EFFECTS OF CLIMATE VARIABILITY ON DODDER INVASION, DISTRIBUTION AND MANAGEMENT IN BELGUT AREA OF KERICHO COUNTY, KENYA

By

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JUNE 2020

DECLARATION

Declaration by the Candidate

This project is my original work and has not been submitted by anybody else for a degree award

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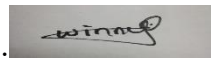
Signature…  ……. Date 4/6/2020

Declaration by the Supervisor

This project report has been submitted for examination with my approval as the University Supervisor.

Dr. James K.A Koske

Signature……. …… Date …04JUNE2020…….

Department of Environmental Science and Education

DEDICATION

I dedicate this work to my parents Mr. Simion Langat and Mrs. Esther Langat and my daughter Gretel Chemutai, they are the people behind my hard work towards this achievement.

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ABSTRACT

Parasitic weeds are plants that have evolutionarily lost autotrophic way of life during their development stages. Dodder, a plant of the *Cuscuta* species, is one such invasive parasitic weed with a wide range of world geographic distribution and host diversity. In Kenya, dodder is common in counties at the Coast, Central, Nyanza, Western and Rift valley. The plant is alleged to parasitize on a variety of perennial crops, wild and domesticated trees and shrubs thus affecting host vigor quality and quantities of crop yields, in particular the socio-economic reliance on crops infested by the weeds is in jeopardy as measures to curb the spread and control it are being sought urgently. Moreover, there are relatively less local research reports on socio-economic, biological and physical factors enhancing its spread, host association and effective control methods. This survey therefore sought to find out implications of climate variability on dodder invasion, association, distribution and management in Belgut area of Kericho County, Kenya. Specifically, the study examined climate variability in the study area between 1988 and 2017 in relation to dodder occurrence and distribution. Historical climate data, consisting of rainfall and temperature, was obtained from the Kericho Meteorological Department for the period 1988 to 2017. The study also identified socio-economically valued plant hosts, impacts and cultural management methods of the dodder control. The Survey of Kenya Topographic Sheet No. 117/3 was used to sample 399 households as the sample size for the study. This was done by first sampling the land segments. The study area covered an area of 200km² and was divided into 1 km² land segments. Yamane's formula was used to determine the sample size and 133 of these land segments were obtained as the sample size. Within each 1 km² land segment, three farm households were purposively selected for acquisition of data based on field accessibility. A questionnaire consisting of items on such variables as socio-economic profiles, historical dodder invasion, hosts and its management, was administered to the heads of the selected households. An observation sheet was used to record GPS locations of dodder occurrence, broad ecological characteristics, host species associations and related characteristics. The data were classified and statistically analyzed ($p \leq 0.05$). Linear regression model revealed that rainfall has been decreasing while temperature has been increasing. The Shannon-Weiner Diversity Index of dodder hosts was 1.89, this implies diversity was on average since the index normally lies between 1.5 and 3.5 for most communities. Simpson Diversity Index was 0.2, This index lies between 0 and 1 and approaches 1 in cases of monoculture. The number of parasitized species were 43 in total, tea was the most parasitized host with 2391 individuals parasitized. Analyzed data map indicate that Waldai and Sigowet wards had the highest relative occurrence and densities of dodder. Six local methods were used for management of dodder and their applications differed significantly by gender of the household head ($\chi^2 = 24.72$, df = 10, N = 124, p = 0.006) and non-significantly with education level of the household head ($\chi^2 = 39.79$, df = 40, N = 124, p = 0.48). Killing of host was reported to be the most effective dodder management method. There is rapid spread of dodder primarily because of the wide host range (Shannon Weiner Index 1.89) and no economical and effective management method. Further research in a multi-disciplinary approach needs to be undertaken urgently to understand the local environment in relation to proliferation as well as determination of the most effective management methods. Prevention of dodder spread is the best way to manage dodder, where infestation has occurred treatment should be done immediately.

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LIST OF ACRONYMS AND ABBREVIATIONS

GoK - Government of Kenya

GPS - Geographic Positioning System

SPSS - Statistical Package for Social Scientists

WRI - World Resource Institute

IPCC -International Panel on Climate Change

WHO -World Health Organization

DEFINITION OF TERMS

Haustoria – A slender dodder projection that penetrates the host and is used to obtain nutrients from the host

Host species- Plants that have been parasitized by dodder

Diversity – A value obtained by using Shannon wiener diversity index

Diversity index- is a result obtained from analyzing data using Shannon weinner diversity formula

Abundance –population of each dodder host species

Climate Variability - Variations in the mean of temperature and rainfall on temporal and spatial scales of Belgut

Belgut Area - in this study is used to refer to former Belgut Division of Kericho District whose boundaries touch both the current Belgut constituency and Sigowet constituencies

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Parasitic weeds belong to the group of plants that have largely lost autotrophic way of life during their development stages (Rathore *et al.,* 2014, Kaiser *et al.,* 2015, Kang *et al.,* 2015). They depend on the host for their nutritional needs, by primarily penetrating the host plant vessels to obtain nutrients using special structures called haustoria (Aly, 2013, Link *et al*., 2014). Different developmental steps are associated with different degrees of parasitism. Facultative parasites like *Rhinathus* and *Melamyprum* species are said to be at the initial of these developmental steps, while obligate parasites are at advanced stages and are either hemi-parasites with chlorophyll containing species like genus *Striga* and *Alectra* of the family Scrophulariacaea, or holo-parasites without chlorophyll like family Orobanchaceae (Kroschel, 2001, Kang *et al.,* 2015). Parasitic plants occur throughout the world in all types of plant communities. Generally, the parasite weakens the host so it produces fewer flowers and viable seeds or reduces the value of timber (Johnsen *et al*., 2015) infections of the host happen through the haustoria (Wang *et al*., 2017). However, some parasites, mostly annual root parasites belonging to Orobanchaceae kill the host and cause considerable economic damage when they attack monocultures (Dhanapal *et al.,* 1996). Much effort is required to control these harmful parasites (Diego *et al.,*2011). Invasion of parasites have both direct and indirect effects that affect the structure and diversity of plant communities at the host level and on all trophic levels, which can be understood and solved through an interdisciplinary study approach (Dunn *et al.,* 2012, Gaba *et al*.,2017).

Dodder is an obligate holo-parasite of Kingdom: Plantae, Phylum: Tracheophyta, Class: Spermatopsida, Subclass: Asteridae, Order: Solanales, Family Convolvulaceae, Genus: Cuscuta, (Al-Snafi, 2016) with approximately 200 dodder species worldwide (Glenn *et al.,* 2006, Goldwasser *et al.,* 2012, Johnson *et al.,* 2016). It appears as yellow (Al-Snafi, 2016), orange or reddish strings like vines winding up a stem and leaves of the host, forming a mat that covers the host in case of severe infestation (Aly, 2013). *Cuscuta* spread vegetatively and by seeds; their seeds have high dormancy and can survive for up to 20

years depending on the environmental conditions and the species, (Goldwasser *et al.*, 2012, Nazari, 2014). Dispersal is thought to occur through contamination of seeds (Glenn *et al.*, 2006). Dispersal through bird fecal matter has also been suggested to have contributed to the widespread distribution of this species (Andy *et al.*, 2016).

Dodder is perennial parasitic herb that attaches itself to the host using haustoria (Ali *et al.*, 2016, Kristen *et al.*, 2017) . Haustorium has a high level of growth and penetrates susceptible tissue of the host. It has no leaves, roots and chlorophyll though some species have very low level of chlorophyll (Hillary, 2001, Johnsen *et al*., 2015).

Dodder leaves have been reduced to alternate minute scales (Mihai *et al.*, 2005,(Johnsen *et al*., 2015, Al-Snafi, 2016). This plant has been listed as one of the plant pests in the plant protection order of 1961 CAP 324 (GoK, 2012) as it competes for water and food with the hosts but majorly attacking young twigs which are likely to die (Nazari, 2014)

This parasitic weed, weakens the host, affect the yields quality and production (Glenn *et al.*, 2006, Aly, 2013). At the University of Massachusetts Cranberry experiment station, total yields were reported to have dropped by 50% in cranberry production (Hillary, 2001). Specific dodder species parasitize specific hosts and its Identification is done using flower corollas and the way capsule open (Glenn *et al.*,2006). Dodder have developed adaptation strategies for survival in that, they have a wide range of host (Kristen *et al.*, 2017). Seedlings germinate when potential hosts have grown and invasion is designed to match the biological processes of the host (Karban, 2008).

Apart from reducing yields, this weed also affect seed quality through contaminating seeds especially small seeded legumes. In most countries including United States of America and Canada legislations prohibiting entry of such contaminated seeds have been developed. This requires the seeds to be cleaned a process that further reduces the quality of seeds. Certain species of Dodder are suspected to be poisonous to livestock and man. A study by (Movsesyan and Azaryan 1974) confirmed that field dodder *Cuscuta campestris* Yuncker. is poisonous to livestock if it exceeds 5% of the forage. Rabbits, cattle and horses were also reported to fall sick when they feed on this species.

Despite of its negative impacts, Dodder has been reported to be beneficial too. According to the World Health Organization (WHO) 80% of the population in the world use herbal medicine and plants have been reported to have a wide range of pharmaceutical value, dodder is listed as one of these plants ((Ali *et al*., 2016, Al-Snafi, 2016). In China, it is reported to have been used as one of the ingredients for herbal medicine used to treat women with premature ovarian failure and secondary amenorrhea (Li *et al*., 2012) and in a review of Traditional uses, constituents and pharmacological effects of small seeded Dodder *Cuscuta planiflora* Ten, *C. Planifora* seeds are reported to treat osteoporosis, osteoarthritis and other pain of the muscles. Also, at Ayurveda it was used to treat Jaundice. (Al-Snafi, 2016). Field dodder *C. campestris* said to be anti-inflammatory, (Ghule *et al., 2011) Cuscuta reflexa* Roxb. Reported to treat diabetes, to be antifungal and an insecticide while *Cuscuta chinensis* Lam. Is reported to prevent and heal prostrate carcinogenesis last but not least Lespedeza dodder *Cuscuta pentagona* Engelmann. Is reported to be used to dye wool (Mihai *et al.,* 2005).

1.2 Problem Statement

Biological invasion of parasitic weeds results in both direct and indirect effects within the host and the entire ecosystem. Dodder infestation therefore, especially on socio-economically important crops poses these effects to the society and affect livelihoods. These effects include reduction of yields which subsequently affect food security, income and revenue from the affected crops and employment opportunities in the agricultural sector. In addition, dodder compromise the nutritional content of the infected crops because it sucks nutrients from these hosts. This will affect the nutritional status of the affected populations in the long run. Dodder also affects the quality of natural ecosystems and in the long run, these effects will be felt by humans through the ecosystem services provided by these natural ecosystems. Moreover, the main economic activity in Belgut area is agriculture being within the country's leading tea growing zone and home to some multinational tea companies, Dodder will have tremendous effects to this practice especially since parasitic weeds are generally known to be difficult to control, the purpose of this study is to look into the association of climate variability on distribution of dodder, effectiveness of management techniques that are being practised by residents and lastly the common host species for dodder in Belgut. These will assist in understanding the biology

and ecology for this plant and identifying sustainable management methods to curb its spread before its becomes a huge problem to Agriculture.

1.3 Research Questions

The research questions, which this study seeks to answer, are the following:

1. How has temperature and rainfall varied for the period 1988 to 2017 in Belgut area of Kericho County?
2. How is Dodder distributed in Belgut area?
3. How is distribution of dodder related to climate variability in the study area?
4. How diverse are dodder hosts in Belgut area?
5. What is the rate of effectiveness of dodder management methods practiced in Belgut area?

1.4 Research Objectives

This study aimed at achieving the following objectives

1. To examine temperature and rainfall variability for the period 1988 to 2017 in Belgut area.
2. To determine how dodder is distributed in Belgut area.
3. To examine how climate variability affects distribution of dodder in the study area.
4. To assess species diversity (abundance and evenness) of dodder hosts in Belgut area.
5. To assess the rate of effectiveness for methods employed by farm households in the management of dodder at Belgut area.

1.5 Hypotheses

The following null hypotheses guided the study:

1. H_o: Climate has not varied significantly from 1988 to 2017 in Belgut area.

2. H_o: Spread and distribution of dodder is not significantly associated with climate variability of Belgut area.

3. H_o: Dodder host diversity is not significant in the study area.
4. H_o: Dodder management methods rate of effectiveness is not significant at Belgut area.

1.6 Justification of the Study

Dodder has been introduced recently in Kenya and minimal research have been conducted on the weed in the country (Otieno,2016). It has however caused huge economic losses particularly to tea farmers who are a majority in the study area. This study will therefore, help in establishing the extent to which dodder has been spread in Belgut area, major dodder hosts and effectiveness of dodder management in order to understand its impact. Dodder being an invasive species has a wide geographic range and host species, these attributes make it spread very fast posing direct and indirect effects to agriculture which is the main economic activity sustaining livelihoods in the study area, these impacts range from affecting reduced productivity of the host plant to even death of the host under severe infestation. Understanding and identifying the spread and distribution particularly in relation with climate variability, is important in understanding dodder and finding effective and sustainable management of this weed. Identification of the hosts and preferred dodder hosts in the study area is also key and will provide useful information to be used in various ways like advising farmers, for example on practices like crop rotation, a practice which have been found to effectively manage dodder in other areas. These findings will also be useful in crop rotation through identifying non-host species which can be used for crop rotation. Finally, evaluating the management methods that have been used by farmers to manage dodder shall be important in assessing most effective and sustainable methods which farmers will further be advised to adopt. In addition, these information help in understanding the biology and ecology of dodder, that is important in improving the available management methods and even establishing new and more effective methods. Particularly in the tea farming sector because the study area depends heavily on tea farming as a socio-economic activity. This would improve yields; safeguard food security and

increases income from agriculture. The information could also be used at the national level by policy makers in policy formulation for the control and management of dodder.

1.7 Conceptual Framework

In the study crops grown, spread and distribution of dodder will be dependent on climate variability. Management method effectiveness shall be dependent on the distribution of dodder and the types of crops it has parasitized together with the distribution of dodder is also dependent on the kind of crops grown. Several factors are intervening variables and can affect the variables in the study as shown in the figure 1 below,

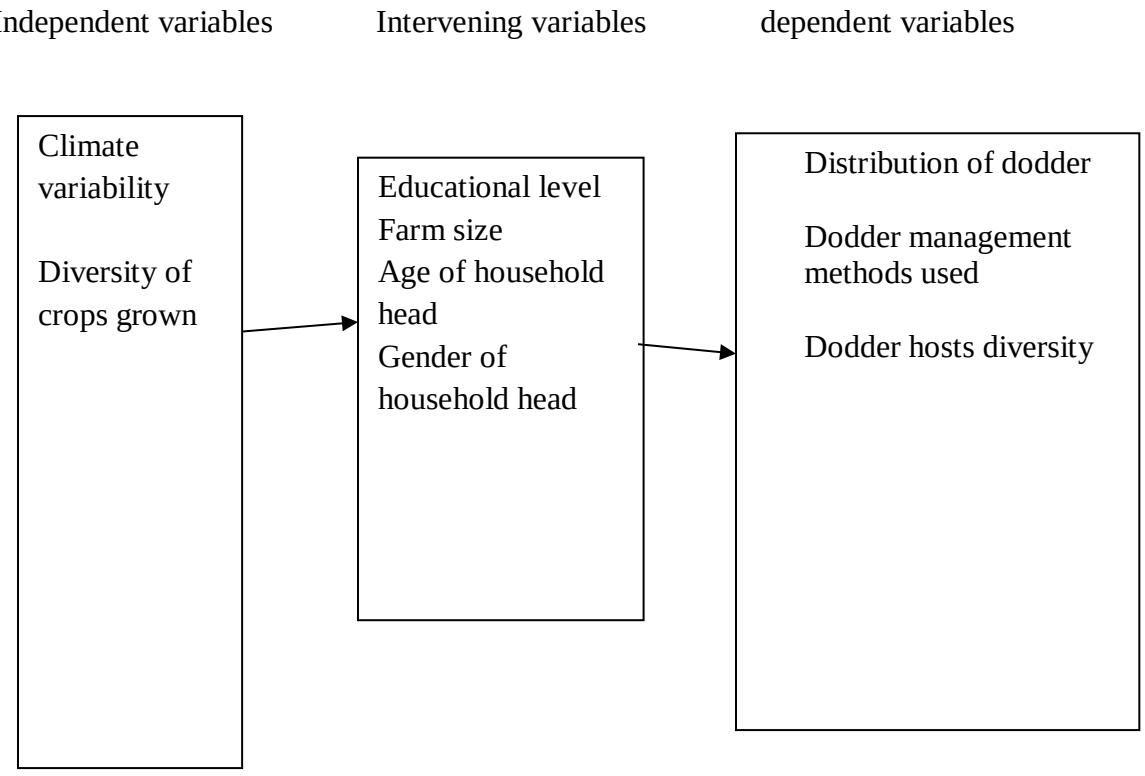

Figure 1. 1: Conceptual Framework

CHAPTER TWO: LITERATURE REVIEW

In this section existing literature will be reviewed for each of the objectives in order to bring out the problem and ways of solving them by setting objectives. In here also ways and methods of achieving the set objectives will be identified and explored.

