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Original paper

ECONOMIC VALUE OF POLLINATION SERVICE OF AGRICULTURAL CROPS IN ETHIOPIA: BIOLOGICAL POLLINATORS

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Abstract

The most important ecosystem service for sustainable crop production is pollination, the mutualistic interaction between plants and animals. Honeybees are being indispensable role in this process. The total economic value of crop pollination worldwide has been estimated at €153 billion annually. Animal pollination of agricultural crops is provided by both managed and wild pollinators. The aim of this study was to determine the economic value of pollination services and vulnerability of Ethiopian agriculture in the face of pollinator decline. An improved approach to determine the economic value of pollination (EVP) services is applied to multiply a crop's total value by a coefficient between zero and one representing the crop's dependency on pollination services for production. The potential production value loss due to lack of pollinators is also computed as the ratio of EVP to economic production value. Then EVP was $ 815.2 million dollars and vulnerability of Ethiopian agriculture due to lack of pollinators 16% in the 2015/16 crop production season. The regional state of Oromia benefited the most followed by the regional states of Amhara and South Nation Nationality People (SNPP). Coffee, the leading crop, has the highest EVP in the country followed by Faba beans and Nug (*Guizotia abyssinica*). Ethiopia has highly benefited from biological pollinators, so protecting them has significant role in the country's economy. Most crops in Ethiopia have no pollination dependency ratio and some minor crop has no production data, incorporating them possible to better estimation of EVP service for the future.

Keywords: biological pollinator, crop vulnerability, economic value, Ethiopia, pollination

INTRODUCTION

One of the most important ecosystem services for sustainable crop production is pollination, the mutualistic interaction between plants and animals (Kjøhl et al., 2011). Out of the 115 crops whose pollen vectors were determined in a recent global study, over 75% depend to some degree upon animal pollination. Among the leading crops that benefit from animal pollination, thirteen are entirely reliant, thirty are greatly dependent, twenty-seven are moderately dependent (Gallai & Vaissière, 2009). The international community has acknowledged how important the diversity of insect pollinators is to support the increased demand for food brought about by predicted population increases. Insect pollination is threatened by several environmental and anthropogenic factors, and pollination crisis has been raised forthcoming (Kjøhl et al., 2011).

Animal pollinators include many insect species, as well as several species of birds and bats (Naban & Buchmann, 1997). Agricultural crops are pollinated by both managed and wild pollinators. European honey bees (*Apis mellifera*) are the most common managed species, as they possess several characteristics that make them good pollinators (NRC, 2007). First, they are generalist pollinators that are physically capable of pollinating many different plant species. Second, they exist in large perennial colonies with up to 30,000 individuals that are available for crop pollination year-round. Third, they are able to forage over large distances, so that their placement within large monoculture fields allows them to provide pollination services over a wide area. Fourth, they communicate with other members of the hive regarding the location of food sources. Finally, honey bees produce honey, a valuable commercially marketed product (Bauer & Wing, 2010).

Bees pollinate by visiting several flowers of the same species in one trip. Honey bees and, to a lesser extent, bumble bees are favored among farmers because of their manageability and comparatively large colonial forager populations (Delaplane et al., 2000; Delaplane et al., 2010), and their indispensable pollination service (Sagili & Burgett, 2011). Many agricultural crops rely to some degree on pollinators for planting the seeds or fruits that we consume or the seeds we sow or breed. About one-third of our food, including animal products, derives from animal-pollinated, mostly bee-pollinated crops (McGregor, 1976).

The total economic value of crop pollination worldwide has been estimated at €153 billion annually (Gallai et al., 2009). The leading pollinator-dependent crops are vegetables and fruits, representing about €50 billion each, followed by edible oil crops, stimulants (coffee, cocoa, etc.), nuts and spices. Honey bees play a central role in agriculture as pollinators and their global economic contribution to food production is estimated between $ 235 and 285 billion annually (Lautenbach et al., 2012). They are valuable to the ecosystem as they pollinate more than 90% of insect-pollinated plants and as generalists are crucial for the buffering of pollination networks (Potts et al., 2010). However, the poisoning of biological pollinators especially honeybees by agrochemicals has been increased over time, and some beekeepers have totally lost their colonies (Ejigu et al., 2009).

