

# Eco-Climatic Factors Influencing the Distribution of Black Ants (*Carebara vidua*) in Western Kenya

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## Abstract

Black ant, *Carebara vidua* (Smith) is an edible insect of critical value in nutrition. The population abundance of black ants has reduced drastically and they have become scarce in all the agro ecological zones in Western Kenya. Understanding factors influencing the distribution and abundance of *C. vidua* remains a challenge as *C. vidua* is an endangered species in many parts of Country Kenya. The decline in the insect population is worrying since black ants are an important source of food across the world. Our study aimed at determining the eco-climatic conditions influencing the distribution of black ants. Several factors and conditions have contributed to the decline in the population of black ants. The study was carried out in different agro ecological zones of Kisumu, Siaya, and Homabay Counties. The research presumed a cross-sectional approach to community representation. The purposive sampling technique was used to select the population for the qualitative study. Data was collected through Focused Group Discussion and Key Informant Interviews to get in-depth knowledge on the factors contributing to the change in the distribution of black ants. Verbatim transcription was done to the audio recorded data then data was translated into English. Thematic analysis was done using ATLAS.ti software version 7.5. The results showed various factors that led to the change in distribution and reduction of the population of black ants emerging across the lower midland zones, the factors include; climate change, advancement in agricultural equipment, land degradation, and habitat destruction. These factors made the emergence of the insect unpredictable. Over the years across the Lower midland zones, there have been changes in the distribution of *C. vidua* and the population of insects emerging has reduced hence the insect is disappearing.

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## Keywords

Black Ant, Ecological Zones, Distribution, Population

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### 1. Introduction

Black ant, *Carebara vidua* is a nutritious edible insect across the globe. It contains nutrients such as proteins, fats, zinc and vitamins [1]. In communities around the Lake Victoria, it is valued as food by humans and can be eaten raw or fried [2]. Interactions between ants of different species may vary under different ecological conditions attributed to human influence on the environment and the impact of global change [3]. The distribution and abundance of *C. vidua* are influenced by biotic and abiotic stresses. Biotic factors include; competition, predation, parasitism, and human activities such as agriculture, urbanization, industrialization, deforestation, and fragmentation, which hinder the subterranean ants from building mounds underground, under rocks and buildings thus affecting the habitat where ants live [4]. The effect of these anthropogenic disturbances on ant communities may include loss of diversity, change in species composition, and alteration in ant-derived ecosystem services such as soil processing. Urbanization has not only resulted in disturbances that destroy the habitat of many species but have also created a habitat that attracts few species to adapt to urban conditions as it is a major threat to biodiversity and responsible for species extinctions. The spread of urbanization affects the richness and abundance of ants [5]. Wildfires give rise to microclimatic changes in areas that have been burned; they reduce moisture and increase temperature. Fire also induces changes in soil properties and leads to a substantial loss of above-ground biomass, contributing to greenhouse gas emissions [6]. These anthropogenic activities jeopardize the safety of ants as sources of food and their future availability [7]. Abiotic factors such as climatic variables may prolong the metamorphosis, survival, and multiplication rate of the insects [8] and regulate the distribution and abundance of *C. vidua*. Among climatic factors; temperature is vital as the majority of ant species are thermophilic.

The world population is increasing at a very high rate [9]. Projections are that by the year 2050, the world population will be 9 billion, leading up to a 70% increase in global food demand compared to the current requirements [10]. This increase in food demand calls for commensurate increases in food production and distribution [11]. Even though food production can be increased with the modern biotechnology through use of genetically modified organisms, there is a demand for alternative sources of proteins from edible insects as conventional sources of protein will not be sufficient to meet the global demand, and sustainable alternative protein sources such as *C. vidua* have to be identified and promoted [12].

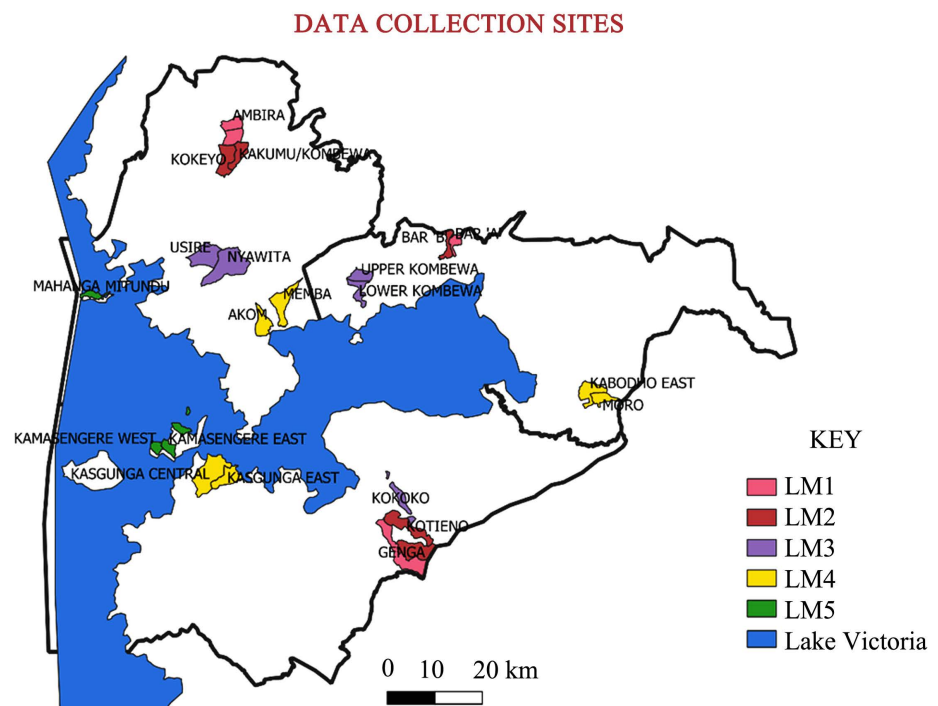
Understanding factors influencing the distribution and abundance of *C. vi-*

