Addis Ababa University

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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

BY

Adane Kebede Gebeyehu

A thesis submitted to the School of Graduate Studies of the Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in Environmental Science

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DECLARATION

This thesis is my original work, has not been presented for a degree in any university and all sources of materials used for the thesis has been gratefully acknowledged.

Adane Kebede

Signature___________________________

Date____________________________

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List of Tables

List of Figures

List of Appendices

List of Acronyms

CBD	Convention on Biological Diversity
DAs	Development Agents
ESRI	Environmental Systems Research Institutes
Fig	Figure
GIS	Geographic Information System
GISP	Global Invasive Species Programme
GPS	Global Positioning System
ILWIS	Integrated Land and Water Information System
Km	Kilo meter
IAS	Invasive alien species
MA	Millennium Assessment
m^2	square meter
m	meter
m a.s.l.	meter above sea level
OK	Ordinary Kriging
PAG	Parthenium Action Group
RGO	Regional Government of Oromia
SPSS	Statistical Package for Social Science
SK	Simple Kriging
UK	Universal Kriging

Abstract

Biological invasion by alien invasive species is now recognized as one of the major threats to native species and ecosystems. P. hysterophorus is believed to have been introduced to Ethiopia during the1970s along with the grain aid during the prolonged drought and/or during the Ethio-Somalian war and by movement of construction materials. The aim of this study was to generate knowledge for a better understanding of the distribution, socio-economic & environmental impacts of P. hysterophorus in the Adami Tulu-Jido Woreda. The biophysical data were collected by using systematic grid method, which is appropriate for distribution mapping using geostatistics. The biodiversity impacts of P. hysterophorus were investigated by assessing other plant species growing in association with P. hysterophorus. The socio-economic impacts were studied by interviewing farmers. The results show that P. hysterophorus was found to be the most frequent and dominant species in road sides, grazing land and crop fields with IVs of 102%, 77.5% & 74.5% respectively. It also has the highest frequency (19.2%). The weed is widely distributed in north-eastern parts of the Woreda. Results also showed that from all the sample species *P. hysterophorus* was found to be the most abundant in road sides (49.1%). Field survey results showed that all the interviewed farmers were aware of *P. hysterophorus*, its ways of introduction into their locality, the agents facilitating its dissemination and places where *P. hysterophorus* is densely populated. *Farmers are generally aware of the impacts of P. hysterophorus. The impacts are on crop production (44%), livestock (30.6%), on human health (18.8%) and has no any benefits attached to environment. This study revealed that P. hysterophorus has become a major pest plant of the wasteland, road sides, wet lands, vacant sites and crop fields and it has the potential to spread all over the Woreda.* Hence it has a significant effect on the economic development of the study area. Integration of different control methods are therefore needed to prevent and control the danger of *P. hysterophorus*.

Key words: alien invasive weed species, *Parthenium hysterophorus*, geostatistics, Adami Tulu-Jido, Central Rift Valley.

1 INTRODUCTION

Biological invasions by non-native species constitute one of the leading threats to natural ecosystems and biodiversity (Joshi, 2001; MA, 2006; CBD, 2005; Baillie *et al*., 2004). The above authors also describe that the impacts of invasive alien species (IAS) on agriculture, forestry, fisheries, and other human enterprises and on human health. In agricultural system, invasive weeds affect the productive capacity of the land and increase agricultural labour time, affecting human well being by threatening the availability of food as well as reducing the time people have for recreation and other non-work activities, such as participation in community events. Moreover, these non-native plant and animal species harm or endanger native plants and animals or other aspects of biodiversity. They have invaded almost every type of native ecosystem and caused hundreds of biological extinctions throughout the world (Joshi, 2001; MA, 2006; CBD, 2005; Baillie *et al*., 2004). One of such an invasive weed species introduced to Ethiopia in a recent past is *Parthenium hysterophorus* (Taye Tessema, 2002; Tamado Tana, 2001; GISP, 2004).

Parthenium hysterophorus is a herbaceous invasive weed that is believed to be originated in tropical America, now occurs widely in Australia and East and South Africa. Its annual procumbent, diffused leafy herb, 0.5-2 m tall, bearing alternate, pinnatified leaves, belongs to the family Asteraceae (Compositae) tribe Helintheae, sub-tribe Ambrosiinae (Navie *et al*., 1996; Hedberg *et al*., 2004). IAS like parthenium weed are species that are introduced to new geographic areas as a consequence of human activities, where they become established and then proliferate and spread, to harm many of human welfare activities and natural systems services (Kirby, 2003; Joshi, 2001).

The recent growth and development of world trade system has strengthened a long-standing trend in the redistribution of IAS in general and parthenium weed in particular (McNeely, 2001; McNeely *et al.*, 2001; Perrings *et al.*, 2005). The opening of new markets or trade routes has also resulted in the introduction of new species either as the object of trade or as the unintended consequence of trade (Enserink, 1999; Cassey *et al.*, 2004; Semmens *et al.,* 2004).

IAS impact native species both directly for example, competing with them for resources such as food and breeding sites as well as indirectly by altering habitat and modifying hydrology, fire regimes, nutrient cycling and other ecosystem processes (Rejmanek *et al.*, 2000; IUCN/SSG/ISSG, 2000; MA, 2006; CBD, 2005). Together, these impacts are resulting in the loss of biodiversity and dramatic changes to ecosystems, which is confirmed by a recent global assessment that showed invasive alien species to have affected 30% of threatened birds (but as much as 67% on islands), 11% of threatened amphibians, and 8% of threatened mammals (Baillie *et al.,* 2004). They also observed that invasion of alien species across the planet is rated as being the second biggest threat to biodiversity behind habitat loss.

Apart from their threat to biodiversity and ecosystem services, invasive species have significant socio-economic impacts. The weed can affect crop production, animal husbandry, human health and biodiversity (Evans, 1997a). IAS in general and *P. hysterophorus* in particular, reduces the effectiveness of development investments by, for example, choking irrigation canals, fouling industrial pipelines and threatening hydroelectric schemes. Indeed, invasive species such as parthenium weed contribute to social instability and economic hardship, placing constraints on sustainable development, economic growth, poverty alleviation and food security (GISP, 2004).

Parthenium weed is thought to have been introduced to Ethiopia probably between 1974 and 1980, and it was also thought to have been introduced during 1980s when drought induced famine triggered a massive multinational relief effort (Hedberg *et al*., 2004; GISP, 2004). The weed was first seen growing near food-aid distribution centers, so it is likely that imported wheat grain was contaminated with its seeds. The weed spread rapidly, and soon came to dominate pastures and crop fields because it has allelopathic properties, releasing chemicals that suppress the growth and germination of neighboring plants (Tadelle Tefera, 2002; Singh *et al*., 2005). Its invasion of Ethiopia has not only had a devastating effect on crop production, but also results in grazing shortages, since the weed is unpalatable to livestock; if it is mixed with fodder, it taints the meat and milk (GISP, 2004).

Parthenium weed *(P. hysterophorus)* invades disturbed land, including overgrazed weak pastures and recently cleared or ploughed lands. Moreover, it will readily colonize disturbed, bare areas along roadsides and heavily stocked areas around yards and watering points (GISP, 2004; Huy and Seghal, 2004; Shabbir and Bajwa, 2006).

To monitor the spread of such invasive alien species *(P. hysterophorus)* different technologies and techniques have been employed among which Geographic Information System (GIS) and Geostatistics are the most widely used. A weed map is, therefore, useful for identifying the affected area and the spatial distribution of weeds, and for providing a control plan. Therefore, this thesis addresses the distribution of *P. hysterophorus* in Adami Tulu-Jido Woreda by using GPS, GIS and Geostatistics as tools.

1.1 Statement of the problem

Even though invasive species, particularly parthenium weed, are causing severe damage to the environment in Ethiopia, there is not much documented information about it. For instance, their geographical distributions, rate of expansion, socio–economic and environmental impacts are little documented in Ethiopia. One of the sites where abundant occurrence of parthenium weed is mentioned is Central Rift Valley (CRV) of Ethiopia. Such knowledge of distribution of the weed assists to design effective controlling mechanisms to curb the impact being caused to the people and their livelihood.

Proper management of weed control and mapping of their spatial and temporal distribution will enhance agricultural as well as socioeconomic development in the Woreda. There has been limited or no effort to systematically and to analytically study the impact of *P. hysterophorus* on households' welfare in the study area. There are few researches made on the impact of this weed in the eastern and north-eastern parts of the country such as by Tamado Tana *et al*. (2002), Taye Tessema (2002) and Tadelle Tefera (2002). However, this research work is different from the above studies in three ways. First, in the area context-impact of parthenium weed differs from one location to another. Second, this research will examine the environmental factors that determine parthenium weed distribution and the level of its status, which was not considered in the studies mentioned above. Third, the study will endeavor to show the distribution pattern of *P. hysterophorus* in the Woreda, which was not dealt with in the above studies.

Furthermore, the socioeconomic and ecological impacts differ from place to place with respect to different agro-ecological context, local socio-economic situations and environmental factors that need to be studied in detail with in the selected study area.

1.2 Research Objectives

1.2.1 General objective

The general objective of this study is intended to examine the extent of socioeconomic and ecological impacts of *P. hysterophorus* and to map the spatial and temporal distribution in the Central Rift Valley of Ethiopia in general and Adami Tulu-Jido Kombolcha Woreda in particular and hence to recommend possible tracking solutions for the betterment of the livelihood and environment.

1.2.2 Specific objectives

- To develop a distribution map for parthenium weed in the Adami Tulu-Jido Kombolcha areas,
- To assess the temporal and spatial distribution of parthenium weed in the Adami Tulu-Jido Kombolcha areas,
- To investigate environmental factors that favor or disfavor the distribution of the species, and
- To assess the socio-economic and environmental impacts of *P. hysterophorus* in the Woreda.

2 REVIEW OF LITERATURE

2.1 Biology and Ecology of Parthenium weed

2.1.1 Description

Parthenium hysterophorus L. (Asteraceae), an alien invasive species, commonly known as parthenium weed, is an annual or short-lived ephemeral herb of central and southern American origin that now has a wide range of distribution through out the earth (Navie *et al*., 1996; Mahadevappa, 1997). Parthenium weed is an extremely prolific seed producer, with up to 25,000 seeds (achenes) per plant but unable to reproduce vegetatively from plant parts (Navie *et al*., 1996; ARMCANZ, ANZECC, 2000), and with an enormous seed bank, estimated at 200,000 seeds per m^2 (Joshi, 1991), it has the potential to be an extremely aggressive colonizer of crops. The seeds spread by floating on still or flood water, blown up by wind, or in mud adhering to animals, vehicles or machinery (Auld *et al.,* 1983).

Parthenium weed, *P. hysterophorus*, is also known by a large number of other common names including parthenium weed (Australia), bitter weed, carrot weed, broom-bush and congress weed (India), false ragweed and ragweed parthenium (USA), whitetop, escobar amarga, feverfew (Caribbean) and `Klidnole' (living alone) or `Feremsis' (sign your land) (Ethiopia) (Navie *et al*., 1996; Tamado Tana *et al.,* 2002; Taye Tessema, 2002).

It can grow up to two meters if there are favorable environmental conditions. Parthenium weed is an aggressive colonizer of areas of poor ground cover and exposed soil such as fallow wastelands, roadsides and overgrazed pastures (Huy and Seghal, 2004; Shabbir and Bajwa, 2006). It does not usually become established in undisturbed vegetation or in vigorous pastures, and there is a marked inverse relationship between existing plant cover and Parthenium weed density (ARMCA&NZ, 2000).

2.1.2 Growth and Production

One of the most important biological characteristics for the success of parthenium as a weed lies on its reproductive ability. Four or more successive cohorts of seedlings may be produced in a season (Pandey and Dubby, 1989). Jayachandra (1971) and McFadyen (1992) reported that flowering can be initiated as early as four weeks after seedling emergence and plants continue to flower for extended periods (6-8 months) under favorable conditions. Following another report, parthenium weed can germinate, grow, mature, and set seed within 28 days (PAG, 2000). In developmental studies, using North American plants, Lewis *et al*. (1988) reported that the time from initial appearance of the first flower bud to the production of mature inflorescence and dispersal of the first achenes was found to be about 30 days, while the time from pollination to achene maturation is only about fourteen days.

There are conflicting reports as to whether parthenium weed is self-compatible or self-incompatible. Lewis *et al*. (1988) detected 95% self-compatibility in the species. They concluded that wind must be the major means of pollen dispersal and self-fertilisation must account for at least some seed production. In contrary to Lewis *et al*. (1988), Gupta and Chandra (1991) stated that parthenium weed appears to be entomophilous (insect pollinated) or at most amphiphilous (pollen dispersed mainly by insects and partially by wind), and that bees, ants, houseflies, and other dipterans frequently visited parthenium weed flowers.

2.1.3 Ecology

Parthenium weed is an aggressive coloniser of disturbed land, able to germinate, grow and flower over a wide range of temperatures and photoperiods (Evans, 1987). It occurs in the humid and sub-humid tropics showing a marked preference for black, alkaline, cracking, clay soils of high fertility, but also able to grow on wide variety of soil types from sea level up to 1800 m a.s.l. (Evans, 1987). Areas receiving less than 500 mm of rainfall are probably unsuitable although the weed has strong adaptive methods to tolerate both moisture stress (Kohli and Rani, 1992) and saline conditions (Hegde and Patil, 1988). Mahadevappa (1997) also noted that parthenium weed has several built-in properties and efficient behavioral mechanisms that enable it to overcome many ecological adversities and thus continue to survive under stress.

Soil moisture appears to be the major contributing factor to both life span and the duration of flowering (Williams and Groves, 1980). Plant biomass production increases with increasing temperature up to an optimum day/night temperature of 33/22°C. Seeds require bare soil to germinate with little or no dormancy. Most seeds germinate within 2 years if conditions are suitable, although up to 12% of buried seeds may be viable after 2 years (Butler, 1984). However, in their study of germination ecology of parthenium weed Tamado Tana *et al*. (2002) stated that viability of the seeds was greater than 50% after 26 months of burial and predicted a half-life of seeds in the soil of approximately three to four years. This indicates the potential build-up of persistent soil seed bank and the difficulty of its eradication. Although freshly harvested parthenium seed require light for germination, it can germinate during any time of the year over a wide range of fluctuating (12/2–35/25°C) temperatures provided adequate moisture is available (Tamado Tana *et al*., 2002).

2.1.4 Distribution

Parthenium hysterophorus L. occurs throughout the tropical and sub-tropical Americas from Florida to southern Brazil and northern Argentina (Dale, 1981). It became the major noxious weed for over the last 25 years in India (Mahadevappa, 1997) and Australia (Navie *et al.,* 1996). In addition, there are reports from Bangladesh (Mahadevappa, 1997), Israel (Joel and Litson, 1986), Taiwan (Peng *et al*., 1988), China and Vietnam (Navie *et al.,* 1996), and Nepal (Mishra, 1991). Parthenium weed has recently reached in Africa, being recorded in Kenya in 1975 in Nairobi herbarium records and it is now a weed in coffee plantations (Njoroge, 1991). It is also present in Madagascar, Mozambique, South Africa, and the Seychelles (Nath, 1988) and in Ethiopia was recorded since 1974-77 (Berhanu G/Medhin, 1992; Fasil Reda, 1994; Frew Mekbib *et al.,* 1996; Hedberg *et al*., 2004). This indicates that parthenium weed has a potential of spreading and may become more prominent in other part of the world in the near future unless measures are taken.

2.1.5 Parthenium weed status in Ethiopia

In Ethiopia, it is believed to have been introduced in 1976/77 with army vehicles from Somalia and has become a serious weed both in arable and grazing lands (Tamado Tana *et al*., 2002). But in contrast to this, Hedberg *et al*. (2004) reported that it was introduced into Ethiopia around 1974. Others also believed that *P. hysterophorus* may have also been spread through the provision of humanitarian emergency food aid. For example, this weed was introduction to Africa through grain shipments for famine relief to Ethiopia (McNeely *et al*., 2001). The weed was first seen in 1980s near food-aid distribution centers in Ethiopia (GISP, 2004). However, currently, it is widely distributed in Ethiopia. In eastern Ethiopia, Tamado Tana and Milberg (2000), and Tamado Tana (2001) reported that parthenium weed is the second most frequent weed (54%) after *Digitaria abyssinica* (63%).

In the central farmlands of East Shewa: Dukem, Bishoftu, Modjo, and Koka areas heavy and widespread infestation occurs mostly on roadsides, wastelands, towns, villages and gardens. One can also see parthenium weed infestation on field borders and in some fields; parthenium weed grew in crop field during fallow period. In Ziway, Awassa and Wolkite, parthenium weed was observed only in the town along the road and near dwelling sites indicating its recent introduction into the area (Taye Tessema, 2002).

High infestation of parthenium weed was observed in sorghum fields around Kobo and in sorghum, maize and tef fields around Robit, Gobie, Woldiya, and Kombolcha both during the growing period and after harvesting time. Similarly, in East Shewa (Wolenchitti, Wonji, Methara), Afar region (Awash, Anano, and Miesso), and West and East Hararghe, heavy infestation of parthenium weed was observed both during fallow and cropping seasons. Similarly in Hataye, Shewa Robit, Ambo, and Nazareth area, parthenium weed has entered crop fields (Taye Tessema, 2002).

In highly infested areas from Woldiya to Alamata, the original grass and shrub vegetation had been very open and the disturbance allowed a dense stand of parthenium weed to cover thousands of hectares of grazing and cultivated lands. From Sirinka to Mersa and then to Dessie, parthenium weed was present on the narrow strip along the main road for several kilometers. Also he reported that in many Woredas of West Shewa: Shoboka, Tibe, Guder, and Wolliso, only localized infestation of parthenium weed was observed on roadsides and rarely in crop fields (Taye Tessema, 2002).

Taye Tessema (2002) also observed that the plant occurred in the towns, usually on roadsides, and vacant sites and grew only at irregular intervals. The introduction in these area is very recent, probably since 1997 for there had been no parthenium weed observed in West Shewa region from 1995 – 1996 (Taye Tessema *et al.*, 1998) during which intensive qualitative and quantitative determination of weeds occurring in these areas took place.

2.2 Determinant impacts of parthenium weed

The impact of parthenium weed on agriculture was summarized by Parsons and Cuthbertson (1992), McFadyen (1992), Navie *et al.* (1996), Tamado Tana *et al*.(2001) and Evans (1997a). The authors also described that the weed could affect crop production, animal production, human health, and biodiversity in its area of infestation. Moreover, parthenium weed has a wide range and potentially lethal impact on man's affair.

