QUANTIFYING CROP DAMAGE BY GREY CROWNED CRANE *BALEARICA REGULORUM REGULORUM* AND EVALUATING CHANGES IN CRANE DISTRIBUTION IN THE NORTH EASTERN CAPE, SOUTH AFRICA.

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ABSTRACT

Complaints of crop damage by cranes on planted maize in the North Eastern Cape, South Africa, have been increasing since the mid-1990's, and in some instances severe losses have been reported. Crop damage by the Grey Crowned Crane *Balearica regulorum regulorum* near the town of Maclear (31º04´S 28º22´E), has been quantified over two growing seasons, and assessed relative to losses caused by foraging Cape Crows *Corvus capensis* and other feeding damage assumed to be caused by insects .Twelve fields were selected based on previous patterns of crop depredation. Maize seed in seven of the fields was treated with the chemical ‗Gaucho' and five fields were planted with untreated maize. In order to determine the source of losses, twenty quadrats (4 m x 4 m) randomly distributed within each field were visited on average every second day, for a period of up to twenty eight days. Results indicate that seed treatments do act as a deterrent to feeding by both cranes and crows, however crane damage is generally insignificant compared to other sources of damage. My study also reviewed past sightings data of the Grey Crowned Crane in an effort to determine if the conversion of former grassland to plantations in this region may have increased foraging activity in maize fields. The data did not allow for clear-cut conclusions regarding changes in distribution or population trends. Conclusions provide direct input into the management of agricultural areas by enabling landowners to take steps to mitigate crop damage. These mitigation measures may either involve the application of seed treatments, or the planting of low risk crops in high risk areas. Future studies should consider the possible detrimental effects of chemical seed treatments on crane biology.

Key words: Grey Crowned Crane; Maclear, Gaucho; crop damage; distribution

CHAPTER I

INTRODUCTION

Cranes are large birds of open habitats that have adapted to life in wetlands and grasslands and have co-existed with growing human societies (Harris 1994). On all the continents on which they occur, they are held in high esteem, and often feature in folklore. Within the past 150 years, human population growth, accelerating resource consumption, indiscriminate hunting, habitat destruction and competition with humans for wetland and grassland habitats, now threaten the survival of seven of the total of fifteen species of cranes. Cranes are among the world‘s most threatened families of birds (Harris 1994; Meine & Archibald 1996; Beilfuss *et al.* 2007).

These fifteen extant species occur on five of the seven continents. The Family Gruidae are not represented in South America and Antarctica (Archibald 1976; Krajewski 1989; Harris 1994; Meine & Archibald 1996; Morrison 1998). Archibald (1976) recognized fifteen species based on the unison calls as the primary characteristic distinguishing species. Krajewski (1989) revised the taxonomic relationships within the extant cranes using DNA- DNA hybridization and this study, together with further work by Fain *et al.* (2007) and Krajewski *et al.* (2010), confirmed the status of the fifteen extant species. Two distinct subfamily groups are recognized within the Gruidae namely the Balearicinae, or crowned cranes and the Gruinae or gruine cranes.

Six species of cranes occur in Africa. The Black Crowned Crane *Balearica pavonina* is near–threatened, the Wattled Crane *Grus carunculatus* and Blue Crane *Anthropoides paradiseus* are vulnerable, the Grey Crowned Crane and Eurasian Crane *Grus grus* are rapidly declining, and the Atlas Mountain population of Demoiselle Crane *Anthropoides virgo* is thought to be extinct (Beilfuss *et al.* 2007).

Southern Africa is home to three species of cranes. The Blue Crane *Anthropoides paradiseus*, the Grey Crowned Crane *Balearica regulorum regulorum* and the Wattled Crane *Grus carunculatus* (Harrison *et al*. 1997; Morrison 1998; Beilfuss *et al.* 2007). This study focuses on the Grey Crowned Crane in the north-eastern sector of the Eastern Cape Province, South Africa, and the conservation challenges associated with increased human interactions and habitat transformation. All three species are present within the study area; however the most abundant species, according to the South African Bird atlas project is the Grey Crowned Crane (Harrison *et al.* 1997; Barnes 2000) (Figure 1).

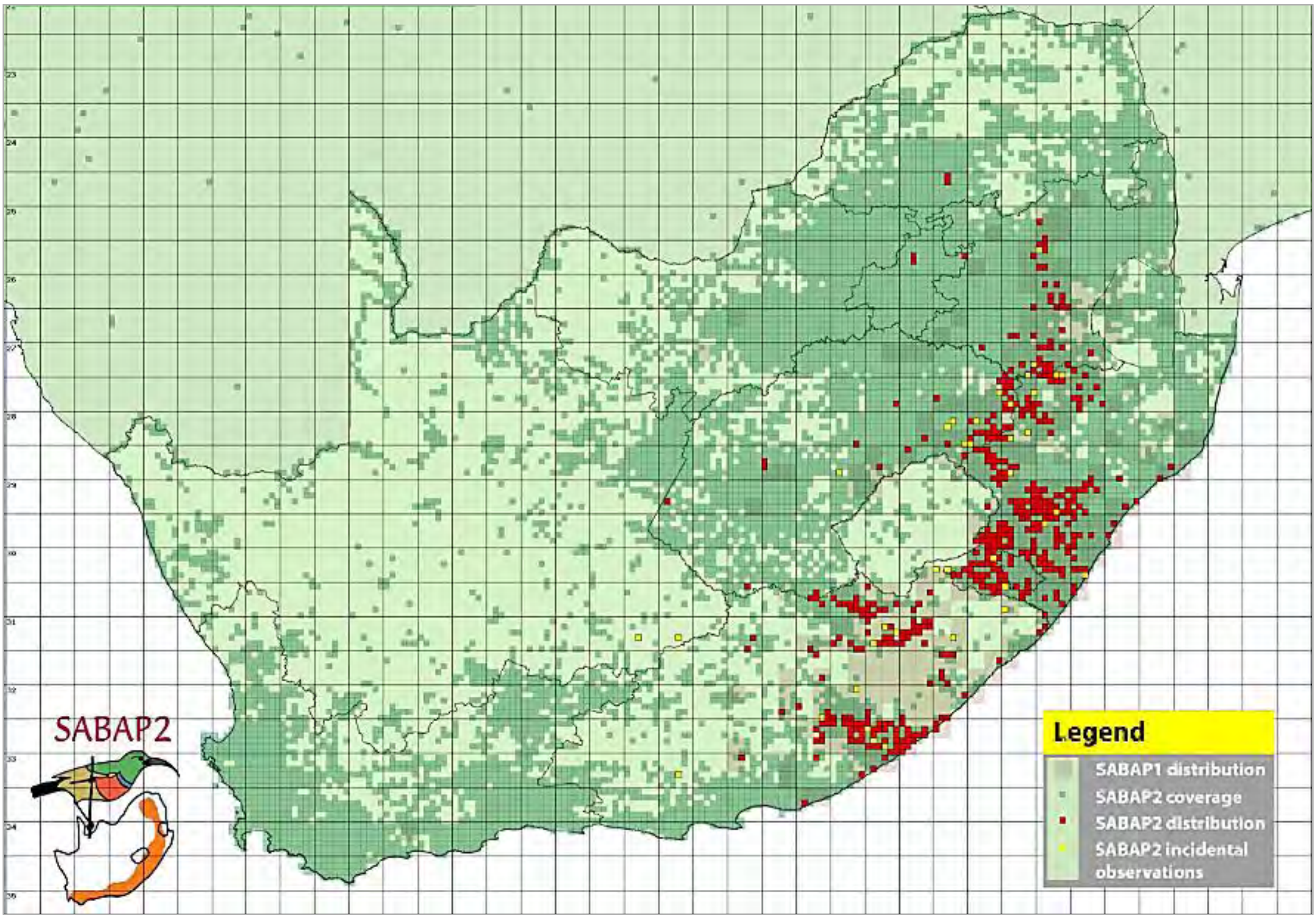

Figure 1: Distribution of the Grey Crowned Crane in South Africa (SABAP 2, 2010).

Species account

The taxonomic history of crowned cranes has been controversial. Snow (1978) and Johnsgard (1983) regarded these two taxa as conspecific, whereas Walkinshaw (1973), Archibald (1976), Wood (1979) and Urban *et al.* (1986) treated them as separate species. Various molecular techniques have been used to study the phylogenetic relationships of this family. Ingold *et al.* (1989) used DNA- DNA hybridization and albumin micro-complement fixation (MC'F) and compared the results to the electrophoretic techniques used by Ingold *et al.* (1987). Krajewski (1989) used DNA- DNA hybridization techniques and Fain *et al.* (2007) used DNA sequencing data from four mitochondrial and three nuclear loci to test previous hypotheses of interfamiliar relationships within the Family Gruidae. Krajewski *et al.* (2010) reviewed the phylogenetic relationships among all fifteen extant species of cranes using mitochondrial genomes to confirm that the genus Balearica is indeed part of the Family Gruidae. All these diverse approaches produced congruent patterns of evolutionary relationships, indicating that the two crowned cranes are best treated as two separate species.

Grey Crowned Cranes occur in developing countries, and are thus threatened primarily by population pressures and associated land-use changes which hinder conservation efforts (Allan *et al.* 1997). These cranes are resident throughout their geographical range, from Kenya to South Africa, but exhibit restricted seasonal movements in response to the abundance and distribution of food and nesting sites (Pomeroy 1980; Johnsgard 1983; Meine & Archibald 1996; Beilfuss *et al.* 2007). The East African population *B.r. gibbericeps* makes up the majority of the Grey Crowned Crane numbers, being most abundant in Uganda, Kenya and Tanzania (Meine & Archibald 1996).

Each of the two crowned crane species has two subspecies. The Grey Crowned Crane is divided into the South African Grey Crowned Crane, *B. regulorum regulorum* (Bennet 1834) and East African Grey Crowned Crane *B.regulorum gibbericeps* (Reichenow 1892).(Walkinshaw 1964; Meine & Archibald 1996)(Figure 2). The two subspecies of Grey Crowned Crane are said to be biogeographically separated by the Zambezi River valley (Beilfuss *et al.* 2007).

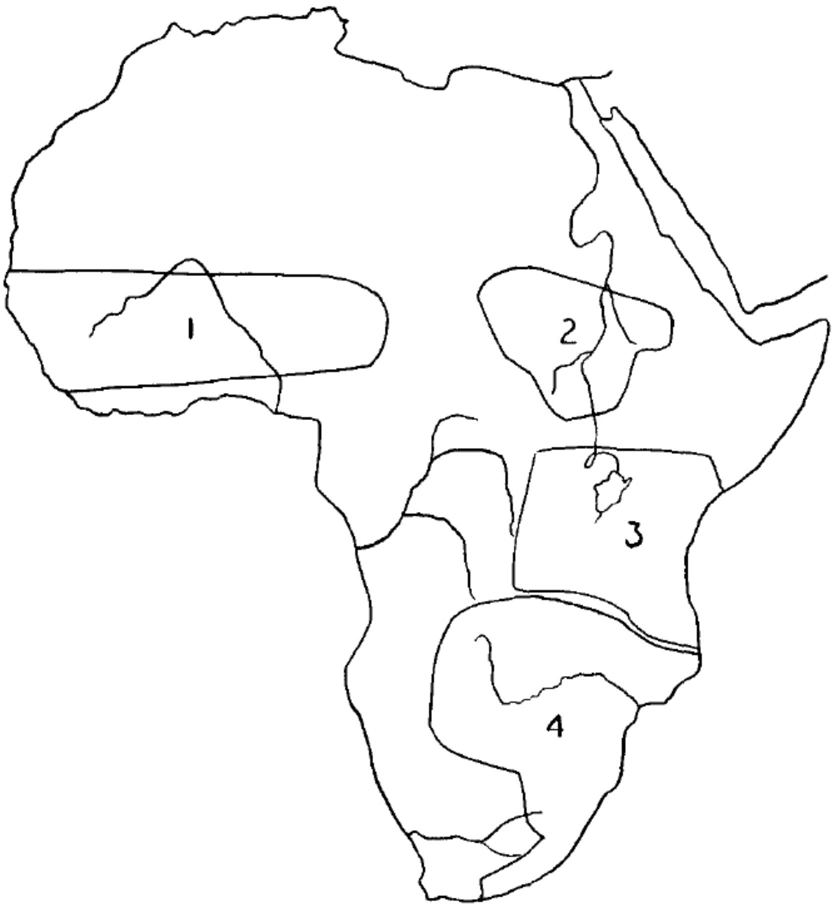

Figure 2: Ranges of the subspecies of the African crowned cranes: (1) West African Black Crowned Crane *Balearica pavonina pavonina* (2) Sudan Black Crowned Crane *Balearica pavonina ceciliae* (3) East African Grey Crowned Crane *Balearica regulorum gibbericeps* (4) South African Grey Crowned Crane *Balearica regulorum regulorum* (Walkinshaw 1964).

The Black Crowned Crane *Balearica pavonina* of west Africa ranges from Senegal to Lake Chad, south to Sierra Leone, Ghana, northern Nigeria, Gambia, the Gold Coast and Guinea, with a small population occurring in the Sudan, western Ethiopia and northern Uganda (Walkinshaw 1964; Johnsgard 1983). The Grey Crowned Crane *Balearica regulorum* occurs in eastern and southern Africa, which includes Uganda, Rwanda, Burundi, Kenya, Tanzania, Malawi, Mozambique, Angola, Zambia, Zimbabwe and South Africa (Walkinshaw 1964; Urban 1986; Harrison *et al.* 1997; Meine & Archibald 1996; Parker 2005).

The South African Grey Crowned Crane *B.r. regulorum* occurs in Angola, Zimbabwe, Mozambique and South Africa. Several hundred kilometres in Zimbabwe separate *B.r. regulorum* from the East African subspecies *B.r. gibbericeps* (Meine & Archibald

1996; Morrison 1998; Barnes 2000; Parker 2005). In South Africa, the geographical range of the Grey Crowned Crane extends from the Eastern Cape to the KwaZulu/Natal Province and from the eastern Free State to the eastern parts of the Mpumalanga Province (Filmer & Holtshausen 1992; Harrison *et al.* 1997; Morrison 1998). The Grey Crowned Crane population is comprised of three core populations, namely the Eastern Cape and Transkei area, the Kwazulu- Natal area and the eastern Free State area. All these populations have shown declining population numbers, with a decline of as much as 55% for Kwazulu Natal population since the 1980's (Barnes 2000).The South African Grey Crowned Crane is endemic to Southern Africa and is considered a ‗vulnerable' species with a declining population. Should current population pressures continue, the species has a 10% chance of extinction within 100 years (Barnes 2000; BirdLife International 2009).

Habits and diet

Grey Crowned Cranes are largely associated with wetlands, but forage extensively in associated dry land habitats. These may include short to medium height open grassland, lightly wooded savanna and agricultural fields (Walkinshaw 1964; Pomeroy 1980; Johnsgard 1983; Meine & Archibald 1996; Harrison *et al.* 1997; Hockey *et al.* 2005). According to Pomeroy (1980), working on cranes in Uganda, they feed mainly in grasslands but require wetlands to breed in and where possible large trees for roosting. Johnsgard (1983), Meine & Archibald (1996) and Hockey *et al.* (2005) give comprehensive species accounts which mention that they forage predominantly in open grassland habitats.

Grey Crowned Crane feed on leaves and especially the seeds of grasses such as couch grass *Cynodon dactylon* and sedges *Cyperus* spp (Hockey *et al.* 2005). They feed by pecking and stripping grass seeds from the stem with an upward motion of the bill and stamp their feet to disturb insect prey. These insects may include locusts, and grasshoppers Family: Acrididae, cutworms Family: Noctuidae, army worms *Spodoptera* spp. and millipedes Family: Sphaerotheriidae. According to Hockey *et al.* (2005) they probably eat fallen grain as well as germinating and planted seeds in crop lands.

Due to the fact that Grey Crowned Cranes have a generalist feeding strategy, the species has generally adapted well to settlement. In East Africa, most crane populations now occur in human-modified environments (Meine & Archibald 1996). The study area selected is well suited to Grey Crowned Cranes, containing large wetland systems which constitute ideal breeding habitat for the species together with open grassland foraging areas.

Use of agricultural lands by cranes

A number of studies have documented the use of agricultural land as a feeding ground for cranes. Greater Sandhill Cranes *Grus canadensis tabida* in particular have been a focus of much research related to agriculture (Reinecke & Krapu 1986; Lockman *et al.* 1987; Iverson *et al.* 1987; McIvor & Conover 1994). Mullins and Bizeau (1978) found Greater Sandhill Cranes to be 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 and 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, mentions that freshly-ploughed fields attract Grey Crowned Cranes in preference to grassland. Johnsgard (1983) mentions that the birds often forage in croplands, particularly in soybeans and groundnuts, this being primarily based on the work of Pomeroy (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. Meine and Archibald (1996) mention in the species account of the Grey Crowned Crane that they 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 supports the fact that cultivated lands are indeed utilized by Grey Crowned Crane as foraging areas.

According to Allan and Ryan (1993) however, 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. These studies into the dietary composition of Sandhill Cranes illustrate the importance of maize within the diet of Sandhill Cranes in particular. No comparable studies of the diet of Grey Crowned Crane have however been undertaken.

Crop damage by cranes

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 (Allan & Ryan 1993). 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* in particular is a preferred food for cranes in many parts of the world (Urban *et al.* 1986; Sugden et.al 1988; Mafabi 1991; Bouffard 1993; Mmari 1993; McIvor & Conover 1994; Su 2003; Lacy & Barzen 2005; Hockey *et al.* 2005). This habit has obvious economic, conservation and management implications for the species (Allan & Ryan 1993). Crop damage is of particular concern. Lockman *et al.* (1987) found that complaints of crop damage attributed to Sandhill Cranes were reported to be rising concomitantly with an increase in crane population numbers in the United States. Blackwell *et al.* (2001) reported that from 1992 to 1996 the United States Department of Agriculture received 670 reports pertaining to depredating Sandhill Cranes in Wisconsin, with reported damages exceeding $ 80 000.00. Crane damage to planted maize in Wisconsin was reported to be increasing since the mid-

1960's, and severe damage had been documented in some areas (Lacy & Barzen 2005).

Many different deterrent methods have been employed to prevent crop damage (e.g. gas cannons, dummies and flagging of the fields) and to deter cranes, but in all cases the birds habituate quickly and soon ignore the disturbances (Bouffard 1993; Lacy & Barzen 2005). Sugden *et al.* (1988) suggested that these methods often fail because birds quickly habituate to scare methods. The use of lure crops is also ineffective as it can concentrate birds from surrounding areas and may cause crop damage in these areas once the lure crops are depleted. Lacy and Barzen (2005) reviewed chemical repellants and suggested that treatment with chemicals which reduce seed damage by insects also reduced damage by Sandhill Cranes, thus building on the work by Dolbeer *et al.* (1998) and Blackwell *et al.* (2001).