*dua* remains a challenge as *C. vidua* is an endangered species in many parts of Country Kenya. The increasing concerns are mass destruction of the habitat as ants are more susceptible to environmental disturbance. They are also dependent on moisture and temperature, thus, found in wetlands. The knowledge of ant species present or absent cannot be enough to predict their influence on ecosystems because they are unevenly distributed and interact differently under various disturbance regimes [13]. Learning more about *C. vidua*'s ecology not only provides a better understanding of the overall ant fauna but also guides their current management, future conservation, and restoration [14]. This study of *C. vidua*'s ecology, which entails its interactions with the abiotic and biotic environment will create knowledge for the future conservation of *C. vidua* as an alternative food source to enhance food security. The study will improve our understanding of the effects of anthropogenic threats on population distribution patterns.

## 2. Materials and Methods

### 2.1. Study Site

The study was carried out in the Homabay, Siaya, and Kisumu Counties of Western Kenya. There are different ecological zones located within the three counties. Data were collected across the lower midland zones: LM 1 to LM 5 of these counties differentiated by climatic parameters and soil characteristics. (Figure 1) shows the map of the study sites of different Lm zones within the counties. The counties are associated with the consumption of *C. vidua*.



**Figure 1.** A map showing the study sites.

## 2.2. Sampling Method

The purposive sampling technique was used in the selection of suitable participants from the sampling frame. Participants were selected based on their knowledge and information contained on the subject of the study [15]. The villagers aided in the selection of Focus Group Discussants on their aspect of living in the area for more than ten years. The cross-sectional approach to community representation was adopted during data collection where males, females, older, and adults beyond forty 45 years of age were involved to get a scope of perspectives on each topic from those that have the general knowledge of the black ant and have witnessed their emergence or occurrence.

Key Informant Interviews were conducted on identified individuals, knowledgeable, interested, and experienced people on the subject who has in-depth information more than the general population of the community. Key informants were older people of age fifty-five and above. Agricultural officers helped to mobilize the communities since they have worked and were familiar with the communities within the sub-county. Twenty-eight FGDs comprising eight participants per LM and fourteen KIIs were conducted on the selected respondents.

## 2.3. Data Collection Process

The data collection tool was structured in topics and sub-topics to facilitate in-depth articulation of the research problem. Qualitative data was collected through Focus Group Discussions (FGD) and Key Informants Interviews and field notes. Audio recorders were used to record the interviews and discussions.

### 2.3.1. Focused Group Discussion

Primary data was collected through Focus Group Discussions from a purposively selected group of individuals to get in-depth information on the eco-climatic factors influencing its distribution.

The focus group of this study consisted of eight participants [16] per group. Explanation involving what is expected of the participants was done. The participants were assured confidentiality of their information and details provided. With the permission of participants, an audio recording device was used to record the discussion. The discussion was done using the local language of the discussants. The facilitator and research assistant moderated the discussion which lasted for fifty minutes.

### 2.3.2. Key Informants Interviews

One-on-one interview with the key informants was used to collect in-depth information on the topic of this study. This method helped to understand individual perspectives on the topic of the matter. The key informants explained what is expected from them including their right to withdraw from the interview of their free will. Informed consent was administered to the key informants and their consent to use an audio recording device aided the data collection process.

Data was explored using an unstructured data collection tool. The probing

technique was used where relevant to enquire more information. The interview lasted for approximately one hour.

### 2.3.3. Field Note-Taking

Field notes were taken during Focused Group Discussions and Key Informants Interview. They included a description of the physical setting of the study, the behavior of the participants, and the unspoken attitude. The notes were used as an immediate resource to reflect during and at the end of the interview. During the interview, they helped in consideration of the discussants' comments and clarified the views and at the end of the interview, the notes were reviewed and information annotation was added to aid in the analysis.