In Ethiopia there is still neither data about the contribution of insect pollination for the whole agricultural production nor on the economic value of pollination services. Hopefully, this study has the potential to change the attitude of communities who use chemicals carelessly and undermine the contribution of biological pollinators especially honeybees to the crop production. The aims of this study were to determine the economic value of pollination (EVP) services and the crop vulnerability ratio (CVR) of Ethiopian agriculture in the face of pollinator decline.

MATERIAL AND METHODS

Study area

The study comprises crop production in Ethiopia, which has a total land area of 1.22 million km^2, with a topography varying from 116 m below sea level at the Afar triangle to 4620 m above sea level at mount Ras Dejen. The periphery encircling the country consists generally of lowland plains with elevations below 1500 m and a mean annual rainfall of less than 500 mm. This area makes up 65 million hectare (61%) of the total surface, mainly pasture land and the home of pastoralists who make up 12% of the population with 26% of the livestock found in the country. The central highland, with an annual rainfall ranging between 500 mm to 1000 mm, is suitable for crop cultivation, comprises 18 million hectare and is inhabited by subsistence farmers (Waktola & Tsegaye, 2003). The country has nine regional state and two city administration, Addis Abeba and Dire Dawa (Education for all 2015 national review report: Ethiopia).

Data needed and Data source

There are four categories of data that are needed to analyse the economic value of pollination. These are choice of crops to be assessed, current knowledge of the impact of animal pollination on yields, price of crops to producers and production levels of crops (Gallai & Vaissière, 2009). As in Gallai et al. (2009), a bio-economic approach was used to calculate the economic value of the impact of pollinator loss as well as the overall vulnerability of the agricultural output to such a loss. The variables used for each crop (i), the quantity produced (Qi), the dependence ratio of the crop (i) on insect pollinators (Di) and the price of crop (i) per unit produced (Pi) for each crop. The central statistical agency (CSA) database was used as a source of data. A report on area and production of major crops, a 2015/2016 agricultural sample survey and annual 2016 average producer price report (from July, 2015 to June, 2016) were used. About 3,601,833.62 ha of land were covered by the tested crops.

Mathematical constants used

The use of an improved approach multiplies a crop's total value by a coefficient between zero and one representing the crop's dependency on pollination services for production. Setting this coefficient equal to one would produce the same results as just calculating the total value of biotically pollinated crops. The bio-economic approach is a variation of the conventional production function method and has been employed by Morse & Calderone (2000) in the case of managed bees but does not account for production costs (NRC, 2007).

Pollinator dependency was categorized (Klein et al., 2007) into six classes: none (class 0; production is not affected by pollinators), little (class 1; absence of pollinators leads to 0 to 10% reduction in production), modest (class 2; 10 to 40% reduction in production occurs without pollination service), high (class 3; animal pollinators contribute to 40 to 90% of production), essential (class 4; production drops more than 90% when pollinators are not available) and unknown (class 5; insufficient data). A dependency value was

Table 1.

List of studied crops, their pollination dependency ratio (PDR) and their area coverage

Crop	PDR	Area coverage (ha)	Crop	PDR	Area coverage (ha)	Crop	PDR	Area coverage (ha)
Faba beans	0.25	443,966.09	Beetroot	0.05	3,364.72	Avocados	0.65	13,665.45
Field peas	0.05	221,415.67	Onion	0.05	29,517.01	Guavas	0.25	2,006.28
White haricot beans	0.05	113,249.95	Potatoes	0.05	70,131.32	Lemons	0.05	1,099.11
Red haricot beans	0.05	244,049.94	Head cabbage	0.05	7,197.70	Mangoes	0.65	14,791.23
Gibto/ Lupin	0.05	16,788.20	Ethiopian cabbage	0.05	33,942.01	Oranges	0.05	3,547.34
Guizotia abyssinica	0.65	281,036.36	Tomatoes	0.05	9,524.42	Papayas	0.05	3,338.01
Chick peas	0.05	258,486.29	Green pepper	0.05	7,449.59	Cotton	0.25	93,600.00
Lentils	0.05	100,692.74	Red pepper	0.05	142,795.16	Coffee	0.25	653,909.70
Grass peas	0.05	159,105.68	Linseed	0.05	85,415.67	Sesame	0.25	388,245.50
Soya beans	0.25	38,166.04	Groundnut	0.05	67,062.40	Rape seed	0.25	29,989.17
Fenugreek	0.05	29,837.65	Safflower	0.25	7,361.30	Mung bean	0.05	27,085.92

