

**CROP DAMAGE BY GREY CROWNED CRANE (*Balearica regulorum*) ON
FARMS IN UASIN GISHU COUNTY, KENYA**

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has never been presented for the award of an academic degree in any other university and should not be copied or reproduced in any format without written authority from the author and/or the University of Eldoret.

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DEDICATION

To my parents, my late father, Mr. Maurice Ngobola Kitui, and my mother, Mrs. Agnes Namalwa Kitui, for believing in me before I could believe in myself, and to my spouse, Lawrence Saruni Nkoyo, and our children, Lionel, Liam, and Grace.

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ABSTRACT

Continued loss and degradation of natural habitats force wildlife species to extend their habitats into farmlands and human-dominated landscapes. The Grey Crowned Crane (*Balearica regulorum*), classified as endangered, is increasingly found foraging in agricultural landscapes due to ongoing habitat loss, raising concerns about crop damage and its effects on local livelihoods and species conservation. This study examined the extent, types, and economic impact of crop damage caused by Grey Crowned Cranes in Uasin Gishu County, Kenya, a key region for national agriculture. Using a purposive sampling method, farms with known crane activity and diverse crops were selected, and data were collected over 21 weeks through direct field observations, weekly photographs, and systematic crop damage assessments. Five common crops, maize, wheat, spinach, millet, and peas, were monitored to determine their vulnerability to crane-related damage. Observations were categorized by damage type (roots, leaves, stems, full or partial loss) and analyzed based on crop growth stages, proximity to wetlands, and crane numbers. Economic impact was measured by comparing yields and revenues from plots affected by cranes to those unaffected. Results showed that maize ($0.18\% \pm 0.06$ SE), spinach (3.01 ± 0.37 SE), wheat (0.14 ± 0.06 SE), and peas (0.06 ± 0.01 SE) suffered significant damage, especially during early growth stages, while millet (0.00 ± 0.00 SE) showed no visible damage. Spinach was the most vulnerable crop, with leaf and stem damage being the most common. Crane behaviors causing crop loss included foraging, pecking, and trampling. The economic analysis revealed notable reductions in yield and income in affected plots, highlighting a real threat to farmers' livelihoods. Nevertheless, the study also indicates that this damage can be prevented using context-specific, non-lethal methods. This study recommends adopting sustainable mitigation actions, such as farmer education, developing wildlife-friendly farming practices, and establishing compensation or incentive programs to offset losses to foster peaceful coexistence between humans and wildlife while ensuring the long-term survival of Grey Crowned Cranes. Overall, the study offers valuable insights into balancing biodiversity conservation with sustainable agriculture in landscapes heavily influenced by human activity.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Continued loss and degradation of natural habitats force wildlife species to increasingly extend their habitats into farmlands and human-dominated landscapes, intensifying conflicts with people as resources diminish (Harich *et. al.*, 2023). Human-wildlife conflicts are defined as interactions between humans and wildlife with negative outcomes. They can also be described as ‘struggles that arise when the presence or behavior of wildlife creates actual or perceived, direct and recurring threats to human interests or needs, leading to disputes among groups of people and negative effects on both humans and wildlife’ (IUCN *et. al.*, 2020). Essentially, human-wildlife conflict involves a direct or perceived interaction where disagreements or clashes happen between wildlife and humans. These conflicts usually involve interaction, intent, or recurrence elements and are often tied to underlying social tensions. They frequently involve species that are of conservation concern.

These conflicts happen when wildlife's needs and behavior harm human goals or when human activities harm wildlife's needs. Climate change, growing human and livestock populations, increased economic activities, and changes in land use have been reported as major contributors to declining wildlife populations in Kenya (Ogutu *et al.*, 2016). While direct wildlife damage is often cited as the primary driver of conflict, the issue can persist even after the damage is reduced, highlighting the need for innovative and comprehensive approaches to resolve the conflict in the long term (Dickman, 2010).

Conversion of natural habitats and conventional agricultural practices has led to biodiversity loss (Tschardtke *et al.*, 2005). Damage to crops and properties, loss of livestock, and loss or injury to humans by wildlife have consequences for people's livelihoods and food and agricultural security.

Many wildlife species exhibit specific dietary requirements, which often compel them to explore larger areas in search of suitable resources, sometimes bringing them into proximity with human settlements. Animal species are remarkably adaptable and have been widely observed in human-dominated environments, mainly due to their ability to exploit anthropogenic resources (Riley, 2019; Lowry, Lill, & Wong, 2013). Even in the absence of a particular ecological driver, such species capitalize on readily available food sources, adjusting their behavior and habitat use accordingly. Over time, individuals or groups may become habituated to human presence, especially where high-calorie or predictable food resources are accessible (Oro. *et al.*, 2013). While this behavioral flexibility enhances survival in modified landscapes, it simultaneously increases the potential for human-wildlife conflict, as their presence may pose actual or perceived risks to people (Redpath *et al.*, 2015).

In Kenya among the wildlife species causing crop damage are elephants (*Loxodonta africana*), baboons (*Papio anubis*), buffalos (*Syncerus caffer*), and hippopotamus (*Hippopotamus amphibious*). Birds are also significant agricultural pests that cause substantial economic losses by feeding on and damaging various crops, leading to increased costs for farmers. This persistent damage directly drives human-wildlife conflict, as affected farmers often resort to lethal control or aggressive mitigation methods to protect their yields. Hence, Human-Wildlife Conflict is a serious obstacle to achieving conservation goals worldwide. Avian crop pests can be extremely persistent

and severely damage a small crop field even with consistent diurnal bird scaring activity (Hiron *et al.*, 2014). Research into avian crop pests on subsistence farms and traditional management techniques has been very limited with crop pest management almost exclusively focusing on one species: the Red-billed Quelea (*Quelea quelea*). This is despite other species like the Village Weavers, (*Ploceus cucullatus*), being important crop pests for subsistence farmers. Therefore, there is limited published knowledge about bird behavior and crop damage patterns in small-scale traditional farming systems in Africa. For example, the red-billed quelea, (*Quelea quelea*), is one of Africa's most notorious cereal pests (Mutisya *et al.*, 2016). All the crops on which quelea feed are annual or biennial cereals, which may be rainfed or irrigated (Allan, 1983). To mitigate this, several measures have been taken to address this issue of crop damage, including petrol bombing.

There are 15 species of cranes (Aves: Gruidae) globally, with only four species of cranes occurring in Africa and only two residents to Kenya: the Grey Crowned Crane and the Black Crowned Crane. Grey Crowned Cranes have a spiky, straw-colored crest, a grey body, a large, distinctive white patch on the wing, a black head with white cheeks, and red throat wattles. (See Figure 1.1 below)



Plate 1.1: Grey Crowned Crane picture

Source: Wamiti, 2025

Grey Crowned Cranes have declined precipitously in the last 30 years (Beilfuss *et al.*, 2007). There are two subspecies of these birds, the East African (*B. r. gibbericeps*) and

Southern African (*B. r. regulorum*) Crowned Cranes that are separated by the Zambezi River system (Archibald, 1996; Mirande & Harris, 2019). The East African Crane comprises most Grey Crowned Crane numbers and is distributed from Northern Uganda and Kenya south to Zimbabwe, Botswana, and Namibia (Archibald, 1996). The species has been listed as endangered on the IUCN Red List of threatened species. A major threat facing cranes in Kenya is habitat loss. This has led to a rapid decline in the populations of the species over the last 45 years. Despite this, Kenya has the largest population 10000-12500 individuals, (Morrison, 2015). The Kenyan population was estimated at 8000 - 10000 individuals after the 2019 and 2023 countrywide census (Wamiti *et al.*, 2020).

In many parts of the world, cranes have coexisted with agriculture for thousands of years, adapting to various situations with a productive population in traditional and low-intensity farming practices (Austin *et al.*, 2018). Grey Crowned Cranes are often found outside protected areas, near human activity and on agricultural lands (Mirande & Harris, 2019). These interactions primarily occur in human-dominated areas where agriculture is prevalent, and cranes benefit from the waste left after harvest or during planting seasons. They rely on farmlands for most of their annual cycle, and all 15 species of cranes depend on varying degrees of croplands and pasturelands. However, the rate of agricultural change has accelerated since the early 1900s across nearly all regions of the world, leading to significant habitat loss, increased conflicts with farmers, and greater impacts on crane populations (Austin *et al.*, 2018). While crane foraging in fields can help farmers by removing invertebrate pests and leftover grain, cranes sometimes uproot newly sprouted maize plants and feed on the attached kernels. As a result, agriculture has been one of the primary drivers of severe population declines in 11 of the 15 crane species worldwide (Austin *et al.*, 2018), as

well as the most affected sector due to crane damage.

Grey Crowned Cranes in Africa exhibit opportunistic foraging behavior and frequently feed in cultivated lands. These cranes are drawn to agricultural fields due to the abundance, accessibility, and high nutritional value of cultivated crops, weeds such as sedges, and insects commonly found in such environments

1.1 Statement of the Problem

As human populations and agricultural activities continue to expand, conflicts between wildlife and humans are becoming more frequent and intense. One such conflict involves cranes, particularly the Grey Crowned Crane (*Balearica regulorum*), whose increasing interaction with farmlands has led to widespread concerns about crop damage and its socioeconomic consequences.

As Mackworth-Praed and Grant (1957) observed, Grey Crowned Cranes can cause significant damage to young crops, especially during germination and early growth stages. Pomeroy (1980) also highlighted the extent of such damage, emphasizing that cranes often pull out maize seedlings to consume the kernels, and their foraging movements within fields result in widespread trampling of tender plants. These behaviors form the primary cause of conflict between farmers and cranes Gichuki (1993).

Olupot *et al.* (2016) notes that declining wetland habitats in Uganda have caused cranes to live in human-modified areas, which unfortunately leads to conflicts. Cranes feed on various crops like maize, millet, sorghum, soybeans, and others. The extent of the damage and the economic impact are not mentioned.

There has not been any research done in Kenya on the issue of crop damage by Grey Crowned cranes, despite König *et al.*, (2020) observation that decision makers need evidence-based information to design management plans and policy instruments to address conflict rather than on assumptions and reports from farmers who cannot quantify the damage to crops.

Despite the increasing frequency of such interactions, a notable lack of empirical research remains on the extent, nature, and economic impact of crane-induced crop damage in Kenya, particularly in Western Kenya. This region, which hosts approximately 50% of the country's population (Wamiti *et al.*, 2020), is highly dependent on agriculture and supports a significant portion of Kenya's Grey Crowned Crane population. However, no comprehensive studies have been conducted to identify which crops are most vulnerable, the quantity of crop losses incurred, or the stages of crop development most susceptible to crane damage.

The absence of such data leaves a critical knowledge gap that hampers the development of effective conservation strategies and informed engagement with farmers. Farmers are likely to attribute all crop damage to cranes without credible evidence, fueling misconceptions and leading to hostile responses. In some areas, this has led to an increase in reports of cranes being poisoned or injured on agricultural lands, which has directly threatened farmer livelihoods.

Therefore, research that quantifies the nature and magnitude of crop damage caused by Grey Crowned Cranes was needed. Understanding which crops are most affected, when, and under what ecological conditions will help improve the accuracy of damage assessments, support evidence-based conservation interventions, and potentially transform negative perceptions among farmers.

Documenting the foraging behavior of Grey Crowned Cranes in agricultural landscapes is essential for developing solutions that reduce crop loss while protecting the species. The rising frequency and severity of their impact on farms emphasize the need for preventative strategies based on ecological evidence. Only by understanding the true extent and causes of crane-related crop damage can long-term coexistence between farming communities and this iconic species be achieved.

Crane-induced crop damage poses a major threat to agricultural productivity, farmers' livelihoods, and conservation efforts. This study aimed to quantify the extent of crop damage caused by Grey Crowned Cranes and evaluate its economic impact on farmers.

1.2 Justification of the Study

Uasin Gishu County is one of the key agricultural hub in Kenya and is often called the country's "grain basket" because of its large-scale production of maize, wheat, and other staple foods. Despite its vital role in ensuring national food security, farmers in the area regularly face challenges such as crop damage from wildlife, pests, diseases, and weather-related stresses. These issues lead to household food insecurity, lower farm incomes, and threaten the region's overall productivity and economic health. However, even with its significance in agriculture, there is limited systematic research on the scope, causes, and socio-economic impacts of crane-induced crop damage.

Uasin Gishu County hosts significant populations of Grey Crowned Cranes, a globally endangered species that relies on the county's mosaic of wetlands, farmlands, and grasslands for breeding, feeding, and roosting. The region's extensive agricultural landscape provides both opportunities and challenges for crane conservation, as the birds often forage in farmlands while facing threats from habitat loss, wetland drainage, and human disturbances.

This study is justified because it aims to fill this knowledge gap by generating evidence on the causes, extent, and impacts of crop damage caused by Grey Crowned Cranes in Uasin Gishu. Such information is essential for informing policies and guiding interventions by county governments, extension officers, conservation agencies, and farmers. By providing locally relevant insights, the research will help develop strategies to reduce crop losses, enhance agricultural resilience, and promote sustainable land-use practices.