## 3. Data Analysis Process

The first process involved transcription verbatim of the audio recording into Microsoft office word with the help of audio codec software. The second process was the translation of transcribed data into the English language for analysis. Translated scripts were reviewed repeatedly for familiarity and to check for recurrent flaws or omitted information. Thematic analysis was then conducted by use of ATLAS.ti version 7.5, where translated data scripts were imported into the software. Codes were critically generated which were further classified into similar families and subsequently themes.

### Ethical Consideration

Ethical approval was obtained from Jaramogi Oginga Odinga University of Science and Technology Ethics Review Committee with approval number ERC/18/11/20-1. Permission and support were also sought from the Local Administration authorizes of the relevant locations.

## 4. Results

Various themes were generated in each lower midland zone of the agro ecological zones.

### 4.1. Lower Midland 1

Climate change, advancement in agricultural equipment, habitat destruction, increased settlement, industrialization, land degradation, and predation were some of the themes generated in this zone.

**Climate Change:** Climate change was generated as a theme that exhibited the significant change in weather patterns or changes in the atmospheric condition over the years as experienced by the participants in the study areas.

Participants noted much concern about the gradual change in the weather pattern over the years. However, they distinguished that in the 1990s there was high rainfall amount compared to the year 2000's especially during the planting seasons. They emphasized that the emergence of *C. vidua* was mostly experienced during the rainy seasons when intense agricultural activities were being carried

out. Many respondents talked of the changing rainfall pattern. In Kisumu County, when talking about the climate parameters, participants compared the temperatures in the 1990s and 2000s echoing the significant differences. Another respondent explained that the temperature change contributed to soil moisture loss which interfered with the condition of *C. vidua* habitat triggering their disappearance.

*“There was a lot of rainfall in the past during the planting season compared to nowadays which we experience little rainfall therefore C. vidua cannot get a chance to emerge.”* (participant 7)

*“Nowadays the sun is too hot and the insects rarely emerge during their season of emergence. I saw them emerging in August last year 2020. In the 1990s the insects were so many then they started reducing in the year 2000.”* (participant 3)

**Advancement in agricultural equipment:** This is a collective theme that encompasses the innovation and use of sophisticated agricultural farm machinery such as tractors. The theme was theoretically linked to farm tools as a code. The code accounts for the gradual changes in the upgrade and application of farm tools over the years. Most participants in Kisumu, however, have adopted the whirling change in modern agricultural technology. When asked about the reasons for the disappearance of *C. vidua*, some participants stated that due to shifting in the use of farm tools from hoes to tractors in land preparation for cultivation could have destroyed the habitat for *C. vidua*. Participants in Siaya County also shared their opinion on the disappearance of *C. vidua* reiterating the shift from hand digging to the use of tractors which were not widely used in the previous years.

*“People were hand digging by use of a hoe, nowadays tractors are being used when farming which was not there in the past. This has contributed to their disappearance since their habitat is being dug deep.”* (participant 1)

**Land degradation:** This theme encompasses the results of various anthropological processes acting upon the land that lowers the value of the biophysical environment. The theme, however, was theoretically linked to codes of soil use, deforestation, charcoal burning, and chemical use.

Participants cited that *C. vidua* was adversely affected by the way residents are putting soil into use. Most participants in Kisumu County talked of the soil used to make charcoal stove liners for economic reasons and as a means of earning a livelihood. Two participants from Kisumu however emphasized that soil harvesting was practiced more due to a lack of alternative jobs in the area. They however noted on the impact of their soil use to have destroyed the habitats of *C. vidua* in the area.

In Siaya County, participants recounted charcoal burning as one of the primary activities in recent days. They noted that in the years 1970, charcoal burning was not a priority though they emphasized the use of firewood as their initial source of energy. Participants observed that charcoal burning was key in the destruction of the habitats of *C. vidua* as they explained that heat generated from

charcoal burning activities was harmful to soil bio-components. Charcoal burning was mostly done in the forests where trees were readily available, an activity that also adversely impacted the available forest cover.

Participants believed that *the C. vidua* population was stressed by the frequent use of toxic chemicals applied during agricultural activities. Another respondent explained further that the chemical pesticides and fertilizers were deemed to cause soil pollution and eventually habitat loss. Chemicals particularly aerosols were frequently being applied to ant hills in amid of destroying the ants. According to participants, the anthill structure has channels that most probably connect to the habitat of *C. vidua*. This aspect plays a role in the eradication of *C. vidua* and its habitat.

*“We are only using the soil to make charcoal stove liners.”* (participant 5)

*“There are no industries, we only practice sand harvesting and the making of charcoal stove liners using the soil.”* (participant 4)

*“People are currently burning charcoal and it never used to be there.”* (participant 7)

*There is a chemical that people are spraying to kill grasses and shrubs for them to cultivate (Roundup) or used to control weeds.* (participant 6)

**Habitat Destruction:** As a theme, it incorporates the anthropological measures that were undertaken instead of destroying the anthills. It was linked to a code of anthill destruction.