2.1 Climate Variability

Global surface temperature is said to have increased by about 0.6°C since the 19th century with most of this increase recorded in 1910 to 1945 and since 1976 to present (Folland *et al*., 2001). Rainfall on the other hand is also said to have increased at the rate of 0.5 to 1% per decade in mid and high latitudes of the northern hemisphere .Contrary to that records show decrease of −0.3% per decade in the sub-tropical regions during the 20th century, this trend is said to have changed and increase in precipitation has been recorded in recent decades (Folland *et al*., 2001)According to IPCC report 1995-2006 were the warmest years of global surface temperature since 1850 (IPCC, 2007) .In a study aimed to look at temperature trends across 60 Kenya's meteorological stations a significant rise in temperature across the stations in the Kenyan highlands was reported. In Kericho a warming trend of 0.2°C per decade was reported for the period 1979-2009 in the minimum maximum and mean temperatures (Omondi et al., 2014). However no significant trends were found for rainfall in an analysis of rainfall data for 1945-2007 for Sudan arid region (Omondi et al., 2014).This changing climate will change the ecological threshold. Seasonal and monthly mean temperatures are often used with other related variables in correlative models of species distribution to predict distribution and abundance trends (Jackson *et al*., 2009). Its thus evident that climate change is connected to invasive alien species yet this fact is largely ignored. Though there is less research articles on climate change and invasive species range shift this field has been studied more in the recent past, the field is regarded to be multidisciplinary yet most research focus on the ecological dimensions, this has only taken into account the immediate impacts of this species leaving out other important impacts like the socio economic effects (Smith et al., 2012)

A simulation of physical mechanism interactions with climate variability over the Lake Victoria basin took into account the moisture transported by the eastern monsoon winds and reported that this affected the rainfall pattern and the rainfall amounts in the

surrounding areas. From the model association between topography moisture circulation and climate variability were used to describe rainfall variability (Anyah *et al.,* 2006). A study looking at rainfall variability in the Great Rift Valley between 1950-2011 using variance and observation of rainfall trends during that period reported decreasing rainfall trend and high variability between seasons (Wakachala *et al.,* 2015)

2.2 Distribution of Dodder and Climate Variability

Invasive species growth and abundance is favored by the warming global surface temperatures which have been recorded throughout the decades. The warming also expand range for these species while the native species die from drought, heat stress and other extreme events (Bradley, 2017). Most terrestrial organisms have been shifting their geographical distribution in altitude and latitude because of the changing climate (Lenoir and Svenning, 2015). A study using a meta-analysis method found out species have shifted in their distribution at a faster rate to higher elevations at a median rate of 11.0 meters per decade, and to higher latitudes at a median rate of 16.9 kilometers per decade. This is even larger in studies with more warming rates such that these latitudinal shifts could effectively track temperature changes. These changes however varied among species meaning that distribution of individual species depend on both the species type and external factors (Ralf *et al.,* 2011). Another shift was also reported in a study looking at the composition of the green mountains during 1964 to 2004 which reported that northern hardwoods expanded to higher altitude and Boreal forests reduced in lower altitude (Bradley, 2017).

In a study looking at soil ecosystem functioning under climate change, plant species and community Effect in the United States, it was found out that while water, relative to increases in carbon dioxide and warming among other interactions, had the largest impact on plant community composition, soil enzyme activity, and soil nematodes. Multiple climate-change factors interactions affect ecosystems, in the study, those interactions were majorly as a result of water changes (Mellissa *et al*., 2010).

Dodder has been introduced to most parts of the world. Invasion is reported to be in temperate and tropical regions, concentrated majorly on the tropical and subtropical regions of the world. Dodder has spread widely and faster because of its wide geographic range for survival and wide range of host, 18 dodder species have been reported in Iran

(Nazari, 2014). The small seeded dodder has been reported to have been native to the mediteranean region and later distributed to some countries incuding Kenya in Africa and also some in Asia Europe and Australia (Al-Snafi, 2016). *C. campestris* is said to have been introduced in South Africa from North America more than 50 years ago (Crocker, 2008). In Kenya dodder is common in counties at the Coast, Central, Western, and Nyanza and Rift valley regions. A study to assess the distribution of five *Cuscuta* species reported that field dodder *C. campestris* was the most widely distributed species of the genus worldwide (Ghule *et al.*, 2011), found in South America, Europe, Asia, Africa and Australia. *Cuscuta gronovii* Willd was reported to be in Canada and has spread to Europe, found mainly along the watercourses, *Cuscuta umbrosa* Beyr also reported to be at eastern Alberta Saskatchewan and Manitoba, clover dodder *Cuscuta epithylum* is said to have originated from Europe and has been distributed around the world (Gomez, 1994) as it is reported to be found scattered in British America and lastly *Cuscuta epilinum* Weihe was also reported to be scattered in North America and Africa. The four species were reported to do well in temperate to sub-tropical climatic conditions while field dodder *C. campestris* was reported to do well in wide climatic conditions yet grow poorly in humid seasons and do well in dry season as they were observed to infest more on sugar beet during summer (Mihai *et al.*, 2005).*C. chinensis* is said to be found in Africa and in the warmer parts of China Asia and Australia whereas *Cuscuta Obtusifora* and *Cuscuta Planifora* are found on Wild plants in Kenya *C. epilinum* Weihe on the other hand is said to have been introduced to Africa (Natrass, 1941).

2.3 Dodder Invasion

Parasitic plants may parasitize the different parts of plants using haustoria and depend on the plants as holo-parasites or hemi-parasites, hemi-parasites may further be classified as obligate or facultative parasites (Estabrook & Yoder, 1998). A study of *Cuscuta monogyna* an oak parasite biology and management in Iran reported that *C. monogyna* produces many seeds during summer which fall on the ground and germinate once the climatic conditions become favorable by growing thin whitish filaments which attach on to grasses and slowly spread to other potential host plants, which are Oak trees in this scenario. On attachment the filaments turn brownish and dodder begins to feed on the host drastically reducing their growth and killing it in cases of severe invasion. It was also noted that germination period

is long and the filaments depends on the distance to the nearest host branches. Livestock Birds and Humans are reported to be vectors in the spread of dodder (Nazari, 2014). Haustoria are produced and attached to the vascular system of the host if the dodder find food beneficial to them in the host (Ali *et al.*, 2016) after the attachment the base of dodder dies and dodder continues to depend on the host for growth spreading to adjacent plants and producing seeds which fall on the ground and grow or remain dormant until there are favorable conditions for germination (Heintze *et al.*, 2001).

2.3.1 Dodder Hosts

Parasitic plants have a wide host range (Shen *et al*., 2006) even though they are host generalists they have preference for certain hosts (Thorogood *et al.*, 2009). There are about 3500–4000 host specific parasitic plants species worldwide (Okubamichael *et al.*, 2016). This species has been classified in 274 genera. Plants in the genus *Cuscuta, Arceuthobium, Orobanche* and *Striga* are the worst economic parasites (Marija *et al.*, 2015). Dodder can attack a wide range of plants from ornamental plants to fruit and non-fruiting (Nazari, 2014) . Grasslands and perennial leguminous plants such as alfaalfa and clover are most preferred dodder hosts, plants of the families gramineae (poaceae) cannot be parasitized by dodder because their vascular layer is protected by sclerenchyma layer, these plants however do support *Cuscuta* in areas with non-host species like the road sides according to Tanase, 2012, *C. campestris* and *C. pentagona* species have been identified to be having a wide host range and geographical distribution worldwide .Despite of this,dodder don't infect monocotyledonous plants because of how vascular bundles are arranged in monocots and also the interspecies signals which are important in connecting the vascular strands (Kaiser *et al*.,2015). Some crop plants reported to be parasitized by *C. campestris* include capsicum, lettuce, onions, tomato, potato, celery, broad beans, red beet, clover, carrot, tobacco and lupin (Crocker, 2008) .*Cuscuta* species were reported in a study carried out in Canada to be host specific .The study reported field dodder *C. campestris* parasitized 116 species, clover weed *Cuscuta epithymum* parasitized 147 species and 175 species were parasitized by swamp dodder *C. gronovii*. The study also found that some *Cuscuta* species have a narrow host range while the other genera have a wide range with some parasitizing different families of plants but preferring specific plants. The host range from primary and secondary hosts too (Mihai *et al*., 2005).

The host preference of dodders was evaluated using a method that was tested on *Cuscuta europaea* at 75 localities in Hungary (Barath, 2012). The method examined 1,189 plant-parasite relationships and found that *C. europaea* parasitize almost every plant, it finds in the natural habitats. However, the intensity of infestations greatly varied among the host species. The plant had most preferred, most avoided and the most frequently parasitized host species. The results revealed that plant species of the nitrogen-poor habitats and species from Poaceae were not their preferred hosts (Barath, 2012).

In a study carried out at Western United States *Cuscuta indecora* and field dodder C. *campestris* were reported to parasitize alfalfa, clover, tomatoes, and potatoes. A study looking at growth and development of C. *chinensis* and its impact on selected crops found out that tomato is a preferred host of *C. chinensis* compared to chilli, and rice (Marambe *et al.*, 2002). Another study to investigate the effect of, *Cuscuta salina* on the structure and dynamics of community in a California salt marsh found that *Salicornia virginica*, was preferred host over *Arthrocnemum subterminale*, *Limonium californicum*, and *Frankenia salina* (Pennings and Callaway, 1996). Both woody and herbaceous plants have been reported to be potential hosts of dodder. *Cuscuta japonica* var. Formosa was reported to have at least 36 hosts species in a study carried out in Taiwan and another survey at Okhotsk coast reported at least 32 host species for the same plant (Heintze et al., 2001).

2.4 Dodder Management

After reviewing literature on dodder distribution spread and hosts. We can clearly note that dodder is a destructive weed and there is need to manage and control it's spread. In this sub-topic on dodder management two items have been reviewed. Firstly, dodder effects are discussed so that as we discuss dodder management we understand the problems that this plant has caused in the society.

2.4.1 Impacts of Invasive Species

Alien species poses ecological and socio-economic impacts on the native species hence the need for effective management of this species (Francesca *et al.,* 2011, Ana *et al.*, 2018). These alien species may become invasive reproduce and spread to an extent of dominating the native species causing changes in ecosystem services and processes which subsequently affect the livelihoods and economic activities in those area (Jayasinghe *et al.*, 2004, Ana *et al.,* 2018). Effects of parasitic infestation on specific host depend on the number of the

individual parasitic species attacking the host and interspecific interactions involved between the host plant and the parasitic plant (Gomez, 1994, Vurro *et al.,* 2017). Dodder have both direct effects and indirect effects on living organisms. Direct effects are majorly on the primary host, when dodder attacks a plant it extracts nutrients from the plant affecting its physiological processes reducing yields in the long run, (Marija and Sava, 2015), one such effects was reported in a study at the Democratic Republic of Congo looking *C. campestris* on cassava plantation. The study reported 47% yield decrease on plantations infested by dodder, this was said to be more if the infestation occurs before the formation of root tubers by the host plant (Mushagalusa *et al.,* 2016). Indirect effects that have been reviewed and have been reported are that livestock that fed on hay with over 50% dodder lost weight, are likely to miscarriage and may experience indigestion. Dodder may also carry viruses like cucumber mosaic virus or tobacco rattle virus (Marija and Sava, 2015), for instance *C. campestris* is said to be a vector for Cucumber Mosaic and African cassava Mosaic Viruses, the later has caused reduced cassava yields in Africa by spreading the African Cassava Mosaic Disease (Mushagalusa *et al.,* 2016).

2.4.2 Dodder Management Methods

Dodder management is challenging because of its seed dormancy properties,dodder seeds can remain viable in soil for upto 30 years or more and germinate when favourable conditions and preferred host species occur (Mushagalusa *et al.,* 2016). Dodder also has intimate physical and physiological association with the host (Vurro *et al.,* 2017), short life cycle and a wide range of host species (Goldwasser *et al*., 2012, Jiang *et al.,* 2013, Johnson *et al.,* 2016)

Control of dodder needs to be supervised by experts on plant pests and diseases according to a study carried out in Iran looking at dodder as a parasite on oak trees. In the study uncontrolled cutting of the Oak trees and planting of pasture in the oak forest are seen as the major practices that have favored the spread of dodder. With regard to this the following control measures were recommended, identifying the infected area and stopping movement and grazing in those area, then mechanically picking the dodder filaments and burn them, sensitizing the farmers and the ranchers and avoid use of chemicals while intensifying research on biological control of the dodder (Nazari, 2014).

Another study carried out in democratic republic of Congo on Cassssava farms also reported that dodder is difficult to control by studying *C. campestris* which was seen to twin tightly around the cassava plants and break the shoots reported that through handpicking, dodder can grow through vegetative propagation of the stem fragments and attach to other cassava stems (Mushagalusa, 2016). Prevention is the best control measure for dodder (Hillary, 2001). Some countries like the United States have adopted legislation for surveillance and quarantine at border to prevent the introduction of *Cuscuta* species into the country (Andy *et al.,* 2016),Seeds found to be contaminated by dodder are devitalized or returned to their origin (Heintze & Young, 2001).

Pre-emergence herbicides when seedlings are found early are said to be effective. However, timing and the mount of herbicides present in the germination layer must be able to effectively kill the seedlings throughout the germination period which may last 2 to 3 months (Hillary, 2001) an example of pre-emergence herbicides that has been used,is thiazopyr which was used on alfa alfa and found to selectively control *C.indocera* (Cudney *et al*., 1993) while Imazethapyr (438 mL ha-1 of a 22.87% a.i. formulation) is said to be possibly work as a post-emergent herbicide (Ghantous and Sandler 2017) .

Other techniques may include management of primary hosts through hand picking of infected hosts to reduce subsequent infection, though it might be tedious. Post emergence options used in cranberry farms used 10% soap solution that burn the stems of the dodder plant before flowering. Post emergence techniques are disadvantageous in that some of the chemicals used may affect the crops. It is important to establish chemicals that kill dodder and do not affect the plants. While using this method it is required to be administered before dodder begin to flower so as to be certain that seeds which will aide more spreading of the plant have not been developed (Hillary, 2001). The seeds not only exacerbate the extend of attack but also increases the chances of attack on crops grown at infected areas in the future because of the high level of seed dormancy dodder have. An example is a bioherbicide with a mixture of *A. destruens* (1.8×10^{10}spores/L) + oil at 7.5% v/v in water + glyphosate at 0.02 kg ae/L + ammonium sulfate 0.125% w/v which was reported to be effective in the control of *C. pentagona* which had infected citrus plants (Jennifer *et al.,* 2008).

Immediate destruction of dodder patches through burning or spraying with sulphuric acid the spots infected is effective and for infections on perennial crops, iron sulphate and copper sulphate are reported to be used though they are not effective as reported by (Nattrass, 1941). One of the post emergence herbicide in the market is Mycoherbicide (Hillary, 2001). Ethofumesate was reported to be effective if used as a pre-emergence pesticide for *Cuscuta australis* R. Br. in a study at a sugar beet field in polis (Giannopolitis, 1979). In addition, intercropping of maize with wheat (*Triticum aestivum* L.) reduced the infection of tomato by *C. pentagona* up to 90%, by reducing dodder seed production and infestation in the future. Amitrole plus Diquat mixture did not kill the seeds of *C. campestris* but reduced the formation of seeds when applied before the flowering stage. Other herbicides found to be effective for the control of dodder in the study were glyphosate, diquat, metsulfuron and clopyralid (Crocker, 2008).

2.5 Research Gaps

There is evidence of changing climate over the years globally and even at local levels from the temperature reviewed, in this study we also expect that climate has been changing in Belgut area, we therefore used temperature and rainfall data because they are the variables associated with extreme events including drought and floods to find out the trends and variability of this variables in the study area since 1988. From the literature reviewed, it is also evident that climate change affects ecosystems and cause shift in terrestrial organism geographic distribution, though this shift is specific to species and external driving forces, it is expected that dodder is not an exception. In this study, effects of climate variability on the distribution of dodder in Belgut area were examined.

From literature reviewed, dodder is found in temperate and tropical regions of the world. With a higher concentration on the tropics and sub -tropics. It was also noted that it had been introduced in Kenya and commonly found in Nyanza, Western, Coast and Riftvalley regions of the country. Belgut being within the mentioned regions is expected that dodder is found in the area. The study will therefore seek to find out how this pararsitic weed has been distributed at the study area. In order to understand its occurrences and spread

Most parasitic plants are generalists and as it has been reviewed they have preferred host, studies on different *Cuscuta* species in different areas have also been reviewed to

emphasize on this. In this study, therefore host diversity for dodder in Belgut area was examined to establish richness and evenness of dodder hosts.

Finally, management of parasitic plants have been said to be difficult, use of pesticides and enacting of legislation to prevent dodder entry into countries have been reviewed for other areas though no particular management method has been reported for Kenya and particularly Belgut area. This study will therefore find out the management methods that are common with the residents of the study area and their level of efficacy with the aim of understanding if this noxious weed is a threat to the socio-economic activities in the study area as it has been reported in other areas reviewed in the literature.

CHAPTER THREE: METHODOLOGY

In this Chapter the type of data and how data will be collected and analyzed to answer research questions and achieve the objectives of the study will be discussed. Firstly, the study area will be described and represented on a map for easy visualization, Then the study design chosen for the study explained after which population of the study area described and subsequently description on how sampling and obtaining of a representative sample size was obtained mentioned and explained. Data collection instruments and procedures are also outlined and lastly data analysis explained.

3.1 Study Area

The study area will be described in detail under this sub-section. Its geographic and physical location, topography, climate and economic activities are listed and explained in detail to help understand the Area.

3.1.1 Location

Belgut, which was purposely chosen as the study area is located in western part of Kericho County in Kenya (Figure 3.1). It borders Kisumu County to the west, Nyamira and Homabay Counties to southwest, Bureti Sub-county to the east, and Kipkelion West Sub-County to the north west. The area lies approximately between longitudes 35° 00’ and 35° 15’ E and between latitude 0°30’ and the 0°10’ S and occupies area of 516.6km². Administratively, Belgut has 6 electoral wards comprising, Waldai, Kabianga, Seretut/Cheptororiet, Sigowet, Kaplelartet and Kapsuser, (Figure 3.1). Further, the area has 16 administrative sub-locations namely, Kiptere, Kebeneti, Chemamul, Kapkitony, Kiptome, Chebirirbei, Koiwalelach, Kabianga, Mobego, Kaborok, Sosiot, Kipsolu, Kapcheluch, Chepkosilen, Ainapkoi and Kapsuser.