Source: Klein et al., 2007; McGregor, 1976; Krombein et al., 1979 and due to a lack of data for each pulses crop (field peas, white and red haricot beans, chick peas, lentils, grass peas, fenugreek and lupin), used the least PDR i.e. 0.05 to not be under estimate the EVP, however Shankar (2015) states that all pulse crops are open pollinated to varying degrees, i.e. pollen must be transferred between flowers in order to achieve seed set. Such mechanisms as wind can achieve pollen transfer or cross pollination, but the most effective method is the utilization of insects. For *Guizotia abyssinica*, Admassu, & Nuru (2000) state that there is 44% yield increment with biological pollinators especially honeybees. Mustard PDR was used for rape seed because it has the same biology and belongs to the same family Brassicaceae.

assigned (Gallai et al., 2009) to each class: Class 0 = 0, Class 1 = 0.05, Class 2 = 0.25, Class 3 = 0.65, Class 4 = 0.95 Class 5 = 0. The economic value of pollination (EVP) and the crop vulnerability ratio (CVR) for each of the nine regional states and the whole Ethiopia were estimated. The economic value of pollination service was calculated (Gallai et al., 2009) as follows:

$$EVP = \Sigma^{I}_{i=1} (P_i \times Q_i \times D_i)$$
$$= \Sigma^{I}_{i=1} (FGVi \times D_i) \text{ -------------- } \textit{equation (1)}$$

For each crop i, i ∈ [1: i] (where i = 53 in this study), (Q_i) is the quantity produced, (D_i) is the pollination dependency ratio and (P_i) is the price per unit. Crop vulnerability ratio (CVR), the potential production value loss due to a lack of pollinators, is computed (Gallai et al., 2009) as the ratio of EVP to economic production value (EV). CVR is stated as follows:

$$CVR = EVP/ EV$$
$$= \Sigma^{I}_{i=1} (P_i \times Q_i \times D_i) / \Sigma^{I}_{i=1} (P_i \times Q_i)$$
$$= \Sigma^{I}_{i=1}(FGV_i \times D_i) / \Sigma^{I}_{i=1}(FGV_i) \% \text{ -------- } \textit{equation (2)}$$

Table 2.

Distribution of crops among categories of pollinator dependency ratio

Pollinator dependence	No. of crops	Percentage crops
0 (none) – 0	20	37.5%
1 (little) – 0.05	22	41.5%
2 (modest) -0.25	8	15.5%
3 (high) -0.65	3	5.5%
4 (essential) -0.95	0	0

Source: own calculation

Table 3.

Economic value of pollination (EVP) service for crops in each regional state

No.	Regional state/City administration	EVP in Birr	EVP in $	Rank	Percentage
1	Tigray Regional state	44552826	2121563	6	0,2605%
2	Afar Regional state	63231	3011	10	0,0004%
3	Amhara Regional state	3918418467	186591356	2	22,9068%
4	Oromia Regional state	8676342382	413159161	1	50,7214%
5	Somali Regional state	1222318893	58205662	4	7,1456%
6	SNNP Regional state	2918537937	138977997	3	17,0616%
7	Benshangul Gumz Regional state	322425420	15353591	5	1,8849%
8	Harerge Regional state	2279524	108549	7	0,0133%
9	Gambela Regional state	138959	6617	9	0,0008%
10	Dire Dawa city administration	819687	39033	8	0,0048%
11	Ethiopia	17105897327	814566539		100,0000%

Source: own calculation

Table 4.