Most participants reported that *C. vidua* was mostly found in places where there were anthills. However, they also reported that people are destroying and removing ant hills from their environments. Participants in Siaya cited the use of toxic chemicals Chlorpyrifos 20% E on the anthills. The primary application of chemicals was aimed at *destroying the termites*. One Participant categorically explained that upon application of chemicals to the termite hills, some of the chemicals find their way into the *C. vidua* habitat and destroy them as well.

Participants observed that upon destruction and removal of anthills, the population of *C. vidua* started to decline gradually.

*“Removal of ant hills and using chemicals to kill the ants has led to the decline of C. vidua.”* (participant 6)

*“Activities were less and there were fewer ant hills. This insect emerged at the same time with termites so being that the anthills have been removed, the insect started declining because their environment had damaged.”* (participant 4)

## 4.2. Lower Midland 2

**Climate Change:** The aspect of climate change has been experienced in the area over the decades. Knowledge of the change in rainfall and temperature parameters was wide among the participants. Respondents stated that change in *rainfall pattern, amount, and distribution* was a contributing factor to the current distribution and threat to the extinction of *C. vidua*.

Respondents believed that rise in temperature has resulted in the increase in soil temperature and consequently reduction of the soil moisture content, alter-



ing the conditions of *C. vidua* habitat.

*“Climate change has led to the disappearance of the C. vidua; change in rainfall pattern since there was enough rainfall, rains had their season unlike today where we cannot predict the pattern and the sun is too hot.”* (participant 3)

**Advancement in Agricultural equipment:** Agriculture is widely practiced in this LM just like LM 1. A participant explained that over the decades they have witnessed several changes taking place in the field of agriculture that most probably influenced the current distribution and population of *C. vidua* in the regions.

Participants reiterated that in the year 1970's, simple agricultural equipment such as hoe and ox-plow were being used in land preparation. Hoes and jembes could not dig to the depth of destroying the insect's habitats. The gradual shift in agricultural equipment has led to the wide use of more advanced tools such as tractors in cultivation and land preparation as explained by the respondents. Participants believed that the use of tractors have contributed to the extinction of *C. vidua*. As explained by the participants that tractors plow goes deep into the soil which possibly destroys the habitats of the existing *C. vidua*. Participants report that initially *C. vidua* could be seen emerging from the farmlands as compared to the current times.

Another respondent explained that the smell of fossil fuel from farm machinery is not friendly to *C. vidua*, and might have contributed to the migration of *C. vidua* to a different setting.

The use of tractors in agriculture is a major land-disturbing aspect as it causes a lot of vibration on the ground, and air and noise pollution.

*“Hand digging and ox plow was being used to cultivate but people have now shifted to the use of tractors which dig deep into the soil and may destroy the habitat of C vidua.”* (participant 3)

**Land degradation:** Respondents stated that land degradation due to anthropogenic activities and natural phenomena has contributed to the already disappearance of *C. vidua* over time.

Participants specified that charcoal burning is one of the major activities carried out in this LM. There are not official designated areas for charcoal burning, therefore, forest locations provide a favorable environment for the activity because of readily available trees. According to another respondent, charcoal burning alters the soil conditions including the moisture content. They explained that the heat generated during charcoal burning might help to answer the current distribution of *C. vidua*.

Respondents reported that charcoal burning emits fumes that are not friendly to insects. *C. vidua* is known by participants to be insects that are mostly thriving in areas with clean air.

Section of participants believed that the effect brought about by the use of chemical fertilizers and pesticides could have contributed to the disappearance of *C. vidua* in this LM. In the years 1970's, organic compounds were frequently



used in the agricultural sector. Participant 2 went ahead to explain that in the years 2000, most organizations have influenced farmers to use their chemical products in controlling weeds, pests, and fertilizers. Respondents reiterated that the uses of these toxic chemicals are not only harmful to *C. vidua* but also the general soil bio components.

Participants believed that the application of the chemicals such as aerosols has accounted for the disappearance of *C. vidua*.

Participants stated that crop residues from the farms are burned by the farmers in the farmland and the effect might be heating of the soil that may result in a conditional change of *C. vidua* habitats influencing their migration. One participant stressed that the smoking effect from the crop residue burning could also explain the disappearance of *C. vidua* in this region. Respondents believe that this might be attributed to the formation of *acidic rainfall* which is a potential threat to *C. vidua* and other soil life.

Currently, soil treatments have advanced to become a major practice in the agricultural sector. Most people have reverted to the use of the chemical oxidation method in soil treatment. The locals asserted that the chemicals used to achieve the process are harmful and destructive to the insect and its habitat.

Soil from the ant hills provides raw materials for modeling charcoal stove liners. Locals dug ant hills to obtain the soil which was a direct destructive aspect. *C. vidua* being associated with ant hills by the participants, will most probably disappear or relocate to another favorable environment.

Participants in Siaya County noted the occurrence of an earthquake as a natural phenomenon in the area. Respondents noted that this might have led to the destruction of the *C. vidua* habitats and a potential result in their deaths.