1.3 Significance of the Study.

The study's importance lies in its potential to guide policy-making to enhance farmer livelihoods. By pinpointing patterns and causes of crop damage, results can assist farmers in implementing effective management strategies to boost yields and secure income. Additionally, the study will help reduce human–wildlife conflicts by offering recommendations that promote coexistence between farming communities and biodiversity. While its primary focus is on Uasin Gishu, the research will contribute to the scientific understanding of crop damage in high-potential agricultural areas and provide adaptable lessons for other regions.

Uasin Gishu County is one of Kenya's major agricultural regions, especially for maize and wheat production. This study is especially timely and relevant. Its findings will help farmers in the county and offer practical recommendations to other areas facing similar human–wildlife conflicts. By connecting ecological research with local agricultural realities, this study can significantly contribute to conservation policy, conflict mitigation, and sustainable land use planning in Kenya and beyond. This thesis and publications from this study will not only add to the knowledge pool on cranes but also

be a reference for researchers, students and scholars interested in doing similar or related studies.

1.4 Research Objectives

1.4.1 Main Objective

To assess crane crop damage in Uasin Gishu County

1.4.2 Specific Objectives

- (i) To determine crop damage by cranes in Uasin Gishu County.
- (ii) To identify crops vulnerable to damage by cranes.
- (iii) To estimate the economic impact of crop damage by cranes .

1.4.3 Research Hypothesis.

- (i) H_{01} : There is no significant crop damage by cranes in the selected farms in Uasin Gishu
- (ii) H_{02} : No specific crops are more vulnerable to crane crop damage as compared to others.
- (iii) H_{03} : There is no economic value of crop damage caused by cranes on farms.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Global human population growth contributes to rising natural resource needs, accelerating the intensification and expansion of agricultural production. The negative consequences of agricultural intensification are further exacerbated by the expansion of agricultural areas, which leads to the loss of natural habitats and fragmentation (Balmford *et al.*, 2012, Dobrovolski *et al.*, 2011; Foley *et al.*, undated) In this way, the expansion of agricultural areas at the expense of natural habitat likely contributes to higher frequencies of human–wildlife interactions (Collins *et al.*, 2010), König *et al.*, 2020). These interactions can have negative consequences for both humans and wildlife. Farmers face losses caused by crop damage, and wildlife faces the possibility of poisoning or other forms of harm.

Wild birds provide numerous benefits to agricultural systems globally, notably their well-documented roles in supplying a variety of ecological services such as pollination, seed dispersal, arthropod pest biocontrol, nutrient cycling, and ecosystem engineering (Whelan *et al.*, 2008; Wenny *et al.*, 2011). Conversely, farmlands offer many bird species fundamental or supplementary foraging opportunities and alternative habitats, particularly when natural habitats are lost or degraded due to anthropogenic activities (Kitazawa *et al.*, 2021). However, various avian groups can also pose significant challenges to crop production. Granivorous birds are linked to damage across diverse field crops, including multiple varieties of cereals and oilseeds in major agricultural regions, especially throughout sub-Saharan Africa (Linz *et al.*, 2011; Kale *et al.*, 2012). For example, De Mey *et al.* (2012) reported that granivorous birds cause annual rice losses estimated at 13.2% in Senegal. Similar substantial losses are experienced by

farmers cultivating other cereal crops, and although precise data are scarce, these losses hold significant implications for food security, particularly in low-income economies with limited capacity for effective integrated pest management (Alwang et al., 2019). Birds can inflict damage to the crops and a loss to the farmers in all the stages of crops right from sowing and planting to harvesting. (Kale *et al.*, 2014). Agricultural damage by wildlife species in the United States is substantial and widespread and is a serious concern to many agricultural producers. (Conover, 2002) estimated that wildlife-related, economic losses to agricultural producers (farmers and ranchers) currently exceed 4.5 billion dollars annually in the U.S.

Regarding maize cultivation across Africa, numerous granivorous bird species are responsible for grain losses; some cause damage throughout the crop's development, while others impact primarily at specific critical stages or seasonally. The forms of damage vary, including the removal of planted seeds and germinated seedlings by species such as doves and pigeons (*Columbidae*), cranes (*Gruidae*), and francolins (*Phasianidae*). Additionally, finches (*Estrildidae*) may pluck leaves and silk from maize crops for nest building during their breeding periods. Manikins may consume developing floral parts, while weavers (*Ploceidae*) and other large-seed eaters (*Fringillidae*) feed directly on maize kernels (Ferber et al., 2012; Mulungu, 2017).

Agriculture-crane interactions can also lead to a two-way effect on cranes and humans. Agriculture and related land use can affect crane habitat and food availability, but cranes can also negatively affect agricultural production. In Moiben area, farmers are converting open lands into agricultural fields and planting crops that cranes feed on. These two-way effects can in turn, lead to various responses, that is, cranes potentially

adapting to changes in agriculture and land use or humans responding to crane foraging by changing agricultural practices and by investing in crop damage prevention or compensatory strategies (Hemminger *et al.*, 2022)

Wide varieties of arable crops attract granivorous birds which leads to significant damage to crop yields globally. The problem of crop damage by birds is faced by the farmers and the losses due to crop depredation by birds are significant in terms of the gross crop yield. Quantifying crop damage by cranes

As a group, cranes are cosmopolitan, occurring worldwide except for South America and the Arctic regions. Most of the species prefer open landscapes with a wide range of visibility and shallow wetlands for breeding, feeding, and roosting (Günter Nowald, 2018). All species of cranes, except for the Siberian Crane, feed on crops such as wheat, maize, rice, soya, and oats occasionally, or regularly at certain times of the year (Austin *et al.*, 2018) The exploitation of these cultivated foods is most common during the non-breeding period in most wetland dependent species. Of the cereal crops, maize *Zea mays* is a preferred food for cranes in many parts of the world (Mafabi, 1991; Reinecke & Krapu, 1986; McIvor & Conover, 1994; Nilsson *et al.*, 2016). Complaints of crop damage attributed to Sandhill Cranes are rising with an increase in crane population numbers in the United States (Hemminger *et al.*, 2022; (McIvor & Conover, 1994b). Cranes are vulnerable to persecution by farmers because of the damage they can inflict on crops as they prefer agricultural lands because of the energy-rich plants they provide, especially those close to wetlands and roost sites (van Velden *et al.*, 2016; Nilsson *et al.*, 2016). Conover, 2001 points out that 89% of crop damage is caused by wildlife. There are costs and benefits attributed to bird activity in agricultural landscapes (Triplett *et al.*, 2012). Breeding commitments and nutritional requirements of cranes change over time depending on the season they are in (Gichuki, 2000). Although many

farmers enjoy having wildlife on their property, wildlife cause significant loss of income through damage to crops or farm infrastructure (up to US\$2 billion annually in the USA alone; (McIvor & Conover, 1994). Reports of crop damage by sandhill cranes in the United States have increased with the growing population of the species (McIvor & Conover, 1994). Crane damage to planted maize and severe damage had been documented in different areas involving different species of cranes. Van Niekerk, 2010 points out that Grey Crowned Cranes are responsible for crop damage in commercial farms in the Eastern Cape of South Africa. According to (Pomeroy, 1980), damage to crops by Grey Crowned Crane in Uganda can be extensive, especially to annual crops in large fields towards the end of the dry season when, presumably, insects are harder to find. This damage to crops is often indirect, as when the birds trample cotton while displaying, or when seedlings are dug up in search of insects. In Kenya, despite reports and complaints from farmers on crop damage by the grey Crowned Crane, no systematic attempt was however made to quantify the damage caused by the birds and ascertain to what extent Grey Crowned cranes are responsible for crop damage.(Plate 2.1 and 2.2 below)



Plate 2.1: A flock of cranes feeding near a mature wheat farm

Source: Wamiti, 2024



Plate 2.2: A flock of cranes in a field with harvested maize.

(Source: Wamiti, 2024)

2.1 Vulnerability of crops to crane depredation.

Crop depredation by birds is a severe problem in the agricultural sector. Damage assessments of common crops indicate that Sorghum was the most affected crop due to depredation followed by pearl millet and combined chickpeas and pigeon peas crops (Kale *et al.*, 2014). Cranes feed more on animal proteins during the egg-production period and for rearing offspring and more on plant foods during the non-breeding periods. (Gichuki, 1993), Energy-rich plant foods are crucial during migration and winter when energy demands increase. Some crane species have morphologies and foraging strategies reflecting their adaptation to special habitats. Intensification of agriculture over the last 50 -100 years in many areas and the increase in concentrated and predictable food resources have resulted in a greater abundance of food for many crane species, particularly harvest residues. Cranes also take advantage of newly sown, sprouted seeds that generally have a higher protein content than waste grains, (Austin *et al.*, 2018).

Grey Crowned Cranes are largely associated with wetlands but also forage extensively in dryland habitats, including short to medium-height open grassland, lightly wooded savanna, and agricultural fields (Pomeroy, 1980; Archibald, 1996). In Uganda, Grey Crowned Cranes feed mainly in grasslands but require wetlands to breed in and where possible large trees for roosting (Pomeroy, 1980). Greater Sandhill Cranes (*Grus canadensis tibia*) has been a focus of much research related to agriculture (Reinecke & Krapu, 1986; McIvor & Conover, 1994; Conover, 2001). Greater Sandhill Cranes are opportunistic and omnivorous feeders, which readily incorporate cultivated lands in their foraging routine during late August and early September in southeastern Idaho. Iverson *et al.* (1987) reported that barley fields constituted about 80% of diurnal habitat use by Sandhill Cranes in Alaska during spring. According to Sugden *et al.*

(1988), Sandhill Cranes foraged in unharvested fields during autumn and were responsible for losses to commercial crops by removing grain and trampling young plants. (McIvor & Conover, 1994) studied the use of barley and maize fields by Sandhill Cranes following the spring planting in northern Utah. Su (2003), working in Wisconsin in spring, found Greater Sandhill Cranes preferred fields of soybean, maize, mint, and oats/rye over other land cover types.

Several studies of Grey Crowned Crane have referred to their use of cultivated lands. Pomeroy (1980) working in Uganda, reports that freshly plowed fields attract Grey Crowned Cranes in preference to grassland. (Johnsgard, 1983) mentions that birds often forage in croplands, particularly in soybeans and groundnuts, as previously documented by (1980). Mmari (1993) found that Grey Crowned Cranes in West Kilimanjaro, Tanzania, forage for food in a wide range of terrestrial and semi-aquatic habitats which included pastures. Archibald, (1996) indicates that the species account of the Grey Crowned Crane forage in croplands for groundnuts, maize, millet, and other items. Muheebwa (2004) points out that Grey Crowned Cranes exploit cultivations, and that maize is particularly important in their diet in Uganda. In South Africa, 56% of records of Grey Crowned Crane are from cultivated lands, 7% of which are recorded on maize fields (Hockey *et al.* 2005). This observation supports the fact that Grey Crowned Crane indeed utilizes cultivated lands as foraging areas.

According to Allan and Ryan (1993), detailed dietary analyses only exist for the Sandhill Crane, with some work done on the fecal analysis of Whooping Cranes by Hunt and Slack (1989). Reinecke and Krapu (1986) found that the composite diet of spring-migrating Sandhill Cranes in Nebraska contained 97% maize. Cranes staging in September in Western Wyoming consumed 60-71% barley and wheat (Lockman *et al.*

1987). Tacha *et al.* (1985) found that wheat constituted > 95% by volume of the aggregate volumes of foods consumed by Sandhill Cranes in Saskatchewan. The availability of agricultural crops and their vulnerability to damage by cranes is influenced by agricultural practices.

The Grey Crowned Crane that occurs in the southern and the southeastern parts of Africa also forages frequently in agricultural lands, including pastures, irrigated areas, fallow fields, recently harvested fields, and newly planted cereal crops (Pomeroy 1980, Gichuki and Gichuki 1992, McCann and Wilkins 1995, Morrison 1998, Gichuki 2000, Muheebwa 2004, Muheebwa-Muhoozi 2001, Van Niekerk 2018). They especially prefer soybeans, ground nuts, millet, potatoes, and maize (Pomeroy 1980, Muheebwa-Muhoozi 2001)

Plates 2.1 and 2.2 show flocks of cranes feeding on agricultural farms.

2.2 Economic quantification of damage

The behavior of wild animal species in agricultural landscapes may confer benefits to growers through the provision of ecosystem services such as control of agricultural pests or inflict costs through direct or indirect damage to crops. Most damage inflicted by birds in agricultural landscapes is to perennial or annual crops. Birds damage crops directly through chewing or removal of plant shoots, stems, foliage, buds, fruit, and seeds (Triplett *et al.*, 2012). Growers may also experience costs by having to change crop type (e.g. growing bird-resistant sorghum for silage in areas where birds inflict substantial damage to corn, Fox *et al.* 1970) or growing practices like early harvesting to avoid or reduce bird impacts (Fleming *et al.* 2002, Tracey *et al.* 2007) or through the replanting of seasonal crops due to seed predation (Wilson *et al.* 1989). Increasing

numbers of previously threatened large grazing birds such as cranes, geese, and swans are causing crop damage along their flyways worldwide (Amano *et al.*, 2008; Le Roy, 2010), which in turn may cause significant crop damage and economic losses (Heinrich and Craven, 1992; Lane *et al.*, 1998; Lorenzen and Madsen, 1986). For example, the number of reported incidents of crop damage caused by common cranes (*Grus grus*), followed by regulated inspections and governmental compensation in Sweden, has increased over the last few decades and was valued at about 200,000 Euros in 2012.