EVP service for biotically pollinated crops

Crop	EVP ($)	Rank	Crop	EVP ($)	Rank	Crop	EVP ($)	Rank
Coffee	2,500,905.0	1	Potatoes	90,280.9	12	Green pepper	14,050.8	23
Faba beans	1,431,599.4	2	Grass peas	85,822.8	13	Mung bean	12,932.8	24
G. abyssinica	1,430,488.6	3	Avocados	85,132.5	14	Safflower	10,192.7	25
Sesame	549,087.7	4	Soya beans	81,145.1	15	Tomatoes	8,139.8	26
Cotton	485,714.2	5	Red haricot bean	66,134.4	16	Papayas	6,174.8	27
Red pepper	383,424.3	6	Onion	57,005.6	17	Oranges	4,473.4	28
Mangoes	175,806.2	7	Groundnut	50,262.1	18	Head cabbage	4,091.3	29
Chick peas	166,539.2	8	Linseed	45,561.6	19	Lupine	3,565.0	30
Field peas	118,422.3	9	White haricot bean	27,764.2	20	Beetroot	3,378.3	31
Rape seed	101,567.4	10	Ethiopian cabbage	27,082.1	21	Guavas	1,622.5	32
Lentils	99,589.2	11	Fenugreek	23,506.0	22	Lemons	1,010.7	33

Source: own calculation

Data Analysis

The collected data were coded, tabulated, analyzed and interpreted using the descriptive statistics of Microsoft Office Excel 2007.

RESULTS

Distribution of crops among categories of pollinator dependency ratio

As CSA report every year, fifty-three major crops are cultivated in Ethiopia. Table 2 shows that thirty-three (62.2%) crops were dependent on biological pollinators from low dependency to high dependency. The other twenty (37.7%) crops were not evaluated due to either zero pollination requirement (cereals crop) or lack of data such as pollination dependency ratio and/or production data. About 41.5 % of the studied crops were laid in little or 5% dependency on animal pollinators.

The economic value of pollination service in Ethiopia and each regional state

The economic value of pollination service was estimated to be $ 814,6 million dollars (17.1 billion ETB) in the 2015/16 production season. Tab. 3 shows that the EVP service across regional state of the country. The Oromia was the first regional state to benefit from biological pollinators followed by the Amhara regional state. The EVP service for the specific production year was 413,159,161 (50,7%) and 186,591,355.6 (22,9%) for Oromia and Amhara and accounts and to the country respectively. The Afar regional state had the lowest economic value of pollination service.

NB: The total all regional EVP were less than Ethiopia's EVP, because data of some such crop as cotton were not found on a regional level but only a national level.

Table 5.

EVP for biotically pollinated crops by categories

Crop categories	EVP in $	Rank	Area coverage (ha)	Rank
Pulses	2,117,020.4	3	1,652,844.17	1
Oilseeds	2,187,160.0	2	859,110.40	2
Vegetables	584,074.8	4	200,908.88	4
Root crops	3,378.3	7	103,013.05	5
Fruit Crops	274,220.1	6	38,447.42	7
Stimulant crop (coffee)	2,500,905.0	1	653,909.70	3
Fiber crop (Cotton)	485,714.0	5	93,600.00	6

Source: own calculation

The economic value of pollination service by crop type

The EVP for the specific crops ranges from $ 2.5 million to $ 1,010.7. From the perspective of Ethiopian agriculture in the specific production year, coffee ($ 2.5 million) had higher pollination economic value, followed by Faba bean ($ 1.431 million) and *G. abyssinica* ($ 1.430 million) respectively and from the studied crops lemons was the lowest with $ 1,010.7.

The economic value of pollination service by crops categories

Table 5 presents the EVP service by for the seven crop categories of pulses, oilseeds, vegetables, root, stimulants, fiber and fruit. Coffee, a stimulant, led the crop categories, followed by oilseeds ($ 2.18 million) and pulses ($ 2.11 million), respectively. Root crops were the lowest crop category in EVP at $ 3378.3.

Table 6.

