Vol. 14(34), pp. 1921-1942, November, 2019
DOI: 10.5897/AJAR2019.14247
Article Number: E0DBD4A62376
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Socioeconomic and ecological consequences of Parthenium weed (*Parthenium hysterophorus L.*) in Boset Woreda, Ethiopia

Gadisa Duguma, Daniel Fitamo* and Firew Kebede

Department of Biology, College of Natural and Computational Sciences, Hawassa University, Hawassa, Ethiopia.

Received 14 June, 2019; Accepted 19 September, 2019

Parthenium weed (*Parthenium hysterophorus* L.), an invasive alien species, has been spreading at alarming rate in Ethiopia, causing biodiversity degradation, yield losses in field and horticultural crops, health problems to human beings and livestock. A study on the socioeconomic and ecological impacts of P. hysterophorus was conducted in five Kebeles (lowest administrative division) of Boset Woreda (District), Ethiopia. Data was collected using Ecological Survey, Semi Structured Interviews, Focus Group Discussion, and Field Observations. 200 quadrats were employed where every plant species found in each quadrat were counted, recorded and identified. Data on informant's perception about the first appearance, infestation levels, agents of dispersal, impact, and cultural management of the Parthenium weed were analyzed using descriptive statistics. Shannon Diversity Index (H′), Species Richness, Evenness, and Jaccard's Similarity Index were executed to evaluate Parthenium's effect on species diversity of the weed flora. 78 Herbaceous plants belonging to 59 genera and 21 families were collected. Poaceae (28.2%) and Asteraceae (16.7%) were the dominant families of weeds observed in the study Kebeles. Digalu and Merko Kebeles had high infestation of *P. hysterophorus* represented by high distribution, abundance, and dominance of the weed, but with corresponding low Richness, H′, and evenness of herbaceous plants. Species Richness of herbaceous flora and abundance of Parthenium weed reveled significant negative association ($P < 0.01$; $R^2 = 0.93$). Most of the informants believed that Parthenium affected crop and livestock production as well as human health. Farmers employed hand weeding, plowing, and manual clearing to manage the weed. For effective use of the weed, Integrated Weed Management approaches are required to check the spread and reduce the adverse impacts.

Key words: Abundance, distribution, diversity, Ethiopia, Herbaceous Vegetation, *Parthenium hysterophorus*, Perception, socioeconomic impacts.

INTRODUCTION

Parthenium weed, *Parthenium hysterophorus* L. (hereafter referred to as Parthenium), belongs to the family Asteraceae, an extremely diverse family with a cosmopolitan distribution (Hundessa and Belachew,

*Corresponding author. E-mail: danielfitamo@gmail.com. Tel: +251-911-996720.

2016; Hundessa et al., 2016). It is described as an annual (Tessema et al., 2010; Khan et al., 2012; Adkins and Shabbir, 2014; Abdulkerim-Ute and Legesse, 2016; Hundessa et al., 2016; Mekonnen, 2017) or, under certain conditions, a short-lived perennial (Adkins and Shabbir, 2014), procumbent (Tessema et al., 2010; Hundessa and Belachew, 2016; Hundessa et al., 2016) or with an erect stem (Tadesse, 2004; Adkins and Shabbir, 2014; Bagachi et al., 2016; Mekonnen, 2017). At maturity, the weed develops several branches in its top half (Tadesse, 2004; Adkins and Shabbir, 2014; Abdulkerim-Ute and Legesse, 2016; Bobo and Abdeta, 2016; Bagachi et al., 2016; Mekonnen, 2017) and becomes a diffused leafy herb with a height of 0.5 to 1.50 m, reaching a maximum of 2 m in good soils (Tessema et al., 2010; Abdulkerim-Ute and Legesse, 2016; Hundessa and Belachew, 2016; Hundessa et al., 2016; Mekonnen, 2017).

Parthenium weed is characterized by deep tap root, pale green leaves and an erect stem that becomes woody gradually (Abdulkerim-Ute and Legesse, 2016; Mekonnen, 2017). The alternately arranged leaves (Tadesse, 2004; Tessema et al., 2010; Bagachi et al., 2016) are simple with stalks (petioles) narrowly winged (Tadesse, 2004) up to 2 cm (Bagachi et al., 2016) or 2.5 cm long (Tadesse, 2004) and form a basal rosette during the early stages of growth (Bagachi et al., 2016; Bobo and Abdeta, 2016). The lower leaves are comparatively large (3 to 30 cm long and 2 to 12 cm wide) (Bagachi et al., 2016) and are strongly dissected (bi-pinnatifid or bi-pinnatisect) (Bagachi et al., 2016; Bobo and Abdeta, 2016) than the leaves on the upper branches (Bagachi et al., 2016). Mature stems are greenish (Tadesse, 2004; Bagachi et al., 2016) and longitudinally grooved (Tadesse, 2004; Bagachi et al., 2016; Royimania et al., 2019), covered in small stiff hairs (hirsute) (Bagachi et al., 2016).

Parthenium, the most obnoxious, allergenic, and environmental pollutant weed (Maszura et al., 2018), which is supposed to have originated in the area surrounding the Gulf of Mexico, Southern USA (Adkins and Shabbir, 2014), West Indies, and Central South America (Bagachi et al., 2016). The aggressive (Maszura et al., 2018) and pernicious weed (Saini et al., 2014) is recognized as one of the top ten worst weeds in the world (Zelalem and Tora, 2019) and has colonized and naturalized in many regions of the world, including Asia, Australia and Africa (Royimani et al., 2018). African countries are at high risk of invasion (Bagachi et al., 2016; Bobo and Abdeta, 2016) and in Africa, Parthenium has become prevalent in the eastern and southern parts of the continent (Royimani et al., 2018).

While *P. hysterophorus* was first documented in Ethiopia in 1968 (Haramaya University, Herbarium) (Lisanework and Sharma, 2013), there is no tangible evidence hitherto concerning its mode of introduction (Tessema et al., 2010; Lisanework and Sharma, 2013). Notwithstanding this, it is supposed that the weed was introduced accidentally as a seed contaminant of food grains imported from overseas where Parthenium occurred on farmlands or during the Ethio-Somalia war in 1976 to 77 by army vehicles (Tessema et al., 2010; Lisanework and Sharma, 2013; Hundessa and Belachew, 2016).

Parthenium is currently spreading at an alarming rate in various parts of Ethiopia (Bobo and Abdeta, 2016; Zelalem and Tora, 2019) mainly following the direction of low slope (Kebede, 2008; Belachew and Tessema, 2015; Hundessa et al., 2016) and waterways (Kebede, 2008; Hundessa et al., 2016). The seeds of the weed are primarily dispersed through transport, agricultural implements (Lisanework and Sharma, 2013; Bobo and Abdeta, 2016; Maszura et al., 2018), crop seeds, wind (Bobo and Abdeta, 2016; Maszura et al., 2018), compost, organic manures (Maszura et al., 2018), flood water, and tire-carried mud of vehicles (Kebede, 2008; Lisanework and Sharma, 2013; Maszura et al., 2018).

Following its introduction into Ethiopia, it dispersed across the whole country within a few years (Tessema et al., 2010). The high germination capacity (Tessema et al., 2010; Abdulkerim-Ute and Legesse, 2016), a high seed production (Tessema et al., 2010; Kilewa and Rashid, 2013; Lisanework and Sharma, 2013; Seta et al., 2013; Saini et al., 2014; Abdulkerim-Ute and Legesse, 2016), an easy distribution mechanism, allelopathic effect on other plants (Tessema et al., 2010; Seta et al., 2013; Abdulkerim-Ute and Legesse. 2016), a short life cycle (Kilewa and Rashid, 2013; Saini et al., 2014; Abdulkerim-Ute and Legesse, 2016), and unpalatability to grazers (Royimania et al., 2019) contributed to the spread of the weed. Likewise, small and light seeds (Kilewa and Rashid, 2013), absence of natural enemy (Lisanework and Sharma, 2013), large viable seed bank (Kilewa and Rashid, 2013; Saini et al., 2014; Abdulkerim-Ute and Legesse, 2016; Royimania et al., 2019), high survival rate and a good adaptation to a wide range of environmental factors (Tessema et al., 2010; Dogra et al., 2011; Kilewa and Rashid, 2013; Saini et al., 2014; Abdulkerim-Ute and Legesse, 2016; Royimania et al., 2019) have been associated with the rapid spread of the weed in Ethiopia.

It aggressively colonizes natural and manmade ecosystems and causes major negative impacts on grassland habitats, open woodlands, riverbanks, flood plains, wildlife parks, open field of settlement areas, and bare areas along road sides (Shiferaw et al., 2018). Consequently, Parthenium causes immeasurable ecological losses each year (Adkins and Shabbir, 2014), through displacement of native flora and fauna as well as the significant decline in local biodiversity (Royimania et al., 2019). On the other hand, Parthenium affects agriculture (crop and livestock production) through its effect on crops and grazing lands. In Ethiopia, the noxious weed species is seriously affecting crop yields (Bajwa et al., 2018) where it has become a grave poser in the cultivation of major crops in eastern part of the country in addition to being a major problem on range and waste lands (Bobo and Abdeta, 2016). Conversely, Parthenium is known to affect animal health, milk and meat production (Shashie, 2007; Hundessa and Belachew, 2016; Royimania et al., 2019). The notorious weed can cause serious allergic reactions (Bobo and Abdeta, 2016; Bajwa et al., 2018), respiratory problems and other health complications (Bajwa et al., 2018) in livestock including eye irritation, skin lesions, anorexia, pruritus, alopecia, dermatitis, diarrhea, mouth ulcers with excessive salivation (Mekonnen, 2017), and sometimes death (Mekonnen, 2017; Birhanu and Khan, 2018) due to rupturing and hemorrhage of internal tissues and organs (Mekonnen, 2017). Besides, the toxins derived from the weed reduce quality of meat, cause tainting in milk, and reduce yields of milk of Goat, Sheep and Cow (Kilewa and Rashid, 2013). Effects of Parthenium are very conspicuous in agricultural ecosystems leading to economic losses to the nation due to reduced crop productivity (Saini et al., 2014). Subsequently, invasion of Parthenium weed in a crop lands may contribute to social and economic instability, causing poverty and food insecurity (Kilewa and Rashid, 2013).

Parthenium clearly poses a major threat to the health of humans (Tamado et al., 2002; Kathiresan et al., 2005; Kumar, 2013; Kilewa and Rashid, 2013; Seta et al., 2013; Zuberi et al., 2014; Hundessa and Belachew, 2016; Maszura et al., 2018). In humans, the weed causes Allergic Respiratory Problems, Mutagenicity (Roy and Shaik, 2013), contact dermatitis (Tessema et al., 2010; Roy and Shaik, 2013; Hundessa and Belachew, 2016), Allergic Rhinitis (Tessema et al., 2010; Kilewa and Rashid, 2013; Hundessa and Belachew, 2016), Asthma, Bronchitis and Dermatitis (Kilewa and Rashid, 2013; Hundessa and Belachew, 2016).

East Shoa, a Zone where the Boset Woreda is located, is one of the areas in Ethiopia with perceptible infestation of the weed (Hundessa and Belachew, 2016; Hundessa et al., 2016). Besides, despite the fact that Parthenium is reckoned to be a culprit to initiate serious damage on crop production, animal husbandry, and biodiversity in Ethiopia, there is still palpable dearth of adequate information concerning the impact of Parthenium weed in the study Woreda. Therefore, this study was conducted to assess the socioeconomic and ecological impact of Parthenium weed in the study area.

METHODOLOGY

Description of the study area

The study area (Boset Woreda/District) lies between 8°24' to 8°51'North latitude and 39°16' and 39°50' East longitude which is located about 125 km south east of the capital, Addis Ababa. It is bounded by Fentale Woreda in the East, Awash River in the West, Arsi Zone in the south and Amhara Region in the north (Figure 1).

The Woreda is divided into 33 Rural Kebeles (the smallest unit of local government) and 9 Urban Kebeles (BWANRO, 2017). Based on the CSA (2007), the total population of the Woreda is estimated to be 142,112. The total area of the Woreda is 1378.4 km^2. The Woreda extends from 1000 up to 2000 m.a.s.l. Notwithstanding this, virtually 90% of the Woreda is below 1500 m.a.s.l. and hence, it predominantly falls within the Kolla (Lowland) Agroclimatic Zone, which is characterized by Warm Climate typical of the Arid and Semi-Arid areas. The Woreda is categorized by hot and dry weather with the annual average temperature in the range of 25 to 37°C and receives an average 700 to 800 mm of rainfall per annum.

The natural vegetation of the study area is principally Savannah Grassland. The vegetation is primarily characterized by Acacia trees with the bushes and shrubs common to the lowlands portion of Ethiopia. Among the important tree species characterizing the area are *Acacia albida (Faidherbia albida), Acacia etbaica, Acacia nilotica, Acacia senegal, Acacia tortilis,* and *Balanites aegyptiaca.* Conversely, *Eucalyptus camaldulensis* is planted around homesteads. The soils of the Woreda is mostly derived from volcanic ash origin, where the major soil types in descending order are Andosols (49.4%), Lithosols (36.1%), Cambisols, Luvisols (11.4%) and Fluvisols (3.1%). A survey of the land in this Woreda (BWANRO, 2017) shows that 26.2% is Arable, 30% Pasture, 15.8% Forest, and the remaining is considered barren, degraded or otherwise unusable. The people of the area practice various income generating activities mainly crop production and animal husbandry. Crop production plays a major role in income generation in the area and cereals such as maize, teff, haricot bean, wheat, barley and sorghum are the major crops grown (BWANRO, 2017).