The problem of crop damage by birds is faced by the farmers and the losses due to crop depredation by birds are in terms of the gross crop yield. Birds can inflict damage to the crops and a loss to the farmers in all the stages of crops right from sowing and planting till harvesting. (Kale *et al.*, 2014) The costs of bird damage can be expressed through direct economic loss (e.g. lower crop yield or down-grading of quality), increased crop management or processing, the cost of control techniques, and the impacts of control measures (White *et al.* 1997, Tracey *et al.* 2007).

2.3 Factors influencing the extent of crop damage by birds.

Avian species inflict losses in agriculture by damaging crops during the sowing, seedling and ripening stages, leading to economic losses to the farming community. Birds are known to cause considerable economic damage to a variety of crops during vulnerable stages in different agroecological regions. The extent of bird damage to any crop depends on several factors like the concentration of local bird population, the total area under the crop, cropping pattern habitat of the area, season, and physiological status of the birds.

The structure of crop plants, characterized by plant height, row spacing, and plant density, is directly related to the accessibility of the plants by birds and rewards for foraging on them (e.g., seeds obtained from sunflower heads (Triplett *et al.*, 2012). The phenological stage of the plants influences the nutritional content of seeds and possibilities of handling and consumption by the birds. Both crop structure and phenology have been shown to be related to bird damage to crops (Bridgeland, 1983; Clark *et al.*, 1982; Hagy *et al.*, 2008). Because weeds serve as alternative foods for birds and, in some cases, attract birds to crop fields before the crop is mature enough to be eaten, weed density within fields also may influence bird abundance and damage to crop fields (Otis and Kilburn, 1988; Hagy *et al.*, 2008). At the field level, the size of crop field, as well as the field perimeter and its complexity (regularity), is expected to be related to bird abundance and damage on the crop fields, because these factors affect the amount and accessibility of food (Clark *et al.*, 1982; Tourenq *et al.*, 2001). Additionally, an abundance of trees on the border of the crop field is expected to positively affect bird abundance and damage in the field, because of their attractiveness to birds as loafing sites (Otis and Kilburn, 1988).

Uasin Gishu County, located in Kenya's Rift Valley, is the nation's "breadbasket," contributing significantly to national maize and wheat supplies (CGIAR, 2021). The county's cool highland climate, fertile soils, and mechanized farming make it ideal for cereal production. However, farmers report increasing challenges from birds feeding on wheat and maize during ripening, with species such as quelea, bishops, and starlings implicated (County Agricultural Reports, 2022).

Unlike lowland regions, Uasin Gishu's large, mechanized farms, interspersed with hedgerows, riparian zones, and forest patches, create unique ecological conditions that may influence bird assemblages and feeding patterns (Otieno, 2022). Climatic

variability, including unseasonal rainfall, is also altering crop phenology, potentially increasing the overlap between bird feeding cycles and crop ripening stages. Despite these emerging challenges, peer-reviewed studies quantifying the extent of bird-induced crop damage in Uasin Gishu are not well documented.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

3.1.1 Location and Size of the study area

The study was done in Uasin Gishu County, one of the 47 counties of Kenya located in the former Rift Valley Province. Uasin Gishu County has its headquarters in Eldoret town. The County lies between longitudes 34°50' East and 35° 37' West and latitudes 00° 03' South and 00° 55' North (Fig 3.1). The County shares common borders with Trans Nzoia County to the North, Elgeyo Marakwet County to the East, Baringo County to the South East, Kericho County to the South, Nandi County to the South West and Kakamega County to the North West. It covers a total area of 3,345.2 Km². The county holds 26.8% of the national population (Kenya National Bureau of Statistics, 2023). Agriculture is the county's major economic source and is very prone to crane damage. The study took place at Ilula (0° 32'19''N, 35°20'19''E) and University of Eldoret farm (0°34'47''N, 35°, 17'54''E).

3.1.2 Climate, Vegetation and Wildlife

Uasin Gishu County is a highland plateau, with altitudes gently sloping from 2,700 meters above sea level at Timboroa in the east to about 1,500 meters above sea level at Kipkaren in the west. The county can be divided into two broad physiographic regions, with Eldoret (2,085 meters) serving as the boundary between them. The topography is higher in the east and slopes down toward the western borders. The plateau terrain in the county facilitates the construction of infrastructure such as roads and the use of modern machinery for farming.

The County lies within the Lake Victoria catchment zone and therefore all the rivers

from the County drain into Lake Victoria. Major rivers in the County include: Moiben, Sergoit, Kipkarren, Chepkoilel and Sosiani. The rivers provide water for livestock, domestic and industrial use.

The County is divided into three zones namely: the upper highlands, upper midlands and Lower highlands. These zones have greatly influenced the land use patterns in the County as they determine the climatic conditions of an area. The geology of the County is dominated by tertiary volcanic rock, with no known commercially exploitable minerals.

There are four main soil types in the County: red loam, red clay, brown loam and brown clay soils. The red loam soils are found mainly in the northern part of the County in Turbo, Moi's Bridge and lower Moiben and this type of soils mainly supports maize, sunflower, and cattle farming. The red clay soils occur around Soy, upper Moiben, and Nandi border areas and they support wheat and maize growing, and the natural vegetation is like that of the areas with red loam soil. The brown clay soils occur mainly on the plateau and cover most of the upper Lessos plateau areas and are good for rearing livestock. Deep brown loam soils occur in high altitude areas of the County around Ainabkoi and Kaptagat that are good for forestry, dairy farming and wheat, pyrethrum, potato, oat, and barley farming.

The County experiences consistent and abundant rainfall, with an average annual range of 624.9mm to 1560.4mm. Rainfall occurs from March to September, with two distinct peaks in May and August. Areas such as Ainabkoi, Kapseret, and Kesses tend to receive higher amounts of rainfall, while Turbo, Moiben, and Soy get comparatively less. Dry spells begin in November and end in February. Average temperatures vary between 21°C. and 32°C. The combination of rainfall and temperature conditions

supports both agriculture and livestock farming.

Eldoret city has the largest population center, as well as the administrative and commercial hub of the County. Uasin Gishu, along with neighboring Trans-Nzoia, are considered Kenya's breadbasket due to their large-scale maize and wheat farms that produce most of the country's total harvest. While the county is known as the country's breadbasket for its agricultural output, it also serves as an important habitat for the Grey Crowned Crane.

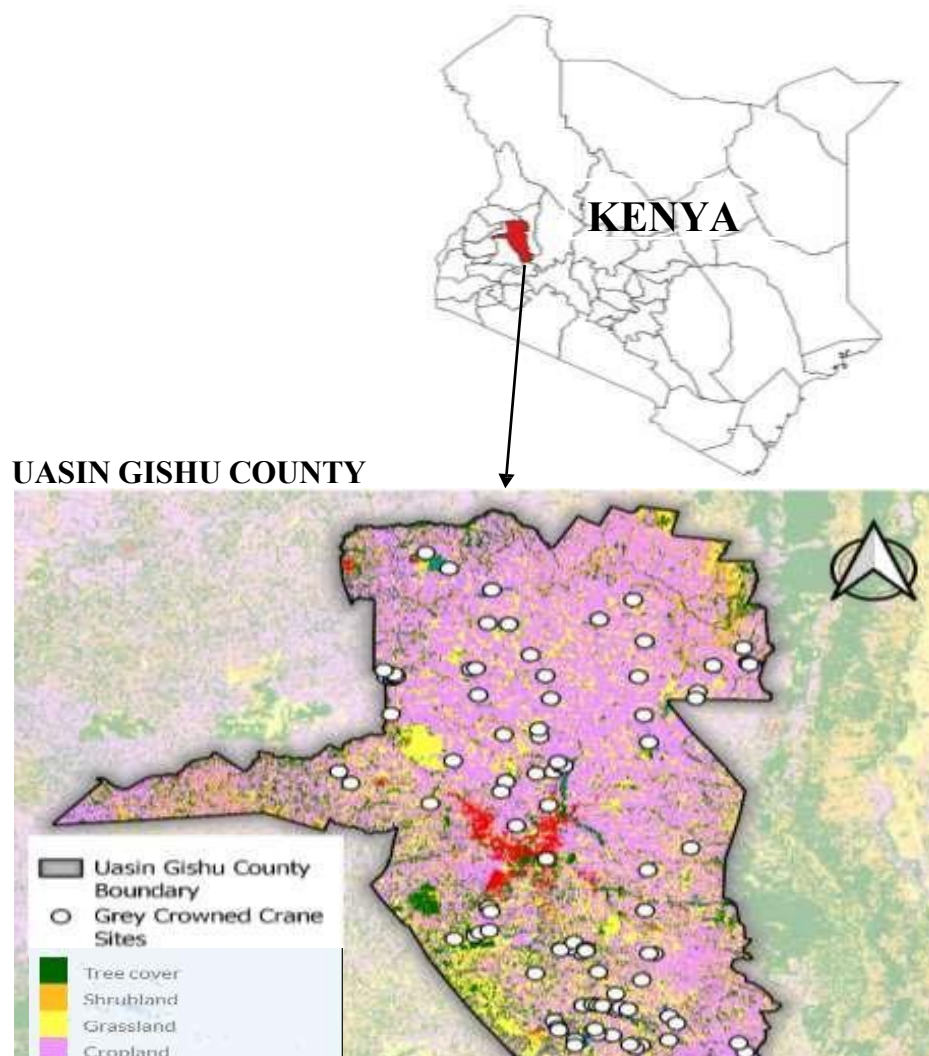


Figure 3.1: Map of Uasin Gishu County, showing Major land uses and distribution of Grey Crowned Cranes in the County

(Source: Author, 2024).

3.2 Study design: Target Population

According to the 2023 National Census Report, the Grey Crowned Crane population of Uasin Gishu County makes up about 26.8% of Kenya's population. The county's economy is mainly driven by agriculture. Since most of the Grey Crowned Crane populations live in farmlands, the human–crane conflict is especially high in this region.

The study utilized the exploratory research study design. Study farms were selected based on both secondary data reviews and primary field investigations. Initial identification of potential study sites was informed by findings from the 2023 Grey Crowned Crane countrywide census by Wamiti *et al.* (2023), (Fig 3.2), which highlighted regions with high crane densities, particularly within agricultural landscapes. This census data provided a broad overview of crane presence across the study area and was a starting point for identifying zones with frequent bird–crop interactions. These findings were further supported by sighting records from the International Crane Foundation (ICF), an organization dedicated to crane conservation that documents observations of Grey Crowned Cranes across several counties, including Uasin Gishu. These records offered information on temporal trends and spatial distribution data useful in pinpointing potential conflict zones (Fig 3.2)

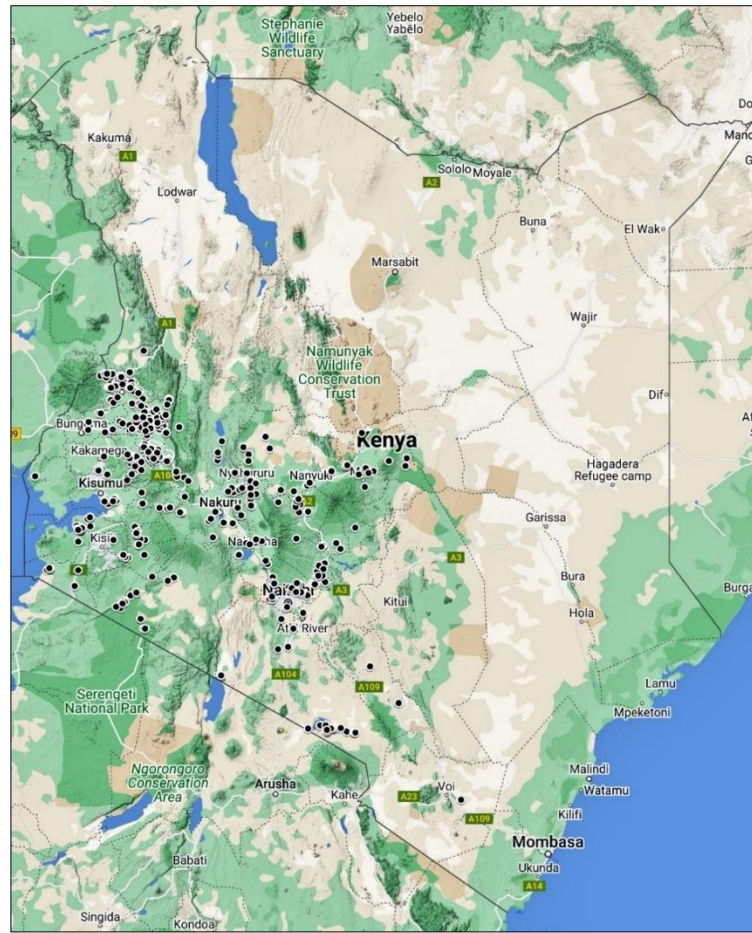


Figure 3.2: Map showing Crane density.