Crop vulnerability ratio in each regional state

No.	Regional state/City administration	CVR	Percentage	Rank
1	Tigray Regional state	0.185	18%	4
2	Afar Regional state	0.217	21%	3
3	Amhara Regional state	0.117	11%	7
4	Oromia Regional state	0.178	17%	6
5	Somali Regional state	0.050	5%	9
6	SNNP Regional state	0.269	26.9%	1
7	Benshangul Gumz Regional state	0.181	18%	4
8	Harerge Regional state	0.056	5%	9
9	Gambela Regional state	0.267	26.7%	2
10	Dire Dawa city administration	0.106	10%	8
11	Ethiopia	0.165	16%	

Source: own calculation

Crop vulnerability ratio

The crop vulnerability ratio of Ethiopia in the 2015/16 production year was 16% for the studied crops. The crop vulnerability ratio in the regional states is shown in Tab. 6. The Gambela and SNNP regional states have the highest crop vulnerability ratio at 26%, followed by Afar 21% and both Tigray and Benshangul Gumz 18%. Both Somali and Harerge Regional state were the lowest at about 5% each.

The contribution of pollination from agriculture GDP in Ethiopia

The GDP from agriculture in Ethiopia increased from 267.80 ETB Billion in 2014 to 274 ETB Billion in 2015. The GDP From Agriculture in Ethiopia averaged 175.60 ETB Billion from 1999 until 2015, reaching a high of 274 ETB Billion in 2015 and a low of 98.30 ETB Billion in 2002 (Ethiopia GDP From Agriculture, 2014; https://tradingeconomics.com/ethiopia/gdp-from-agriculture)

Contribution of pollination in Agriculture

GDP = (EVP/GDP from Agriculture) × 100
= (17.1 ETB Billion/274 ETB Billion) × 100
= 6.24

To estimate the contribution of honeybee from biological pollinators, each crop type must be studied. However, different scholars estimated that out of all biological pollinator, honeybees contribute 80% of pollination service and the EVP service by honeybees was estimated $ 652,197,976.96. Additionally, 50.79 million kg of honey was produced and sold at a cost of the national average $ 2.8/kg (CSA, 2016) bringing in a total revenue of $ 142,212,000. The benefit of pollination service from honeybee over honey production was 4.58. Therefore, the contribution of honey bee for pollination service was 4.58 times greater than the honey production.

DISCUSSION

Of the major agricultural crops cultivated in Ethiopia, about thirty-three (62.2%) crops depended on biological pollinators. This result was lower than that of Gallai & Vaissière, (2009) who reported that out of 115 crops, whose pollen vectors had been determined in a global study, over 75% depend to some degree upon animal pollination. This study only included major crops and not any minor ones. Pollinators include many insect species primarily the honeybee. About 5,916,100 honey bee colonies were found in Ethiopia (CSA, 2016) but the poisoning of honeybees by agrochemicals has increased (Ejigu et al., 2009). The level of pollinator dependency varies dramatically among crops (Klein et al., 2007). About 41.5% of the studied crops have lied on little level pollination dependency ration, this was due to lack of pollination dependency ratio data for pulse crops; this enforced categorized them into little level of dependency ratio.

The EVP service was 815.2 million dollar, about 6.24% of the agricultural GDP. From the total EVP service, about 80% was the contribution of honeybee from the biological pollinators, so the contribution of honey bee for pollination service was 4.58 times greater than honey production. The Oromia and Afar regional states have the highest and the lowest EVP service respectively, due to the EVP service being highly correlated with the production level. Crop-type dependence on pollination ranges from zero dependence to complete dependence. The economic values of pollination by crop type vary according to the selected type of crop pollination dependency ratio, production level and market value. Coffee had the highest EVP service due to the highest market value compared to other crops. The faba bean had the second highest EVP service because of its relative highest production with medium market value. Accordingly, due to the highest market value of coffee as a stimulant crop category, it had the highest EVP service from all other crop categories.

Crop vulnerability ratio (CVR) is the potential production value loss due to a lack of pollinators and is expressed in percentage (Gallai et al., 2009). The CVR for Ethiopian agriculture was 16% but was the highest in the Gambela and SNNP regional states at 26%. Followed by Afar 21% and both Tigray and Benshangul Gumz at 18%. The CVR value for the Somali and Harerge Regional states was the lowest, below the country average at 5%. This is due to the various crop types with different pollination dependency ratios.

This research measured the economic value of biological pollinators and crop vulnerability ratio of the food production in the face of declining insect pollinator number. Using a bio-economic approach, the contribution of biological pollinators to the production of agricultural crops was calculated to be $ 815.2 million, which is about 6.24 % of the total value of the agricultural GDP. Information is provided for policy makers and for extension service in the national agriculture to protect biological pollinators especially honeybees from the use of pesticide, insecticide and herbicides.

