOCs in future sustainable agriculture are envisioned.

Keywords: Biotic and Abiotic stress, Plant defense, , Talking plants, VOCs, Signaling,

1. Introduction

Plants eavesdrop on their neighbors through the detection of volatile organic compounds (VOCs). These compounds can, as mentioned, be emitted from the root system, but can also be found airborne and floral as well. The ability to detect and respond to VOCs of most competitive neighbors is an important strategy for individual plants since it enables them to adjust their physiological status and growth pattern accordingly, especially in the early stages of their life (Stephen and Harry 2006).

As it is well established fact that plants produce many volatile metabolites and a small subset of these compounds is identified by animals and humans, and the volatile profiles are defining elements of the distinct flavors of individual foods. Flavor volatiles are derived from an array of nutrients, including amino acids, fatty acids, and carotenoids. In tomato, almost all of the important flavor-related volatiles are derived from essential nutrients (Baldwin, 2010). The predominance of volatiles derived from essential nutrients and health-promoting compounds suggest that these volatiles provide important information about the nutritional makeup of foods (Stephen and Harry 2006).

Contrary to the long-held idea that plants are uncommunicative, recent research has made it clear that many species conduct lively and informative conversations with one another. Scientists have revealed that plants communicate through the air, by releasing odorous chemicals called volatile organic compounds (VOCs), and through the soil, by secreting soluble chemicals into the rhizosphere and transporting them along thread-like networks formed by soil fungi. In addition, this is more than mere gossip: these signals warn neighbors of the many dangers facing plants (Baldwin, 2010).

Volatile organic compounds (VOCs), first theorized by plant scientists Jack Schultz and Ian Baldwin in the early 1980s, are now a well-known form of plant communication. Maple tree (**Acer**) saplings (ramp up their own defenses in the presence of herbivore-damaged neighbors.

In late 1990, however, a drop of more carefully designed experiments began to yield convincing evidence to the contrary. In 2000, Karban showed that wild tobacco plants grown in close proximity to sagebrush plants whose leaves had been clipped became resistant to herbivores, ostensibly in response to VOCs released by the sagebrush. Other researchers soon reported similar VOC-induced defense responses, both intra and interspecies in several other plants, including lima bean, broad bean, barley, and corn. Moreover, in 2006, Karban showed that VOCs released by damaged sagebrush induce herbivore resistance in plants growing at distances of up to 60 cm, well within the range of sagebrush neighbors in nature. By now, the wonder of VOC-based plant communication is well established. Different researches demonstrated that volatile cues increase fitness in receiver plants. In one experiment, lima bean plants exposed to herbivore-induced VOCs lost less leaf mass to herbivores and produced more new leaves than controls (Kost and Heil, 2006). But very little information available that demonstrates volatile signaling between neighboring plants can benefit the emitting plant, prompting some researchers to suggest that “eavesdropping” is a more accurate description of what has been observed than “intentional” communication.

2. Impact of Environment on Volatile Compound Emission

A variety of emission responses are observed from stressed plants. Although all environmental stresses bear similarities, e.g. any stress typically leads to reductions in leaf photosynthesis rates, different stresses differently affect volatile emission rates, and the responses can be different for constitutive and induced emissions. In addition, for any stress, the effects depend on stress severity and duration. Mild stress characteristically first results in physiological responses those are quickly reversible upon a return to non-stressed conditions. Such physiological responses typically result from changes in substrate availability for all stresses and from changes in enzyme activity for temperature stresses. Thus, the effects can be positive, e.g. due to enhanced substrate availability for isoprene emission upon mild drought stress or due to enhanced substrate availability and enzyme activity upon mild heat stress. For other mild stresses, the effects can be negative or occasionally no effects can be observed. Mild stress seldom elicits release of stress volatiles, or if it does, the elicitation is minor. More severe stress typically leads to major reductions in constitutive emissions and release of characteristic stress volatiles. The available evidence demonstrates that the release of stress volatiles is stress dose dependent (Baldwin and Schultz, 1983; Rhoades, 1983; Heil and Silva Bueno, 2007; Heil and Karban 2010).

3. Impact on Biotic and Abiotic stress

Emission of VOCs can be induced at any time from leaves of all plant species following abiotic (Loreto *et al.,* 2006; Loreto and Schnitzler, 2010) or biotic stresses (Dicke and Baldwin, 2010). Results from many studies have demonstrated that emission of isoprenoids, the most abundant group of VOCs (Guenther *et al.,* 2006), is stimulated by abiotic stresses and improves plant resistance either by direct quenching of reactive oxygen species (ROS) (Loreto and Velikova, 2001), or indirectly by stabilizing cell membranes (Velikova *et al.,* 2011). However, protection of cell membranes to avoid toxic accumulation of ROS is only one among the many roles of VOCs that may be exploited in agriculture.

Grapevines are generally well-adapted to arid and semi-arid climates, and they appear to primarily rely on drought avoidance mechanisms in water stress situations. In terms of the response of the grapevine to drought conditions, rootstock can have an impact on the gas exchange and water status. The mechanism of drought tolerance, rootstock anatomy, stomatal regulation, physical and chemical responses are the main contributing factors during grapevine drought stress responses (Tsegay*et al.,* 2014; Lovisolo*et al.,* 2016).

Plant volatiles are the metabolites that plants release into the air. Plants are champion synthetic chemists; they take advantage of their anabolic ability to produce volatiles, which they use to defend themselves against biotic and abiotic stresses and to deliver information- and potentially disinformation- to mutualists and competitors alike. Volatiles have provided plants with solutions to the challenges associated with being rooted in the ground and immobile (Baldwin *et al.,* 2006; Baldwin, 2010; Dudareva *et al.,* 2006; Kessler *et al.,* 2008; Kostand Heil, 2006).