(Source: Kenya Countrywide census 2023 Report; and International Crane Foundation sightings)

To validate and contextualize the secondary data, a preliminary field survey was undertaken. This involved physical visits to the identified locations and participatory engagements with local farmers. Informal interviews and discussions were conducted to understand firsthand the nature and frequency of bird activity, crop damage patterns, bird species involved, and traditional or contemporary deterrent methods in use. Farmers shared personal experiences, often pointing to specific field locations or crop types that attracted birds. This participatory approach enriched the selection process with local knowledge and ensured that farmers' contributions were integrated into site

selection. A preliminary survey was undertaken to distinguish crop damage explicitly caused by Grey Crowned Cranes from damage inflicted by other bird species. This involved identifying patterns of crop destruction typically associated with cranes, including the size, shape, and distribution of the damaged areas, as well as the birds' unique feeding and foraging behaviors. Observations focused on identifying bird species commonly foraging in the study sites, and photographs of the crop damage caused by different species were taken for comparison. Specific feeding behaviors such as pecking, pulling, and probing were documented and compared with existing literature to confirm whether cranes were responsible for the observed damage.

From the above process, a purposive selection of farms was made. The selection of these farms was guided by both practical considerations and the need to ensure a representative sample. The study was conducted in two large-scale farms out of 9 that were sampled and practicing diverse crop regimes, offering a broad perspective on the interactions between cranes and different types of crops.

These farms were chosen based on three main criteria: a high frequency of bird activity or reported crop damage, diverse crop regimes, and typical representation of farming systems. The selected farms were also geographically distributed to capture variability across the landscape. In this case, we focused on either side of the Marura wetland, which is an important breeding, foraging, flocking, and roosting site for the cranes. They served as focal sites for observing avian activity, collecting data on damage to crops, and later quantifying crop loss during the study period.

3.3 Data Collection

This study was designed to quantify and characterize Grey Crowned Crane crop depredation, employing a mixed-methods observational design centered on systematic field sampling and direct observation. Crop damage was quantified using randomly placed quadrats within affected fields to record the total and damaged crop unit counts, providing a measurable loss percentage and categorical classification of damage types (e.g., partial or fully damaged).

Quantitative data was collected weekly over twenty-one weeks across five crops: Maize, Millet, Peas, Spinach, and Wheat. Within each field plot, the field was partitioned into square quadrats measuring 5 meters by 5 meters (25 m²), forming the basic sampling unit. This quadrat size was chosen based on its suitability for detecting localized damage while remaining practical for manual data collection. A grid system was laid over the farm using measuring tapes and ropes to accurately mark out each quadrat within the defined strata.

To determine the total number of quadrats per field, the overall farm area (in square meters) was divided by 25 m². From this total, five quadrats were randomly selected per farm using a random number generator online, ensuring each had an equal chance of inclusion and eliminating sampling bias. The selected quadrats were demarcated using wooden stakes and string and were labeled with unique identification tags to ensure consistent reference points throughout the data collection period as shown in Fig 3.4. This randomized and stratified sampling design enabled the study to capture spatial variation in crop damage, particularly between field margins and interior zones, while providing standardized, replicable units for comparing patterns across different farms and experimental treatments.

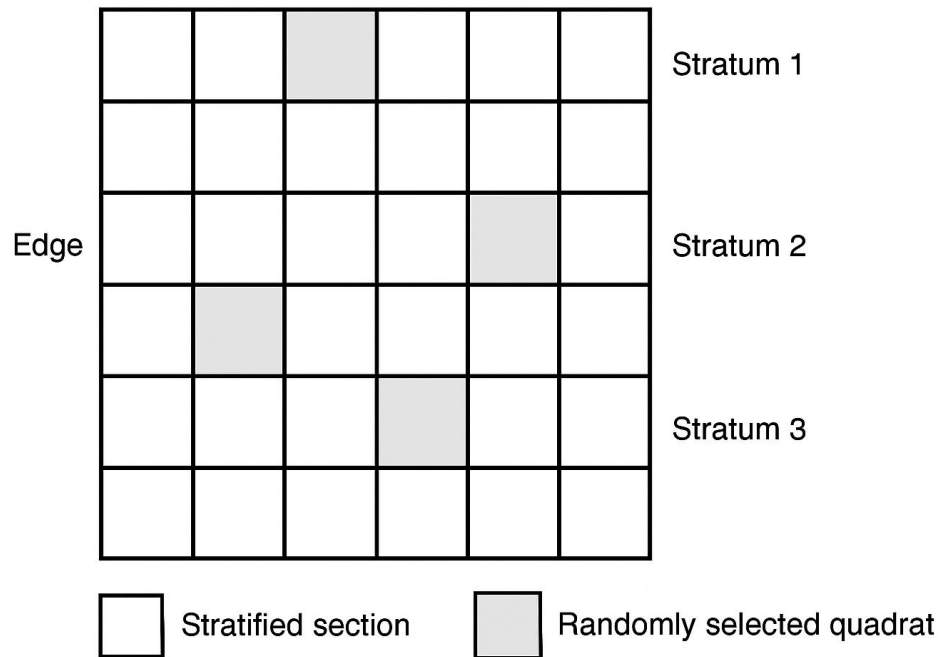


Figure 3.3: Diagram showing how the quadrants were randomly chosen.

Within these quadrants, visual assessments were carried out to record the extent of crop damage, identify affected crop types, and quantify the number of damaged plants. Photographic documentation was conducted using digital cameras to capture consistent damage patterns across all plots.

Crop damage data were collected alongside information on crane abundance at each site. The damage assessment considered the severity of destruction, that is, we collected the number of not damaged crops, partially damaged, and totally damaged (uprooted) per quadrant, the location within the field, and the frequency of crane and other bird activity (The absence and presence of cranes and other bird species in the plots). Economic losses were estimated by comparing market prices of affected crops against the quantity and quality of yield lost due to crane interference. These economic assessments were supported by standard yield benchmarks provided by the Ministry of Agriculture.

3.1.5 Data Analysis and Presentation techniques

Objective 1: To determine crop damage by cranes in selected farms in Uasin Gishu County.

Crop damage caused by cranes and other birds was compared to determine whether cranes were responsible for most of the damage or if it were other birds. Both visual and analytical data support the findings. The results on crop damage to various crops are presented, including observations on damage caused by cranes and other birds.

Objective 2: To quantify the extent of crop damage by cranes in selected farms in Uasin Gishu County.

The number and of crops that were damaged were looked at but due to the difference in density in terms of the number of crops per quadrant, it was quantified that in percentages. (Number of crops destroyed divided by the number planted).

Objective 3: To estimate the economic impact of crop damage by cranes in selected farms in Uasin Gishu County

To estimate the economic impacts of crop damage, the yield per acre was calculated and compared to the ideal yields provided by the Ministry of Agriculture. The difference indicated the economic loss farmers incurred due to the presence of birds on the farms.

All statistical analysis was performed in R 3.3.0 (R Core Team 2025) within the R-studio graphical user interface (Posit team 2025). With the crop damage data collected across five crops: Maize, Millet, Peas, Spinach, and Wheat which had different plant number per quadrant. To allow for comparison across crops, the percentage number of crops destroyed was calculated by dividing the number of crops destroyed by the

number of crops planted in the quadrant multiplied by a hundred. Prior to initiating any statistical analysis, the data distribution was investigated by plotting a histogram and performing the Shapiro-Wilk test of normality. By plotting the response variable (number of plants damaged per quadrants), and undertaking the Shapiro-Wilk test of normality test, the data distribution did not conform to a normal distribution ($w = 0.2465$, $p\text{-value} < 0.001$) and was highly skewed towards the left.

With the data coming from a non-normal distribution after testing it using the Shapiro-Wilk normality test ($W = 0.2465$, $p\text{-value} < 0.001$), the analysis was performed using the Generalized Linear Model (GLM). The response variable, plant destruction was continuous so the GLM model was performed using the Gamma family link which is the ideal model for modeling non-negative continuous data. The data also contained true zeros where no crop damage was recorded. To allow fitting the data to the GLM Gamma family link, the log 10 transformation was used, after which the data was tested to ensure it had not changed its distribution. The data was analyzed using the GLM Gamma family link since all the data was positive, and though it had more zeros, the zero-inflated model was not used since the zeros were true zeroes that is the zeroes indicated where no crop damage had occurred. Results are presented using photos, tables and graphs.

CHAPTER FOUR

RESULTS

4.1 Crops damaged by cranes and other birds

The number of cranes observed within the farms monitored during sampling ranged from a minimum of two cranes to a flock of 85 individuals with a mean of 19.23 ± 2.29 SE (n=110) as shown in Table 4.1 below. Other birds recorded as crop destroyers included Speckled Mousebirds, Doves, Guinea Fowls, Weavers, Starlings, Widow Birds, and Speckled Pigeons, which were present on the farms during times both when cranes were present (65 times) and when they were absent (45 times). Visual documentation showed direct crop damage in the field (Plate 4.2) as a pictorial presentation of the agricultural effects related to cranes and other birds. The photographic evidence revealed regular and identifiable patterns of crop disturbance caused by cranes and other bird's activity. Specifically, signs of uprooted seedlings,



Plate 4.1: Bean crop plucked off by a crane (a) and maize plant pecked by a crane (b).

Source: Author, 2024

defoliation, and pecking damage were observed in maize, spinach, peas, and wheat.



Plate 4.2: Cranes and other birds (Egyptian Geese) in a non matured wheat field.

(Source: Wamiti, 2025)

Table 4.1: The mean, standard error, maximum, and minimum percentage of crops destroyed by birds.

Crop type	Mean Percentage \pm standard error of crops destroyed	Maximum percentage of crops destroyed per quadrant per crop	Minimum percentage of crops destroyed per quadrant per crop
Maize	0.1812 \pm 0.064	9.2873	0.0000
Millet	0.0000 \pm 0.000	0.0000	0.0000
Peas	0.0560 \pm 0.009	0.2899	0.0000
Spinach	3.0113 \pm 0.375	13.1579	0.0000
Wheat	0.1448 \pm 0.060	2.6909	0.0000

Results on the vulnerability of the different crops to damage, showed that spinach was significantly vulnerable to damage (13.1579%) as compared to the other crops, as shown in Table 4.1 above. Crop damage caused by cranes and other birds was observed in four of the five crops monitored with results showing maize (9.3%), spinach (13.2%), peas (0.3%) and wheat (2.7%) except for millet (0.000%) where no damage was recorded. Table 4.2 further presents the effects of the presence of cranes and other birds in the sampled farms.

Table 4.2: Results on the effect of cranes and other bird's presence, number of cranes and age of the plants.

Predictor	Estimate (β)	Std. Error	t-value	p-value	Significance
(Intercept)	0.6.473	0.1669	3.877	0.0002	***
Number of cranes	0.001.211	0.0001626	7.448	<0.05	***
Birds present (Cranes only)	0.009.594	0.01057	0.908	0.365974	
Other birds only	0.009614	0.007577	1.269	0.206963	
Age of plants	-0.00003301	0.0000084	-3.919	0.000149	***
		24			

***: Significance of the predictor

Results on the effects of the presence of cranes and other birds in the farms showed no evidence that the presence had a significant effect on crop damage ($p=0.365974$), Table 4.2 above. However, the model results showed that the number of cranes had a significant positive relationship with the extent of crop damage ($p=<0.05$) as shown in Table 4.2. This shows that the higher the number of cranes in a farm, the higher the significance of the destruction to the crops. The age of the plants also had a negative relationship with the extent of crop damage ($p=0.000149$). This indicates that crops are more vulnerable to cranes and other birds during the early stages after planting. The presence of other birds in the farm did not have a significant relationship with crop damage ($p=0.206963$). However, the intercept, which was the presence of other birds and cranes, had a positive relationship with crop damage ($p=0.0002$). This showed the

additive effects of mixed flocks of cranes and other birds on crop damage, causing more damage than the presence of non-mixed flocks

4.2 Crops susceptible to damage by cranes.

The extent of crop damage was also dependent on plant part, with leaves and stems being the most significantly vulnerable parts ($p < 0.05$) as opposed to the plant being uprooted ($p = 0.626281$). The part destroyed was dependent on the crop. All the recorded damage on spinach was on the leaves ($p < 0.05$), while the destruction on maize and wheat was on both the leaves and the stem ($p < 0.05$) when the maize seedlings were newly germinated as shown in Table 4.3 below.

Table 4.3: Results, on the vulnerability of the five crops at different ages to cranes and other birds and the most targeted crop part.