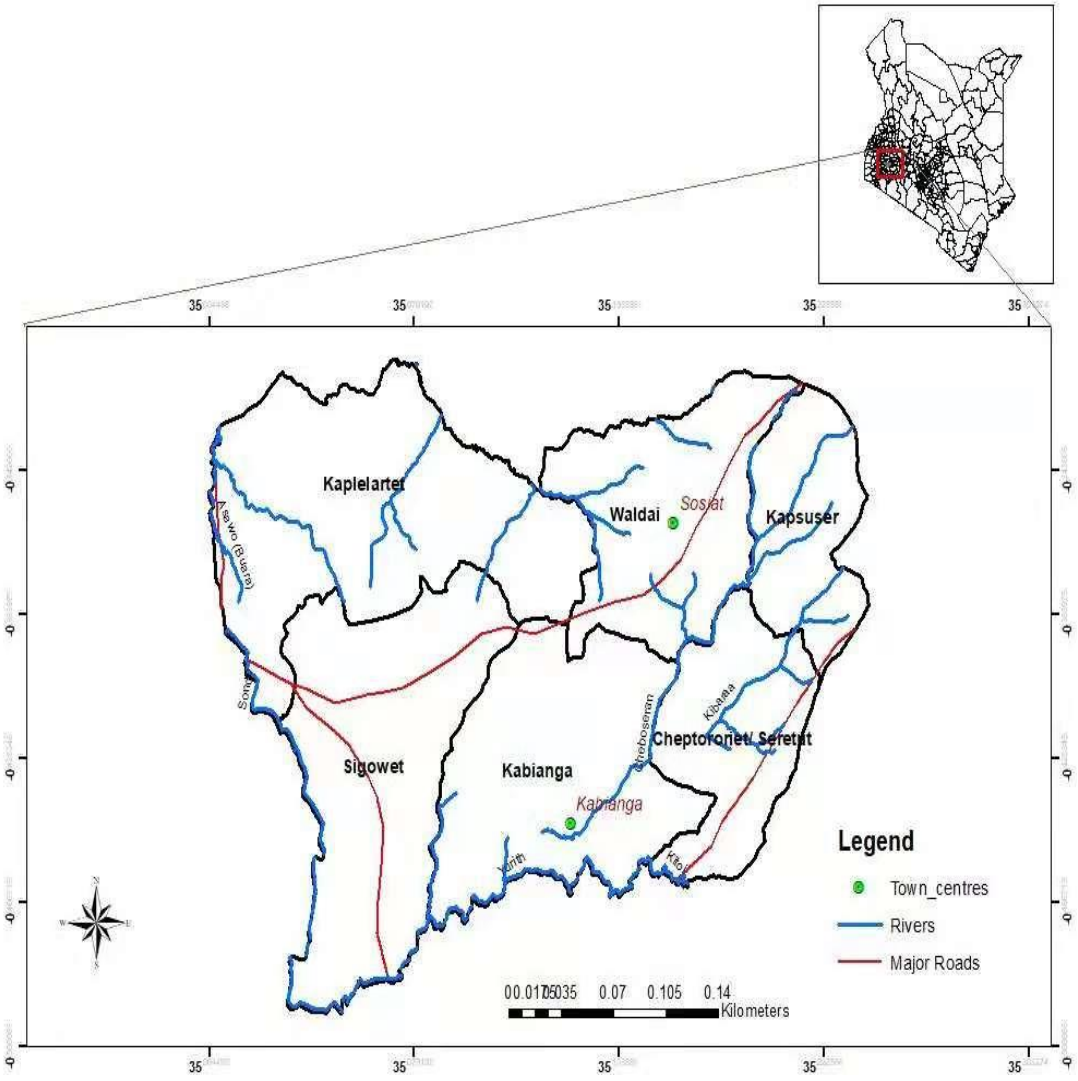

Figure 3. 1: Map of Belgut area, (source WRI, 1999)

3.1.2 Topography

The area lies along the southwestern edge of Kenya Highlands forming a hilly shelf between the Mau escarpment and the lowlands of Nyanza. Most of the area is characterized by undulating topography that gradually develops to a flatter terrain in the south. The overall slope of the land is from east to west and drainage is in that direction. The altitude varies from 2700m from the eastern part to about 1800m from the southern part and falls to about 1600m in the west bordering Kisumu. On average, the area lies 2000m above sea level and it is for this reason that it enjoys a cool climate throughout the year. Rivers spread evenly within the area and this gives its inhabitants easy access to water. (GoK, 2013).

3.1.3 Climate

The area receives high rainfall (more than 1400mm average annual rainfall, except for the southern part of Belgut that are relatively dry with less than 1300mm average annual rainfall. Rainfall is evenly distributed throughout the year. The change in altitude and other factors cause the temperatures to vary from 20 degrees Celsius at the border with Kisumu County to 18 degrees Celsius around Kapsuser (GoK, 2013).

3.1.4 Economic Activities

Agriculture is the major socio-economic activities in the study area. The main agricultural cash crops are tea and coffee, while maize is both a cash and subsistence crop. The area has been classified into two ecological zones based on soil types, rainfall and altitude; high potential zone, well suited for agriculture and forestry and medium potential zone, suited for coffee and maize growing and for both beef and dairy farming, towards the south. This area stretches towards the western section of Belgut bordering Homa Bay and Nyamira Counties, where maize and sugarcane are grown and dairy cattle kept only to a small scale (Kilel, 2015)

3.2 Study Design

Descriptive survey design was chosen for this study, this design entails inquiry on description of the facts about a phenomenon event or experience. It is a method of choice when straight descriptions of phenomena are desired. This design is useful for researchers who want to know who, What, and where of events according to (Sandelowski, 2000, Peniel 2016). This study described a number items as stated in the objectives including, dodder occurrence spread, hosts and management. GPS was used to take coordinates of dodder locations. The coordinates would be plotted on a map for visualization and interpretation of dodder occurrence. The study would also describe whether there exist a relationship between dodder spread and climate variability by use of historical climate data obtained from the Metrological department and respondents opinions on dodder spread over the years .Dodder hosts were recorded at every sampled household and the data would be used to describe dodder host diversity i.e. evenness and abundance by running Shannon Weinner and Simpsons diversity Indices .Lastly dodder management methods used and their efficacy was recorded and the data would be used the most commonly used methods and the most effective one in dodder control and management.

3.3 Population

The target population in the study were farm household's heads of Belgut area. There are 44,790 households distributed in a total of 202,591 individuals of whom 102,886 are males and 99,705 are females (GoK, 2009). The population is distributed on an area measuring 516.6km² and thus a density of 392 persons per Km². (GoK, 2009)

3.4 Sampling Procedures

Random and purposive sampling methods were used in the study. 1km² land segments were sampled at random from Survey of Kenya Topographic sheet 117/3 of 1971.This random sampling was done by assigning each of the 1Km² land segments on the map a number, there were 200 squares. on a blank paper numbers 1 to 200 were written down and each of the numbers were plucked and wrapped up. All the wrapped pieces of papers were then put in a jug and shaken to mix them, then 133 pieces were drawn randomly from the jug and unwrapped. All the segments whose numbers were drawn from the jug are the ones sampled for the study. Three farm households in each of the land segments sampled were

then sampled purposively by selecting the nearest, most accessible household within the land segment.

3.5 Sample Size

The Sample size for the study was obtained by applying Yamane's formula (Yamane, 1967) to calculate sample size as follows

$$n = N/1+N * (e)^2$$

Where; *n* is the desired sample size, *N* is the total 1km² land segments selected for the study and the total number of households in Belgut and e- is acceptable sampling error 95% confidence level, p=0.05

In the study *N*=200 (area occupied by land segment to be sampled in Belgut). Hence: $n = 200/1+200(0.05)^2 = 133.333$. The sample size for this study was therefore be 133km² land segments. Sample size for households was calculated as, *N*= 44750 (no. of households in Belgut). Hence $n = 44790/1+44790(0.05)^2 = 399.4594$. To arrive at the 399 households, three households were sampled either purposively by selecting the most accessible household within the 1 km² land segment or snowballing sampling method in each 1 km² land segment. Purposive sampling was chosen to save time and resources whereas snowballing were chosen so that more households with dodder infestations are reached.

3.6 Instruments

Research instruments used in this study were questionnaire, observation sheet and photographs. The questionnaire was used to record the date, questionnaire number and then divided into three sections which recorded various details. The first section was structured to collect socio-economic characteristics of the household farm in order to understand these households. The second section contained questions on climate variability and dodder occurrence, seeking respondents' opinions on whether climatic variables (temperature and rainfall) affect dodder occurrence. Lastly, questions on weed control including, common weeds and weed management in the selected farm households were recorded as seen in Appendix 1. After which questions on dodder came up, these questions asked about the presence of dodder in those farm, dodder history, dodder management and uses were asked. A 5-point Likert scale was used to select responses in this questionnaire. Observation

sheets presented as a table were also designed to capture information on dodder host species and the individual numbers for each species and also the GPS coordinates giving the locations of this hosts. In addition, Camera was used as one of the instruments to collect information on dodder host and take photos on how dodder attach and infest on some of the host plants in the field. These photos also assisted in identification of the host. Lastly a GPS was used to take the coordinates for dodder hosts.

Before the actual data collection, piloting of data collection instrument was done 2 weeks earlier. During this exercise,50 farm households within the study area excluding farm households selected for this study participated. Piloting was important in identifying any gaps of the data collection instruments before the actual data collection exercise and to measure the test-retest reliability. Internal consistency reliability for related items was measured using Cronbach's alpha by computing the responses for related questions and all the items had a value greater than .7 meaning that the instrument was reliable. Questions in the questionnaire were designed to achieve the objectives of the study and ensure validity of the instruments.

3.7 Data Collection Methods

Both primary and secondary data were required to achieve the objectives of this study. Primary data was obtained from the sampled farm households through administration of questionnaires to the household heads, marking locations of the presence of dodder in the farms and finally identifying and recording the host species on the observation sheet, a variety of clear photographs were taken to illustrate different parts of the plants including the fruits and flowers and showing how dodder attach to these plants were captured. These photographs were used in host identification and in presenting how dodder infects the host. Secondary data of temperature and rainfall were obtained at the Kericho Kenya Meteorological Station, Station No. for the period 1988-2017. The rainfall and temperature data were used to determine climate variability and trend analysis for the period.

The questionnaires were pilot tested on a population with same characteristics as the sample population and not the actual sample population to ensure reliability of the instrument and identify any corrections that would be made before the actual field work began.

Navigation using the map and geographic information system technique was done to locate the land segments sampled for the study using the nothings and eastings of the Belgut area topographic sheet 117/3 (GoK, 1971). Navigation was done on the map prior to the field work so as to locate the sampled land segments. A sample of dodder was also carried along for easy identification in the field by the respondents. Three households within the 1km² land segment were selected by purposive and snowballing sampling methods. In the selected household, introduction was done and permission was sought to administer a questionnaire to the household head. When the questionnaire had been filled, it inform on whether to proceed to the farm and collect more data with the observation sheet. For households that the heads say dodder was present in their farms, permission and assistance was further sought in conducting site visits. Coordinates for the locations where dodder occurrence was observed was recorded using Global Positioning System (GPS Navigation download from google play). The coordinates were further put down on an observation sheet. Observation sheets and cameras were also used to record and capture dodder hosts respectively, twining pattern of dodder around the host was also observed and photographed. This process was conducted in all 396 sampled households.

3.8 Data Analysis

Data was extracted from the questionnaire to an Excel. After the field visits the filled questionnaires were sorted by date. On a new spread sheet all the variables were inserted along the rows and the responses for each of the questionnaire along the columns of the spread sheet. Numbers were used to code qualitative data by assigning a number to each of the responses for easy analysis. Analysis was done using of such tools as least-squares regression to identify linear trends in climate parameters i.e. temperature and rainfall. Anomalies and moving averages for Rainfall and Temperature data obtained were computed and plotted on a graph to show climate variability of the study area, chi-square and One-way ANOVA for associations among variables, Shannon-Wiener Diversity Index to determine dodder hosts diversity.

$$H' = -\sum_{i=1}^{S} Pi\ LnPi.$$

Where *Pi* is the proportion of individuals found in the i^{th} species and *Ln* is the natural logarithm. This equation assumes that all species are represented in a sample and that the sample was obtained randomly. Shannon Weiner Diversity Index increases as both evenness and richness increase and is usually between 1.5 and 3.5 for most communities Since Shannon wiener measures both abundance and evenness. Simpson Diversity index was used to determine the evenness of dodder host.

$$D = \sum n(n-1)/N(N-1)$$

n = the total number of organisms of a particular species
N = the total number of organisms of all species**.** Simpson diversity index is a number between 0 and 1 ,0 means infinite diversity, while 1 means no diversity (Kerkhoff, 2010)

Finally, a crosstabulation was run to establish the effectiveness of dodder management methods used and a clustered graph was generated to visualize the results. A distribution map was developed using the dodder location coordinates and ARGIS Software to show relative occurrence and densities of dodder. Dodder host identification was done using host plants images which captured the plant parts including leaves flowers and fruits. For some plants whose local names were known, the books (Agnew and Shirley, 1994 and Henk *et al.*, 1994) were used to obtain their scientific names and families. Results were discussed in relation to the set objectives and presented in tables, graphs, maps and charts. From the discussion, conclusions and recommendations were made regarding effects of climate variability on dodder invasion, host species, distribution and management in the study area. Issues for further research were also be suggested.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

In this chapter, results obtained from the data collected using the research instruments chosen for this study which included questionnaires, observation sheets and photographs will be presented and discussed. The responses from the questionnaires were coded on an excel sheet and analyzed using both Microsoft Excel and SPSS software. The results are presented in tables and graphs in the chapter. These results are important in achieving the set objectives for the study. Results from other related studies from literature are also cited and compared with the results obtained. Results for each objective are presented and discussed in separate sections under this chapter, starting with demographic characteristics in section of 4.1 below.

4.1: Demographic Characteristics

The socio-economic information collected for this study were, gender and age of the household head, educational level of the respondents, size of household, size of farm household, and crops and trees grown in the selected farm households.

These information is important in understanding the target population and generally being a descriptive design, we are able to describe the population and relate some of these information to the objectives of the study, like dodder management and occurrences. The information was obtained by use of a questionnaire then coded in an excel sheet and further transferred to SPSS software for analysis. Some of the information was however analyzed on Microsoft Excel. Frequencies, percentages, means and mode were computed. Results obtained were as presented in table 4.1 below

Table 4. 1: Socio Economic Characteristics of the Respondents

Gender		
	Frequency	Percent
N	399	100
male	277	69.3
female	122	30.5

	Mean	St. dev
Household Age	42.22	12.58
Size of household	6.18	2.36
Farm Size	1.92	1.90

Education Level		
	Frequency	Percent
None	21	5.3
Primary	188	47.0
Secondary	157	39.3
University	16	4.0
Other	17	4.3

4.1.1 Gender of Respondents

The total number of respondents for this study was 399 household heads as obtained from the Yamanes formulae explained in chapter 3 above. The proportions of the respondents by gender was 69.4% males and 30.6% females. We can therefore conclude that most households in the study area are headed by males and only 30.6% are headed by females as seen in table 4.1. Being a typical Kenyan society where most households are headed by males ,this agrees with (Institute of Economic Affairs, 2008) Publication which reported that 71.1% of the households in Kenya are headed by males and the remaining 28.9 by females. In Rift valley where the study area is located, the same report indicates that 73.7% of the households were headed by male and 26.3% by females. Another study reported 74% male headed household in Kericho County, and 20% female headed household (MOA, 2014).

4.1.2 Age of Respondents

Age of the household head can be related to significant decisions in a family, especially on farm use and management in Belgut area because the main activity here is farming. In question 2 age of the household heads were recorded and analyzed by use of SPSS giving the following results (N=399, Mean = 42.22, St.dev = 12.58) Majority of the respondent were 35 years old. The mean age of the respondents was 42 years as seen in table 4.1 above. From these results we realize that most of the households are headed by young people most of whom are still youths. The results were significant (t = 67.06 df = 398 p = 0.000)

4.1.3 Education Level of Respondents

Knowledge obtained from going to school also adds to how one makes decisions on use of the land. In question 3 of the questionnaire (Appendix 1) educational level for the household heads were recorded ranging from those who had never attended school to those who had gone to university level. The highest number of respondents were primary school leavers who dropped or just cleared their primary school education and never proceeded, they formed 47.1% of the total selected, followed by those who had completed their secondary school at 39.3 %. Another 5.3% of the respondents had not been to school while 4% had reached university level the remaining 4.3% had a diploma certificate as seen in table 4.1 above. The results agrees with (GoK, 2016), who reported that the primary school net enrolment rate was 99 percent and secondary school net enrolment rate was 59 percent in Kericho county. The differences in this enrollment has been explained and several factors linked to this trend in the report. There was no significant relationship between gender and education level. (χ^2 = 8.42, df = 4, N = 399, p=0.07). The household heads education level was not determined by their gender. Management of dodder being a parasitic weed requires knowledge on its biology and ecology, basic scientific knowledge is therefore important for decision making, with most household heads being primary school leavers they are highly likely not having this knowledge and this would affect their ability to manage and control dodder in their farms.

4.1.4 Size of Household

The size of household could also be a determinant to what people tend to grow on their farms the number of individuals in each of the sampled households were recorded and analyzed. The results obtained were (N= 399 mean =6.2, St. dev 2.36). Highest percentage

of the respondents had 5 members in the household, Majority of the respondents had a household size of between 5 to 7 members. This means two parents or a parent and Children. The average number of individuals in each household was 6 (see table 4.1),say mother ,father and 4 children, thus the findings agrees with fertility rate findings by (GoK, 2016) in Kericho County ,4 children per woman .The results also agree with (MOA, 2014) report, which reported an average of 5 members per household in Kericho County where the study area is located. The results were tested with one-sample T-test and were found to be significant ($t = 52.31$, $df = 398$ $p = 0.00$).

