Coffee leaf miner ecosystem: Case study on Agro ecological distribution and Socio-economic impact of coffee leaf miner Leucoptera coffeella

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Abstract

Coffee is essential natural resource that plays a great role in social, cultural, economic and political values in the study area. However, it is under production constraint and challenge caused by different factors. One of the most challenging factors in coffee production is coffee leaf miner (Leucoptera coffeella L.). This research was aimed to assess the Agro-ecological distribution and socio economic impact of the pest in the study areas so as to address the challenges of coffee production using pest management strategies of the pest. Both primary and secondary data were used and total of 147 sample households coffee farms were used for the investigation. Data were analyzed using descriptive statistics; percentage, inferential statistics and frequency rank weight method. The study discovered the spatialoccurrence of the pest is higher in Woinadega followed by Dega and Kollaagro climate zone, respectively. Woinadega agro climate zone is suitable for severe distribution of pest. This is becauseof moisthumid and warm tropical climatic conditions which is important for best proliferation or multiplication of pest. However, most of the populations in the area depend on coffee product; the pest reduces yield of coffee in relation to other factors. It is suggested that creating community awareness, strengthening the best traditional and community based management system, introducing improved coffee plant, encouraging local people to participate in the protection and management of the pest could be the possible alternatives to overcome problems caused by coffee pest.

Key words: 1. Coffee agro-ecology, 2. socio-economicimpact, 3.Coffee leaf miner

Introduction

Historically, the origin of coffee (Coffea arabica L.) was the montane rainforests of Kaffa in South-Western Ethiopia (Logan, 1946; Beiber, 1948; Kieran, 1969; EWNHS, 1996). Since then, early written testimonials and legendary thoughts depicted as that Kaffa Zone or area is not only the cradle of Coffea arabica/ Arabica coffee but also the name of coffee were transferred from the name of "Kaffa"clan living around and coffee user in line with other forest resources.

Complementary, according to UNESCO (2010), the origin and center of the genetic diversity of Coffee arabica lies in the southwestern region of Ethiopia, Kaffa kingdom, Makira Kebele of Buni village. Coffee is described as Buna in Amharic, native Ethiopian language in which the name was driven from the Buni village in Decha district of Kaffa Zone, where coffee was originated (Bunoo Bulletin, 2011).

Overwhelmingly as a natural part of the ecosystem (naturally grown shrub) coffee was found in Kaffa and spread to different parts of Ethiopia as well as different parts of the world society (Stellmacher, 2005; Reichmann, 2007; Ayele Kebele, 2011). However, the production of coffee is of an enormous relevance for Ethiopia, playing a dominant role in economic, social, cultural and environmental terms (Stellmacher, 2006). Annually, an average of about 150,000 tons of coffee is produced in Ethiopia and the livelihood of about 15 million people depends directly or indirectly on the production, processing and export of coffee (EEA, 2000; Stellmacher, 2006). Moreover, the Ethiopian coffee production is dominated by smallholder agriculture, contributing with more than 90 percent to the total harvest (Dercon, 2002; Ayele Kebele, 2011). Similarly, about 25% smallholder farmers and their families produce 80% of world coffee production, that is an important source of cash income and responsible for significant employment (ICO, 2010). It accounts for 70% of the foreign exchange earning, 10% of the government revenue and employs 25% of the domestic labor force (Yilma *et al*., 2000). Coffee is the second most traded commodity next to oil in the world today and is the most widely traded product which produced highly in developing countries and it is the back bone of the Ethiopia's economy (Vaast *et al*., 2006).

Therefore; this commodity plays a great role in social, cultural, economic and political values around the world. Even though many species of coffee exist for commercial production, Coffee Arabica and Coffee canephor took the principal share and more than 60% of global coffee production is based on Coffee Arabica (CAB International, 2006). Ethiopia contributes a total of 7 to 10% coffee induction to the world (FAO, 2010). Coffee production has been one of the pillars of the world economy and it is an important export commodity in Ethiopia. Coffee is grown in a range of varying agro-ecological conditions and its ecologies have highly variable climates, soils, elevations ranging from 550 to 2400m (CHEWARDO, 2017).

Despite its economic, social, cultural and spiritual value as well as has lion share to the economy of the study area; coffee suffers from very much production constraints including pest.