Plant volatile blends are dominated by four biosynthetic classes: terpenoids, compounds with aromatic rings, the fatty acid derivatives and volatiles derived from amino acids. Terpenoids play a central role in generating the chemical diversity of plant volatiles and appear to have been under strong diversifying selection. Methanol and ethylene are two the most commonly emitted plant volatiles (Baldwin, 2010; Maffei, 2010; Blande*et al.,* 2007).

Most plant volatiles help in communication to the outside world, providing information to other organisms about a plant's physiology (e.g., its sexual receptivity, fruit maturity, insect damage, oviposition, and competitive status). They can also transmit information within a plant and potentially between plants. Green leaf volatiles, ethylene and perhaps other plant volatiles transmit information within plants, affecting transcript abundance or directly activating defense responses in distal branches that are not well connected by the private communication channels of the vascular system. Plants are known to change their metabolism in response to other long-distance signals. This change in resource allocation priorities likely reflects the more severe consequences of resource competition than of attack from herbivores and pathogens for a plant's fitness (Baldwin, 2010; Dudareva*et al.,* 2006; Lovisolo*et al.,* 2016; Choudhary*et al.,* 2008).

When plants are attacked, they attract predators and parasitoids of the attacking herbivores with volatile blends that provide information about the location, activity and perhaps even developmental stage of the attacking herbivore. The more information about attacking herbivores a plant can encode into its volatile emissions, the more effectively a carnivore will be able to respond to a plant's 'cry for help' and the more likely the carnivore will benefit the plant by disposing of its attackers (Baldwin *et al.,* 2006; Baldwin, 2010; Dicke and Baldwin 2010; Engelberth*et al.,* 2014).

The floral bouquets also contain potent repellants to the unbidden guests of flowers: nectar robbers and florivores. These repellants likely signal the presence of high concentrations of less volatile toxins and other deterrents in the flower. The blends released from ripe fruits are highly attractive to potential seed dispersers, and since many fruit volatiles are derived from amino and fatty-acids, the blend likely represents the true nutritional value of the fruit to a potential disperser (Baldwin *et al.,* 2006; Baldwin, 2010).

4. Impact on Agriculture

Plants can detect their neighbors by stimuli sensed either through their leaves or by root exudates. The researcher also found that a brief and light touch to the leaf has an impact on above and below ground communication, affecting the pattern of biomass allocation and reducing their attractiveness for herbivore insects. The chemical composition of the soil is a key factor in the lifespan of any plant as conveys signals not only about the presence of surrounding neighbours but also their physiological status. Intriguingly, some reports demonstrated that brief touch stimuli perceived by the leaves can affect belowground plant interactions. The recent study demonstrated the extraordinary capacity of maize roots to discriminate between belowground signals and then to respond differentially according to the stress status of their neighbours (Rhoades, 1983).

Whether they are studying volatiles drifting on the breeze or phytochemicals zipping through subterranean fungi, researchers are now bent on elucidating the relevant receptors and deciphering the molecular lingua franca of plant communication. They could then begin to clarify the ecological significance of the phenomenon and, potentially, help farmers grow hardier crops (Kost and Heil 2006).

Understanding how plants perceive airborne volatile signals, for instance, could inform the genetic engineering of crops that are hypersensitive to cues from sacrificial "beacon" plants that are deliberately damaged to emit signals that trigger neighboring plants to activate their antipredator and/or antipathogen defenses. And if researchers could pinpoint the compounds that act as vectors for stress cues passed between roots, they could potentially "train" crop seedlings to better cope with drought and other stresses. Plants maintain memory of any stress event they have experienced (Crisp *et al.,* 2016; Hilker *et al.,* 2016), and this memory is able to influence the response to forthcoming stressful situations. Factors able to shape the plant's stress memory are referred to as "priming stimuli", among which plant VOCs play a crucial role because, due to their volatility, they can quickly reach distant plant parts (Heil and Kost, 2006; Mauch-Mani *et al.*, 2017). A "primed" plant shows an earlier, stronger, and faster response upon further stress occurrence, thereby resulting in increased resistance and/or tolerance (Conrath *et al.*, 2015; Mauch-Mani *et al.,* 2017). VOCs have been extensively demonstrated to prime defenses against herbivorous insects (Kim and Felton, 2013), pathogens (Ameye *et al.,* 2015), and environmental stresses (Cofer *et al.,* 2018). Defense priming against pathogens has also been considered as a sort of "green vaccination" (Luna-Diez, 2016). Green leaf volatiles (GLVs) such as Z-3-hexenyl acetate, ubiquitously and rapidly released after mechanical damage of leaf tissues (Brilli *et al.,* 2011), have been reported to prime resistance of wheat plants to the fungal pathogen *F. graminearum* (Ameye *et al.,* 2015) and to reduce the damage occurring to maize plants during cold stress (Cofer *et al.,* 2018). Other VOCs such as methyl salicylate (MeSA) and monoterpenes (i.e., camphene and pinene) (Riedlmeier *et al.,* 2017) have been found to actively participate in the mechanisms leading to systemic acquired resistance (SAR) (Dempsey and Klessig, 2012). Low concentrations of methyl jasmonate (MeJA) have been demonstrated to prime plant defenses by modifying the epigenetic status of wound-inducible genes in rice, thereby enhancing responsiveness to wounding (Bertini *et al.,* 2018). Even methanol, ubiquitously emitted from plant leaves during cell division and cell wall expansion (Nemecek-Marshall *et al.,* 1995), seems to act as a priming stimulus when released from damaged tobacco leaves by enhancing resistance to the pathogenic bacterium *Ralstoniasolanacearum* (Dorokhov *et al.*, 2012). In addition, antibacterial defenses have also been reported to be primed by VOCs such as nonanal in lima bean plants treated with benzothiadiazole (BTH), a synthetic salicylic acid analog (Yi *et al.,* 2009). Compared to the direct induction of defenses in plants, priming does not incur in an energetically costly activation of metabolic pathways (van Hulten *et al.,* 2006; Martinez-Medina *et al.,* 2016) and therefore represents a sustainable method to develop novel crop protection strategies.