4.1.5 Size of Household Farm

Size of farm households also affect decisions on farm use and management the respondents were asked how much land they own in acres and the responses were analyzed to give the following results (N= 399, mean 1.92 St. dev 1.90) A majority of the respondents had 1 and 2 acres whereas 50% of the total respondents have from 1.3 acreage of land to 0.1 acres. The mean size of household farm in the study area was 1.9 see table 4.1 above. These is generally regarded as small scale farming according to (Coff *et al*., 2015) who regards small scale farming to people cultivating less than an acre to 10 acres of land. Being small scale farmers, they are more prone to food insecurity. With infection of dodder in these farms they are even more vulnerable.

4.1.6 Crops and Trees on the Selected Farm Household

A general overview on the commonly planted crops and trees in Belgut were recorded using a questionnaire. These information is important in understanding dodder hosts in farm households with dodder infestation. The responses for the trees and crops found in the household farms were coded on an excel sheet and presented in figure 4.1 and figure 4.2 below.

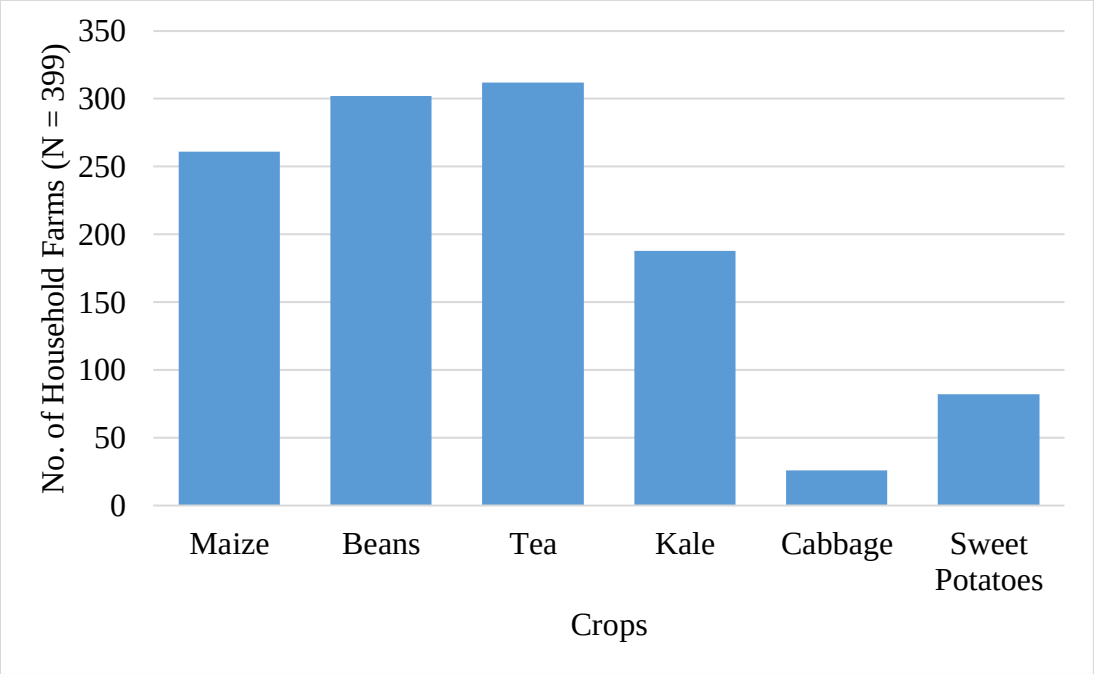

Figure 4. 1: Crops Grown in Belgut Area.

Out of the 400 respondents, those who grew maize were 261 while 138 did not have maize on their farms. In addition, 75% of the respondents grew beans and 78.2% grew tea. Further,188 of the respondents grew kale this was equivalent to 47.1% of the total respondents. Only 6.5% grew Cabbage on their farms. Lastly,20.6 % planted sweet potatoes on their farms. Hence the most common crop among the respondents was tea, followed by beans, maize and kale. cabbage is not very common since only 6.5% of the respondents grew the vegetable in the study area as presented in figure 4.1 above. A non-parametric test on related samples was run on SPSS and it revealed a significant relationship between distribution of all the crops planted by the respondents in the study area $p = .001$ is $p \leq 0.05$.

In the study also, names of commonly grown tree species in Belgut area were recorded in the questionnaire. These names are useful in understanding the target population and how dodder chose their hosts. The names of trees were coded on an excel sheet and a graph showing how these trees are distributed in the study area was generated as seen in figure 4.2 below

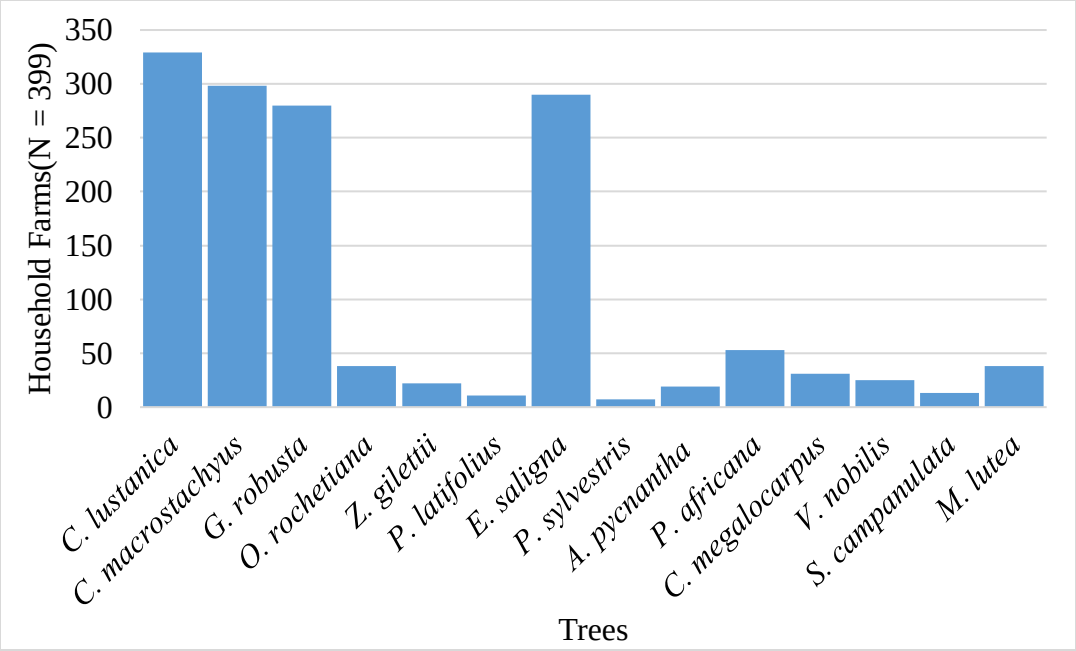

Figure 4. 2: Tree Species Grown in Belgut Area

Most common tree species as presented in figure 4.2 was *C. lustanica, C. macrostachyus G. robusta* and *E. saligna*. *C. macrostachyus* is the only indigenous tree among this common tree species. We can therefore say the population of the area prefer exotic tree to indigenous ones, the other tree species recorded occurred in relatively few households as show on figure 4.2 above.

4.2 Climate Variability

The third objective of the study was examining how distribution of dodder is associated with climate variability. Hence, data on rainfall and temperature variability were collected to understand how climate has varied before associating it with dodder occurrence. Firstly, respondent's opinions on rainfall amounts, durations and onset were recorded. For temperature, temperature changes were recorded by asking whether it has become warmer or cooler with time, over the past ten years because this is the period most of them could recall how these variables have been changing. The information was collected using a questionnaire and these opinions were measured using a five-point Likert scale. The responses were coded in an excel sheet and total scores for the positive and negative questions were obtained after which frequencies and percentages were generated.

4.2.1 Respondents Perception on Climate Variability

Three variables including rainfall amounts, rainfall onset and rainfall durations were tested for rainfall variability, a five-point Likert scale was used and total scores computed. The adequate reliability for inter-item scale Cronbach's Alpha was calculated for each of the items and is expected not be less than 0.7 for a reliable scale. As expected all the inter-item reliability of Likert scale had a value greater than 0.7 with. That measuring rainfall onset was found to be 0.92, that for rainfall amounts was 0.770, 0.924 for rainfall duration. All these values were above the accepted 0.7 Cronbach's Alpha meaning that our scale is reliable and measures opinions for the same items.

For rainfall amounts 222 respondents scored 8 points and 13 scored 10 points. Twenty-four % of the respondents got a score less than 5 and the other 76% scored more than 5 points. From these results it can be conclude that residents of Belgut area feel that rainfall has been increasing in amounts over the years in Belgut area. For rainfall onset majority of the respondents agreed that rainfall has come early in the recent years with a majority of the respondents 184 scoring 8 points out of 10. On rainfall duration majority of the responds scored a low score of 4 points. In conclusion we can say that rainfall durations have been shorter in the recent years at Belgut area according to the respondent's experiences.

Respondents views and experiences on temperature variations were tested using 5-point Likert scale with internal reliability of 0.941 and the results revealed that 84% of the respondents said that temperature has been increasing with a score of 6 points. The results agree with the historical data analysis which also show an increase of temperature over the years.

4.2.2 Rainfall Variability and Trends Between 1987- 2017 in Belgut area based on Historical Data

Rainfall is one of the key variable in determining climate variability. In this study analysis of rainfall data of Kericho Weather station which is the nearest station to Belgut area shows that rainfall has been slowly declining in the area, Using the linear regression Model as seen in figure 5 below the rate of change is defined by the slope of the regression line which -1.35 per year for the total annual rainfall

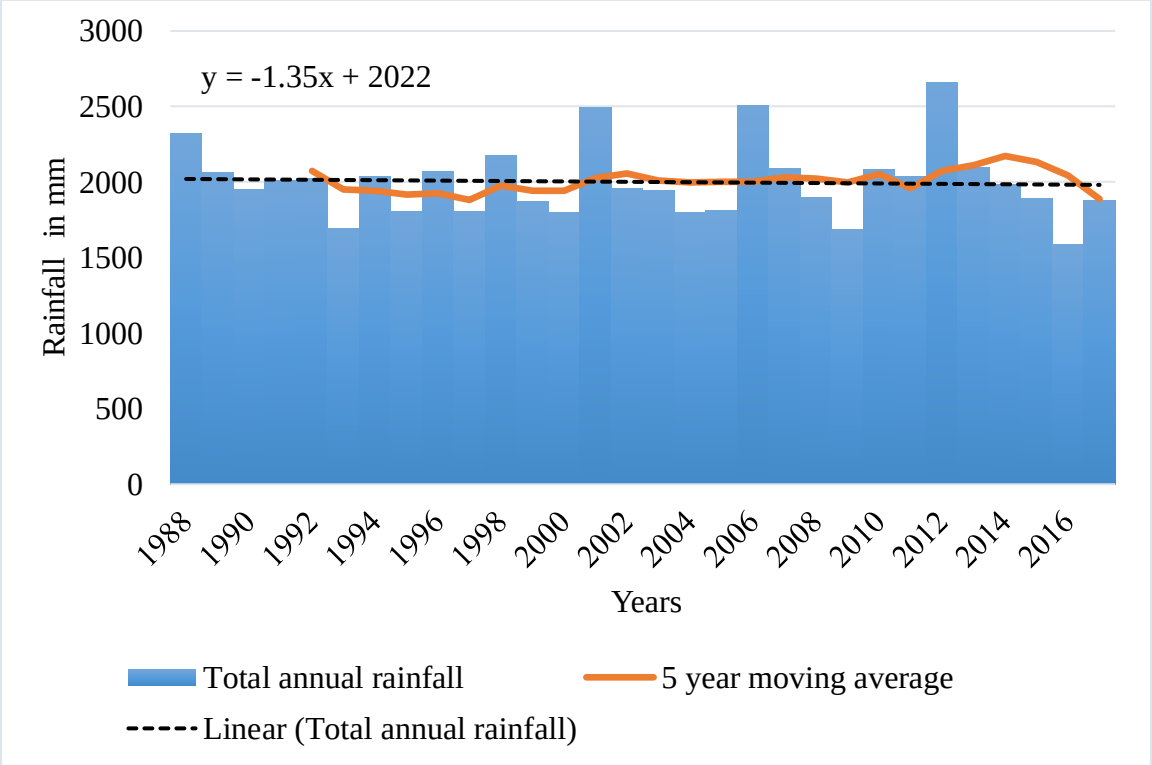

Figure 4. 3: Total Annual Rainfall Linear trend and 5 year Moving Average for the Period 1988 to 2017

The year 2016 was the driest year with minimum total annual rainfall of 1586.9 mm recorded. On the other hand, 2012 was the wettest year which recorded the maximum total annual rainfall of 2657.1 mm. as seen in figure 5 above

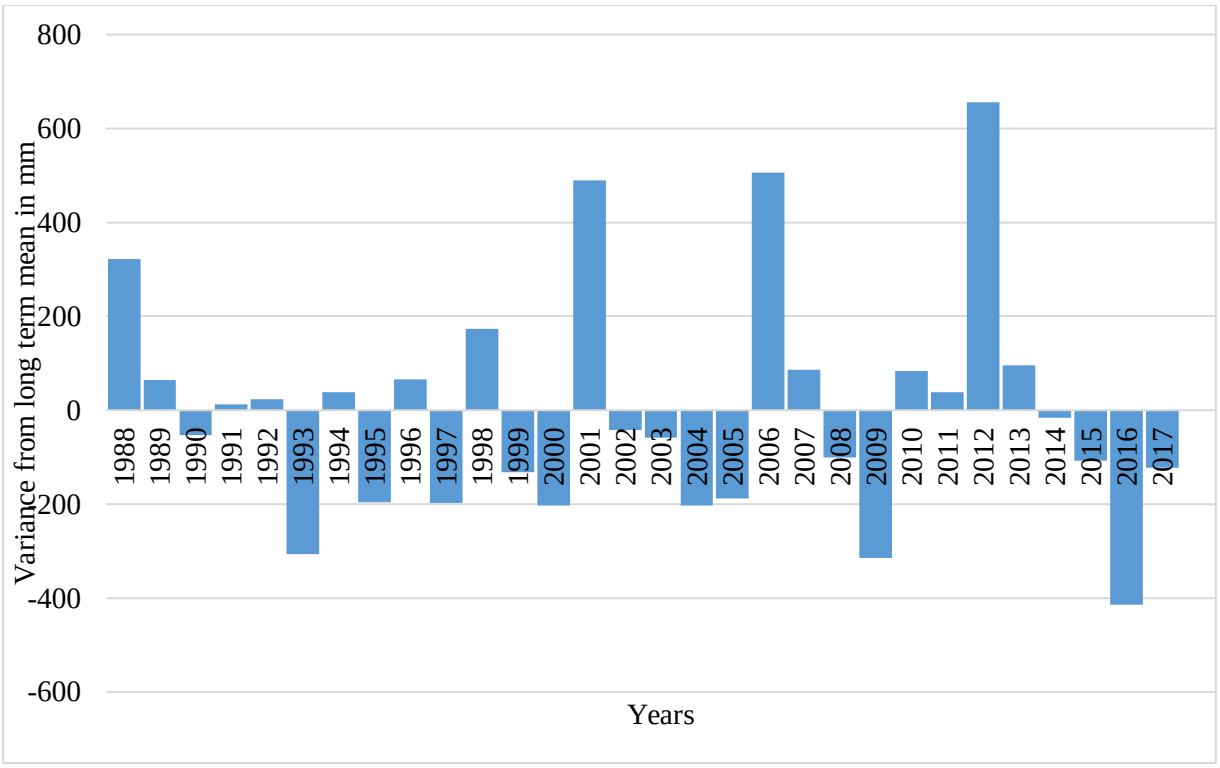

Figure 4. 4: Variance from Long Term Mean of Rainfall for the period 1988 to 2017

The mean annual rainfall for Kericho between 1988 to 2017 was 2001.057 mm with 243.4 mm standard deviation. Rainfall anomalies ranges from +654 to -416, 16 years recorded annual total rainfall below average and the remaining 14 recorded annual total rainfall above the average. Total annual rainfall recorded during the year 2012, 2006, 2001, 1988, 1998, 2013, 2007, 2010, 1996, 1989, 1994,1992 ,1991 and 2011 were above the average. while the annual total rainfall recorded in the years 2014, 2002, 1990, 2003, 2008, 2015, 2017, 1999, 2005, 1995, 1997, 2000, 2004, 1993, 2009 and 2016 were below the average. As shown on figure 6 above

4.2.3 Temperature Variability and Trends in Belgut area Based on Historical data.

For temperature variability analysis both maximum and minimum daily temperatures were obtained from the Meteorological department Kericho Station. The mean temperatures were computed and used to plot a graph of mean daily temperatures for the period 1988 to 2017 as seen in figure 4.7 below. Mean monthly temperatures for the years 1988 to 2017 were also computed and plotted in a graph (figure 4.5).