Data collection

Based on the consultation with the Woreda Agricultural Experts on the severity of the invasion and distribution of Parthenium in the Woreda, and subsequent information collected during reconnaissance survey, 5 Kebeles were selected (Merko and Digalu: High Parthenium Infestation; Sifa, Tiyo, and Bekektu: Moderate Infestation). Subsequently, a study on the distribution, abundance, socioeconomic and ecological consequences as well as people's awareness/perception of *P. hysterophorus* and cultural management practices employed to deal with the weed was conducted in the five Rural Kebeles of the study Woreda during the main cropping season (July to September) of 2017.

Perception of local people on socioeconomic and ecological effects of Parthenium weeds

A total 110 sample households were randomly selected from the overall of 3751 Households (Table 1) in the 5 Kebeles using Fluid Surveys Team (2014) method. Subsequent to the determination of the number of Households representing each Kebele employing proportional sampling technique (Dale, 2006; Trochim, 2006), the respective informants/farmers were randomly selected in each of the 5 Kebeles. Besides, key informant interviews, Woreda experts (Crop Extension, 4; Human and Veterinary Medicine, 4 each), and development agents/DAs (2 from each Kebele) were purposively selected. Semi structured interview (SSI) was conducted to collect requisite data from all the informants.

Focus Group Discussions (FGD) were conducted with eight selected farmers representing Elders, Women, Literate, Illiterate, Youth, Poor and Rich Farmers, etc. in their respective Kebeles. Direct observations were also made during the study period. The Interview Questions, and Discussion Topics meant for SSI, and FGD, respectively, were translated to Afan Oromo (the Local Language) from English. The cardinal points captured in the above instruments principally include the following: (1) Informants view of the first appearance of the weed in the area (2) whether the

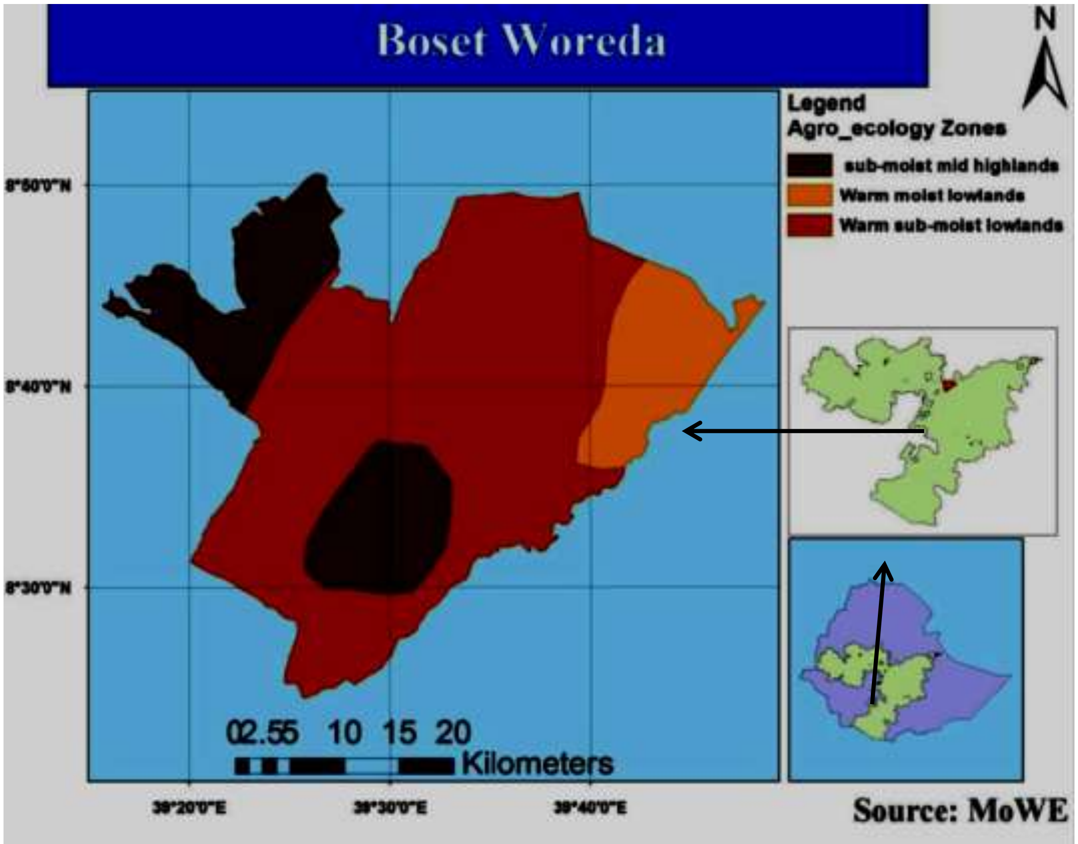

Figure 1. Map of the study area (Boset Woreda). Source: Ministry of Water Resources and Energy, MoWE (2017).

Table 1. Number of Households (HHs) and the selected Farmers (Informants).

Kebele	Total number of households	Number of HHs/informants selected
Sifa	415	12
Tiyo	1702	50
Bekektu	676	20
Digalu	571	17
Merko	387	11
Total	**3751**	**110**

informants knew the agents for the fast spread of the weed in the study area, (3) Informants view on the impacts of the weed (4) the types of measures used so far to control dissemination of the weed in the study area. Finally, the interviewees' responses were collected and analyzed.

Sampling of weed species

Field identification of Parthenium was conducted using plant characteristics thoroughly described in Grierson and Long (2001) and Tiwari et al. (2005). A survey on Parthenium distribution and herbaceous plant species grown in affected areas were carried out in the selected five Kebeles of the Woreda. At each selected Kebele, two parallel transects of each 1 km length and 500 m apart from each other and varying in terms of slope, drainage and soil types (Belachew and Tessema, 2015), and land use were established for plant data collection. In each Kebele, accordingly, herbaceous vegetation data associated with Parthenium were collected from 40 evenly spaced 1 m × 1 m sample quadrats at fifty meter interval. The numbers of plants were recorded per species in each quadrat following Wittenberg et al. (2004). Identification included both local and scientific name of each plant species. Many of weed species collected from the quadrats were identified in the field. For species difficult to identify in the field, voucher specimen were collected, pressed and dried properly and transported to Hawassa University for identification and proper naming. The nomenclature of the plant species followed the flora of Ethiopia and

Eritrea (Hedberg and Edwards, 1995).

Data analysis

Evaluation of within-community diversity

The Species Richness and the Abundance of herbaceous plants (Plant m^{-2}) were determined for each quadrat sampled. Diversity of the species for the vegetation data was analyzed using Shannon Diversity Index (H′) (Shannon and Wiener, 1949) using the following formula:

$$H' = -\sum pi(lnpi)$$

Where H' = Shannon diversity index; Pi = the importance value of the i^{th} species; S = total number of species in the sample quadrat.

$$E = H'/\ln S$$

Where E = Evenness

The evenness of species was calculated as it explains how equally abundant each species would be in the plant community and high evenness is a sign of ecosystem health. The evenness or equitability assumes a value between 0 and 1 with 1 being complete evenness and 0 a single species dominating the area. One Way ANOVA followed by a Post Hoc pairwise comparison (Tukey-HSD test at $\alpha < 0.05$ level) was performed using SPSS 16.0 (SPSS, 2007) in order to identify significant differences ($P < 0.05$) between average values of the Species Richness, Evenness, and Shannon Diversity between the five Kebeles.

Between-community diversity

The similarity of the standing vegetation (herbaceous vegetation layer) among the sample sites in the study area were compared using Jaccard's coefficient of similarity (JCS) (Magurran, 2004). JCS = a /a + b + c, where JSC = Jaccard's Coefficient of Similarity; a = species common to quadrat 1 and 2; b = species present in quadrat 1 but absent in quadrat 2; c = species present in quadrate 2 but absent in 1. The coefficient has a value from 0 to 1, where 1 reveals complete similarity and 0 complete dissimilarity.

Assessment of weed frequency, abundance, density and dominance

Frequency, Abundance, Density (Ramadhan and Amzath, 2013), and Dominance (Taye et al., 1998) was determined as described below:

$$\text{Frequency (\%)} = \frac{\text{Number of Quadrats in which a plant occurred}}{\text{Total number of Quadrats studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a plant in all Quadrats}}{\text{Total number of Quadrats in which the plant occurred}}$$

Density = Total number of Quadrats studied

$$\text{Dominance} = \frac{\text{Abundance of a species}}{\text{Total abundance (of all species)}} \times 100$$

RESULTS AND DISCUSSION

Species composition of herbaceous plants in the study *Kebeles*

The Herbaceous plants collected belong to 59 genera and 21 families. The family Poaceae was represented by the highest number of species (22 species), accounting for 28.2%. This was followed by Asteraceae (16.7%), Fabaceae (7.7%), Convolvulaceae (7.7%), and Solanaceae (6.4%), whereas Euphorbiaceae, Polygonaceae and Amaranthaceae constitute 5.1% each (Table 2). It is worth noting that the aforementioned 8 families alone represent the bulk of (82%) herbaceous species documented in the study area. The families were also reported to be economically important and common in different parts of Ethiopia (Firehun and Tamado, 2006; Lisanework and Sharma, 2013). Besides, in agreement with the present study, Poaceae, Asteraceae (Etana et al., 2011; Seta et al., 2013; Ayele et al., 2014; Gebrehiwot and Berhanu, 2015), Fabaceae (Etana et al., 2011), Solanaceae (Etana et al., 2011; Seta et al., 2013), Euphorbiaceae (Seta et al., 2013), and Amaranthaceae (Etana et al., 2011; Seta et al., 2013; Gebrehiwot and Berhanu, 2015) were the most dominant families in terms of number of species in Parthenium affected areas.

Frequency of occurrence, abundance, density and dominance of herbaceous flora

Averaged across all sites, there was considerable variability in the distribution of the weed species in the five Kebeles studied. Accordingly, the frequency of the herbaceous flora ranges from 93% (*Cassia tora*) to 5% (*Ageratum conyzoides, Amaranthus hybridus* and *Bidens pilosa*). Besides, *Argemone mexicana, Cynodon dactylon, Digitaria abyssinica* and *Parthenium hysterophorus* were species with high degree of dispersal with frequency that ranged from 83.5 to 87.5% (Table 3). The distribution of the most frequent weeds mentioned previously, although variable among the 5 Kebeles studied, it is worth noting that *P. hysterophorus* had comparatively lower value in Sifa Kebele (77.5%) but revealed relatively high occurrences, particularly in Digalu (87.5%) and Merko (90%) Kebeles (Figures 2 to 6). In a Parthenium invaded areas, *C. tora* (82%) and *C. dactylon* were commonly reported species (Karaki, 2009). In their review on harmful effect and management of Parthenium, Jayaramaiah et al. (2017) indicated that *C. tora* was one of the plants which was found to compete with *P. hysterophorus* weed since its extract have an allelopathic potential.

As to Banerjee and Srivastava (2010), frequency of an individual species represents its spatial pattern, importance and the evenness of spatial distribution in community as well. Hundessa et al. (2016) reported that Parthenium weed invaded a wide range of environmental

Table 2. Number and proportion of plant species within the eight top diverse families observed in the five Kebeles of the study area.

Family	Number of species	Percent (%)
Poaceae	22	28.2
Asteraceae	13	16.7
Fabaceae	6	7.7
Convolvulaceae	6	7.7
Solanaceae	5	6.4
Euphorbiaceae	4	5.1
Polygonaceae	4	5.1
Amaranthaceae	4	5.1
Total	64	82

Table 3. Frequency, abundance, dominance, and density of herbaceous species averaged over the study Kebeles.

S/N	Scientific name	Local name	Family name	LC	F (%)	A (N^o/m^2)	D (%)	D' ($\underline{No}/m^2$)
1	*Ageratum conyzoides* L.	Aremagunyato(O)	Asteraceae	A	5	1.2	0.97	0.055
2	*Sorghum arundinacieum (Desv.) Stapf*	Matane(O)	Poaceae	A	16.5	1.23	0.99	0.17
3	*Achyranthes aspera* L.	NF	Amarantaceae	A	6	1.05	0.87	0.09
4	*Sonchus asper (*L.) Hill	NF	Asteraceae	A	8.05	0. 83	0.66	0.135
5	*Agrostis alba L.*	NF	Poaceae	A	6	0.8	0.61	0.06
6	*Solanum nigrum* L.	K'ey-awuti-i(A)	Solanaceae	A	10.5	0.87	0.72	0.115
7	*Amaranthus spinosus* L.	NF	Amaranhaceae	A	11	1.11	0.89	0.13
8	*Solanum incanum* L.	Imbway (A)	Solanaceae	A	8	1.37	1.01	0.1
9	*Amaranthus hybridus* L.	NF	Amaranthacea	A	5	0.87	0.68	0.055
10	*Snowdenia polystachya Fresen*	Muja(A,O)	Poaceae	A	7.5	0.91	0.72	0.085
11	*Amaranthus dubius* Thell.	NF	Amaranthaceae	A	10.5	0.88	0.73	0.115
12	*Sida alba* L.	NF	Malvaceae	P	9	1.1	0.83	0.12
13	*Ambrosia maritime* L.	NF	Asteraceae	A	7.5	1	0.78	0.08
14	*Sida acuta Brum. f.*	NF	Malvaceae	P	7.5	0.95	0.72	0.08
15	*Alternanthera sessilis* (L.) DC	NF	Amaranthaceae	A	26.5	1.27	0.94	0.605
16	*Setaria verticillata (L.) P. Beauv.*	NF	Poaceae	A	7	1.13	0.86	0.11
17	*Anagalis arvensis* L.	Henenur(O)	Primulaceae	A	20	1.28	0.97	0.33
18	*Setaria pumila Michx*	NF	Poaceae	A	7	1.05	0.88	0.08
19	*Argemone Mexicana L.*	Medafe(A)	Papaveraceae	A	87.5	5.27	3.83	4.64
20	*Setaria abyssinica L*	NF	Poaceae	A	11.5	0.92	0.77	0.135
21	*Artemisia arborescens* L.	NF	Asteraceae	A	9.5	1.1	0.87	0.065

Table 3. Contd.