It can be a successful strategy but for that more research should be carried out in this area. Nowadays, the availability of new analytical technologies such as high-resolution Proton Transfer Reaction "Time-of-Flight', mass spectrometry (PTR-TOF-MS) make possible instantaneous and highly sensitive detection of the whole spectra of VOCs with high resolving power (Graus *et al.*, 2010). This can provide *in vivo* a complete and high-throughput measurement of the entire blend of VOCs (the "volatome") emitted from plant leaves. Phenotyping the volatome could allow non-invasive screening of plant VOC profiles, assisting breeders in the selection of cultivars that successfully perform under changing environmental conditions and associated biotic stressors (Araus and Cairns, 2014). PTR-TOF-MS analysis could also enable a real-time diagnosis of the crop health status (Niederbacher *et al.,* 2015), by monitoring in air the occurrence of specific VOC emissions (i.e., MeSA, sesquiterpenes) as stress biomarkers triggered by abiotic and biotic constraints (Karl *et al.,* 2008; Chalal *et al.,* 2015). Moreover, variations of VOC emission patterns over time can be used for precision agriculture purposes to monitor plant growth and development in the field. Likewise genomics and high throughput platforms for imaging and remote-sensing, real-time highly resolved VOC detection generate massive amount of data (Gandomi and Haider, 2015). This production of 'big data' requires computational analysis to extract patters and identify features useful for phenotyping (Singh *et al.,* 2016). Implementation of machine learning tools to process information on VOC emissions along with environmental parameters collected in the field by multiple sensors will allow exploration of big data in order to measure plant performance and recognize early symptoms of stress.

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EJED 2(1) 2019: 92 – 108

Ethiopian Journal of Environment and Development

http://www.du.edu.et/duj

Determinants of Rural Youth Participation in Non-Farm Income Generating Activities: the Case of East Gojjam Zone, Ethiopia

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Received: 23 April, 2019 /Accepted: 8 July 2019

Abstract

Rural youths are forced to look for non-farm income generating activities to sustain and secure their livelihoods as well as to supplement their agricultural activities. However, their participation in nonfarm activities is influenced by various and yet empirically unidentified factors in East Gojjam Zone. Thus, the aim of the study was to identify factors that determine the participation of rural youths in non-farm income generating activities in the study area. The study drew a sample of 360 rural youths through systematic random sampling technique from three woredas of East Gojjam Zone. Data were collected using interview schedule, focus group discussions and key informant interviews. Descriptive statistics were applied to characterize the sample households' demographic, economic and institutional factors. The finding of the survey indicated that participation in non-farm income generating activities is significantly influenced by eight variables. These variables are family size of the household, marital status, education level, land ownership, credit usage, market distance, mass media exposure and frequency of the household received extension service in a year. Among these variables market distance, land ownership and extension contact have negatively affected participation of youth in non-farm income generating activities. Agricultural extension service was skewed towards rural youth who engaged in agricultural activities at the expense of those who engaged in non-farm income generating activities. Market distance was also found to have a negative nexus with participation in non-farm income generating activities. Among several challenges which hinder rural youths from participating in non-farm income generating activities, lack of *working capital and lack of working place were the major ones. This study concludes that rural youths in the study area faced different challenges to engage in non-farm income generating activities. Among those major challenges lack of working capital was the first bottleneck to start non-farm business in the study area. Thus, rural development strategy should give emphasis on promoting non-farm activities in rural areas to improve overall wellbeing of the rural youths.*

Key words: *rural youth, non-farm income generating activities, employment*

Introduction

Rural youth in developing countries make up a very large and vulnerable group that is seriously affected by international economic crisis. Globally, three-quarters of the poor live in rural areas, and about one-half of the population is young. Climate change and the growing food crisis are also expected to have a disproportionately high impact on rural youth (Paul B. 2010). The Food and Agriculture Organization of the United Nations (FAO) estimates that nearly half a billion rural youth "do not get the chance to realize their full potential" (FAO, 2009).

Rapid population growth which brought about reduction of cultivable land, erosion, loss of soil fertility and biodiversity have resulted in decreasing agricultural productivity and negative effect on people's income as well as accelerated rural poverty (Sheheli, 2012). According to IFAD (2001), poverty remains predominantly a rural phenomenon despite rapid urbanization observed in most developing and transition countries. There are over one billion youth (aged 15-24) in the world, 85 percent of these youth live in the developing countries and about 50 percent of youth population in developing countries live in rural areas (United Nations, 2007). They constitute a reasonable force propelling rural economy, nonetheless, poverty is still pervasive among rural youth who face numerous challenges in order to achieve and maintain their livelihoods. ILO (2004) reported that youth have difficulties in accessing livelihood opportunities globally.