Predictor	Estimate (β)	Std. Error	t-value	p-value	Significance
(Intercept)	0.07952	0.1192	0.667	0.505137	
Crop (Maize)	-0.0032	0.003621	-0.877	0.381012	
Crop (Peas)	-0.0002	0.005349	-0.035	0.972016	
Crop (Spinach)	0.0176	0.004608	3.815	0.000155	***
Crop (Wheat)	-0.0025	0.004377	-0.570	0.568979	
Plant part damaged (leaf)	0.1091	0.004870	22.413	<0.05	***
Plant part damaged (leaf)	0.1044	0.007967	13.104	<0.05	***

and stem)					
Plant uprooted	0.0072	0.01487	0.487	0.626281	0.07952
Age of plants	-0.000003997	0.000005991	-0.667	0.504985	

Table 4.4: Results on the vulnerability of the five crops to cranes, other birds, and non-bird species

Predictor	Estimate (β)	Std. Error	t-value	p-value	Significance
(Intercept)	0.6517	0.1888	3.451	0.000612	***
Crop (Millet)	0.003235	0.006317	-0.512	0.608806	
Crop (Spinach)	0.04758	0.005724	8.313	<0.05	***
Crop (Wheat)	-0.002980	0.005779	-0.516	0.606366	
Only cranes	-0.02628	0.01261	-2.084	0.037765	*
Non birds only	-0.02803	0.005811	-4.824	<0.05	***
Other birds only	-0.02312	0.008403	-2.751	<0.05	**
Date	-0.00003129	0.000009481	-3.300	<0.05	**

Results on the effects of vulnerability of the crops to cranes, other birds and non bird species in the farm, the model showed that the the presence of crane had a slightly significant effect onn the crop damage ($p= 0.037765$) However, the model showed that the number of cranes had a significant positive relationship with the extent of crop damage ($p=<-0.0001$) as shown in Table 4.2. This shows that the higher the number of cranes in a farm, the higher the significance of the destruction to the crops The age of the plants also had a negative relationship with the extent of crop damage ($p=0.001045$).

This indicates that crops are more vulnerable to cranes and other birds during the early stages after planting and the date of the planting differs across the various crop types. The presence of other birds in the farm had a significant relationship with crop damage ($p=0.006182$). However, the intercept, which was the presence of other birds, cranes, and other wildlife (non-birds), had a positive relationship with crop damage ($p=0.00612$). This showed the additive effects of mixed flocks of cranes and other birds on crop damage, causing more damage than the presence of non-mixed flocks, and more damage when there was no record of cranes or other birds ($p<0.05$)

Cranes were also seen uprooting maize and peas after germination (Plate 4.3). There was however no record of crane destroying millet during the data collection period.

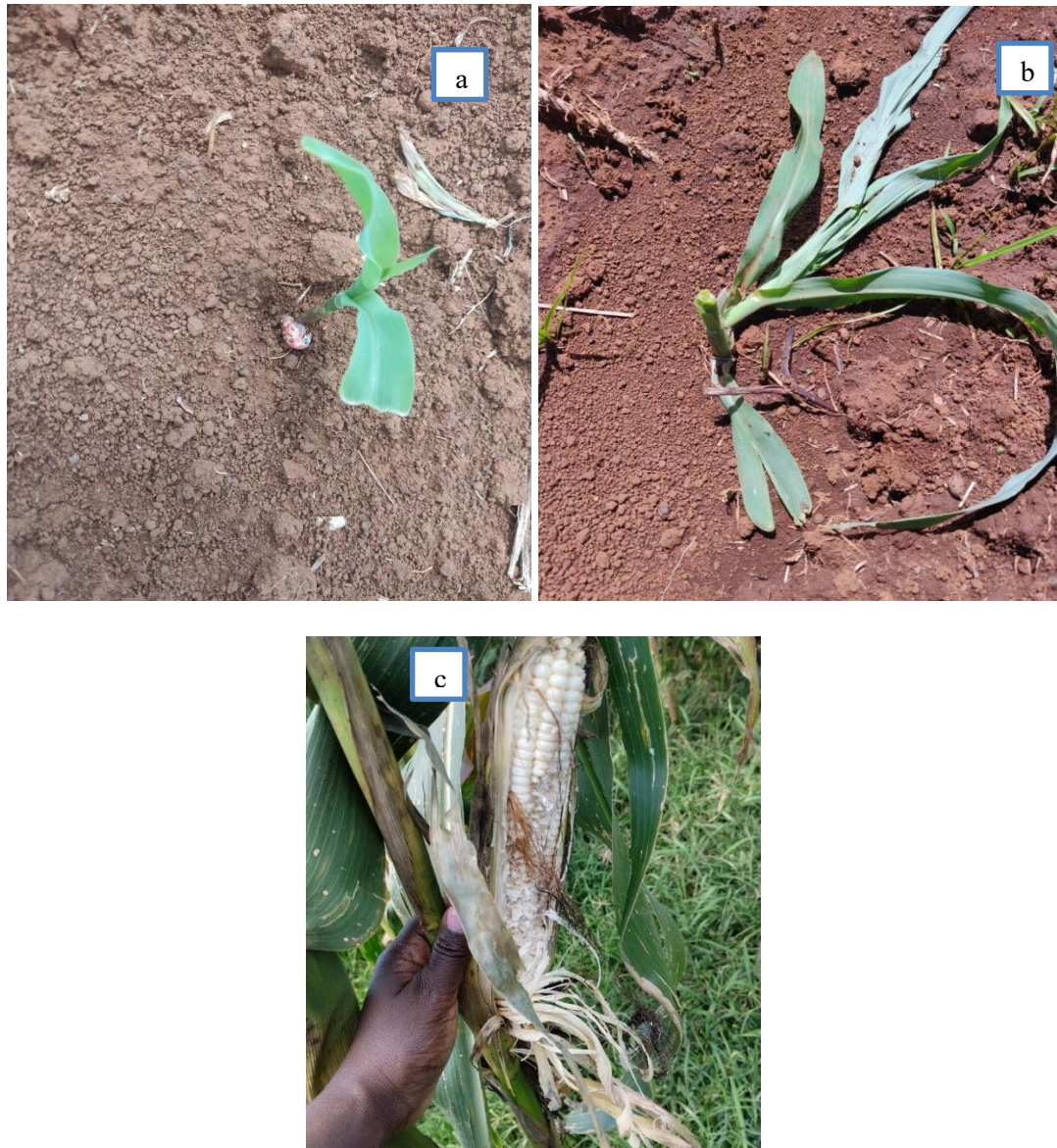


Plate 4.3: Showing pictures of Maize plucked (a), trampled (b), uprooted and pecked(c) by Grey Crowned Cranes

(Source: Author, 2024)

Plate 4.4 above shows the different ways that cranes were destroying maize crop, On the top left, there is the exposure of the kernel by cranes, Trampling(top right) and pecked(bottom right). Table 4.4 below further shows the statistical results on the maximum number of plants destroyed by cranes and other birds per crop type.



Plate 4.4: Grey Crowned Crane on a wheat field

(Source: Wamiti, 2024)

The photo above (Plate 4.4) shows a Grey Crowned Crane in a not mature wheat field eating the leaf of the plant.

Table 4.5: Statistical results showing the maximum number of plants destroyed by cranes and other birds per crop type

Crop type	Mean per quadrant	Standard Error of crops per quadrant	Min number of crops per quadrant	Max number of crops per quadrant
Maize	514.35	51.61	341	701
Millet	10054.80	5889.35	2292	18750
Peas	1054.58	941.03	623	6234
Spinach	137.7692	60.88	24	250
Wheat	65608.80	17174.9	38750	89600

To allow for comparison of the damage, the statistics were calculated on the percentage number of crops destroyed per quadrant, by dividing the number of crops destroyed by the total number of plants planted in the quadrant, multiplied by a hundred. From table 4.5 and figure 4.1, the mean of the crops per quadrant is shows difference in the densities of the crops per quadrant, Maize (514.35), Millet (10054.80), Peas (1054.58), Spinach (137.7692), and Wheat (65608.80)

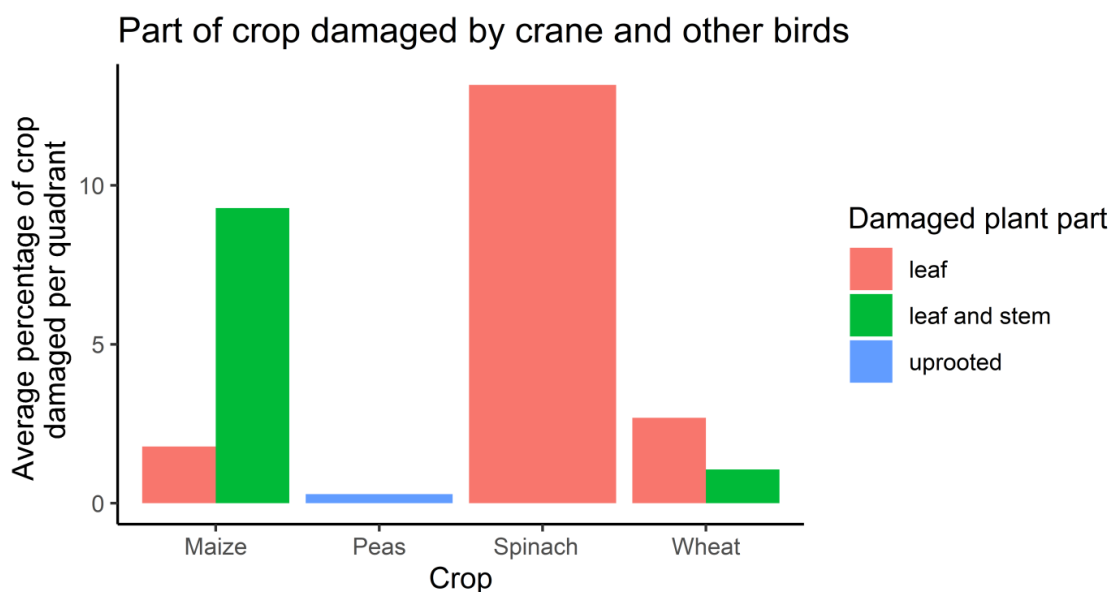


Figure 4.1: Crop damage across the four crops monitored showing the different part targeted by cranes and other birds

Results in figure 4.1 above reveal a clear variation in the extent and type of crop damage caused by cranes and other birds across different crop types. Spinach recorded the highest damage levels (13.16%), primarily affecting leaves, indicating a strong preference for broad-leafed vegetables. Maize also experienced considerable damage (9.28%), especially to both leaves and stems, while wheat recorded moderate leaf and stem damage levels, (2.69%). Peas were the least affected (0.29%), although it was the only crop where uprooting damage was observed, a behavior typically associated with cranes extracting seedlings for nutrient-rich cotyledons.

4.3 Economic quantification of crop damage by cranes.

Quantitative crop damage assessment showed different vulnerability levels among the studied crops. Maize was most affected, with 1.3% fully damaged and 37.4% partially damaged. Leaf and stem damage were recorded at 36.3% and 23.6%, respectively. Wheat experienced significant full damage at 50%, with the other half showing

extensive leaf damage. Interestingly, spinach had no full damage but showed high partial damage at 56.3% and 43.7% full leaf damage. In contrast, millet showed no measurable damage in any category, suggesting resistance or avoidance by cranes. Peas exhibited a unique pattern with 100% root damage (Table 4.6).

Table 4.6: Percentage of degree at which cranes and other birds damaged crops

Crops	Fully Damaged (%)	Partial Damaged (%)	Not Damaged (%)	Leaf Damage (%)	Stem Damage (%)	Root Damage (%)
Maize	1.3	37.4	0.0	36.3	23.6	1.3
Millet	0.0	0.0	0.0	0.0	0.0	0.0
Peas	0.0	0.0	0.0	0.0	0.0	100.0
Spinach	0.0	56.3	0.0	43.7	0.0	0.0
Wheat	50.0	0.0	0.0	50.0	0.0	0.0

Results showed a significant decrease in both yield per acre and income in plots affected by cranes across all the five crops. For example, maize yield dropped from an ideal 4,320 kg/acre to approximately 2,039.6 kg/acre due to exposure to crane and other birds, resulting in a revenue loss of Kshs. 102,618. The largest revenue loss was observed in Spinach, where expected income declined from Kshs. 560,000 (ideal) to Kshs. 199,920 with exposure, leading to a loss of Kshs. 360,080. Millet, although not physically damaged, showed a yield reduction likely related to indirect effects such as soil disturbance or competitive foraging behavior. The smallest revenue loss was wheat (Kshs. 63,397.50), although the damage rate remained significant (Table 4.7) below.

These figures highlight farmers' economic challenges due to crane-related and other birds crop damage, underscoring the urgent need for effective mitigation strategies as the losses were significant.

Table 4.7: Economic Comparison of Crane-Exposed vs Ideal Crop Yields

Crops	Maize	Millet	Peas	Spinach	Wheat
Mean Yield/ Quadrant (kg)	12.60	6.94	5.48	15.40	16.40
Estimated Yield/ Acre (kg)	2039.6	1123	887	2499	2654.7
Ideal Yield/ Acre (kg)	4320	3000	2000	7000	3500
Price per kg (Kshs.) (2024)	45	150	90	80	75
Revenue (Crane- Exposed) (Kshs.)	91,782	168,450	79,830	199,920	199,102.50
Revenue (Non- Exposed) (Kshs.)	194,400	450,000	180,000	560,000	262,500
Revenue Loss (Ksh)	102,618	281,550	100,170	360,080	63,397.50

Results in table 4.7 above shows that yields obtained from fields exposed to cranes and other birds result in significant economic losses, with spinach experiencing the highest revenue loss.

CHAPTER FIVE

DISCUSSION

5.1 Crop Damaged by Cranes.

Results study revealed that grey-crowned cranes cause crop damage in Uasin Gishu County, particularly during the early growth and grain-filling stages of cereals such as maize and wheat. Grey Crowned Cranes are often attracted to young maize and wheat plants because these crops provide a readily available and nutritious food source, especially when natural habitats are degraded. The tender shoots are soft, rich in moisture and nutrients, and easy for the cranes to pluck and digest. In addition, newly planted fields often harbor insects and worms that cranes feed on while foraging, leading them to disturb or uproot seedlings in the process. The open nature of farmlands also offers cranes good visibility against predators, making them feel safe while feeding. As wetlands and grasslands continue to shrink due to human activities, cranes increasingly turn to farmlands with young cereal crops as alternative feeding grounds, resulting in occasional conflict with farmers.