22	*Sonchus oleraceus* L.	NF	Asteraceae	A	8.5	0.8	0.67	0.085
23	*Bidens pilosa L.*	Yeseyit'anmerfe(A)	Asteraceae	A	5	0.6	0.48	0.05
24	*Savignya parviflora (Delile) Webb*	NF	Brassicaceae	A	6.5	1	0.81	0.08
25	*Rumex abyssinicus Jacq.*	Mek'meko(A)	Polygonaceae	A	20.5	1.2	1.1	0.3
26	*Cassia tora L.*	Yefiyel-abish(A)	Fabaceae	A	93	13.49	11.1	12.62
27	*Rhyncossia malacophylla (Spreng.) Boj.*	NF	Fabaceae	A	9	0.82	0.64	0.14
28	*Chloris amentnytea Hochest*	NF	Poaceae	A	14.5	1.15	0.93	0.16
29	*Polygonum salicifolium Brouss ex* Willd.	Gumamila (A)	Polygonaceae	A	14.5	0.92	0.78	0.18
30	*Chenopodium album* L.	Amedmaho(O)	Chenopodiaceae	A	15.5	0.87	0.69	0.17
31	*Phyllanthus amarus Schumach. & Thonn.*	NF	Phyllanthaceae	A	14	0.91	0.7	0.155
32	*Plantago lanceolata* L.	Gort-eb(A)	Plantaginaceae	P	7	1.37	1.1	0.115
33	*Convolvolus arvensis* L.	NF	Convolvulaceae	P	9.5	1.35	1.05	0.13
34	*Pimpinella anisum L.*	NF	Apiaceae	A	10.5	0.83	0.69	0.11
35	*Crotalaria sp.*	NF	Fabaceae	A	18	1.53	1.2	0.52
36	*Parthenium hysterophorus* L.	Fermsisa(O)	Asteraceae	A	83.5	15.72	12.9	13.25
37	*Cyperus rotundus* L.	Kundi(O)	Cyperaceae	A	9	1.62	1.26	0.15
38	*Panicum maximum Jacq.*	Sar(A)	Poaceae	P	29	1.9	1.42	0.67
39	*Cyperus squauiflorus (*Torr) Matiff	NF	Cyperaceae	P	30.5	1.41	1.05	0.68
40	*Oxygonum sinuatum* (Meisn.) Dammer	Rafu hare/Sogdo(O)	Polygonaceae	A	13.5	1.21	0.9	0.185
41	*Cynodon dactylon (L.) Pers.*	Serdo (A)	Poaceae	P	87.5	6.16	4.6	5.41
42	*Oxalis corniculata* L.	NF	Oxalidaceae	P	21	0.91	0.71	0.2
43	*Cynodon nlemfuensis Vanderyst*	NF	Poaceae	P	20	1.13	0.85	0.6
44	*Orobanche minor* Smith	Sete-yejib-ras(A)	Orobanchaceae	A	9.5	1.05	0.81	0.095
45	*Datura innoxia* Mill.	NF	Solanaceae	A	12	0.92	0.72	0.135
46	*Oplismenus hirtellus (L.) P.Beauv.*	NF	Poaceae	P	6.5	0.74	0.6	0.1
47	*Datura stramonium* L.	Manji(O)	Solanaceae	A	8	0.87	0.72	0.085
48	*Nicandra physaloides* (L.) Gaertn*.*	NF	Solanaceae	A	8.5	0.89	0.7	0.095
49	*Desmodium adscendens (*Sw.) DC.	NF	Fabaceae	A	10	0.84	0.67	0.105
50	*Mercurialis annua L.*	NF	Euphorbiaceae	A	11.5	1.1	0.87	0.095
51	*Dinebra retroflexa (Vahl) Panz.*	NF	Poaceae	A	8.5	0.85	0.67	0.09
52	*Mentha arvensis* L.	NF	Labiatae	A	11	1.13	0.85	0.135
53	*Digitaria abyssinica (A.Rich.) Stapf*	Ura(O)	Poaceae	P	85	2.92	2.22	2.5
54	*Matricaria chamomilla* L.	Kamomela(A	Asteraceae	A	11.5	1.02	0.8	0.145
55	*Digitaria horizontalis Willd.*	NF	Poaceae	A	11.5	0.9	0.7	0.13
56	*Leucasmartinicensis* (Jacq) R.Br	Bokuferda(O	Labiatae	A	27.5	0.85	0.67	0.29
57	*Digitaria sanguinalis (L.) Scop.*	NF	Poaceae	A	12	0.87	0.68	0.13
58	*Lantana camara* L.	Yewof kolo	Verbenaceae	P	14	1.47	1.16	0.21

Table 3. Contd.

59	*Digitaria ternata (A.Rich.) Stapf*	Hufe(O)	Poaceae	P	24	1.25	0.98	0.31
60	*Ipomoea hederifolia L.*	NF	Convolvulaceae	A	18.5	1.26	0.97	0.3
61	*Digitaria velutina (Forssk) P, Beauv.*	Shubo(O)	Poaceae	A	19	1.14	0.93	0.235
62	*Ipomoea cordofana* Choisy in DC.	NF	Convolvlaceae	A	23.5	1.36	1.08	0.315
63	*Echinochloa crus-galli (L.) P.Beauv.*	Asandawa(A	Poaceae	A	39	2.01	1.52	0.97
64	*Ipomoea carica* (L) Sweet	NF	Convolvulaceae	A	15.5	1.05	0.84	0.16
65	*Echinochloa colona (L.) Link*	NF	Poaceae	A	16.5	1.35	1.06	0.22
66	*Ipomoea acuminate (*Vahl) Roem and Schultes	NF	Convolvulaceae	A	17.5	1.08	0.87	0.17
67	*Eleusine indica (L.) Gaertn.*	NF	Poaceae	A	10.5	1.15	0.93	0.12
68	*Indigo feraspicata* Forssk.	Ye'ayitmisir (A)	Fabaceae	P	17.5	0.93	0.77	0.205
69	*Eragrostis cilianensis (All.)Vign. ex Janchen*	NF	Poaceae	A	20	1.52	1.16	0.365
70	*Heliotropium cinerascens* DC and ADC	Banganapsi(O)	Boraginaceae	A	15	0.95	0.75	0.18
71	*Eriochloa fatmensis (Hochst. & Steud.) Clayton*	NF	Poaceae	A	15.5	1.22	0.98	0.185
72	*Guizotia scabra(Vis) Chiov.*	NF	Asteraceae	A	20.5	1.93	1.05	0.36
73	*Euphorbia heterophylla L.*	NF	Euphorbiaceae	A	18	1.12	0.9	0.195
74	*Galansoga parviflora Cav.*	Ye shwaarem(A)	Asteraceae	A	27.5	1.34	1.11	0.46
75	*Euphorbia hirta L.*	NF	Euphorbiaceae	A	21.5	1.44	1.12	0.31
76	*Euphorbia thymifolia L.*	NF	Euphorbiaceae	A	23	1.69	1.37	0.34
77	*Euphorbia indica Lam.*	NF	Euphorbiaceae	A	21	1.27	1.01	0.265
78	*Xanthium strumarium L.*	Metene	Asteraceae	A	36	1.83	1.41	0.93

LC = Life Cycle; F = Frequency; A = Abundance; D = Dominance; D' = Density.

habitats. Khan et al. (2013) and Kilewa and Rashid (2013) indicated that invasion and distribution of Parthenium weed could be due to ecological and morphological characteristics of the weed that enable it to adapt a wide climatic and soil conditions, photo insensitivity, and drought tolerance. According to Tessema et al. (2010) and Hundessa et al. (2016), Parthenium grow in different habitats from hot arid and semi-arid low altitude to humid high-mid-altitude (900 to 2500 m). It flourishes on any type of soil (sandy, loamy or clayey) (Tessema et al., 2010) and in different habitats, that is, roadsides, rangelands, crop fields (Tessema et al., 2010; Hundessa et al., 2016), wastelands, villages, gardens (Niguse Hundessa et al., 2016), national park, water ways, bank of rivers, urban green spaces, grasslands, bush lands and forestlands, crop field borders and urban settings (Hundessa et al., 2016) indicating its adaptability to different climate and soil types (Tessema et al., 2010; Hundessa et al., 2016). The noxious weed *P. hysterophorus* expanded in horrible rate in most districts of East Shewa (Hundessa et al., 2016), which is a region where the Study District is located. Conversely, *P. hysterophorus* (15.72) followed by *Cassia tora* (13.49) had the highest average abundance in the study area, while *Bidens pilosa* was a species with the lowest abundance value of 0.6 (Table 3). Apart from this, *Cynodon dactylon* and *Argemone Mexicana* revealed sizable mean abundance (over the Study Area) of 6.16 and 5.27, in that order, with the corresponding higher values observed in Tiyo (10.81 and 10.53, respectively) and Sifa (8.97 and 9.46, respectively) Kebeles. Notably, the *P. hysterophorus* exhibited relatively lower abundance in the aforementioned Kebeles (Tiyo and Sifa). Nkoa et al. (2015) indicated that the weed abundance is associated with density or frequency, and hence, Maszura et al. (2018) suggested density and frequency could influence the abundance positively in their study. Species

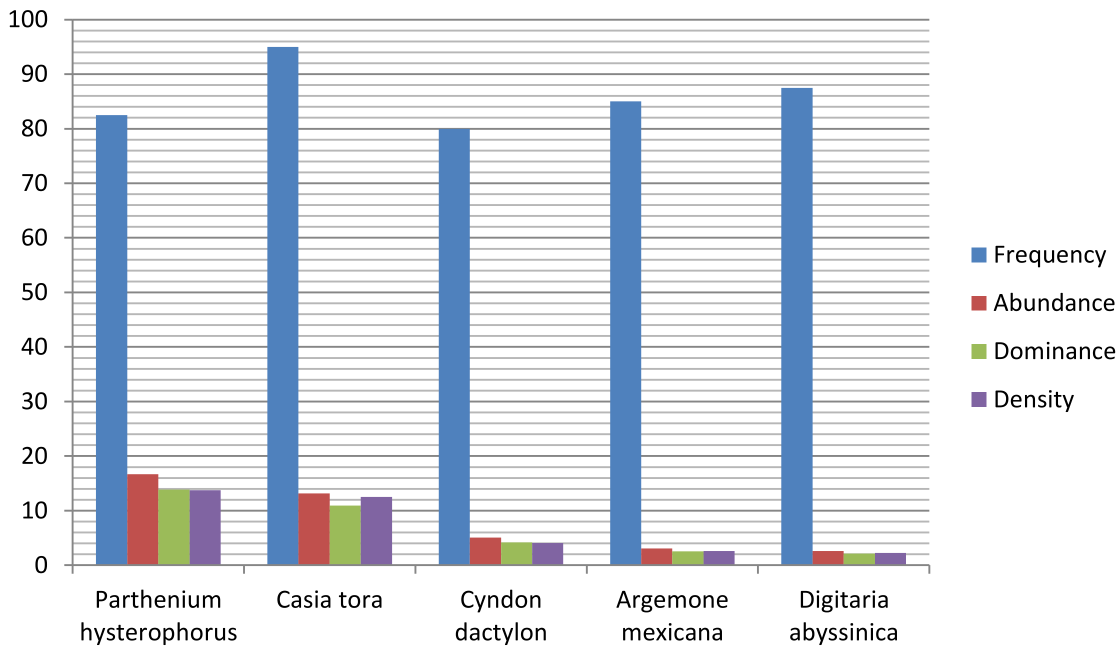

Figure 2. Frequency, abundance and dominance of the top five herbaceous plants identified from Bekektu Kebele.