In societies governed by elders and where control of resources is in the hands of older people, young people have little opportunities to express their interests and needs. This explains why youth issues have not received much needed attention in development policies. Despite the fact that burning problems at present day relates to rural youth globally, not much have been done to collect information about them in many countries and knowledge about their livelihoods remain fragmented among service providers (Waldie, 2004). Living standard of the rural poor would only be uplifted when they receive income from economic activities (Ahmed et al., 2007; Al-amin, 2008; and Ahmed, 2009). Undoubtedly, the plight of rural youth would be alleviated through their involvement in income generating activities. Understanding income generating activities pursued by rural youth is highly imperative in developing policies and services aimed at reducing rural poverty.

Land is an important determinant of livelihood in rural areas. As population increases and land scarcity becomes critical, non-farm activity and migration may become the only way out of poverty for land poor farmers as well as primary source of livelihood for the new generation of rural resident. It has been argued that the de-linking of rural livelihood from farming has been on the rise for the past few decades in Africa (Bryceson, 1996, 2002; Rigg, 2006). If land-scarce farm households participated in the non-farm sector to diversify income and cope with shocks in the past, non-farm employment may now become the only source of employment for the children from such farm households. This situation is further reinforced by changes in youth aspirations fueled by increased information and improved access to roads, which reduces transaction costs (Sosina and Stein, 2014). Although rural areas of Africa have been typically associated with agriculture, the non-farm sector is an important source of employment and income. When considering national employment statistics, it does not seem very significant because national statistics report only primary employment. On average, rural non-farm employment accounts for 10% of full-time employment in Africa (Haggblade *et.al.* 2007).

The majority of the youth in Ethiopia live in rural areas where farming has been traditionally the main livelihood of the people. As the state owns all land in Ethiopia, rural residents have been guaranteed access to land through a law that grants them a right to obtain agricultural land for free. However, it has become increasingly more difficult to fulfill this right for the young generation. Ethiopia currently faces severe land scarcity in parts of the highlands where population densities have become very high and farm sizes have become very small. As a result, land as a safety-net is eroding and landlessness is emerging among the youth who are unable to stay on their parents' land (Sosina and Stein 2014).

Agriculture remains the main source of income for rural areas of East Gojjam Zone. The farming system of the area is mixed which is crop and livestock production. As the sector depends on land, most landless groups of the population can't get resource to engage in the sector. As a result, these rural landless youth are suffering from unemployment. In the Zone, a total of 157,467 youths live in rural Kebele Administrations.

According to CSA (2016), 157,467 youths are found in rural kebele administrations of East Gojjam zone. East Gojjam Zone Agricultural Office reported that 24,150 youths are involved in agricultural activities, 28,181 youths are involved in nonfarm activities and 52,320 are involved in neither in agriculture nor in non-farm activities. The Zone described that 52,320 youths are not involved in agricultural sector due to lack of access to land and other unidentified problems. However, the reason why these youths are not involved in non-farm activities is not yet studied. Although similar studies have been conducted in Ethiopia on participation in non-farm income generating activities, the problem is context specific and needs further attention. Thus, identifying those factors that affect the non-farm participation of rural youths in this specific zone is necessary if there is a need to participate rural youths in non-farm income generating activities.

Materials and methods

Description of the study area

The study was conducted in East *Gojjam zone*. It is 298 km from Addis Ababa and 265 km from regional capital city. It is bordered in the South by *Oromia Region*, in the West by W*est Gojjam*, in the North by *South Gondar*, and in the East by South Wollo; the bend of the Abay River defines the Zone's northern, eastern and southern boundaries. Its highest point is Mount *Chokie* (also known as Mount *Birhan*) which is found at 4,100 metres (13,451 ft). Towns and cities in East *Gojjam* include *Bichena*, *Debre-Markos*, *Debre Werk*, and *Mota*.

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this Zone has a total population of 2,153,937 of whom 1,066,716 are men and 1,087,221 are women; with an area of 14,004.47 square kilometers, *East Gojjam* has a population density of 153.80. The average rural household has 1.1 hectare of land (compared to the national average of 1.01 hectare of land and an average of 0.75 for the Amhara Region) and the equivalent of 0.6 heads of livestock. 11.4% of the population is in non-farm related jobs. In the zone there are about 18 woredas which are classified into three agro-ecological zones i.e. two woredas are *Dega*, four woredas are *kola* and the rest are *Weyena Dega*.

Study Population

Rural youths of *East Gojjam* zone with an age range of 15 to 29 were the study population of this study. About 157, 467 rural youths in the zone are considered for this very study (EGZAO, 2009 E.C)

Sampling Techniques

East *Gojjam Zone* was selected purposively based on the severity of the problem and nearness to Debre Markos University. Then three sample woredas were selected randomly from the total of 18 woredas which are found in the zone. The selected woredas were Dejen, Sinan and Gozamen Wereda. From these woredas, a total of 6 kebeles (two from each woreda) were also selected randomly. Proportional to sample size sampling techniques was applied to determine number of youths from each Kebeles as well as to determine the number of participants and non participant youths in non-farm income generating activities. To consider gender issue from both groups, male and female respondents were also included proportionally. Finally, a total of 398 sample respondents were selected from both groups through systematic random sampling method. However, due to budget shortage and other related problems the total sample size was minimized to 360 sample respondents. Among the total of 360 sample respondents, 195 and 165 youths were participants and non-participant in non-farm income generating activities respectively.