*“Human activities such as charcoal burning has led to the disappearance of the C. vidua due to the heat produced when burning.”* (participant 1)

*“Increase use of chemicals to kill the ants’ family has led to the reduction of the black ant.”* (participant 3)

*“The soil has become acidic and there is low organic matter, people tend to burn crop residues at the farm which is a problem to the soil fertility.”* (participant 6)

*The soil from the ant hills is being used for making charcoal stove liners.* (participant 1)

*“There are earthquakes in the area that may be interfering with the habitat of the insect.”* (participant 7)

**Habitat destruction:** The Locals reported that the habitat for *C. vidua* was being destroyed in the process of destroying the ant hills around the houses and on the farmlands. Ants were known for destroying houses and plants.

In Siaya County, some people were using kerosene and salts to destroy and kill the ants in their natural settings. Participants believe that this practice destroyed the habitats of insects.

*“Removal of ant hills is a factor contributing to the disappearance of C. vidua because they live next to the anthills.”* (participant 2)

*“Destroying ant hills affect the habitat of C. vidua because people use kerosene and salt, gladiator, to destroy these ant hills and these chemicals spread under the ground and may reach the habitat of C. vidua and kill them.”* (participant 1)

### 4.3. Lower Midland 3

**Climate change:** climate change as referred to denotes the significant changes in the weather pattern as experienced in these regions. Various factors ranging from anthropological to natural phenomena might have contributed to the change in the climate. Climate, being significant as a determinant of the atmospheric condition including the soil moisture content, is a potential determinant of *C. vidua*'s distribution.

Participants talked about the difference between the past and current atmospheric conditions with a unison experience of higher rainfall amount compared to the current weather status. Participant 7 stated that in the years 1970 rainfall amount was high until 1983 when there was a partial drought. Participants mostly experienced *Carebara vidua* emergence during the rainy season, in the morning hours at around 10:00 am when it was cool. The atmospheric condition becomes phenomenal to the distribution of *C. vidua* when participants report a change in the distribution as a result of climate change.

Respondents reported on the application of the *knowledge of weather patterns* to predict the emergence of *C. vidua* and events in the agricultural calendar. Participants have since acknowledged the changes in climatic trends and associated their impact with the current distribution of *C. vidua*. Rainfall and temperature parameters determined the soil moisture condition. The current higher temperatures have significantly impacted the soil moisture content and soil temperature. Respondents believed that this factor has a potential effect on the conditions of *C. vidua* habitat which might explain the current distribution of *C. vidua*.

*“Currently there is a lot of sun which has brought a lot of heat, too much heat has made insects like C. vidua start disappearing.”* (participant 3)

*“Weather patterns have changed; there were a lot of rain that was enough for the soil but when the drought started, there was a drought in 1983.”* (participant 7)

*“The place is not as cool and wet as it used to be, we have destroyed our environment by cutting the forests, trees, and shrubs. We should maintain our environment to enhance a lot of rain.”* (participant 7)

**Advancement in agricultural equipment:** Agriculture as one of the key activities in this region, has evolved over the past and recent decades. This has established changes in the application of technology in agriculture from the use of simple to complex machinery in agricultural practices.

Participants reported on the use of ox-plow and hoes for farming in the years 1970's. Another respondent added that this agricultural equipment was less harmful to the habitats of *C. vidua* and the general soil biota. The locals stressed that; this equipment could not dig deep beneath the ground to interfere with the

*C. vidua* habitat which could explain the previous distribution of *C. vidua* in this LM.

Participants emphasized the current wide and consistent use of tractors to plow and in the general land preparation procedures. Participants believed that tractors are an associative factor in the destruction of *C. vidua* habitats as attributed to their aspect of digging deep into the ground and potentially destroying *C. vidua* habitats and disturbing the insects. The community believed that the disappearing *Carebara vidua* in this region could be explained by the *evolutions* in the agriculture sector.

*“Traditionally, we used to dig with hoes which could not interfere with the underground living organisms because tractors were not there. In the traditional world, there were polygamous men with 2 to 4 wives, they had many children who could help in the farm activities.”* (participant 2)

*“Modern farming using tractors are destroying the habitat of *C. vidua*”* (participant 1)

**Land degradation:** Anthropogenic activities and natural occurrences have contributed to land degradation, thus interfering with the land biotic components of this region. It’s a threat to the habitat of *C. vidua* and subsequently influences their distribution.

Participants reported on the making of bricks as one of the major economic activities of the residents. They reiterated that brick making involves digging of land to obtain soil, a process that leads to the destruction of *C. vidua* habitats. Brick-making has been increasing over the decades as the demand keeps shooting with change in time. The locals noted that the possible increase in brick making and demand might be a causal factor in the disappearance of *C. vidua*.

Brick making process demands fire as an essential, and so is charcoal burning which was also widely practiced in this area. These activities are unintentionally practiced in potential places where *C. vidua* is likely to emerge. Participants explained that the heat produced in both cases has resulted in the eradication of *C. vidua* and subsequently their disappearance.