Lack of data and unclearness of the available data was hard to completion this task. Most of the crops which are grown in Ethiopia still no PDR data. Additionally, due to lack of production data of pumpkin, apple, tangerine, pears (high food and market value especially in Tigray region and Raya Kobo district of Amhara region), pineapples, and water melon are not included in this study. Hence, those effects are enforcing under estimate the EVP service. Then recommendation leads to incorporate such missed data will be truly estimated the EVP service.

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REFERENCE

Abrol, D.P., & Shankar, D.A.U. (2015). Role of pollination in pulses. Advanced in pollen spore research Vol. XXXIII:101-103. Today & Tommorow's Printers and punlishers, New Delhi- 110 002

Admassu, A., & Nuru, A. (2000). The effect honeybee pollination on seed and oil content of *Guizotia abyssinica* L, In First National Conference of Ethiopian Beekeepers Association, Addis Ababa Ethiopia.

Bauer, D.M., & Wing, I.S. (2010). Economic consequences of pollinator declines: a synthesis. *Agricultural and Resource Economics Review*, *39*(3), 368-383.

Council, N.R. (2007). Status of pollinators in North America.

Central Statistical Agency Agricultural Sample Survey 2015/16. (2016) Volume I Report on Livestock and Livestock Characteristics

Central Statistical Agency Agricultural Sample Survey 2015/2016 (2016 E.C.) Volume I Report On Area and Production of Major Crops

CSA report on 'Annual Producer Price for 2016 in Ethiopia'.

Delaplane, K.S., Mayer, D.R., & Mayer, D.F. (2000). *Crop pollination by bees*. Cabi.

Delaplane, K.S., Thomas, P.A., & McLaurin, W.J. (2010). Bee pollination of Georgia crop plants.

Education for All 2015 National Review Report: Ethiopia

Ejigu, K., Gebey, T., & Preston, T.R. (2009). Constraints and prospects for apiculture research and development in Amhara region, Ethiopia. *Livestock Research for Rural Development*, *21*(10), 172.

Ethiopia GDP from Agriculture (2017). Retrieved December 12, 2018, from https://tradingeconomics.com/ethiopia/gdp-from-agriculture

Gallai, N., & Vaissière, B.E. (2009). Guidelines for the economic valuation of pollination services at a national scale. Rome, FAO.

Gallai, N., Salles, J.M., Settele, J., & Vaissière, B.E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological economics*, *68*(3), 810-821.

Kjøhl, M., Nielsen, A., & Stenseth, N.C. (2011). *Potential effects of climate change on crop pollination*.

Food and Agriculture Organization of the United Nations (FAO).McGregor, S.E. (1976). *Insect pollination of cultivated crop plants* (Vol. 496). Washington (DC): Agricultural Research Service, US Department of Agriculture.

Klein, A. M., Vaissiere, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society of London B: Biological Sciences*, *274*(1608), 303-313.

Krombein, K.V., Hurd Jr, P.D., Smith, D.R., & Burks, B.D. (1979). Catalog of Hymenoptera in America north of Mexico. Volume 1. Symphyta and Apocrita (Parasitica). *Catalog of Hymenoptera in America north of Mexico. Volume 1. Symphyta and Apocrita (Parasitica).*

Lautenbach, S., Seppelt, R., Liebscher, J., & Dormann, C.F. (2012). Spatial and temporal trends of global pollination benefit. *PLoS one*, *7*(4), e35954.

Morse, R.A., & Calderone, N.W. (2000). The value of honey bees as pollinators of US crops in 2000. *Bee culture*, *128*(3), 1-15.

Naban, G.P., & Buchmann, S.L. (1997). "Services provided by pollinators." In Daily, G.C., ed. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC.

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution, 25*(6), 345–353. DOI:10.1016/j.tree.2010.01.007

Sagili, R.R., & Burgett, D.M. (2011). Evaluating honey bee colonies for pollination: a guide for commercial growers and beekeepers.

Waktola, A., & Tsegaye, B. (2003). Biotechnology related policy, management and negotiation competence: case study from Ethiopia.