While foraging by cranes in fields may be beneficial to farmers by removing invertebrate pests and waste grain, cranes can uproot newly sprouted maize plants and feed on the attached kernel (Lacy & Barzen 2005). Lacy and Barzen (2005) also noted that beyond the 17th day after germination, maize kernels retain no endosperm and are not vulnerable to crane damage. This may however vary according to environmental variables (e.g. soil temperature) which influence how many days it takes for all of the endosperm in maize kernels to be metabolized.

Mackworth-Praed and Grant (1955) stated that Grey Crowned Cranes can cause considerable damage to young crops in East 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. No systematic attempt was however made to quantify the damage caused by the birds and ascertain to what extent Grey Crowned Crane are responsible for crop damage.

It had earlier been stated that Grey Crowned Crane are associated with wetlands and grassland habitats (Walkinshaw 1964; Pomeroy 1980; Johnsgard 1983; Meine & Archibald 1996; Harrison *et al.* 1997; Hockey *et al.* 2005) however no attempt had been previously made to ascertain to what extent these variables may impact on crop damage.

Complaints of crop damage by cranes on planted maize in the North Eastern Cape have been increasing since the mid-1990's, and severe losses have been reported in some instances (J.Smallie pers.comm.[1]). The primary aim of this study was to quantify the damage caused by Grey Crowned Cranes relative to other sources of crop loss, using the analyses of field measurements. Crane damage was compared to the losses caused by Cape Crows *Corvus capensis* and other identified factors, such as damage caused by other feeding, assumed to be by insects, trampling by game and livestock or through unknown causes. The effects of altitude (wetlands) and vegetation type are also evaluated as potential variables which may impact on crop damage.

‗Gaucho' ™ (Bayer), is a seed treatment registered for the control of various insect pests of maize seed. It is being used on several farms within the study area, and my preliminary investigations suggested that this chemical may act as a deterrent to cranes; however a detailed study was necessary to confirm these findings.

Evaluating changes in distribution and abundance of Grey Crowned Crane

The North Eastern Cape is historically an isolated agricultural district, dependent on rangeland stock farming using winter pastures, as well as on maize and potato crops (Griffin 2006). Since 1990, large areas within the Maclear district have been afforested (H.Lechmere-Oertel pers. comm.[2]). Maize production within the Eastern Cape region has also increased according to the South African Grain Laboratory (2008) with further increases likely as agricultural production will need to expand by approximately 3% per annum in order to meet the demand for food in South Africa (du Toit *et al.* 2000). This increase in production will in itself lead to more conflict with species that share the resources, and thus crop damage complaints are likely to increase.

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[2] Helen Lechmere-Oertel. Former Environmental Officer. PG Bison. Private Bag X1, Ugie, 5470.

It is known that afforestation has a negative impact on grassland bird diversity. Large-scale commercial afforestation in South Africa, and elsewhere in the world, can potentially have a profound impact on the biota inhabiting the regions afforested, in addition to having far-reaching water-budget, economic and sociological implications (Bigalke 1980; Macdonald 1989) This is not surprising, considering the radical extent of the habitat changes brought about by timber cultivation, especially when open and largely treeless ecosystems are transformed to monocultures of closed-canopy forests consisting of alien tree species. This issue is currently intensely relevant to efforts to conserve biodiversity. It is also a highly controversial subject and debates between the proponents of the various interest groups involved are frequently charged with emotion and acrimony (Allan *et al.* 1997). This is not restricted to Southern Africa, with studies conducted in the United Kingdom by Sykes *et al.* (1989) and in the United States by Coppedge *et al.* (2001).

Armstrong & van Hensbergen (1996) looking at the bird assemblages of three small, different-aged pine habitats and an indigenous wooded habitat near Stellenbosch, South Africa, found that bird species richness and abundance were found to be higher in the indigenous habitat than in any of the pine habitats during each season sampled (excluding summer) (Armstrong & van Hensbergen 1996).

Murray *et al*. (2007) found that the overall abundance of all bird species was significantly lower in exotic sites by reviewing available literature on the effects of exotic vegetation. In addition it was found that by grouping bird species into different foraging guilds revealed that those species that forage on the ground under open canopy and those that hawk in the air, on shrubs and on herbaceous plants were significantly less abundant in exotic sites. This demonstrates that although exotic plants might not affect species richness the effects on other measures of ecosystem structure, such as overall abundance, and abundance of taxa within particular foraging guilds, can be quite substantial. Therefore, it is important that other descriptors of ecosystem structure are considered in addition to species richness in order to understand the range of effects of exotic plants in native vegetation.

Alan *et al*. (1997) found that afforestation significantly reduced the species diversity of grassland birds in Mpumalanga Province, South Africa, with the diversity of all grassland birds and globally threatened grassland birds being significantly and negatively correlated with the extent of afforestation. Grassland bird diversity declined even when the percentage area under plantation was relatively small. Grey Crowned Crane was described as a characteristic species of open grassland and marshy habitats within this study.

Natural fire regimes are another factor affecting grassland biomes which change as a consequence of afforestation. In general, the grassland fire regime is one of regular fires occurring mainly during late autumn, winter and spring (Berliner & Desmet 2007). Fire regimes affect the tiller initiation of individual grass species which, in turn, affect the production of grass forage. The absence of fire, together with the host of other factors brought about by afforestation, together with change in land-use, are detrimental to grassland. The vegetation becomes moribund and provides less suitable habitat. Fires which inevitably occur are more severe than they would otherwise have been, being detrimental to both biodiversity and infrastructure (Goldammer & de Ronde 2004).

Due to the changes in land-use which had taken place within the study area over the past two decades, primarily in the form of afforestation and an increase in maize production, it was necessary to ascertain to what extent these changes may have influenced changes in abundance and distribution of Grey Crowned Crane. Changes in the distribution of the Grey Crowned Crane within the study area were assessed by comparing my own sightings for the period 2005 – 2007 with past sighting records. These data were sourced from the records of the East London Museum for the period 1978- 1995, the South African Crane Working Group (SACWG) for the period 1995-2009, as well as the records of the Coordinated Avifaunal Roadcounts (CAR) (1998- 2008) for the same map units.

Objectives of the study

The main objectives of my study are therefore as follows:

- To determine whether Grey Crowned Cranes are responsible for crop damage to maize in the North Eastern Cape and quantify the damage caused by the birds
- To determine to what extent vegetation type and altitude (wetlands) may influence crane foraging
- To determine the age at which maize plants are most susceptible to crop damage
- To determine whether seed treatments used in the control of insect pests on maize may influence crane feeding behavior
- To determine whether changes in land-use may have had any influence on the distribution and abundance of cranes within the study through the analysis of observer records (recognizing the short comings of this method of data collection)

The main hypotheses I tested were: (1) plant height is related to the susceptibility of the maize plants to crane damage. Mackworth- Praed and Grant (1955) stated that Grey Crowned Cranes cause considerable damage to young crops; however no attempt has previously been made to quantify this statement. I wanted to establish at what age maize plants were most susceptible to damage.

(2) Seed treatment reduces crane feeding. A pilot study (MHvN) seemed to indicate that cranes avoid treated crops, but no quantified assessments were made. Treating maize seed could have economic implications, by not only increasing the cost of planting, but possibly reducing seed damage by birds.

(3) For distribution, I tested the null hypothesis that land use change has had no effect on crane distribution in this area. Large scale afforestation has taken place in the Maclear area since 1990, and I wanted to determine to what extent these changes in land-use had influenced distribution and abundance.

CHAPTER II

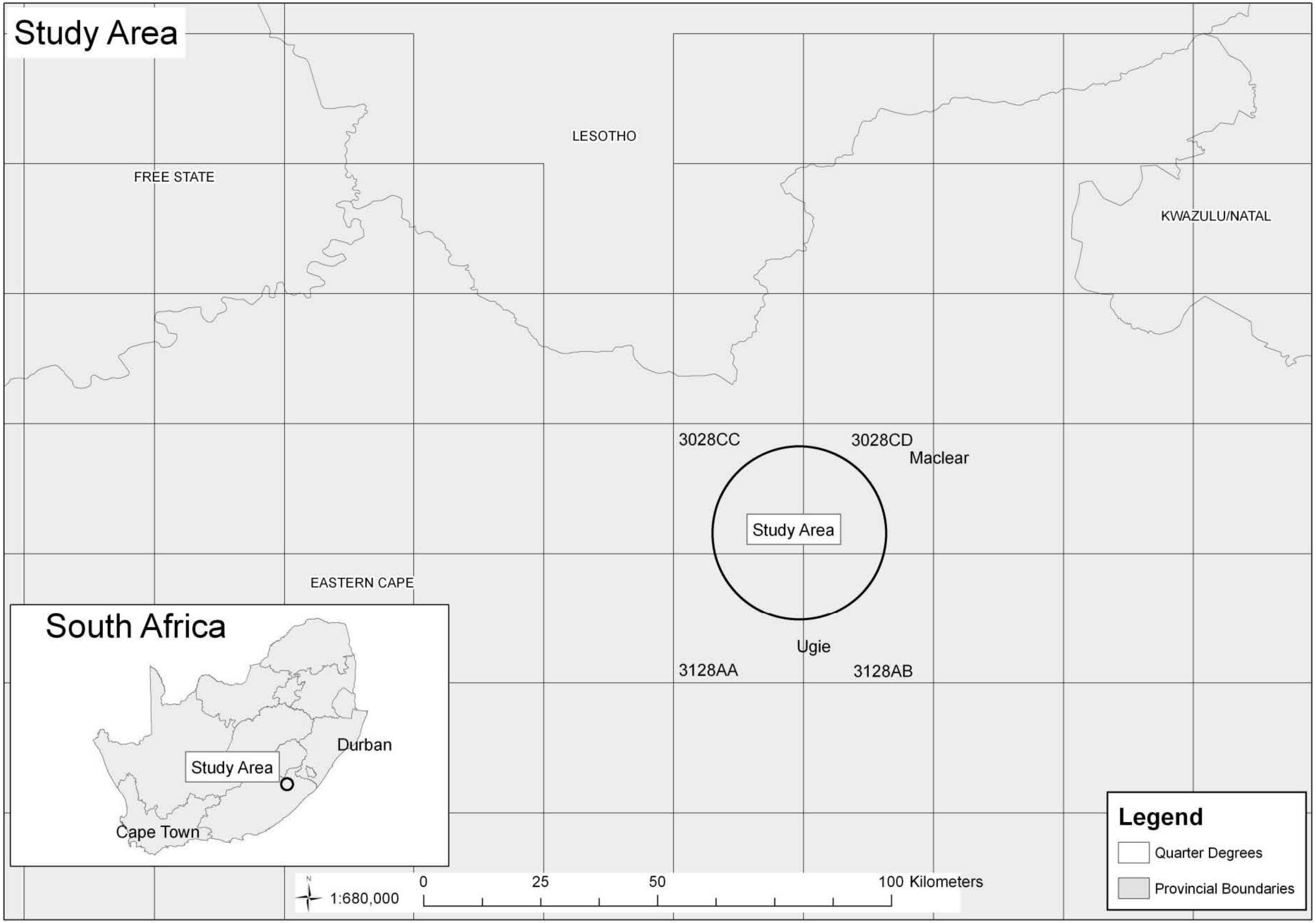
STUDY AREA

Study Area

Locality

The Maclear district is located at 32° 42‘ to 32‘ °21‘S; 27°55‘ to 28°30‘E at the southern end of the Drakensberg mountain range in the north of the Eastern Cape Province in South Africa. The general study area consists of five quarter degree square units, covering an area of approximately 3400 km^2 (Figure 3). The altitude ranges from 1160 m to 1920m within the study area, however all the quadrats sampled in the 2005 and 2006 season were situated at an elevation of 1200m to 1450m. The steeply incised river valleys and shallow soils in places, generally did not allow for the cultivation of the land to take place above or below these altitudes.

Figure 3: Map of South Africa indicating study area.



Climate

The mean circulation over southern Africa, which includes the Drakensberg region, is anticyclonic throughout the year. In winter, the subsidence of air causes atmospheric stability and consequently a distinct dry season. In summer, the subsidence inversion may rise above the escarpment resulting in an influx of humid air from the warm Mozambique current of the Indian Ocean by South Easterly winds (Tyson *et al.* 1976; Tyson 1986). The Drakensberg is one of the best-watered, least drought – prone areas of southern Africa. Annual precipitation varies from 1000mm in the foothills to 1800mm on the escarpment.

The Maclear district is characterized by summer rainfall (November to March), which accounts for 70% of the annual total, with a mean annual precipitation of 890mm (Figure 4). The mean annual temperature is 14.6 ºc with 26 frost days per year, which is indicative of a cooler, sub-montane form of warm-temperate climate (Mucina & Rutherford 2006). Rainfall data obtained from the PG Bison forestry office in Ugie for the period 2002 to 2006 provided corresponding rainfall figures, with an annual average of 868mm being recorded over a five year period. Variations in temperature are considerable both seasonally and between day and night, the highest temperatures (up to 35 ºc) occur in summer on north facing slopes at lower altitudes, while the lowest temperatures (down to -20 ºc) occur during winter nights on the summit plateau (Tyson *et al.*1976; Tyson 1986).

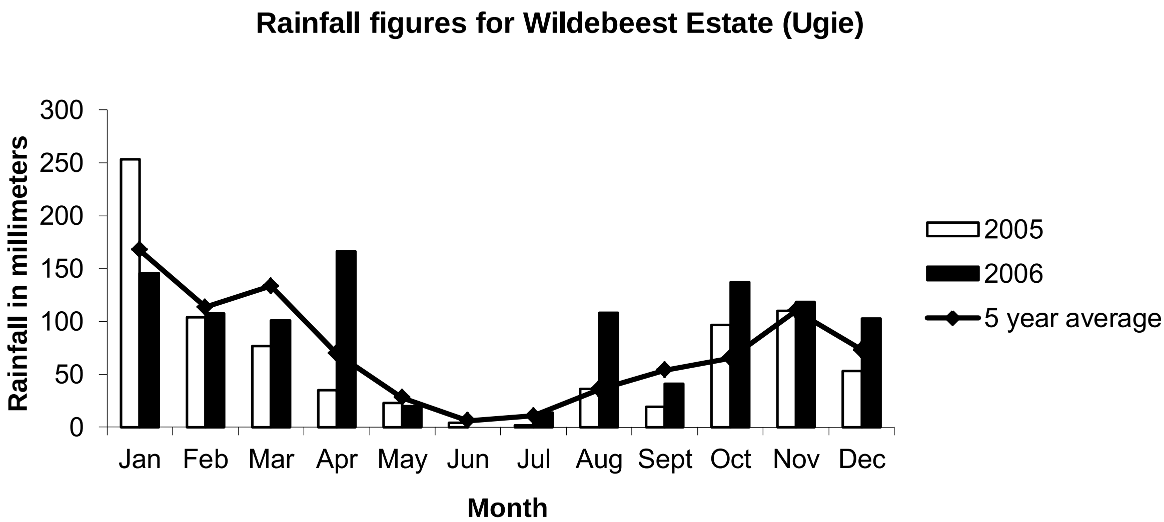


Figure 4: Mean monthly rainfall figures for 2005 and 2006 with 5 year average (PG Bison 2007)

Geology and soils

The geology is dominated by an underlying sedimentary structure of mudstones and sandstones of the Karoo Sequence. This sequence is comprised of the Tarkastad Subgroup (Beaufort Group) and Molteno Formation. Intrusive dolerites of the Jurassic period cut these sedimentary layers, with extensive outpourings of basic lavas associated with the dolerites and occasional pictrite intrusions (Karpeta & Johnson 1979).

The Katberg formation (Tarkastad Subgroup) is characterized by yellowish-grey to light greenish grey lithofeldspathetic sandstones up to 30 metres thick with subordinate bluish-grey and reddish –grey mudstones. The sandstones themselves consist of a repetition of mutually truncating, trough cross-bedded channelfill sand lenses up to 1m thick. Mud- pebble conglomerates are often present at the base. The Molteno Formation is characterized by the occurrence of medium to coarse-grained, often pebbly, light-grey to yellowish- grey sandstones alternating with massive, soft, pale –olive mudstones and subordinate grey shale. The sandstones are composed largely of quartz with a low feldspar content (<5%). Mudstone pebble conglomerates are common. The higher altitude areas are overlain by the Elliot Formation, which consists of grayish-red or greenish-grey mudstone and subordinate sandstone. Outcrops of fine grained Clarens Formation sandstone; pale –orange to pink in colour are also present (Karpeta & Johnson 1979). Basalt lavas generally occur above 1700m, where they overlie the above mentioned sedimentary layers.

The dominant soils on the sedimentary parent material, belonging to the oxidic soil group, are generally well drained, with a depth of 800mm and a clay content of 15-55%. Soil forms represented are Hutton, Clovelly, Griffin and Oatsdale. On the volcanic parent material (dolerite) the soils are represented by the forms Balmoral, Shortlands and Vimy (Fey 2005; Mucina & Rutherford 2006). Optimal maize production requires deep fertile and well drained soils rich in organic matter; however it can be grown on most soil types ranging from deep heavy clay to light sandy soil. Field trials have indicated that loam or silty loam surface soils and brown silt clay loam which have a fairly permeable sub soil layer, are the ideal soil types for the production of maize (Agrisnet 2010). These conditions are found within the study area. Soil type therefore, has a direct influence on the nature of crop production within an area by influencing the selection of suitable species which can be utilised for optimal production.

Vegetation

The vegetation of the Ugie and Maclear area has been described by Mucina and Rutherford (2006) as primarily Drakensberg Foothill Moist Grassland (Gs 10 in their tabulation) though East Griqualand Grassland (Gs 12) and Southern Drakensberg Highland Grassland (Gs 4) are also present. This vegetation type occurs at an altitude of 880 -1860m with the landscape characterized by moderately rolling hills. Much of the landscape is incised by river gorges which are covered in forb- rich grassland, and is dominated by the grasses *Themeda triandra* and *Tristachya leucothrix.*

The grassland is described as ‗sour' with *Eragrostis curvula, Elionurus muticus* and *Heteropogon contortus* also present. Diagnostic species include hardy forbs such as *Walafrida densiflora, Cucumis zeyheri, Cucumis hirsutus, Berkheya onopordifolia, Speramacoce natalensis, Kohautia cynanchica, Tephrosia macropoda, Tephrosia multijuga, Richardia brasiliensis, Gomphrena celosoides, Aster bakerianus, Alysicarpus rugosus, Helichrysum coriaceum* and *Helichrysum rugulosum.* Trees and shrubs occur in sheltered sites, rocky hills and ridges (Mucina & Rutherford 2006).