Respondents noted that carbon (IV) oxide produced during the burning of bricks and charcoal has a potential effect on the current distribution of *C. vidua*. Another participant cited that *the biology* of *C. vidua* demands clean air, thus contaminated air might influence its disappearance.

*“People are cutting down the trees and use them to build houses, burn charcoal and most people had built houses in the habitat of *C. vidua*”* (participant 5)

*“Brickmaking has affected the habitat because of the heat that interfered with its habitat and killed them or made them relocate.”* (participant 8)

**Habitat destruction:** Humans have taken diverse measures in the effort to destroy ant hills which results in the potential eradication of *C. vidua* habitats.

Participants recounted the mass distribution of ant hills in the year the 1960s and *C. vidua* were mostly known to them to be emerging around the anthill environment. Anthills distribution therefore might influence the distribution of *C. vidua*.

Respondents reported that various reasons triggered the destruction or removal of anthills. However, most participants were in consensus that ants were destroying their structures and crops and as such, they had to be controlled. Locals reported destroying ant hills using toxic aerosols. Another local added that channeling these aerosols into the anthills was not only harmful to ants but also to *C. vidua*.

Respondents reported that the soil from ant hills is useful in the sector of agriculture. The farmers mixed the soil from the ant hills with the soil from their farms to improve soil fertility. Some participants stressed that this aspect has contributed to the digging down of ant hills hence the destruction of their habitats. Participants believed that the change in the *C. vidua* could potentially be connected with the destruction of anthills.

*“People were few and ants from the anthills were destroying the houses, this made people to destroy them. If an anthill that is 50 m away has been destroyed, then the C. vidua will not emerge around there because termites are related to C. vidua”* (participant 1)

#### 4.4. Lower Midland 4

**Climate change:** Participants noted the changes in the atmospheric conditions over the years and the weather aspect was important in forecasting the agricultural activities. The respondents emphasized the difference in rainfall parameters as the cause of insect disappearance. In the years 1980, adequacy of rainfall amount was reported by the participants. Locals reiterated further that rainfall impacted the soil moisture content and water table level which influenced the emergence of *C. vidua*.

Participants reported the increase in temperature which might have a causal effect on the disappearance of *C. vidua* as a result of a change in the soil moisture content.

*“It is because there has been less rainfall in the area. Temperature has become too high. Some insects depend on the moisture of the soil; they can be found in some wet areas.”* (participant 4)

**Advancement in agricultural equipment:** Participants stated the wide use of hoes and hand digging tools in the year 1970's as opposed to the current use of tractors in the agricultural sector. They explained that the impact of tractors has contributed to the gradual disappearance of *C. vidua* as a result of habitat destruction. The respondents cited that heavy machines in agriculture are associated with noise, land disturbance, and toxic emissions. *C. vidua* is known by participants to be 'silent' insects and as such, causing land disturbance may trigger their disappearance. When elaborating on emissions, participants reiterated that smoke and oil spillage from the tractors are not eco-friendly to *C. vidua* and other soil biota components. The locals imply that the frequent use of fossil fuel machinery in agriculture is a potential determining factor in the current distribution of *C. vidua* in this zone.

*“Hand digging was practiced and it was not deep this was not affecting the habitat or reproduction of C. vidua”* (participant 2)

*“The kind of farming we practice nowadays is affecting C. vidua; tractors are digging so deep even past the depth where C. vidua was living.”* (participant 4)

**Land degradation:** Various measures contributed to land degradation in this LM as reported by the participants. The aspect of land degradation has gradually increased over the recent decades due to uncontrolled human activities.

Participants have recounted the use of organic fertilizers in the year the 1980s to improve soil fertility in the agricultural sector. They expounded that the use of extract from *Tithonia diversifolia* plant as organic compounds in agriculture was less harmful to soil biota composition and added that this element has potential cause in the past distribution of *C. vidua*. As reiterated by the participants, there are emerging changes in trends in the agricultural sector leading to the wide use of inorganic fertilizers to improve soil value. A participant stated that inorganic compounds are toxic and impacting on the soil biota components. Another participant added that soil precipitation as a factor is a peril to *C. vidua* and its habitat.

Participants were aware that the spillages of inorganic fertilizers were harmful to *C. vidua* and its habitat. The locals believe that these practices have potentially contributed to the disappearance of *C. vidua*. Participants noted the wide practice of charcoal burning in the region over the recent decades. They explained that charcoal burning generates heat to the ground and produces carbonated air which is not eco-friendly to *C. vidua* and its habitat. Compared to other lower midlands, charcoal burning is not much intensive in this region.

*“Charcoal burning can kill C. Vidua because the heat may kill it, though charcoal burning is not much in these areas it never used to be there”* (Participant 3)

*“We are now using tractors, chemical fertilizers which are affecting and destroying them.”* (participant 1)

*“We were never using chemical fertilizers to plant and now we are using, these chemical fertilizers are killing them.”* (participant 5)

**Habitat destruction:** Participants stated that *C. vidua* is currently not being experienced as a result of their habitat destruction due to human activities. Respondents reported that *C. vidua* mostly emerges in areas near the anthills. However, residents destroy ant hills around their vicinities for economic importance. When asked about the reasons for ant hill removal, they talked about the use of anthill soil in the making of charcoal stoves due to its clean debris and uniform texture, whereas some believe it has medicinal value on wounds.