2.2.1 Effects on crop production

In India, according to Khosla and Sobti (1981), about 40% sorghum (*Sorghum bicolor L.*) yield reduction due to parthenium weed was recorded. Channappagoudar *et al.* (1990) also reported that the presence of parthenium weed in irrigated sorghum in India reduced grain yields from 6.47 to 4.25 tons/ha (34.3%) and decreased grain weight by 30%. However, its overall impact on the production system is multifaceted, both direct and indirect, thus making it difficult to quantify losses (Evans, 1997a).

Other than direct competition for nutrients, water and sunlight, allelopathic effects of parthenium weed on other plant is another important biological characteristic for the success and its aggressiveness as a weed. In many studies water soluble phenolics (caffeic acid, ferulic acid, vanicillic acid, anisic acid, and fumaric acid) and sesquiterpene lactones, mainly parthenin, have been reported from the roots, stems, leaves, inflorescence, achenes fruit and pollen of parthenium weed (Jarvis *et al.,* 1985; Kanchan and Jayachandra, 1979, 1980a; Hedge and Patil, 1988; Pandy *et al.,* 1993).

These chemicals have been observed to exhibit an inhibitory effect both on the germination and growth of a wide variety of crops including pasture grasses, cereals, vegetables, other weeds and even tree species (Evans, 1997a; Navie *et al.,* 1996; Tadelle Tefera, 2002). Kanchan and Jayachandra (1981) and Dayama (1986) reported that the growth and nodulation of legumes were inhibited by parthenium weed because of the inhibitory effect of allelochemicals on nitrogen fixing and nitrifying bacteria. Further, parthenium weed pollen was found to reduce the chlorophyll content of leaves to which it comes in contact with and can interfere with the pollen germination and fruit set of the nearby species (Kanchan and Jayachandra, 1980b). Towers *et al*. (1977) also reported that heavy accumulation of parthenium weed pollen on the stigmatic surface caused 40% reduction in the grain filling of maize and predicted that the weed may still exhibit an inhibitory influence on crops even when grown at a considerable distance.

2.2.2 Effects on animal production

According to Evans (1997a) the impact of parthenium weed on livestock production is both direct and indirect by affecting grazing land, animal health, milk and meat quality, and marketing of pasture seeds and grain. The occurrence of parthenium weed in grasslands was observed to reduce the forage production in addition to making the land less fertile (Vartak, 1968). In India, for instance, the weed can reduce the pasture carrying capacity by up to 90% (Nath, 1988). In Australia, Chippendale and Panneta (1994) identified that parthenium weed could completely dominate grazing land, resulting in a weed monoculture and reduced stocking rate of up to 80%, with a net annual loss of AU$ 16.5 million.

Studies in India on toxicity of the weed to cattle and buffaloes have shown that a significant amount (10 – 50%) of the weed in the diet can kill these animals within 30 days (Narasimhan *et al*., 1977, 1980; More *et al*., 1982). Animals fed parthenium weed developed dermatitis with pronounced skin lesions, became highly emaciated, and eventually died due to the rupture of tissues and haemorrhages in their internal organs (Nisar Ahmed *et al*., 1988). Taints of meat have been detected from sheep given a diet of 30% parthenium weed (Tudor *et al*., 1982) and tainting of milk has also been reported from cows (Towers and Subba Rao, 1992).

2.2.3 Effects on health

Parthenium weed is also known to cause human health problems like asthma, bronchitis, dermatitis, and hay fever (Anonymous, 1976; Kololgi *et al*., 1997; Srirama Rao *et al*., 1991). It is reported that continued close contact with parthenium weed can develop allergic eczematous contact dermatitis (AECD) while inhalation of pollen can cause allergenic rhinitis which can develop into bronchitis or asthma if the pollen enters the respiratory tract during mouth breathing (Evans, 1997a). *P. hysterophorus* is known to be the causative agent of this reaction, and is one of the very reactive toxic classes of compounds known as sesquiterpene lactones (Towers, 1981).

There has been an epidemic of hundreds of cases of parthenium weed dermatitis in India and several cases have been reported from USA (Subba Rao *et al*., 1977; Towers, 1981). It is also reported that there is an increasing incidence of respiratory allergies in India, with 7% of sample of Bangalore residents were affected by allergenic rhinitis due to parthenium weed pollen, and 42% of patients suffer from nasobronchial allergy (Towers and Subba Rao, 1992).

In Australia about 15% of individuals regularly exposed to parthenium weed developed dermatitis, with another 7-15% developing respiratory problems (McFadyen, 1992). Tanner and Mattocks (1987) hypothesised that parthenium weed contaminated animal feed leads to tainted milk and the hepatotoxic parthenin reacts synergistically with copper in causing Indian Childhood Cirrhosis (ICC).

2.2.4 Effects on biodiversity

Weeds can compute with indigenous plant species for resources (including, sunlight, moisture, nutrients and even for spaces) (IUCN/SSC/ISSG, 2000). Besides, the impacts of invasive alien species are immense, insidious, and usually irreversible and they may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats (IUCN/SSC/ISSG, 2000; Shabbir and Bajwa, 2006). Furthermore, invasions may alter hydrology, nutrient accumulation and cycling, and carbon sequestration on grasslands (Polley *et al*., 1997). The global extent and rapid increase in invasive species is homogenising the world's flora and fauna (Mooney & Hobbs, 2000) and recognized as a primary cause of global biodiversity loss (Czech & Krausman, 1997; Wilcove & Chen, 1998).

Parthenium hysterophorus, because of its invasive capacity and allelopathic properties, it causes a lot of damage to natural ecosystems. It has been reported as causing a total habitat change in native grasslands, open woodlands, riverbanks, and flood plains (McFadyen, 1992; Chippendale and Panetta, 1994). It releases allelopathic chemicals that inhibit the germination and growth of pasture grasses, legumes, cereals, vegetables, other weeds species and even trees in the field (Tamado Tana, 2001; Tadelle Tefera, 2000; Kohli *et al*., 1985; Adkins and Sowerby, 1996).

The allelopathic potential of *P. hysterophorus* is believed to play an important role in the ability of the plant to displace natural vegetation and interrupt natural succession in the natural environments. *P. hysterophorus* displaces the native as well as exotic species and also medicinal plants (Shabbir and Bajwa, 2006). They further explain that, the domination of parthenium weed affects the biodiversity. The population of many common medicinal plants growing in the wastelands of Islamabad might be rapidly declining because of the aggressive colonization by *P. hysterophorus* (Shabbir and Bajwa, 2006).

2.3 Control of parthenium weed

So far, no single method of parthenium weed control has been proved satisfactory as each method suffers from one or more limitations such as inefficiency, high cost, impracticability, environmental safety and only temporary relief (Bhan *et al*., 1997; Mahadevappa, 1997). Hence, there is an urgent need to adopt an integrated parthenium weed management approach by amalgamating more than one option. The components of integrated management such as prevention, manual, mechanical, cultural, chemical and biological control measures are briefed in the following sections.

2.3.1 Prevention

The easiest way to avoid parthenium weed is to prevent it from establishing in the first place (PAG, 2000). Simple precautions, such as sowing of uncontaminated crop and pasture seeds, cleaning of cultivating and harvesting vehicles before moving them into non-infested areas, and short term quarantine of stock that have been in parthenium weed infested areas will reduce the spread of parthenium weed (Navie *et al*., 1996; PAG, 2000; Parsons and Cuthbertson, 1992). Maintenance of grass crown cover in problem areas (heavily grazed areas, watering points, roadsides, and holding paddocks, etc.) and spot spraying of isolated outbreaks with a residual herbicide were recommended as they reduce the occurrence and distribution of parthenium weed (PAG, 2000). Further this group suggested that maintaining good hygiene on the field and property can also prevent the spread of parthenium weed. Seed-check vehicles and controlling the movement of animals can also help to control in the field.

2.3.2 Manual and Mechanical control

Manual and mechanical control methods are reported to be very expensive and cannot be employed everywhere, and the relief from these methods is temporary and needs to be repeated (Bhan *et al*., 1997). Mowing or slashing of parthenium weed is not recommended for it results in rapid regeneration of plants from lateral shoots (Gupta and Sharma, 1977;

Haseler, 1976). However, deep ploughing greater than 7 cm soil depth to bury seeds or repeated harrowing to destroy the seedlings before sowing is recommended (Bhan *et al*., 1977; Tamado Tana, 2001). Bhan *et al*. (1997) also suggested that the plants should be uprooted to prevent regeneration from the remaining lateral shoots and that such operation should be done before flowering and when the soil is moist enough to facilitate easy removal. The latter author also noted that hand pulling is recommended only in small areas like in gardens, flower beds, intensively cultivated fields or high value crops since manual removal is not cost effective. Mahadevappa (1997) and Bhan *et al*. (1997) recommended that only persons insensitive to parthenium weed allergy shall be engaged; Gupta and Sharma (1977) also suggested that protective clothing should be worn and subsequently washed to prevent the possibility of allergic reaction.

2.3.3 Cultural control

Growing of competitive crops to suppress parthenium weed was also suggested as alternative but, since parthenium weed grows in different ecology, the scope of this practice is limited to only certain situation (Bhan *et al.,* 1997). Kandasamy and Sankaran (1997) conducted two field experiments at Tamil Nadu, India, to evaluate the competitive ability of major field crops (cereals, millets, oilseeds, and pulses) and other plants competitive with parthenium weed. They reported that growing of maize, sorghum and sunflower significantly reduced the parthenium weed population by reducing its branching, growth and flower head production as compared to other crops. In these crops, dry matter accumulation of parthenium weed was reduced by more than 80% and the yield reduction due to parthenium weed in maize, sorghum and sunflower was only 12.3, 14.7 and 14.1%, respectively, indicating the competitive ability of this crops with parthenium weed.

2.3.4 Chemical control

Bromacil, diuron and terbacil, at 1.5 kg/ha (Kanchan and Jaychandra, 1977), diquat at 0.5 kg/ha (Dhanraj and Mitra, 1976) were reported to effectively control parthenium weed. Spraying 2 kg/ha of 2, 4-D sodium salt or 2 l/ha of MCPA in 400 L. of water was found effective to control parthenium weed at the seedling stage (Bhan *et al*., 1997). Balayan *et al*. (1997) also reported 1-2% solution of glyphosate with or without surfactant and Metribuzin at 1-2 kg/ha gave 90-98% visual toxicity on parthenium weed and advocated the supremacy of chemical control over other control measures on the bases of quick relief, time saving and cost effectiveness.

Chemical pollution of the environment, enormous cost, danger of toxicity to non-target plants, necessity of the chemical application in non-agricultural areas, rapidity of re-invasion of treated areas soon after the effect is diminished are the draw backs of chemical control (Singh, 1997). Similarly, Bhan *et al*. (1997) reported that chemical control alone is not justifiable as the effect of herbicide will always be of temporary nature and repeated operations are required which will not remain cost effective. As parthenium weed is a weed of wasteland and road side, a common man will never invest his money in this venture. Moreover, plants suppressed by chemicals have been observed to regenerate after remaining dormant for a few days. Chemical treatment can only kill existing population at the given sites but cannot prevent the entry of the seeds from neighbouring places.

2.3.5 Biological control

Biotic factors suppress the plant within its native range as compared to its increased fitness or vigour in their absence (Evans, 1997b). Hence, the fact of parthenium weed undoubted vigour in Australia and India compared with its limited importance in the countries of origin suggests that biotic factors contribute to its suppression there. If the natural enemies were introduced, the ability of the plant to compete with pastures and crops could conceivably be reduced to the point where it was no longer of economic importance (Haseler, 1976). Therefore, biological control appeared to offer the best, long-term solution for the management of parthenium weed and which is environmentally benign.

Biological control of parthenium weed was first proposed in India in 1970 and a brief survey of insects attacking it was made in West Indies (Bennet and Cruttwell, 1971).

2.4 Geostatistics for spatial analysis

Geostatistics is concerned with "the study of phenomena that fluctuate in the space and/or time", (Olea, 1991). Geostatistics offers a way of describing the spatial continuity that is an essential feature of many natural phenomena and provides adaptations of classical regression techniques to take advantage of this continuity (Isaaks and Srivastava, 1989). Moreover, geostatistics offers a collection of deterministic and statistical tools aimed at understanding and modeling spatial variability (Deutsch and Journel, 1998). The main application of geostatistics is the prediction of attribute values at unsampled locations (Kriging) (ESRI, 2003).

The geostatistical spatial data modeling begins with the study of the variability of a sample set, observed as points, that is considered representative of the attribute variation. A theoretical semivariogram is fitted for the sample set and is used to determine weights for the sample neighborhoods considered in the inference process (Webster and Oliver, 2001). Therefore, the geostatistical inference procedures, the kriging and the stochastic simulation, use the sample set and a correlation model to estimate attribute values in spatial locations different from the samples locations (Isaaks and Srivastava, 1989).

The kriging procedure aims to estimate z values based on a weighted mean approach of the z-sampled values of a local neighborhood. The kriging weights are determined from the basic hypothesis of minimum variance of the error estimation and make use of the theoretical semivariogram in order to calculate the covariance between two locations (Isaaks and Srivastava, 1989; Webster and Oliver, 2001). The spatial distribution of *P. hysterophorus* was determined by using the basic tools of geostatistics called variogram (Webster and Oliver, 2001).

The variogram (γ) was calculated using equation 1 (Isaaks and Srivastava, 1989):

$$h(\gamma) = 0.5\ E\ [\{Z_i(x)-Z_i(x+h)\}]^2 \ldots\ldots 1$$

Where x and x+h are two sample points, separated by distance h. E [.] is the mathematical expectation and $Z_i(x)$ is the density of the *P. hysterophorus* at sample point location x.

The theoretical variogram which was used to measure the strength of statistical correlation of the *P. hysterophorus* density as a function of distance h (Webster and Oliver, 2001) is presented in fig 1.

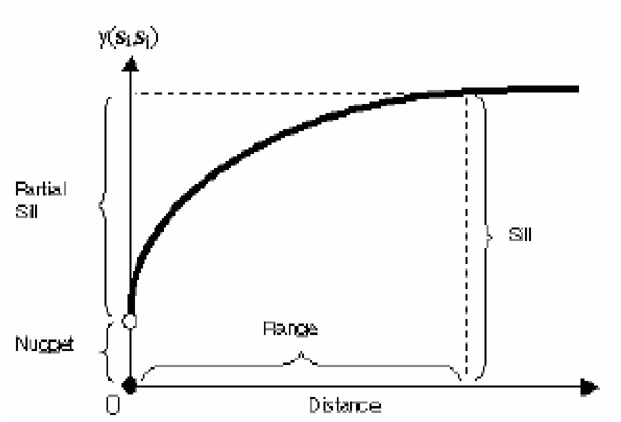


Fig. 1 Theoretical features of a variogram (where (Si, Si) is location coordinate of location i (ESRI, 2004).

3 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

The study was conducted in Adami Tulu-Jido Kombolcha Woreda, which is part of the East Showa Zone of the Oromia Regional State. Geographically the area is located between 38°20' and 38.5°5' and 7°35'and 8°05'. The Woreda covers an area of 1403.3 km^2, and is bordered by Southern Nations, Nationalities and Peoples' Regional State (SNNPRS) in the west and North West, Dugda-Bora Woreda in the north, Arsi Zone in the east and Arsi-Negele Woreda in the south (Fig.2). Ziway (Battu) town is the administrative center of the Woreda.

Ecologically, Adami Tulu-Jido is found in what is known as the Central Rift Valley of Ethiopia in the southern part of Addis Ababa. Significant parts of the main rift valley lakes of Ziway, Abijata and Langano are also found in the Woreda. The Woreda's land mass lies between 1500 & 2300 m a.s.l. except area around Mount Aluto. Major rivers in the Woreda include: Bulbula, Jido, Hora Kalio and Gogessa. The Woreda is within sub-tropical agro-climatic Zone (OSG, 1999; RGO, 2003).

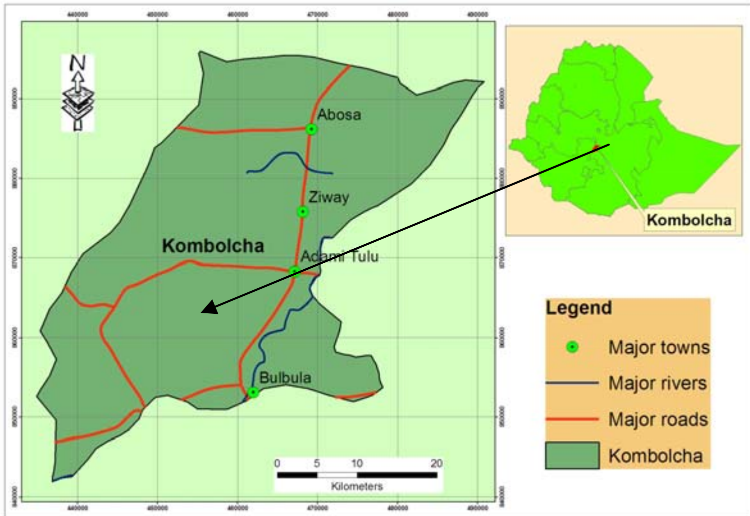


Fig.2. Map of Adami Tulu-Jido Kombolcha Woreda

3.1.2 Topography

The Woreda is found in the northern part of the Central Rift Valley. The relief of the area is characterized by plain and flat stretched land, with some small mountains, hills and gorges (Fig. 3 and 4) (RGO, 2003).