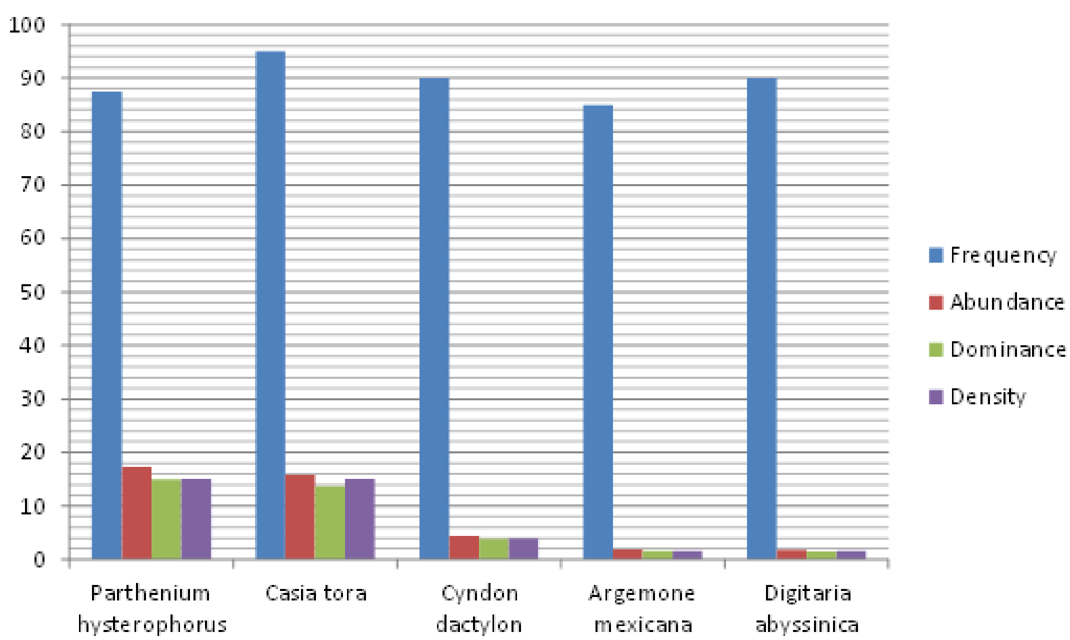

Figure 3. Frequency, abundance and dominance of the top five herbaceous plants identified from Digalu Kebele.

depending on frequency values distribution and abundance can vary both temporally and spatially, and may therefore, differ regionally in response to the species life history, habitat characteristics, resource availability as well as based on natural and anthropogenic disturbances (Banerjee and Srivastava, 2010). Moreover, sound knowledge on species abundance is also requisite for the efficient management of introduced generalist species, which may live in a wide range of environmental conditions (Banerjee and Srivastava, 2010). As in the

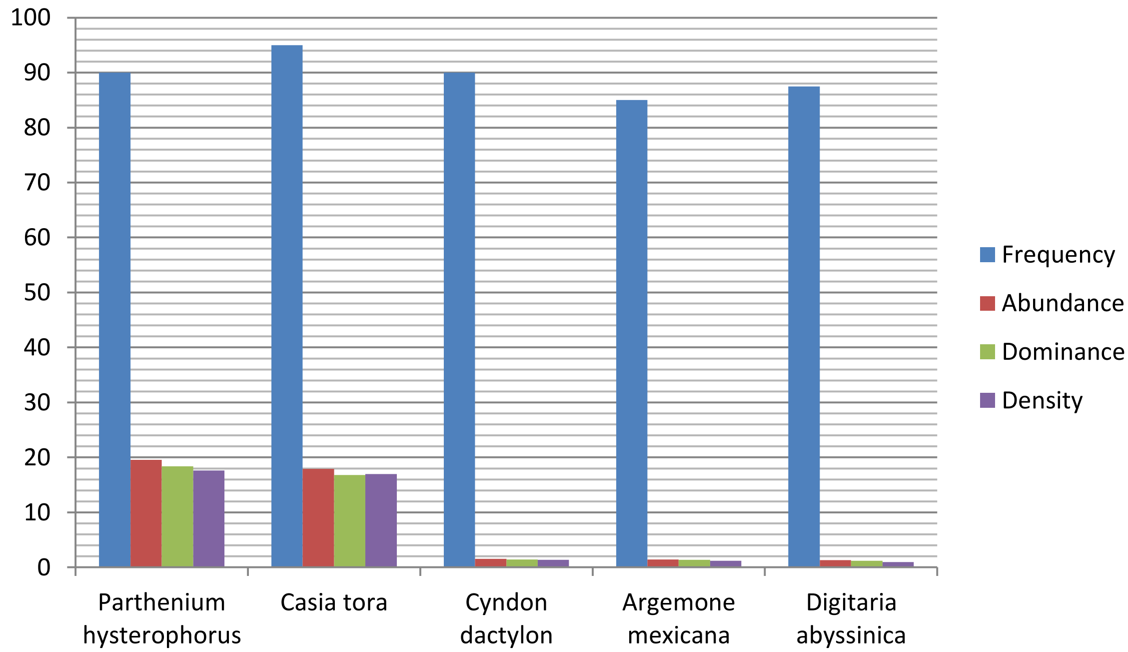

Figure 4. Frequency, abundance and dominance of the top five herbaceous plants identified from Merko Kebele.

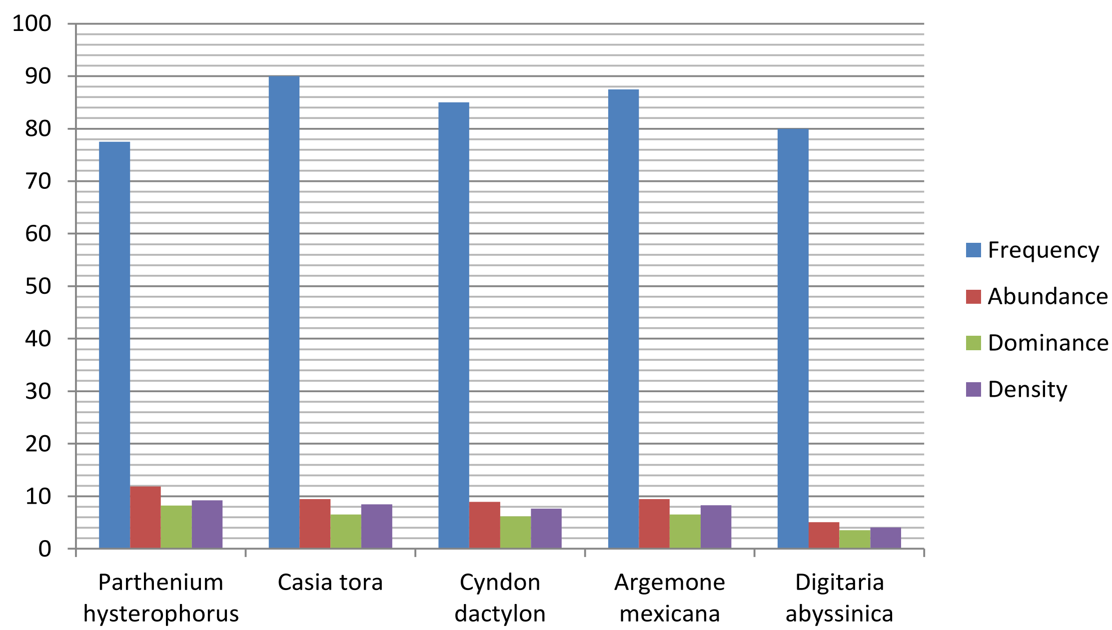

Figure 5. Frequency, abundance and dominance of the top five herbaceous plants identified from Sifa Kebele.

case with abundance, *P. hysterophorus* surpassed the weeds observed in the present study in terms of the average density (13.25) and dominance (12.9). Likewise, *Cassia tora* followed by *Cynodon dactylon*, *Argemone mexicana* and *Digitaria abyssinica* showed relatively higher mean values of density (12.62, 5.41 and 4.64, respectively) and dominance (11.1, 4.6 and 3.83, respectively). As with frequency and abundance, dominance and density of *Parthenium hysterophorus* (as well as other common weeds) varied between the study

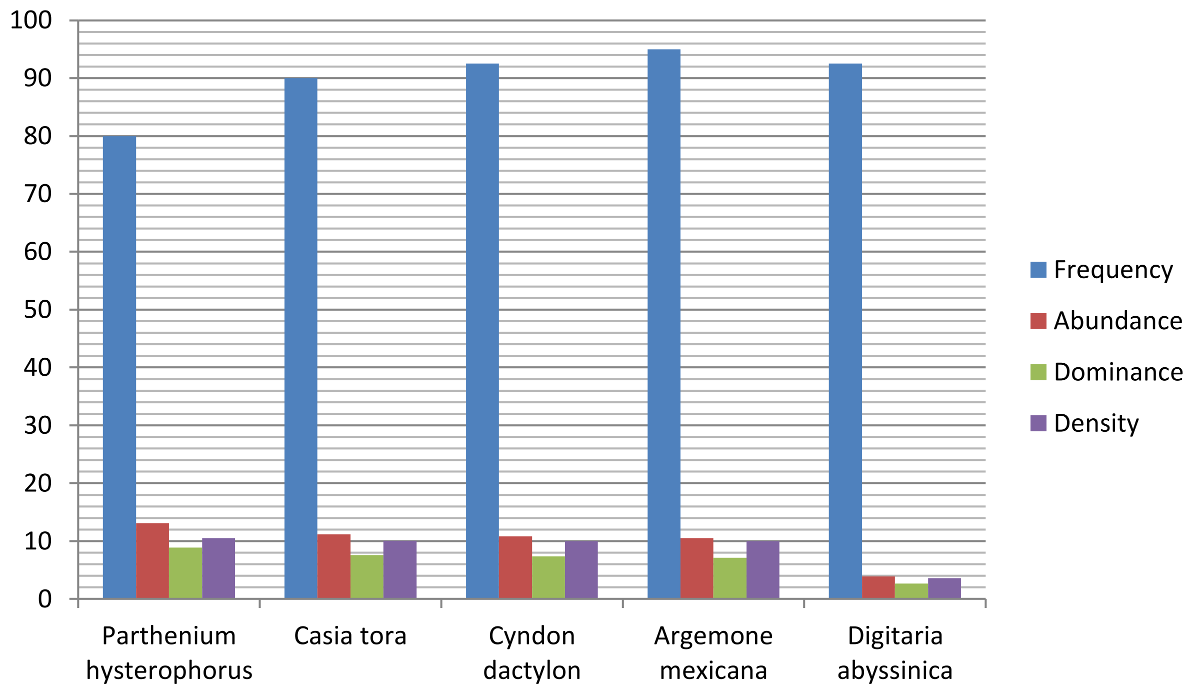

Figure 6. Frequency, abundance and dominance of the top five herbaceous plants identified from Tiyo Kebele.

Kebeles with the highest recorded density and dominance found in Merko (17.63 and 18.37) followed by Digalu (15.12 and 15) and Bekektu (13.75 and 13.85). Density, which measures the strength of species in the community, is considered as one of key important character in determining community structure (Banerjee and Srivastava, 2010). On the other hand, Parthenium is one of the major dominant invader weed (Hundessa et al., 2016). Likewise, Bufebo and Elias (2018) indicated that Parthenium has become the most dominant weed in much of the low lands of Wello (Ethiopia), which agroclimatically correspond to the study area. Moreover, in their study in the Gamo Gofa area, Ethiopia, Gebrehiwot and Berhanu (2015) reported that Parthenium weed was highly dominant species. In a similar vein, Khan et al. (2013) pointed out that in rangelands, and roadsides, dominance of Parthenium weed over other weeds was conspicuous.

On the contrary, Sifa and Tiyo revealed comparatively lower density and dominance of the *P. hysterophorus* in the present study (Figures 2 to 6). Although diverse factors (perhaps the interplay among the factors) could account for the variation in the density of *Parthenium hysterophorus*, the discrepancy in weed densities might be due to natural selection (Maszura et al., 2018). As to the graphs depicting the frequency, abundance, and dominance of the five prevalent weed species across the Kebeles studied, *Cassia tora* had the highest frequency in all except Tiyo (Figures 2 to 6). Apart from this, when averaged over the study area, the selfsame species still maintains high degree of dispersion (average 93%) followed by *Argemone mexicana* (87.5%) and Cynodon dactylon (87%). On the contrary, it is worth noting that *Parthenium hysterophorus* stood out in terms of both abundance and dominance in every kebele (Figures 2 to 6). The closest rival to Parthenium weed in Abundance as well as Dominance is *C. tora*. Besides, *Cynodon dactylon* and *Argemone mexicana*, particularly in Tiyo and Sifa, revealed their relative presence in terms of either abundance or dominance (Figures 2 to 6). The higher frequency, abundance, and dominance values of *C. tora, Argemone mexicana, and Xanthium strumarium* (Figures 2 to 6) suggested that these species can grow in competition with *Parthenium*. The survey conducted in India by Wahab (2005), also showed that species like *C. tora, C. auriculata, H. suaveolens,* and *M. jalapa* suppressed *Parthenium* in natural habitats.

Impact of Parthenium weed on herbaceous species diversity

As is presented in Table 4, Sifa Kebele had the highest total number and average number of herbaceous species which was followed by Tiyo Kebele. In contrast, Merko accommodated the least total number and average number of species (Richness) in the present study. Although the mean Richness of herbaceous species of Sifa exceeds that of Tiyo, the same were statistically comparable ($P > 0.05$). Besides, both Kebeles revealed statistically higher average ($P < 0.05$) Richness of herbaceous species than the other three Kebeles (that is,

Table 4. Mean ± SD of Richness, Evenness, and Shannon diversity of different herbaceous plant species in the 5 Kebeles studied.