The process of anthill removal is key since they also use toxic aerosols to achieve their purpose. The locals recounted that ant hills have channels that potentially connect to *C. vidua* habitat and result, *c. vidua* are also terminated. Anthills that respondents associate with the emergence of *C. vidua*, may account for the current distribution of *C. vidua*.

*“Off late even the children born in the 1990s do not know about C. vidua.*

*People have dug ant hills so much especially when they want to use the soil from anthills to smear houses.” (participant 1)*

*“People started digging out ant hills and there has been less rainfall; these have made *C. vidua* to start reducing.” (participant 4)*

#### 4.5. Lower Midland 5

**Climate change:** LM 5 is not prone to rainfall like other lower midland zones, however, participants reported on the aspect of climate change over the decades.

This zone is known for little rainfall per annum ranging between 700 mm - 800 mm, despite that, participants have reported a decline in rainfall amount over the years with the increase in temperature which ranges between 22.4°C - 22.7°C [17]. *C. vidua* is known to participants to emerge during the rainy season. The respondents noted that the decline in rain experienced with increased temperature has contributed to the disappearance of the insect.

*“We had a lot of rainfall compared to nowadays because there were many trees which have been cut; our mountains had many trees and bushes that attracted rainfall.” (participant 5)*

*“This place has a high temperature that could be leading to the disappearance of *C. vidua*. This is because when it takes time to rain these insects that live in the soil die.” (participant 5)*

**Advancement in agricultural equipment:** Technology in agriculture has made it possible for the shift from hand digging to the used machinery in farming. Participants have reported on the current wide use of tractors in farming as a replacement for hand digging tools. Respondents believe that tractors are digging deep beneath the ground, hence affecting the potential habitats of *C. vidua*. These types of machinery also spill oil on the farm while in use along with the smoke emissions. Locals believe that the spillage and emissions are not eco-friendly to *C. vidua* and as such, they trigger their disappearance.

*Carebara vidua* also known by the participants as “silent” due to their nature, do not like a disturbance in the environment. Another local explained that the use of tractors causes a lot of vibration and disturbance in the *c. vidua* environment potentially resulting in their disappearance.

*“We were hand digging, we never used tractors on our farms. Nowadays tractors are digging deep into the soil and destroying the habitat of *C. vidua*.” (Participant 5)*

*“Our method of farming has affected them; tractors have interfered with the habitat of *C. vidua*; the older people were not allowing anyone to use tractors because they believe tractors damage the soil.” (participant 1)*

**Land degradation:** Respondents reported frequent charcoal burning as one of the economic activities in the region. The locals noted that charcoal burning produces heat that is harmful to *C. vidua* and other soil biota components. They further stated that the smoke produced during charcoal burning has an impact on the ecosystem. They also explained that their effect on the air contamination

and subsequent formation of acidic rain is harmful to *C. vidua* and could warrant their disappearance.

Participants talked about the current use of inorganic fertilizers and pesticides. Another respondent explained that when inorganic compounds find their way to the soil, they become toxic to *C. vidua* and its habitat.

“Charcoal was being burned but not at the high rate as it is being done today.” (participant 1)

“People were not farming the crops like tomatoes that need to be sprayed with chemicals. Pesticides that are currently being used have also killed them.” (participant 8)

**Habitat destruction:** Participants reported on the destruction and removal of ant hills in the area. Anthills were removed due to various reasons such as the use of anthill soil in the making of charcoal stoves, and the effect of ants on crops and temporary houses.

Participants noted that *C. vidua* emerges some meters around the anthills. Respondents believe that the application of toxic aerosol on ant hills interferes with soil biota composition and the subsequent disappearance of *C. vidua*.

“There were so many ant-hills which have been destroyed, and the rainfall has reduced.” (participant 1)

“They used to emerge from anthills. The ant hills were removed and this made *C. vidua* relocate.” (participant 4)

## 5. Discussion

The findings of the study have shown that over the years across the LMs there have been changes in the distribution of *C. vidua* and the population of insects emerging has reduced due to climate changes; rainfall patterns and amount. This study is in agreement with the study of [18] which reports that the population dynamics of insects have been influenced by climate change. The rainfall pattern has changed as there used to be heavy rainfall which was predictable during the emergence of *C. vidua*. The insects were many and could only emerge during the period of heavy rainfall when the soil was moist since *C. vidua* is a subterranean ant. However, due to changes in climate, heavy rainfall cannot be predicted and this has affected the emergence of black ants as they are seasonal insects which emerges only on specific months. This finding confirms the study of [19] which states that termites and other subterranean ants live in a moist environment in the soil. The period of emergence is associated with the agricultural calendar as the weather pattern predicted when the farm activities were to take place. The weather pattern has changed and the population of *C. vidua* has gradually declined; the month and year of emergence can no longer be predictable as the temperature has increased affecting soil moisture content and hence the distribution of the insect. There are no previous studies that support our findings. LM 5 has become too hot due to climate change hence the insect has not been experienced for many years ago.