Since this study was conducted to represent the zone, the sample size was drawn from the total youths living in the zone The total number of sample respondents were determined by using the simplified formula provided by Yamane (1967) cited in Udayakumara *et al*. (2010) at 95% level of confidence interval, with 0.05 level of precision. $n = \frac{N}{1+N(e^2)}$, where, N- total population/ sampling frame of the study, n- sample size, e – level of precision at 0.05. The total number of youths in the zone is 157467.

$$n = \frac{N}{1+N(e)^2} = \frac{157467}{1+157467(0.05)^2} = 398$$

Type of Data, Sources and Methods of Data Collection

Both qualitative and quantitative data were collected from primary and secondary sources. Primary data were collected through interview schedule and focus group discussion. Interview schedule was used to collect data from 398 sample respondents. Focus group discussion and key informant interview were conducted with group of elders, extension workers and Woreda agricultural office workers. Five discussants of elders from each woreda were involved in focus group discussion to describe the overall condition of youth participation in non-farm activities and the observed determinants. Key informant interview was conducted with extension workers and woreda agricultural office workers. Secondary data were collected from reports of different concerned organizations, published and unpublished reports, articles, and journals which are related to this study.

Methods of Data Analysis

Both qualitative and quantitative data which were collected from primary and secondary sources were analyzed by using different methods of data analysis. The qualitative data were analyzed through narration, whereas, the quantitative data was analyzed using simple descriptive statistics such as frequency, mean, standard deviation, and inferential statistics such as t-test and chi-square test. The basic data analysis tools which were used for this were Statistical Package for Social Science (SPSS) and STATA software. The qualitative data obtained from focus group discussions and key informant interviews were stated in narrative form. Econometric model (binary logistic regression) was employed to analyse major determinants of rural youth participations in non-farm income generating activities.

Variables and their definitions

Dependent variable: - the dependent variable of the study was participation in non-farm income generating activity which takes the value 1 for those youths who participated in nonfarm income and zero for those who did not participate. Non-farm income was used to identify the level of participation.

Independent variables:-

Sex: is a dummy variable representing the respondent's sex. Men and women have different access to resources and opportunities. Women are subject to discrimination in labor, credit and a variety of other markets and they own less property compared to men. Women have long been constrained in the activities in which they are permitted or able to participate, by tradition, religion, or other social mores. Both Ellis (1998) and Newman and Canagarajah (1999) point out the activities in which women are involved are more circumscribed than those for men.

Therefore, it is expected that sex and involvement in non-farm income generating activities are negatively related in female youth groups.

Marital status-It is a categorical variable. Married youths are expected to involve in different income generating activities than unmarried ones because they do have different responsibilities for their families. There is a significant positive effect of marital status on rural youth involvement in non-agricultural income generating activities. This implies that married rural youth were more involved in non-agricultural income generating activities than unmarried rural youth. Greater responsibilities associated with marriage could be the possible explanation for the finding (Victor 2014).

Educational level of respondent: educational level refers to the schooling level of the respondent in years. Education determines the capability of finding a job (Warren, 2002). Better-educated members of rural populations have better access to any non-farm employment on offer, and are also more likely to establish their own non-farm businesses. This variable is expected to have a positive effect on youth participation in non-farm income generating activities.

Family size: Family size refers to the size of household members in Adult Equivalent. Family size either determines the availability of family labor or, large family size demands large amount of production to feed its members. In the context of limited income generating opportunities, having more productive household members facilitates diversification into multiple activities, thereby dissipating risk (Gala, 2006). This variable will affect participation positively or negatively.

Land ownership: -The majority of young people in rural Ethiopia do not have their own farmland. So that, for those youth who do not have land will participate in non-farm income generating activities. Therefore, land ownership and non-farm participation are negatively related.

Size of land owned: Land size refers to the size of land owned by the respondent in hectare (10,000m^2). This variable is a basic asset for majority of the rural livelihoods. More land size holding means more cultivation and more possibility of production which in turn increases farm income (Tesfaye, 2003).Therefore, land size and non-farm participation are negatively related. Diminishing farm sizes and a decline in return to labor in farming under population pressure may encourage rural households to diversify their employment and sources of income (Tesfaye, 2003).

Livestock holding: - livestock holding is the number of livestock owned by the respondent. It is measured by Tropical Livestock Unit (TLU). Livestock benefit much and perceived as the accumulation of wealth status, use for draft power, manure, income from sale of milk, butter and sale of live in times of risk to buy necessities. The household having larger size of livestock can have better chance to have better income from livestock. The more livestock owned by the household will be the less possibility of the households to participate in non-farm activities. On the other hand, poor households who owe no or less livestock are likely to relay on sources of income other than livestock. Therefore, it is expected that livestock holding is negatively related to non-farm participation.

Credit service and usage: - refers access to credit service. One of the principal problems for rural households and individuals wishing to start a business, whether in the farm or non-farm sector, is access to capital or credit. Without start-up funds, or with only little cash available for investment, households are limited to a small number of activities which yield poor returns, partly because of the proliferation of similar low entry barrier enterprise. Youths who have access and able to afford to credit will be able to engage in to non-farm income generating activities. In the case of access most households may have access to credit but if they did not use the credit service access only may not affect the decision to participate in non-farm income generating activities. Hence, it is expected that, youths having access to and used credit service are believed to participate in non-farm income generating activities therefore, it is expected that access to credit services and participation of youths are positively related.

Distance from market center: - Distance from market center refers to the nearness or farness of the youth's residence from the "nearest" market place in walking hours. It is measured by walking hour. Access to market and other public infrastructure may create opportunities of more income by providing in diversifying livelihood strategies through non-farm employment, easy access to input and transport facilities; youths nearer to market center have better chance to engage in non-farm activities. For this reason the variable is expected to be related negatively with participation.