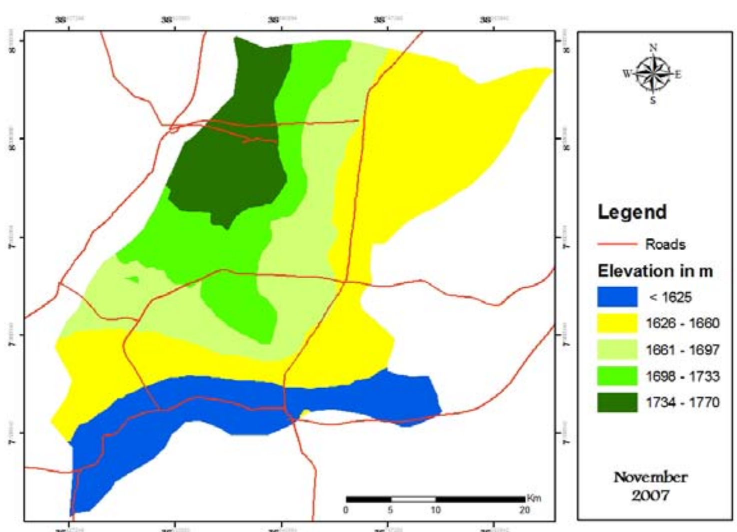


Fig. 3 Elevation map of the sampling points in the Adami Tulu-Jido Kombolcha Woreda

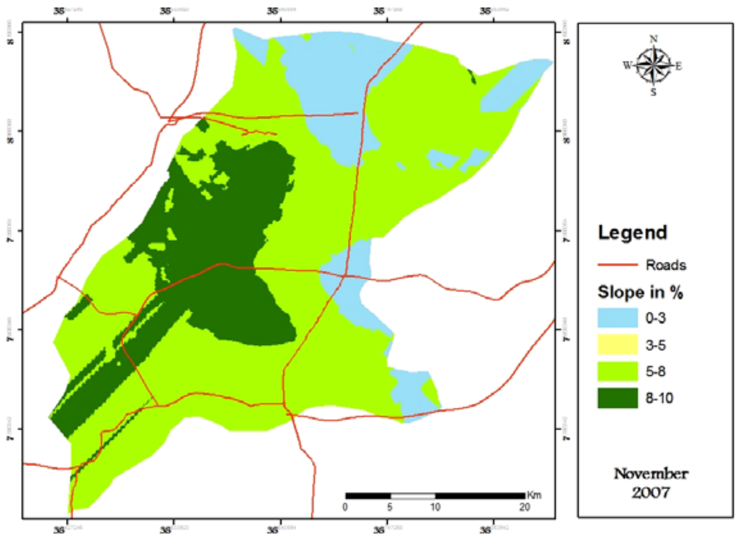


Fig.4 Slope map of Adami Tulu-Jido Kombolcha

3.1.3 Vegetation and wild life

The major natural vegetation of the Woreda belongs to woodland and savanna (Acacia-wood land and Savannah and Cenchrus- grasslands). Species composing the vegetation predominantly belong to the genera *Acacia* and *Balanites*. Major wildlife of the Woreda are warthog, duiker, monkey, tortoise, ape, greater kudu, great white pelican, flamingo, hippopotamus, ostrich, bush buck, duck, hyena, rabbit, and kerkero. A small part of the Shalla-Abijata National Park is in the Woreda (OSG, 1999; RGO, 2003).

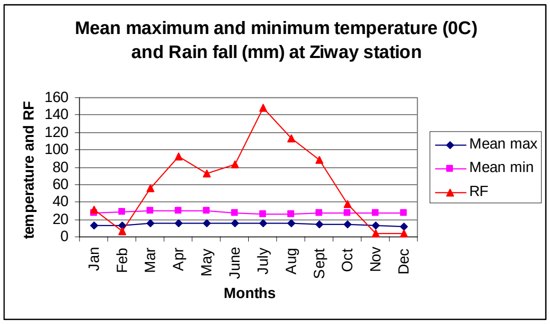
Fig.5 The stand of parthenium weed (a) at road side of Ziway (b) at Edo Gojola area

3.1.4 Geology and Soil

The parent material consists of volcanic rocks of basalt and tuffs with rare rhyolites and soils are whitish with coarse texture and freely draining. About 60.4%, 30.4% and 9.2% of the Woreda were covered by Andosols, Rendzinas and phaeozems, and Luvisol soils respectively (RGO, 2003). However, Vitric Andosols and Mollic Andosols dominate the Woreda. Provided that there is adequate moisture, most of these soils are among the most productive soils in the world. Other soils that are found in the Woreda include luvic phalozems and lithosols. Andosols soils originate from volcano-lucustine deposits with volcanic ashes, ciders, pumic (graves) lapilli. Fluvisols are derived from allvuium on the lakes shores and along the Meki River. Gleyic-Mollic flvuisols are derived from lacustrine deposited along the shore of Lake Ziway. They are deep, black, fine loamy and partly sodic (RGO, 2003).

3.1.5 Climate

The Woreda has semi-arid and arid agro-climatic Zones. It receives an average annual precipitation of 759.7 mm (RGO, 2003). The annual rainfall varies from a low of 513.92 mm in 1979 to a high of 1096.1 mm in 1976. About 41.49% of the annual rainfall is recorded during the period from June to September. The driest months are November and December; only 0.58% of the annual rainfall is recorded during this period. The mean annual temperature is 19.98°C at Ziway station while it is 20.04°C at Adami-Tulu station. The mean monthly temperature varies from 18.5°C to 21.6°C. May is the hottest month with mean maximum temperature of 28°C. the coolest month is December with minimum temperature of 10.7°C. The average air relative humidity is 72.75%, varying from 68% (November) to 78% (July and September) on the monthly average (RGO, 2003).



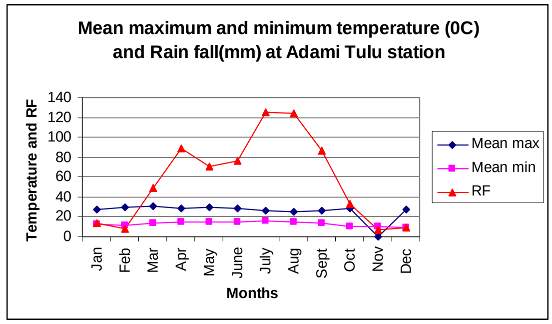


Fig. 6 Average means temperatures and rain fall at Ziway and Adami-Tulu stations

3.1.6 Population

The total population of Adami Tulu-Jido was 111,926 (28.5% urban) in 1994 (CSA, 1994). The economically active (15-64) were 50% of the total population. Children below 15 years were 48%, while the elderly (65 years and above) were only 2%. Females were 49.3% of the urban and 50.3% of the rural population. The average household size in the Woreda was 4.6, with 4.9 and 4.2 for rural and urban respectively. The population density was 86 persons per km^2 in the mentioned year (OSG, 1999).

3.2 Methodologies

3.2.1 Vegetation Survey

Sampling design

The samples of biophysical data were collected by using systematic grid sampling techniques. In systematic grid sampling, samples are taken at regularly spaced intervals. An initial location or time is chosen at random, and the remaining sampling locations are defined so that all locations are at regular intervals over an area (grid) (Cressie, 1993). Systematic grid sampling is used for mapping the spatial patterns or trends over time of *P. hysterophorus.* At each grid points a 1 m by 1 m area was selected for collecting biophysical data.

The combination of non-probability (purposive sampling) and random sampling techniques were employed. The study area is selected using purposive sampling techniques. Major PAs in Adami-Tulu-Jido Komblcha Woreda, where more dominated by *P. hysterophorus* selected. Furthermore, among the Adami-Tulu-Jido Komblcha,“ Wolin Bulla”, “Rasa Migira”, “Negalign”, “Abosa”, “Elka Jalamo”, “Edo Gojola”, Abina Germamo”,“Worjo Weshgula”,”Widana Garbi Boramo” and “Adami Tulu” Kebeles/PAs were selected using purposive sampling techniques.

A random sampling technique was used to determine the number of households who participated in the assessment of socioeconomic and ecological impacts of the parthenium weed. Moreover, the sample size was determined according to Bartlett *et al*. (2001).

3.2.2 Sampling of biophysical data

Data for the study was collected by combining physical survey with socio-economic survey. Present day distribution of *P. hysterophorus* was assessed using systematic regular grid sampling technique. This involved overlying regular grids of 2 km (L) x 2 km (W) over the map of the study area, and collecting density per unit area of *P. hysterophorus* at the intersection of each grid. At each grid spot, additional data on physical attributes such as crop type often cultivated, slope, aspect, soil texture, soil fertility, and special biophysical attributes that farmers suggest were collected. At the same spot, density of the species nine years back was obtained by interviewing nine elderly farmers selected based on cluster sampling technique. The clusters (in which the population is divided into mutually exclusive groups and draws sample of the groups to interview randomly) are three villages closest to the grid corner, and three elderly farmers were selected from each village and interviewed. The average density estimate provided by the nine interviewed farmers for the spot were recorded as density for the period nine years before present. The grid intersections were navigated using GPS, and at each spot the coordinates and altitudes were registered from the GPS reading.

The data collected mainly include ground truth data identified with transect walk and the coordinates are recorded with GPS, the current density of the *P. hysterophorus* was recorded by counting each plant head per square meter (m^2) in every plot. The past density also collected by interviewing nine elderly farmers from nearby three villages (three elders from each village) and taking their averages for the past nine years back data in the same area. Moreover, the density and the frequency of all the wild species in the selected area were collected by counting in each 50 by 50 cm quadrats. Assessment was conducted in different habitats (sectors): cultivated lands, vacant and/or waste lands, roadsides, lakeshores and in grazing lands and woodlands to draw exhaustive inventory of parthenium weed infestation.

3.2.3 Sampling of weed species

The impacts of parthenium weed on biodiversity were assessed, using the importance value index to describe its importance. The importance Value index is useful to compare the ecological significance of a particular species (Lamprecht, 1989; cited in Girma Balcha *et al*., 2004). During the survey, all wild species growing along different wastelands, roadsides and wetlands as well as grazing lands were collected and identified by referring to Flora of Ethiopia and Eritrea in the National Herbarium of Ethiopia, Addis Ababa University. The weed study was made following the list count method suggested by Raju and Reddy (1998) and Shabbir and Bajwa (2006). The weeds were collected by counting stem of each species per 50 cm by 50 cm quadrats. The importance value (IV) is the sum of the relative density (RD) and relative frequency (RF) of species in a stand. The sampling was conducted randomly in all selected plots of Adami Tulu-Jido Kombolcha Woreda. Finally the compiled data were analyzed for biodiversity studies using the following equations:

$$RF(\%) = \frac{Absolute frequency value for Parthenium speices}{Total absolute frequency for all species} * 100 \qquad \ldots\ldots\ldots\ldots 2$$

$$RD(\%) = \frac{Absolute density for given species}{Total absolute densit for all species} * 100 \qquad \ldots\ldots\ldots\ldots 3$$

$$IV(\%) = RD + RF \qquad \ldots\ldots\ldots\ldots 4$$

3.2.4 Socioeconomic Survey

The study site i.e. Kebeles or Peasant Associations (PAs) were selected based on purposive sampling technique for socioeconomic study. Representative Kebeles/PAs in the Woreda were selected, then representative villages within association, and farmers within villages. Fields were selected regardless of size, and on the grounds of accessibility (adjacent to road) and whether it carried the required amount of *P. hysterophorus* i.e. its degree of infestation. These Kebeles were selected because; they are good prospects for accurate information and also are highly infested by *P. hysterophorus* in the Woreda. The number of samples was determined based on Bartlett *et al*. (2001), techniques. Additionally, using semi-structured questionnaires data were collected to make analysis on the socio-economic and environmental impacts of *P. hysterophorus*. The total number of respondents was 160 at $\alpha = 0.05$ level. This is more reliable and representative to give accurate analysis inference on the socio-economic and ecological impacts of the parthenium weed in the Woreda.

3.2.5 Environmental factors data

Finally, data on major environmental factors and crop management practices believed to influence *P. hysterophorus* distribution in each field were collected by observation and feel methods with the help of DAs and farmers (soil texture and fertility, topography, type of crop and current land use type), measurement (altitude, slope, aspect), interviewing farmers (number of ploughings before planting, fertilizer use, and crop pattern) or from secondary sources (administrative Kebeles, rainfall, temperature, humidity). Environmental and crop management variables of nominal type (Soil texture, soil fertility, crop type, current land use, fertilizer use) were converted into binary dummy variables that take the value 1 if the field belongs to the category or 0 if it does not. Altitude, number of ploughings, density of both past and present (per m^2) and slope in % were quantitative variables and hence measured on an interval scale.

3.2.6 Data analysis

The biophysical data obtained from the field were analyzed using Ms-Excel, Geostatistics and ArcGIS 9.1 software. The data from Ms-Excel imported into ArcGIS. In ArcGIS, spatial analyst and Geostatistical analyst components were used to synthesis maps of past and present distribution of *P. hysterophorus,* elevation and slope. Similarly, maps of some of the quantitative parameters such as slope and altitudes were mapped to investigate the association between the distribution of the weed and physical parameters. Similarly, correlation and regression analyses were performed for the weed density and other physical parameters such as slope to investigate which factors favor the species and to evaluate the fitness of the model. The socioeconomic and other biophysical data are analyzed by using SPSS Version 13.0 software. The plot data (slope, altitude, soil texture and fertility, farm management, current land use, crop type, and other biophysical data), the results were used to determine the correlation between the rate of distribution and density of the parthenium weed in the study area. It was also used to determine the potential distribution of parthenium weed in the Woreda.

Experimental variogram

In this research the experimental variogram which is the variogram computed from the sample data (Webester and Oliver, 2001) was assessed at different lag sizes (cut-off) before fitting the model. The appropriate lag spacing for the experimental variogram was determined by generating and visually inspecting several experimental variograms. The variogram were calculated with different lag spacing by observing which variogram best revealed the spatially dependent correlation of the data (Isaaks and Srivastava, 1989) and also with visual observation (Webester and Oliver, 2001). The model fitting was done for the empirical variogram values.

Spherical model (equation) was used for predicting *P. hysterophorus* weed density in this research. This model rises from the nugget value almost linearly and reaches an absolute sill value at distance of range (Webster and Oliver, 2001). The spherical model is described to be the best model for vegetation parameters prediction (Wallace *et al*., 2000).

Spherical model:

$$\gamma_s(h) = C_o+C_1\ [(\frac{3}{2}(\frac{h}{a})-\frac{1}{2}(\frac{h}{a}))^3] \quad \text{for } h<=a \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots..5$$

And $\gamma_s(h) = C_o+C_{1,}$ for h >a

Where C_o = nugget, C_1= sill, h= distance, a= range (Isaaks and Srivastava, 1989)

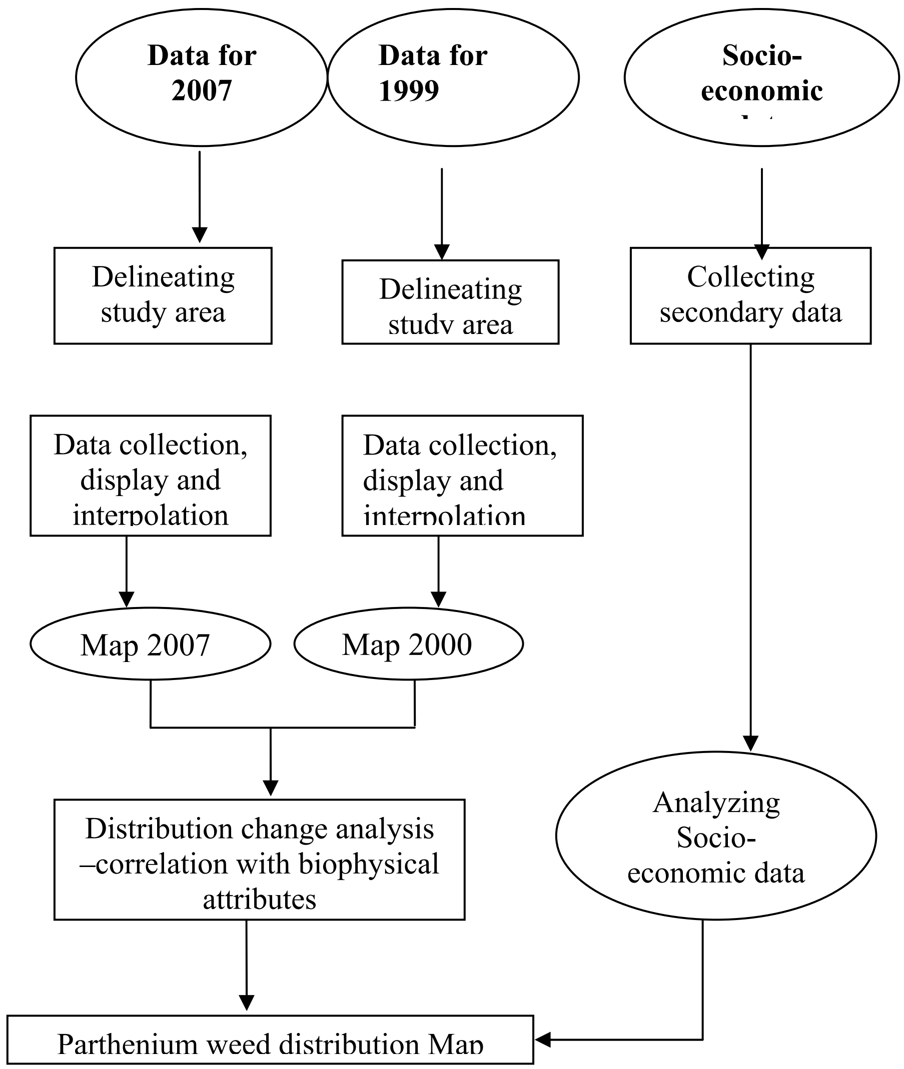


Figure 7 Summary of flow chart that shows general methodology of the study

Kriging

The aim of kriging is to estimate the value of a random variable at one or more unsampled points or over larger blocks, from more or less sparse sample data on a given support (Webester and Oliver, 2001).

Two kriging methods were selected and assessed for *P. hysterophorus* weed distribution prediction. These methods include: Simple Kriging (SK) and Ordinary Kriging (OK).
These kriging methods were tested for their best performance, OK was found the best method and the actual prediction mapping of parthenium weed was done using this method.

In the actual map production using kriging, four major steps were taken in this research. These steps were determination of the variogram, fitting a model to the variogram prediction of the values at the nodes of a fine meshed grid and finally presentation of the results (Chiles and Delfiner, 1999; ILWS, 2001; Isaaks and Srivastava, 1989; Webester and Oliver, 2001). A general overview of the methods employed in the assessment of parthenium weed is presented in Fig. 7.

Table 1 Kriging parameters for *P. hysterophorus* computed using variogram analysis.

Type of environmental factors	**Model type**	**Nugget Effect**	**Sill**
Elevation	Spherical	0	513.48
Current density	Spherical	765.16	298.86
Past density	Spherical	72.864	0
Slope	Spherical	3.966	2.4204
Current land use type	Spherical	1.083	0.26263

If a variogram displays a leveling-off behavior, then the variogram value at which the plotted points level off is known as the "sill" (Fig. 1). The value of the sill is usually equivalent to the traditional sample variance. The distance at which the variogram values level off is known as the "range." The range designates the average distance within which the samples remain correlated spatially. Variograms that do not demonstrate a leveling off imply that the range is beyond the maximum appropriate distance represented.