According to African journal of plant science, the coffee plant is the target of a large number of pests, among which the coffee leaf miner (Leucoptera coffeella) is the leading one.

A coffee leaf miner (Leucoptera coffeella) is the larva of an insect that lives in and eats the leaf tissue of coffee plants. This insect feeds on the palisade parenchyma cells of the leaves (Crowe, 1964; Ramiro *et al*., 2004), causes considerable damage to the plants being considered the principal pest of this crop. /Leucoptera coffeella/ is a pest attacking only coffee plants (Reis, 1986) and it owes its name to the passageways formed in the epidermis of the leaf as a consequence of destruction of the palisade tissue used by the caterpillars for food. Coffee production costs and challenges are high in regions where there is a high incidence of coffee leaf miner (GUÉRIN-MÉNÈVILLE) (Lepidoptera: Lyonetiidae).

Materials and methods

Description of the study area

Location of the study area

The study was conducted at South Nations Nationalities and Peoples Region of Ethiopia, Kaffa Zone, particularly Chena Woreda. The Woreda was chosen because of its high coffee producing potential in Kaffa Zone (KZLFD, 2017). Chena is one of the ten Woreda's and one administrative town found in Kaffa Zone. The name Chena comes from one of the provinces in the former Kingdom of Kaffa, whose administrative center had been at Wacha. Part of the Kaffa Zone, Chena is bordered on the south by the Bench Maji Zone, on the west by Bita, on the north by Gewata, on the northeast by Gimbo and on the east by Decha. Towns in Chena include Shisho-inde. This Woreda is found in the Southwestern part of Ethiopia which is 78km, 541km and 815km far from Bonga, Addis Ababa and Hawassa, respectively.

Besides, other study area the selected study areas such as Dahera, Gawtata and Kulish Kebele's are found 18km, 26km and 7kms away from Wacha town, respectively and the Woreda lies between 07^{0} 09'01"N latitude and 035^{0}48'51''E Longitude (CHEWARDO, 2017).

Most of the command area at present is covered with coffee plants and it is the base for their economy, and has cultural and social issue for the growers of this area. The geographic location of the study area is depicted below.

Both primary and secondary source of data were used for this study to have original and ground information. The primary data gathered through house hold survey questionnaires, focus group discussion (FGD), interview and direct observation techniques.

Secondary data sources include different literature, published researches, map sources, books, journals, document analysis and internet.