Farm income: - refers to youth's income from his/her farm. As the farm income increases the interest to engage in to non-farm income generating activities will decrease. So that, farm income and youth's participation in non-farm income generating activities is negatively related

Rural life preference: - Rural life preference has a significant positive effect on involvement in non-agricultural income generating activities. This implies that rural youth who have higher rural life preferences also are increasingly involved in non-agricultural income generating activities. Due to improved social amenities in the rural areas as well as improved linkages to urban centers, rural youth who desire to work in non-agricultural sectors would prefer to live in rural areas all things being equal. According to Winters et al. (2009), greater access to infrastructures is hypothesized to be positively linked to non-agricultural activities and negatively related to participation in agricultural activities. De Janvry et al. (2005) found that proximity to county capital influenced participation in rural non-agricultural.

Social Networks: - Individuals and households with better social networks have greater opportunities in the non-farm sector. Once again, this discriminates against the poorest, who suffer from a lack of (useful) social networks and are, therefore, unable to capitalize on informal opportunities and remain excluded from formal support systems (Smith, 2000). Those youths you do have better social networks will have a great chance to engage in non-farm income generating activities.

Mass media exposure: - As mass media exposure of rural youth increased there is a significant positive influence on their involvement in non-agricultural income generating activities (Victor 2014). This could be the result of improved access to information on available income generating opportunities. Young job seekers usually get information on available job vacancies through advertisement on mass media. This variable will positively affect youths participation in non- farm income generating activities

Extension contact: extension contact is negatively related to involvement of rural youth in non-agricultural income generating activities. Increased extension contact resulted in decreased involvement in non-agricultural income generating activities. The skills and knowledge imparted by extension agents were irrelevant to non-agricultural income generating activities.

Result and Discussion

Existing Non-Farm Income Generating Activities

Like other parts of rural areas in the country, in East Gojjam zone both farm and non-farm income generating activities are available. In the zone, the following non-farm income generating activities are currently undertaken by youth, these are;-petty trade, handcraft, fuel wood selling, cobble stone construction, metal work, wood work, daily laborer and mining are non-farm income generating activities which are currently available in the zone. Among the above mentioned non-farm income generating activities available in the study area daily laborer was the first mostly rural youths involved in even though it was not sustainable and enough for their lives.

The second mostly engaged in nonfarm activity is petty trading/merchandizing activity. Some people in the rural area trade different items. The main items that were brought to the market were charcoal, timber, fire wood, and those items for home consumption, crop, livestock and others. These items are mostly merchandised by males. Females are mainly engaged in petty trade and alcohol (*Tella* and *Arekie*) trade. Preparing and selling of Food is also done in the area laterally with Alcohol marketing.

Stone quarrying is the other activity rural youths were participating in the area to generate income. The main resources available in the area are stone and sand which are used for the construction purpose. It is done mostly by organized groups who have got permission from Woreda mineral office and KAs. Stone quarrying is the program forwarded by the government to those youths who are jobless living in the rural kebeles. Handicraft activities like waving, pottery and metal work are among nonfarm activities done in the area. During FGD held with selected persons some part of the community do these activities as their major sources of income.

Status of rural youth participation in non-farm activities

Based on the survey result shown in figure 1 below, among the total 360 sample respondents 45.96 % rural youths did not participant in non-farm income generating activities. This indicated that most of rural youths face different challenges to engage in non-farm business.

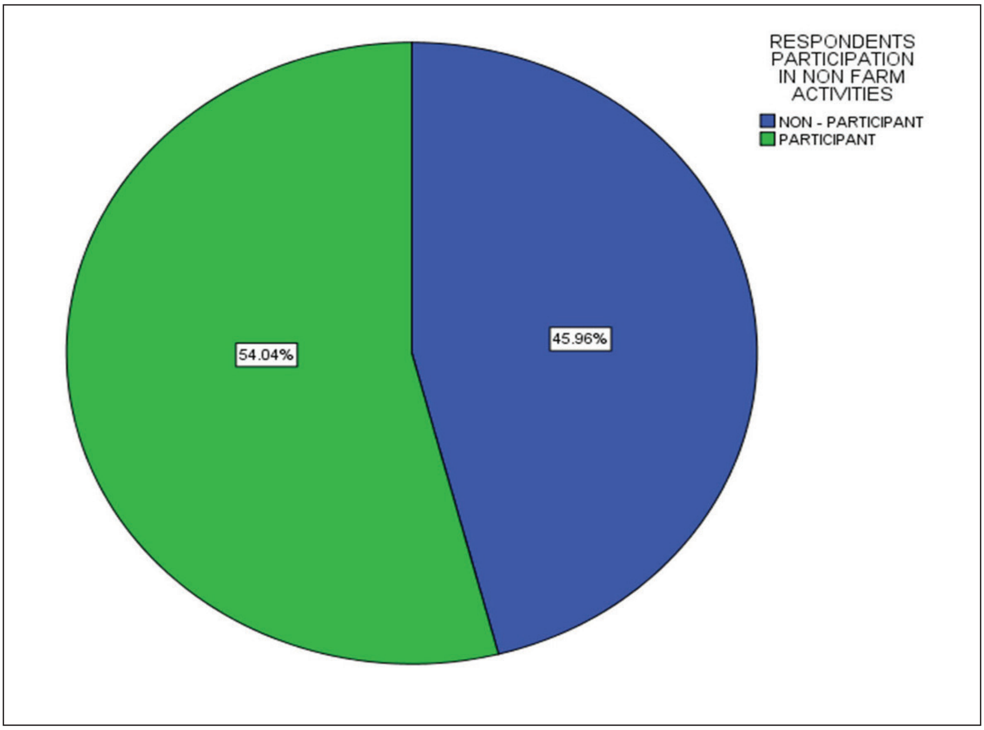

Figure 1: *Status of rural youth participation in non-farm income generating activities*

Determinant of rural youth participation in non-farm income generating activities

The pseudo R^2 is one of the most commonly used measure of model goodness of fit. The lower values of the pseudo R^2 indicates how well the dependent variable is explained by the explanatory variables included in the model. The logit result of this study turned out to be fairly low (pseudo R^2 = 0.0828). This clearly implies that the dependent variable of this study (participation in non – farm income generating activities) is well explained by the explanatory variables included in this study. Caliendo & Keopeinig (2005) had also explained that the pseudo R^2 indicates how well the model explain the participation probability of rural youth on non – farm income generating activities. A low R^2 value means participated youth do not have much distinct characteristics overall and as such finding a good match between participated and not participated youth becomes easier (Yibeltal, 2008).