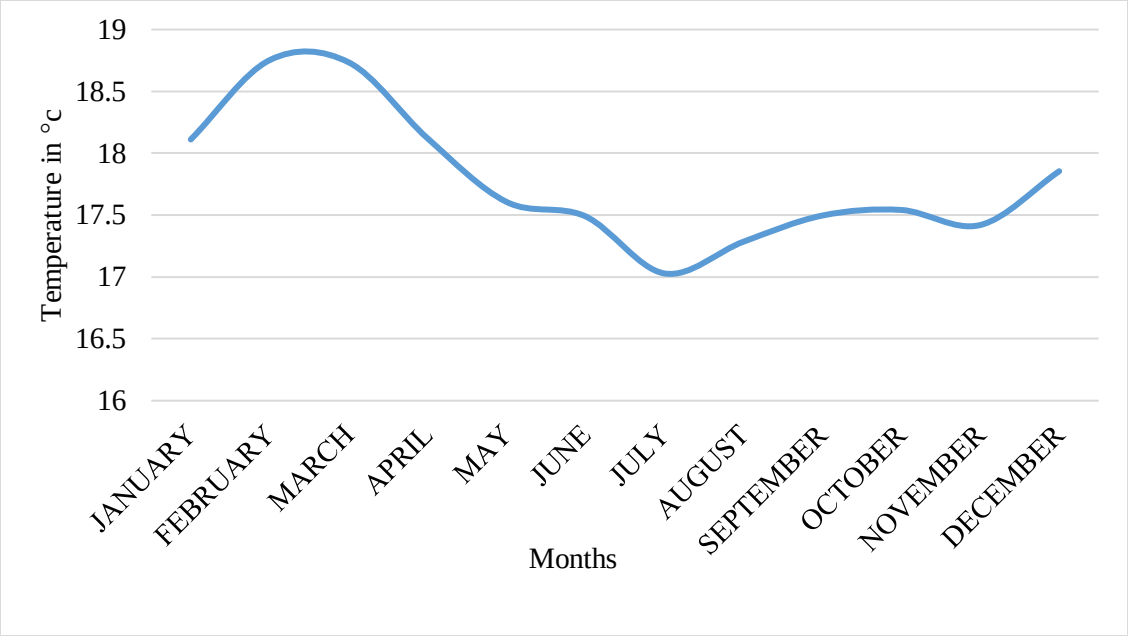

Figure 4. 5: Mean Monthly Temperatures for The Years 1988 to 2017

The month of February recorded the highest mean monthly temperature of 18.8 for the period according to the results. On the other hand, the lowest temperature of 17.0 was recorded during the month of July then temperatures began to rise again in the remaining months of the years.

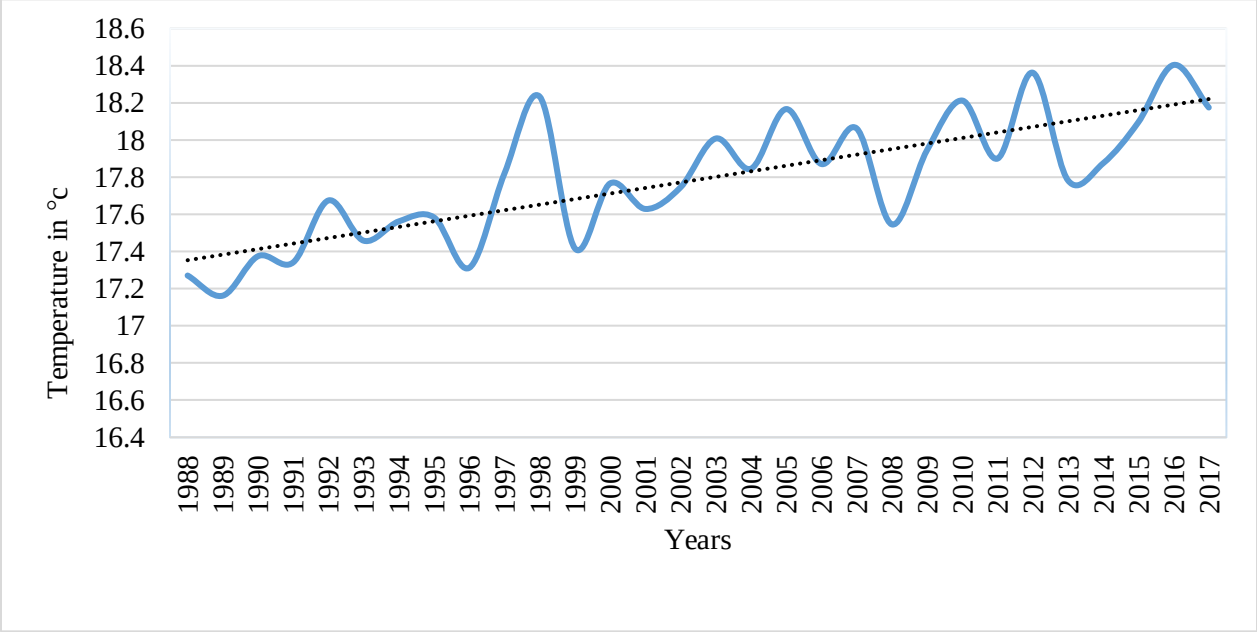

Figure 4. 6: Mean yearly Temperatures, and Linear trend for the period 1988 to 2017.

From the trend line for the mean yearly temperatures have generally been increasing with the lowest mean of 17.2 having been recorded in 1989 and the highest of 18.4 recorded in 2016. In addition, temperature for the years 1988 to 2017 were analyzed to detect its trend and variability in the study area during this period. Results show that temperature has generally been increasing in the study area.

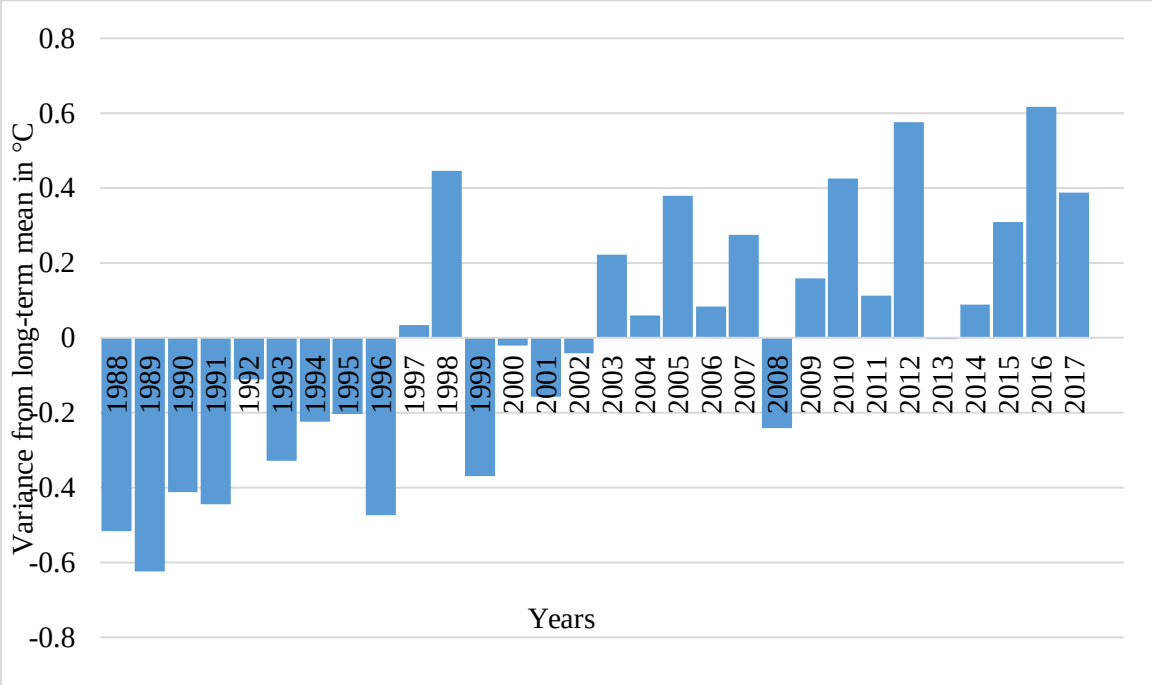

Figure 4. 7: Variance of Temperature from Long Term Mean of 17.8 For the period 1988 to 2017

Mean temperatures for the study area range from a minimum of 17.2 °C in the year 1989 to a maximum of 18.4 °C in 2016 with an annual average of 17.8 °C. Graph of temperature deviation from long term mean show inter-annual variability in temperature and the trend has been increasing above the long term mean since 2002 all the way to 2017 except in 2008 when the mean temperature was below the long term mean .This explains the warming trend which is being experienced.

4.3 Dodder Distribution in Belgut Area

For this study, it is important to establish how dodder has been distributed in the study area besides being one of the objective in the study, it will also assist in achieving the other objectives. In this regard, questionnaire was used to find out whether dodder was present in the selected farms. For those who did not know dodder. A sample was shown to them to

assist in identification. If they said dodder was present in the farm, GPS coordinates of dodder locations in the field were taken using GPS Coordinates software from Google play Store using a smart phone. The northings and eastings were recorded on the observation sheet. These coordinates were later entered in an excel sheet and uploaded to ArcGIS Software to show the points of distribution on a map as presented in figure 4.9 below

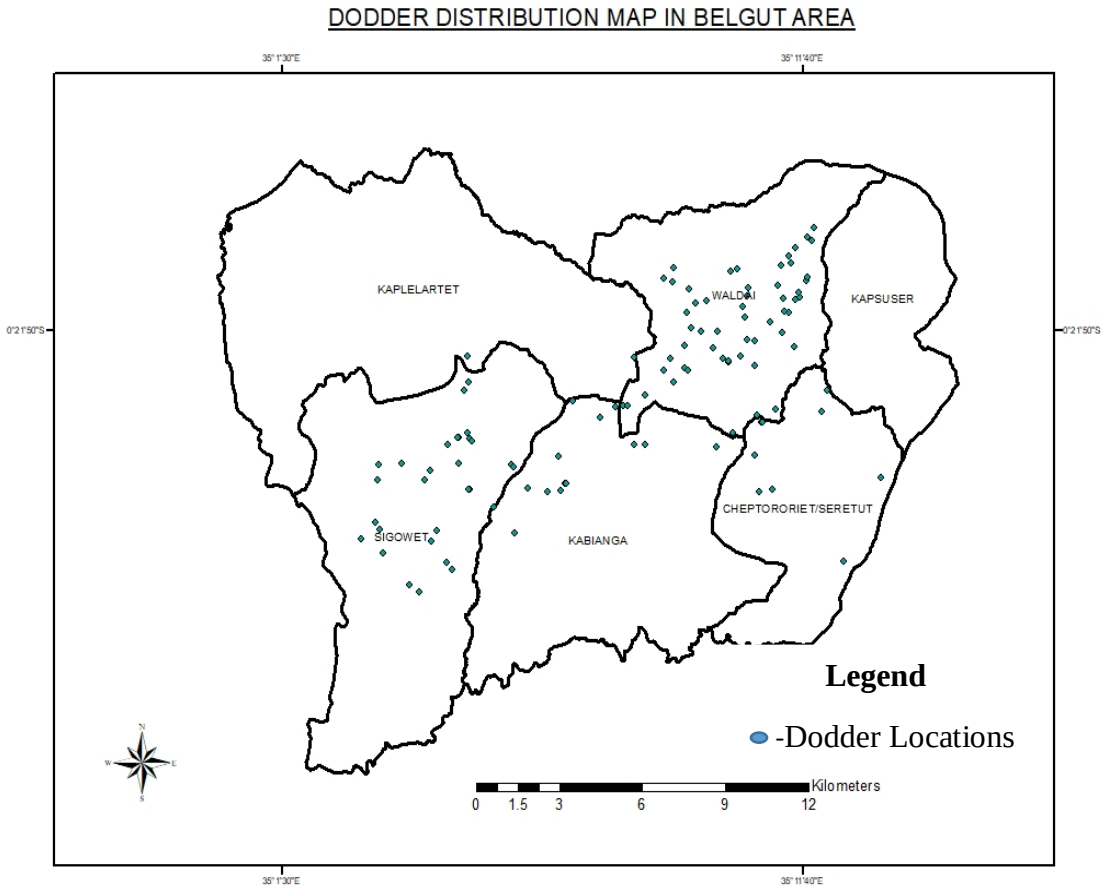

Figure 4. 8: Dodder Distribution in Belgut Area.

Dodder was found mostly on roadside vegetation, in poorly managed farms dodder infected crops in the immediate farms and grow into the farms (see plate 1) uncultivated fields and on tea plantations along the road side. It was observed that dodder is widely distributed in Waldai and Sigowet and scattered in Kabianga and Cheptororiet, wards as plotted in figure 4.8 above.

Out of the 399 households that were sampled for the study, 124 households had dodder on their farms while the remaining 275 had no dodder present on the farm. These was equivalent to 31% distribution in the sampled households. (See table:4.2).

Plate 4. 1: Dodder Infestation on Road Side Vegetation

(Taken 22nd August 2017 at Kiptere location Koiyat village)

Table 4. 2: Frequency of Dodder among Households of Belgut Area

	Frequency	Percent
N	399	100.0
Household farms with dodder on farm	124	31.1
Households farms with no dodder on farm	275	68.9

4.4 Dodder Distribution and Climate Variability

Effects of climate variability on dodder occurrence was tested using a five-point Likert scale, Cronbach's scale reliability was 0.94 in establishing relationship between dodder and rainfall amounts, variation and 0.95 in establishing the relationship between dodder and temperature variations.

Regarding, whether changing rainfall temperature affect dodder occurrences 65% of the respondents did not know. While 19% of the respondents disagree that changing rainfall affect dodder occurrence and 15% agreed that rainfall variability affected dodder. From the results we can conclude that the respondents did not feel that rainfall variability affected dodder occurrences. As seen in figure 4.9 of this report.

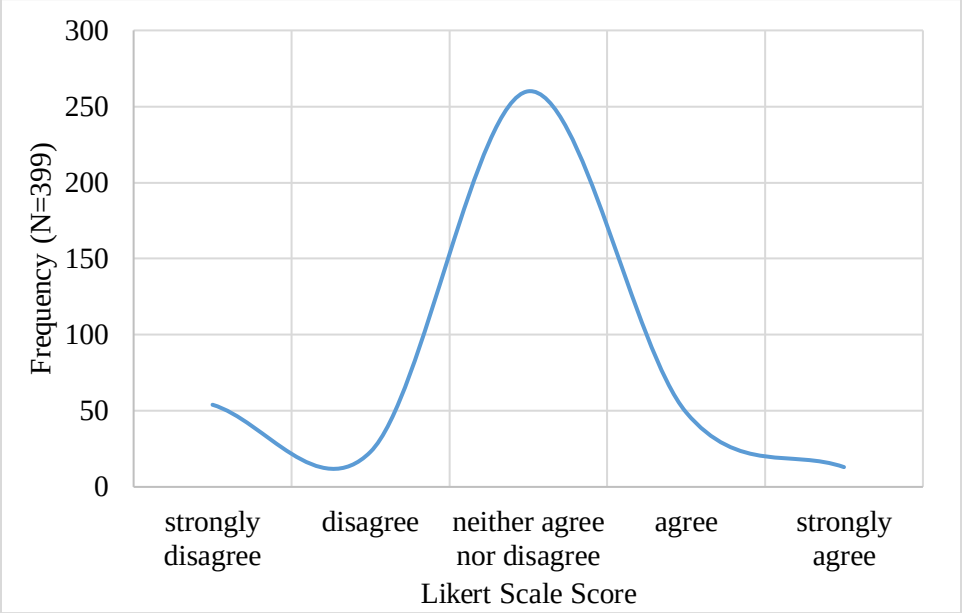

Figure 4. 9: Respondents Opinions on Whether Changing Rainfall Patterns affects Dodder Occurrences

On the other hand,65% of the respondents could not tell whether changing temperature affect dodder occurences,18% disagreed and 15% agreed that temperature variability affect dodder occurrence. Seen in figure 4.10 below

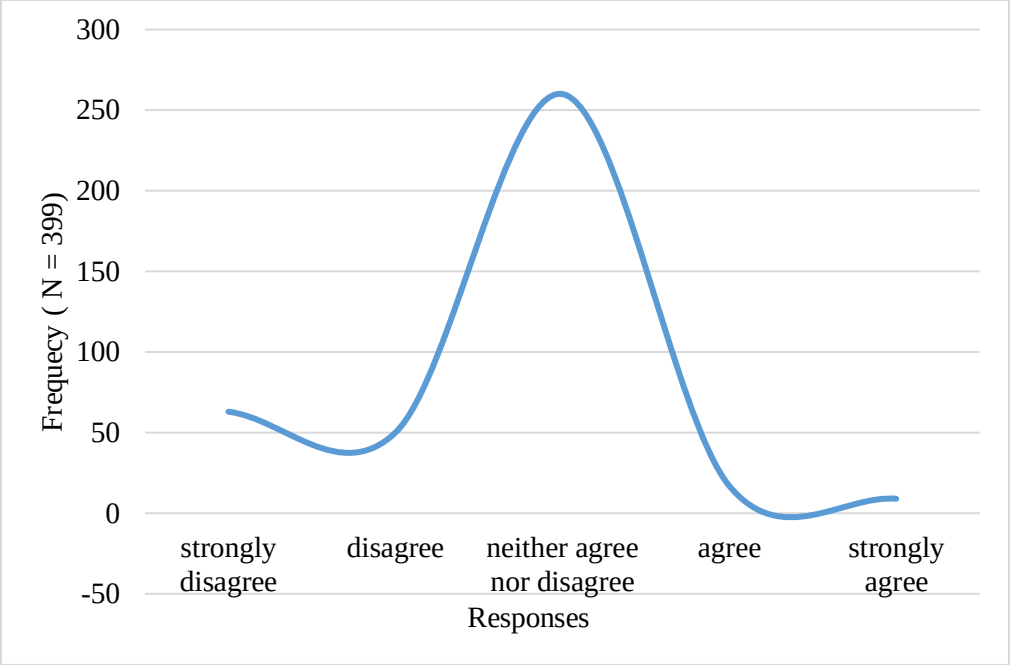

Figure 4. 10: Respondents Opinions on Whether Changing Temperature affect Dodder Occurrence in Belgut Area.