Kebele	Number of Quadrats	Total Number of Species	Richness	Evenness	H´
			Mean ± SD	Mean ± SD	Mean ± SD
Bekektu	40	68	50.6±8.09 [a]	0.63±0.06[a]	2.65±0.17 [a]
Digalu	40	67	51.1±8.98 [a]	0.59±0.04[b]	2.47±0.15[b]
Merko	40	65	47.3±9.10 [b]	0.49±0.04[c]	2.07±0.16 [c]
Sifa	40	74	63.3±5.39 [c]	0.70±0.05 [d]	2.99±0.40 [d]
Tiyo	40	70	60.6±4.76 [c]	0.64±0.03 [a]	2.74±0.07 [e]

H´ represents Shannon Diversity Index. Means with different superscript letters are significantly different ($P<0.05$).

Bekektu, Digalu and Merko). On the other hand, the mean Richness values of Bekektu and Digalu were not statistically different ($P > 0.05$), but both Kebeles had significantly higher average Richness than Merko Kebele (Table 4).

Sifa revealed the highest values for Evenness (E) and Shannon Diversity Index (H') that were significantly different ($P < 0.05$) from the same in other Kebeles (Table 4). In Merko, on contrary, appraisal on Evenness and Diversity showed the lowest mensurations which were significantly different ($P < 0.05$) from the rest. Although Bekektu and Tiyo revealed statistically similar ($P > 0.05$) mean Evenness values, the same had significantly different Shannon Diversity Index (H’). In this regard, it is worth noting that the average Species Richness of Bekektu and Tiyo Kebeles differed significantly, which could have contributed to the significant variation in terms of H’. Conversely, Bekektu and Tiyo Kebeles had Evenness and Shannon Diversity Index that differed significantly ($P < 0.05$) from other Kebeles (Table 4). As Table 4 presents, Digalu and Merko exhibited statistically different ($P <0.05$) mean E and H' values. The abovementioned results regarding the effect of Parthenium on Diversity parameters are consistent with Qureshi et al. (2018) who reported that Parthenium invasion exhibited variable impacts across districts and invasion status by reducing Species Number per Plot (S), Species Richness (R), Species Evenness (J'), and Shannon Index of Diversity (H'). Similarly, Kumar (2014) noted that there was a sharp decline in the native Biodiversity Index, Evenness and Species Richness over the time, clearly indicating the threat of Parthenium on native biodiversity of other weeds. Besides, Tafese (2015), and Abdulkerim-Ute and Legesse (2016) indicated that Parthenium has the capacity to decrease the composition and diversity of plant species. According to Masum et al. (2013), Teka (2016), and Qureshi et al. (2018), Parthenium weed is known to exert significant impact on the natural communities as they cause their displacement and hence exert imbalance in the natural and agricultural ecosystems. Parthenium weed rapidly invades new surroundings and often replaces the indigenous species and pose a serious threat to biodiversity (Khan et al., 2013). Infestation of Parthenium weed can degrade natural ecosystem because it has a very high invasive capacity and allelopathic properties which has the potential to disrupt any type of natural ecosystem (Kumar, 2014).

Wide environmental adaptability, drought tolerance, photo and thermo-insensitivity (Khan et al., 2013; Qureshi et al., 2018), high seed production (Abdulkerim-Ute and Legesse, 2016; Qureshi et al.,2018), short life cycle (being an annual) (Qureshi et al., 2018), small and light seeds capable of long distance travel via water (Abdulkerim-Ute and Legesse, 2016; Qureshi et al., 2018), wind, birds (Qureshi et al., 2018), animals and vehicles (Abdulkerim-Ute and Legesse, 2016; Qureshi et al., 2018), machinery, stock feed (Abdulkerim-Ute and Legesse, 2016), longevity of seeds in soil seed banks, strong competition and allelopathy contribute to the invasiveness of Parthenium weed (Qureshi et al., 2018).

The impact of Abundance of Parthenium weed on the Species Richness of the five study kebeles is graphically presented in Figure 7. The same figure laid it bare that Species Richness of herbaceous flora and Abundance of Parthenium weed had significant negative association ($P = 0.006$) with the slope (b) = -1.046. Besides, $R^2 = 0.93$, which is the Coefficient of Determination, indicates that 93% of the variation in the Species Richness is explained by the Model ($Y = -1.04644X + 85.2428$) and hence, 93% of the variation in Species Richness is due to the Abundance of Parthenium Weed in the Study Kebeles. Furthermore, the R, which is the square root of the R^2, depicts the Linear Correlation between the Observed and the Model Predicted values of the Species Richness where its large value (that is, $0.93^{1/2} = R = 0.96$) represents strong relationship between them. Moreover, the significance value of the F-Statistic ($P < 0.05$) from the ANOVA test revealed that the variation explained by the model ($Y = –1.04644X + 85.2428$) is not due to chance or it is real. Consequently, there is a strong negative correlation ($P < 0.05$) between the Richness of Herbaceous Flora and the Abundance of Parthenium weed in the study kebeles (Figure 7). In a similar vein, Seta et al. (2013) found that there was a high negative correlation between mean Parthenium Density and Shannon Diversity Index with $R^2 = 0.89$, $p < 0.001$, which portrays the effect of Parthenium on the biodiversity of

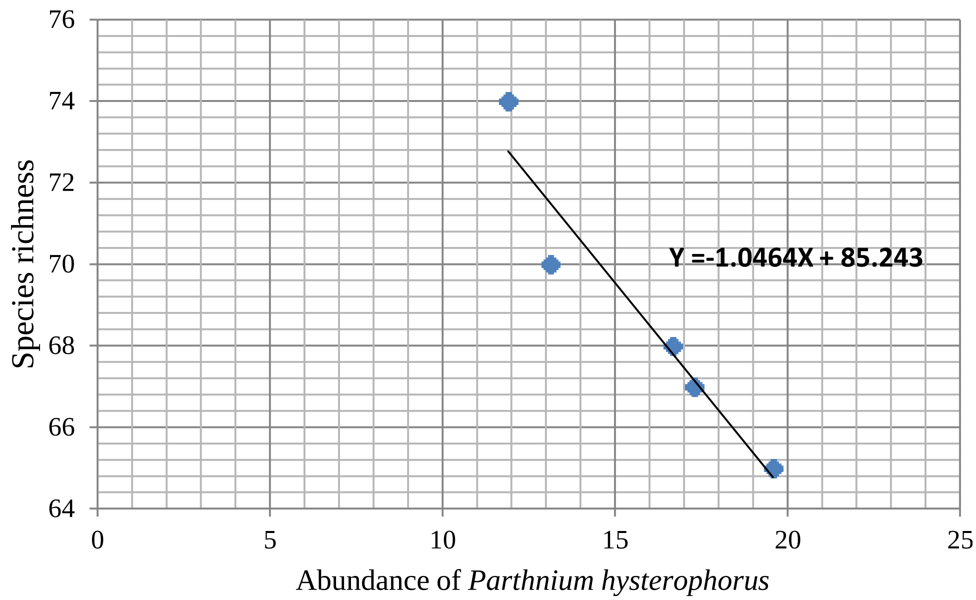

Figure 7. The effect of abundance of Parthenium weeds on species richness of herbaceous flora in the five kebeles of the present study. P = 0.006; R2 =0.93; Slope (b) = -1.046.

Table 5. Jaccard's coefficient of similarity (Similarity Index) of herbaceous plant community in the study Kebeles of Boset Woreda.

	Bekektu	Digalu	Merko	Sifa	Tiyo
Bekektu	1				
Digalu	0.85	1			
Merko	0.80	0.82	1		
Sifa	0.78	0.76	0.72	1	
Tiyo	0.79	0.77	0.75	0.87	1

plants.

Invasive and Alien Species (IAS) can impact Species Diversity, Richness, Composition, Abundance and Interactions (including Mutualisms) (Reaser et al., 2007). Likewise, Shiferaw et al. (2018) indicated that Introduced invasive species could decrease habitat complexity which tends to engender a reduction in abundances and/or species richness (Shiferaw et al., 2018). These processes can eventually cause population declines and resultant species extirpations and extinctions (Reaser et al., 2007). Consequently, Invasive Alien Species (IAPS) pose a global threat to the conservation of biodiversity through their proliferation and spread, displacing or killing native flora and fauna (Shiferaw et al., 2018) and affecting ecosystem services (Bufebo and Elias, 2018; Shiferaw et al., 2018), reducing native species abundance and richness, and decreasing genetic diversity of ecosystems (Bufebo and Elias, 2018).

Similarity in composition of herbaceous species

Similarity index was also calculated as it explains the similarity of plant species composition among different study Kebeles in Boset Woreda. The result showed a similarity index value of 0.72 to 0.87 among the study kebeles (Table 5). The higher (0.87) and lower (0.72) similarities were observed between Sifa/Tiyo and Merko/Sifa, in that order. As indicated by Adane Kebede (2008), if the similarity index is below 60%, it is said that the two locations or soil types have different weed communities. Belachew and Tessema (2015) stated that when the similarity indices for the dissimilar locations exceed 60%, it can be reasoned that the locations display comparable weed community, which hence makes it possible to employ similar weed management decisions/ alternatives.

Socioeconomic impacts of Parthenium weed

Characteristics of respondents involved in the study

Table 6 presents information gathered about respondents regarding their age, sex, educational (for all Informants), work experience, household size, livelihood activities and

Table 6. Characteristics of Informants that participated in the study.

Characteristics of the informants		Farmers		DAs		WEs		Vets		HWs	
		F	%	F	%	F	%	F	%	F	%
Sex	Male	110	100	9	90	4	100	4	100	3	75
	Female	0	0	1	10	0	0	0	0	1	25
Age (years)	18-30	0	0	6	60	1	25	1	25	1	25
	31-40	0	0	2	20	1	25	2	50	3	75
	41-50	0	0	2	20	2	50	1	25	-	-
	51-60	31	28.2	0	0	0	0	0	0	-	-
	61-70	32	29.1	0	0	0	0	0	0	-	-
	71-80	39	35.4	0	0	0	0	0	0	-	-
	>80	8	7.3	0	0	0	0	0	0	-	-
Education	Illiterate	47	42.7	0	0	0	0	0	0	-	-
	Read and write	39	35.5	0	0	0	0	0	0	-	-
	Primary education	18	16.4	0	0	0	0	0	0	-	-
	Secondary education	6	5.4	0	0	0	0	0	0	-	-
	Level Ш	0	0	3	30	0	0	0	0	-	-
	Diploma	0	0	2	20	0	0	1	25	-	-
	B.Sc.	0	0	5	50	4	100	3	75	4	100
Work experience (Years)	1-5	-	-	0	0	0	0	0	0	-	-
	6-10	-	-	0	0	0	0	1	25	1	25
	11-15	-	-	6	60	1	25	1	25	2	50
	16-20	-	-	3	30	1	25	1	25	1	25
	>20	-	-	1	10	2	50	1	25	-	-
Household size (Number)	1-3	35	31.8	-	-	-	-	-	-	-	-
	4-6	55	50.0	-	-	-	-	-	-	-	-
	>6	20	18.2	-	-	-	-	-	-	-	-
Livelihood activities	Farming only	20	18.2	-	-	-	-	-	-	-	-
	Animal husbandry	8	7.3	-	-	-	-	-	-	-	-
	Mixed farming	82	74.5	-	-	-	-	-	-	-	-
Other income sources	Firewood/charcoal selling	14	12.7	-	-	-	-	-	-	-	-
	Petty trade	52	47.3	-	-	-	-	-	-	-	-
	Daily labor work	44	40.0	-	-	-	-	-	-	-	-

DA: Development Agent; WE: Woreda Crop Extension Experts; Vets: Veterinarians; HW: Health Workers.

other income sources (for selected farmers). Most of the study participants were males. While the Farmers were >50 years old, the other respondents (DAs, Woreda Agricultural Experts, Veterinarians, and Health Professionals) were < 50 years of age. Conversely, the educational level of farmers extends from those that were Illiterate up to the secondary educational level whereas the other informants had Level III to B.Sc. (College/University). Education is fundamental to appreciate the newly emerging problems and their impacts and it is reckoned as one of the most crucial factors that impinge on the dissemination and adoption of new technologies (Hundessa and Belachew, 2016).

Although most of the farmers (78.2%) who participated in the present study were illiterate (42.7%) or just can only read and write (35.5), which coincided mainly with age group above 50, they are generally regarded as an important repository of traditional knowledge and wisdom as well as know the area pretty well than their younger counterparts. As to Hundessa and Belachew (2016), Age is essential in the appraisal of the year at which Parthenium was first introduced as well as to examine

Table 7. Informants view on the impacts of *P. hysterophorus* on crop production.

Type of impact	A (F)	A (%)	B (F)	B (%)
Yield reduction	62	56.4	8	80.0
Intensive labor requirements	81	73.6	9	90.0

F = Frequency; A = Number/Percentage of Farmers; B = Number/Percentage of DAs.

and note the differences of the problems and impacts before and after the weed introduction.

Most of the Government employed Respondents garnered over 10 years of experiential knowledge (Table 6). 81.8% of the farmers had a household size < 7, with a size of 4 to 6 accounting for half of the total. On the other hand, most of the farmers (74.5%) made known that they depended on mixed farming for their livelihood, which is quite typical of the farming communities in the rural parts of Ethiopia. Apart from this, the off-farm income is mainly derived from petty trade (43%) and working as daily laborer (40%).