The logistic regression result showed that participation in non-farm income generating activities is significantly influenced by eight variables. These variables are family size of the household, marital status, education level of the respondent, land ownership, credit usage, market distance, mass media exposure and number of times the household received extension service in a year. Among these variables market distance, land ownership and extension contact negatively affect participation of youth in non-farm income generating activities. In the case of extension contact, extension workers most of the time only give extension service for those youth who are engaged in agricultural activities and in the case of market distance those youths who are far from the market may be discouraged to engage in different activities.

The result showed that youth who had better schooling have high likelihood to participate in non-farm income generating activities. Marital status of youths affected participation positively. Youths who are married participated in non-farm income generating activities because they have responsibilities to feed their family. In respect to land ownership, it affected participation negatively because those youth who do have land prefer to engage in farming than to engage in non- farm activities. Having credit access does not mean that youth can get and utilize credit in this study. Credit usage highly affected the participation than access as it was discussed in the descriptive part. Most of youth had access to credit but those who used credit were very low in number and percentage. Credit usage affected the participation of youth in non-farm income generating activities positively and significantly. The result from FGD clearly indicated that the basic reason of youth to not participate in non-farm income generating activities is lack of initial capital. Therefore, if youth get credit, they can involve in the non-farm activities and that is way credit usage affect participation positively.

Market distance is another factor which affected youth participation in non-farm income generating activities. According to the result of this study market distance negatively affected the involvement of youth in non-farm income generating activities. This might be because if youth live very far from the main market, they may not get transport to sell their products and they may not get enough information about different activities in the market. It discouraged them not to engage in non-farm income generating activities. Mass media exposure of rural youth had a significant positive influence on their involvement in non-agricultural income generating activities. This might be the result of having access to information on available income generating opportunities. Young job seekers usually get information on available job vacancies through advertisement on mass media.

The result of this study was supported by similar study which were conducted in India by Victor C. 2014 on his study he found that the involvement of rural youth in non-farm income generating activities was affected by marital status, education level, mass media exposure and extension contact.

Table 1: Determinants of Rural Youth Participation in Non – farm Income Generating Activities.

Logistic regression   Number of obs = 354
LR chi2(11) = 40.48
Prob> chi2 = 0.0000
Log likelihood = -224.18065   Pseudo R^2 = 0.0828

Independent Variables	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
GENDER	.0011579	.2909159	0.00	0.997	-.5690267	.5713425
FAMSIZE	-.3850806	.2010836	-1.92	0.055*	-.7791972	.0090359
MARISTAT	.6365144	.2715798	2.34	0.019**	.1042279	1.168801
EDULEVL	.1424731	.0877691	1.62	0.105	-.0295512	.3144973
LANDONW	.5704568	.3006081	1.90	0.058*	-.0187243	1.159638
CREDITUSE	-.5780954	.2847142	-2.03	0.042**	-1.136125	-.0200659
MARKTDIS	.0553286	.0365482	1.51	0.130	-.0163045	.1269617
MASSMEXP	-.5902206	.2529899	-2.33	0.020**	-1.086072	-.0943694
EXTENCONT	-.7125571	.2530347	-2.82	0.005***	-1.208496	-.2166181
RULIFEPR	-.1876584	.2402359	-0.78	0.435	-.6585121	.2831954
_cons	3.951165	1.610709	2.45	0.014**	.7942331	7.108097

*Note: ***, **,* Significant at <1%, 5% and 10% probability level respectively*

One of the chief objectives of this study was to find out the major determinants of rural youth participation in non – farm income generating activities. Binary logistic regression is the best econometric model often used for such empirical investigations. Thus, this study run the model and the output of the model is presented in Table 1 above. The predicted model output indicated the fact that participation in non – farm income generating activities is significantly influenced by the following independent variables.

Credit Use: Credit use was expected to have a positive impact on rural youth participation in non – farm income generating activities. However, the model result was turned out against this expectation. As can be seen in Table 1 above, participation in non – farm income generating activities has reduced by .578 units for users than non – users. This may be explained by the fact that credit use has promoted rural youth capability to purchase land and other productive augmenting resources and technologies to stay in the agricultural business.

Land Ownership was found to be the most important determinant of participation in non – farm activities. This variable has negatively influenced the dependent variable of this study. The predicted model indicated that landownership causes a 0.57 units decrease in participation in non – farm income generating activities. This might be having land will encourage the youth to engage in farm activities than in non-farm activities.

Extension contact affected participation in non – farm income generating activities negatively. The model result revealed that access to extension service didn't encourage farmers' participation in non – farm income generating activities. The model result above made clear that the probability of participation in non – farm income generating activities decreases by .71 units for respondents with extension contact as compared to those without extension contact. In other words, increased extension contact resulted in decreased involvement in non-agricultural income generating activities. The basic reason of this was extension workers only give advice as well as other services for those youth who participate in farming activities.