4.5 Dodder Hosts

As mentioned earlier, dodder is said to generally have a wide range of host. the study sought to find out the dodder host in Belgut area by use of photographs and recording of their names on the observation sheet. The information is important in establishing most preferred dodder host in the study area and the possible socio-economic losses associated in order to be able to control its spread. The plants were identified at the National Museums Herbarium and a table of the host plants in Belgut was generated in Appendix X.From the table 43 species of 26 families were found to be parasitized by dodder in the study area, Dodder has a wide range of host, however it shows preference to certain hosts. Most Preferred host for dodder according to this study is Tea (*Camellia Sinensis*) with 2391 individuals parasitized and is the highest number recorded for all individual plant species parasitized in the study area (plate 4.2 and appendix VII)

Plate 4. 2: Tea Plant Parasitized by Dodder.
Taken 25th August 2017 at Seretut

The other preferred host included *Barleria micrantha* and *Caesalpinia decapetala*, Species of the family Euphobiaceae were the most preferred with a total of 5 species parasitized, followed by families Rosaceae and Asteraceae both with 3 species each as seen in Appendix VII. The least preferred species according to this study's findings were *Eriobotrya japonica* (Thunb), *Olinia rochetiana* A.Juss, *Ocimum suave* Wild. and *Psidium guajava* L. All the host plant recorded have been listed in Appendix VII indicating the species name, families, common and Kalenjin names for some of them and the individual numbers parasitized for each species in the study area

Glomerate dodder is reported to grow mostly on members of the Asteraceae Family, especially sunflowers (Helianthus) and other tall herbaceous species (Cristine and Lauren 2013 .) this results agrees with this study since it has identified *Eyryops chrysanthemoides* and *Vernonia adoensis* Walp species which are members of this family to be among the dodder hosts. Sweet basil (*Ocimum basilicum* L.) of the family Lamiaceae has also been found to be a common host of *Cuscuta Campestris* Yunck.(Mousavi *et al.*, 2018). This also agrees with this study which has found some members of this family including plectranthus *punctatus* A.J. Paton and *Ocimum suave* Wild. to be among the dodder hosts.

A study to investigate resource choice in *Cuscuta europaea* used Hawthorn (*Crataegus monogyna*) one of dodder host cuttings subjected to different nutrient supplement levels. Results showed the trends in host rejection by dodder, with probability of acceptance positively correlated with resource value of the host. The study reported that dodder would likely attach to plants or plant parts with nutrient supplements and the parasite possesses responses that may be used to effect rejection and acceptance of resources (Kelly, 1992). These results can explain why tea *Camellia Sinensis* is the most preferred dodder host in the study. The results show that 2391 individual tea plants were found to be parasitized by dodder in the study (Appendix IX). Tea is a major cash crop grown by farmers in Belgut area and because of its economic benefits the residents provide nutrient supplements to the crop, through ways like applying of fertilizers and weeding to get rid of weeds which competes for the soil nutrients with the crop

Tea, Nandi Flame, Loquats, K-apples, Mauritius thorn and Acacia are some of dodder hosts reported by (Otieno, 2016) and also found out in the study. From these results, dodder has infested on several socio- economically important crops including Tea as seen in plate 4.2 and appendix VII, Coffee has also been parasitized in plate 4.3, Loquats in plate 4.6, and maize is also one of the host plant seen in plate 4.5. Dodder can kill and injure host (see plate 4.4) in this study the host species found to have been killed by dodder were mostly Mauritius as it can be seen in plate 4.3

To establish the diversity of dodder hosts. Dodder hosts and individuals parasitize for each of the host plants were input into an excel sheet, then Shannon wiener and Simpson's diversity index were calculated (Appendix IX). The Shannon wiener diversity index of

dodder host was 1.89 while Simpson diversity was 0.2 which means that dodder host have high diversity in richness and low evenness. Shannon wiener increases with both species richness and evenness and is mostly between 1.5 and 3.5 (Kerkhoff, 2010). Shannon wiener index was on average implying that dodder host species richness was at average. Simpson diversity index which measures evenness was 0.2 implying that the species evenness was high for the dodder hosts. Dodder host species therefore had an average richness and high evenness in this study hence can potentially parasitize more plant species and cause havoc to the community (Appendix IX)

Plate 4. 3: Mauritius thorn Infested and Killed by Dodder
Taken on August 29th at Kaborok waldai ward

Dodder can attack and kill some host species (Plate 4.3) Mauritius thorn is one such host which dodder can kill. In the study area it was noted that most fences of Mauritius thorns infested by dodder had dried up.

Plate 4. 4: Coffee Plant Parasitized by Dodder
Taken on September 2nd 2017 at Chemoroch village of Waldai ward

Dodder also parasitize crops of economic important. Coffee was among such crops parasitized (Plate 4.4). When dodder infest on the crop production level drops and nutritional content of the seeds is compromised since dodder suck nutrients from coffee.

Plate 4. 5: *Vernonia adoensis* Walp which has been infected and injured by dodder

Taken at Cheribo Waldai ward 0n 2nd September 2017

Dodder attack the plants tissues to obtain food nutrients from these plants in the process injuring these plant tissues. It may eventually kill it in cases of severe infestation. Plate 4.5 demonstrates how dodder penetrates the plant by use of haustoria. When the host plant dies dodder also begins to dry since there is no longer a source of food for its survival.

Plate 4. 6: Dodder on Maize Plant
Taken at Cheronget Waldai ward on 27th August 2017

Infection on maize plant as seen in plate 4.6 poses food insecurity by reducing yields and compromising the nutritional content of the harvested grain. This also applies to infestation of dodder on Loquat plant in plate 4.7 the plant will not be able to produce fruits once infected. In case of severe infection, the fruit trees may dry up and die completely

Plate 4. 7: Dodder on Loquat Fruit Plant
Taken at Cheptenye Waldai Ward on 27th August 2017

4.6 Dodder Management Methods and Effectiveness

Dodder is a dangerous weed and poses a lot of threat to socio-economic activities like farming and livestock keeping, for this reason it's important to control its spread and find ways to manage it where it has already infested on crops. In this study, most common weed types of Belgut and the management methods that have been used to manage these weeds were examined. This was done by use of questionnaire and the responses coded and analyzed using Microsoft Excel. After which dodder itself was looked at. Firstly, we looked at the dodder history and mode of spread as per the respondent's opinions then the management methods that have been used at household's farms where dodder has infested on the farms. Lastly, the respondents were asked to rate effectiveness of the methods used. Responses for these were also coded and analyzed using Microsoft Excel and the results were presented in tables graphs and pie chart under each of the sub-heading as discussed and presented below.

4.6.1 General Weed Management

Before looking at dodder management, the study investigated the weed types in Belgut area household farms and how these weeds have been managed by the residents. Data collected was used to generate the graph in figure 4.11, below

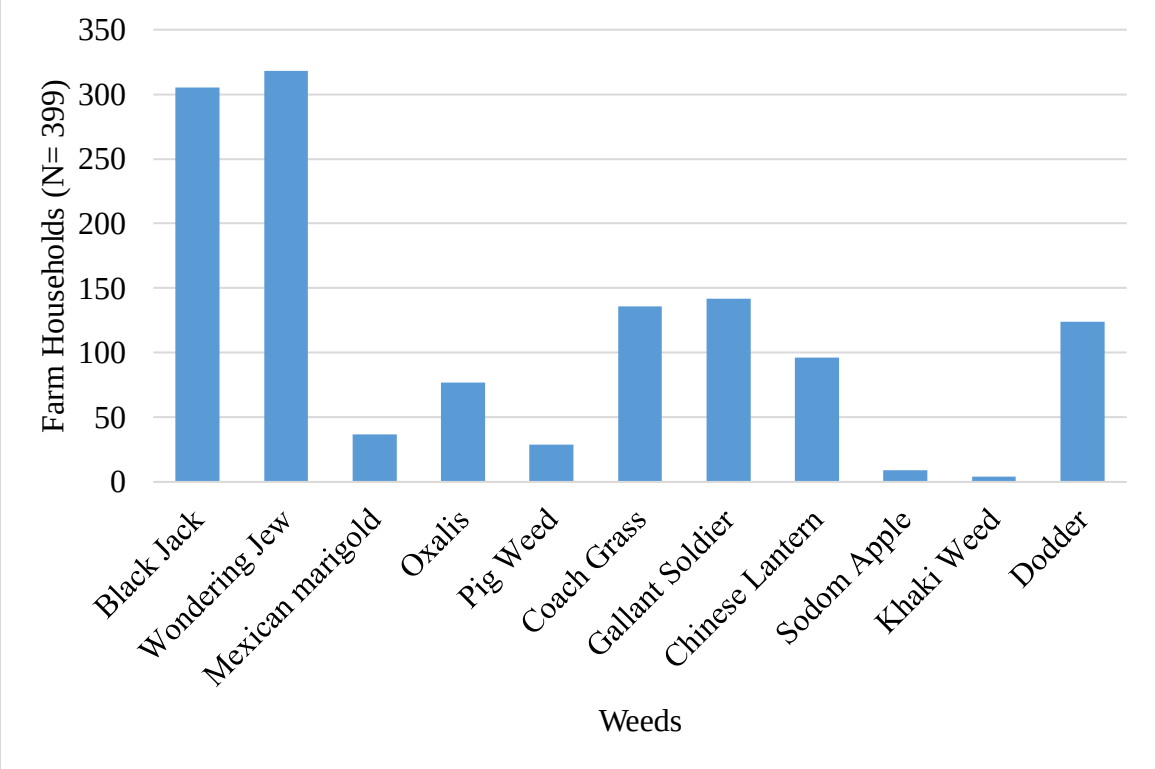

Figure 4. 11: Common Weeds of Belgut Farm Households

From the Bar graph. The study found out 10 weed types which occur in the study area. The most common weeds in Belgut area was Black Jack *Bidens pilosa* and Wandering Jew *Commelina communis*, found in over 300 household farms out of the 399 sampled. Sodom Apple *Solanum incunam* and Khaki Weed *Alternanthera caracasana* had the least occurrences. Other weeds found on the farm households are Mexican Marigold *Tagetes minuta*, Oxalis *Oxalis dehradunensis*, Pigweed *Amaranthus spinosus*, Coach Grass *Elymus repens*, Gallant Soldier *Galinsoga perviflora* and Chinese Lantern *Nicandra physalodes* (L.) Gaertn

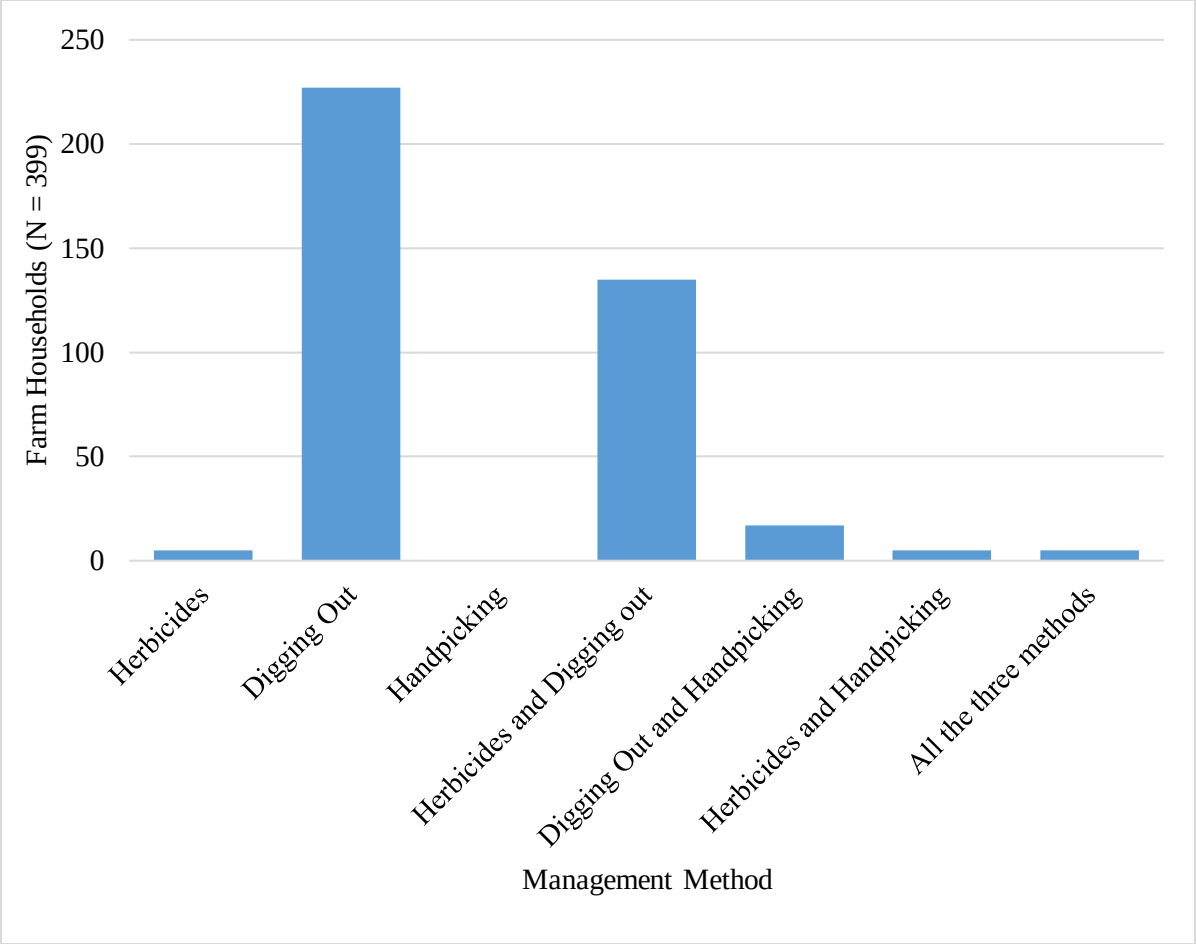

Figure 4. 12: Weed Management Methods in Belgut Farm Households

From the graph its evident that commonly used method in weed management is digging out of the weeds among residents of Belgut Use of both herbicides and digging out of the weeds is also common with the residents of the study area. Very few households used Herbicides only for weed management, use of herbicides and handpicking is also not very common with the residents. These results agree with that of (Ngugi, 2015) in his study of weed problems and control in Kenya where he found out that most annual weeds were easily controlled by digging out and use of herbicides. However, he found out that weeds like Oxalis, Couch grass and star grass were difficult to control. His report further agrees with this research finding on the fact that small-scale farms use hand cultivation using Jembe and Panga in weed management. From the results in table 4.1, it can be seen that the average size of the farm households is 1.9 acres. This is generally regarded as small-

scale farming and thus digging out of the weeds is the most common method of weed management.

4.6.2 Dodder History in Belgut Area

Dodder is an invasive parasitic weed that has been introduced to the study area. Under section 3-part b, of number 13 in Appendix 1 the number of years dodder has been present on the selected farm households were recorded and analyzed. Dodder has been present in Belgut for an average of approximately 5 years (N-124 mean = 4.74 STD = 4.34). This result is significant from the t-test results (t= 12.142, df =123, p=0.00). The results also agree with that of Otieno (2016) who reported that dodder is new in Kenya ,having been reported first in the year 2007 and in 2013 it was spotted in Nandi County .

4.6.3 Dodder Mode of Spread

Opinions on the mode with which dodder spread was collected by use of questionnaire and the responses coded and analyzed by use of Excel the information is important in establishing whether the household heads are aware about the mode of spread of dodder before trying to manage and control its spread. Results on these opinions are presented in the Table 4.5 and Figure4.13 below

Table 4. 3: Perceptions on how Dodder Spread

	Frequency	Percent
N	124	100
Seed Dispersal	20	16.1
Vegetative Propagation	90	72.6
I don't Know	2	1.6
Seed dispersal and Vegetative Propagation	12	9.7

Dodder spread very fast, from the results of the study in table 4.3 72.6% of the sampled households with dodder on their farms said that dodder spread by vegetative propagation, Dispersal is said to be by humans especially school going children who pick it on their way to school and drop them on various destinations. Also, during firewood collection dodder may be collected with the firewood and carried along with them, birds are also said to aid the spread of this plant .16% of the respondents however said that the weed is spread by

seeds this can be confirmed ,because dodder has flower as it can be seen in plate 4.8 below, another 9% of the respondents believe that dodder can reproduce by both seeds and vegetative propagation and the agents of dispersal are humans, birds, livestock and mechanical machines like tractors and Jembes when shared in Land preparation. Livestock can aid in dodder spread when they feed on dodder seeds as part of their forage, the seeds don't get digested and they pass in the dung to other places thereby introducing dodder to the place. 2% of the respondents did not know how dodder spread.