The variogram value at which the model appears to intercept the ordinate is known as the "nugget." The spatial characteristics of these nuggets impart unexplained variability in the modeling of the variable (Webester and Oliver, 2001). A nugget represents two, often co-occurring, sources of variability. One source derives from spatial variability at a scale smaller than the minimum lag distance, and hence it cannot be modeled with the present sampling scheme. The other genesis of a nugget is experimental error which is sometimes referred to as the "human nugget." Interpretations made from variograms depend on the size of the nugget because the difference between the nugget and the sill (if there is one) represents the proportion of the total sample variance that can be modeled as spatial variability (Webester and Oliver, 2001).

4 RESULTS AND DISCUSSION

4.1 Distribution of parthenium weeds in the Woreda

4.1.1 Past distribution of *P. hysterophorus*

Farmers in the study area believe that *P. hysterophorus* was introduced into the area following road construction project of the highway from Modjo to Awassa in 1999/2000. Indeed, the invasion of *P. hysterophorus* in the Woreda began before nine years. Since then it expanded at alarming rate in all directions mainly following slope gradient (Fig. 8).

In areas where parthenium infested highly its rate of infestation is strong enough to cover large areas (Fig. 8). The analysis also showed that, past and current density (per m^2) of the parthenium weed is positively related ($r = 0.822$). Furthermore, the relation between past and current density is significant at $p < 0.01$ (0.00).

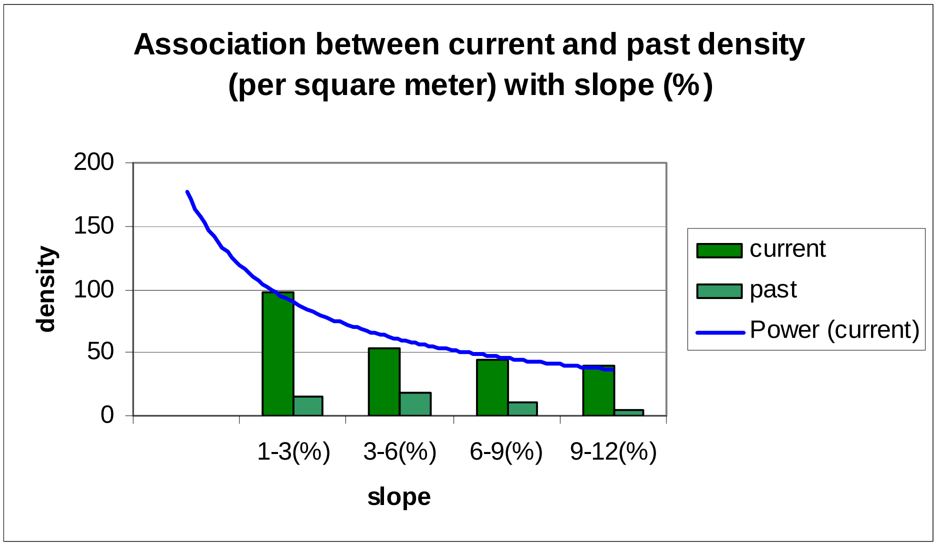


Fig.8 Association between parthenium weed density with slope

As figure nine below depicts the density of *P. hysterophorus* in the past was highly concentrated at Negalign and part of Elka Jelemo following the main road from Modjo to Awassa. *P. hysterophorus* was highly concentrated around north-eastern part of the Woreda, close to Lake Ziway with maximum value of 61 plants per m^2. The next highest density range occurred at Abosa, Wollin Bulla, Ziway, part of Edo Gojola, Elka Jelemo, and Abina Garmamo Kebeles in the Woreda. Generally past density distribution of parthenium weed occurred following the main road in the north-east parts from Abosa town down to Ziway city.

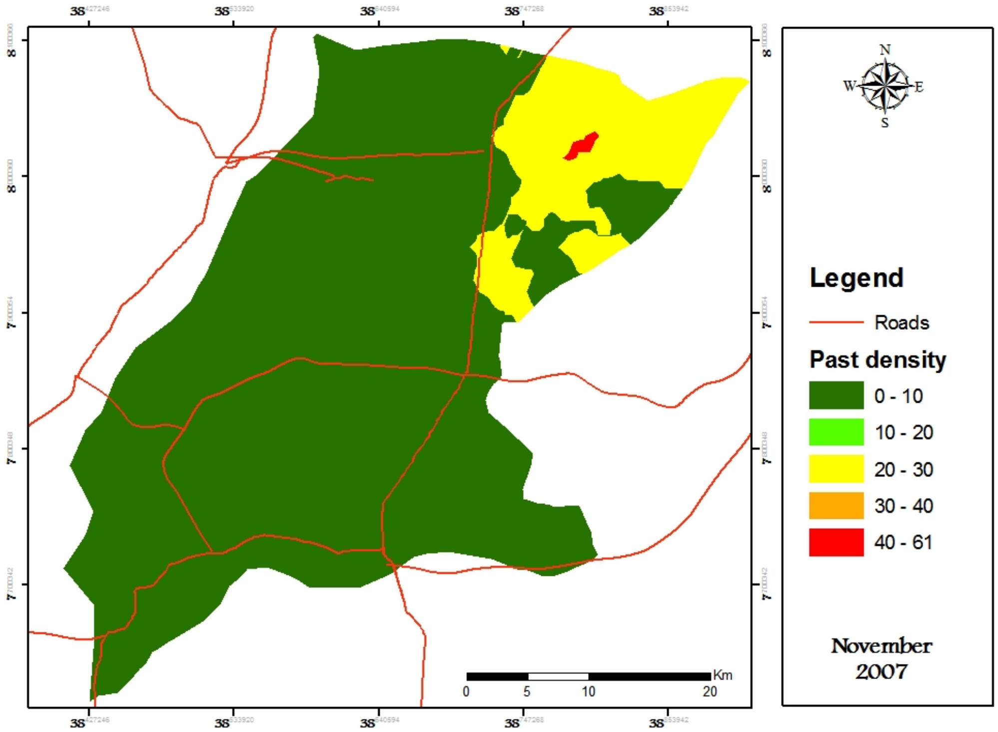


Fig 9 Parthenium weed distribution nine years ago in the study area

Even though, there are different factors that favor fast distribution of the weed, flooding and movement of vehicles are the major factors. This radiation occurs particularly in the direction of low slope and waterways. Fig. 8 also depicted that the correlation between slope and distribution of the weed in the different Kebeles within the Woreda. From the figure it can be seen that there is no strong association between density of infestation and ground slope. This is also true statistically as there is weak and negative, correlation between parthenium weed density and slope in the study area (r = -0.052). This could be due to the generally flat topography of the area. Although slope does not appear a limiting factor for dissemination of *P. hysterophorus* in the Woreda, however, parthenium weed was also observed in areas of relatively higher altitudes of the Woreda particularly at Rasa Migira. This is against the normal route of flooding. But according to key informants and farmers this is happening due to construction activities and vehicles and other human activities.

4.1.2 Current distribution of *P. hysterophorus*

Though parthenium weed in the Woreda was introduced recently, it is covering large area in the Woreda as shown in Fig. 10. The figure reveals that the infestation is radiating from a localized source, which confirms the perception of the locals. The localized infestation of parthenium weed was observed on roadsides, and the highest densities that overlap with the map were also recorded in the field from the north eastern parts of the Woreda, close to Lake Ziway. The highest density (plants per m^2) was 319 at around Edo Gojola.

Furthermore, the high infested northeastern part of the Woreda is also the area that had the highest infestation of *P. hysterophorus* in the past (Fig. 9). In particular, following both sides of the main road, at Abosa, Negalign, Elka Jelemo, Abina Garmamo, and Ziway city showed a high infestation. These Kebeles are those adjacent to Lake Ziway and may have relatively better moisture contents in the Woreda.

Generally the weed is found in areas of low altitude and flatter topography and near to areas towards Lake Ziway (Fig 10). As also shown by the overlap of highest density spots from Figs. 8 and 10, there is a correlation ($r = 0.822$) between past as well as current distribution of *P. hysterophorus* and it is significant at $p < 0.05$. In areas of high *P. hysterophorus* density in the past there was also a high relative density per m^2 currently as depicted in Fig. 10. This is probably due to high viability of the parthenium weed seed banks in soil (Tamado Tana, 2001). Thus parthenium weed density per m^2 is often increasing in every generation, unless intervention is taken to control its spread. Bhan *et al*. (1997) also suggested the same patterns.

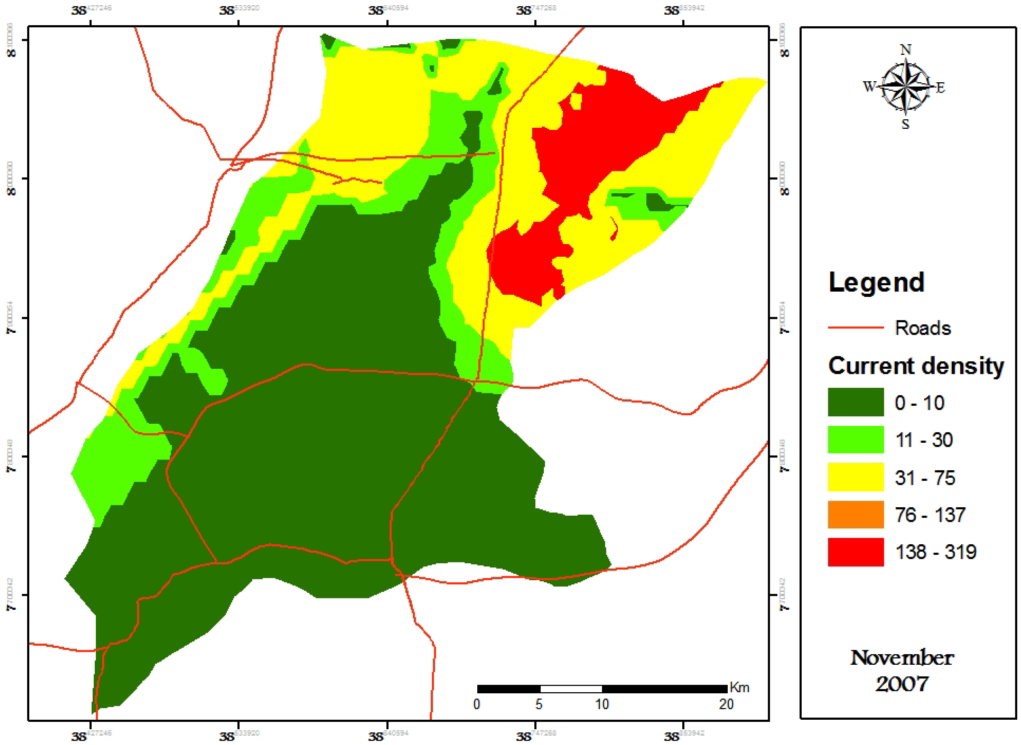


Fig.10 Map of *P. hysterophorus* current density distribution in Adami Tulu-Jido Kombolcha

4.1.3 Environmental factors that favor or disfavor the distribution of the species

Soil texture and both past and current parthenium weed density per m^2 are positively correlated r = 0.209 and r=0.258, respectively. This correlation is significant at $p= 0.05$ (0.01 and 0.001 respectively), and also there is negative co-relation between soil fertility and past and current density (-0.222 and -0.267 respectively). Thus there is a correlation between the past and current density of *P. hysterophorus* and texture of soil but its fertility in the study area is negatively correlated and do not influence parthenium weed distribution in the study area. In other words soil texture will favor the fast distribution of *P. hysterophorus,* while its fertility does not affect despite the fact that parthenium weed can grow in any type of soil environment. There is also weak but positive correlation between past and current density and number of plough per season r = 0.052 and r= 0.111 respectively (Table 2).

Parthenium hysterophorus density (past and current) and fertilizer application are also positively but weakly correlated (r = 0.271) and (r = 0.366) respectively. These correlations are significant at *p= 0.01* (0.001) and *p= 0.05*(0.000) respectively. The Kebeles with high infestation of *P. hysterophorus* used fertilizer. There is positive but weak correlation between current land use and both past and current density of parthenium weed in the Woreda r = 0.126 and r = 0.127 respectively (Table 2).

On the contrary, the distribution of *P. hysterophorus* did not show strong variation with altitude, slope and aspect in the study area. The correlation between altitude and both past and current density of the parthenium weed is negative and weak (r = -0.053 and r= -0.025 respectively). This implies that there is no strong correlation between altitude and parthenium weed density. This may be due to the absence of significant difference in elevation in the Woreda (Fig.2). Moreover, there is also no significant correlation between aspect and parthenium weed distribution. Thus rate of parthenium weed distribution is not influenced by both elevation and aspect in the study area. This observation differ from the study by Tamado Tana (2001), who showed that altitude, rainfall, month of planting, number of weedings and soil type were the major environmental/crop management factors influencing the species distribution in the study area. In the present study, however, soil texture, land use type, crop type, number of plough before sawing, and application of fertilizer favor the fast distribution of parthenium weed, while elevation, slope, soil fertility and aspect do not favor its fast dissemination into different Kebeles.

Table 2 Results of correlations of some of biophysical data

Parameters		Altitude(m)	Current density(per m^2)	Past density (per m^2)	Slope (%)	Soil texture	Soil fertility	Aspect	Current land use	No of plough	Fertilizer use
Altitude	Pearson Correlation	1	-0.025	-0.053	0.181*	0.097	-.187*	-0.063	-0.164*	-0.060	-0.003
	Sig.(2-tailed)		0.762	0.518	0.026	0.237	0.022	0.446	0.044	0.462	0.971
Current density	Pearson Correlation	-0.025	1	0.822**	-0.004	0.258**	-0.267**	-0.104	0.126	0.111	0.366**
	Sig.(2-tailed)	0.762		.000	0.958	0.001	0.001	0.207	0.123	0.176	0.000
Past density	Pearson Correlation	-0.053	0.822**	1	-0.025	0.209*	-0.222**	0.004	0.127	0.052	0.271**
	Sig.(2-tailed)	0.518	0.000		0.758	0.010	0.006	0.960	0.122	0.525	0.001
	N***	150	150	150	150	150	150	150	150	150	150

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
*** N is total number of grid points

4.1.4 Infestation of ***P. hysterophorus***

Parthenium weed was observed in the Woreda to grow on roadsides, wastelands, in towns, villages, gardens, waterways, grasslands, wetlands and in crop fields both during cropping season and after harvest. However, regarding the time when the weed is introduced to the Woreda, farmers varied considerably on their perception. Few indicated that the weed was observed in the Woreda nearly nine years ago while the majority of the farmers have the perception that it was introduced to the Woreda recently (Fig. 11).

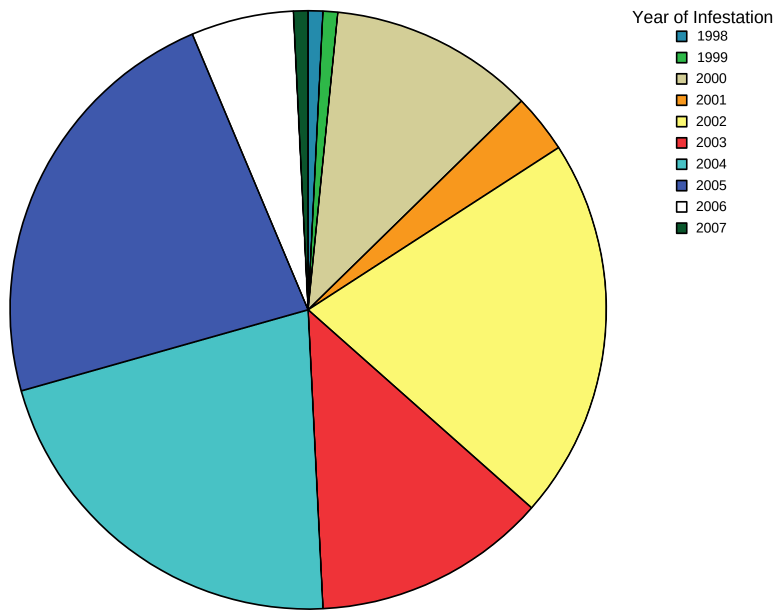


Fig. 11 Year of infestation of *Parthenium hysterophorus* (in %) as perceived by farmers in the study area of the Adami Tulu-Jido Kombolcha Woreda

The intensity of parthenium weed infestation of crop fields in the Woreda varied from field to field depending on the time of the weed's introduction into the area and the efforts made by the farmers to control it. It recently became a major crop weed across Wolin Bulla, Rasa Migira, Elka Jalamo, Negalign, and Edo Gojola Kebeles of Adami Tulu-Jido Kombolcha Woreda (Table 3 and Figs. 9 and 10). Severe infestation, which corresponds to more than 20 plants per m^2 density or scale of 5 (Table 3), was observed in sorghum, maize and wheat fields around Rasa Migira, Elka Jalamo, Negalign, and Edo Gojola and in sorghum, maize and tef fields around Rasa Migira both during the growing period (May-September, 2007) and after harvesting time. The scale of importance of the parthenium weed for these areas was also 4 except Edo Gojola (3) showing very serious or heavy yield reduction due to the weed.

Similarly, in Wolin Bulla, Adami Tulu, Worjo Weshgula, Widana Garbi Boramo and Edo Gojola heavy infestation of parthenium weed in the sorghum and maize field as well as irrigated land was observed both during fallow and cropping seasons. In Adami Tulu, parthenium weed had entered crop fields having a scale of infestation 3 and importance of 2 (Table 3).

Table 3 Distribution and scale of parthenium weed infestation in Adami Tulu-Jido Kombolcha

Location	Altitude (m)	Texture class	Infested habitat*	Scale of infestation (0 – 5)**	Importance (1 – 4) ***
Wolin Bulla	1673	Sandy loam	5	5	3
Negalign	1691	Sandy loam	5	5	4
Rasa Migira	1763	Sandy clay	5	5	4
Elka Jalamo	1660	Sandy loam	4	5	4
Edo Gojola	1657	Sandy	5	5	3
Ziway	1647	Sandy	3	5	3
Widna Garbi Boramo	1667	Sandy	1,2,3	2	1
Adami Tulu	1660	Sandy clay	3	3	2
Abina Garmamo	1654	Sandy	1,2,3	5	3
Worjo Weshgula	1670	Sandy clay	4	1	2
Kemo Gerbi	1648	Sandy clay	1,3,4	5	3
Anano Toro	1668	Sandy	4	3	2
Widna Gerbi	1676	Sandy clay	4	3	2
Tulcha	1662	Sandy	1	2	1
Abosa	1662	Sandy loam	1	2	3

*Infested habitats: 1 = road sides; 2 = range lands; 3 = gardens and villages; 4 = crop fields; 5= all habitats;

**Scale of infestation: 0= no parthenium weed in the field, 1= beginning or presence of parthenium weed only on road sides, 2= presence of parthenium weed infestation on road sides and
non- crop lands, 3= infestation on road sides, non-agricultural lands and beginning on crop lands, 4= infestation on crop fields up to 20 plants per m^2 and 5= severe infestation of parthenium weed (> 20 plants per m^2).
*** Importance of parthenium weed in the area: 1 = no parthenium weed in the crop field; 2 = not serious (present at low density); 3 = serious (moderate yield loss); 4 = very serious (heavy yield loss).