However, the rate of damage attributed solely to cranes was significantly lower compared to the combined effect when other granivorous bird species were present. This suggests that while farmers often perceive cranes as major culprits, their role in crop destruction may be overstated compared to other more destructive flocking granivores such as quelea (*Quelea quelea*), bishops (*Euplectes spp.*), starlings (*Sturnidae*), pied crows, speckled pigeons, and speckled Mousebirds (*Colius striatus*). Otieno *et al.*, (2022) reported that land-use and land-cover change, especially due to wetland conversions and agricultural intensification in Uasin Gishu, strongly reorganizes bird community composition, creating clear patterns of “winner” and “loser” species within agricultural landscapes. Similar trends have been observed in

the Lake Victoria Basin, where farmland conversion reshaped avian richness and guild structure. Intensive farming practices exert negative effects on disturbance-sensitive taxa compared to natural habitats and as reported in Zimbabwe and elsewhere in Sub-Saharan Africa by Musekiwa & Muposhi (2017).

However, in spite of the foregoing losses, agricultural landscapes support a substantial proportion of species, often more than urban habitats. Aronson *et al.*, (2014), reported that cranes and other granivorous birds persist in farmland settings and interact directly with crops. These findings demonstrate that crop vulnerability is strongly influenced by crop structure and growth stage. Spinach's broad succulent leaves make it particularly susceptible to pecking and trampling and this is consistent with reports of high leaf damage in leafy vegetables by granivorous birds in East Africa as observed by Ogada, (2014).

Maize seedlings, with their tender leaves and fleshy stems, provide an attractive food source, which explains the substantial damage observed. This pattern is also documented in studies on Red-billed Quelea (*Quelea quelea*) and other granivorous species in the Sahel by Bruggers & Elliott (1989). In contrast, wheat's narrow leaves appear less palatable, which may explain the lower damage levels than on spinach and maize. The uprooting of peas aligns with known crane foraging behavior, where seedlings are pulled out for cotyledon consumption, similar to observations made in Uganda and Rwanda where Grey Crowned Cranes uproot legumes and tubers (Nampindo *et al.*, 2011).

From an economic standpoint, these results highlight potential crop-specific risks. Due to extensive foliar loss, leafy vegetables such as spinach face the most significant yield reduction. In contrast, maize and wheat farmers face cumulative losses over larger

acreage due to stem and leaf damage. The uprooting of peas, though less frequent, can significantly impact germination success and establishment. These results reinforce the importance of developing targeted management approaches. For instance, physical protection such as netting or fencing is recommended for spinach, synchronized planting to reduce exposure windows for maize and wheat, and early-stage protection for legumes like peas. The observed patterns support the broader ecological understanding that agricultural landscapes, especially those with monocultures, are hotspots of bird-agriculture conflict. However, they also underscore the need to balance food security with conservation of cranes and other farmland-dependent species as observed by Sutherland *et al.*, (2020).

More importantly, this study findings indicates that while cranes alone inflict measurable crop damage, the highest levels of economic loss arise when cranes are present alongside other granivorous species, such as weaverbirds, doves, and quelea. This aligns with ecological studies showing that generalist and granivorous guilds are among the “winner species” in agricultural mosaics, as they exploit accessible food resources in farmlands thus agreeing with Tschardtke *et al.*, (2011).

Cranes, with their robust beak morphology that is adapted for digging and handling larger seeds, primarily damage sprouting maize and legumes, while smaller granivores such as quelea and doves intensify damage during later grain-filling stages as noted by Kremen & Miles, (2012). Thus, crop losses are amplified not by the presence of cranes alone but by the synergistic feeding pressure from multiple bird taxa exploiting different crop growth phases.

Another critical finding was the synergistic effect of mixed flocks. Crop loss was significantly higher in fields where cranes were observed feeding alongside other

granivorous birds. This may be explained by cranes inadvertently “facilitating” access for smaller birds by trampling down stems or disturbing vegetation, which allows flocking species to exploit the crop more efficiently. Conversely, the presence of large flocks may also attract cranes into fields more frequently, intensifying the overall rate of damage. Similar patterns of facilitation in mixed-species flocks have been documented in agricultural landscapes, where species interactions amplify damage beyond what each species would cause independently thus agreeing with Otieno, (2022).

From a management perspective, these findings emphasize the importance of distinguishing between direct crane damage and cumulative avian damage in high-production areas like Uasin Gishu. Interventions focusing solely on cranes would be ineffective and potentially harmful to conservation efforts, especially considering their endangered status. Instead, control strategies should target the more destructive, flocking species such as quelea, while also promoting coexistence approaches for cranes. This may involve using non-lethal deterrents such as synchronized planting, visual deterrents, and hawk-kites to reduce overall bird pressure, without unnecessarily persecuting cranes.

The above observation aligns with findings of earlier studies across Sub-Saharan Africa by which have consistently identified the Red-billed Quelea as the most damaging avian pest of cereals, with localized outbreaks capable of stripping entire fields within days (In contrast, cranes, being territorial and less gregarious, typically occur in smaller groups, and their feeding is more dispersed. The relatively lower magnitude of crane-induced crop damage found in this study could therefore reflect their different foraging ecology compared to quelea and other weavers that feed in massive flocks (Benjamin *et al.*, 2024).

Importantly, the perception of cranes as the “primary crop pest” in some farming communities may stem from their visibility in fields, their large body size, and their tendency to forage during daylight hours when farmers are present. In contrast, smaller granivores such as quelea often descend in large numbers, feed rapidly, and depart, sometimes leaving behind more severe but less directly observed damage. This misperception underscores the need for evidence-based awareness campaigns to ensure that farmers’ negative attitudes toward cranes are not disproportionately influenced by their visibility rather by their actual impact.

Finally, the foregoing findings have important implications for conservation. Misattributing crop damage to cranes risks fostering negative attitudes and retaliatory actions against an already threatened species, which could undermine conservation efforts in the region. By showing that cranes contribute to crop loss but are not the main cause compared to other granivorous birds, this study supports a more nuanced, science-based approach to farmer education, compensation schemes, and integrated pest management.

Photographic evidence captured in this study was consistent with the results of crop damage by cranes and other birds as reported with Ndang’ang’a et al., (2013). The images portray uprooted maize plants, trampled wheat seedlings, and disturbed spinach beds, each reinforcing the reality that cranes are not passive visitors in agricultural fields but contribute to crop damage. The visual evidence also showed cranes depend mostly on vegetation during the flocking season when they are in large numbers. Anecdotal data during crane monitoring by the International Crane Foundation show that, the behavior of cranes tapping their feet on vegetation shows that cranes are more dependent on insects when they have chicks which would explain why damage is higher during flocking than during breeding though this needs more testing and analysis. From

an ethological perspective, the observed behavior of cranes, such as pecking at soft plant parts and trampling during movement, corresponds with their foraging ecology. As observed by Archibald, (1996), Cranes are omnivorous and opportunistic feeders. During breeding and migratory periods, they forage in open fields, exploiting both plant material and invertebrates found in fields. Fields with recent ploughing or irrigation may attract them due to increased prey availability, thereby intensifying damage. This agrees with Sherry, 2016, who notes that birds make foraging choices such as deciding where to feed, which path to follow, how long to persist in a food patch, what foods to pursue or bypass, whether to join a group, and how to balance feeding with other considerations.

Foraging birds can cause damage to crops in agricultural landscapes, but their feeding habits may also help control insect pests and weed seed germination. Many of the birds that eat seeds on the ground and on weed plants may eat weed seeds, potentially contributing to natural weed control. Although most birds that forage in farmland eat insects, it was extremely hard to confirm what they were eating, except for birds that actively hunt insects, like the ones that catch insects on the fly. Bird foraging in crops was prevalent during the wet season, when crops were growing the fastest, and crop damage at this time, especially for crops grown as single crops, were substantial. In all these fields, other species of birds were recorded and the observation was the species most likely to cause the most damage was the pied crows, Speckled Mousebirds, Speckled Pigeon, and village Weaver birds. This was also observed by Ndang'ang'a et al. (2013), who noted that species most likely to cause crop damage in crop fields were identified as Speke's Weaver, Speckled Mousebird, and Baglafaecht Weaver.

Results showed cranes probing, cutting, pecking, and grazing on the crops. The probing was used to uproot the crops to access the kernels of grown crops, cutting was used for foraging of leaves, pecking, and grazing while looking for leftover seeds and insects either on the leaves or in the soil. Avian species, particularly cranes, exhibit diverse foraging behaviours that significantly impact agricultural landscapes as observed by Hemminger *et al.*, (2022). These behaviors, including probing, cutting, pecking, and grazing, are employed by cranes to access various food resources within cultivated fields. Probing, characterized by the insertion of the beak into the soil or substrate, serves as a means for cranes to uproot crops, thereby exposing the kernels of developed plants. Sherry, (2016) notes that this behavior enables the birds to access a concentrated source of nutrients, especially when other food sources are scarce. Cutting, on the other hand, involves the severing of plant material, such as leaves and stems, to facilitate foraging. This behavior allows cranes to exploit the vegetative parts of crops, particularly when seeking essential nutrients or moisture which agrees with Montràs-Janer *et al.*, (2020) and Yokokawa *et al.*, (2023).

Additionally, cranes may engage in pecking, which entails the rapid striking of the beak against a surface to dislodge seeds, insects, or other small food items as noted by Hiron *et al.*, (2014). Grazing, a more generalized foraging strategy, involves the consumption of vegetation directly from the ground or plant surfaces. These varied foraging techniques reflect the adaptive strategies employed by cranes to exploit available resources within agricultural environments. The beak morphology of these birds identified were similar to that of cranes whose beaks are generalist beaks adapted to omnivorous and opportunistic feeders. The extent of crop damage inflicted by cranes is thus directly linked to the spatial and temporal availability of food resources, as observed by Botson *et al.* (2016).

The foregoing observations validate the use of participatory visual monitoring (PVM), an increasingly important method in community-based conservation research. As noted by Hill, (2004) , the engagement of local farmers in capturing and validating damage enhances trust in scientific findings and contributes to the documentation of indigenous knowledge.

5.2 Extent of crop damage by cranes on farms

Findings of this study indicated that Grey Crowned Cranes do cause measurable crop damage on farms in Uasin Gishu County. However, the extent varies depending on crop type, growth stage, and surrounding ecological factors. Cranes were particularly associated with damage to cereals such as maize and wheat, especially during the early germination stage when seedlings are vulnerable to uprooting, and during the grain-filling stage when maturing seeds are exposed. During the non-breeding season, cranes are mostly in flocks and together in large numbers. This may explain why the number of cranes is more important and related to the extent of crop damage than just the presence of cranes (Wachu et al., 2025).

The trampling effect of cranes, given their large body size, also contributed to localized damage, particularly in smaller plots and near wetland edges where cranes are more likely to forage. During the flocking season, paired cranes and those looking to pair engage in constant display dancing, increasing the crops' trampling. As indicated earlier, Uasin Gishu County also hosts almost a quarter of the crane population in Kenya and is also one of the counties with large scale maize and wheat farms making the farms a favorable flocking areas for cranes. It would be good to undertake a study in other counties where cranes are found and compare the results with this study to

understand whether crop damage is different based on crane population.

Results revealed a complex pattern of crop-specific susceptibility to crane damage. Maize, being tall and nutritionally rich with accessible kernels, suffered high partial and foliar damage during the germination stage. Leaf and stem injury suggest that cranes might forage on vegetative parts before cob maturity, supporting earlier findings by Muthoni *et al.* (2019), who noted that cranes in East Africa exploit early-stage crops more frequently due to easier digestibility and soft tissues. The assessment of crop damage caused by cranes requires a comprehensive evaluation of both the quantity of crops present and the proportion that have been destroyed, offering a holistic understanding of the impact on agricultural yields, Hemminger *et al.*, (2022).

Initial analysis revealed substantial variation in the mean number of crops per quadrant across different crop types, with wheat exhibiting the highest mean, followed by millet, peas, maize, and spinach, indicating varied preferences or accessibility of cranes to these crops in agreement with the results of Borad *et al.*, (2001). The standard deviation results further clarifies the variability within each crop type, highlighting the inconsistent nature of crop distribution across quadrants, which may be influenced by factors such as soil conditions, microclimate variations, or localized crane activity. Examining the maximum and minimum crop counts per quadrant provides a range of crop abundance, essential for understanding the potential scope of crane foraging and damage inflicted, with wheat demonstrating the highest potential for both abundance and, consequently, potential damage as noted by Nilsson *et al.*, (2016). It is important to consider that post-harvest losses in grain crops can be significant, with estimates suggesting that at least 10% are lost in developing countries, and losses can reach up to

40% as observed by Montràs-Janer *et al.*, (2020).