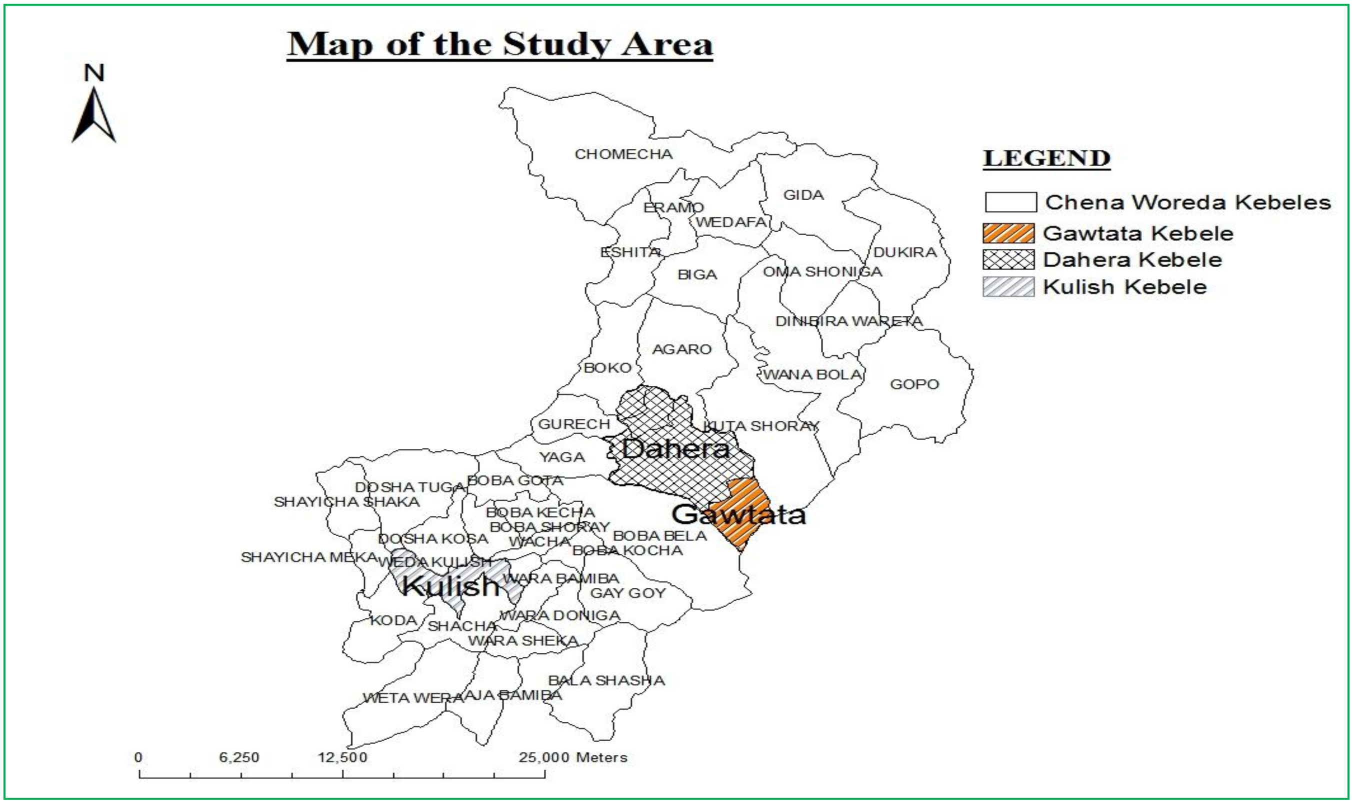
Based on their coffee production potential, three different agro-ecological Kebele's were purposely selected for this study using nested design. These were Kulish, Dahera and Gawata (Dega, Woinadega and Kola) respectively. These Kebele were selected purposely and the respondents were made by using simple random sampling method.

As a result, 126 sample respondents were taken for the questionnaires, i.e. 44 respondents from Kulish, 51 respondents from Dahera and 31 respondents were taken from Gawtata Kebele. The numbers of selected respondents from each Kebele were varied because of variation of the total number of population in each Kebele. Focus group discussion is another qualitative method of data collection instrument which involves 4 model farmers from each Kebele's.

Additionally, for interview 9 respondents were purposely selected from the Woreda agricultural office experts. In the study site, 138 respondents involved from three Kebele's and 9 respondents from office of Agriculture. Total respondents who involved in this study were 147.Thus, the sample size was determined depending on Cochran's formula as below.

The sample sizes of the households were determined based on the formula (Cochran's, 1977) below. The formula helped to determine the required sample size.

This simplified formula assumes a 95% confidence level and the maximum variance (p = 0.5).



Data Collection Tools: Preliminary survey was conducted before performing the study, which was used to grasp or overview the general outlook on physical future or topography, temperature, rainfall, weather condition, accessibility, flora or vegetation type, fauna or animal types, birds and other related life's, economic activities, anthropology or social organization, clan and speculation of the study area size. So, the chosen Kebele and document analysis were taken to get some guide line and for problem identification about the title and objective. After site observation and problem identification, the questionnaires were prepared and distributed for the respondents.

Then focus group discussion and interview held with respondents about coffee leaf pest to have additional information. Physical features like altitude and location of sample collected by using GPS instrument from Agricultural Growth Program (AGP). Photographs were taken to show pest severity and distribution during data collection.

Methods of data analysis

Data collected from questionnaires were analyzed by using Microsoft excel version 20 or spread sheet program and SPSS version 20 software and the results of analysis were presented using descriptive statistic such as percentage, frequency distribution and in table form. Data that obtained from focus group discussion and interviews has been managed by connecting the evidences observed in narration form comparatively. The close ended questions from questionnaire were discussed using tabulation of variables with fraction values. Open ended question from interview and discussion were grouped into different categories and summarized based on similarity.