The area has been identified as a centre of endemism (Drakensberg centre) with approximately 18% of the overall plant species endemic, and four genera endemic to the region. It is however poorly conserved with none of this vegetation type falling into formally protected areas within the Eastern Cape (Berliner & Desmet 2007).

The Drakensberg Foothill Moist Grassland vegetation type is often evident on disturbed, ploughed or heavily overgrazed sites (cf.Cohen 2005). This would indicate a secondary status of many of the representative plant communities within the area. These communities are well maintained outside of forestry areas, but heavily overgrazed in the former Transkei region.

The area has a high timber and agricultural potential. Timber has been identified as one of the industries which has a high rural development and poverty alleviation potential for the province, and is therefore often used as a vehicle for socio-economic development within the province. The Eastern Cape is the only province in the country where large areas are still available for afforestation, therefore prioritising the need for systematic conservation planning in order to avoid biodiversity loss (Berliner & Desmet 2007).

Currently the extent of forestry land in this area is 83 280 hectares, of which approximately 33 000 hectares is planted with *Pinus radiata*, *P elotii* and *Eucalyptus* spp. All the plantation forestry within the North Eastern Cape is owned and managed by PG Bison (H.Lechmere-Oertel pers comm.[3]). Plantations have been established on East Griqualand Grassland, Southern Drakensberg Highland Grassland and Drakensberg Foothill Moist Grassland vegetation types.

The study area in general consists of a grassland biome with a complex mosaic of mainly pine plantation blocks, cultivated land (mainly maize) and montane grassland used for formal (managed) and informal (normally intensive) grazing. As plantations mature, these stands become an increasing fire hazard firstly as a result of the old grassland within the plantation blocks and secondly, by the external fire risk on the plantation boundaries (Goldammer & de Ronde 2004). Bufferzones and other fire breaks (external and internal) have to be burned annually along strategic lines to meet the seasonal wildfire threat as grassland fuels cure. Fire protection forms the basis of burning fire breaks after grassland curing sets in, within areas marked by tracer belts before curing starts. The external north- western boundaries of the plantations in the area are usually burnt first, as this is the direction from which most wildfires originate (Goldammer & de Ronde 2004). This annual burning of some areas, and the exclusion of fire from other areas, alters plant and biodiversity assemblages.

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CHAPTER III

MATERIALS AND METHODS

Crop damage sampling methodology

Study sites were selected based on patterns of crane occurrence established from the distributional data for cranes in the region. This was derived from the records of the East London Museum for the period 1978-1995, the Southern African Bird Atlas project (Harrison *et al.* 1997) and my own fieldwork. Direct observation of cranes feeding, as well as the presence of foraging signs (e.g., probe holes, faeces and feathers), was used to verify that cranes were feeding within the fields. The fields which were selected were dry land agricultural fields, with no form of irrigation taking place.

Three study sites were initially selected within the Maclear area for the 2005 planting season. On the farms Fairbridge, Mondamin and Orpen, two fields each were selected. Ten quadrats of 10m x 10m were randomly placed on each field, and were marked out by using wooden stakes 0.5 m in length. The top 50 mm of each stake was painted white. This was done in order to locate the quadrats, once maize plants were of similar height to the stakes. The size of the quadrats was determined based on the Central Limit Theorem which states that if the sample size is large enough, the distribution of means will follow a Gaussian distribution even if the population is not Gaussian. Since most statistical tests (such as the t test and ANOVA) are concerned only with differences between means, the Central Limit Theorem enables these tests to work well even when the populations are not Gaussian. For this to be valid, the samples have to be reasonably large. Assuming the population does not have an unusual distribution, a sample size of ten or more is generally enough to invoke the Central Limit Theorem (Quinn & Keough 2002; Motulsky 2005).

In order to refine the size of the quadrats, crop damage observations where plotted against the several quadrat sizes. The quadrat size was then selected from the point at which 95% of the observations fell within a Gaussian distribution, resulting in a

10m x 10m quadrat. Consultation was also sought with Kevin Shaw, ornithologist for Cape Nature and Leon- Jacques Theron, manager of the South African Crane Working Group. A pilot study (MHvN) conducted in October 2005 had tested the initial sampling methodology and was used to refine both the size of the quadrats used relative to the Central Limit Theorem, as well as the sampling technique. This pilot study did not provide any quantitative results and therefore the results have not been included.

In 2005 a total of 60 quadrats were sampled: 30 quadrats were planted with maize seed treated with ‗Gaucho' and 30 quadrats were planted with untreated maize seed. The quadrats were sampled every second day on average, in order to determine the cumulative extent of damage within each quadrat. It was found during the initial pilot study, that damage was discernible up to the fourth day after damage had occurred, provided there had been no rain in the preceding period and weather conditions had remained favourable. Due to the large distances between fields, and the number of quadrats to be sampled, monitoring of the quadrats daily was not possible given the resources available. The data collected, indicating the type of damage, the severity of the damage and the date were then entered onto a spreadsheet designed for the purpose.

In order to reduce the unexpectedly high variance and increase the chances of finding statistically significant differences between the treatments, the quadrat sizes were reduced to 4m x 4m in the 2006 season. The sample size was increased to 260 quadrats with additional farms Esperando, Pot Luck, Frankskead and Strathmore added. The increase in the number of replicates within the sampling sites provided more of a representative sample within the fields. Among these quadrats, 131 quadrats were planted with maize seed treated with ‗Gaucho' and 129 quadrats were planted with maize which was untreated (Figure 5) (Appendix 1).

During both seasons, 2005 and 2006, the quadrats were surveyed for a period of up to twenty eight days after the maize plants had emerged from the surface of the ground. A pilot study (MHvN) showed that maize plants are most susceptible to depredation by cranes up to 14 -17 days after the plants had broken the surface of the ground. After this period, the kernel of the maize seed disappears and cranes are no longer interested in planted maize. These findings were comparable to those of Lacy and Barzen (2005) working on Sandhill Cranes in the United States.

Figure 5: Abigail Jack monitoring maize plants in 4m X 4m quadrat. Notice white corner marking on quadrat.

Maize plants within each quadrat were counted and damage by Grey Crowned Cranes, Cape Crows *Corvus capensis*, trampling, other feeding and unknown damage was documented on a spreadsheet. .Plant heights of 10 randomly selected maize plants from within each quadrat were measured and documented in order to give an average plant height per quadrat per day. Plant damage was then calculated as a percentage of the total number of plants within each quadrat and extrapolated to the entire field for each of the forms of damage mentioned.

Discerning the different types of maize crop damage

Grey Crowned Crane damage

Maize seedling damage by Grey Crowned Crane is generally within the plant row and several plants within the row are removed (Figure 6). The seedlings are removed from the ground and the whole kernel of the maize seed is consumed. Signs of foraging (eg size of probe hole, feathers, foot prints) are also used to support the observation (Figure 7).

Figure 6: Crop damage by Grey Crowned Crane. Notice seedling beside probe hole.

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Figure 7: Probe holes by Grey Crowned Crane.

Crow damage

Maize seedling damage by Cape Crows is often only an individual plant, however feeding on several plants within a row was recorded. Crows tended to move between rows, rather than down the row, as with cranes. The probe holes made by crows are smaller than those made by Grey Crowned Cranes (Figure 8).The maize seedlings were not necessary removed from the probe hole, and the kernel was often consumed below the soil surface (Figure 9).

Figure 8: Probe hole by Cape Crow.

Figure 9: Crop damage by Cape Crow. Notice seedling still remaining.

Other Feeding

Damage as a result of ‗other feeding' was described as such if neither signs of crane or crow where seen, and in most cases the aerial parts of the seedling had been eaten off. In many cases the kernel was still present in the ground and could be seen. This type of damage was observed to be caused by Egyptian Geese *Alopochen aegyptiacus*.

Trampling

Damage was recorded to having been caused as a result of trampling if foot prints of the animal could be identified, frequently caused by cattle or game animals.

Unknown damage

Damage was recorded as unknown damage if the plant was visibly damaged, however no signs of active feeding could be seen (Figure 10).

Figure 10: Unknown damage.

Crop damage data analysis

The data were plotted on histograms to determine whether the data had a Gaussian (normal) distribution. Since the data were not normally distributed I used non-parametric tests Spearman's R and Mann Whitney U (Sokal & Rohlf 1995).

Spearman's correlations were run to determine the correlation between plant age and crop damage, and rainfall and crop damage, in both treated and untreated fields. Chi-squared goodness-of-fit-tests were applied to test for differences between plant age and crop damage on both treated and untreated fields. I report P-values associated with the model variables at 0.05. Statistical analyses were performed using Prism version 4 (Motulsky 2005).

A cost benefit analysis was undertaken in order to determine whether the use of Gaucho was a cost- effective mitigation measure to deter crane feeding. Such data would be invaluable to landowners, wanting to know whether to use the chemical as an effective seed treatment to prevent damage by cranes specifically.

Crop damage distribution analysis

All the quadrats irrespective of the type of damage were graphically displayed using Arcview GIS 9. Individual maps indicating crane, crow and other damage were then generated to determine to what extent altitude, distance to lower lying areas (wetlands) and vegetation type may be related to crop damage.

Methodology for abundance and distribution

Three data sets, containing 2775 records, were combined in order to establish broad changes in distribution and abundance. Grey Crowned Crane observation records obtained from the East London museum for the period 1978- 1995 were sorted to include only the records for the Maclear and Elliot districts. My own sightings data collected over the period 2005 -2006, together with data obtained from the South African Crane Working Group (SACWG) 1996- 2009 were used. In order to analyse the data sets, all the sightings had to be converted to Global Positioning System (GPS) coordinates. Where the survey data did contain 1: 50 000 map reference numbers, but no GPS coordinates, a coordinate had to be generated for each observation record. These formed the basis for the ―quarter degree square records" used in the first published bird atlas (Harrison *et al.* 1997).

The results obtained from this combined data set were then compared to the results from the Coordinated Avifaunal Roadcounts (CAR) (on-going, see review by Young *et al.* 2003) in order to establish whether changes in population trends could be determined. All the data sets, including the CAR records, were collected from roads within the study area. The methodology used for collecting of the CAR records, did however use a formalised methodology and were collected biannually in summer and winter. The three data sets formally mentioned, were collected on roads, throughout the year.

GPS coordinates were prepared by creating a centroid for each of the 1: 50 000 tiles present in the study area. Random numbers were then computer generated for each of the tiles, to which the sightings data, which contained a map reference number (1: 50 000), could be added. (Random numbers had to be generated, as several sightings took place within the same 1: 50 000 tile).These random numbers were then inserted into a polygon image for the vegetation unit Gs 12 within the study area. Grey Crowned Cranes were known to occur within this vegetation type based on sightings records, and would unlikely have been distributed randomly across the entire study area, particularly in high altitude areas of the study area.

The data sets were combined into one attribute table and graphically displayed using Arcview GIS 9 on 1: 50 000 maps. Spatial layers of afforestation, vegetation type and roads were then added to establish broad geographic and temporal changes of crane distribution and abundance.

Due to the fact that much of the survey data was obtained by volunteers, some sampling biases are likely. Areas which were surveyed were not evenly distributed across the study area, not all the sites were surveyed every year, and weather conditions influenced the detection of cranes. Given these constraints the data still provided a good indication of broad changes in distribution and abundance over time.

Abundance and distribution statistical analysis

Broad changes in distribution and abundance were analysed using point density in Arcview 9. The data did not allow the Kernel method of home range determination to be applied (Mitchell 1999). Linear regression was then used to determine differences between group size and season, mean adults per season and mean adults per year. I report P-values associated with the model variables. Statistical analyses were performed using Prism version 4, and report significance levels at 0.05.

CHAPTER IV

RESULTS

In order to establish whether Grey Crowned Crane pose a potential problem to agriculture and current land-use practices in the North Eastern Cape, it was necessary to a) determine whether or not crowned cranes are indeed responsible for crop damage and b) determine the extent of crop damage caused by crowned cranes. Once the aforementioned questions have been answered it would then be necessary to determine the factors contributing to crop losses on individual farms by evaluating possible key variables. The following three identified variables were considered: 1) age of plants damaged; 2) the effect of seed treatments on crop damage, and 3) the distance from areas of crop damage to lower lying areas (i.e. wetlands utilised by the cranes for roosting, feeding and possibly nesting). Regression analysis was used to establish to what extent the above mentioned variables impact on crane and crow feeding behaviour.

The collective sightings dataset was analysed to ascertain whether or not the available data provide any evidence for changes in distribution and abundance of Grey Crowned Crane within the North Eastern Cape. Road networks as well as known land use changes, such as forestry were overlaid over both sightings and crop damage data to determine whether or not any correlation existed.

Crop damage

In order to compare the datasets (2005 & 2006) of maize seedling damage which was collected in quadrats planted with maize seed treated with Gaucho, and quadrats in which seed was untreated, percentages of crop damage were used. These figures were used as the actual seedling planting densities employed by the individual farmers vary between farms and fields, and the quadrat size had been modified between 2005 and 2006. Damage was recorded as the number of seedlings removed per damage type, relative to the total number of seedlings per quadrat. In all instances ‗*n*' was used to describe the number of quadrats unless otherwise stated. The different classes of crop damage are presented in tabular format for both 2005 and 2006.

Quantification of crop damage 2005

60 quadrats of (10m x10m) were monitored for the 2005 season. 30 quadrats were untreated and 30 quadrats were treated (Gaucho). Histograms and the Kolmogorov-Smirnov goodness- of- fit test of crane damage for both treated and untreated fields in 2005 did not show a Gaussian (normal) distribution for the data collected. Mean crane damage on untreated fields in 2005 amounted to 4.10% (624 plants) of the total of 15 223 plants counted. Mean crow damage amounted to 0.05% (7 plants) and unknown damage to 1.55%. Collectively damage from all the crop damage classes namely: crane, crow, unknown, other feeding and trampling amounted to 6.77% of the total of 15 233 plants monitored (Table 1).

Table 1: Number of plants sampled for untreated and treated quadrats (2005).

Type of observation (2005)	Total treated plants	% of total plants	Total untreated plants	% of total plants
Crane Damage	34	0.23%	624	4.10%
Crow Damage	13	0.09%	7	0.05%
Unknown Damage	19	0.13%	236	1.55%
Other Feeding	49	0.33%	156	1.02%
Trampling	65	0.44%	7	0.05%
Undamaged plants	14545	98.78%	14193	93.23%
Total plants sampled	**14725**		**15223**	

On the fields treated with Gaucho, crane damage accounted for 0.23 % (34 plants) of the total of 14 725 plants. Crow damage amounted to 0.09% (13 plants) of the total. Collectively damage for all the treated crop damage classes was recorded as 1.22 % of the total of 14 725 plants monitored.

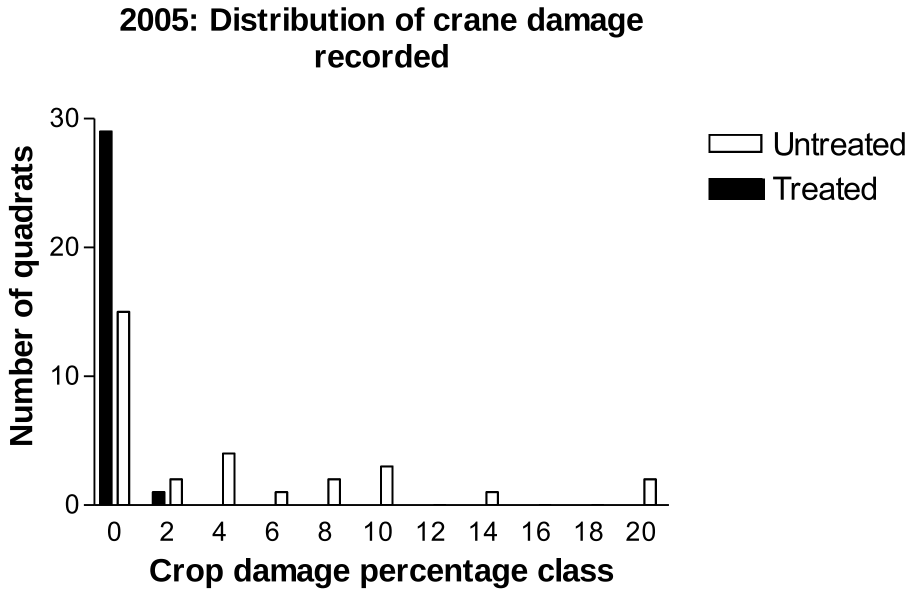

Figure 11: Distribution of average crane damage in untreated and treated quadrats in 2005.

The distribution of crane damage (Figure 11) showed that 75% of crane damage for untreated quadrats was within the range of 0 % — 7.69%, with the maximum damage recorded as 19.10 % and 19.52% on two quadrats on the farm Mondamin. Treating crops reduced the 75% percentile to 0.19% with a maximum of 2.87% of the plants damaged.

The Chi Squared (χ^2) test using the number of plants damaged by cranes in both treated and untreated fields relative to the number of plants not damaged by cranes showed that treating crops with Gaucho had a significant impact on reducing crane damage (χ^2= 543.661, df=1, $P < 0.001$). The Mann Whitney U test displayed congruent results when using the average percentage of crane damage per quadrat (Mann Whitney U =259, P=0.0045). Treating crops with Gaucho was thus shown to significantly reduce feeding by Grey Crowned Cranes in 2005. No significant difference was however found between treated and untreated fields in relation to crow damage (χ^2= 1.657, df=1, P =0.1980). Treating crops with Gaucho was therefore not shown to have any significant impact on crow feeding behaviour.

When comparing the different types of damage per quadrat (Figure 12), the number of quadrats experiencing crop damage in untreated fields was higher than in treated fields, with the exception of crow damage. Crow damage on treated quadrats (10 %, n=3) was greater than untreated quadrats (6.6%, n=2). Treating crops with Gaucho was however shown to be insignificant in affecting crow feeding (χ^2= 0.9761, df=1, P = 0.3232).