The mean percentage of crop destruction provides a critical insight into the actual impact of cranes on crop yields, revealing that spinach suffers the highest mean percentage of destruction, followed by maize, wheat, and peas, with millet showing remarkably zero destruction. The findings from this study reveal notable variation in both crop abundance and the extent of crop damage across the different crop types surveyed. Wheat was the most abundantly cultivated crop, followed by millet, peas, maize, and spinach. The high standard deviations observed, particularly for wheat and millet suggest uneven spatial distribution of these crops, potentially reflecting variations in land suitability, agronomic preferences, and farmer decision-making.

In terms of crop damage, spinach exhibited the highest mean percentage of destruction with considerable variability and a maximum recorded loss. Such levels of damage indicate a high vulnerability of spinach, which may be attributed to its soft foliage and high palatability to herbivores or insect pests as noted by Kale *et al.*, 2014. Another possible explanation that increases spinach damage is that by frequent harvesting, the leaves are always fresh and thus more palatable and nutritious which means cranes can target them throughout the time they are in the farm. Maize followed with a mean damage percentage of 0.18% and a maximum of 9.29%, suggesting that while damage is generally limited, specific locations experience substantial loss. Wheat, despite its extensive cultivation, exhibited relatively low damage levels which is attributed to its structural characteristics, density and the effectiveness of existing management practices. Peas showed the lowest mean damage among crops with recorded losses, though a maximum damage in some quadrants points to localized vulnerabilities that

may require targeted interventions.

Interestingly, millet showed no damage in any of the surveyed quadrants. This might be attributed to its lower palatability or effective protection methods used by farmers, making it a resilient crop choice in areas vulnerable to damage from wildlife or pests. Similar findings have been reported by Conover M., (2002) in other human–wildlife conflict studies, where less palatable crops suffer minimal losses

The foregoing results have significant implications for crop management in areas facing agricultural losses. Crops such as spinach and maize could benefit from targeted protection efforts, including physical barriers, crop diversification, or adjustments in planting schedules. The resilience of millet indicates a potential for promoting its cultivation as part of risk-reduction strategies in high-conflict regions. Further research is needed to explore the spatial and temporal patterns of crop damage, particularly concerning proximity to wildlife habitats, seasonal crop cycles, and the presence of mitigation strategies. Integrating ecological monitoring with farmers' knowledge may aid in developing adaptive, evidence-based interventions for sustainable crop production in wildlife-affected landscapes.

In most cases, cranes were observed feeding in small family groups or pairs, consistent with their social ecology, which limits the level of destruction they can cause compared to highly gregarious species, such as quelea. This suggests that while cranes do contribute to crop loss, their impact may not be as widespread or economically damaging as often believed by local farmers. Similar observations have been reported in Uganda and Rwanda, where farmers blamed cranes for large-scale crop destruction,

even though field assessments showed more extensive damage from smaller, flocking granivorous birds. This is mostly attributed to the large size of cranes making them more visible to farmers than the smaller, more destructive birds such as mouse-birds and queleas.

5.3. Economic Quantification of damage

Crop damage by birds remains a serious issue for subsistence farmers, as demonstrated by a study in western Kenya by Hiron *et. al.*, (2014), where human bird scarers were ineffective in preventing substantial sorghum losses to Village Weavers and African Mourning Doves. Findings regarding economic losses are notably significant, particularly within subsistence and smallholder agriculture. Farmers in the study area experience yield reductions ranging from 40% to 70%, resulting in revenue losses that exceed Ksh 100,000 per acre in numerous instances.

The revenue loss associated with spinach, per acre, arises not only from its high market value but also from the crop's perishability. Damaged spinach is seldom capable of being stored or salvaged, in contrast to cereals which can be dried or processed. Furthermore, spinach requires more frequent harvesting, and recurrent crane intrusions result in consistent income loss. These results are consistent with the findings of Mwakatobe *et al.* (2014), who reported that vegetable growers endure significant losses due to bird-related encounters, primarily attributable to the immediacy of loss and limited recovery options.

Despite exhibiting no direct damage, millet yield was significantly lower in plots affected by cranes. This raises the likelihood of indirect ecological interactions such as soil compaction caused by cranes impacting root respiration or allelopathic stress

resulting from disturbed plant-soil interactions. Furthermore, farmers may prioritize the protection of high-value crops, such as maize or spinach, inadvertently exposing millet to secondary damage.

In comparison to a study by Otieno et al. (2014) on a rice scheme, it was observed that the estimated annual loss was 407 tonnes, or 7.7% of the potential yield for the entire irrigation scheme, excluding bird-scaring costs. This was equivalent to Ksh. 40.7 million annually at 1 United States Dollar =87 Kenyan Shillings, representing a 31.1% loss of net income. Inclusive of bird scaring costs, annual losses were Kshs. 20,763/ha equivalent to 39.5% of net income. The estimated annual rice damage due to *Quelea quelea* was more than that due to the combined number of other granivorous birds. This result, therefore, concurs with the findings from the current study that there is a substantial loss from bird-exposed fields.

Additionally, the loss of revenue decreases farmers' passion to reinvest in the next season, leading to a poverty trap. This is primarily a concern since many African conservation programs enhance coexistence without providing economic compensation. When the burden of coexistence falls entirely on farmers, the long-term sustainability of conservation becomes questionable. It is also essential to consider the psychological toll. Farmers may feel powerless, disregarded by authorities, or forced to choose between safeguarding their livelihoods and following conservation laws (Ogra, 2009). This can lead to unlawful retaliatory actions, such as poisoning or egg destruction, as has been reported in crane habitats worldwide by Li *et al.*, (2020).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The outcomes of this study highlight the complications of crane-related crop damage, which spans ecological, economic, and emotional domains. The distinguished crop responses, varied damage patterns, and stark economic magnitudes disclose an immediate need for interdisciplinary methodologies. Solutions must be evidence-based, participatory, and context-sensitive, integrating the lived realities of farmers with conservation imperatives.

1. There is clear evidence that cranes, along with other bird species, contribute to crop damage; however, the extent of the destruction is influenced more by the number of birds present than by their mere presence. When cranes forage alongside other birds, the level of damage increases significantly.
2. Younger plants tend to be more vulnerable to this damage than mature ones.
3. Observations across various crops, including maize, peas, spinach, and wheat, show that different parts of the plants are targeted, with leaves and stems being particularly susceptible, especially in maize and spinach.
4. Most of the damage by cranes occurs during the early stages of crop growth, particularly in wheat and maize. Overall, this bird-induced damage leads to notable economic losses for farmers.

6.2 Recommendations

The following are some of the recommendations based on the findings;

6.2.1 Policy and Management Recommendations

To mitigate crop damage caused by cranes and other birds, several management strategies are recommended.

1. Targeted scaring and deterrent measures should be implemented, particularly during the early stages of crop growth when crops like maize and wheat are most vulnerable. This can include non-harmful chemical, visual and auditory deterrents, or organized community patrols. In the United States of America, International Crane Foundation has linked up with an agro-veterinary company to manufacture anthroquinone, a non-harmful chemical deterrent method due to its taste and coat seeds during planting to deter Sandhill cranes from destroying crops during the early germination stages where most of the damage occurs in maize. The chemical can also be applied as a foliar which would reduce leaf damage, one of the most targeted crop parts.
2. Crop zoning and adjusted planting schedules can also help reduce risk by rotating or staggering crops less susceptible to bird damage. Building resilience through strategic cropping practices and capacity development is essential and recommended. During the early breeding stage of the cranes when they have small chicks and therefore have reduced flying schedules, one feasible strategy would be the use of crop zoning, whereby less susceptible crops like millet as shown by this study can be planted along the borders of more vulnerable crops

to act as natural buffer zones. This approach will not only diminishes damage but also help maintain biodiversity and soil health

3. Habitat management, through establishing buffer zones or diversionary feeding areas away from croplands, can redirect birds and reduce pressure on farms.
4. Educating farmers about bird behavior and non-lethal control methods is crucial, alongside community-based monitoring to detect hotspots and allow timely interventions.
5. Modifying planting schedules to prevent the peak periods of crane presence can also reduce the likelihood of damage, mainly for high-value or highly susceptible crops.
6. Compensation or incentive schemes for farmers experiencing severe losses or those adopting bird-friendly practices should also be explored.

6.2.2 Recommendations for further research:

1. Research should also explore the effectiveness of different bird deterrent methods, both traditional and innovative, in reducing damage without negatively affecting bird conservation. As crop damage remains a critical concern for global agriculture, necessary innovative solutions to minimize losses and enhance food security should be explored.
2. Long-term ecological studies should be conducted to help understand how landscape changes including wetland degradation and land-use changes, influence bird movements and crop interactions.
3. Research should be conducted on alternative livelihood options and crop varieties less susceptible to bird damage to offer sustainable solutions for farmers living in bird-prone areas.

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APPENDICES

Appendix I: Ministry of Agriculture Benchmarks.

1. MAIZE:

- Yield Projection Recap per acre
 - Plant population: 21,600
 - Average cob weight: 200g (grains only)
 - Projected yield: 4,320 kg
 - Equivalent in 90-kg bags: ~48 bags

- Revenue Estimate

Estimated based on the average farm-gate price in Uasin Gishu (as of 2024–2025), which typically ranges from Ksh 4,000–5,000 per 90-kg bag.

Price per Bag (90kg) Total Revenue (48 bags)

Ksh 4,000 Ksh 192,000

Ksh 4,500 Ksh 216,000

Ksh 5,000 Ksh 240,000 (high end)

- Estimated Cost of Production (Per Acre)

Input/Activity	Estimated Cost (Ksh)
----------------	----------------------

Certified seed (H6213, 10kg)	3,500
------------------------------	-------

Basal fertilizer (NPK, 50kg)	5,000
------------------------------	-------

Top dressing (CAN, 50kg)	3,000
--------------------------	-------

Input/Activity	Estimated Cost (Ksh)
Ploughing and harrowing	6,000
Planting labor	2,500
Weeding (2 rounds)	4,000
Pest control (fall armyworm)	2,000
Harvesting & shelling	3,500
Transport to buyer/mill	3,000
Total Estimated Cost	~32,500 Ksh

2. GREEN PEAS

Ideal Yield of Green Peas (per acre)

Production Type	Pod Yield (Fresh Peas)	Grain Yield (Dry Peas)
Good management (ideal case)	2.0 – 2.5 tons (2,000–2,500 kg)	900 – 1,200 kg

Note: Green peas are often harvested as fresh pods, not dried, especially for local or export markets.

What You Need for Ideal Yield

- Certified seeds (e.g., varieties like Asili, Green Feast, Sugar Snap)
- Spacing: 30 cm between rows, 10 cm between plants
- Basal fertilizer: Use well-decomposed manure + starter NPK (e.g., 17:17:17)

- Trellising (for climbing types) improves airflow and reduces disease
- Pest control: Especially for aphids, cutworms, powdery mildew
- Timely harvesting boosts quality and plant productivity
- Fresh green peas sell for Ksh 50–120 per kg, depending on the season and market access (higher prices in dry months like Jan–Feb).
- Potential gross income at 2,000 kg/acre × Ksh 80/kg = Ksh 160,000 per acre

3. SPINACH

Ideal Spinach Yield Per Acre

Yield Type	Quantity (kg per acre)	Notes
Good management	5,000 – 7,000 kg	Fertilized, well-spaced, weekly harvest

What Influences High Yield?

- Variety: Use high-yielding varieties like *Fordhook Giant*, *Bloomsdale*, or hybrids like *Columbia FI*.
- Spacing: 30 cm between rows, 10–15 cm between plants.
- Fertilization: Well-decomposed manure + NPK starter, CAN or urea for top dressing.
- Harvest Method: Regular picking of outer leaves encourages regrowth (cut-and-come-again).
- Pest & Disease Management: Control downy mildew, leaf spots, and aphids.

4. WHEAT

Ideal Wheat Yields per Acre:

Farming System	Ideal Yield (kg/acre)	Tons/acre	Bags/acre (90 kg bags)
Traditional (low input)	800 – 1,200 kg	0.8 – 1.2	9 – 13 bags
Improved rainfed practices	1,500 – 2,200 kg	1.5 – 2.2	17 – 24 bags
Irrigated & well-managed	2,500 – 3,500+ kg	2.5 – 3.5+	28 – 39+ bags
Research/experimental farms	Up to 4,000+ kg	4.0+	44+ bags

Practices to Achieve Ideal Yields:

- Certified high-yielding varieties (e.g., Njoro BW2, Eagle10, Duma43 for Kenya)
- Proper land preparation and timely planting
- Use of recommended fertilizer rates (NPK at planting, top-dress with urea or CAN)
- Good weed, pest, and disease management
- Proper harvesting and post-harvest handling

5. MILLET

Ideal Yield of Finger Millet:

Condition	Expected Yield (tons/ha)
Improved rainfed farming	2.0 – 3.0 tons/ha

Practices to Achieve Ideal Yields:

- Use high-yielding, disease-resistant varieties (e.g., IE 3775, U15, or regional varieties).
- Apply balanced nutrients, especially nitrogen and phosphorus.

- Ensure timely planting (ideally at the onset of rains).
- Practice line sowing for easier weeding and better plant spacing.
- Implement moisture conservation techniques in dry areas.
- Control weeds and pests (like stem borers and blast disease).