Result

Pilot Study: On the basis of the evolved framework, an instrument with 27 statement questions representing the three factors was developed for analysis. Likert Scale was used to measure the responses of potential occurrences of the pest.
The reason for this analysis was to establish the need for the support systems required by the stakeholders. The questionnaire was subjected to external validation by experts. The pilot studies with 45 potential coffee growers as respondents were carried out. Cronbach's alpha results showed 0.93 percent reliability. Through Confirmatory factor analysis, all items of the questionnaire were validated. The result is analyzed as the following ways and steps:

According to the respondents, presences of coffee miner pest were major challenge to coffee production and productivities and it reduces coffee yield. Based on the response revealed from questionnaires, moderate numbers of coffee leaf miner pest were distributed relatively in Dega, while coffee leaf miner pest distribution were more sever in Woinadega and merely pest infected leaf or normal looking leaf found in Kolla agro-ecology. Additionally, the FGD, interviewees, Key informants and field observation also pointed the pest infected leaf high in Woinadega, moderate in Dega and low in Kolla agro ecosystem respectively. This means on the right way with respondents of questionnaires responses. Conversely, pest population per leaf/per tree was more in Woinadega, moderate in Dega and normal looking around Kolla. This is because of the suitable humidity and hot temperature in Woinadega agro ecosystem.

Socio-economy of most residents' depends on the crop production and importantly used crop products as for their day today income. Which means 30 respondents (23.8%) from three Kebele's responds major income sources were crop production and the highest ratio were covered with coffee production. The socio-economy of the sample respondents shows significant difference between different agro-ecosystem. Coffee has social, cultural, spiritual, historical and traditional values. Coffee and all activities of the societies have been two sides of a coin relationship.

According to the interviewees, FGD, document analysis and direct observation, the main socio-economy of the respondent depend on coffee production. Means cash crop and cereal crops basically on coffee production.

Coffee leaf miner had adverse effect on coffee production such as yield loss, quality loss, coffee death and coffee wilt. Accordingly, the percentage of respondents on each effect of leaf miner were, 12(23.5%) quality loss, 13(25.5%) yield los, 11(21.6%) coffee death, 7(13.7%) leaf wilt and 8(15.7%). Sample respondents from Dahera respondsas high amount yield loss occurs. Whichare 13(25.5%).Consequently, 9(20.5%) quality loss, 13(29.5%) yield los, 7(15.9%) coffee death, 8(18.2%) leaf wilt and 7(15.9%). Others from Kulish reveals as highly yield loss occurs which is 13(29.5%).Eventually, 9(29.0%) quality loss,8(25.8%) yield los,4(12.9%) coffee death, 5(16.1%) leaf wilt and 5(16.1%) others in Gawtata. Therefore; the highest percentage in Gawtata is quality loss which is 9(29.0%).

As a result, statistically there is significant difference of socio-economic impact resulted among three agro-ecology sites at 0.001with confidence value of 0.05.In addition to those respondents of questionnaires, the researcher considers the point which rose from the FGD and interviewees and refers the documents from the Woreda agricultural office. So, as information gathered from all sides of respondents, the main socio economic impact of pest were frequent reductions of coffee bean or coffee yield loss. As a result, coffee leaf miner pest is one of the main challenges of coffee production for coffee growers. This directly or indirectly affects the income sources, reduces social harmony, and minimizes cultural view and economic value of the growers.

As the finding of current study indicates that, the views of respondents with respect to the pest distribution across altitudes and socio-economic impact that were to some extent concurrent among farmers, experts and field observations.

Because of different factors, the range of coffee pest occurrence was varied in different ago-ecology. Based on the responses taken from respondents of questionnaires, FGD and interviewees of the office experts and from observation, the occurrence of pest were more recorded during dry season than in rainy season in the study area. Some authors suggested that rain was the main source of coffee leaf miner adult and larval mortality in tropical areas, particularly during the rainy season (Villacorta, 1980; Campos *et al.,* 1989). This result was in line with the finding of Veja *et al*. (2006), in which under wet conditions, plants had very low infestation levels of pest because of water entering the mine and drowning the larvae.

Similarly, the higher occurrences of coffee leaf miner were observed at mid altitudes and lower incidence was occurred at low altitudes. In fact, the pest infestation was reported to be an issue of farmers of mid altitudes than high and low altitudes. The present study showed that coffee leaf miner was present throughout the year in coffee farms at low and high elevations; its occurrence was variable among months and differed between elevations.