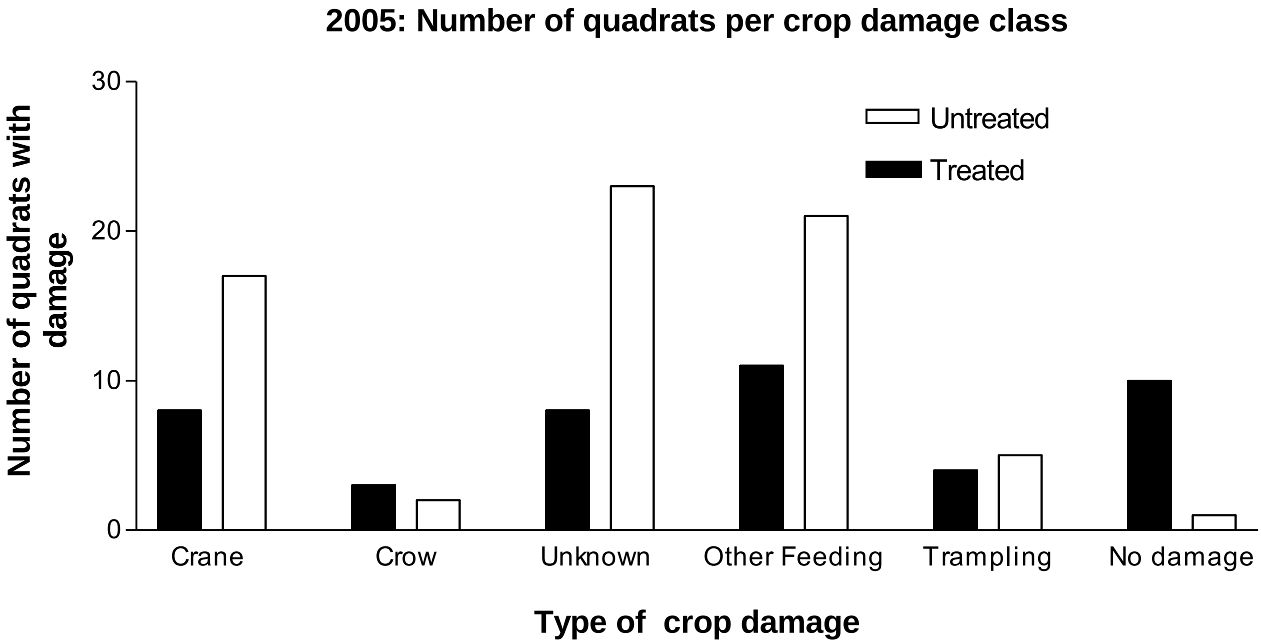

Figure 12: Number of quadrats which experienced crop damage of 60 quadrats sampled (2005).

When analysing the number of quadrats which were recorded with no damage in both treated and untreated quadrats, treating crops with Gaucho in 2005 was shown to have a significant effect in reducing overall damage (Mann Whitney U =315, P=0.04).

Quantification of crop damage 2006

In the 2006 planting season the number of quadrats surveyed was increased to 260 quadrats of 4m x4m. 129 quadrats were untreated and 131 quadrats were treated with Gaucho. Histograms and the Kolmogorov- Smirnov goodness- of- fit test of crane damage for both treated and untreated fields did not show a Gaussian (normal) distribution for the data collected. Mean crane damage on untreated fields in 2006 amounted to 3.06% (296 plants) of the total of 9666 plants counted. Mean crow damage amounted to 2.70% (261 plants) and unknown damage to 0.18% (8 plants). Collectively damage from all the crop damage classes namely: crane, crow, unknown, other feeding and trampling amounted to 7.32% (339 plants) of the total of 9666 plants monitored (Table 2).

Table 2: Number of plants sampled for untreated and treated quadrats (2006).

Type of observation (2006)	Total treated plants	% of total plants	Total untreated plants	% of total plants
Crane Damage	94	0.91%	296	3.06%
Crow Damage	75	0.73%	261	2.70%
Unknown Damage	8	0.08%	17	0.18%
Other Feeding	148	1.44%	128	1.32%
Trampling	14	0.14%	6	0.06%
Undamaged plants	9973	96.71%	8958	92.68%
Total plants sampled	**10312**		**9666**	

On the fields treated with Gaucho, crane damage accounted for 0.91% (94 plants) of the total of 10312 plants. Crow damage amounted to 0.73% (75 plants) of the total. Collectively damage for all the treated crop damage classes was recorded as 3.29 % of the total of 10 312 plants (Table 2).

The distribution of crane damage (Figure 13) showed that 75% of crane damage for untreated quadrats was between 0%—1.51%. Two outlying records of 55.88% and 84.37% were recorded each within a single quadrat on the farm Esperando. Treating crops with Gaucho reduced the 75% percentile to 0.0% with a maximum of 12.04% crane damage recorded on one quadrat on the farm Orpen.

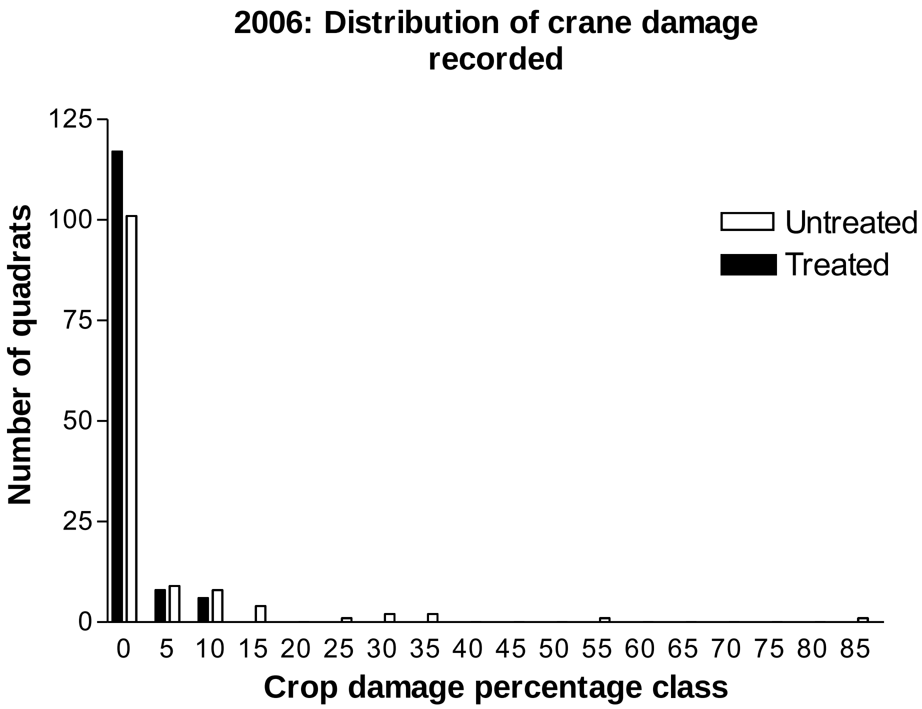

Figure 13: Distribution of average crane damage in untreated and treated quadrats in 2006.

The Chi Squared (χ^2) test using the number of plants damaged by cranes in both treated and untreated fields relative to the number of plants not damaged by cranes showed that treating crops with Gaucho had a significant impact on reducing crane damage (χ^2= 120.6, df=1, P < 0.0001). When using the Mann Whitney U test to test the average percentage of crane damage per quadrat however, treating crops with Gaucho was shown to be insignificant (Mann Whitney U =9038, P=0.1538). This test compares the medians of two different groups and therefore due to the fact that there are large numbers of zero values within the result, this test can be excluded in favour of Chi squared which is a more robust test.

A significant difference was also found between treated and untreated fields when testing the number of plants damaged by crows (χ^2= 118.2, df=1, P <0.0001). Based on the above tests, Gaucho significantly affected both crane and crow feeding behaviour in 2006 by reducing the amount of feeding on maize plants. When comparing the different types of damage per quadrat (Figure 14), the number of quadrats experiencing crop damage in untreated fields was higher than in treated fields, with the exception of ‗other feeding' and trampling.

The damage recorded for ‗other feeding' on treated quadrats (n=64) was marginally higher than in untreated quadrats (n=63). This was however not shown to be significant using averages of damage per quadrat (Mann Whitney U =8321, P=0.9993) or total plots (χ^2= 0.4511, df=1, P =0.5018).Trampling was not seen to be affected by seed treatments and is considered as a random event independent of whether seed is treated or not.

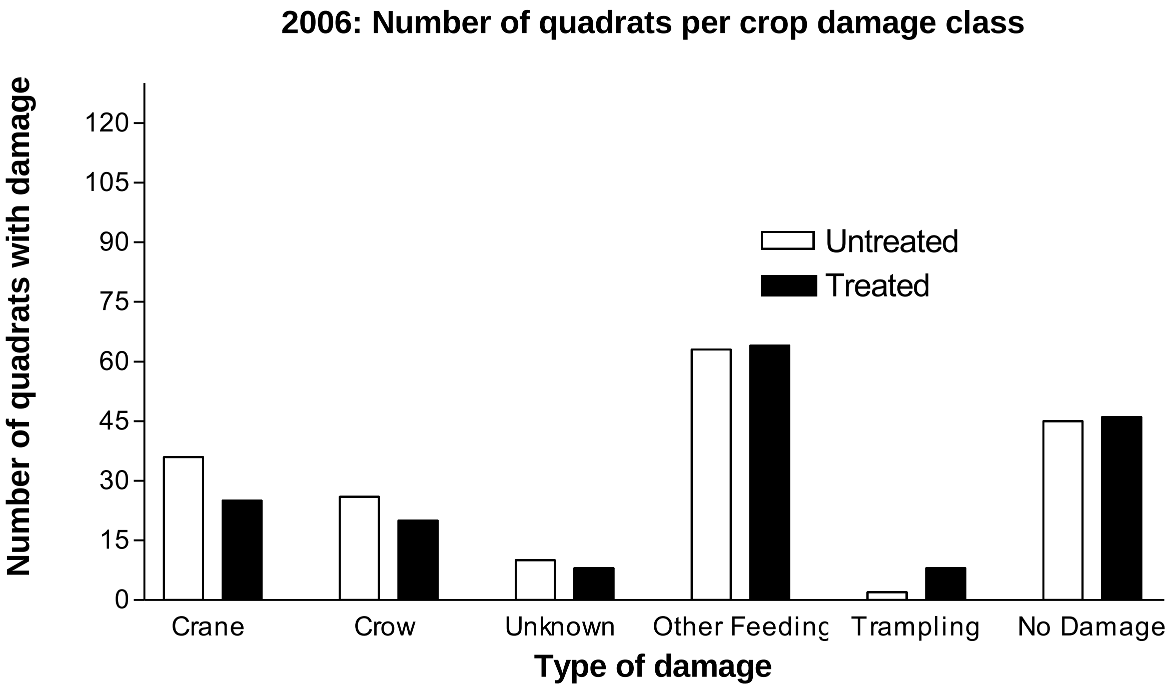

Figure 14: Number of quadrats which experienced crop damage of 260 quadrats sampled (2006).

On the basis of the tests that have been conducted, the results indicate that Gaucho has a significant effect on feeding behaviour of both cranes and crows, based on investigation at a quadrat level. Due to the fact that samples were collected over different seasons, using different scales at different sites within the landscape, direct comparison of the samples was not possible.

Dynamics of crop damage

In order to test for covariation between plant age and crop damage I used the non-parametric *Spearman's r* and linear regression as the data were not normally distributed. No correlation existed between plant age and the average crane damage per quadrat on treated quadrats (Spearman r = -0.02075; P=0.9149) linear (r^2=

0.0037, P= 0.7547).Treating crops with Gaucho had no effect on the age at which cranes feed on maize plants (Figure 15).

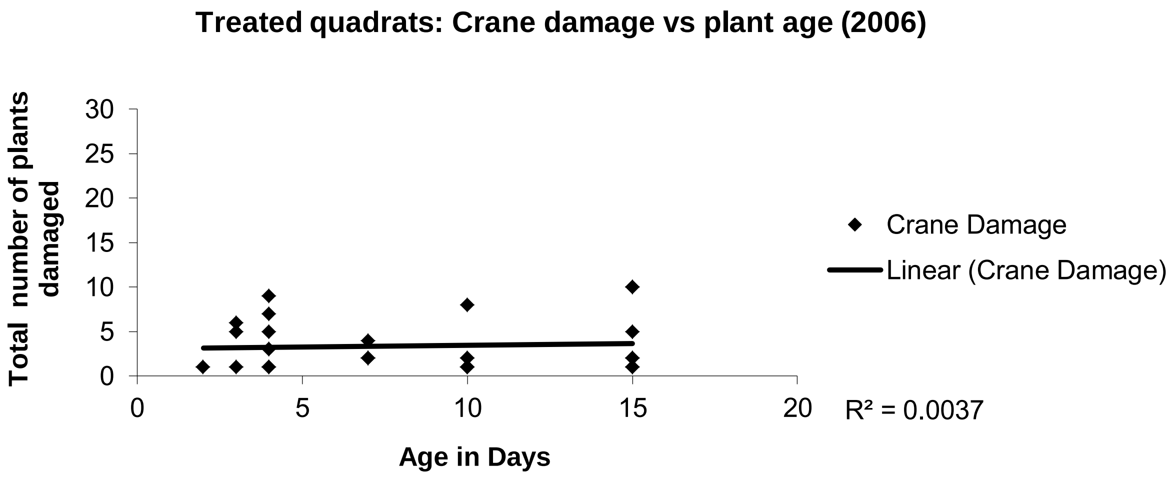

Figure 15: Total number of plants damaged by cranes on treated quadrats relative to plant age (2006)

On the untreated quadrats the covariation between plant age and crop damage by cranes was found to be only marginally significant (r^2=0.07985, P= 0.0332). Cranes feed on young maize plants up to 16 days after the plumule appears at the soil surface. Untreated maize plants are therefore more vulnerable to damage during the first two weeks of plant development (Figure 16). Crop damage on treated maize seed (mean =0.89) was lower than for untreated maize seed (mean=3.83) irrespective of plant age. (χ^2= 120.6, df=1, P < 0.0001).

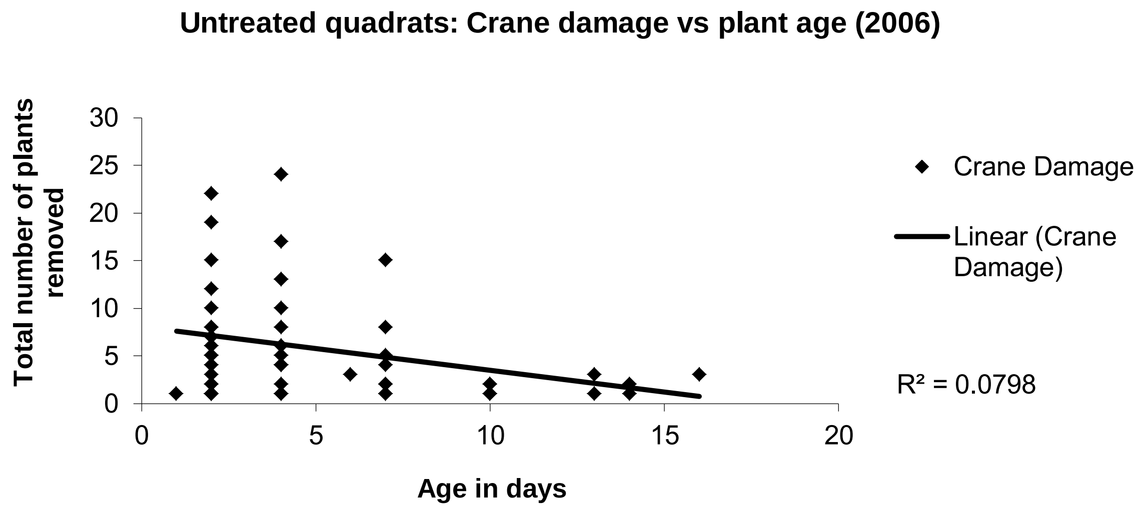

Figure 16: Total number of plants damaged by cranes on untreated quadrats relative to plant age (2006)

Distribution of crop damage

In order to determine the variables influencing crane feeding behaviour, all the study sites were geographically displayed. All the quadrats in the 2005 and 2006 season were situated at an elevation of 1200m to 1450m. In order to determine whether proximity to low lying areas (wetlands) had any influence on feeding behaviour a Triangular Irregular Network (TIN) was created using Arcview GIS 9 of the study area. This image provided a visual representation of the relief of the landscape and enabled all the lower lying areas (wetlands) to be highlighted (Figure 17). It was previously stated that Grey Crowned Cranes are associated with wetlands; however it was uncertain whether crop damage in particular would be influenced by these landscape features. This variable was however difficult to test since the altitude range within the study sites was limited by the activities of the farmers.

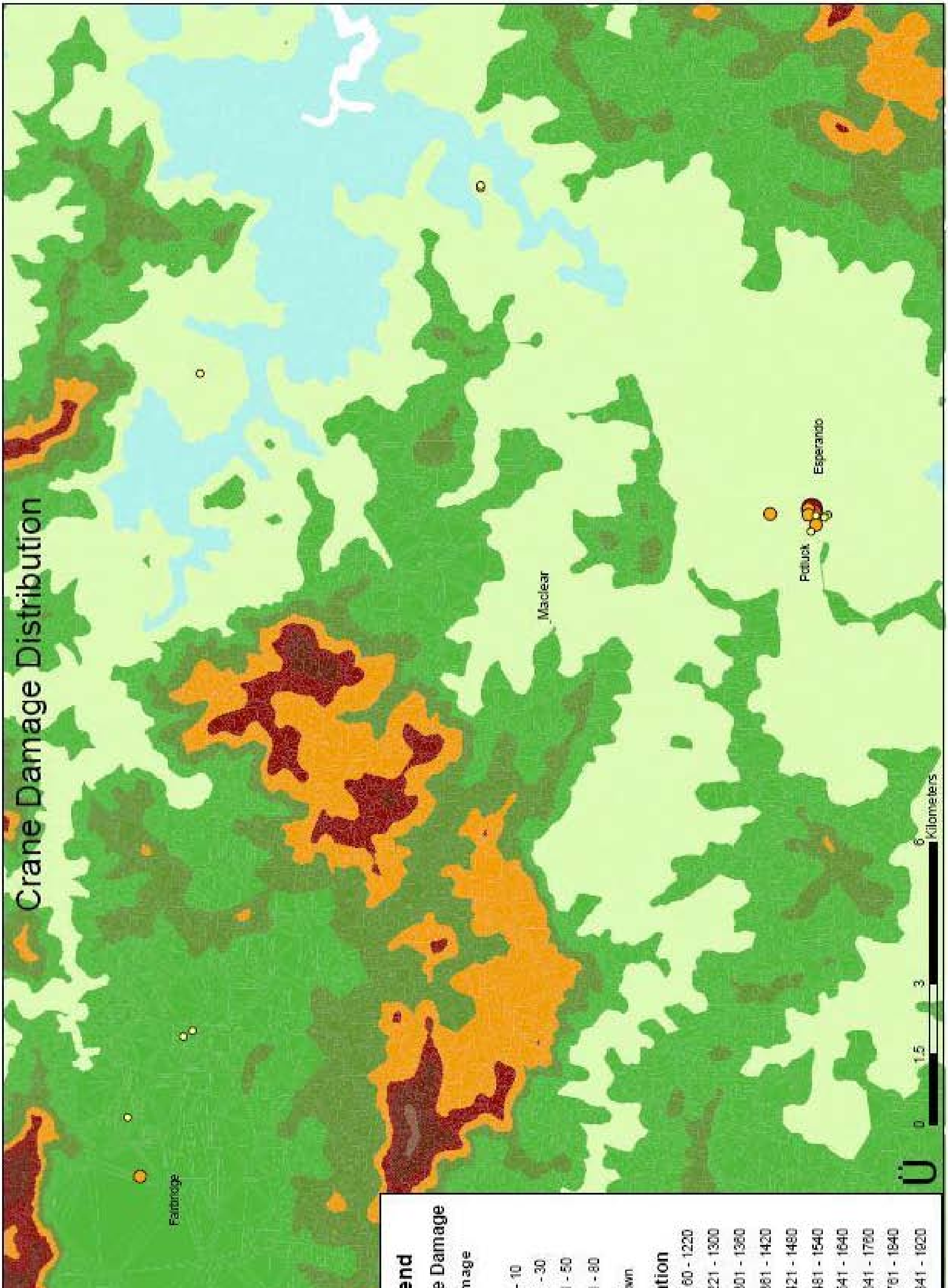

Figure 17: TIN image indicating the distribution of crop damage in relation to the lower lying areas

The initial TIN image was then reclassified into five different classes with a 20m interval between 940m and 1500m. A rastor image of the area was then created in order to highlight low lying areas. The colour blue was used to indicate the lowest altitude and white for the higher altitude areas (Figure 18). Crop damage by crowned crane was then overlaid from the various study sites to ascertain to what extent lower lying areas may influence crop damage.