Wide range distribution of the weed in the Woreda as well as observation of its growth in all forms of ecosystem conforms to previous study reports. For instance, Taye Tessema (2002) reported parthenium weed to grow in different agro-ecological Zones, from hot arid and semi arid low altitude to humid high mid altitude (920 at Awash and 2350 at Chelenko) m a.s.l. as well as on any type of soil (sand, loam or clay) and in different habitat (roadsides, wastelands, rangelands, villages, towns, gardens, crop fields and shore sides). Hedberg *et al*. (2004) also reported that parthenium weed can grow at altitude of 900-1800 m a.s.l. This indicates that the species has wider ecological amplitude and adaptability.

According to the farmers in the Woreda, grazing land and roadside are the two highly infested habitats (Table 4), while about 49.1% of the farmers also indicated that the weed first appeared on road side.

Table 4 Farmers view of the first appearance of the weed in the Woreda of the study area

Habitat	Frequency	Percent (%)
Grazing land	8	5
Irrigated land	10	6.2
Road side	79	49.1
Waste land	30	18.6
Grazing and irrigated land	1	0.6
Grazing and road	5	3.1
Irrigated and road side	9	5.6
Irrigated and Waste	2	1.2
Road side and Waste	15	9.3

Farmers' view of the infestation habitat conforms with field observation. It was noted that, parthenium weed population is high in places where the soils are disturbed constantly for purposes of construction of road, buildings, and waterways for irrigation channels. Therefore, the extensive density along roadsides in different Kebeles might be due to the routine disturbance and grading of road verges and transportation of sands and gravels from parthenium weed infested to non-infested areas. This observation is in line with Shabbir and Bajwa (2006), GISP (2004) and Huy and Seghal (2004). This might have helped the dispersal of the weed thereby contributing to severe infestation and invasion of parthenium weed in the Woreda particularly in the Rasa Migira (Fig. 10).

According to interviewed farmers and DAs, the weed was spread into the Woreda through vehicles during road construction from Modjo to Awassa through different means since 1999/2000. In addition, construction materials had played a significant role for fast rate of dissemination/distribution of the weed.

Many mechanisms were suspected by farmers as a means for its fast distribution in the Woreda (Table 4). According to farmers, these dissemination mechanisms include: wind 6.3%, flood 46.3%, and vehicles 51.2% and other mechanism 41.3%. Among these major dispersal mechanisms flooding and vehicle 46.3% and 51.3% respectively, took the lead for its fast rate of distribution in to different Kebeles within the Woreda.

Table 5 Farmers view on the agents for the fast spread of parthenium weed in the Woreda

Means of introduction	Frequency	Percent (%)
Through fodder	2	1.3
Human activity	5	3.1
Animal movement	5	3.1
Vehicle	82	51.2
Seed	8	5
Wind	10	6.3
Flood	74	46.3
Other mechanism	66	41.3

Farmers also included livestock as a mechanism for the weed distribution. This is because of unrestricted movement of animals to Lake Ziway for watering. These mechanisms identified by farmers agree with studies of other scholars such as Auld *et al*. (1983), who stated that local dispersal of *P. hysterophorus* seeds occur locally by wind and water, while motor vehicles, machinery and livestock movements, crop and pasture seeds contribute for long distance dispersal.

In areas weeding is not done as frequently and systematically, it is very common to see dense stands of parthenium weed as pure stands. It is also observed that the weed grows in the fallow period in fields where only one or few crop is grown in a year. According to the farmers and field observation, parthenium weed has been observed in the field germinating and growing even during dry periods with one or two showers. This might be due to its relative low moisture requirement for germination and its drought resistance capacity thereby suppressing other plant species (Taye Tessema, 2002.)

4.1.5 Farmers' practices to control *P. hysterophorus*

Like other weeds, control of parthenium weed in the Woreda is entirely based on cultural and labour intensive practices such as tillage, hand weeding, mowing, hoeing and slashing.

These control methods are currently practiced by more than 90% of farmers (Table 6). Unlike large-scale farms in developed and developing countries, small-scale farmers prepare their land using repeated oxen ploughing and/or hoeing. Almost all (> 99.9%) of the farmers in the Woreda use oxen and/or hand hoeing for ploughing their plots and about 41.9% of the farmers ploughed three times before sawing (Appendix 6). This traditional method of ploughing practice was not an efficient method to control parthenium weed distribution; rather it increases from time to time since its invasions. Because of extended root system deep into the soil, mature plants of parthenium weed are difficult to remove completely (Bhan *et al*., 1997). Most of the farmers in the study area began to take measure since 2005, while quite large numbers do not take any measure at all (Table 7). Still few farmers were observed to mow parthenium weed infested fields at first and then plough using ox-plough. Still, uprooting is

difficult unless ploughing is done at the time when there is enough moisture in the soil to ease uprooting of parthenium weed. Further, most farmers suggested that, the fields with high infestation of *P. hysterophorus* are difficult to mow and plough.

Table 6 Farmers' response on the type of measures to control dissemination of parthenium weed in the study area

Methods of control of parthenium weed	Frequency	Percent (%)
Weeding and burning	147	91.9
Fallowing	1	0.6
chemicals	5	3.1

Table 7 The period in which *P. hysterophorus* was observed and farmers started taking control measures in different Kebeles in the Woreda

Period of control action taken by farmers	Frequency	Percent (%)
2000	1	0.6
2002	2	1.2
2003	2	1.2
2004	9	5.6
2005	57	35.4
2006	39	24.2
2007	6	3.7
Total	160	99.4

In the Rasa Migira, Elka Jalamo, Negalign, and Edo Gojola parts of the Woreda, intensive hand weeding and/or hoeing and burning were practiced in crop fields like maize and sorghum to control further dissemination (Table 6). But farmers, who practiced hand weeding and/or hoeing (91.9%), suggested that the parthenium weed multiplies in the next crop season hence, this method is not a permanent solution to control further spread. This agrees with the report of Bhan *et al*. (1997) who suggested that manual and mechanical control methods give temporary solutions because *P. hysterophorus* covers large areas. These authors also stated that no single method of control of *P. hysterophorus* has proved satisfactory as each method suffers from one or more limitations. Mowing or slashing of *P. hysterophorus* is not recommended since this would result in rapid regeneration of plants from lateral shoots (Gupta and Sharma, 1977). It is suggested that *P. hysterophorus* should be uprooted to prevent regeneration from the remaining lateral shoots and that such operation should be done before flowering and when the soil is moist enough to facilitate easy removal.

However, by weeding and/or hoeing and burning, farmers tried to keep the level of infestation of their crop fields low though some farmers reported to suffer from parthenium weed associated health problems such as allergy and dermatitis (18.8%, n=160) including in some cases headaches and fever (Appendix 5). To avoid the problems, farmers wear plastic bags while hand weeding. However, farmers do not want to weed parthenium weed from communal lands, such as field borders, wastelands, water ways and road sides. Hence, it grows and sets seeds in these areas from where it re-infests and spreads itself to other areas. In some cases, farmers are advised by experts from the agriculture office of the Woreda to eradicate by mowing and/or slashing parthenium weed growing in their village, garden, fields, roadsides, and grass lands through campaigns.

4.2 Socio-Economic and Environmental Impacts of *P. hysterophorus*

Of the interviewed farmers, 86.3% in the Woreda were aware of the problem the weed causes on crop and/or grazing land. Some of these respondents consider *P. hysterophorus* to be the most important weed both in the grazing land and crop field. However, in the Wollin Bulla almost all farmers consider it as a roadside weed only (65%, N=20). These figures show that the problem caused by the weed is not currently felt equally by all farmers across the Woreda. However, as reported by Haseler (1976) the initial occurrence of *P. hysterophorus* in a new area usually occurs along roadsides and it is from this foothold that it spreads extensively into agricultural land, as observed in Wollin Bulla (personal observation). Moreover, the interviewed farmers and other professionals reported that there is no benefit attached to the weed thus far.

The farmers interviewed indicated that *P. hysterophorus* has a number of socio-economic impacts that include effect on crop and livestock production, human health and biodiversity (Table 8). These findings are in line with the studies by Kohli & Rani (1992) and Evans (1997a) who reported a number of environmental and agricultural problems, such as the loss of crop productivity, fodder scarcity, biodiversity depletion and health problems for human beings and livestock. Therefore, *P. hysterophorus* contributes to social instability and economic hardship, placing constraints on sustainable development, economic development, poverty alleviation and food security.

Table 8 Types of damages caused by parthenium weed as ranked by farmers

Types of damage	Number of respondents (%)	Remark
Crop production	**44**	Reduction of yield quality and quantity
Livestock	**30.6**	Health and productivity
Health impacts	**18.8**	Human health
Impacts on biodiversity	**100**	It has no environmental benefits

4.2.1 Effects on biodiversity

The survey made in Adami Tulu-Jido Woreda revealed a total of 21 weed species that were associated with *P. hysterophorus* (Table 9 and appendices 2 and 3). The most important families, based on the number of family, were Compositeae (6) followed by Gramineae (4), and it is noteworthy that two of the weeds ranked by farmers as most troublesome (Table 10) were quite recently introduced *P. hysterophorus* L. and *Argemone mexicana* L. Furthermore, *A. mexicana* L. was also reported by the farmers to be recent introduction to their areas. Hence, there is reason to be aware of the danger of introduction of new species. Almost all the selected areas of Kebeles in the Woreda had a heavy infestation of *P. hysterophorus* except Wollin Bulla.

Table 9 List of weed species in Adami Tulu-Jido Kombolcha (field observation)

Scientific name	Family name	English name	Local name	Origin	Worst affected area
Galinsoga parvifolra	Compositae	Gllant soldier	Aba Tabo	Peru	Range land and crop field
Xanthium strumarium L. (X.abyssinicum)	Compositae	Cocklebur	Metene	Central America	Crop field
Oxygonum sinuatum	Polygonaceae	Double thorn	Rafu hare/Sogdo	*NF	Range land and crop field

Digitaria velutina	Gramineae	NF	Shubbo(O)	NF	Range land
Datura stramonium L.	Solanaceae	Thorn apple	Manji(banji)	Abyssinia	Range land, and crop field
Bidens pilosa L.	Compositae	Black jack	Chigogot	Tropical America	Range land
Cyperus rotundus	Cyperaceae	Purple nutsedge	Kundi	NF	Road side and crop field
Cynodon dactylon L.	Gramineae	Bermuda grass	Korto	NF	All habitats
Snowdenia polystachya	Gramineae	NF	Muja	NF	Range land
Alternanthera pungens L. (= A. repens)	Amaranthaceae	NF	Safela	NF	Crop field and west land
Commelina latifolia	Commelinaceae	Water maker	Laluncha	NF	West land
Erucastrum pachypodium	Cruciterae	NF	NF	N F	Rang land and crop field
Guizotia seabra	Compositae	NF	NF	NF	Rang land
Tribulus terrestris	Zygophyllaceae	Puncture vine	NF	NF	Crop field
Xanthium spinosum L.	Compositae	Spiny cocklebur	Yeset Milas	Central and South America	Rang land and crop field
Parthenium hysterophorus L.	Compositae	Congress weed	Farmsisa	Mexico and central America	Road side and range lands
Solanum indicum	Solanaceae	NF	Inbawy		West land
Lantana camera L.	Verbenaceae	Lantana	Yewofe kolo	USA	Road side and west land
Setaria pumila (=S.pallide-fusca)	Gramineae	NF	Yewisha sendedo	NF	West land
Cyperus regitidipholus	Cyperaceae	NF	NF	NF	Rang land and crop field
Argemonne mexicana	Papaveraceae	Mexican poppy	NF	Central America	Road side and west land

*NF Not Found

The analysis of the data collected from grazing land of the study area revealed that *P. hysterophorus* was accompanied by nine other weed species. *Galinsoga parviflora* (Aba Tabo) was the most dominant plant species, with an importance value (IV) of 61.15% (Table 10). This was followed by *P. hysterophorus* and *Digitaria velutina* (Shero) with IV of 22.65% and 21.09% respectively.

This area was also inhabited by a high diversity of weeds; a total of ten species was found in this sector followed by crop field, which has also nine plant species. However, *P. hysterophorus* is becoming the most dominant weed species within a short time since its introduction.

Parthenium hysterophorus with the highest IV (i.e101.5%), followed by *Cynodon dactylon* L. (Korto) species with IV values of 25.84% were observed in road side. It is particularly roadsides sector in which parthenium weed highly dominates and competes with other native and non- native roadside plant species. Moreover, this sector also consists of the least compositions of plant species even compared with the same sectors without parthenium weed invasions. This is a clear indication for allelopathic potential of *P. hysterophorus.* Similarly, Krishnamurthy *et al*. (1997) described the allelopathic nature of *P. hysterophorus* and its impact on plant diversity. Allelopathic interference also has been well-demonstrated in Parthenium weed and almost all the plant parts, including pollen and trichomes, are allelopathic (Kohli & Rani, 1992; Evans, 1997a). Tadelle Tefera (2002) also described that the impacts of aqueous extracts from Parthenium weed leaf, stem, flower and root parts exhibited allelopathic activity on tef seed germination and seedling growth.

The crop field sector in another plot area were found to be least dominated by parthenium weed and maximum management were practiced. The analysis of data collected from this field of the study area, reveled that *P. hysterophorus* was accompanied by eight other plant species. *Oxygonum sinuatum* (Rafu hare), *C. dactylon* and *P. hysterophorus* codominant with IVs 30.78%, 24.99% and 23.05% respectively (Table 10). However, *P. hysterophorus* had a frequent to occasional level of occurrence in this sector.

The analysis of data conducted on wet land (shore side) indicated that there were only two species, *P. hysterophorus* and *C. dactylon* with IVs 31.43% and 101.22% respectively. This sector was the least diversed and dominated by *C. dactylon* (Table 10). However, this sector soon or later will invaded by *P. hysterophorus* if not any control action taken by responsible agents.

Analysis of data collected from waste land showed that it was inhabited by six plant species. *P. hysterophorus* and *Lantana camara* (yewofe kolo) were codominating the plots with IVs of 62.53% and 50.52% respectively (Table 10). Plot six which was also belong to crop field sectors, dominated by *O. sinuatum* and *P. hysterophorus* with IVs 37.7% and 29.2% respectively. However, in this plot parthenium weed is becoming dominant and completely might dominate within a short time, because of its allelopathic potential.

Analysis of grazing land in another Kebele also exhibited a total of four weed species associated with *P. hysterophorus*. *P. hysterophorus* was the most dominant weed species of this sector, *G. parvifolra*, and *Guizotia seabra* (Hada Dima) as codominant. *P. hysterophorus* had the highest IVs of 77.26% (Table 10).

Parthenium hysterophorus was also the most dominant weed species of crop field in different Kebele with IVs of 74.52% (Table 10). The observation further revealed that most of the field was vegetated with other weed species, such as *G. parvifolra* and *Cyperus rotundus*. Road side in another sectors also highly dominated by *P. hysterophorus* with IVs of 75.87% and followed by *C.dactylon* with IV of 55.12%.

The analysis of the data collected again from the roadside in the Woreda showed that *P. hysterophorus* was extremely dominant and associated with only four weeds species. Among them *P. hysterophorus* had the highest IV (95.41%). Being codominant with *P. hysterophorus*, *C. dactylon* showed the second highest IV (33.61%) (Table 10). Analysis of data collected from control site, showed that, *C.dactylon* dominates this sector with IV (48.88%). This plot was not invaded by parthenium weed.

Parthenium hysterophorus has become a major weed of various habitats in different Kebeles in the Woreda in a relatively short time. According to farmers of the study sites, DAs and my personal observation, both water and air are suspected to be the major agents of its spread in arable as well as non-arable parts of the Kebeles.

The high relative IV of *P. hysterophorus* may be attributed to its aggressiveness and allelopathic effects on the neighboring plants (Kohli *et al*., 1985; Adkins& Sowerby, 1996). Naviel *et a*l. (1996) and TamadoTana (2001) emphasized several other aspects of the ecology of this weed that appear to contribute to its aggressiveness, including the size and persistence of its soil seed bank, the high viability of seeds when buried, a fast germination rate, and the innate dormancy mechanism of its seeds. Joshi (1991) recorded that *P. hysterophorus* is an extremely prolific seed producer, with up to 2,500 seeds per plant, and that it has an enormous seed bank in abandoned fields. Once dominant, *P. hysterophorus* continues to persist as a pure stand or weed monoculture until it is managed (Shabbir and Bajwa, 2006). It was noticed during the survey that *P. hysterophorus* prefers to invade areas that have been recently disturbed and where topsoil is removed. This, in turn, minimizes the competition from native species and enhances the chances of survival of the *P. hysterophorus*, invading plant. It is further demonstrated that this weed has aggressively colonized the open land, pasture, wasteland, wetland, and crop land of Adami Tulu-Jido Woreda. This was also reported by Shabbir and Bajwa (2006) in Islamabad.

Table 10. Importance value (IV) of species in different habitats in selected sectors/areas (source: survey result)

Weeds of selected habitat	IV (%)										
	Range land	Road side	Waste land	wet land	Waste land	Crop field	Range land	Crop field	Road side	Road side	Control
Galinsoga parvifolra	61.2	—	19.2	—		—	10.9	26.9	—	—	—
Xanthium strumarium (X.abyssinicum)	—	—	—	—	—	—	—	—	—	—	4.86
Oxygonum sinuatum	9.42	—	30.8	—	—	37.7	—	—	—	8.91	—
Digitaria velutina	21.1	—	—	—	—	—	—	—	—	—	21.5
Datura stramonium L.	12.9	—	15.4	—	—	17.7	—	9.83	—	—	—
Bidens pilosa L.	12.3	—	—	—	—	—	—		—		—
Cyperus rotundus	—	12.1	—	—	—	—	—	26.9	—	10.1	48.9
Cynodon dactylon L.	15.2	25.8	25	101	—	—	45.7	—	55.1	33.6	22.3
Snowdenia polystachya	3.64	—	—	—	—	—	—	—	—	—	—
Alternanthera pungens L.(= A. repens)	—	—	15.4	—	—	—	—	—	—	—	—
Commelina latitalia	—	—	—	—	7.18		—	—	—	—	—
Erucastrum pachypodium	—	—	17.3	—	5.25	—	—	—	—	—	—
Guizotia seabra	—	—	—	—	—	—	8.37	—	—	—	—
Tribulus terrestris	—	—	—	—	—	—	—	—	—	—	4.86
Xanthium spinosus L.	7.3	—	—	—	—	13.9	—	—	—	—	30.3
Parthenium hysterophorus L.	22.7	102	23.1	31.4	—	29.2	77.3	74.5	75.9	95.4	—
Solanum indicum	—	—	—	—	62.5	—	—	—	—	—	—
Lantana camera L.	—	—	—	—	5.25	—	—	—	5.52	—	—
Setaria pumila	3.64	—	—	—	50.5	—	—	—	—	—	—
Cyperus regitidipholus	—	—	—	—	—	11.9	—	—	—	—	—
Argemonne mexicana	—	2.8	—	—	—	—	—	—	—	—	2.8

In a survey of grazing land and control site, and also on road sides and wet land, it was found that *P. hysterophorus* and *C. dactylon* had a high degree of sociability and these formed large stands under different habitats. Naithani (1987) observed that *Senna uniflora* had a good sociability with *P. hysterophorus* and that this plant overgrew with *P. hysterophorus* in India. In crop field and wet land, *O. sinuatum* exhibited a high sociability with *P. hysterophorus*. The codominance of *O.sinuatum* was clearly evident in these sectors.