Crop production

Impacts of *Parthenium* weed on crop production: A little more than a half (56.4%) of farmers and 80% of development agents (DAs) considered that the infestation of *Parthenium* weed cause yield reduction (Table 7). In general, the responses of the study participants could have been influenced by the distribution of the weed in the Agricultural Fields. As noted during the field observation, the infestation of Parthenium weed in the cropped area varied from field to field depending on the time of its introduction into the area and the efforts made by the farmers to control the weed with heavy infestation of Parthenium weed was observed along the margins of the field crops. Conversely, the issue of yield reduction proceeding from the Parthenium weed was appreciated by all Woreda Agricultural Experts as well as by most of the participants of the FGD. As to Adkins and Shabbir (2014), Parthenium weed is capable of invading a variety of crops including those cereals which are the major crops cultivated in the study area namely, wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), Tef (*Eragrostis tef* Zucc. Trotter) and sorghum (*Sorghum bicolor* L.). Self-same authors indicated that Parthenium weed has been shown to decrease yields by as much as 40% in India and by as much as 28% in Ethiopia. Apart from this, Masum et al. (2013) pointed out that leaf aqueous extracts of *P. hysterophorus* revealed substantial inhibitory effects on seed germination and seedling growth of three cereal crops, that is, *Oryza sativa, Triticum aestivum* and *Zea mays*; but also three Crucifer vegetables, that is, *Raphanus sativus, Brassica campestris, Brassica oleraceae*, and two Asteraceae species, that is, *Ageratina adenophora* and *Artemisia dubia.* On the other hand, most of the Farmers (73.6%) and DAs (90%) believed that Parthenium impinges on the crop production by way of the intensive labor requirement that is needed to deal with crop fields affected by the weed (Table 7). Likewise, discussants who participated in the FGD and Woreda Agricultural Experts intimated similar issues pertaining labor requirement to the impact of Parthenium on the crop production. Accordingly, most discussants and agricultural experts conceived that Parthenium weed affected crop production by suppressing growth, reducing moisture of the soil, poor grain fill, and ultimately resulting in yield loss.

Several studies (Tamado, 2001; Tamado et al., 2002; Masum et al., 2013; Kumar, 2014; Abdulkerim-Ute and Legesse, 2016; Teka, 2016; Mekonnen, 2017) have indicated about the losses of yield of a variety of crops ascribed to the Parthenium weed. Parthenium weed can infest the land where cereals, vegetables and horticultural crops found and reduce agricultural productivity due to its allelopathic effect (Tefera, 2002; Nihanthan et al., 2013; Abdukerim- Ute and Legesse, 2016; Shikha and Jha, 2016; Shinde, 2016). Field crops: [Maize (*Zea mays* L.), Sorghum (*Sorghum bicolor* L. Moench), Finger Millet (*Eleusine coracan* L. Gaertn.), Cotton (*Gossypium hirsutum* L.), *Haricot Bean* (*Phaseolus vulgaris* L.), Tef (Eragrostis tef Zucc. Trott.], Vegetables [Potato (*Solanum tuberosum* L.), Tomato (*Lycopersicon esculentum* Mill.), Onion (*Allium cepa* L.), Cabbage (*Brassica oleracea* L.), and Carrot (*Daucus carota* L.)], and Orchards [Citrus (*Citrus spp*.), Mango (*Mangifera indica* L.), Papaya (*Carica papaya* L.) and Banana (*Musa spp*.)] were found to be infested by Parthenium (Tessema et al., 2010). Parthenium weed is known to be allelopathic with root and shoot leachates and is capable of reducing growth and germination of numerous crops (Kumar, 2014). Parthenium has Parthenin, Hysterin, Hymenin, and Ambrosin, and attributable to these chemicals, it exerts strong allelopathic effects on different crops (Kaur et al., 2014). Parthenin has been reported as a germination and radical growth inhibitor in a variety of dicot and monocot plants (Kaur et al., 2014).

Crop losses are engendered mainly due to allelopathic effects (Abdulkerim-Ute and Legesse, 2016) and its capacity to compete (Kumar, 2014; Abdulkerim-Ute and Legesse, 2016) for common resources like nutrients and moisture and its competitive nature is relatively very much higher than expected from a similar crop weed (Abdulkerim-Ute and Legesse, 2016). Besides, the effect of Parthenium crop productivity stems from the huge

Table 8. Types of impacts of *P. hysterophorus* on livestock production as perceived by key informants.

Type of impact	Number of farmers	(%)	Number of DAs	(%)
Spoil the quality of milk and meat	62	56.4	6	60
Encroaching grazing lands and suppressing grass species	34	30.9	8	80
Effects on livestock health	55	50	7	70

amount of Pollen it produces (Kaur et al., 2014; Kumar 2014; Teka, 2016), on an average 624 million/plant, which are carried away at least to short distance in clusters of 600 to 800 grains, and settles on the vegetative and floral parts (Kaur et al., 2014), including stigmatic surface of other plants and eventuates in inhibition of fruit or seed setting (Kaur et al., 2014; Kumar, 2014; Abdulkerim-Ute and Legesse, 2016; Teka, 2016) in maize, tomato, beans, and capsicum (Kaur et al., 2014; Kumar, 2014; Teka, 2016).

Livestock production (livestock production and health)

Impacts on animal health: As to the Veterinarians involved in the present study, allergic skin reactions, anorexia, pruritus, dermatitis and diarrhea were the prevalent animal health problems in the study area. Parthenium is poisonous to livestock when it is consumed or repeatedly in contact with the weed (Tafese, 2015). Every plant parts of Parthenium at any stage of growth are toxic to livestock (Mekonnen, 2017). Parthenium toxicity to livestock entails allergic skin reactions (Kumar, 2014; Tafese, 2015), Alopecia (Kaur et al., 2014; Kumar, 2014; Mekonnen, 2017), dermatitis (Knox and Paul, 2013; Masum et al., 2013; Kaur et al., 2014; Kumar, 2014; Tafese, 2015; Mekonnen, 2017), anorexia (Kaur et al., 2014; Kumar, 2014; Tafese, 2015; Mekonnen, 2017), Pruritus (Kaur et al., 2014; Tafese, 2015; Mekonnen, 2017), diarrhea (Kaur et al., 2014; Kumar, 2014; Tafese, 2015; Mekonnen, 2017), become highly emaciated (Knox and Paul, 2013), and death in extreme cases (Knox and Paul, 2013; Kaur et al., 2014; Kumar, 2014; Tafese, 2015) such as due to rupturing and hemorrhaging of internal tissues and organs (Knox and Paul, 2013; Masum et al., 2013; Mekonnen, 2017).

According to the farmers and the discussants involved in the FGD, the animal health impacts of Parthenium prevail mostly during the wet season (Summer). As a rule, seeds of Parthenium can germinate during any season of the year if the moisture is available (Abdulkerim-Ute and Legesse, 2016). Saving the high moisture requirement during germination, there are no observable climatic conditions that could restrain the germination of Parthenium in Ethiopia (Tamado et al., 2002). Consequently, the moisture stress may be the key factor that may restrict the germination Parthenium seeds during the dry season (Abdulkerim-Ute and Legesse, 2016).

Impacts on livestock production: 56.4 and 60% of the farmers and DAs, respectively, expressed their feeling that the Parthenium weed could spoil the quality of Milk and Meat. Besides, virtually a third of informant farmers (30.9%) and 80% of the development agents observed that the weed has already colonized grazing fields, thus causing fodder/feed scarcity. Moreover, sizable proportion of the selfsame informants made known that the notorious weed may affect the livestock production through its effect on livestock health (Table 8). On the other hand, the Woreda Agricultural Experts revealed that *Parthenium* weed, due to infestation of the different land uses, could reduce livestock production by way of the toxic chemicals it releases (that inhibits the germination and growth of plants including pasture grasses and affects the health of the stock), reducing stock growth or by inflicting mechanical damage.

According to 30% of discussants in the focus group discussion, they have encountered milk having bitter taste at least once. Apart from this, 20% of them are aware of the fact that the weed is infringing the grazing areas, particularly in areas highly affected by the weed. Conversely, it was noted during the field observation that *P. hysterophorus* dominated some of the grazing lands in the most affected Kebeles. The hepatoxic allelochemical *Parthenium* adversely affects animal health, and the quality of milk (taste bitter) and meat (Shashie, 2007; Kaba, 2008). Although Parthenium is usually not grazed by cattle as it is not palatable due to its irritating odor, bad taste and presence of trichomes, stray cattle, however, are often forced to feed on this weed during periods of fodder scarcity, thereby resulting in impairment of both quality and quantity of milk (Kumar, 2014). In general, conversely, goats and sheep have been found browsing the plant (Mekonnen, 2017). However, leaves of Parthenium, whenever eaten, can result in tainted sheep (Masum et al., 2013; Kumar, 2014) and goat meat (Mekonnen, 2017) and make diary milk unpalatable due to its irritating odor (Masum et al., 2013; Kumar, 2014; Mekonnen, 2017). Besides, like the case with cattle, the weed can also reduce milk yield of the caprine animals (Mekonnen, 2017).

Parthenium reduces production of livestock by way of scarcity of animal fodder and through invading pasture lands as well as due to various animal health problems

(Tafese, 2015). Parthenium releases chemicals that inhibit the germination and growth of pasture grasses and other plants, which reduces the species biodiversity (Abdulkerim-Ute and Legesse, 2016), pasture carrying capacity (Abdulkerim-Ute and Legesse, 2016; Teka, 2016), forage productivity (Kumar, 2014; Abdulkerim-Ute and Legesse, 2016; Teka, 2016). Conversely, Adkins and Shabbir (2014) elaborated that Parthenium weed contains a number of potential allelochems which are not only poisonous to livestock, but also can alter the microbial composition of the rumen of the dairy cattle, which consequently can impart bitter taste to the milk and the meat. In line with the present findings, Shashie (2007), Karki (2009), Yadav (2010) and Adkins and Shabbir (2014) reported that Parthenium weed impacted the livestock production by affecting grazing land, animal health, milk and meat quality.

Human health: As to the Woreda Health Experts, health problems that are believed to be associated with Parthenium including allergic and irritating dermatitis and allergic reaction of the respiratory organs, particularly in those areas highly affected by the weed. Besides, the some of the most affected individuals manifest cough, sneezing, rhinitis, and enhanced lacrimal discharge (shedding tears). Conversely, when the issue of possible health impacts related to Parthenium was raised to discussants of the FGD and farmers, some of the discussants and 56% of the latter mentioned that some individuals could develop certain kind of skin allergies (allergic dermatitis), problems in the throat area associated with cough. Moreover, the DAs in the study Kebeles also intimated that they have received complaints from some farmers about health problems (dermatitis) during the weeding season.

Mekonnen (2017) pointed out that every part of Parthenium at any stage of growth is toxic to humans. Besides, when milk from the livestock grazed around Parthenium invaded grazing land could be hazardous to man (Masum et al., 2013). It has been established that Parthenium weed is related to health problems for some people living or working in close proximity to it (Masum et al., 2013). When humans come in contact with this weed, they may develop sensitivity to the plant which may then manifest as an allergy-type response (Kumar, 2014; Masum et al., 2013). The usual Allergens found in the weed are Parthenin, Coronopilin, Tetraneuris and Ambrosin (Kaur et al., 2014).

In human, the pollen grains, air borne pieces of dried plant materials, and roots of Parthenium (Masum et al., 2013; Kaur et al., 2014; Mekonnen, 2017) can cause allergy-type responses like photo-dermatitis (Masum et al., 2013; Tafese, 2015; Mekonnen, 2017), asthma (Tessema et al., 2010; Masum et al., 2013; Kaur et al., 2014; Kumar, 2014; Tafese, 2015; Abdulkerim-Ute and Legesse, 2016; Mekonnen, 2017), skin rashes (Kumar, 2014; Tafese, 2015; Mekonnen, 2017), peeling skin (Tafese, 2015; Mekonnen, 2017), puffy eyes (Tafese, 2015; Abdulkerim-Ute and Legesse, 2016; Mekonnen, 2017), excessive water loss (Tafese, 2015; Mekonnen, 2017), swelling and itching of mouth and nose (Tafese, 2015; Mekonnen, 2017), constant cough (Mekonnen, 2017), Rhinitis (Tessema et al., 2010; Masum et al., 2013; Kaur et al., 2014; Kumar, 2014; Tafese, 2015; Abdulkerim-Ute and Legesse, 2016; Mekonnen, 2017), eczema (Kumar, 2014; Tafese, 2015; Abdulkerim-Ute and Legesse, 2016; Mekonnen, 2017), severe contact dermatitis (Masum et al., 2013; Kaur et al., 2014; Kumar, 2014), allergic Bronchitis (Masum et al., 2013; Kaur et al., 2014; Tafese, 2015), black spots and blisters around eyes (Kumar, 2014; Abdulkerim-Ute and Legesse, 2016), burning rings and blisters over skin (Kumar, 2014; Abdulkerim-Ute and Legesse, 2016). Besides, Tessema et al. (2010) reported that the major allergenic symptoms caused by Parthenium were sneezing, coughing, running noses, itching of eyes and the skin, headaches, stomach ache and fatigue (Tessema et al., 2010). Moreover, Kumar (2014) indicated that Parthenium may induce increased allergic reaction to other plant species (cross sensitivity).