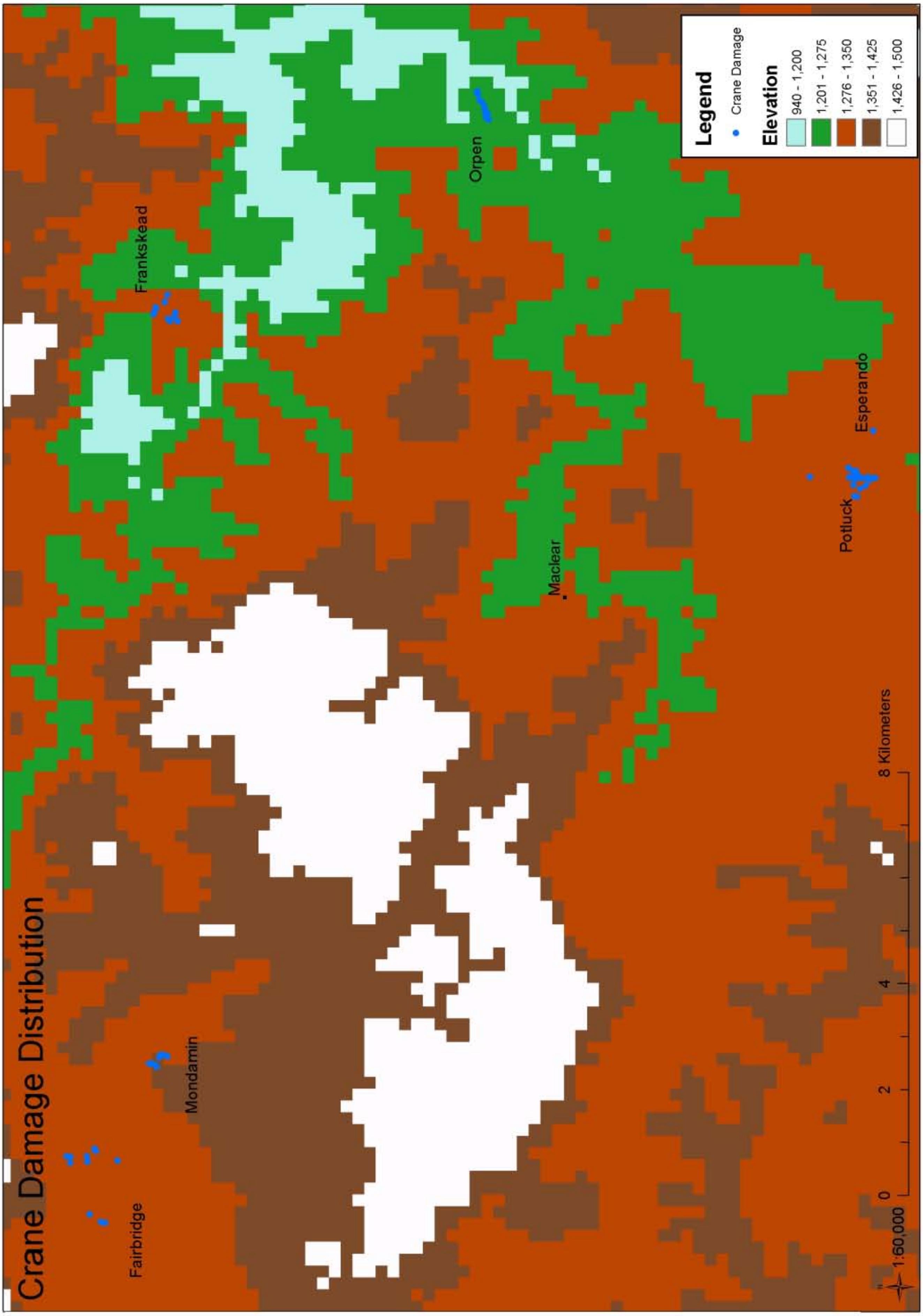

Figure 18: Map of rastor image indicating the reclassified altitude classes between 940 m and 1500m with crane crop damage represented.

Altitude was not seen to play any significant role in affecting crane feeding behaviour since the altitude variation between the study sites was marginal (r^2= 0.0838, P= 0.530)(Figure 19).

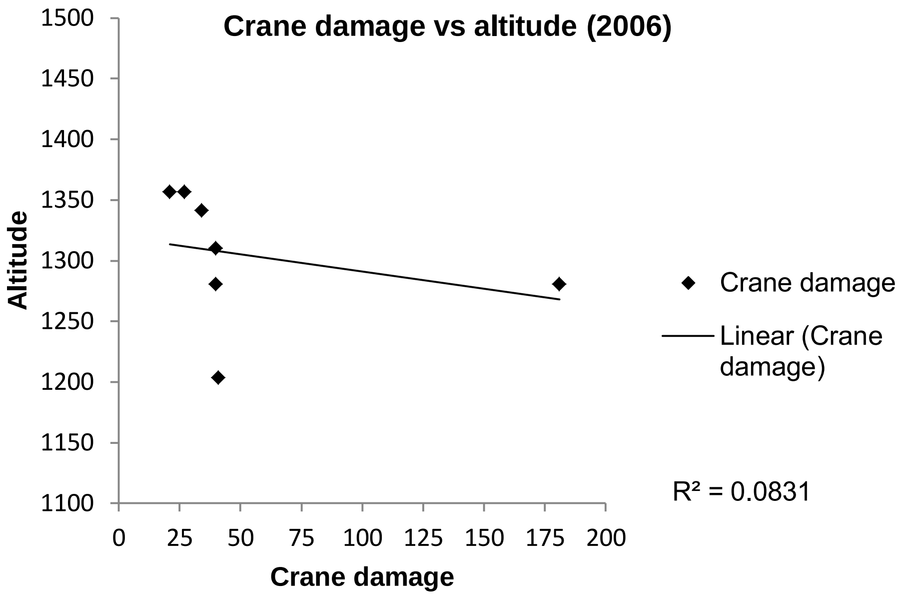

Figure 19: Linear regression of crane crop damage in relation to altitude (2006)

In order to ascertain to what extent wetlands played a role in crane feeding behaviour, digital colour orthophotographs derived from DWAF 1:20 000 scale aerial photographs which were clipped to the national 1:10 000 grid sheets were used to digitize wetlands within a 5 km buffer of the study sites (DWAF / Ukhahlamba District Municipality 2005). The wetlands within a 5km buffer of all the farms, irrespective of whether or not crop damage was experienced were then digitized to determine the effect of wetlands on crane feeding behaviour (Figure 20).

Figure 20: Initial orthophoto image of Pot Luck farm with a 5km buffer depicted in pink, with the digitized wetlands.

The wetlands within the 5km buffer were then numbered and the distances between each of the study sites and all the wetlands were then measured to ascertain to what extent distance from wetland to feeding area may affect crane feeding behaviour (Figure 21). This exercise was conducted for the entire study area and distances were measured between each study site and all of the identified wetlands within the study area (Figure 22).

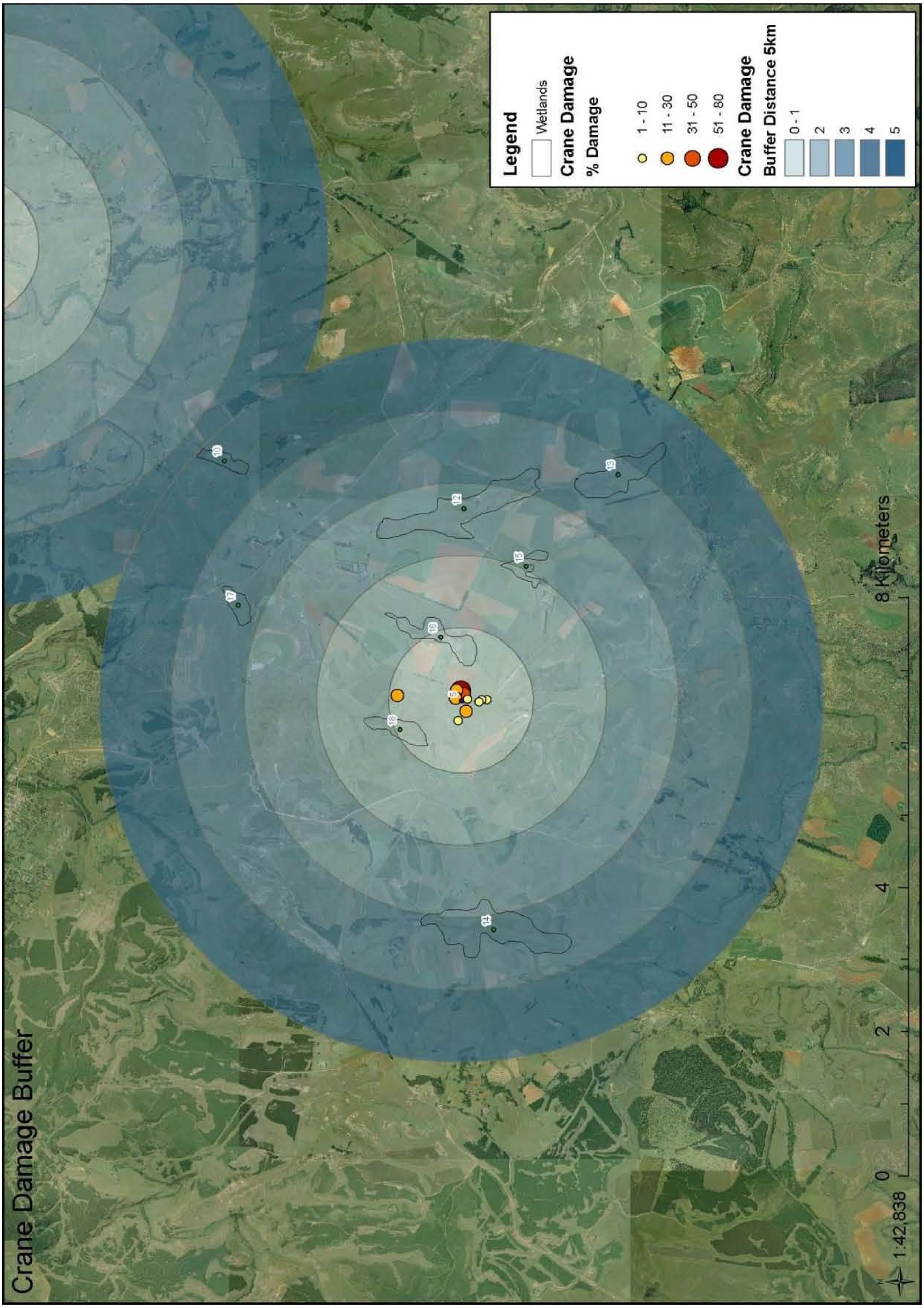

Figure 21: Esperando farm with 5 km buffer. Wetlands and crane damage densities have also been indicated

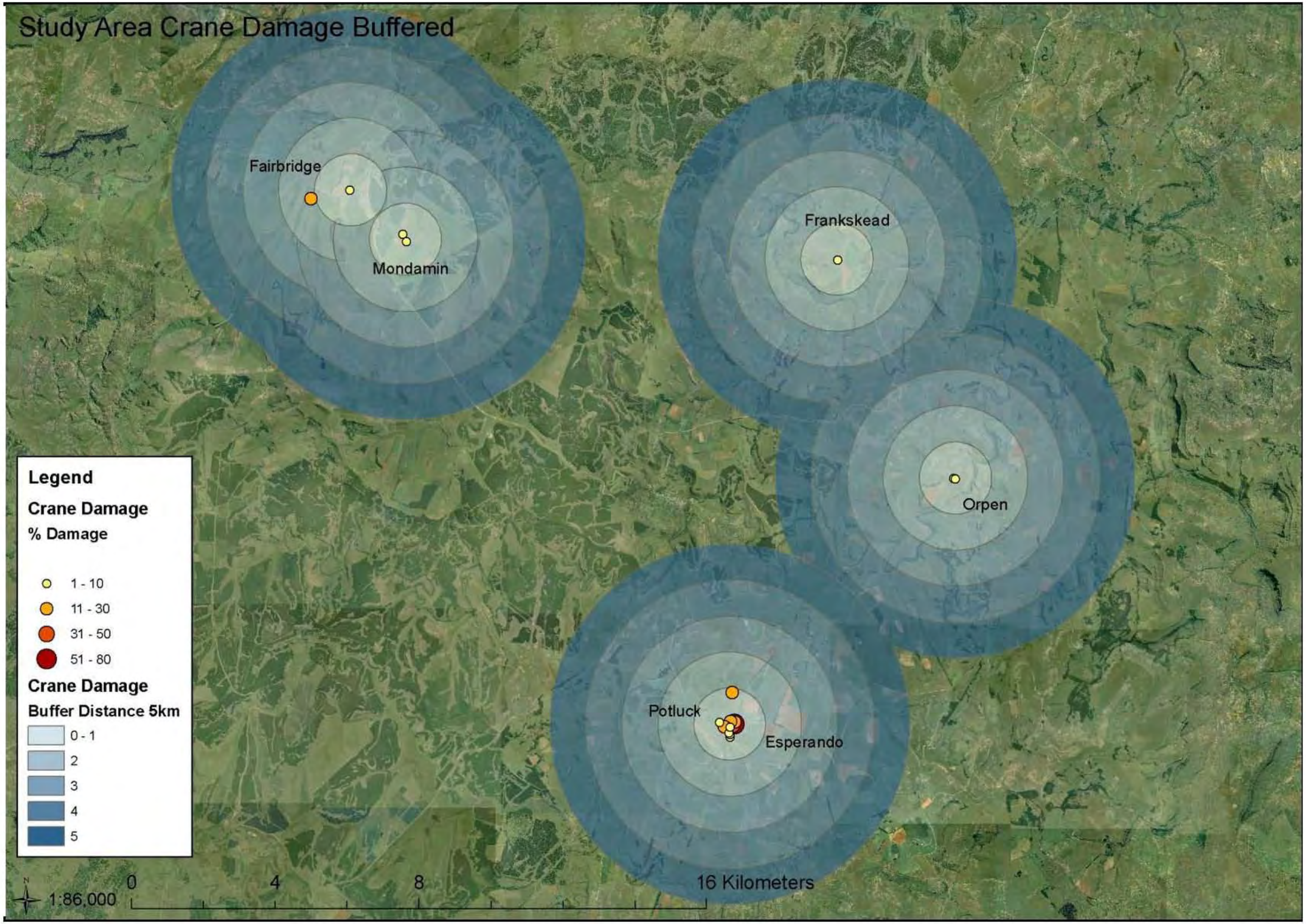

Figure 22: Study area with 5km buffers depicted and crane damage densities.

Linear regression did not show any significance between the number of wetlands within the 5 km buffer and crane crop damage values for each of the study sites when combining both treated and untreated crops (r^2= 0.0149, P= 0.7941)(Figure 23).

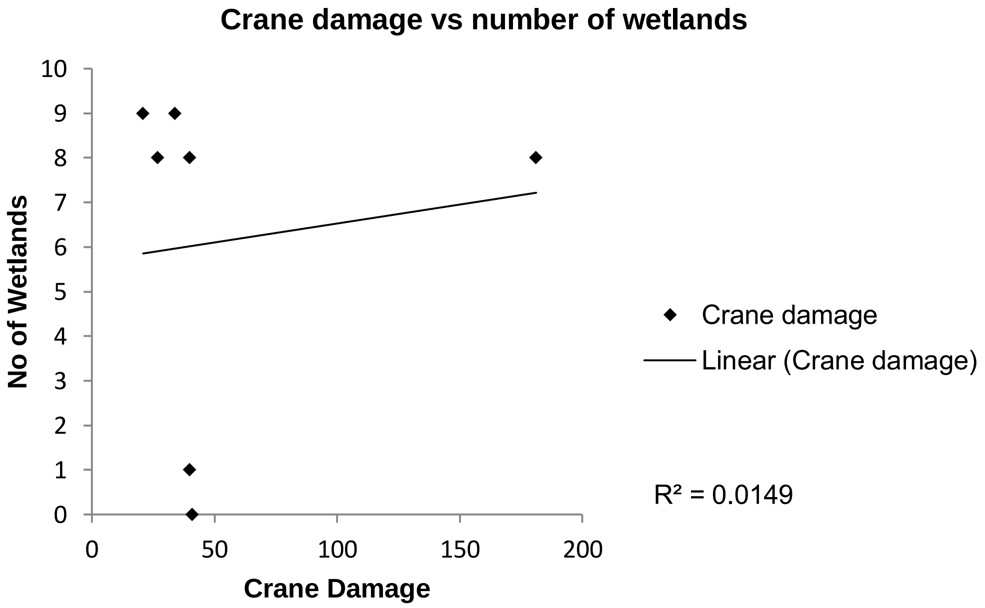

Figure 23: Linear regression of the number of wetlands in relation to crop damage by crowned crane.

Linear regression showed a significant difference between the number of wetlands within the 5 km buffer and plots treated with Gaucho (r^2= 0.8698, P= 0.0208)(Figure 24). This is not likely to have any causative effect on feeding behaviour.