From the interviews conducted during the study, all of the respondents noticed the impact of *P. hysterophorus* on loss of biodiversity. In grazing lands, and roadsides, one can easily observe the prominent influence of *P. hysterophorus* on the composition and importance values of other plant species (Table 10). Haseler (1976) suggested that this may be due to many factors like wider adaptation across climates, photo insensitivity, and drought tolerance. Similarly, Krishnamurthy *et al*. (1997) described the allelopathic nature of *P. hysterophorus* and its impact on plant diversity. McFadyen (1992) also reported that *P. hysterophorus* is causing a total habitat change in grasslands, open woodlands and floodplains.

The present study also revealed that *P. hysterophorus* has become a major pest plant of the wasteland, road sides crop fields and metropolitan areas of Edo Gojola, Negalign and Elka Jelmo and it has the potential to spread all over the Woreda. This weed survey of Adami Tulu-Jido showed a high frequency of *P. hysterophorus* in general; however, the RF of the weed in different sectors of the Kebeles ranged from 1.92-19.2% (Appendix 2).

4.2.2 Effects on crop production

About 71.3% farmers who participated in the survey ranked that the infestation of parthenium weed causes yield reduction, while 15% of the interviewed also indicated quality deterioration (Table 11). Furthermore, 87.5% of the interviewed farmers concluded that the heavy infestation of parthenium weed leads to intensive labour use for weeding and hand hoeing and choking irrigation canal thus increasing cost of agricultural production.

Field crops, such as tef (*Eragrostis tef*), wheat (*T. vulgare*) and maize (*Zea mays*) were found to be the most infested by parthenium weed (Table 12). However, in the surveyed areas, infestation of parthenium weed in the crop field 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 by weeding and burning.

Table 11 Farmers' view on the impacts of *Parthenium hysterophorus* on crop productivity

Types of impact	Frequency (number of responses)	Percent (%)
Yield reduction	114	71.3
Quality reduction	24	15.0
Intensive labour requirement	140	87.5
Increase inputs	6	3.8

Table 12 Plants those resist the impact of *P. hysterophorus*

Plants most affected by parthenium weed	*Frequency (N) N=160	Percentage of responses (%)
Wheat	101	63.1
Tef	101	63.1
Sorghum	16	10
Maize	11	6.9
Grasses	116	72.5

* N is equal to 160 to all cases

The Woreda is known for the production of maize, sorghum, wheat, tef and other crops; and also produces different types of vegetables. Moreover, maize, wheat, tef, and sorghum are used as staple food. Maize is the most dominant crop and used as staple food for an estimated 89.9% of the population, whereas wheat (56.3%) and tef (54.4%) are used as both staple food and commercial crops. However, parthenium weed mostly attacks wheat and tef (63.1%) and to less extent maize and sorghum and beyond that it also attacks fodder (72.5%). More than 65% of farmers agreed on the effect of *P. hysterophorus* on crop production by suppressing growth, yield loss, poor grain fill and by reducing moisture of the soil. *P. hysterophorus* has also caused change of taste on the food. In India 40% sorghum yield reduction was reported by Channappagoudar *et al*. (1990) and Khosla and Sobti (1981). They also reported that the presence of P. *hysterophorus* in irrigated sorghum reduced grain yields from 6.47 to 4.25 tons/ha and decreased grain weight by 30%. In eastern Ethiopia 40 to 97% sorghum yield reduction was observed due to the impact of *P. hysterophorus (*Tamado Tana *et al*., 2002). However, the exact impact that parthenium weed is causing on the productivity of crops in economic terms is not well assessed in the Woreda. Therefore, it needs a daily follow up to quantify the environmental as well as economic costs due to *p. hysterophorus* in the Woreda.

4.2.3 Effects on animal production

Since *P. hysterophorus* was recently introduced weed, its impacts on animal productivity are not well known and observed. However, its impact was prompted by 30.6% of the respondent farmers (Table 13). Further 19.1% of the total respondents observed that this weed has already colonized grazing fields, thus causing fodder/feed scarcity. Evans (1997a) indicated that the impact of parthenium weed on livestock production is as direct as indirect by affecting grazing land, animal health, milk and meat quality, and marketing of pasture seeds and grain. Based on the field survey it was known that parthenium weed is replacing native grass species (Table 13). Farmers also reported that the milk and meat of animals grazing on parthenium weed is bitter and tasteless.

In some villages *P. hysterophorus* could completely dominate grazing land, resulting in a weed monoculture and reduced stocking rate. In addition, according to farmers, this was coupled with additional expenses for labour and extensive use of other inputs to control the parthenium weed infestation.

Table 13 Types of effects of *P. hysterophorus* on livestock production as perceived by farmers

Types of Effect of Parthenium weed on livestock	Frequency N=160 for all cases	Percentages of responses (%)
Impacts of parthenium on livestock	49	30.6
Reduction of productivity	32	20
Quantity change and reduction	17	10.6
Encroaching grazing lands and suppressing grass species	31	19.1
Effect on livestock health	0	0
Decline families income level	3	1.9

Although, animals usually avoid parthenium weed, it may be consumed in situation where the weed forms almost pure stands as observed in Edo Gojola, Negalign and Elka Jelemo Kebeles (Fig 10). Even though there was no report on the deaths of animal due to parthenium weed in the Woreda, studies in India on the toxicity of the weed to cattle and buffaloes have shown a significant amount (10-50%) of the weed in the diet can kill these animals within 30 days (Narasimhan *et al*., 1977, 1980; More *et al*., 1982). In Australia, Chippendale and Panneta (1994) stated that cattle grazing in *P. hysterophorus* invaded pastures were marketed with a lower weight compared to those from weed free areas, accounting for more losses to the producer. Vartak (1968) indicated that the impact of *P. hysterophorus* on grasslands could reduce forage production. On the other hand *P. hysterophorus* can reduce the carrying capacity of grazing land by up to 90% (Nath, 1988). Nisar Ahmed *et al*. (1988) reported that animals fed on *P. hysterophorus* developed dermatitis with pronounced skin lesions, became highly emaciated, and eventually died due to the rupture of tissues and hemorrhages in their internal organs. The impact of *P. hysterophorus* on animal health was also reported by Kololgi *et al*. (1997) where it causes respiratory disease like bronchitis.

4.2.4 Effects on human health

Parthenium hysterophorus is also known to cause human health problems such as asthma, bronchitis, dermatitis and hay fever in a prolonged contact (Anonymous, 1976; Kologi *et al*., 1997; Srirama Rao *et al*., 1991). The human health problem due to parthenium weed is not common in the Woreda. However, there are about 18.8% (n=160) cases in the Woreda, who showed sign of allergy and dermatitis.

There is quite high number of individuals who were also affected by parthenium allergy and/or dermatitis though it is recently introduced to the Woreda (Appendix 5). However, the number of individuals who are affected will be increased unless control measure is taken. About 8.1% of individuals currently exposed to parthenium weed allergy and about 14.4% of individuals also suffer from dermatitis in the study area. Because of the recent introduction of the parthenium weed in the Woreda, it did not show a heavy health problem.

Other workers like Anonymous (1976); Srirama Rao *et al*. (1991); Kololgi *et al*. (1997) and Handa *et al*. (2001) also reported effects of *P. hysterophorus* on human health like hay fever, asthma, bronchitis and dermatitis. Evans (1997a) and Towers and Subba Rao (1992) also reported that close contact with P. *hysterophorus* could cause allergic contact dermatitis while inhalation of pollen can cause allergic rhinitis, which can develop into bronchitis or asthma in susceptible humans. In India, reports of committing suicide are available due to the chronic problem of *P. hysterophorus* (Kololgi *et al*., 1997).

5. CONCLUSION AND RECOMMENDATIONS

Conclusion

Parthenium hysterophorus is an invasive alien weed that can be expected to continue its dissemination because of the negligence of not only farmers but also the local government to control it. It is growing in farmlands, roadside, grazing lands, wastelands, wetlands and in towns and villages, gardens. It can germinate and produce seeds throughout the year and can cause a serious problem in humans, animals and crop production and biodiversity.

This study tried to reveal the farmers' perception on the impact that can be caused by *P. hysterophorus*. Farmers in the study area were aware of *P. hysterophorus* since 2000, though its infestation is increasing from year to year. On the other hand, it was apparent that *P. hysterophorus* is found densely populated on roadsides, and grazing lands. There was no much effort done by all responsible bodies including farmers. *P. hysterophorus* was observed to grow in any season of the year at different stages, which is at shattering stage, at flowering and seedling stages. This implies that any intervention intending to control *P. hysterophorus* should take into consideration of the ability of *P. hysterophorus* to grow at every season of the year.

It was observed that the impact of *P. hysterophorus* decreases the abundance of plant species on rangelands, wastelands and road sides. Moreover *P. hysterophorus* affects livestock production, productivity, and health including human beings. However, there was no record from health posts on diseases caused by *P. hysterophorus* on livestock and human health. It was concluded that much has not been done to aware the local people on the danger of *P. hysterophorus* causing impacts on biodiversity.

Many of the farmers in the study area are aware of that *P hysterophorus* poses threat for the loss of biodiversity. The endangered plant species include grasses, forage plants, and various other species that are economically important for various purposes.

Parthenium hysterophorus has become a major pest plant of the grazing land, roadside, wasteland, wetland as well as cultivated land and it has the potential to cover all over the Woreda, even beyond the boundary of the Woreda, and threatening the biodiversity of the Woreda. Rainfall, month of planting, number of weedings, fertilizer use, crop type & pattern and soil type and/or soil texture were the major environmental/crop management factors influencing the species distribution in the study area. Maps predicting the severity of the impact and damage in the Woreda could thus be used to localize areas requiring interventions most urgently.

Recommendations

- Consistent effort should be practiced to control *P. hysterophorus* till the complete seed bank is exhausted because of its high and continuous seed production ability throughout the year.

- However these practices need the integration of the community and responsible governmental and non-governmental organizations. Further, quarantine measures should be adopted to check the introduction of weed to non-infested area through transportation of consumer goods, by movement of livestock and flooding.

- Further study is required to identify the health hazards, impact on biodiversity of *P. hysterophorus,* and its management strategy should be developed to control at national level.

- Joint projects should also be established to prevent and control the danger of *P. hysterophorus* at regional level.

- Farmers should be trained both by governmental and non-governmental organizations on how to prevent and/or control further introduction and dissemination of the weed.

- Priority Kebeles in the Woreda should be identified based on the prediction map of current density distribution of *P. hysterophorus* to act accordingly and to control further dissemination of *P. hysterophorus*. Hence, these places are potential sources for the dissemination of the weed into croplands.

6 REFERENCES

Adkins, S. W. and Sowerby, M. S. (1996). Allelopathic potential of *Parthenium hysterophorus* L. in *Australia. Plant prot*.Q.**1**, 20-23.

ARMCANZ, ANZECC (Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers) (2000). Weeds of National Significance parthenium weed *(Parthenium hysterophorus* L.) strategic plan. National weeds strategy Executive Committee, Launceston.

Anonymous (1976). Parthenium, a new weed in India. *PANS* **22**: 280-282.

Auld, B. A., Hosking, J. and McFadyen, R. E. (1983). Analysis of the spread of tiger-pear and parthenium weed in Australia. *Australian weeds* **2**: 56-60.

Baillie, J. E. M., Hilton-Taylor, C. and Stuart, S. N. (2004). 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN – the World Conservation Union, Gland.

Balayan, R. S., Yadav, A. and Malik, R. K. (1997). Easy and efficient control of carrot weed (*Parthenium hysterophorus* L.) CCSHAU, Hisar. Extn.Bull. p. 8.

Bartlett, J. E., Kotrlik, J. W. and Chadwick, C. Higgins, C. C. (2001). Organizational Research: Determining Appropriate Sample Size in Survey Research. *Information Technology, Learning, and Performance Journal*, Vol. **19**, No. 1 pp 43-50.

Bennett, F. D. and Cruttwell, R. E. (1971). Memorandum on the possibilities of biological control of *Parthenium hysterophorus* L., Compositae. In: McFadyen, R. C. (ed.), Biological control against parthenium weed in Australia (1992). *Crop Protection* **11**: 400-408.

Berhanu, Gebere Medhin (1992). *Parthenium hysterophorus*, a new weed problem in Ethiopia. FAO *Plant Protection Bulletin* **40**: 49.

Bhan, V. M., Kumar, S. and Raghuwanshi, M. S. (1997). Future strategies for effective parthenium management. In: Mahadevappa, M. and Patil, V.C. (eds), Proceedings of the 1st International Conference on Parthenium Management, 6 - 8 October 1997, University of Agricultural Sciences, Dahrwad, India, 90-95.

Butler, J.E. (1984). Longevity of *Parthenium hysterophorus* L. seed in the soil. *Australian Weeds* **3**: 6.

Cassey, P. M., Blackburn, G. J., Russell, K. E., Jones and Lockwood, J. L. (2004). Influences on the transport and establishment of exotic bird species: an analysis of the parrots (Psittaciformes) of the world. *Glob. Change Biol.* **10**, 417–426.

CBD (Convention on Biological Diversity) (2005). Invasive Alien Species. Convention on Biological Diversity. http://www.biodiv.org/programmes/crooscutting/alien.

Central Statistical Authority (CSA) (1994). The 1994 population of housing census of Ethiopia: Results for Oromia region. Volume I, part I.

Channappagoudar, B. B., Panchal, Y. C., Manjunath, S. and Koti, R. V. (1990). Studies on influence of parthenium on sorghum growth under irrigated conditions. *Farming Systems* **6**: 102-104.

Chiles, P. and delfiner, P. J. (1999). Geostatistics: Modeling Spatial Uncertainty. Wiley, New York.

Chippendale, J. F. and Panneta, F. D. (1994). The cost of parthenium weed to the Queensland cattle industry. *Plant Protection Quarterly* **9**: 73-76.

Council of the regional state of Oromia (2001). Sub-regional atlas of central oromia. Bureau of planning and economic development, physical planning department. Finfinne.

Cressie, N.A. (1993). Statistics for spatial data. John Wiley & Sons, New York.

Czech, B. & Krausman, P. R. (1997). Distribution and causation of species endangerment in the United States. *Science*, **277**: 116-117.

Dale, I.J. (1981). Parthenium weed in Americas. A Report on the Ecology of *Parthenium hysterophorus* in South Central and North America. *Australian weeds* **1**: 8-14.

Dayama, D.P. (1986). Allelopathic effect of *Parthenium hysterophorus* L. on growth, nodulation and nitrogen content of Leucaena leucocephala. *Leucaena Research Reports* **7**: 36-37.

Deutsch C. V. and Journel, A. G. (1998). *GSLIB Geostatistical Software Library and User's Guide*. Oxford University Press, 1998.

Dhanraj, R. E. and Mitra, M. K. (1976). Control of *Parthenium hysterophorus* L. with diquat. *PANS* **22**: 269 - 272.

Enserink, M. (1999). Biological invaders sweep in, *Science* **285**: 1834-1836.

ESRI (2003). Arc GIS 9. Using Arc GIS Geostatistical Analyst. United States of America.

ESRI (2004). Arc GIS 9. Environmental Systems Research Institute, Redlands, California.

Evans, H.C. (1987). Fungal pathogens of subtropical and tropical weeds and the possibilities for biological control. *Biocontrol News and Information* **8**: 7-30.

Evans, H.C. (1997a). *Parthenium hysterophorus:* A review of its weed status and the possibilities for biological control. *Biocontrol News and Information* **18**: 89-98.

Evans, H.C. (1997b). The potential of Neotropical fungal pathogens as classical biological control agents for management of *Parthenium hysterophorus.* In: Mahadevappa, M. and Patil, V.C. (eds), Proceedings of the 1st International Conference on Parthenium Management, 6 - 8 October 1997, University of Agricultural Sciences, Dahrwad, India, 55-62.

Fasil, Reda (1994). The biology and control of parthenium. In: Rezene Fessahaie (ed.), Proceedings of the 9th annual Conference of the Ethiopian Weed Science Committee, 9 - 10 April 1991, Addis Ababa, Ethiopia. EWSS, Addis Ababa, 1-6.

Frew Mekbib, Solomon Kebede and Mashilla Dejene (1996). Prevalence and distribution of *Parthenium hysterophorus* L. in eastern Ethiopia. *Arem* **1**:19-26.

Girma Balcha, Kumelachew Yeshitela and Taye Bekele (2004). Proceedings of a National Conference on Forest Resources of Ethiopia: Status, Challenges and Opportunities. 27-29 November 2002. 272 pp

GISP (Global invasive Species Programme) (2004). Africa Invaded*:* The Growing Danger of Invasive Alien Species. Global invasive Species Programme, Cape Town. http://www.gisp.org/downloadpubs/gisp%20africa%202.pdf

Gupta, S. and Chandra, S. (1991). Aerobiology and some chemical parameters of *Parthenium hysterophorus* pollen. *Grana* **30**: 497-503.

Gupta, O. P. and Sharma, J. J. (1977). Parthenium menace in India and possible control measures. *FAO Plant Protection Bulletin* **25**: 112 - 117.

Handa, S., Sahoo, B. and Sharma, V. K. (2001). Oral hyposensitization in patients with contact dermatitis from *Parthenium hysterophorus*. *Contact Dermatitis* **44**: 279-282.

Haseler, W. H. (1976). *Parthenium hysterophorus* L. in Australia. *PANS* **22**: 515-517.