Marital Status: This variable has significantly influenced participation in non – farm activities at 10% significant level. As can be learnt from the predicted model the probability of participation in non – farm activities rises by 0.64 units for married respondents. This may be explained by farm land shortage which urged them to participate in non-farm activities to fulfill the basic needs of their family. This econometric result was also supported by focus group discussants. They described that married youths are more involved in non-farm activities compared to single once.

Mass Media Contact: Contact with mass media was expected to improve rural youth participation in non – farm income generating activities. However, the model result turned up against the expectation. From the model it is apparent that a unit increases in mass media contact decreases participation in non – farm income generating activities by .59 units. The negative impact of mass media on participation in non – farm income generating activities may have some explanation. First, it may be due to lack of access to mass media. Second, it may be due to the fact that the media isn't working in areas related to rural employment creation and non – farm income generating activities.

Market Distance: The estimated logit model indicated that a unit increase in distance reduces participation in non – farm income generating activities by .055 units.

Challenges Rural Youths Facing to Participate in Non-Farm Income Generating Activities

From the HH survey in different KAs can understand all of the respondents want to participate in one or more nonfarm income generating activities. But all of the respondents mentioned different challenges they faced to enter in to nonfarm business. Among them the following reasons are found and summarized below

Table 2: Respondents Challenge to participate in Non-farm Activities

Challenges	Frequency	Percent
lack of working capital	120	47.4
absence of working place	66	26.1
waiting for better job	24	9.5
lack of commitment	17	6.7
lack of interest	18	7.1
lack of training	2	.8
lack of skill	6	2.4

According to the household survey and the discussion held with focal groups and key informants the major challenge to start nonfarm business is lack of working capital. From the descriptive statics of HH survey as shown in the above table 47.7% of the respondent's problem was lack of starting capital. The only supplier of the credit in the area is Amhara Credit and Saving Institute (ACSI). ACSI gives the credit mainly for agricultural input purchase purpose; however, it can also give credit for nonfarm business. Collateral is necessary to get the credit. Lack of collateral or guarantee makes the rural youths unable to get the credit access. Lack of working place, unavailability or poor performance is the second main problem of the area. As shown in the table 8; 26.1% of the respondents' thought it as a major problem that restricted them from participation in nonfarm income generating activities. From the discussion held with focal groups and key informants there is not any enabling environment to run nonfarm activities for rural youths. In addition to these, waiting for better job, lack of commitment & interest from rural youths, lack of training and skill and knowledge gap were the major challenges that enforced rural youths to preserve from nonfarm income generating activities.

Conclusion and Recommendation

Conclusion

This study is aimed at identifying factors that determine rural youth participation in non-farm income generating activities in East Gojjam zone. Qualitative & quantitative techniques were employed to get a better understanding regarding these issues. The household survey was the tool for collecting data about currently existing and emerging non-farm income generating activities, determinate factors of rural youths to participation in non-farm income generating activities, the challenges and opportunities of rural youths in relation to their participation in non-farm income generating activities. FGD & KII were also employed to get deep knowledge in the study topic.

The logistic regression result showed that participation in non-farm income generating activities was significantly influenced by eight variables. These variables are family size of the household, marital status, education level of the respondent, land ownership, credit usage, market distance, mass media exposure and number of times the household received extension service in a year. Among these variables market distance, land ownership and extension contact negatively affected participation of youth in non-farm income generating activities. In the case of extension contact, extension workers most of the time give extension service only for those youth who are engaged in agricultural activities. Market distance affected those youths who were far from the market and may be discouraged them not to engage in different activities.

Among factors studied in this paper extension contact of rural youth found as one of the determinant factors under individual characteristics. Extension contact was negatively related with participation in non – farm income generating activities in a significant way. Access to extension service didn’t encourage farmers’ participation in non – farm income generating activities. The basic reason of this was extension workers only give advice as well as other services for those youth who participate in farming activities.

Rural youths in the study area face different challenges to engage in non-farm income generating activities. Among those, the major challenge to start nonfarm business was lack of working capital. Working place unavailability or poor performance is the second main problem of the study area. Respondents thought these two major problems restrict them from participation in nonfarm income generating activities. From the discussion held with focal groups and key informants there was not any enabling environment to run nonfarm activities for rural youths. Therefore, it is possible to conclude that rural youths are not participating enough in nonfarm income generating activities in the study area. This means that rural youth unemployment is the major problem in the study area.

Recommendations

Lack of starting capital and working place were the major challenges of rural youth to engage in non-farm income generating activities in the study area. So different GOs & NGOs should facilitate mechanisms through which rural youths can get free access to financial capital and working place.

Lack of technical & entrepreneurial skill is the other factor that constraint rural youth in the area to join nonfarm income generating business. Different government and non- government organizations like TVET should focus on giving both technical & entrepreneurial skill trainings.

Extension contact was one of the major determinants which affected rural youth participation in non-farm income generating activities. Therefore, extension agents should give emphasis for non-farm activities as farming activities.

Infrastructural development especially electricity and road are less developed in the area and stated as the basic challenge to join the nonfarm income generating activities. Many nonfarm business activities need electricity and marketing different products also need road construction. So infrastructural development in road, electricity, water, education, health & communication should develop well.

Acknowledgement:

The authors gratefully thank …. for the immense support provided and financial support to carry out this task. Special thanks also goes to East Gojjam zonal officials district administrators, development agents, and farmers for their imaginative opinions and cooperation during the field work.

Conflicts of Interest:

The authors declare that they have no competing interests

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