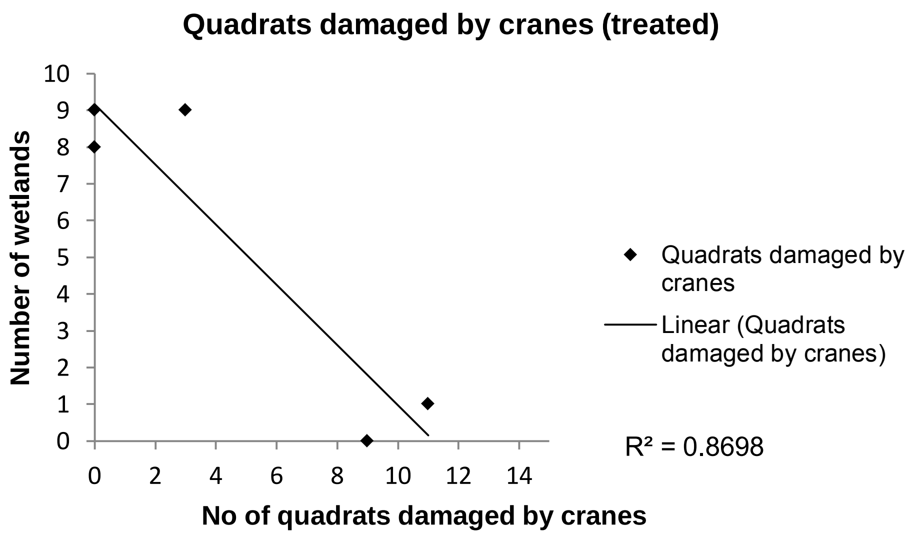

Figure 24: Linear regression of the number of wetlands in relation to crop damage by crowned crane on treated quadrats.

Linear regression did not show a significance difference between the number of wetlands within the 5 km buffer and quadrats untreated with Gaucho (r^2= 0.0184, P=0.827) (Figure 25).

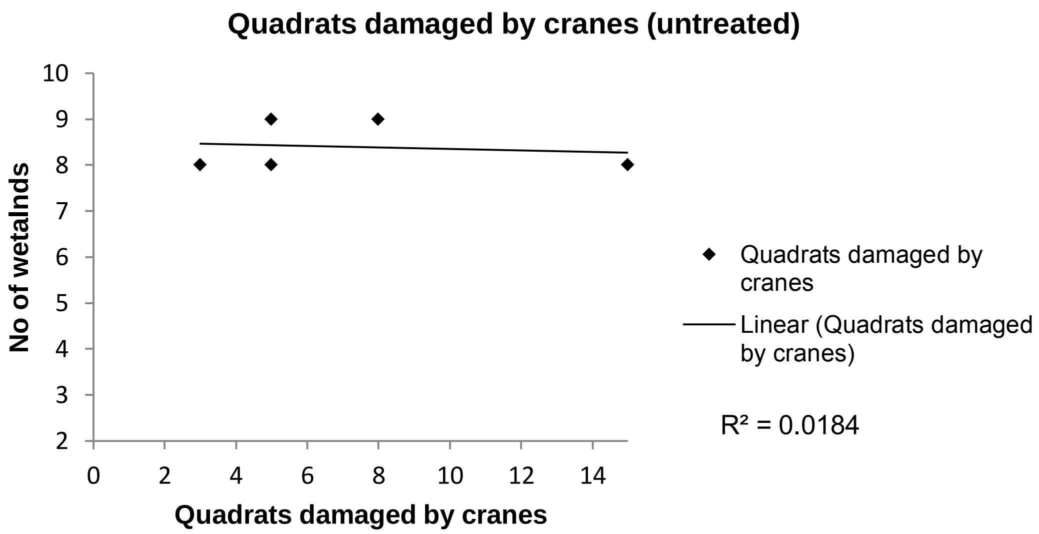

Figure 25: Linear regression of the number of wetlands in relation to crop damage by crowned crane on untreated quadrats.

The study sites where evaluated according to the vegetation type and all fell within the East Griqualand Grassland vegetation type (Gs 12) according to Mucina and Rutherford (2006). Due to the fact that all the study sites fall within this vegetation type, this variable was considered insignificant in affecting crane feeding behaviour (Figure 26).

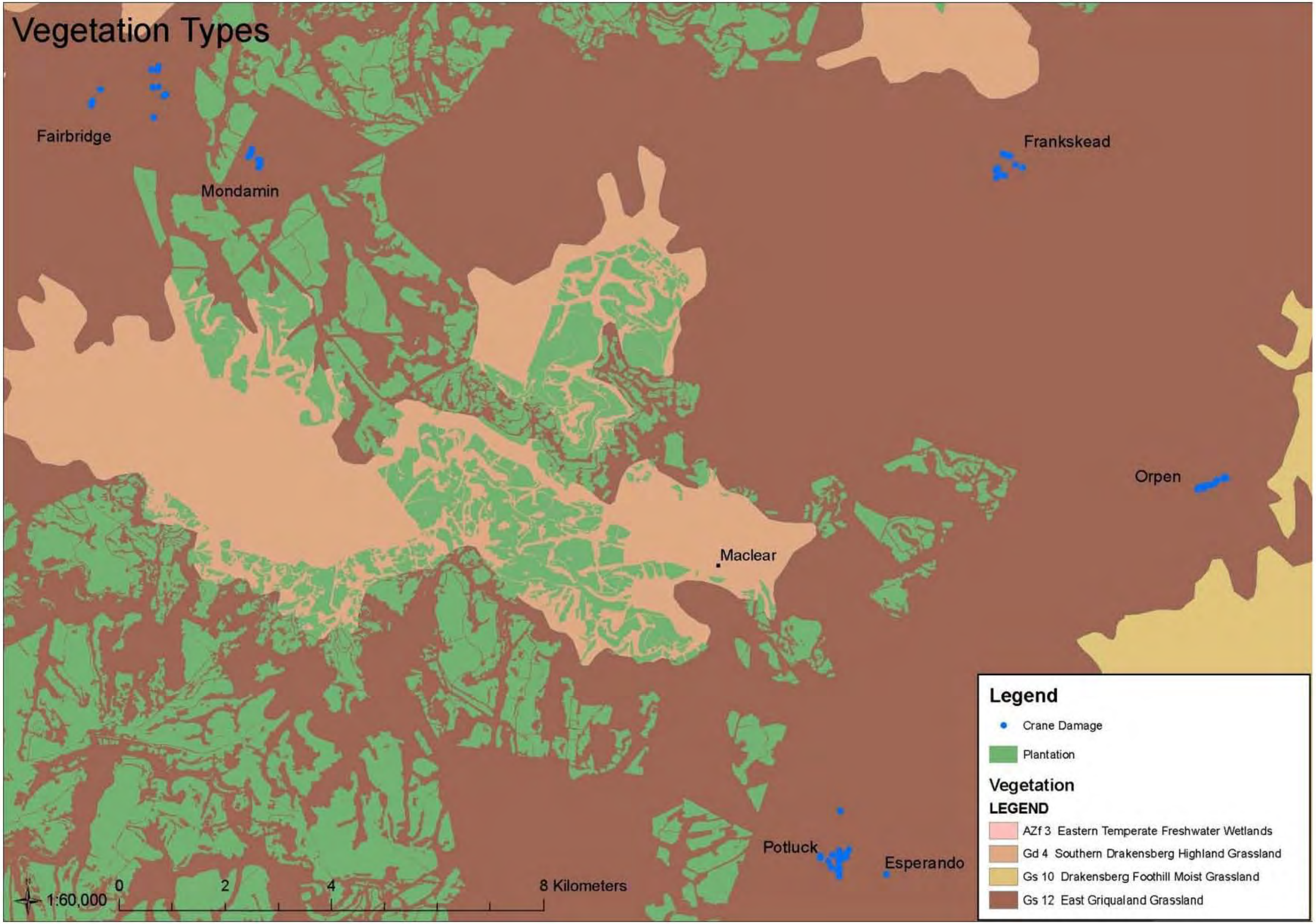

Figure 26: Study sites overlaid on vegetation type (Mucina & Rutherford 2006).

Distribution and abundance of Grey Crowned Crane

For distribution and abundance, I tested the null hypothesis that land use change has had no effect on crane distribution or abundance within the study area. Large scale afforestation has taken place in the Maclear area since 1990, and I wanted to determine to what extent these changes in land-use had influenced both distribution and abundance.

Four datasets were used in order to establish broad changes in distribution. Grey Crowned Crane observation records obtained from the East London museum for the period 1978 -1995 were sorted to include only the records for the Maclear and Elliot districts, and only records of adults and juveniles. These survey data had to be converted to Global Positioning System (GPS) coordinates as they were identified only by 1: 50 000 map reference numbers for each observation record. This formed the basis for the ‗quarter degree square records' used in the first published bird atlas (Harrison *et al.* 1997). In order to generate GPS points for each of the observations, random points were generated for each of the five ‗quarter degree squares' within the study area, once a centroid for each quarter degree square had been generated. A polygon image was then digitized around the East Griqualand Grassland vegetation type (Gs 12), where crowned crane were known to occur. Grey Crowned Cranes were unlikely to have been distributed randomly over the entire landscape with 56% of survey records in South Africa being on cultivated lands and 13% in grasslands (Hockey *et al.* 2005). The random points generated for the observation records were then randomly distributed within the polygon image and point densities generated for these values.

My own sightings data collected over the period 2005 -2006, as well as sightings data from the South African Crane Working Group (SACWG) 1995- 2009 were combined and geographically displayed. These records contained GPS coordinates and could therefore be imported directly onto the orthophoto image obtained (DWAF / Ukhahlamba District Municipality 2005). All the sighting data were displayed with vegetation type, crop damage by crowned crane and plantation overlaid (Figure 27).

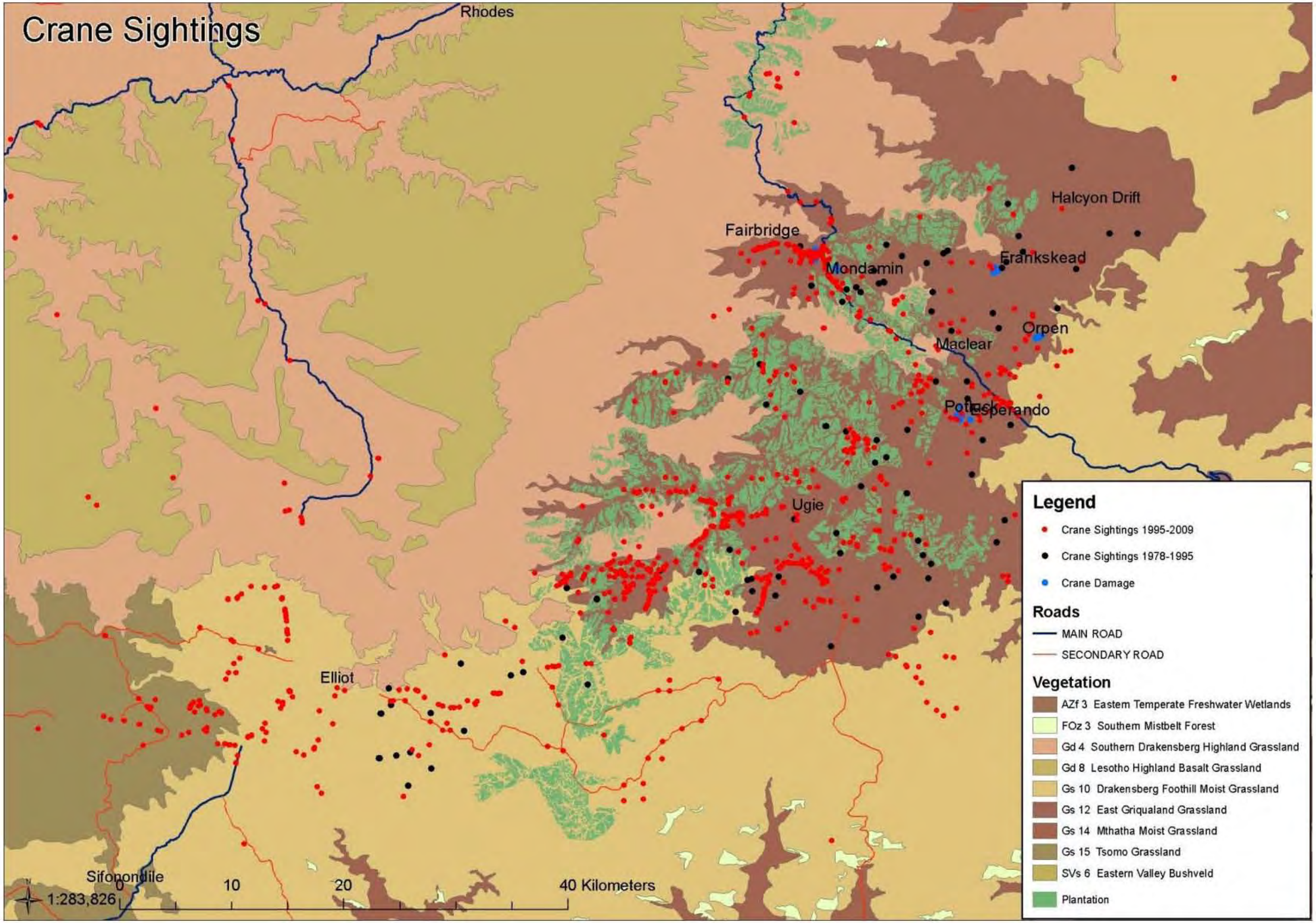

Figure 27: Grey Crowned Crane sightings data overlaid on vegetation type and road network (Mucina & Rutherford 2006).

In order to establish broad changes in distribution, a Hawth's tool application was used in Arcview 9 to generate fixed point density estimates of the sightings (Mitchell 1999). These points were then graphically displayed in order to discern distribution patterns (Figure 28). Sightings data were collected mainly along roads stochastically throughout the year for both of the data sets used. This method of collection only provided details of presence and absence of crowned crane however did not provide details of habitat use specifically. Due to the limitations of the data being collected as points only, only broad patterns of distribution and abundance could be approximated.

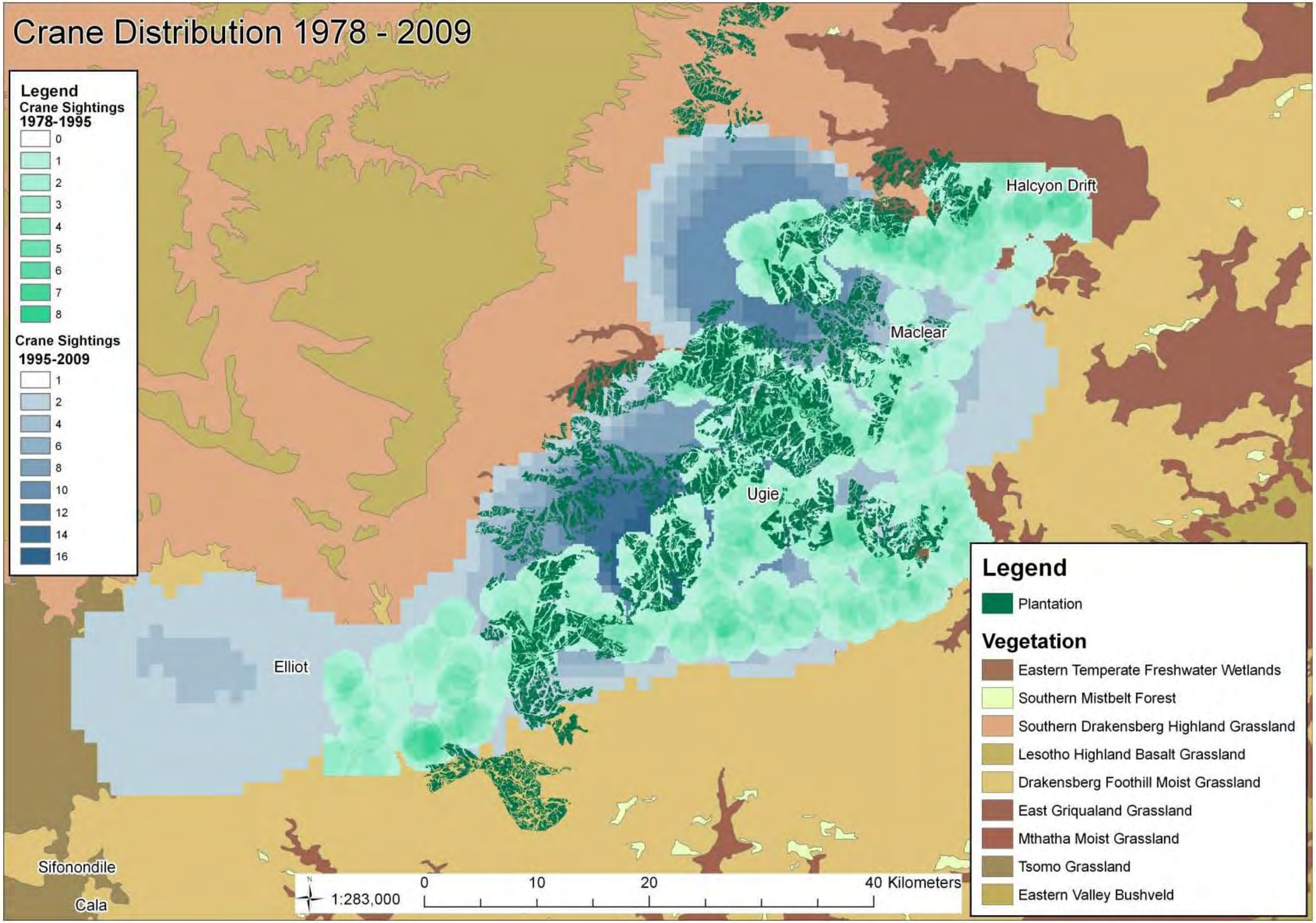

Figure 28: Map indicating vegetation type overlaid with the distribution and abundance of crane sightings. Commercial forestry indicated in green.

Linear regression using the total numbers of juvenile and adult crowned crane sightings for the period 1978- 2009 showed a significant increase in Grey Crowned Crane numbers (r^2= 0.2636, P= 0.0175)(Figure 29). This may be attributed to an increase in the number of sightings records obtained for the period 1999-2009. Average crane numbers however showed a significant decrease in crane population numbers using linear regression (r^2= 0.02032, P= 0.0208) (Figure 30).