Hedberg, I., Friis, I., Edwardes, S. and Mesfin Tadesse (Eds.) (2004). Flora of Ethiopia and Eritrea. V. 4: P.2. Addis Ababa, Ethiopia. Uppsala, Sweden.

Hegde, B.A. and Patil, T.M. (1988). Isolation and purification of sesquiterpene lactone from the leaves of *Parthenium hysterophorus* L. - its allelopathic and cytotoxic effects. *Current Science* **57**: 1178-1181.

Huy, Q.L. and Seghal, R. N. (2004). Invasion of *Parthenium hysterophorus* in Chine- Pine forests and its allelopathic effects.

ILWIS (2001). ILWIS 3.0 Academic, user's guide. Unit Geo Software Development Sector Remote Sensing and GIS, IT Department, International Institute for Aerospace Survey and Earth Science, Enschede.

Isaaks, E. H. and Srvastava, R. M. (1989). Applied Geostatistics Oxford University Press, New York.

IUCN/SSC/ISSG (2000). IUCN Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species. IUCN – the World Conservation Union Species Survival Commission, Invasive Species Specialist Group. http://www.iucn.org/themes/ssc/publications/ policy/invasivesEng.htm.

Jarvis, B.B., Pena, N.B., Rao, M.M., Comezoglu, N.S., Comezouglu, T.F. and Mandava, N.B. (1985). Allelopathic agents from *Parthenium hysterophorus* and Baccharis megapotamica. In: Thompson, A.C. (ed.), The chemistry of allelopathy, Biochemical interactions among plants, American Chemical Society, Washington D.C., 149-159.

Jayachandra, M. (1971). Parthenium weed in Mysore state and its control. *Current science* **40**: 568-569.

Joel, D. M. and Litson, A. (1986). New adventive weeds in Israel. *Israel Journal of Botany* **35**: 215-223.

Joshi, D. (2001). Alien invasive species: a global threat to biodiversity. The Katmandu Post *23* Dec.

Joshi, S. (1991). Biocontrol of *Parthenium hysterophorus* L. *Crop Protection* **10**: 429-431.

Kanchann, S. D. and Jaychandra, K. A. (1977). Post emergent chemical control of congress grass. *Pesticides* **11**: 55-56.

Kanchan, S. D. and Jayachandra, K. A. (1979). Allelopathic effects of *Parthenium hysterophorus* exudation of inhibitors through roots. *Plant and soil Bulletin* **53**: 61-66.

Kanchan, S. D. and Jayachandra, K. A. (1980a). Allelopathic effect of *Parthenium hysterophorus* L. II. Leaching of inhibitors from aerial vegetative parts. *Plant and soil* **55**: 61-66.

Kanchan, S. D. and Jayachandra, K. A. (1980b). Pollen allelopathy - a new phenomenon. *New Phytologits* **84**: 739-746.

Kanchan, S. D. and Jayachandra, K. A. (1981). Effect of *Parthenium hysterophorus* on nitrogen-fixing and nitrifying bacteria. *Canadian Journal of Botany* **59**: 199 - 202.

Kandasamy, O. S. and Sankaran, S. (1997). Biological suppression of parthenium weed using competitive crops and plants. In: Mahadevappa, M., and Patil, V. C. (eds), *Proceedings of the 1st International Conference on Parthenium Management*, 6 - 8 October 1997, University of Agricultural Sciences, Dahrwad, India, 33-36.

Khosla, S. N. and Sobti, S. W. (1981). Effective control of *Parthenium hysterophorus* L. *Pesticides* **15**: 18-19.

Kirby, A. (2003). Alien species cost Africa billions. BBC News Science http://news.bbc.co.uk/2/hi/science/nature/2730693.stm

Kohli, R. K., Kumari, A. and Saxena, D. B. (1985). Auto and teletoxicity of *Parthenium hysterophorus* L. *Acta Univ. agric. Brnol.* (Czechoslovakia) **33**, 253-263.

Kohli, R. K. and Rani, D. (1992). Identification and bioefficacy of soil chemics of Parthenium. In: Tauro, P. and Narwal, S. S. (eds), Proccedings of the 1st National Symposium on Allelopathy in agro-ecosystems, Hisar, India, Februaray 1992. Hisar, Haryana agricultural University, 196-198.

Kololgi, P. D., Kololgi, S. D. and Kololgi, N. P. (1997). Dermatological hazards of parthenium in human beings. In: Mahadevappa, M. and Patil, V. C. (eds), *Proceedings of the First International Conference on Parthenium Management*, 6 - 8 October 1997, University of Agricultural Sciences, Dahrwad, India, 18-19.

Krishnamurthy, K., Ramachandraprasad, T. V., Munjyappa, T. V. and Venkata Rao, B.V. (1997). Parthenium a new pernicious weed in India. *Technical Series No. 17*, University of Agricultural sciences, Bangalore, India. pp 46.

Lewis, W. H., Dixit, A. B. and Wender, H. J. (1988). Reproductive biology of *Parthenium hysterophorus* (Asteraceae) *Journal of Palynology* **23-24**: 73-82.

MA (Millennium Assessment) (2006). Ecosystems and Human well-being: Current state and trends. Volume 1. *Millennium Ecosystem Assessment. Island Press, Washington.* http://millenniumassessment.org//en/products.global.condition.aspx.

Mahadevappa, M. (1997). Ecology, distribution, menace and management of parthenium. In: Mahadevappa, M. and Patil, V. C. (eds), *Proceedings of the 1st International Conference on Parthenium Management*, 6 - 8 October 1997, University of Agricultural Sciences, Dahrwad, India, 1-12.

McFadyen, R. C. (1992). Biological control of parthenium weed in Australia. *Crop protection* **11**: 400-407.

McNeeley, J. A., Mooney, H. A., Neville, L. E., Schei, P. and Waage, J. K. (2001). Global Strategy on Invasive Alien Species. IUCN – the World Conservation Union, Gland.

McNeely, J. A. (2001). An introduction to human dimensions of invasive alien species. In McNeely, J. A., (ed). *The Great Reshuffling. Human Dimensions of Invasive Alien Species*, Gland, IUCN: 5–20.

Mishra, K. K. (1991). *Parthenium hysterophorus* L., a new record for Nepal. *Journal of Bombay Natural History Society*. **88**: 466 - 467.

Mooney, H. A. & Hobbs, R. J. (2000). Invasive Species in a Changing World. Island Press, Washington, DC.

More, P. R., Vadlamudi, V. P. and Qureshi, M. I. (1982). Note on the toxicity of *Parthenium hysterophorus* in livestock. *Indian Journal of Animal Science* **52**: 456-457.

Naithani, H. B. (1987). *Parthenium hysterophorus* a pernicious weed in Arunachal Pradesh and Nagaland. *Ind. Forester* **113**, 709–710.

Narasimhan, T. R., Murthy, K. B. S., Harindranath, N. and Subba Rao, P. V. (1977). Characterization of a toxin from *Parthenium hysterophorus* and its mode of excretion in animals. *J. Biosci*. Vol. **6**, No 5, pp. 729–738.

Narasimhan, T. R., Ananth, M., Narayana, S. M., Rajendra, B. M., Mangala, A. and Subba Rao, P. V. (1980). Toxicity of *Parthenium hysterophorus* L.: Partheniosis in cattle and buffaloes. *Indian Journal of Animal Science* **50**: 173-178.

Nisar Ahmed, M., Rao, R. P. and Mahendar, M. (1988). Experimental introduction of acute toxicity in buffalo calves by feeding *Parthenium hysterophorus* L. *Indian Journal of Animal Science* **58**: 731-734.

Nath, R. (1988). *Parthenium hysterophorus* L. - a general account. *Agricultural Review*. **9**: 171-179.

Navie, S. C., McFadyen, R. E., Panetta, F. D. and Adkins, S. W. (1996). The biology of Australian Weeds 27: *Parthenium hysterophorus* L. *Plant Protection Quarterly* **11**: 76- 87.

Njoroge, J. M. (1991). Tolerance of *Bidens pilosa* and *Parthenium hysterophorus* L. to paraquat (Gramaxone) in Kenya coffee. *Kenya-Coffee* **56**: 999-1001.

Olea, R. A. (1991). Geostatistical Glossary and Multilingual Dictionary. International Association for Mathematical Geology Studies in Mathematical Geology. Oxford University Press, New York. No. 3, 177p.

PAG (Parthenium Action Group) (2000). Parthenium weed. Information document. http://www.chrit.tag.csiro.au/parthenium/information.html

Pandy, H. N. and Dubey, S. K. (1989). Growth and population of an exotic weed *Parthenium hysterophorus* Linn. *Proceedings of Indian Academy of sciences, plant sciences* **99**:51-58.

Pandy, D. K., Kauraw, L. P. and Bhan, W. M. (1993). Inhibitory effect of parthenium (*Parthenium hysterophorus* L.) residue on growth of water hyacinth (*Eichhornia crassipes* Mart Solms.): I. Effect of leaf residue. *Journal of Chemical Ecology* **19**: 2651-2662.

Parsons, W. T. and Cuthbertson, E. G. (1992). Noxious weeds of Australia. Inkata press, Melbourne, 692 pp.

Peng, C. I., Hu, L. A. and Kao, M. T. (1988). Unwelcome naturalization of *Parthenium hysterophorus* (Asteraceae) in Taiwan. *Journal of Taiwan Museum* **41**: 95 - 101. http://www.consecol.org/vol6/iss1/art1.

Perrings, C., Dehnen-Schmutz, K., Touza, J. and Williamson, M. (2005). How to manage biological invasions under globalization, *Trends in Ecology and Evolution* **20**(**5**): 212-215.

Polley, H. W., Johnson, H. B. & Mayeux, H. S. (1997). Leaf physiology, production, water use, and nitrogen dynamics of the grassland invader Acacia smallii at elevated CO_2 concentrations. *Tree-Physiology, **17***(**2**), 89-96.

Raju, R. A. and Reddy, N. M. (1998). Phytosociological studies of rainy season weeds with special reference to *Imperata cylindrica* (L.) Raeuhl in Gadavari Delta. *Ind. J. Weed Sci.* **30**, 182–188.

Rejmanek, M., Richardson, D. M., Higgins, S. I. and Pitcairn, M. (2000). Ecology of invasive plants: State of the art. In McNeely J.A., (Ed.), *The Great Reshuffling. Human Dimensions of Invasive Alien* Species, Gland, IUCN: 5–20.

Semmens, B. X., Buhle, A. K., Salomon, C. V. and Pattengill-Semmens (2004). A hotspot of non-native marine fishes: evidence for the aquarium trade as an invasion pathway. *Mar. Ecol. Prog. Ser.* **266**, 239–244.

Shabbir, A. and Bajwa, R. (2006). Distribution of Parthenium weed (*Parthenium hysterophorus* L.), an alien invasive weed species threatening the biodiversity of Islamabad. *Weed Biology and Management* **6**, 89–95.

Singh, S. P. (1997). Perspectives in biological control of parthenium in India. In: Mahadevappa, M. and Patil, V. C. (eds), *Proceedings of the 1st International Conference on Parthenium Management*, 6-8 October 1997, University of Agricultural Sciences, Dahrwad, India, 22-32.

Singh, P. H; Batish, R. D; Pandher, K. J. and Kohli, K. R. (2005). Phytotoxic effects of *Parthenium hysterophorus* residues on three *Brassica* species. *Weed Biology and Management* **5**, 105–109.

Srirama Rao, P., Nagpal, S., Rao, B. S., Prakash, O. and Rao, P. V. (1991). Immediate hypersensitivity to *Parthenium hysterophorus*. II. Clinical studies on the prevalence of parthenium rhinitis. *Clinical Experimental Allergy*: **21**: 55-62.

Subba Rao, P. V., Mangala, A., Subba Rao, B. S. and Prakesh, K. M. (1977). Clinical and immunological studies on persons exposed to *Parthenium hysterophorus* L. *Experiential* **33**: 1387 - 1388.

Tadelle Tefera (2002). Allelopathic Effects of *Parthenium hysterophorus* Extracts on Seed Germination and Seedling Growth of Eragrostis tef. *J. Agronomy & Crop Science* **188**, 306—310. (Availableat: http://www.blackwell-synergy.com/action/showpdf. Last accessed July 10, 2007)

Tamado Tana & Milberg, P. (2000). Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of Parthenium hysterophorus. *Blackwell Science Ltd Weed Research* **40**, 507-521.

Tamado Tana (2001). Biology and management of parthenium (*Parthenium hysterophorus* L.) in Ethiopia. *PhD thesis*. Swedish University of Agricultural Sciences, Uppsala.

Tamado Tana, Schütz, W. and Milberg, P. (2002). Germination ecology of the weed *Parthenium hysterophorus L*. in eastern Ethiopia. *Ann. Appl. Biol.***140**: 263-270.

Tanner, M. S. and Mattocks, A. R. (1987). Hypothesis: plant and fungal biocides, copper and Indian childhood liver disease. *Annals of Tropical Paediatrics* **7**: 264 - 269.

Taye Tessema, Yohannes Lemma and Belayneh Anthenh (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*. 14-18 September 1998, University of Stellenbosch, South Africa.

Taye Tessema (2002). Investigation of Pathogens for Biological control of Parthenium (*Parthenium hysterophorus* L.) in Ethiopia. *PhD thesis*, Humboldt–Universitat zu Berlin, Landwirtschaftlich-Gartnerischen Fakultat, Berlin. 152 pp.

The Government of the regional state of Oromia: Oromia economic study project office (1999). Water resource base line survey. Final report. Volume XII: map album.

Towers, G. H. N, Mitchell, T. C., Rodriguez, E., Bennett, F. D. and Subba Rao, P. V. (1977). Biology and Chemistry of *Parthenium hysterophorus* L., a problem weed in India. *Journal of Scientific and Industrial Research* **36**: 672-684.

Towers, G. H. N. (1981). Allergic eczematous contact dermatitis from parthenium weed (*Parthenium hysterophorus*). In: Wilson, B. J. and Swarbrick, J. T. (eds), *Proceedings of the 6th Australian Weeds Conference*, Gold Coast, Queensland, 143-50.

Towers, G. H. N. and Subba Rao, P. V. (1992). Impact of pan-tropical weed, *Parthenium hysterophorus* L., on human affairs. In: Richardson, R. G. (ed.), Proceedings of the 1st International Weed Control Congress, Melbourne, ed. R. G. Richardson **1**: 134-138.

Tudor, G. D., Ford, A. L., Armstrong, T. R. and Bromage, E. K. (1982). Taints in meat from sheep grazing *Parthenium hysterophorus*. *Australian Journal of Experimental Agriculture and Animal Husbandry* **22**: 43-46.

Vartak, V. D. (1968). Weed that threatens crop and grass lands in Maharashtra. *Indian farming* **18**: 23-24.

Wallace, C. S. A., Watts, J. M. and Yool, S. R. (2000). Characterizing the spatial structure of vegetation communities in the Mojave Desert using geostatistical techniques. *Computers and Geoscience*, **26**: 397-410.

Webester, R. and Oliver, M. A. (2001). Geostatistics for Environmental Scientist. John Wiley & Sons, LTD, New York.

Williams, J. D. and Groves, R. H. (1980). The influence of temperature and photoperiod on growth and development of *Parthenium hysterophorus* L. *Weed Research* **20**: 47-52.

Wilcove, D. S. & Chen, L. Y. (1998). Management costs for endangered species. *Conserv. Biol.,* **12**, pp. 1405-1407.

7 APPENDICES

Appendix 1 parthenium density, altitude and slope in association of GPS reading

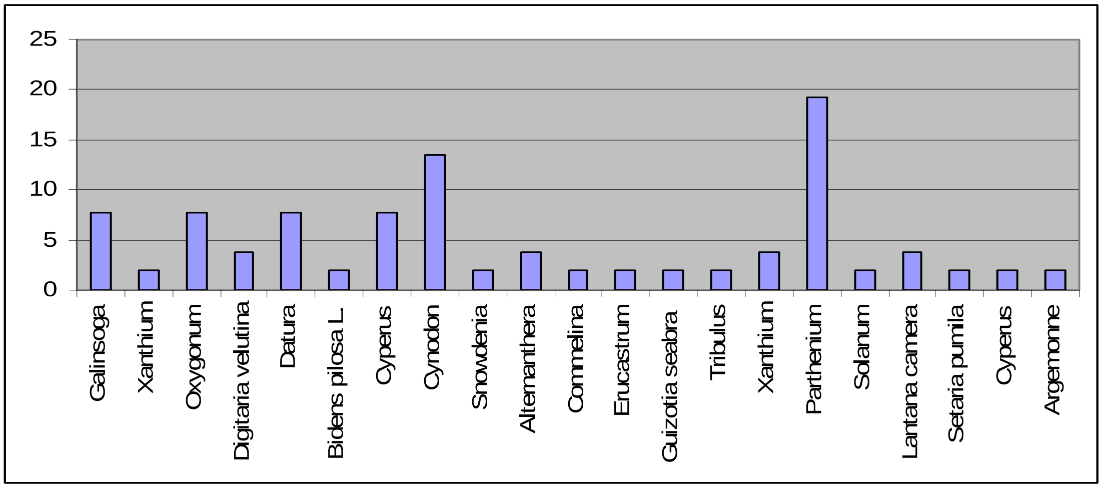
Northing (m)	Easting(m)	Elevation(m)	Current density(per square meter)	Past density(per square meter)	Slope (%)
469434	877240	1641	15	3	7
470432	883205	1644	0	0	4
469717	881638	1645	137	10	5
466952	879858	1643	17	5	6
466982	879551	1646	319	43	6
465489	849388	1600	0	0	3
467379	849061	1594	0	0	3
468630	848597	1594	0	0	3
469975	849885	1593	0	0	2
468949	851572	1598	0	0	4
464988	869593	1666	0	0	1
463131	869973	1675	0	0	8
461149	870401	1687	0	0	4
459277	870856	1687	0	0	5
458687	869082	1691	0	0	4
460453	868546	1689	0	0	1
462264	868003	1673	0	0	4
464032	867257	1672	0	0	3
465927	866694	1664	2	0	2
467738	865980	1657	0	0	3
468362	853319	1612	0	0	5
466557	852840	1609	0	0	5
464618	852782	1612	0	0	9
468958	878364	1643	169	41	5
461579	852447	1615	0	0	3
463530	852541	1643	0	0	4
465493	854292	1602	0	0	2
466135	854292	1617	0	0	4
464303	854673	1619	0	0	4
462418	854944	1617	0	0	3
456289	852004	1597	0	0	3
458211	851243	1596	0	0	3
460206	850590	1599	0	0	5
462109	850255	1601	0	0	3
463806	849497	1589	0	0	6
453524	856126	1609	0	0	3
451613	856180	1610	0	0	5
450919	854389	1598	0	0	4
452747	853770	1598	0	0	4
454631	853018	1598	0	0	4
461119	856598	1627	0	0	3
461118	854515	1616	0	0	4
459347	854913	1615	0	0	3
457465	855391	1611	0	0	4