Farmers' perception and management of Parthenium weed

Farmers' perception on the first appearance of the weed

Regarding the time when the weed was introduced to the study area, interviewed key informant farmers varied considerably on their perceptions. However, all the informants knew the local name of the weed as it is called *Feremsisa* which means sign to leave the land. The majority (57.27%) of the informants had the perception that it was introduced to the areas 22 years ago (Table 9). During focus group discussion, significant number of participant farmers elaborated that Parthenium weed was introduced into their area following the Rail Way route from Dire Dawa to Addis Ababa in 1990s. Since then it expanded at alarming rate in all directions mainly following the main road. According to the informants, the weed was spread into the areas through vehicles during road construction and through different means since 1990s. In addition, construction materials had played a significant role for fast rate of dissemination/distribution of the weed. It was also noted that in the focus group discussion those local farmers having awareness about the early introduction of the weed to the area, had better elaboration and perception about the weed than those that perceived its recent introduction to the study area.

In line with this study, Tamado (2001) indicated that Parthenium weed was first reported from Ethiopia in 1988 at Dire Dawa and Hararge, subsequently spreading through the Eastern route of Ethiopia particularly along Dire Dawa-Addis Ababa railroad line. On the other hand, Seta et al. (2013) reported that the first appearance of

Table 9. Year of infestation of *P. hysterophorus* (%) as perceived by key informants (Farmers, n = 110) in the study Kebeles of Boset Woreda.

Year	Frequency	Percent
1991	9	8.2
1996	63	57.3
2001	32	29.1
2006	6	5.4

Table 10. Farmers' (n = 110) view of the first appearance of Parthenium weed in the study area.

Land use type	Frequency	Percent
Grazing land	5	4.5
Roadside	97	88.2
Wasteland	8	7.3

Parthenium in Gedeo Zone (Ethiopia) was observed mainly in specific localities of Dilla town at the beginning of 2001 where donated food grain was stored and temporary station for grain carrying trucks.

Concerning the first appearance of the Parthenium in the study Kebeles, majority of the informant farmers (88.18%) indicated that the weed first came along mainly on the roadsides followed by wasteland and grazing land (Table 10). Likewise, all discussants agreed that the weed was first observed on roadsides. Conversely, the Woreda Agricultural Experts and the DAs elaborated that its first appearance on roadside could be due to transportation of sand and gravels from Parthenium infested area to non-infested area for the purpose of construction and during grading of road verges. When discussants of the FGD were inquired about the possible ways for introduction of the weed such as soil transported from somewhere else to the areas for what so ever reason, a couple of them pointed out that certain vehicles came up loading livestock with some amounts of sands to keep their balance and the trucks might have shed sand in the areas during loading and unloading of the livestock.

In agreement with the present study, Niguse Hundessa et al. (2016), in their study on the Distribution and Abundance of Parthenium in East Shewa and West Arsi Zones of Ethiopia, found that the invasion of Parthenium was first perceived on roadside, which later radiated to different habitats and expanded at alarming rate in all directions. In a similar vein, Seta et al. (2013) also reported that most Parthenium invasion was observed along roadsides of town due to long distance dispersal of the seed by the vehicles and farm implements. The same authors maintained that the weed seeds may have arrived with introduced grain and vehicles that carry the grain.

Informants' perception on infestation levels and agents of weed dispersal

In congruence with the case with the first appearance of the weed, 96.43 and 86.59% of the informant farmers in high (Digalu and Merko) and moderate (Bekektu, Sifa, and Tiyo) infested Kebeles, respectively, perceived that Parthenium weed to be denser along the roadsides followed by Wastelands. Likewise, all Development Agents from both infestation levels recognized that dense infestations, principally on roadsides, but in the wastelands as well. Conversely, the farmers and DAs made known that cultivated lands, grazing lands, and river banks were land uses that were also considerably infested by Parthenium (Table 11). Corresponding information acquired from FGD also depicted that roadsides and wastelands support dense Parthenium vegetation. In addition, the Woreda Agricultural Experts clearly indicated that barren lands, roadsides, fallow farmlands, and grazing lands were highly invaded, especially in high infestation Kebeles. Apart from this, during direct field observation, it was noted that Parthenium weed population was high in places where the soils were disturbed constantly for purposes of construction of road and hence the weed prevailed along the roadsides, rangelands, as well as on wastelands. This observation is in line with reports from Masum et al. (2013), and Kassa (2016), who reported that *Parthenium* can adjust heavily to disturbed and barren or uncultivated lands from their study areas. Besides, Seta et al. (2013) reported that the Farmers placed Parthenium first attributable to its high spread and invasion observed on roadsides and margin of farmlands. Tessema et al. (2010) noted that, Parthenium was observed to thrive on roadsides, vacant sites, towns, villages, gardens,

Table 11. Informants' perception on the dispersal status of *Parthenium.*

Abundance of *Parthenium* weed in different habitats	Infestation level							
	High				Moderate			
	A (F)	A (%)	B (F)	B (%)	A (F)	A (%)	B (F)	B (%)
Grazing land	19	67.86	2	50	51	62.20	3	50
Cultivated land	22	78.57	2	50	61	74.39	4	66.67
Roadside	27	96.43	4	100	71	86.59	6	100
Wasteland	25	89.29	3	75	69	84.15	6	100
River banks	17	60.71	2	50	44	53.66	2	33.33

High infestation level: Kebeles = Digalu and Merko; = Number of Farmers = 28; and Number of DAs = 4. Moderate infestation level: Kebeles = Bekektu, Sifa, and Tiyo; Number of Farmers = 82; Number of DAs = 6. A = Farmers; B= DAs; F=Frequency.

Table 12. Informants' perception on agents facilitating dispersal of *Parthenium* from place to place.

Agents for the spread of the weed	Infestation level							
	High				Moderate			
	A(F)	A (%)	B (F)	B (%)	A(F)	A %)	B (F)	B (%)
Through fodder	13	46.43	2	50	64	78.05	3	50
Animal movement	19	67.86	2	50	75	91.46	3	50
Transport of construction materials	16	57.14	3	75	72	87.80	5	83.33
Seed	18	64.29	3	75	73	89.02	4	66.67
Wind	21	75	3	75	76	92.68	5	83.33
Flood	27	96.43	4	100	77	93.90	6	100

waterways, grasslands and in crop fields both during the crop season and after harvest so long as enough moisture is available.

Table 12 reveals that 96.43% of the Farmers from high infestation areas and 92.90% of those from moderate infestation areas responded that flood is the most important means for the fast dissemination of *Parthenium* weed. Apart from this, the farmers also put across that wind, animal movement, seeds (of other crops), and transport of construction materials as agents of dispersal for Parthenium. This response was confirmed by DAs from both infestation levels as well as from the overall consensus reached by discussants over the same issue during the FGD. Furthermore, the agricultural experts elaborated that of the various factors that promote fast distribution of the weed, flooding and transporting of construction materials like sand and soils are the major agents in the study area. In addition, the Woreda Agricultural Experts suggested that the high seed dispersal by the movement of vehicles might have helped the dispersal of the weed thereby contributing to severe infestation and invasion of *Parthenium* weed in the high infestation Kebeles.

On the other hand, the information acquired during the direct field observation also made evident that those spots along the flood course and mostly inundated areas have relatively high infestation compared to other nearby areas. In agreement to the present study, Hundessa and Belachew (2016) reported that the major agents for fast dispersal of *P. hysterophorus* in the East Shoa and West Arsi Zones, Ethiopia, include vehicles (65%), wind (55%), flood (46%), livestock (45%), seeds (41%) and construction materials (28%). Likewise, the study conducted by Kebede (2008) reported that flood and vehicle were the major dispersal agents of the weed. According to Beyene and Tessema (2015), farmers noted that *P. hysterophorus* was disseminated due to the movement of the cattle, by flood, with seeds by the farmers during market exchange and by wind. Seta et al. (2013) found that apart from the extensive dispersal of Parthenium seed which was mainly with introduced grain (food aid), the weed was dispersed by way of vehicle, farm implements, flood and animal movement.

Existing management practices of Parthenium weed

The result of the survey indicated that about 89.1% of the farmers and 90% of the development agents indicated that hand weeding is employed as a predominant cultural method followed by plowing and manual clearing to control the weed in the study Kebeles (Table 13). Besides, 11.8% of the farmers and 30% of the DAs acknowledged about the use of Herbicides to manage

Table 13. Informants' response on the type of measures to control dissemination of *Parthenium* weed.

Method of control of *Parthenium* weed	Farmer		DAs	
	Frequency	%	Frequency	%
Hand weeding	98	89.1	9	90
Oxen plowing	74	67.3	6	60
Manual/mechanical clearing	65	59.1	5	50
Herbicides	13	11.8	3	30

Parthenium weed. It is worth noting that literally no farmer is willing to spare the meager resource he has to be spent on purchasing herbicide/s exclusively meant for dealing with Parthenium. Notwithstanding, acting on the advice of the DAs and Woreda agricultural experts, some farmers have utilized those Herbicides (e.g., 2-4D) on cereals (e.g., Teff and maize) to control the broad-leaved plants/dicots, which could also contain Parthenium. Likewise, Agricultural Experts of the Woreda explained that *Parthenium* removal in Farmlands is mostly done by hand weeding; however, it is not feasible to carry out hand weeding for infested pastures and wastelands of wider coverage. On the other hand, the agricultural experts indicated that hand weeding and/or hoeing is not a permanent solution to control the invasions as the weed multiplies itself in the next crop season.

During the FGD, discussants indicated that traditional methods often employed in the study area to contend with Parthenium weed were hand weeding and plowing where most of them plow their plots three times before sowing. Despite their effort, however, they still reckon that the cultural methods happened to be not always effective as the same could not stop the spread of the weed over time and space in the study area.

Various methods, namely physical, chemical, bio-herbicidal, and integrated, are being practiced to manage Parthenium weed across the globe (Kaur et al., 2014). In agreement with the present study, Hundessa and Belachew (2016) found that tillage and hand weeding were the most practiced control methods used against Parthenium. Likewise, farmers in Parthenium infested areas of Ethiopia often try to maintain their lands free of the weed through hand hoeing, hand weeding (Tessema et al., 2010; Seta et al., 2013; Beyene and Tessema, 2015; Mekonnen, 2017), herbicides (Hundessa and Belachew, 2016), burning (Seta et al., 2013; Beyene and Tessema, 2015), intensive cultivation, and inter-cropping (Tessema et al., 2010),

In croplands, Mekonnen (2017) suggested that hand hoeing and weeding before the plant blooms should be done, which should be repeated 3 to 4 times in a season to check for all the flushes. Kaur et al. (2014) also stated that manual uprooting of Parthenium before flowering and seed setting is the most effective method; uprooting the weed after seed setting will increase the area of infestation. Besides, such physical control like hand weeding involves a time consuming and unpleasant job, made worse by the health hazards involved with handling Parthenium weed (Kaur et al., 2014). Moreover, chemical control is conceived to involve a number of negative impacts including its high cost in vast area, possible negative impacts upon human and animal health, and environment as well as resource poor farmers of Ethiopia may not afford the purchase of herbicides (Mekonnen, 2017). As to Tamado and Milberg (2004), no single method of control of *P. hysterophorus* has proved satisfactory as each method suffers from one or more limitations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The author expresses their gratitude to Hawassa University for financial support. They would like to express their heartfelt gratitude to the Woreda Administration, Woreda Experts (Agricultural, Veterinary, and Health), DAs of the Kebeles studied, and farmers who participated in the study.

REFERENCES

Abdulkerim-Ute J, Legesse B (2016). *Parthenium hysterophorus* L: Distribution, Impact, and Possible Mitigation Measures of in Ethiopia. Tropical and Subtroptropical Agroecosystems 19:61-72.

Adkins S, Shabbir A (2014). Biology, ecology and management of the invasive *Parthenium* weed (*Parthenium hysterophorus L*.). Mini Review. Pest Management Science 70(7):1023-1029.

Ayele S, Nigatu L, Tana T, Adkins SW (2014). Impact of Parthenium weed (Parthenium hysterophorus L.) on the above-ground and soil seed bank communities of rangelands in Southeast Ethiopia. Global Journal of Pest Diseases and Crop Protection 2(1):66-78.

Bagachi A, Raha A, Mukherjee P (2016). A Complete Review on *Parthenium Hysterophorus* Linn. International Journal of Recent Advance Pharmaceutical Research 6(1):42-49.

Banerjee T, Srivastava RK (2010). Estimation of the Current Status of Floral Biodiversity at Surroundings of Integrated Industrial Estate-Pantnagar, India. International Journal of Environmental Research 4(1):41-48.

Bajwa AA, Tamado T, Chauhan BS, Adkins SW (2018). Effect of Parthenium weed on maize yield at different competition durations in Ethiopia 2018. 21st Australasian Weeds Conference 9-13.

September 2018. Sydney, New South Wales, Australia.

Belachew K, Tessema T (2015). Assessment of Weed Flora composition in *Parthenium* (*Parthenium hysterophorus L.*) infested area of East Shewa Zone, Ethiopia. Malaysia Medical Biological Research 2(1):63-70.