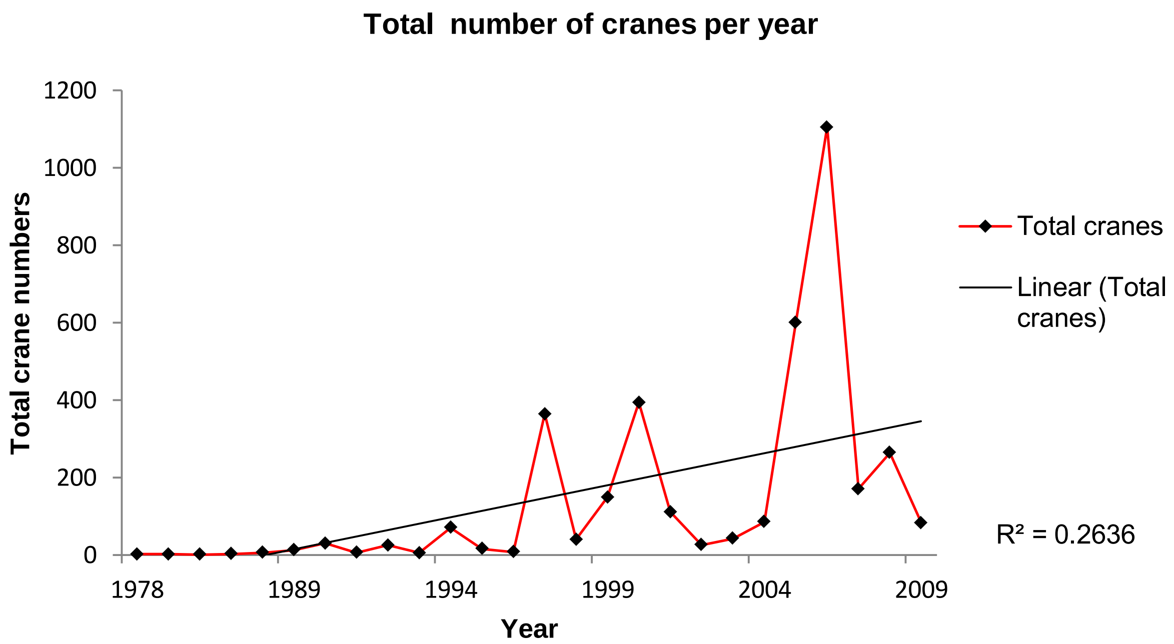

Figure 29: Linear regression of total crowned crane numbers.

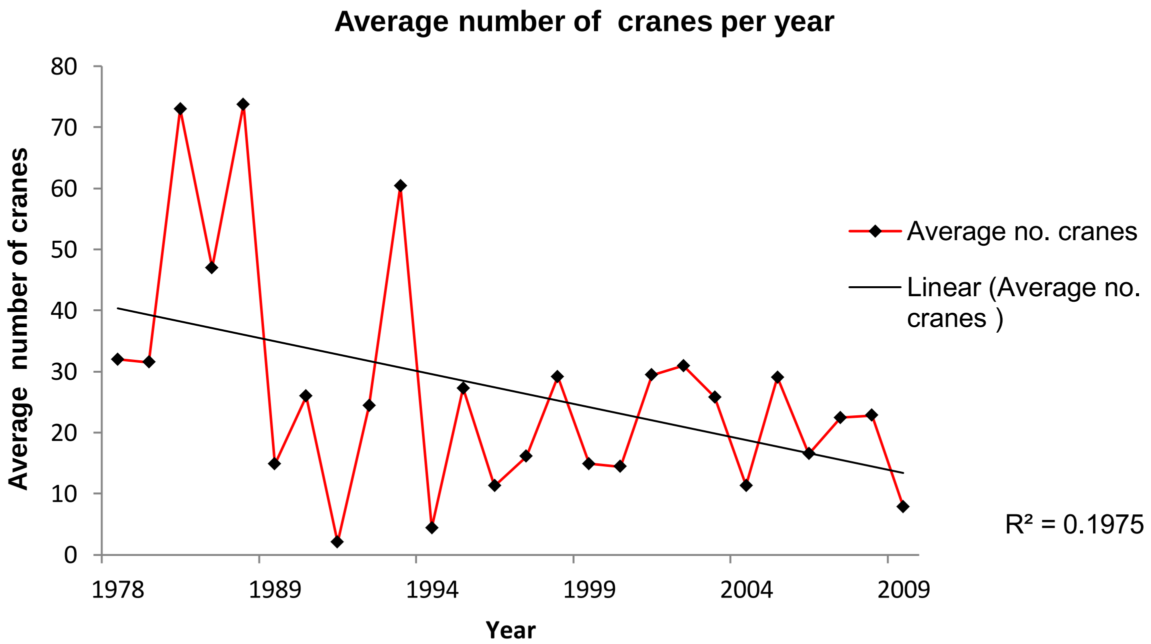

Figure 30: Linear regression of average crowned crane numbers.

With the analysis that was conducted, at the scale that the data were collected, clear-cut changes in distribution over the period 1978- 2009 were difficult to ascertain. The 1995- 2009 dataset did seem to indicate that the distribution of Grey Crowned Crane may have expanded in both a North West and westerly direction since 1978; however this may be attributed to increased effort in the collecting of sightings data by the field staff appointed by the South African Crane Working Group (SACWG) for the period 1995 -2009. Linear regression using the total numbers of cranes from the Coordinated Avifaunal Roadcount (CAR) dataset for the period 1998 to 2008 (r^2= 0.3704, P= 0.0469)(Figure 31) indicated a declining population trend, congruent with the results obtained from average crane numbers.

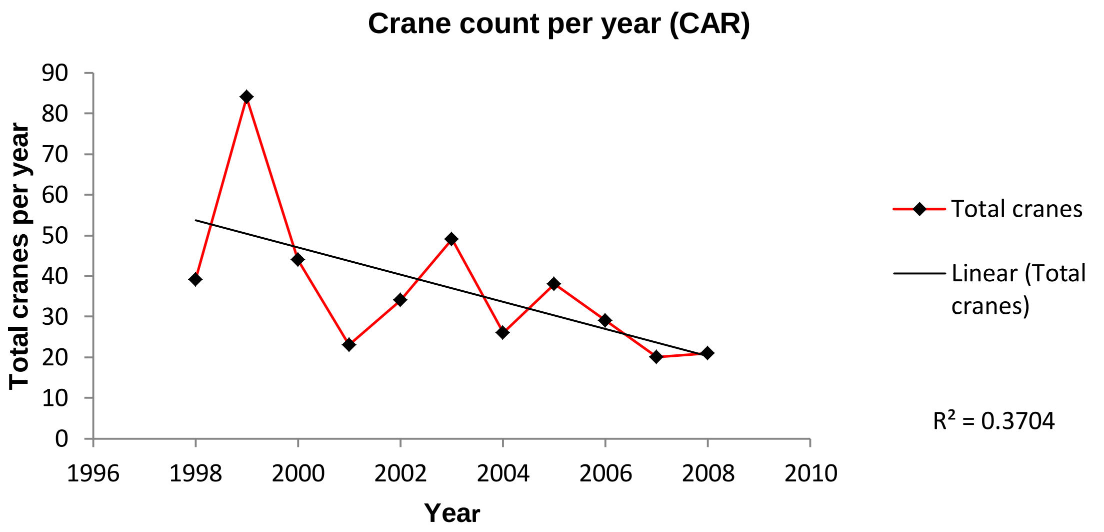

Figure 31: Linear regression of total CAR count crane numbers 1998-2008.

Linear regression of the average adults per season did not yield any significant results for both winter and summer population fluctuations. Given the fact that the CAR count has a well-defined sampling methodology, the results obtained from these counts are more likely to yield population trend data over time rather than the stochastic data collection used to obtain much of the records. Comparing the different sampling strategies, does however indicate how different the techniques may yield different results over time.

CHAPTER V

DISCUSSION

Bird damage situations occur when there is an economic loss, threat to human health and safety, or a nuisance problem. The problem is a worldwide phenomenon and may have serious economic and human implications, either directly or indirectly. Crop damage caused by pest bird species is an economic problem in agricultural areas world-wide.

In order to justify control programs and to evaluate the overall effect and related costs of control programs, information on the losses is essential. Blackwell *et al.* (2001) report that from 1992 to 1996 the United States Department of Agriculture (USDA) and Wildlife Services programme (WS) received 670 reports pertaining to nuisance or depredating Greater Sandhill Cranes *Grus canadensis tabida* in Wisconsin, with reported damages exceeding $80 000; 72.4 % of the reports were related to crane damage to maize.

The damage to emerging maize in the United States, for example, was estimated at up to $ 49 million in 1971 (De Grazio 1978). De Grazio (1978) mentions that there is a lack of information on bird- caused economic losses worldwide, but that for Africa in particular, crop loss estimates by birds are almost totally lacking. Mackworth-Praed and Grant (1955) stated in their handbook of the birds of Eastern and North Eastern Africa, that Grey Crowned Cranes could cause considerable damage to young crops in East Africa. Pomeroy (1980) substantiated this and mentioned that damage to crops by Grey Crowned Crane in Uganda was extensive, although there had been no systematic attempts to quantify the damage by cranes. This was supported by Mafabi (1991) and Muheebwa (2004) who mention that Grey Crowned Cranes are responsible for damage to millet, germinating maize and groundnuts in Uganda.

Assessing bird crop damage

Limited information is available on crop damage by cranes in general; particularly the quantification of the damage caused and the available data all relate to non-African species. Bouffard (1993) provided an overview of crop depredation by Sandhill Cranes in the United States, but did not attempt to quantify the damage caused. He mentioned that although African cranes and Sandhill Cranes differ with regards to behaviour and feeding ecology, many of the techniques applicable to control of crop depredations for Sandhill Cranes may be applicable in Africa. A wide variety of crops are said to be eaten by cranes of which maize and small grains are preferred; cranes may be more destructive per individual than waterfowl according to Bouffard (1993).

Sugden *et al*. (1988) determined the use of cereal fields by foraging Sandhill Cranes *Grus canadensis,* in Saskatchewan, Canada using observations along roadside transects measured twice daily. Results of this study indicated that 95% of crane observations took place on cereal fields; however, no systematic attempt was made to quantify the damage to crops or to provide any quantitative data on feeding rates. McIvor and Conover (1994) determined the impact of Greater Sandhill Cranes foraging on maize and barley crops by analysing qualitative data in Utah and south western Wyoming in the United States of America. In their study, 12 maize fields and 9 barley fields were selected based on accounts of crop damage received by farmers. Exclosures were erected which precluded crane feeding. Maize fields were sampled when plants were 15-20cm and no longer susceptible to crane damage. All shoots were counted between the consecutive plants in a row. In barley fields, four quadrats of 0.25m^2 were sampled at 1m diagonally from each exclosure corner. Actual levels of depredation were not measured since the variance among the measured variables was high, probably due to planting techniques or poor seed germination.

Lacy and Barzan (2005) working on Sandhill Cranes in the United States of America determined that germinating maize was selected by cranes. The study was conducted in both chemically treated and non-treated fields and evaluated the effectiveness of seed treatments in deterring crane feeding. Plots of 40 metres long by 15 maize rows wide were used in each of the fields studied. These aforementioned plots were treated as two 20-metre segments per plot. These plots yielded a sample size of 30, 20-metre maize row segments to measure maize seedling density. The 30 20-meter seedling density samples were then averaged for each individual field. For each year, because planting densities varied among farmers, fields and years, the average seedling densities of the plots used was subtracted from average seedling densities of unused plots (within the same field). This enabled a difference between fields to be generated that was independent of the initial seeding density used.

According to Dolbeer *et al*. (1994) bird damage to maize can be estimated by measuring the length of damage on the ear of the maize plant or by visually estimating the percentage loss of kernels and converting this to yield lost per hectare (ha). This method is however only applicable to maize damage on the ear of the mature plant and not relevant with regards to determining damage to maize seedlings or planted seed loss. Losses of agricultural crops to birds can also be estimated indirectly through avian bioenergetics. By estimating the number of birds of the depredating species feeding in an area, the percentage of the crop in the birds' diet, the caloric value of the crop, and the daily caloric requirements of the bird species, a projection of the total biomass of crop removed by birds on a daily or seasonal basis can be established.

Several techniques, primarily focusing on seed loss of the mature plant, have been used on a number of other bird species in order to attempt to quantify bird crop damage. Dolbeer (1975) used both template and visual methods of estimating bird damage to sunflower heads in Ohio, in the United States of America. Manikowski and Da Camara –Smeets (1979) estimated crop damage on sorghum and millet in Chad caused by red- billed quelea *Quelea quelea*, village weaver *Ploceus cucullatus*, yellow-backed weaver *P. melanocephalus*, greater blue-eared glossy starling *Lamprotornis chalybaeus* and mourning dove *Streptopelia decipiens*. Ears of sorghum were examined at 5m intervals along 3-5 lines across each field from edge to edge. Each succeeding transect was directed at 40 degrees from the preceding transect within 6 plots of I hectare located 0-1200m from the edge of the field. Within these transects each ear was examined for the number of damaged or undamaged seeds. In the case of millet, the same transect system was used together with a constructed gauge, in order to estimate the damage to the ear. This gauge was made of two lengths of wire which was graduated in 1cm intervals to aid the damage assessment. Percentages of damage were then calculated as a ratio of the sum of the total damage to the ear which was within the gauge. The percentage loss of both millet and sorghum was then calculated by taking the product of the percentage of damage per ear multiplied by the percentage of damage in the field.

Weatherhead *et al.* (1982) used energetics and life history information coupled with independent information from captive red- winged blackbirds *Agelaius phoeniceus* to provide indirect assessments of maize crop damage in Quebec, Canada. Otis *et al.* (1983) estimated bird damage to sprouting rice fields using sampling points which consisted of paired plots located on transects placed randomly across the fields. One of the plots was protected from bird damage through the use of a wire exclosure. Losses within the plots were then extrapolated to the entire field.

Gillespie (1985), working on the impact of ducks on ripening barley crops in New Zealand, measured crop damage by using a 0.5m quadrat which was placed along 4 transects at 4m intervals within fields. These transects bisected the length and breadth of each field within the study area. Within each quadrat the length of each barley ear damaged by ducks was measured and the weight of grain lost estimated.

Basili and Temple (1999) used demographic, physiological and ecological data to develop deterministic models of dickcissel *Spiza americana* crop damage on maize in Venezuela. The model synthesized all the existing information to provide a preliminary assessment of crop damage.

According to Somers and Morris (2002), researchers have, in the past, attempted to determine the economic impact of bird damage to various crops by estimating loss of yield on both regional scales and national scales. These studies indicate large-scale trends and are useful to economists; however, they are probably less useful to individual farm owners working on much smaller scales where damage varies in magnitude seasonally and locally. Little work has been done in the past 50 years to aid management of bird depredation problems, or to improve understanding of how birds forage. Previous research in North America has focused on estimating regional loss of yield for economic purposes, and largely ignored small-scale variation in crop damage. If a bird depredation problem is perceived, farmers need to know how to identify areas of their farms that are most susceptible to bird damage in order to focus their deterrent efforts most efficiently (Somers & Morris 2002).

In order to determine the damage to maize seedlings, I assessed crop damage in the North Eastern Cape using multiple quadrats randomly distributed over seven farms. This technique was developed primarily from the work of McIvor and Conover (1994), Lacy and Barzen (2005) and a combination of the aforementioned studies. This method of sampling provided the quantitative data necessary to draw conclusions regarding crop damage by Grey Crowned Crane on maize and provided accurate qualitative data necessary to determine the economic value of crop damage by the cranes. Grey Crowned Cranes are responsible for crop damage, though when viewed critically do not come across as being of economic consequence from a commercial farming perspective. This may not be the case elsewhere in Africa where small scale subsistence farming is the norm, and where any loss may be significant in terms of the expected yields of the farms.

Use of seed treatments as a deterrent

The concept of using chemical seed treatments as a deterrent to reduce crop damage is not a recent development. Walter (2003) mentions that the Sumerians apparently used sulphur for pest control as early as 4500 years ago, and that the Chinese used toxins extracted from plants at least 3000 years ago. These forms of pest control were primarily aimed at reducing insect damage to seed for storage purposes. Progress with insecticides in particular, was initiated through the rediscovery and introduction of plant derived substances. Pyrethrum, as an example, derived from the daisy *Chrysanthemum cinerariifolium*, was prepared into an insecticidal powder and used at the beginning of the nineteenth century. Inorganic chemicals containing sulphur, arsenic and mercury were also introduced during this period. The most notorious of these insecticidal arsenicals was known as Paris - green (copper aceto-arsenite) which became widely used by the 1870's to control various herbivorous insect pests (Walter 2003).

The use of chemical treatments to reduce damage to plants as a result of bird depredation is more recent. Askham (1992) evaluated the use of methyl anthranilate as a bird repellent, first patented by Kare in 1961 (patent no: 2,967,128) by conducting feeding trials using common starlings *Stunnus vulgaris* and American robins *Turdus migratorius* on cherries, grapes and blueberries. These trials were supported by earlier findings of Meilgaard *et al.* (1987) and Bean and Mason (1987) that anthranilates as well as other benzoic acid derivatives appeared to be viable as bird repellents.

Dolbeer and Ickes (1994) conducted a series of tests to determine the effect of mixing dry Portland cement or plaster-of-Paris with California wild rice *Zizania aquatica* fed to captive red-winged blackbirds *Agelaius phoeniceus* in relation to other grains. Birds would not eat cement- or plaster-treated rice when untreated rice was available and no mortality occurred when birds were offered only treated rice over a four-day period. Treating grain with cement or plaster did not kill redwings but cement or plaster was seen to act as useful bird repellent for seed grain. Millet was strongly preferred over wild rice by red-winged blackbirds, indicating that millet would be an excellent candidate as a lure crop for wild rice production and as a bait for trapping or delivering a chemical to red-winged blackbirds. Belant *et al.* (1997) evaluated the effectiveness of dolomitic lime as a feeding deterrent on captive brown- headed cowbirds *Molothrus ater* and Canada geese *Branta canadensis* using 1- and 2-choice tests on millet and whole-kernel maize. Lime mixed with millet or whole-kernel maize at 25, 12.5, and 6.25% (g/g) reduced cowbird and goose feeding in 4 day, 2-choice (treated or untreated grain) cage trials. Reductions in total food intake occurred for both species during similar 1-choice tests with lime (25% [g/g]) and millet or maize. Body mass of cowbirds and geese increased or remained constant during the 2-choice tests indicating the effectiveness of lime as a deterrent.

Avery *et al.* (1997) evaluated 2 structurally related compounds, anthrone and anthracene, for repellency to rice-eating birds. In choice tests with individually caged red-winged blackbirds *Agelaius phoeniceus* anthraquinone and anthrone produced comparable reductions in consumption of treated rice, however, only anthraquinone suppressed consumption of untreated rice as well as treated rice. Anthracene was seen as the least effective of the 3 compounds.In large flight enclosures, red-winged blackbirds discriminated strongly against 0.25% anthraquinone-treated rice. Observations of videotaped birds revealed no evidence of contact irritation or unpleasant taste; rather post-ingestive illness, as evidenced by one vomiting bird, suggesting therefore that anthraquinone repellency was due to learned behaviour.

Dolbeer *et al.* (1998) found that Flight Control™, a 50% anthraquinone formulation, was an effective foraging repellent for captive Canada geese *Branta canadensis* , and brown-headed cowbirds *Molothrus ater* as a seed repellent. In 7-day pen feeding trial experiments Flight Control was shown to be a potential avian feeding repellent. Further lab and field studies were needed however to refine minimum repellent levels and to enhance the retention of anthraquinone on treated vegetation.