455531	855764	1613	0	0	6
467186	864128	1651	0	0	2
465241	864532	1664	10	0	5
470231	873305	1653	10	0	2
463415	865124	1666	0	0	5
461608	865627	1670	0	0	7
459824	866266	1679	0	0	5
457995	866651	1698	0	0	12
457568	864886	1745	0	0	6
459126	864107	1725	0	0	3
460527	863445	1673	0	0	7
452445	860728	1662	0	0	4
454074	859879	1662	0	0	4
455816	859081	1648	0	0	3
457632	858261	1639	0	0	3
459305	857378	1628	0	0	1
462125	862454	1663	0	0	6
463829	861572	1659	0	0	5
462643	860235	1659	0	0	6
469792	875553	1647	103	15	5
462480	860077	1660	0	0	8
460676	860518	1671	0	0	6
458812	860997	1701	0	0	9
456965	861492	1689	0	0	8
455193	861946	1684	0	0	8
453288	862481	1685	0	0	8
465504	871479	1660	0	0	5
467416	870924	1655	4	0	4
469147	870476	1670	0	0	2
468664	868658	1647	1	0	3
466823	869040	1660	18	0	1
465717	878862	1667	0	0	2
467386	878064	1654	30	10	3
468708	877460	1641	63	7	4
468451	875489	1645	135	49	4
471498	888341	1635	109	61	3
469966	887841	1660	20	5	3
467488	888229	1678	0	0	2
465392	889144	1690	0	0	2
470722	886361	1640	50	10	3
470577	885491	1647	100	50	3
470576	885189	1638	0	0	2
469257	885282	1661	0	0	2
467807	885707	1666	0	0	2
467466	884674	1664	0	0	2
468497	884195	1656	0	0	2
469410	884046	1646	0	0	2
466593	879924	1668	0	0	2
464832	880587	1662	0	0	1
463092	881261	1687	0	0	4

462058	881460	1713	0	0	9
462325	879909	1729	0	0	10
464035	879425	1680	0	0	5
466749	881910	1668	0	0	4
468789	881207	1646	0	0	5
468995	881150	1641	15	0	2
468977	880166	1640	77	5	1
468467	879391	1643	5	0	1
469539	884827	1650	5	0	2
467645	885038	1667	0	0	3
465812	884898	1677	0	0	1
463826	884965	1684	0	0	2
463335	883206	1687	0	0	3
465068	882571	1675	0	0	4
471012	886825	1645	70	15	5
469460	887744	1662	0	0	4
468323	888888	1685	0	0	1
466561	889280	1690	0	0	2
466308	888461	1680	0	0	3
466294	887635	1681	0	0	1
469978	887556	1660	75	10	3
470043	888881	1662	5	1	6
468316	889291	1683	0	0	1
466739	889687	1692	0	0	2
467127	887707	1679	0	0	3
468746	887189	1662	0	0	1
469755	886664	1662	0	0	3
471008	886604	1640	15	1	12
470523	884991	1643	28	3	4
466693	875699	1659	1	0	9
464790	875829	1668	0	0	6
462995	876077	1683	0	0	4
459988	890153	1738	0	0	3
459823	888394	1729	153	17	3
459290	886691	1740	0	0	10
459007	884786	1749	0	0	6
461158	876412	1706	0	0	4
459296	876719	1734	0	0	5
459125	875077	1695	0	0	2
463132	875113	1692	0	0	3
463184	874937	1671	0	0	1
465372	874847	1662	0	0	1
467324	874633	1651	0	0	3
457253	886904	1761	23	5	2
457766	888697	1765	73	15	1
458182	890461	1770	0	0	6
458502	875586	1716	0	0	13
457980	873782	1712	0	0	7
459791	873180	1696	0	0	6
461742	872524	1687	0	0	4

463617	872003	1674	0	0	4
468206	873485	1648	43	10	5
466431	873815	1666	0	0	5
463788	874308	1675	0	0	9
462075	874724	1692	0	0	6
460297	875159	1690	0	0	8

Appendix 2 Frequency of some of the weeds in Adami Tulu-Jido Woreda



Appendix 3 Relative Frequency (RF) and Relative Density (RD) of species in different habitats in selected sectors/areas

	RF (%)						RD (%)					
Weeds of selected habitat		plot 1	plot 2	plot 3	plot 4	plot 5	plot 6	plot 7	plot 8	plot 9	plot 10	plot 11
Galinsoga pavifolra	7.7	53.5	__	11.5	__	__	__	3.23	19.2	__	__	__
Xanthium strumarium	1.92	__	__	__	__	__	__	__	__	__	__	
Oxygonium sinuatum	7.7	1.72	__	23.1	__	__	30	__	__	__	1.21	2.94
Digitaria velutina	3.85	17.2	__	__	__	__	__	__	__	__	__	__
Datura stramonium	7.7	5.17	__	7.69	__	__	10	__	2.13	__	__	17.7
Bidens pilosa	1.92	10.3	__	__	__	__	__	__	__	__	__	__
Cyperus rotundus	7.7		4.42	__	__	__	__	__	19.2	__	2.42	__
Cynodon dactylon	13.5	1.72	12.4	11.5	87.8	__	__	32.3	__	41.7	20.2	41.2
Snowdenia polystachera	1.92	1.72	__	__	__	__	__	__	__	__	__	8.82
Alternthera pungens	3.85	1.72	__	11.5	__	3.33	__	__	__	__	__	__
Commelina latitalia	1.92	__	__	__	__	3.33	__	__	__	__	__	__
Erucastrum pachypodium	1.92	__	__	15.3	__	__	__	__	__	__	__	__
Guizotia seabra	1.92	__	__	__	__	__	__	6.45	__	__	__	__
Tribulus terrestris	1.92	__	__	__	__	__	__	__	__	__	__	__
Xanthium spinosus	3.85	3.45	__	__	__	__	10	__	__	__	__	2.94
Parthenium hysterophorus	19.2	3.45	82.3	3.85	12.2	43.3	10	58.1	55.3	56.7	76.2	26.5
Solanum indicum	1.92	__	__	__	__	3.33	__	__	__	__	__	__
Lantana camara	3.85	__	__	__	__	46.7	__	__	__	1.67	__	__
Setaria pumila	1.92	1.72	__	__	__	__	__	__	__	__	__	__

Cyperus regitidipholus	1.92	—	—	—	—	—	10	—	—	—	—	—
Argemonne mexicana	1.92	—	0.88	—	—	—	—	—	—	—	—	—

Appendix 4 Questionnaire for data collection to assess perceptions of farmers on the distribution and socio-economic and environmental impacts of parthenium weed.

Assessing & mapping the Present distribution of parthenium weed in the Adami Tulu-Jido Kombolch Area, in the central rift valley of Ethiopia

Perception and reactions of farmers on the distribution and impacts of parthenium weed

House Hold Survey Questionnaire No ____________

UTM/Location of HH: _________

Survey area:

Region ________ Zone _________Woreda _______Village ________

PA __________________

Date of Interview_______________

Name of Interviewer ___________________

Name of Head of household____________________ Age _____ Sex______

I. General information about the respondents.

We would like to know the extent of the parthenium weed problems in the village.

1. For how long did you live in this village? (Year)_________________

No	Name	Age	Sex	Relationship	Education	Occupation
1						
2						
3						

Part II: Biophysical and socioeconomic information of *P. hysterophorus.*

Section A: impact on biodiversity

1. Do you know parthenium weed (*P. hysterophorus?*) 1. Yes 2. No

2. What is the local name of the *P. hysterophorus*? __________________________.

3. Since when the parthenium weed seen in this area? __________________.

4. Where did it first appear?

1. Range land 2. Irrigated land 3. Road side 4. Cropland 5. Others (please specify) ____.

5. How do parthenium weed expanding in your village?

1. Through fodder 2. Through human 3 Through animal 4. Through vehicles 5. others (please specify) ______________________________.

6. Is there any soil fertility problem in your farm due to *P. hysterophorus*?

1. Yes 2. No

7. When did you first realize the problem? (Year)________.

8. On which plot? plot No.	9. What indicators did you observe? code a.	10. What management practices have you applied to address the problem? Code b	11. Did you see any improvement? Yes ____1 No _____2

Code a: yield decline____2, soil structure and color change____2, decline the composition of vegetation in grazing land_____3, decline income of the family______4, others (please, specify) _____5.

Code b: Following _____1, crop rotation ______ 2, Intercropping ______ 3, manure __________ 4, Fertilizer 5, mulching ______ 6, Legume trees _______ 7, others (please, specify) _____ 8.

12. Does parthenium weed has ecological importance?

1. Yes, go to question 13 2. No

13. If yes, what are they?

1. Increase fertility of soil
2. Serve us wind break
3. Used as fodder for animals
4. Control soil erosion
5. Others (please, specify)____.

14. Is there any land which is not invaded by partheinum weed?

1. Yes, go to question no. 31. 2. No

15. If yes, which land use type?

1. Crop land 2. Grazing land 3. Irrigated land 4.Waste land

5.Others (please, specify) ____.

16. Why it is not invaded by parthenium?

1. It is far from land which is invaded by parthenium
2. I am removing the weed while it is seedling
3. The crop land is not suitable for the parthenium
4. Cattles are not allowed to go to crop land
5. Others (please, specify) ____.

17. How much area of land wasted due to parthenium weed in the Woreda? ___________.

No	Land use	Land wasted due to parthenium weed (%)	Land wasted due to parthenium weed (ha)	Remark
1	Agricultural land			
2	Pasture land			
3	Forest /open wood land			
4	Wet land /water bodies			
5	Industry land			

6 Others

7 Total area of land wasted

---

18. Which species dominates the grazing lands?

1. Parthenium weeds 2. Grass 3.Others (please, specify) ______________.

19. What change have you observed in the grazing lands in terms of species composition Cover since the last 5 years?

1. Natural grass has increased
2. Natural grass has decreased
3. Parthenium weed has increased
4. Parthenium weed has decreased
5. Others (please, specify) ____.

20. What change have you observed in the grazing lands in terms of species composition Cover since the last 110 years?

1. Natural grass has increased
2. Natural grass has decreased
3. Parthenium weed has increased
4. Parthenium weed has decreased
5. Others (please, specify) ____.

Section B: crop production

1. Is there any weed problem in your farm? 1. Yes, go to question No 2. 2. No

2. on which plot? Plot no.(code a)	3. What is the problem? Code b	4. When did you first observe the parthenium? (year)	5. Did you take any protection measure? Yes___1. No__2	6. When did you start taking these measures? (Year).	7. Did you see any improvement or change after the measure? Yes___1, No_____2

Code a. wheat____1, barley___2, maize___3, sorghum___4, teff___5, grazing land____6, others (please, specify) _____7

Code b. reduction of products___1, reduction of quality____2, increase inputs____3, increase lobour____4, others (please specify) ______5.

8. Is there a decline in land productivity in your farm due to parthenium weed?

1. Yes 2.No

9. How are you ploughing your farm currently?

	1. Oxen	2. Hoe	3. Mechanized machines
2 years ago	1. Oxen	2. Hoe	3. Mechanized machines
5 years ago	1. Oxen	2. Hoe	3. Mechanized machines
10 years ago	1. Oxen	2. Hoe	3. Mechanized machines

10. How many times do you plough your farm?

1. Once 2. Twice 3. Three 4. Four 5. Others

11. Do you use fertilizer regularly in your farm? 1. Yes 2. No

12. If yes, which type of fertilizer are you using?
1. DAP 2. Urea 3. Manure 4. Others ________________.

13. What is the land cover currently in your farm? (code a)	14. What type of crop you are producing? (Code b)	15. On what type of crop the parthenium weed is common? (Code b)	16. What major impacts did you observe due to the presence of parthenium weed? (Code c)

Code a: grazing____1, farming___2, vegetable and fruits_____3, vegetation_____4, bare land____5, others (please specify)______6.

Code b: wheat____1, barley___2, maize___3, sorghum___4, teff___5, grazing land____6, others (please, specify) _____7.

Code c: intensive labour____1, yield reduction____2, health problem____3, others (please specify) ____4.

17. How foresee the expansion of parthenium weed in this area?
1. Very fast 2. Fast 3. Moderate 4 slow 5. Others __________.

18. What will be the consequences in terms of crop production loss?
____.

19. What problems will the invasion of parthenium weed cause to your farm in the coming 5-10 years, if you do not take any protection measures?
1. Productivity will decline
2. It will increase the cost of inputs
3. It reduces the quality and quantity of cattle production
4. Others (please, specify)
5. I don't know

20. Was a similar problem?

5 years ago	1.Yes	2.No
10 years ago	1.Yes	2.No
15 years ago	1.Yes	2.No

21. Do you think that production per unit area has been decline since the last 10 years due to the expansion of parthenium? 1. Yes 2. No.

22. Is there any income level change since the last 10 years? 1. Yes 2. No

23. If yes, what do think about the causes for declining of income/ output level?

24. The invasion of parthenium weeds in your village and in your farm land
1. Affect the quality of crop and animal outputs
2. Affect the quantity of crop and animal outputs
3. Affect the income level and welfare of the society

4. Decline the inflow of tourist into the area

5 Hamper the movement of the people

6. Others (please, specify) ____.

25. Which crop type is more important in your family as staple food and economically?

1.Wheat 2. Maize 3. Barley 4. Sorghum 5. Tef 6.Others (please, specify)

Section C: livestock production

1. Is there a grazing land currently in your village?

1. Yes 2.No

2. If No, was there 5 years ago? 1. Yes 2. No

10 years ago 1. Yes 2.No

3. If yes, How much ____________ ha (unit)?

4. Which species dominates the grazing lands?

1. Parthenium weeds 2. Grass 3.Others (please, specify) _______________.

5. What change have you observed in the grazing lands in terms of species composition Cover since the last 5 years? 10 years

1. Natural grass has increased

2. Natural grass has decreased

3. Parthenium weed has increased

4. Parthenium weed has decreased

5. Others (please, specify) ____.

6. Is there any thing that you used to get and but you lost due to the change in the grazing 1and? 1. Yes 2. No

7. If yes, what are they? ____

8. Has the invasion of parthenium weed negatively affected your cattle productivity?

1. Yes 2. No

9. If yes, what are some of these negative impacts?

1. Cattle productivity declines

2. Quality of cattle product declines

3. Declines the income level of the family

4. Take too much labour and time of the family

5. It affects the taste of their products

6. Others (please, specify).____.

10. How much money you lost due to this effects of parthenium on animal productivity?

11. Has the invasion of parthenium weed negatively affected your cattle productivity?

1. Yes 2. No

12. If yes, what are some of these negative impacts?

1. Cattle productivity declines

2. Quality of cattle product declines
3. Declines the income level of the family
4. Take too much labour and time of the family
5. It affects the taste of their products
6. Others (please, specify).____.

13. How much money you lost due to this effects of parthenium on animal productivity? ____________

14. Do you think that production per unit area has been decline since the last 10 years due to the expansion of parthenium? 1. Yes 2. No.

15. Is there any income level change since the last 10 years? 1. Yes 2. No

16. If yes, what do think about the causes for declining of income/ output level? _________________

17. The invasion of parthenium weeds in your village and in your farm land
1. Affect the quality of crop and animal outputs
2. Affect the quantity of crop and animal outputs
3. Affect the income level and welfare of the society
4. Decline the inflow of tourist into the area
5 Hamper the movement of the people
6. Others (please, specify) ____.

Section D: health impacts on human and animal

1. Is there any health problem due to the presence of parthenium weed in your village? 1. Yes, go to question no.50 2. No

2. What is that?
1. Allergy 2.Dermatitis 3.Asthma 4.Others (please, specify) ______________________

3. Did any member of your family got dermatitis?
1. Yes, go to question no51. 2. No

4. Is there any medication to cure the dermatitis?
1. Yes, go to question no. 52 2. No

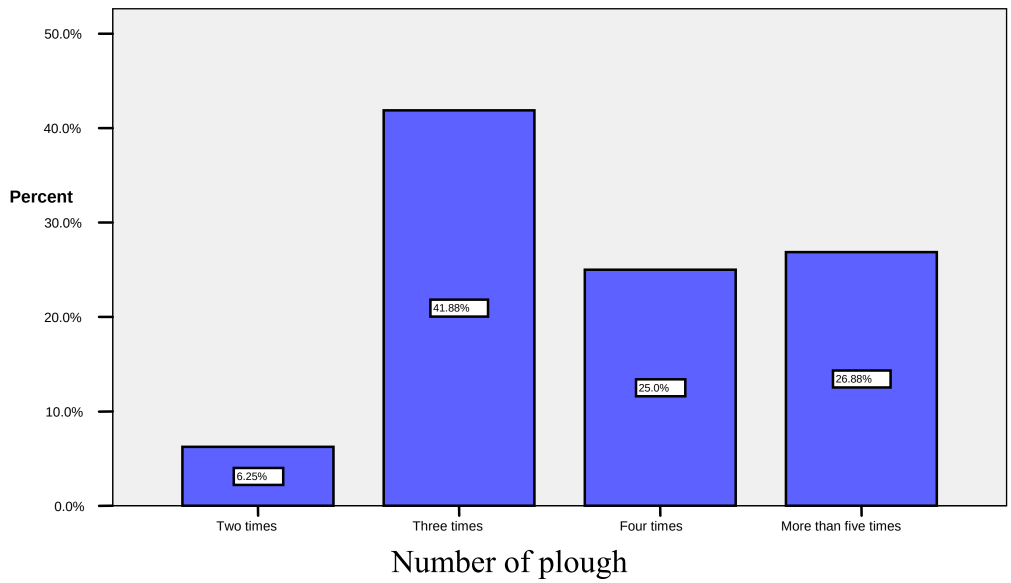
5. Is there any cultural medication to cure dermatitis? 1. Yes, go to question no53. 2. No

6. Does parthenium weed has any allergy effects. 1. Yes 2.No

Appendix 5 Percentage responses on the impacts of *P. hysterophorus* on human health

Type of health impacts	Frequency (in number)	Percentage (%)
Allergy	13	8.1
Dermatitis	23	14.4
Asthma	3	1.9
The overall impacts due to parthenium	30	18.8

Appendix 6 Number of plough in which farmers practiced before sawing in the Adami Tulu-Jido, 2007



Appendix 7 *Parthenium hysterophorus* at different growing stages in Adami Tulu-Jido Kombolcha