Appendix II: R Core model codes.

```
#Instruction to get the data

setwd("C:/Users/User/Documents/Vivian analysis")

#Loading packages used in the analysis

library(vegan)

library(plyr)

library(ggplot2)

library(fitdistrplus)

library("ggpubr")

library(multcomp)

library(gridExtra)

library(grid)

library(ggpubr)

library(car)

library(GGally)

library(lme4)

library(MASS)

library(e1071)
```

```
library(MuMIn)

require(tibble)

require(reshape2)

require(xlsx)

library(dplyr)

library(data.table)

library(rbenchmark)

library(DHARMA)

library(emmeans)

#importing the data to R

Viviandata<-read.csv("MSc data_VN_JM_Final_modified_updated.csv")

#investigating data characteristics

str(Viviandata)

head(Viviandata)

names(Viviandata)

# converting categorical data to factors

Viviandata$Crop<-factor(Viviandata$Crop)

print(Viviandata$Crop)

Viviandata$Farm<-factor(Viviandata$Farm)

print(Viviandata$Farm)
```

```
Viviandata$Quadrant<-factor(Viviandata$Quadrant)
```

```
print(Viviandata$Quadrant)
```

```
Viviandata$cranes_presence<factor(Viviandata$cranes_presence)
```

```
print(Viviandata$cranes_presence)
```

```
Viviandata$Presence_of_other_wildlife<factor
```

```
(Viviandata$Presence_of_other_wildlife)
```

```
print(Viviandata$Presence_of_other_wildlife)
```

```
Viviandata$Presence_of_crane_habitat<factor(Viviandata$Presence_of_crane  
_habita)
```

```
print(Viviandata$Presence_of_crane_habitat)
```

```
Viviandata$Adjacent_crops<-factor(Viviandata$Adjacent_crops)
```

```
print(Viviandata$Adjacent_crops)
```

```
Viviandata$Method_of_planting<-factor(Viviandata$Method_of_planting)
```

```
print(Viviandata$Method_of_planting)
```

```
Viviandata$Other_species_only<-factor(Viviandata$Other_species_only)
```

```
print(Viviandata$Other_species_only)
```

```
Viviandata$wildlife_present<-factor(Viviandata$wildlife_present)
```

```
print(Viviandata$wildlife_present)
```

```
Viviandata$Birds_present<-factor(Viviandata$Birds_present)
```

```
print(Viviandata$Birds_present)
```

```
Viviandata$Plant_damaged_part<-factor(Viviandata$Plant_damaged_part)
```

```
print(Viviandata$Plant_damaged_part)
```

```
#To ensure date is recognized by R as date
```

```
Viviandata$Date<-as.Date(Viviandata$Date)
```

```
print(Viviandata$Date)
```

```
#converting measures appearing as integers to numeric
```

```
Viviandata$Number_of_crops_per_Quadrant <-  
  as.numeric(Viviandata$Number_of_crops_per_Quadrant)
```

```
print(Viviandata$Number_of_crops_per_Quadrant)
```

```
Viviandata$Number_of_damaged_crops_per_quadrant <-  
  as.numeric(Viviandata$Number_of_damaged_crops_per_quadrant)
```

```
print(Viviandata$Number_of_damaged_crops_per_quadrant)
```

```
Viviandata$Fully_Damaged <- as.numeric(Viviandata$Fully_Damaged)
```

```
print(Viviandata$Fully_Damaged)
```

```
Viviandata$Partial_Damaged <- as.numeric(Viviandata$Partial_Damaged)
```

```
print(Viviandata$Partial_Damaged)
```

```
Viviandata$Not_Damaged <- as.numeric(Viviandata$Not_Damaged)
```

```
print(Viviandata$Not_Damaged)

Viviandata$Leaf_damage <- as.numeric(Viviandata$Leaf_damage)

print(Viviandata$Leaf_damage)

Viviandata$Stem_damage <- as.numeric(Viviandata$Stem_damage)

print(Viviandata$Stem_damage)

Viviandata$Not_Damaged <- as.numeric(Viviandata$Not_Damaged)

print(Viviandata$Not_Damaged)

Viviandata$Other_destruction <- as.numeric(Viviandata$Other_destruction)

print(Viviandata$Other_destruction)

Viviandata$Uprooted_plants <- as.numeric(Viviandata$Uprooted_plants)

print(Viviandata$Uprooted_plants)

Viviandata$Number_of_cranes <- as.numeric(Viviandata$Number_of_cranes)

print(Viviandata$Number_of_cranes)

Viviandata$Distance_of_damaged_crop_to_plot_edge_in_cm <-
  as.numeric(Viviandata$Distance_of_damaged_crop_to_plot_edge_in_cm
  )

print(Viviandata$Distance_of_damaged_crop_to_plot_edge_in_cm)

Viviandata$In_between_plants<- as.numeric(Viviandata$In_between_plants)

print(Viviandata$In_between_plants)

Viviandata$Height_of_crop<- as.numeric(Viviandata$Height_of_crop)
```

```
print(Viviandata$In_between_plants)

#Checking data structure after conversion

str(Viviandata)

#calculating summary statistics

mean(Viviandata$Number_of_crops_per_Quadrant)

min(Viviandata$Number_of_crops_per_Quadrant)

max(Viviandata$Number_of_crops_per_Quadrant)

sd(Viviandata$Number_of_crops_per_Quadrant)

length(Viviandata$Number_of_crops_per_Quadrant)

se <- (25003.88 / sqrt(451))#se=sd/sqrt(n)

se

#summaries statistics of number of plants by quadrant by crop

aggregate(Viviandata$Number_of_crops_per_Quadrant,list(Viviandata$Crop)
,mean)#mean crops per quadrant by crop

aggregate(Viviandata$Number_of_crops_per_Quadrant,list(Viviandata$Crop)
,sd)#Standard deviation crops per quadrant by crop

aggregate(Viviandata$Number_of_crops_per_Quadrant,list(Viviandata$Crop)
```

```
,max)#maximum crops per quadrant by crop

aggregate(Viviandata$Number_of_crops_per_Quadrant,list(Viviandata$Crop)
, min)#minimum crops per quadrant by crop

aggregate(Viviandata$Number_of_crops_per_Quadrant,list(Viviandata$Crop)
,length)

Maizestandard_error<-(51.60794 / sqrt(215))

Maizestandard_error

Milletstandard_error<-(5889.34763/ sqrt(60))

Milletstandard_error

Peasstandard_error<-(941.03054/ sqrt(36))

Peasstandard_error

spinachstandard_error<-(60.87738/ sqrt(65))

spinachstandard_error

wheatstandard_error<-(17174.90060/ sqrt(75))

wheatstandard_error

#Checking the distribution of the data

histogram<-hist(Viviandata$Percentage_of_crops_damaged_per_quadrant)

histogram
```

```

#summaries statistics of percentage of plants damaged per quadrant by crop

aggregate(Viviandata$Percentage_of_crops_damaged_per_quadrant,list(Vivia
  ndata Crop),mean)#mean crops per quadrant by crop

aggregate(Viviandata$Percentage_of_crops_damaged_per_quadrant,list(Vivia
  ndata$Crop),sd)#Standard deviation crops per quadrant by crop

aggregate(Viviandata$Percentage_of_crops_damaged_per_quadrant,list(Vivia
  ndata$Crop),max)#maximum crops per quadrant by crop

aggregate(Viviandata$Percentage_of_crops_damaged_per_quadrant,list(Vivia
  ndata$Crop),min)#minimum crops per quadrant by crop

aggregate(Viviandata$Percentage_of_crops_damaged_per_quadrant,list(Vivia
  ndata$Crop),length)#numberof samples by crop

Maizestandard_error<-(0.93532890 / sqrt(215))

Maizestandard_error

Milletstandard_error<-(0.000000/ sqrt(60))

Milletstandard_error

Peasstandard_error<-(0.05607671/ sqrt(36))

Peasstandard_error

spinachstandard_error<-(3.01130697/ sqrt(65))

spinachstandard_error

wheatstandard_error<-(0.51730135/ sqrt(75))

wheatstandard_error

```

```

# Plotting bar plot of plant part damage per crop and saving as jpeg

damagedplantsonly<-droplevels(subset(Viviandata,Plant_damaged_part
  !="none"))

tiff(file="Part of the plant damaged by crop type.jpeg", width=15, height=8,
  units="cm", res=1000)

ggplot(damagedplantsonly, aes(x = Crop, fill = Plant_damaged_part)) +
  geom_bar(position = "dodge", stat = "identity", aes(y =
    Percentage_of_crops_damaged_per_quadrant)) +
  labs(title = "Part of crop damaged by crane and other birds",
  fill = "Damaged plant part")+xlab("Crop") +
  ylab("Average percentage of crop \n damaged per quadrant") +
  theme(panel.grid.major = element_blank(), panel.grid.minor =
    element_blank(),
    panel.background = element_blank(), axis.line = element_line(colour =
    "black"))

dev.off()

# Plotting bar plot of planted versus damaged crop and saving as a jpeg

damagedplantsonly<-droplevels(subset(Viviandata,Plant_damaged_part

```

```

!="none"))

tiff(file="Part of the plant damaged by crop type.jpeg", width=15, height=8,
      units="cm", res=1000)

ggplot(damagedplantsonly, aes(x = Crop, fill = Plant_damaged_part)) +
  geom_bar(position = "dodge", stat = "identity", aes(y =
    Percentage_of_crops_damaged_per_quadrant)) +
  labs(title = "Part of crop damaged by crane and other birds",
        fill = "Damaged plant part")+xlab("Crop") + ylab("Average percentage of crop
    \n damaged per quadrant") +
  theme(panel.grid.major = element_blank(), panel.grid.minor =
    element_blank(),
        panel.background = element_blank(), axis.line = element_line(colour =
    "black"))

dev.off()

#Checking and testing if response variable (percentage of destroyed crops) is
  normally distributed

hist(Viviandata$Percentage_of_crops_damaged_per_quadrant)#data is skewed

shapiro.test(Viviandata$Percentage_of_crops_damaged_per_quadrant)#test
  show data not normally distributed

```

```
#Transforming data to check if it will be normally distributed

log_Percentage_of_crops_damaged_per_quadrant<-
  log10(Viviandata$Percentage_of_crops_damaged_per_quadrant+ 10)

hist(log_Percentage_of_crops_damaged_per_quadrant)

shapiro.test(log_Percentage_of_crops_damaged_per_quadrant)

print(log_Percentage_of_crops_damaged_per_quadrant)

Viviandata$log_Percentage_of_crops_damaged_per_quadrant      <-
  log_Percentage_of_crops_damaged_per_quadrant

str(Viviandata)

names(Viviandata)

sqrt_Percentage_of_crops_damaged_per_quadrant<-
  sqrt(Viviandata$Percentage_of_crops_damaged_per_quadrant)

hist(sqrt_Percentage_of_crops_damaged_per_quadrant)

shapiro.test(sqrt_Percentage_of_crops_damaged_per_quadrant)

cube_Percentage_of_crops_damaged_per_quadrant<-
  Viviandata$Percentage_of_crops_damaged_per_quadrant^(1/3)

hist(cube_Percentage_of_crops_damaged_per_quadrant)
```

```

shapiro.test(cube_Percentage_of_crops_damaged_per_quadrant)

#subset data to only when birds were present in the farms

Only_where_wildlife_present<-droplevels(subset(Viviandata,wildlife_present
      !="None"))

print(Only_where_wildlife_present)

names(Only_where_wildlife_present)

#Running the model for analysis

model <-glm(log_Percentage_of_crops_damaged_per_quadrant ~
      Number_of_cranes+wildlife_present
+Date, family = Gamma(link = "log"), data = Only_where_wildlife_present,
      na.action = na.omit)

#Summary of the model

summary(model)

#Testing which crops are vulnerable

Viviandata$Crop<-relevel(Viviandata$Crop,"Millet")

modell <-glm(log_Percentage_of_crops_damaged_per_quadrant
      ~Crop+Plant_damaged_part

```

```
+Date, family = Gamma(link = "log"), data = Viviandata, na.action = na.omit)
```

```
#Summary of the model
```


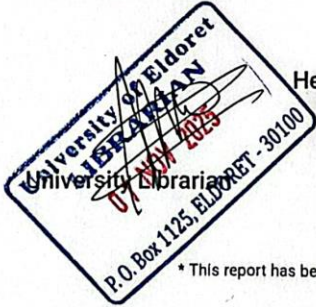
```
summary(model1)
```

```
#getting citation of R and RStudio to include in references
```

```
citation()
```

```
RStudio.Version()
```

Appendix III: Similarity Report

 <p>University of Eldoret Pursuing the frontiers of knowledge and innovation</p>	
<p>University of Eldoret Certificate of Plagiarism Check for Thesis</p>	
Author Name	Kitui, Vivian Nekesa SNAT/WLM/M/003/21
Course of Study	Type here...
Name of Guide	Type here...
Department	Type here...
Acceptable Maximum Limit	Type here... <input type="checkbox"/>
Submitted By	similarity@uoeld.ac.ke
Paper Title	CROP DAMAGE BY GREY CROWNED CRANE (Balearica regulorum) ON FARMS IN UASIN GISHU COUNTY, KENYA
Similarity	7%
Paper ID	4638990
Total Pages	95
Submission Date	2025-11-07 11:54:54
Signature of Student	Signature of Guide
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