Beyene H, Tessema T (2015). Distribution, Abundance and Socio-Economic Impacts of Parthenium (Parthenium hysterophorus) in Southern Zone of Tigray, Ethiopia. Journal of Poverty, Investment and Development 19 (2015):22-29.

Birhanu A, Khan PR (2018). The distribution, status and mitigation methods of *Parthenium hysterophorus* L. in Ethiopia: A review Journal of Medicinal Plants Studies 6(4):05-10.

Bobo A, Abdeta C (2016). A Review on the Distribution, Biology and Management Practices of Parthenium Weed, (*Parthenium hysterophorus* L.) in Ethiopia. Journal of Biology and Agrcultural Healthcare 6:5.

Bufebo B, Elias E (2018). Distribution and Socio-economic Impacts of Invasive Alien Plant Species in Ethiopia. A Review on Open Journal and Plant Science 3(1):26-33.

BWANRO (2017). Annual report. BWANRO (Boset woreda agriculture and natural resource office) East Shoa Zone of Oromia Regional State, Ethiopia.

Central Statistical Authority (CSA) (2007). FDRE CSA Agricultural Sample Survey: Report on area and production of Belgium season crops for Private peasant holding, Addis Ababa, Ethiopia.

Dale A (2006). Population sampling method for research studies. Definition and use. International Journal Social Science Research Methodology 9(2):79-82.

Dogra SK, Sarvesh KS, Romita S (2011). Distribution, Biology and Ecology of Parthenium hysterophorus L. (Congress Grass) an invasive species in the North- Western Indian Himalaya (Himachal Pradesh). African Journal of Plant Science 5(11):682-687.

Etana A, Kelbessa E Soromessa T (2011). Impact of Parthenium hysterophorus L. (Asteraceae) on Herbaceous Plant Biodiversity of Awash National Park (ANP), Ethiopia. Management Biology Invasions P. 2.

Firehun Y, Tamado T (2006). Qualitative and quantitative assessment of weeds in flora of Sugarcane plantations of Wonji-Shoa and Metahara. Ethiopia. Journal of Weed Management 1:1-1.

Fluid Surveys Team (2014). Calculating the Right Survey Sample Size. Available on http: //fluidsurveys.com/university/how-to-avoid-non-response-error.

Gebrehiwot N, Berhanu L (2015). Impact of *Parthenium* on Species diversity in Gamo Gofa, Ethiopia. Scholarly Journal of Agricultural Science 5(7):226-231.

Grierson AJ, Long DG (2001). Flora of Bhutan. Royal Botanical Garden. Edinburgh 2(3):187.

Hedberg I, Edwards S (1995). Flora of Ethiopia and Eritrea. P. 7. National Herbarium, Addis Ababa University, Addis Ababa, Ethiopia.

Hundessa N, Belachew K (2016). Socioeconomic Impacts of Parthenium hysterophorus L. in East Shewa and West Arsi Zones of Ethiopia. International Journal of Agricultural Research Innovation and Technology 6(2):5-11.

Hundessa N, Tessema T, Belachew K (2016). Distribution and Abundance of Parthenium (*Parthenium hysterophorus* L.) in East Shewa and West Arsi Zones of Ethiopia. Journal of Bioliogical Agricultural Health 6:5.

Jayaramaiah R, Ramesh BN Krishnaprasad BT Sunil KR Pramodh G Ramkumar C Sheshadri T (2017). Harmful effects of Parthenium hysterophorus and management through different approaches -A Review. Annals of Plant Sciences 6(05):1614-1621.

Kaba W (2008). Perceived Socio economic Impact of Parthenium Weed and Its Effect on Crop Production in Babile, Haramaya and Tulo Districts, East and West Hararge Zone, Ethiopia. M.A. Dissertation, Department of Rural Development and Agricultural Extension, School of Graduate Studies, Haramaya University, Ethiopia 88 p.

Karki D (2009). Ecological and Socioeconomic impact of *Parthenium hysterophorus L.* invasion in two urban Areas in Nepal. A Dissertation Submitted for the partial Fulfillment of Masters of Science in Botany, Kathmandu, Nepal.

Kassa T (2016). Parthenium hysterophorus (Asteraceae) Expansion, Environmental Impact and Controlling Strategies in Tigray, Northern Ethiopia: A Review. Journal of Drylands 6(1):434-448.

Kaur M, Aggarwal NK, Kumar V, Dhiman R (2014). Effects and Management of *Parthenium hysterophorus*: A Weed of Global Significance. International Scholarly Research Notices P. 12.

Kathiresan RM, Gnanavel I Anbhazhagan R Padmaria SP Vijayalakshmi NK Arulchezhian MP (2005). Ecology and control of *Parthenium* invasion in command area. In: Proceedings of Second International Conference on Parthenium Management 5-7 Dec 2005. Bangalore, India pp. 77-80.

Kebede A (2008). The distributions of Parthenium weed (*Parthenium hysterophorus* L. Asteraceae) and some of its socio-economic and ecological impacts in the Central Rift Valley, Adami Tulu-Jido Kombolcha Woreda, Ethiopia. M.Sc. Thesis. Addis Ababa University, Ethiopia 76 p.

Khan H, Khan BM, Gul H, Muhammad AK (2012). Chemical control of Parthenium hysterophorus L. at Different Growth Stages in non cropped Area. Pakistan Journal of Botany 44(5):1721-1726.

Khan H, Marwat KB, Hassan G. Khan MA (2013). Socioeconomic Impacts of Parthenium (*Parthenium hysterophorus* L.) in Peshawar Valley, Pakistan. Pakistan Journal of Weed Science Research 19(3):275-293.

Kilewa R, Rashid A (2013). Invasion and Distribution of *Parthenium hysterophorus* Weed in Kyerwa District in Kagera Region, Tanzania. International. Journal of Science Research 4:1.

Knox J, Paul MS (2013). *Parthenium hysterophorus* and its management through botanical. Journal of Crop and Weed 9(2):207-209.

Kumar A (2014). *Parthenium hysterophorus* L. and its Impact on Living World. Indian Journal of Science Research 4(1):8-14.

Kumar D (2013). Distribution and Effect of *Parthenium hysterophorus L*. in Mehari, sub water shed of Rajouri Forest Range. International Journal of Science Research 2:6.

Lisanework N, Sharma JJ (2013). *Parthenium* weed invasion and biodiversity loss in Ethiopia. African Crop Science Conference Proceedings 11:377-381.

Magurran AE (2004). Measuring Biological Diversity. Blackwell Publishing, Oxford 256 p.

Masum SM, Hasanuzzaman M, Ali MH (2013). Threats of *Parthenium hysterophorus* on agroecosystems and its management: A Review. International Journal of Agriculture and Crop Science 6(11):684-697.

Maszura CM, Karim SMR, Norhafizah MZ, Kayat F, Arifullah M (2018). Distribution, Density, and Abundance of Parthenium Weed (*Parthenium hysterophorus* L.) at Kuala Muda, Malaysia. International Journal of Agronomy 8 p.

Mekonnen G (2017). Threats and Management Options of Parthenium (*Parthenium hysterophorus* l.) in Ethiopia. Agricultural Research AND Techniques: Open Access Journal 10:5.

Nihanthan K, Sivachandiran S, Marambe B (2013). Control of Parthenium hysterophorus L. and its impact on yield performance of Tomato (*Solanum lycopersicum* L.) in Northern Provinces of Sri Lanka. Tropical Agricultural Research 25(1):56-68.

Qureshi H, Arshad M, Bibi Y, Ahmad R, Osunkoya OO, Adkins SW (2018). Multivariate Impact Analysis of Parthenium Hysterophorus Invasion on Above-Ground Plant Diversity in Pothwar Region of Pakistan. Applied Ecology and Environmental Research 16(5):5799-5813.

Reaser JK, Laura AM, Cronk Q, Poorter MD, Elrege LG, Green E, Kairo M, Latasi P, Mack RN, Mauremootoo J, O'Dowd D, Orapa W, Sastroutomo S, Saunders A, Shine C, Thrainsson S, Vaitu L (2007). Ecological and Socioeconomic Impacts of Invasive Alien Species in Island Ecosystems. Environmental Conservation 34(2):1-4.

Roy CD, Shaik M (2013). Toxicology, Phytochemistry, Bioactive compounds and pharmacology of *Parthenium hysterophorus.* Journal of Medicinal Plant Studies 1:3.

Royimania L, Mutangaa O, Odindia J, Zoloa KS, Sibandaa M, Dube T (2019). Distribution of *Parthenium hysterophorus* L. with variation in rainfall using multi-year SPOT data and random forest classification. Remote Sensing Applications: Society and Environment 13:215-223.

Saini A, Aggarwal NK, Sharma A, Kaur M, Yadav A (2014). Utility Potential of *Parthenium hysterophorus* for Its Strategic Management. Advances in Agriculture 16 p.

Seta T, Assefa A, Mesfin F, Balcha A (2013). Distribution status and the impact of parthenium weed (*Parthenium hysterophorus* L.) at Gedeo Zone (Southern Ethiopia). African Journal of Agricultural Research 8(4):386-397.

Shannon CE, Wiener W (1949). The Mathematical Theory of Communication. University of Illinois Press, Urbana, Illinois.

Shashie A (2007). The impacts of *Parthenium hysterophorus L.* on the Rangeland Ecosystem Dynamics of the Jijiga Rangeland, Ethiopia. M.Sc Thesis. Haramaya University, Ethiopia 117p.

Shiferaw W, Demissew S, Bekele T (2018). Invasive Alien Plant Species in Ethiopia: Ecological Impacts on Biodiversity: A Review Paper. International Journal of Molecular Biology 3(4):169-176.

Shikha R, Jha AK (2016). Evaluation of effect of leaf extract of Parthenium hysterophorus L. on seed germination, seedling growth and fresh weight of Phaseolus mungo. American Journal of Research Communication 4(2):86-103.

Shinde NV (2016). Allelopathic effect of Parthenium hysterophorus L. on crop plants. International Journal of Applied Research 2(4):730-734.

SPSS 16.0. (2007). SPSS 16.0.0 (September 13, 2007). Statistical Package for the Social Sciences (SPSS). SPSS Incorporated. IBM, Chicago, Illinois. USA.

Tafese T (2015). Phytochemistry and Antimicrobial Activity of Parthenium hysterophorus L.: A Review. Science Journal of Analytical Chemistry 3(3):30-38.

Tamado T (2001). Biology and Management of Parthenium hysterophorus L. in Eastern Ethiopia. PhD Thesis Presented to the School of Graduate Studies of Swedish University of Agricultural Sciences Uppsala, Sweden P 75.

Tamado T, Schütz W, Milberg P (2002). Germination ecology of the weed *Parthenium hysterophorus L*. in Eastern Ethiopia. Annal Applied Biology 140(3):263-270.

Tessema T, Rupschus C Wiesner M Rezene F Firehun Y Ulrichs C Büttner C (2010). Parthenium Weed (*Parthenium hysterophorus* L.) Research in Ethiopia: Impacts on Food Production, Plant Biodiversity and Human Health. Ethiopia. Journal of Agricultural Science 20:128 - 150.

Taye T, Yohannes L, Belayneh A (1998). Qualitative and quantitative determination of weed occurrence in wheat in west Shewa zone of Ethiopia. 10th Regional Wheat Workshop For Eastern, Central and Southern Africa. Sept. 14-18, 1998, University of Stellenbosch, South Africa pp. 160 -172.

Tefera T (2002). Allelopathic effects of Parthenium hysterophorus L. extracts on seed germination and seedling growth of Eragrostis tef. Journal of Agronomy and Crop Science 188:306-310.

Teka K (2016). *Parthenium hysterophorus* (Asteraceae) Expansion, Environmental Impact and Controlling Strategies in Tigray, Northern Ethiopia: A Review. Journal of the Drylands 6(1):434-448.

Tiwari S, Adhikari B, Siwakoti M, Subedi K (2005). An Inventory and Assessment of Invasive Alien Plant Species of Nepal. IUCN-The World Conservation Union, Nepal 115 p.

Trochim WMK (2006). Research Methods Knowledge Base. Accessed from http://www.socialreserchmethods.net/kb/samprob.php. On November 2006.

Wahab S (2005). Management of *Parthenium* through an integrated approach initiatives, achievements and research opportunities in India. In: Proceeding of the Second International Conference on Parthenium Management. 5-7 December 2005, Bangalore, India pp. 55-59.

Wittenberg R, Simons SA, Mauremootoo JR (2004). Instrument and tools for assessing the invasive alien species in Africa. CAB. International. Nairobi, Kenya.

Yadav N, Priyanka S Sitara J Suruchi K Sarita KVBharit SR Sinha MP (2010). Effect of methanioc Extract of *Parthenium hysterophorus L*. on Hematological Parameters in Wistar Albino rat. International Quarterly Journal of Life Science 2:357-363.

Zelalem G, Tora A (2019). Assessment of Farmers’ Perception on the Effects of *Parthenium hysterophorus* on Grazing Land and Dairy Production in Damot Gale Woreda Wolaita Sodo, Ethiopia. International Journal of Medicinal Plants and Natural Products 5(1):1-7.

Zuberi MI, Gosaye T, Hossain S (2014). Potential Threat of Alien Invasive Species: *Parthenium hysterophorus L.* to Subsistence Agriculture in Ethiopia. Sarhad Journal of Agriculture 30(1):117-125.