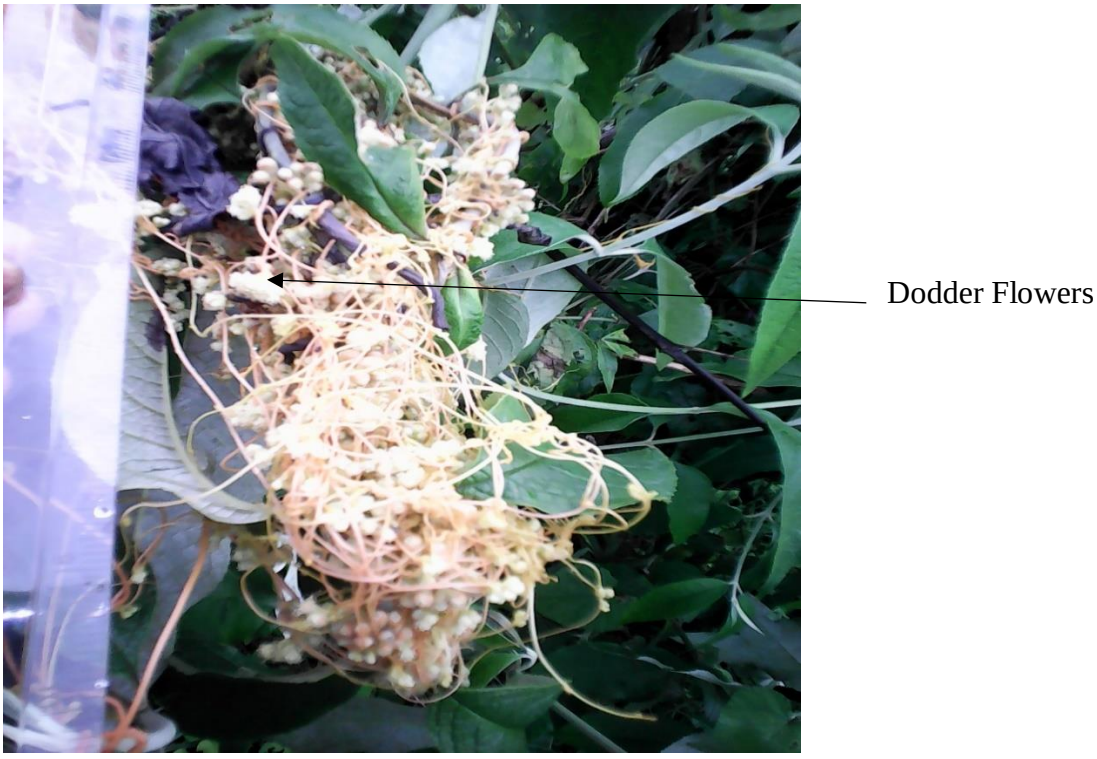

Plate 4. 8: Dodder Flowers

4.6.4 Dodder Management Methods and its Effectiveness

Dodder management and control is one of the hardest thing to do according to the respondents. With the use of a questionnaire, information on the management methods that have been employed and the rate of effectiveness for each of the methods measured using a 5-point scale, Rating effectiveness from very high to very low at the household farms with dodder infestation. The responses were collated, analyzed and results presented in the figure 4.13 and 4.14 below

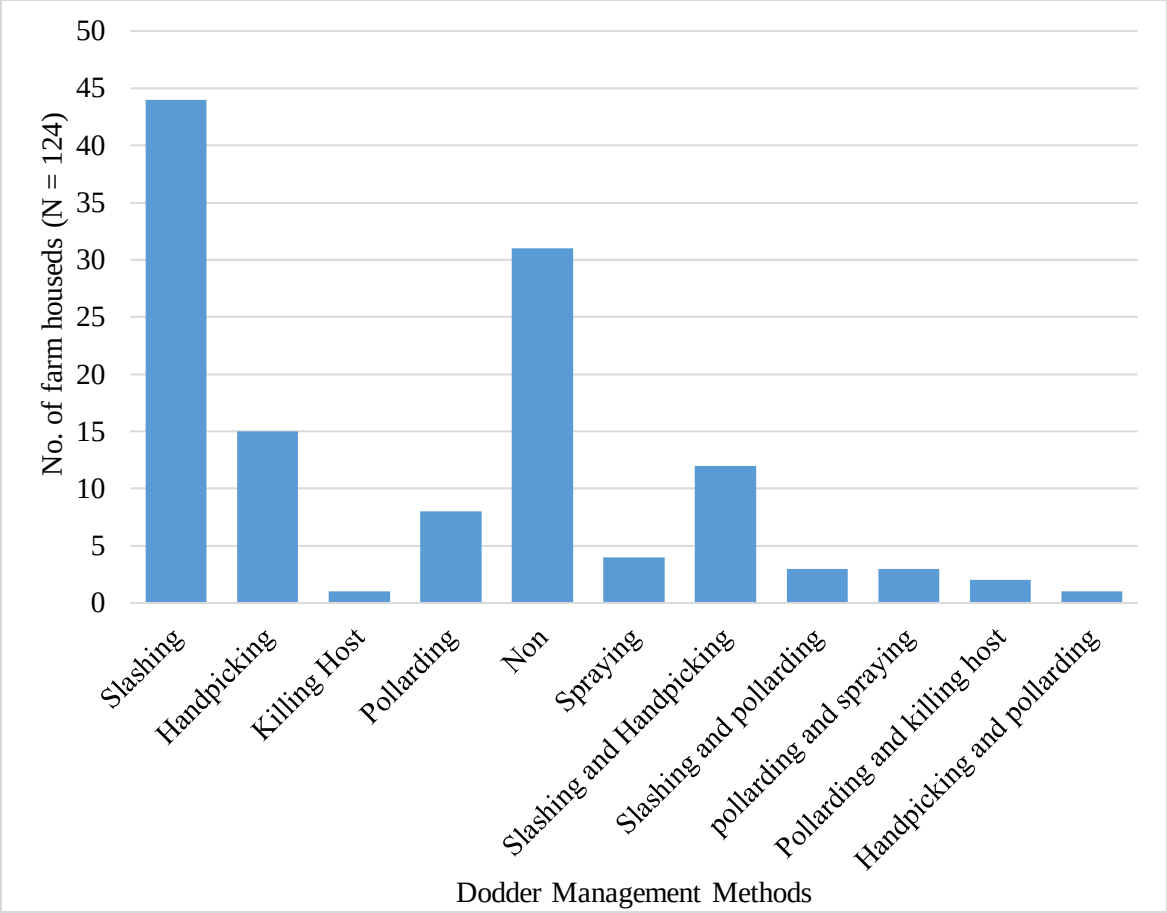

Figure 4. 13: Dodder Management Methods Employed in Belgut Area

From the results in Figure 4.13 above, the most commonly used method in dodder management is slashing, the method involves removal of dodder tendrils from the host using a slasher. With this method, some parts of dodder that attached to the host remain inside the host and may regrow. Other commonly used methods from the results were handpicking, which involves pulling out of dodder from the host and throwing them on bare ground with no plants, majorly on the roads where they can't find potential host to attach to and hence die on these bare grounds. The other method used is pollarding. Here, parts infested by dodder are cut off, this method was commonly used where dodder infested Tea plantations and trees. Some households reported not to have employed any method to manage dodder, majorly households where the infestation is not so severe and where dodder had infested on road side vegetation or abandoned areas of the farm only meaning the farm households in these areas did not feel threatened with the presence of dodder on their farms. Spraying of dodder with herbicides, just like it has been done with other weeds

is one of the methods also employed by the respondents to manage dodder in Belgut. The herbicides that were reported to have been used was round up which contains 360g / L Glyphosate. Some respondents said the method did not kill dodder completely. They said that dodder would wilt for sometimes then sprout again. Others however reported the method to have been effective pointing out that it's important to check mixing ratio and the timing. This however requires further research to establish the correct mixing ratio and the appropriate timing. Other research carried out by (Linjian et al., 2013) agrees with this findings, the study used *C.campestris* in an effort to find out whether use of herbicides can help in control of parasitic weeds and reported that herbicide resistant crop technology could be used for the control of parasitic plants .

In cases of severe infestation some household farms have killed the dodder host, this was said to be the last resort when all the other methods have failed to control dodder spread. Killing of host was mostly done for less economically important vegetation like life fences and road side vegetations. This was also intended to help reduce spread of this weed to other crops and plants.

A chi-square test of independence showed a significant relationship between the gender of the household head and dodder management method employed in the households these two variables, (χ^2 = 24.72, df = 10, N = 124, p = 0.006) and phi and Cramer's v value of. 447.Majority of Male headed households prefer slashing method. While most of the female headed households used handpicking as dodder management method (see appendix V). We can infer that the results did not occur by chance but is actually true for the entire population. There was however no significant relationship between education level and dodder management method used (χ^2 = 39.79, df = 40, N = 124, p = 0.48). In addition, One-way ANOVA was performed to find out if a relationship exists between the age of the household heads and dodder management, the results showed no significant relationship (F = 1.07, df = 10, 113) = 1.065, P = 0.395). One-way ANOVA was also computed to compare the number of years dodder has infested the farm households with the management method used in the households and no significant results were obtained (F (10, 113) =1.236 p = 0.276).

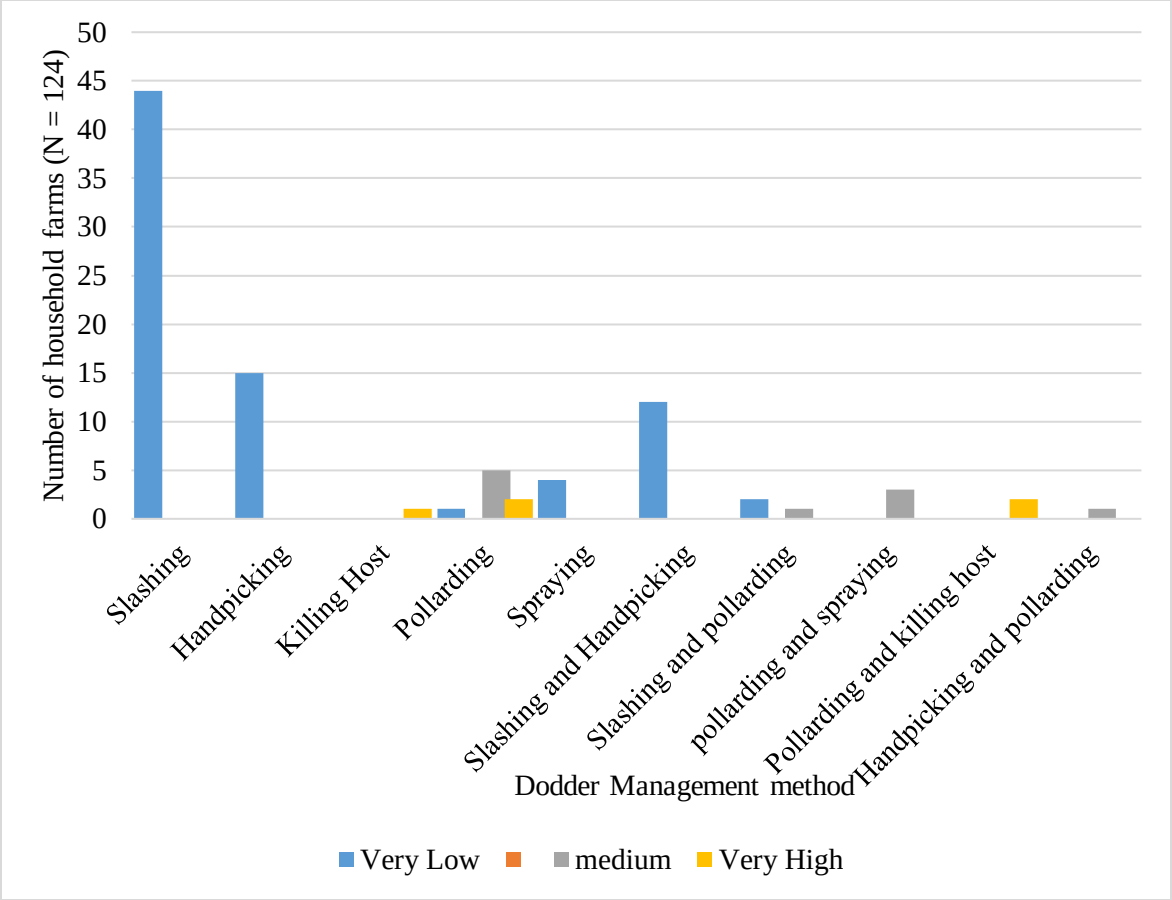

Figure 4. 14: Effectiveness of Dodder Management Methods Employed

From the results in figure 4.14 we note that a total of 93 household were managing dodder on their farms using various methods, 15 of the farm households did handpicking and all these households found the method to be very low in managing dodder, they say that dodder regrew on the host plants after a while. This should be because haustoria's remain in the plants when pulling out, enabling dodder to regrow later.44 households managed dodder by slashing dodder strings off the host, the method was also said to be very low in managing dodder. Haustoria's also remained in the plants and would later grow on the plant. One of the household reported killing dodder host by burning it with the dodder, the method was had high effectiveness, However, it was found not to be sustainable since you lose the dodder host too in the process of burning, and this is why most of the people have not employed this method, for fear of losing the dodder hosts which are important economically. Pollarding is one of the method used to manage dodder as seen in plate 4.9 below. It was found to be effective to some level. Out of the 7 households who have used

this method, 2 found it highly effective ,and 5 found the effectiveness of this method at the medium level, this is because they said dodder re-appeared after sometime in the farms, one household head said that dodder re-infested his tea plantation after 3 years, this could be because dodder seeds had remained and now germinated and reestablished itself on the plantations or dodder could have come from neighboring areas infested by the parasite through various vectors of dispersal. and re-infest the plantation.

Spraying of dodder with glyphosate was found be less effective, 4 households who had used this method, said that dodder would wilt for sometimes, then it re-emerges. One household head however reported to have effectively managed dodder using this chemical pointing out that the rate of effectiveness depends on the concentration of the herbicide used and application timing, the higher the concentration the more effective the chemical, he however couldn't provide the actual ratios. According to (Hassar *et al.*, 2009) these is true for glyphosate resistant crops which were reported to have stopped growing between 3 to 4 weeks after application of glyphosate and later re-grew, this is reported to be dependent of the host parasite interactions and the level of resistance of the host.

Another 12 households have combined both slashing and handpicking and the effectiveness is still very low.3 households did slashing and pollarding and witness a medium level of effectiveness. Pollarding and spraying was also said to be fairly effective by the 3 households who have used this method. Pollarding and killing of host was very effective. pollarding and handpicking had medium effectiveness. The 21 households who have used more than one management method, used a second method when the 1st one failed to effectively manage dodder. This demonstrates how some households are experiencing huge losses as a result of dodder plant. And trying all means to try and manage dodder and its effect.

Plate 4. 9: Pollarded Tea crop
Taken at Ngariet Waldai ward on 26th August 2017

4.6.5 Importance of Dodder

In this section we discuss and present the results on the benefits of dodder. The data collected using questionnaires was analyzed by use of SPSS and presented in the table 4.6 and figure 4.16 below. This information is important in understanding the characteristics of dodder.

Table 4. 4: Benefits of Dodder Mentioned by the Respondents

	Frequency	Percent
N	124	100
Non	90	72.6
Medicinal	10	8.1
Animal feed	21	16.9
I don't Know	3	2.4

From table 4.4 above we notice that dodder has some benefits from the respondent's views, though a good proportion said that dodder is not beneficial at all. 8% of the sampled population said that dodder has medicinal value, they said that dodder juice can heal wounds and also burnt ash of dodder plant can be applied on wounds. This results agree with that of (Ghule *et al., 2011)* who reported that *C. campestris* is anti-inflammatory . 17% of the respondents said that dodder is animal feed, that both goats, sheep and cows feed on the plant. This result agrees with (Marija and Sava, 2015) report,who have however warned that excess intake of dodder, i.e exceeding 50% of the forage may cause indigestion and miscarriage in animals. The other benefit of dodder in literature is for biological control, particularly field dodder *C. Campestris* has been used in the biological control of *Mikania micrantha* in South China and has been reported to affect the biomass of *M.micranta* spread and abundance and also inhibited the flowering of the infected *M. micrantha* plants.(Shen *et al.*, 2005).

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

To establish dodder impacts, control and management in Belgut area. Data on dodder distribution in relation to climate variability, major dodder hosts species and management methods effectiveness were studied using questionnaire, observation sheets, photographs and climatic data obtained from the Kericho Meteorological department. The data was analyzed by use of statistical software's including SPSS and Ms Excel to generate results. From the results the null hypothesis was rejected since climate has been changing for the period 1988 to 2017 examined, with a decrease in rainfall and increase in temperature. This variability has however not affected dodder occurrence according to the residents hence null hypothesis was accepted for the case of climate variability in association to dodder distribution

Null hypothesis was rejected in the case of dodder host. there was significant dodder host diversity in the study area. The most preferred dodder host was tea. For dodder management method rate of effectiveness, the null hypothesis was accepted, the most common management method was handpicking with very low effectiveness, Pollarding was said to be effective, although not sustainable. When we weigh the benefits and the problems posed by dodder according to the respondent's views, we find that dodder has more economic and ecosystem losses and so finding a way to manage and control it's spread is required.

Dodder spread very fast considering that it was introduced to the study area some 5 years ago yet it had already reached 31% of the households' farms. It is urgent to find methods to control its spread and further economic losses especially in Tea plantations, which is a major source of income to the residents of the study area. However, on the other hand it's unfortunate that the Ministry of Agriculture Kericho West Sub-County office had no documented information on this weed and the effects it has on Agricultural activities, a major income generating activity in the study area and has done nothing about this weed which is continuing to cause economic losses and affect livelihoods in Belgut. Some residents said they reported the matter to the KTDA Tea extension officers who have done nothing about it also. When Field Service Coordinator Momul Tea Factory Company Limited was asked about his knowledge of the weed and how it has affected the tea farmers,

He says he is aware about the weed and Tea Research Foundation was conducting research on this weed at the time but KTDA has done nothing about it despite receiving complaints from the farmers. Its recommended that research findings on dodder by other individuals and entities should be shared so that the biology and ecology of this weed is well understood with the aim of finding an effective sustainable method to control this parasitic weed. (Otieno, 2016) reported that a letter was written in 2014 by the then Director Tea Research foundation of Kenya to the Nandi and Kericho counties County Executive committee members stating that dodder is a noxious weed and combined efforts were required in management of Dodder. But nothing much has been done to manage this weed apart from the exchange of letters.

5.2 Conclusions

From this study we can make the following conclusion

1. Climate varied between 1988 and 2017. Rainfall has been decreasing and temperature have been increasing
2. Dodder has been distributed in a clumped distribution pattern in Belgut area, Waldai, Sigowet, and parts of Kabianga Wards have individuals clustered together, whereas Kapsuser, Kaplelartet, Cheptororiet and part of Kabianga wards have less or no individual of dodder plants. Occurrences is not affected by climate variability. Its survival is heavily dependent on the host plant
3. Dodder has a wide range of host .and prefer certain host the host diversity indices revealed high host richness and high evenness
4. There is a good number of dodder control and management methods that have been practiced by household farms of Belgut but only the killing of the host proved effective in completely getting rid of dodder. Pollarding is effective too but this has to be done in good time before dodder flowers

5.3 Recommendations

Following the results and conclusions of the study, the following are the recommendations

1. Dodder distribution and spread can be minimized by sensitizing the community, particularly school going children about the effects of dodder and how to minimize spread because they were found to be the main agents of dispersal in the study area,

this should be done by the Ministry of Education at schools, Ministry of Agriculture, and other institutions like KTDA and churches in the area. Distribution and spread can also be minimized through use of certified crop seedlings to be provided by the Ministry of Agriculture.