This result was in accordance with finding of Flores (2010), in that the proportion of mined leaves was significantly greater in the low/mid versus high elevation farm. This might probably be because of suitable warm and humid tropical climatic condition of the Woinadega (Dahera) which enable the pest to proliferate rapidly or it might be due to predation

High pest population were found in the simple-shade coffee forest than in complex-shade and abandoned coffee forest. This is in line with the findings of Nestel *et al*.(1994), who investigated the role of shaded and un-shaded coffee agro-forests on population dynamics of coffee leaf miners in Mexico and contrary with (Rutherford, 2006) finding in which the infestation grade was found to be higher in plantations under a high level of shade.

Various studies suggested that weather variables, particularly temperature and rainfall, were the primary factors determining abundance and distribution of coffee leaf miner and its natural enemies (Reis *et al*., 1976; Villacorta, 1980; Gravena, 1983; Flórez and Hernandez, 1985; Campos *et al*., 1989; Tuelher *et al*., 2003; Conceiçao, 2005).

According to recent study, coffee leaf miner occurrences on leaves of different ages within coffee plants wereassessed. But, the pest has been very common and recorded on older leaves or mature coffee plant leaves than remaining ages of coffee. This is in accordance with the findings of (Walker and Quintana, 1969; Nantes and Parra, 1977; Guerreiro-Filho, 2006) in that; older leaves were more susceptible to coffee leaf miners damage than younger leaves.

According to (LMC, 2000) over 25% of population of Ethiopia is dependent on coffee for their livelihoods. Biotic as well as a biotic factors in relation with the pest reduce coffee production in the study area as well. This directly or in directly influence the socio-economy of the society in that their economic, social, cultural, medicinal, psychological and traditional value and their coffee have been linking as two sides of one coin.

This study confirms that the crop losses due to pests were the major threat to incomes of rural families and to food security worldwide (Savary, 2014). The coffee insect pests, especially the coffee leaf miner (Leucoptera coffeella) affect coffee production (Gallardo *et al*., 1988, James *et al*., 2015). The pest causes the green famine for the study area.

Conclusion

From the current study the following conclusion had made;

According to the current study, the pest severity was varied from place to place. The proportion of mined leaves was higher during the dry season than the rainy season, and also at mid than low/high elevation. That means the severity of pest population is varied and relatively high in Woinadega than Dega and Kolla agro-ecologies. Not only this, but also the pest incidence was high in mature or old coffee leaves than others.

For all location along the altitudinal gradient of study areas, pests were ranked as the major constraint for coffee production, followed by diseases, low soil fertility, lack of extension services, and changes in weather patterns. For the low altitude, poor flowering and old coffee trees were also mentioned to be the cause of low yields.

The pattern of coffee leaf miner is one of an important pest that reduces coffee utilization and reduces the cultural, social, traditional, medicinal, economic and psychological values of coffee. The results of this study provided valuable information in order to improve the knowledge of the spatial distribution of the coffee leaf miner in the coffee fields.
Generally, Understanding the impacts of weather variables and agro-ecology up on pest population dynamics is important for managing pests.

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Pest incidence in the coffee garden

According to direct observation during field survey five sample coffee trees were taken from each Kebele's randomly in order to check up pest occurrence.

DEGA

Tree: 1 = 12 leaf per tree pest incidences
Tree: 2 = 8 leaf per tree pest incidences
Tree: 3 = 6 leaf per tree pest incidences
Tree: 4 = 8 leaf per tree pest incidences
Tree: 5 = 10 leaf per tree pest incidences

Average pest occurrence appear

WOINADEGA

Tree: 1 = 44 leaf per tree pest incidences
Tree: 2 = 28 leaf per tree pest incidences
Tree: 3 = 32 leaf per tree pest incidences
Tree: 4 = 21 leaf per tree pest incidences
Tree: 5 = 50 leaf per tree pest incidences

High pest occurrence appear

KOLLA

Tree: 1 = 2 leaf per tree pest incidences
Tree: 2 = 0 leaf per tree pest incidences
Tree: 3 = 0 leaf per tree pest incidences
Tree: 4 = 1 leaf per tree pest incidences
Tree: 5 = 1 leaf per tree pest incidences

Very low pest occurrence appear