The findings showed that the use of farm tools such as tractors has caused damage to the habit of *C. vidua* since tractors dig deeper into the soil where the underground insects live, this also exposes the eggs or the immature insects to the hot sun during cultivation in cases where cultivation is done during the reproduction stage unlike in the past when people could only use hoes and ox plow for the cultivation of land where most of the lands were undisturbed where the insect was mostly emerging from. Tractors have caused air and noise pollution as it produces Carbon (iv) oxide (CO<sub>2</sub>) gas which may cause breathing problem for *C. vidua* and the formation of acid rain that destroys the habitat of the insect. This confirms the study of [20] which states that the omission of gases such as CO<sub>2</sub> are affecting atmospheric air and they are also deposited to the ground through rainfall. Noise and vibration made by tractors during cultivation have made the insects relocate to some unknown places as land has been disturbed and gases emitted in the air.

The findings of this study showed that the habitat of soil-dwelling insects has been lost due to anthropogenic activities, including deforestation which has reduced the forest cover hence changing the rainfall pattern and increasing the air temperature. These have caused changes in the distribution of the insect across the LMs as its population trend, are declining over the years. Charcoal burning has negatively affected the life of the underground living organisms as heat generated increases the temperature of the soil which tends to kill the *C. vidua* or alter their reproduction capabilities and cause migration of these insects to other unknown places, the carbon emitted from toxic smoke also suffocates the subterranean insects. This confirms the study of [21] which states that fire burning influences soil-dwelling organism through soil heating and produces noxious smoke which causes death to the subterranean living organisms.

Over the years, continuous and inefficient use of chemical fertilizers, and pesticides on the farm have destroyed the ecosystem of *C. vidua*, which in turn has polluted the soil where *C. vidua* lives. Pesticides, herbicides, and fungicides have contaminated the soil and killed the soil-dwelling invertebrates. The intensive use of agrochemicals has been influenced by most research organization which have encouraged farmers to be controlling weeds, pests, and diseases to be using the agrochemicals; this, in turn, has led to the reduction of the population of *C. vidua*. The application of aerosol chemicals in anthills to destroy the ants has caused havoc in the environment in which *C. vidua* lives as there is a connection channel between the nests of termites and *C. vidua* underground [22]. These agrochemicals have negative influence in the community of black ants as it one of the major factor causing extinction of this insect.

The use of soil in the making of charcoal stove liners, briquettes, and bricks for economic purposes has contributed to the loss of habitat as a large surface area of soil is dug and removed. During the brick making, the heat generated increases the soil temperature which kills and suffocates the insect, the CO<sub>2</sub> produced during brick making is harmful to the health of subterranean insects.

Habitats of ground-dwelling insects such as *C. vidua* have been lost and destroyed through the application of harmful chemicals such as gladiators to the anthills to kill the ants to destroy the hills. Since the nests of *C. vidua* are built near the nests of termites, these harmful chemical spreads along with the *C. vidua* nests and in turn kills them. This has affected the population dynamics of *C. vidua* over the years across the LMs since most of them are killed and the survived ones tend to migrate hence influencing the distribution. The ant hills were being destroyed due to competing use of land for agricultural purposes as the population increased since the available land could not support the growing population. Kerosene and salts could sometimes be used to destroy the ants in the process of destroying the ant hills this suffocates black ants as kerosene blocks the air spaces in the soil. In the 1980s backward when people never used to destroy the anthills, *C. vidua* was emerging in plenty around the areas associated with the hills. The environment around the ant hills could support the survival of *C. vidua* because the environment is moist. The hills were being destroyed due to various reasons; anthill soil was fertile and was used for farming, and making charcoal and the ants were destroying crops and madhouses as well.

## 6. Conclusion

Changes in the distribution of black ants were attributed to anthropogenic activities such as land degradation, and intensification of agriculture which led to the advancement of agricultural equipment such as tractors, climate change, and habitat destruction through damaging of termite hills and the use of chemicals to kill them. The decline in the population of black ants emerging over the years has become a scientific and societal challenge to many researchers and entomologists since there are no previous studies done on *C. vidua* at a particular.

## 7. Recommendation

Entomologists should do more research on *Carebara vidua* because there are limited previous studies done about the insect and no recent studies are done.

Government and other stakeholders should aid in the funding of the management of *C. vidua*, provide programs for the conservation of endangered species, and implementation of national regulations that govern the use of insects as food and feed to promote sustainable consumption. The community and the government should work together to take some action for protection and management of the *C. vidua* in zones in which they are still emerging as there are some communities which are still experiencing their emergence but in low numbers.

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## Conflicts of Interest

There is no competing interest.

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