2. Crops that were found to be preferred dodder host can be grown on rotation with those that are not common dodder host to try and eradicate the dodder on infected farms. This should be done with expert advice for it to be successful in managing dodder spread.

5.4 Areas for further Research

1. Further research should be carried out to establish how dodder spread vary with spatial climate variability since temporal climate examined in the study did not show major effects on dodder spread
2. Research also needs to be undertaken by research institutions like Tea Research Foundation, Universities and KARI to identify more effective and sustainable methods for dodder control and management in area already infected as it is evident that dodder is a threat to major sources of livelihoods and food security and no effective management method have been adopted
3. Use of glyphosate and other chemicals that have been used to manage dodder needs to be further investigated by the Agricultural Research Institutions mentioned in No.2 above through conducting experimental research to establish the concentration and timing of applying the herbicide in order to successfully manage dodder.

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APPENDICES

Appendix I Household Questionnaire

This questionnaire is used to collect data for academic research purposes by the student, information provided will be handled with confidentiality

Official use: Date _____ Questionnaire number. _____ . Gps Location _____

Instructions

Please Tick in the bracket against your answer and fill on the space provided where applicable.

Section 1: Information about the household

1. Gender of household head

   a.) Male [ ] b.) Female [ ]

2. Age of household head in years? _____

3. Highest education level of the household head

   a.) None [ ] b.) Primary [ ] c.) Secondary [ ] d.) University [ ] e.) Other [ ]

4. Size of the household _____

5. Size of the household farm _____

6. Name crops and trees in your farm

Section 2: Distribution and climate variability

7. a) Rainfall has come early in the past 10 years

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

b). Rainfall amounts has reduced for the past 10 years

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

c). Rain durations has been lengthening in the past 10 years

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

d). The onset of rainfall has delayed compared to the past 10 years

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

e). Heavy rains have been received in the past 10 years

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

f). Rainfall have been received for shorter durations in the past 10 years

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

g) Changing rainfall trends has affected the occurrence of dodder

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

h) Rainfall variation does not affect dodder occurrence

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

8 a) It is warmer now compared to the past 10 years ago

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

b). Ten years ago, it was colder

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

c) Temperature variation affect dodder occurrence

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

d) Changing trends in temperature does not affect dodder occurrence

a) Strongly disagree [ ] b.) Disagree [ ] c.) Undecided [ ] d.) Agree [ ] e.)Strongly agree [ ]

Section 3: Weed control and management

11. Which are the weed types on your farm?

12. How do you manage the weeds?

a) Spraying with herbicides b) Digging them out c) Handpicking

13. a) Is there dodder in your farm?

a) Yes [ ] b) No [ ]

b) If yes in a above, for how many years has it been there? _____

c) Which are the major dodder hosts? _____

d) Which method have you used to manage dodder in your farm?

1) Slashing 2) Handpicking 3) Killing the host 4) Pollarding 5) Non

6) Spraying with herbicides

e.) How does dodder spread?

1) Seed dispersal 2) Vegetative propagation 3) Not sure

f) What are the benefits of dodder?

1) Non (2) Medicinal (3) Animal Feed (4) Not sure

14. Effectiveness of these dodder management methods that have been

Methods	Effectiveness
	Very low → Moderate → Very high
Slashing	
Hand Picking	

Killing the Host

Pollarding

Spraying with Herbicides

Thank you for your time

Appendix II Observation Sheet

Observation sheet for the host species and locations

Observation sheet number _____

Date_____

Household no.	Host species	Individual numbers for each species	GPS locations

Appendix III Cronbach's Reliability Test Results for Likert Scales

	Cronbach's Alpha
N	2
Rainfall onset	0.92
Rainfall amounts	0.77
Rainfall durations	0.92
Temperature changes	0.94
Relationship between dodder and rainfall changes	0.94
Relationship between dodder and temperature changes	0.94

Appendix IV Mean Annual Rainfall and Standard Deviation for the period 1988 - 2017

N	30.00
Mean Annual Rainfall	2001.06
Rainfall Standard Deviation	243.40

Appendix V Relationship between Dodder management and Gender of Household Head

Management Method	Male	Female
N	124	
Slashing	37	7
Handpicking	7	8
Killing Host	1	0
Pollarding	8	0
Non	24	7
Spraying	4	0
Slashing and Handpicking	8	4
Slashing and pollarding	0	3
pollarding and spraying	3	0
Pollarding and killing host	1	1
Handpicking and pollarding	1	0

Appendix VI Life Fences Parasitized by Dodder

Taken at Cheptarit village of Kiptere ward on 23 August 2017

Appendix VII Dodder plant on Tea Plantation

Taken at Ngariet Waldai ward on 25th August 2017

Taken at Chebungungon of Seretut ward on 2 September 2017

Appendix VIII Table of Dodder Locations Coordinates.

Q. NO.	x	y
222	35.085375	0.371666
221	35.085445	0.394772
220	35.0861	0.396437
216	35.085808	0.37955
359	35.22666667	0.409305556
364	35.18027778	0.41275
365	35.17877778	0.401513889
366	35.09963889	0.404416667
367	35.07525	0.424388889
223	35.11719444	0.410222222
196	35.08661111	0.397388889
195	35.18541667	0.468277778
194	35.07852778	0.433972222

193	35.10497222	0.411569444
191	35.08661111	0.397388889
189	35.08044444	0.43625
188	35.06647222	0.440972222
187	35.06963889	0.442888889
186	35.181	0.3915
183	35.06383333	0.404
182	35.20794444	0.433861111
173	35.20663889	0.450166667
172	35.07347222	0.427666667
171	35.14308333	0.383277778
170	35.16677778	0.364027778
169	35.15761111	0.351138889
167	35.07144444	0.408944444
259	35.11502778	0.401944444
257	35.18644444	0.350138889
256	35.27852778	0.374583333
254	35.19613889	0.335416667
253	35.19613889	0.335416667
252	35.19336111	0.353916667
251	35.15608333	0.368416667
250	35.19558333	0.34875
249	35.18754444	0.344
248	35.19813889	0.332638889
247	35.19216667	0.33875
246	35.18977778	0.341111111
245	35.18447222	0.411833333
244	35.17641667	0.3665

243	35.15244444	0.3795
242	35.14927778	0.375916667
241	35.15244444	0.3795
240	35.15827778	0.363111111
239	35.15608333	0.375194444
238	35.15147222	0.372388889
237	35.15811111	0.363055556
236	35.15661111	0.358333333
235	35.19186111	0.368861111
234	35.18983333	0.358305556
233	35.15708333	0.375972222
232	35.17888889	0.366888889
231	35.20075	0.3885
229	35.17869444	0.374472222
228	35.15975	0.355611111
222	35.17669444	0.350888889
221	35.20233333	0.381805556
220	35.18555556	0.387694444
219	35.21994444	0.40825
218	35.1975	0.3365
217	35.17491667	0.356555556
216	35.19077778	0.343277778
213	35.19191667	0.354527778
210	35.19330556	0.352166667
157	35.18375	0.361361111
146	35.18794444	0.364472222
149	35.07302778	0.691027778
152	35.16147222	0.364111111

164	35.17963889	0.389333333
212	35.11972222	0.385055556
210	35.08236111	0.396333333
206	35.16619444	0.399138889
205	35.171625	0.394888889
204	35.19588889	0.347777778
202	35.27852778	0.374583333
213	35.17580556	0.359666667
214	35.18136111	0.3915
224	35.084337	0.382013
225	35.128505	0.390298
217	35.056195	0.409011
227	35.15202778	0.348972222
228	35.07316667	0.406277778
64	35.085375	0.371666
59	35.1175	0.409986111
65	35.14927778	0.348
66	35.17032222	0.373222222
67	35.15255556	0.344944444
208	35.1685	0.372305556
206	35.17044444	0.373166667
205	35.17419444	0.371611111
204	35.16519444	0.369138889
203	35.17319444	0.345375
202	35.16322222	0.354722222
201	35.17965556	0.389347222
265	35.13597222	0.386583333
264	35.13966667	0.371805556

263	35.13597222	0.386583333
262	35.13952778	0.39825
261	35.11141667	0.412527778
209	35.13369444	0.387055556
276	35.17625	0.353555556
273	35.08661111	0.397388889
272	35.05519444	0.422111111
271	35.08225	0.396333333
269	35.05658333	0.404583333
268	35.14313889	0.398361111
289	35.05777778	0.431180556
281	35.10044444	0.405166667
280	35.18805556	0.354194444
278	35.18844444	0.357944444
277	35.137607	0.38673
301	35.09375	0.417166667
300	35.08591667	0.411819444
296	35.08558333	0.411833333
295	35.08241667	0.404083333
294	35.056195	0.409011
302	35.078998	0.398204444
327	35.085375	0.371666
326	35.128505	0.390298
325	35.10054222	0.425031111
324	35.08044444	0.43625
320	35.05672222	0.424222222
319	35.22683333	0.411083333

Appendix IX: Dodder Hosts

Kipsigis Name	Botanical Name	Family	Common Name	Individuals parasitized
Cheptolelyon	*Euryops chrysanthemoides*	Compositae		38
Tebengwet	*Vernonia adoensis* Walp	Asteraceae		6
Sigowet	*Solanum aculeastrum* Dunal	Solanaceae		11
Turgwot	*Barleria micrantha*	Acanthaceae		1525
Chepkomon	*Caesalpinia decapetala*	Caesalpiniaeae		1777
	Halleria lucida L.	Stilbaceae		303
Labotwet	*Solanum campylacanthum* Hochst.	Solanaceae		186
Mosonoitet	*Croton megalocarpus* Hutch.	Euphorbiaceae		24
Tebeswet	*Croton microstachyus*	Euphorbiaceae	Croton	102
Tagamaminik	*Rubus pinnatus* Willd.	Rosaceae		2
Obot-kawet	*Phytolacca dodecandra* L'Herit	Phytolaccaceae	Poke – Weed	3
Senetwet	*Senna didymobotrya* (Fresen) H.S. Irwin and Barneby	Fabaceae		6
Kimolwet	*Vangueria madagsacariensis* Gmel.	Rubiaceae	Vangueria	35
Kaiyepa	*Dovyalis caffra*	Salicaceae	Kie apple	148
Kaldit	*Neoboutonia macrocalyx* Pax	Euphorbiaceae		4
Maberiat	*Psidium guajava* L.	Myrtaceae	Quava	1
Kawat	*Coffea arabica* L.	Rubiaceae	Coffee	28
Chaiyat	*Camellia Sinensis*	Theaceae	Tea	2391
Kwambulu	*Eucaliptus Saligna*	Myrtaceae		48
Mobet	*Markhamia lutea* m (Benth) K. Schum	Bignoniaceae	Markhamia	7
	Sambucus Africana Standl.	Adoxaceae		1
Pirirwet	*Ocimum suave* Wild.	Lamiaceae		4
Kimelet	*Tragia brevipes*	Euphorbiaceae		3

Sagek	*Gynandropsis gynandra*	Capparaceae	Spider Plant	50
Chepoteri	*Lantana Camara* L.	Verbenaceae	Wild Sage	5
Kambit	*Acacia pycnantha* Benth.	Fabaceae	Golden Wattle	2
Kuriot	*Vepris nobilis* (Delile) W.Mziray	Rutaceae		2
	Duranta erecta L.	Verbenaceae	Duranta Yellow	470
Singorwet	*Cyathula polycephala* Baker.	Amaranthaceae		19
Sebetaiyet	*Spathodea 79fricana79te* Beauv.	Bignoniaceae	Nandi flame	3
Avacado	*Persea americana*	Lauraceae	Avacado	4
Museset	*Olinia rochetiana* A.Juss	Penaeaceae		1
Labotwet	*Solanum terminale* Forssk	Solanaceae		16
Tendwet	*Prunus 79fricana* (Hook F.) Kalkm	Rosaceae	Red Stink Wood	5
Bandiat	*Zea mays*	Poaceae	Corn	5
Chemul-Chemanam Belyon	*Phylanthus nummularifolius*	Euphorbiaceae		3
Macheket	*Tabernaemontana stapfiana* Britten	Apocynaceae		3
Moronget	*Plectranthus punctatus* A.J. Paton	Lamiaceae		2
Cheptendere t	*Tabernaemontana stapfiana* Britten	Apocynaceae		41
Lakuat	*Eriobotrya japonica* (Thunb)	Rosaceae	Loquat	1
Chepkumiat	*Psidia ponculata* D.C Vatke	Asteraceae		3
kwamama	*Conyza newii* Oliv and Hiern	Asteraceae		2
Cypress	*Cupressus lusitanica*	Cupressaceae	Tarakwet	11

Appendix X: Simpsons and Shannon Weinner Diversity Indices of Dodder Host

Dodder host species	N	pi	lnpi	pi*lnpi	pi	Pi^2
E.chrysanthemoides	38	0.005205479	-5.258043467	-0.027370637	0.005205479	2.7097E-05
V. adoensis Walp	6	0.000821918	-7.103870158	-0.005838797	0.000821918	6.75549E-07

S.aculeastrum Dunal	11	0.001506849	-6.497734354	-0.009791107	0.001506849	2.27059E-06
B. Micrantha	1525	0.20890411	-1.565879938	-0.327118754	0.20890411	0.043640927
A.Senegal	1777	0.243424658	-1.412947799	-0.343946334	0.243424658	0.059255564
H.Lucida L.	303	0.041506849	-3.181896822	-0.132070512	0.041506849	0.001722819
S. campylacanthum Hochst.	186	0.025479452	-3.669882953	-0.093506607	0.025479452	0.000649202
C. megalocarpus Hutch.	24	0.003287671	-5.717575797	-0.018797509	0.003287671	1.08088E-05
C. Microstachyus	102	0.013972603	-4.270656814	-0.059672191	0.013972603	0.000195234
R.pinnatus Willd.	1	0.000136986	-8.895629627	-0.001218579	0.000136986	1.87652E-08
P.dodecandra **L**'Herit	3	0.000410959	-7.797017338	-0.003204254	0.000410959	1.68887E-07
*S. didymobotrya (*Fresen*)* H.S. Irwin and Barneby	6	0.000821918	-7.103870158	-0.005838797	0.000821918	6.75549E-07
V.Madagsacariensis Gmel.	35	0.004794521	-5.340281566	-0.025600409	0.004794521	2.29874E-05
D.caffra	148	0.020273973	-3.898417353	-0.079036407	0.020273973	0.000411034
N.macrocalyx Pax.	4	0.000547945	-7.509335266	-0.004114704	0.000547945	3.00244E-07
P. guajava L.	1	0.000136986	-8.895629627	-0.001218579	0.000136986	1.87652E-08
C. arabica L.	28	0.003835616	-5.563425117	-0.021339165	0.003835616	1.47125E-05

C. Sinensis	2391	0.327534247	-1.11616266	-0.365581496	0.327534247	0.107278683
E. Saligna	48	0.006575342	-5.024428616	-0.033037339	0.006575342	4.32351E-05
M. lutea m (Benth) K. Schum	7	0.000958904	-6.949719478	-0.006664115	0.000958904	9.19497E-07
S. Africana Standl.	1	0.000136986	-8.895629627	-0.001218579	0.000136986	1.87652E-08
O. suave Wild.	4	0.000547945	-7.509335266	-0.004114704	0.000547945	3.00244E-07
T. brevipes	3	0.000410959	-7.797017338	-0.003204254	0.000410959	1.68887E-07
G. gynandra	50	0.006849315	-4.983606622	-0.034134292	0.006849315	4.69131E-05
L. Camara L.	5	0.000684932	-7.286191715	-0.004990542	0.000684932	4.69131E-07
A. pycnantha Benth	2	0.000273973	-8.202482447	-0.002247255	0.000273973	7.5061E-08
V. nobilis (Delile) W.Mziray	2	0.000273973	-8.202482447	-0.002247255	0.000273973	7.5061E-08
D. erecta L.	470	0.064383562	-2.742896932	-0.176597474	0.064383562	0.004145243
C. polycephala Baker.	19	0.00260274	-5.951190648	-0.0154894	0.00260274	6.77425E-06
S. campanulata Beauv.	3	0.000410959	-7.797017338	-0.003204254	0.000410959	1.68887E-07
P. americana	4	0.000547945	-7.509335266	-0.004114704	0.000547945	3.00244E-07
O.rochetiana A.Juss	1	0.000136986	-8.895629627	-0.001218579	0.000136986	1.87652E-08

S. terminale Forssk	16	0.002191781	-6.123040905	-0.013420364	0.002191781	4.8039E-06
*P. africana (*Hook F.) Kalkm	5	0.000684932	-7.286191715	-0.004990542	0.000684932	4.69131E-07
Z.mays	5	0.000684932	-7.286191715	-0.004990542	0.000684932	4.69131E-07
P.nummularifolius	3	0.000410959	-7.797017338	-0.003204254	0.000410959	1.68887E-07
A. oppositifolia	3	0.000410959	-7.797017338	-0.003204254	0.000410959	1.68887E-07
P. punctatus A.J. Paton	2	0.000273973	-8.202482447	-0.002247255	0.000273973	7.5061E-08
T. stapfiana Britten	41	0.005616438	-5.182055756	-0.029104707	0.005616438	3.15444E-05
E. Japonica (Thunb)	1	0.000136986	-8.895629627	-0.001218579	0.000136986	1.87652E-08
P.porculata	3	0.000410959	-7.797017338	-0.003204254	0.000410959	1.68887E-07
C.newii	2	0.000273973	-8.202482447	-0.002247255	0.000273973	7.5061E-08
C. lusitanica	11	0.001506849	-6.497734354	-0.009791107	0.001506849	2.27059E-06
Total	7300			1.89537438		0.217518108
SW diversity index= 1.89537438009046 Simpson's diversity index= 0.217518108463126						