Blackwell *et al.* (2001) evaluated the use of anthroquinone –based Flight Control™ and methyl anthrailate-based Rejec-iT™AG 36 as a nontoxic avian foraging repellent in 2 choice pen tests with captive Greater Sandhill Cranes *Grus canadensis tabida* fed with whole-kernel maize. This was building on the work of Dolbeer *et al.* (1998) who worked on Canada geese and brown- headed cowbirds. Tests showed that both repellents were effective at deterring cranes from treated maize in feeding trails, but neither had been tested under field conditions.

I evaluated the use of Gaucho' ™ (Bayer) as a seed treatment, which is a chemical listed for the control of false wire worm, *Somaticus spp, Psammodes spp, Gnathocerus spp, Herpicius someri ;* black maize beetle *Heteronychus arator* and wireworm of the Family: Elateridae.(Bayer 2008; Myburgh 1989). Farmers have been using this chemical in the Maclear area for at least the last 5 -7 years, though the exact start of use is uncertain. Gaucho was shown to significantly affect crane feeding behaviour and effectively reduced the relatively high rate of depredation during the early period of plant development.

Gaucho is described as being an ‗imidacloprid' having the molecular formula of $C_9H_{10}ClN_5O_2$ and has a toxicity of LD50 450 mg kg^{-1} for a rat (Bayer, 2008). As an imidacloprid this chemical is potentially lethal to birds, should enough of the chemical be ingested (H. Bouwman pers comm.[4]). It is unclear whether avoiding seeds treated with the chemical has or will become learned behaviour by the birds, as in the case reported by Avery *et al.*(1997) using anthraquinone repellency on red-winged blackbirds. The possibility also exists that the colour of the seed treatment (blue) may act as a deterrent to crane feeding, however this will need to be tested.

Jongman *et al.* (2000) found that captive long-billed corellas *Cacatua tenuirostris* when offered a choice of green-dyed and plain whole oats showed a preference on the first day for the plain food. It was shown however that this was not a lasting effect where birds had the opportunities to feed consecutively. Further toxicology tests will need to be undertaken to ascertain to what extent this chemical might affect cranes. Currently (2010) Gaucho treated seed costs R1500.00 per bag which contains approximately 60 000 kernels or R80.00/ 250 grams/ 100kg seed (P Lindsay pers comm[5]). Untreated maize seed costs in the region of R700 per bag without any additives. Treating seed with Gaucho would therefore significantly add to the cost of planting should it be used as a bird deterrent only and would not be economically feasible particularly when viewed in terms of subsistence agriculture practices in the rest of Africa.

Is damage significant?

Estimates in North America indicate that overall bird damage to maize results in the loss of less than 1% of the total North American crop, but can reach as high as 10–15% in certain areas (Somers & Morris 2002). Dolbeer *et al.* (1994) mention that a survey in 1981 indicated that 330 000 tons of maize worth U$ 31 million were lost as a result of blackbird depredation in the United States.

Farms within the study area of the North Eastern Cape plant maize seed at a planting rate of 60 000 plants per hectare for irrigated fields and a rate of between 35 000 to 37 000 plants per hectare for dry land agriculture (Andrew McFarlane pers comm[6]). Yields per hectare vary between 10 to 12 tons per hectare for irrigated

[4] Professor Henk Bouwman. Eco- toxicology expert. North West University.
[5] Phillip Lindsay.Agricultural sales representative.
[6] Andrew McFarlane. Maclear commercial farmer

fields and 7 to 8 tons per hectare for dry land agriculture. All the study sites were farmed under dry land agricultural conditions. If current production rates are taken at 7500 kilograms per hectare, with a planting rate of 35 000 plants per hectare on average, each maize plant would yield 214 grams.

In the 2005 season, damage by cranes on treated maize fields amounted to 7.27 kg of potential production loss. Maize currently fetches R1275.00 per ton (Safex 2010) thus equating to R1.27 per kilogram, and representing a loss of R9.23 on treated fields in 2005. On the untreated fields, damage by cranes amounted to 133.53 kg of potential production loss equating to roughly R169.59 at current market prices. Crow damage on treated fields amounted to 2.78 kg (R3.53) and 1.5kg (R1.91) on untreated fields respectively. Damage on treated fields as a result of ‗other feeding‘, which could be attributed to insects, amounted to 10.48kg (R13.30) and 50.50kg (R64.14) on untreated fields. Damage on treated fields as a result of ‗unknown‘ factors, possibly due to insects, amounted to 4.06kg (R5.15) and 50.50kg (R64.14) for untreated fields. In 2005, damage by crowned crane on untreated fields was significantly more than any other form of damage.

For the 2006 season, damage by cranes on treated maize fields amounted to 20.11 kg of potential production loss representing a loss of R25.55 on treated fields in 2006. On the untreated fields, damage by cranes amounted to 63.34 kg of potential production loss equating to roughly R80.45 at current market prices. Crow damage amounted to 16.05 kg (R 20.38) on treated fields and 55.85 kg (R70.93) on untreated fields. Damage as a result of ‗other feeding‘ assumed to be insects, resulted in a loss of 31.67 kg (R 40.22) on treated fields and 27.39 kg (R34.78) on untreated fields. Damage on treated fields as a result of ‗unknown‘ factors, possibly due to insects, amounted to 1.71kg (R2.17) and 3.63kg (R4.62) for untreated fields.

When viewed critically, damage by Grey Crowned Crane on large commercial farms was not seen to be economically important relative to losses which may be incurred by disease and insects. Insect damage will occur throughout the growing period, however monitoring of plants only took place for a period up to 28 days. Cherret *et al.* (1971) suggested that as much as 44 million tons of maize where lost in Africa due to insect damage, a loss of 20% of annual production. According to G. Pringle (pers comm[7]), agronomist for Pannar seed South Africa, reports of as much as 50% to 60 % damage to fields have been reported due black maize beetle *Heteronychus arator* and maize stalk borer *Busseola fusca* in the Orange Free State area of South Africa. This supports my contention that damage by Grey Crowned Crane, relative to losses that may be incurred by insects, is not economically significant whether on treated or untreated fields.

Is damage a perception?

If birds are feeding on crops, farmers need to know how to identify those areas of their farms that are most susceptible to bird damage so that they may focus their deterrent efforts more efficiently (Somers & Morris 2002). Cranes in Africa display limited regional movements according to food and breeding site availability. Bouffard (1993) mentions that due to the fact that long range migrations do not take place as with Sandhill Cranes, their breeding seasons are less compressed and consequently more time is spent in breeding territories and less time in flocks. Flocking generally occurs in the nonbreeding season and since the birds do not need to store energy for migration, hyperphagia is not normally exhibited. Feeding generally occurs near roosts in short vegetation, and all African species, except for Wattled Crane, readily feed on crops. Crop damage may also occur during the breeding periods as was recorded by Mafabi (1991) for Grey Crowned Crane during incubation in Uganda.

Bouffard (1993) suggests that crop depredation in Africa will be less intense but will extend over longer periods due to the fact that cranes do not migrate. The longer duration will ensure that the cranes are present when crops are vulnerable and will increase the likelihood of cranes habituating to scare control measures. As a result damage control efforts may be more expensive and less effective than similar efforts for Sandhill Cranes. Control efforts may be more complicated on small subsistence farms, where there are more farmers to deal with and where depredation may have a relatively greater impact on the farmer. The most effective control of crop damage is through the use of a combination of methods which should reduce the vulnerability of crops, the use of scare techniques and possibly through the provision of lure crops.

[7] Grant Pringle. Agronomist. Pannar seeds.

Ohsaka (1994) working on cranes in Japan, mentions that a possible solution to crop damage may be to disperse some of the cranes to other areas. The possibility or application of this within the study area, or South Africa as a whole, would be limited. Most suitable habitats for re-establishment or translocation of cranes are at a premium, with most having already been transformed as a result of various anthropogenic factors.

No one control technique is effective all of the time. Changing local agricultural practices may reduce crop depredations by changing crops to species which the cranes do not prefer. Stubble fields should also not be ploughed until all the vulnerable crops in the area have been harvested, as cranes prefer to feed in harvested fields and may therefore not be attracted to un-harvested, vulnerable fields. Burning or grazing of the native grassland areas may also improve the availability of natural foods for cranes by removing the tall rank vegetation (Bouffard 1993) This is supported by Sugden *et al.* (1988) who mention that Sandhill Cranes tended to use harvested cereal fields in preference to swathed (windrowed) cereal.

Gillespie (1985) working on ducks in Otago, New Zealand, found that crop damage was localised and appeared to be extremely variable from year to year. Several farmers experienced recurring damage annually and lost substantial quantities of grain while some fields were left completely untouched. Similar conditions were experienced within the study area, with some study sites experiencing very high levels of damage on individual quadrats (> 80% Esperando farm) and some farms experiencing very low damage (0% Orpen) (Appendix 1).

The perception of damage on fields within the study area is complicated by the fact that Grey Crowned Cranes are a conspicuous large bird species and farmers may therefore assume that damage is taking place with the birds‘ presence in fields. Through the use of the recommendations mentioned by Bouffard (1993) together with providing accurate information regarding crane damage and the dissemination thereof to all members of the farming community, farmers and conservation bodies would be in a better position to make decisions with regards to management on their properties.

Distribution and abundance of Grey Crowned Crane

The datasets analysed using Arcview GIS 9 did not indicate any significant change in distribution within the spatial scales at which the data were collected. The sightings data which were analysed had been collected at different levels of effort, over different time periods using different observers. Due to the stochastic nature of the datasets, it was therefore difficult to make any conclusive interpretations regarding changes in distribution. As a result of the nature of the data, being ‗presence/ absence data', a high degree of error was present within the dataset and therefore it was also not possible to determine population trends. Given these limitations, the data did provide broad geographic distribution patterns over time (1978- 2009) over a small geographic area (3400m^2). These changes indicated a slight range expansion in both a North West and westerly direction, possibly due to an increasing population. These changes may not be significant regionally or nationally given the scale at which the data were collected. Interestingly the presence of plantations did not seem to adversely affect crane distribution or abundance since large numbers of sightings took place within plantation areas. This may have been due to the fact that within the plantation areas, large wetland systems are present which serve as breeding and foraging areas for Grey Crowned Crane. The data analysis did however shed light on the differences between the data capture techniques, by comparing the results of the CAR count with the three other combined observation data sets, which may not indicate population trends. Given the fact that the CAR data has a formalised monitoring strategy, it is more likely to indicate population trends over time. A further study into the determination of habitat use by Grey Crowned Crane would provide additional insights into wetland habitat use by the cranes, and would support the protection and management of wetlands within the plantation areas.

Crowned cranes in Africa

Crowned crane are widely distributed in Kenya south of 4^0 N latitudes but absent from the dry South West and the equatorial forest areas of the West of the country. Lewis and Pomeroy (1989) mention that this distribution represents the eastern limit of the range of the species. Most records of sightings are said to refer to *Balearica* *pavonina gibbericeps* with over 800 birds counted in 1960km^2 in Kisii district in 1965. Kenyan crowned cranes are now classified as *Balearica regulorum gibbericeps* with occasional records of *Balearica pavonina ceciliae* in the extreme north-west.

In Zambia crowned crane occur in small flocks of up to 50 outside of the breeding season and between 150 – 200 on the Kafue flats, Basanga and Liuwa plains. Populations of a maximum of 500 were recorded in the Luangwa Valley with a total population estimate at 5000 in 1993. According to Dowsett *et al*. (2008) the population was not known to have declined or to be persecuted. In Malawi the population has been declining since the 1970's when it was described as ‗common' in some areas, notably the Limphasa Dambo. Declines have been attributed to excessive human pressure, hunting and the drainage of marshes and dambos for cultivation purposes. The largest concentration recorded was 23 in 1993 (Dowsett-Lemaire & Dowset 2006), with a total population estimate of 450 by Beilfuss *et al.* (2007).

Populations of crowned crane in Uganda at the end of the 1970's were estimated in the tens of thousands and thought to be increasing. Recent work has however shown that numbers are declining markedly. Muheebwa (2004), using results from roadside counts, determined that there may be as few as 13 200 birds remaining in Uganda, showing a decline of 62% since 1985. Carswell *et al.* (2005) estimated the population to be about 35 000 and ascribed the decline to loss of breeding sites.

The population in central Mozambique was estimated at 100 -200 birds by Parker (2005) with a single crowned crane seen in the Maputo Elephant Reserve, in southern Mozambique, in November 1997. Parker (2005) also suggests that the species may be vulnerable to persecution as a result of illicit bird trade. There are no current data for the northern sector of the country, but Beilfuss *et al.* (2007) suggested that by 2004 there were no more than 200 birds in Mozambique.

Barnes (2000) estimated the southern African population to number no more than 3000 and global population estimated at between 85 000 to 95 000, belonging primarily to the subspecies *B.r. gibbericeps.* Large scale declines and population fragmentation, suggested that at least 20% of the population had been lost within the last three generations. The population decline in South Africa being primarily attributed to habitat loss, deliberate and accidental poisoning, collisions with powerlines and the capture of chicks to be eaten, sold or kept as pets.

According to the status survey of cranes in Africa in 2005 by Beilfuss *et al.* (2007) the Grey Crowned Crane was rapidly declining. The East African subspecies *B.r. gibbericeps* was said to have declined significantly across all nations within its range where status surveys have been conducted. Baker and Baker (2004) mention that the species is now far less common in Tanzania than in the 1980's and that exact numbers are unknown. Huge losses have taken place in recent years primarily as a result of the trade in wild birds. Similar reports for Kenya, Uganda, Zambia, Malawi, Mozambique and Rwanda are recorded. On the basis of the records, Beilfuss *et al.* (2007) estimated the population of *B.r. gibbericeps* to be in the region of 43 000-55 000, thereby showing a decline of more than 50 % in the past 20 years.

The population of *B.r. regulorum* appears to be more stable with a population of > 4000 birds in South Africa, and unknown to low numbers in other southern African countries (Beilfuss *et al.* 2007). The estimated population for *B.r. regulorum* was 7 000-9 000, with an overall population estimate for *Balearica regulorum* at 50 000-64 000. This species was considered by Meine and Archibald (1996) to be the most secure of Africa's resident cranes but clearly this is no longer the case.

Available data indicate declining population numbers for the Grey Crowned Crane throughout the range of the species. When considering that the North Eastern Cape is viewed as one of three core breeding areas of the species in South Africa, and appears to be more stable than other African populations (Beilfuss *et al.* 2007), it is of utmost conservation importance to ensure the continued existence of the species within the study area. Attempts should be made to limit the factors affecting the species decline within the region in order to ensure the survival of the species as a whole, particularly when considering the instability of the remaining fragmented African populations. Cranes are subject to high mortality as a result of power line collisions (Shaw *et al.* 2010; Jenkins *et al.* 2010). In South Africa the core energy grid comprises over 350 000km of power lines with significant increases likely in future. Large terrestrial and wetland species are prone to collisions with > 700 Blue

Crane and >100 Grey Crowned Crane recorded collisions collected over a 12 year period through the use of aggregated incidental records rather than structured surveys. This only provides an initial indication of the nature and scale of the problem and may have significant negative effects on the populations of cranes (Jenkins *et al.* 2010). Unless these mortalities can be significantly reduced the population in South Africa will become increasingly fragmented and no longer viable from a conservation perspective.

The future of cranes

Crop depredation problems in general are being exacerbated by the fact that the world's population continues to increase and requires more extensive agricultural land and greater quantities of natural resources. As a result, the area available to other species is being reduced and competition for resources is increasing. There is an urgent need to conserve remaining natural environments and species if biodiversity is to be maintained (Wojtaszekova 2008).With global environmental change, as a result of habitat loss and climate change, has come an increasing recognition of the importance of services that ecosystems provide to human society and how dependant our global village is upon these services (Mace *et al.* 2000). Species with low reproductive rates and limited or localised distribution, such as the Grey Crowned Crane in South Africa, may be more adversely affected by land transformation and are of special conservation concern (Armstrong & van Hensbergen 1998).

The human population of southern Africa (comprising South Africa, Lesotho and Swaziland) is expected to increase to levels of 70 – 90 million by 2035 (du Toit *et al.* 2000). To meet the increasing food demand, agricultural production will need to increase by 3% per annum. Maize production in South Africa increased from 72 200 tons in 2005/2006 to 81 100 tons in 2006/2007, showing a 12 % increase (SAGC 2008). South Africa is characterized by high variations in yield due mainly to fluctuations in seasonal precipitation. Maize production in South Africa is generally divided into two primary areas, namely a dry western area (western Free State and North West provinces) and a wetter eastern area (eastern Free State). When using the CERES-Maize simulation model to model various climate change scenarios in the aforementioned areas, du Toit *et al.* (2000) found that maize yields would either remain the same or decrease by 10% to 20%. Some marginal areas in the western section would become unsuitable for maize production, while areas in the East would remain unchanged or increase production levels. The study area falls roughly between the two areas mentioned and therefore may see shifts either increasing or decreasing maize yield. As a result of this, and the increased demand for maize, more areas are likely to be turned into maize fields in order to meet the increasing demand. Climate change however, is not seen to be a likely driver affecting crane population numbers in future, within the study area, since according to du Toit *et al*. (2000) the climate within the region is likely to remain unchanged.

In 1973 more than half of the total world area planted in maize (111 million hectares) lay in developing countries. Of this total, Africa accounted for 17.2 % of the area planted, but less than 8% of the world‘s total supply. In 1997, the world produced 580 million tons of maize of which almost half (259 million tons) originated from developing countries. The total yield in Africa increased from 1991- 1997 by 2.9% due to an increase in both area planted and maize production. From 1997- 1999 southern and eastern Africa devoted 41% of cereal growing area to maize production (McCann, 2005). These trends substantiate the fact that throughout Africa, maize production is likely to increase, and concomitantly with this, complaints of crop damage can be expected to become more frequent as more areas are converted to maize.

Major land transformations have taken place within the study area since 1990, particularly with regards to afforestation and crop production. Afforestation has severe consequences for biodiversity as it causes changes in the plant and animal communities of the planted areas and the species of the indigenous habitat are eliminated or reduced in numbers (Allan *et al.* 1997). These influences do not appear to have adversely affected crane distribution given the data available. This may be attributed to the large number of wetlands still within the study area both in and outside of the plantation areas. Maintenance of crane population numbers may be related to the maintenance of the health of the wetland systems as breeding areas, however this will have to be tested directly. The North Eastern Cape population of Grey Crowned Crane is an important population particularly when viewed in terms of the African perspective. Every effort should be made, by both agricultural organs of state, private enterprise, landowners and conservation bodies to ensure the long term survival of cranes in this area as a whole. Walter (2003) mentions that change is not inevitably underpinned by good science, and even if fundamental scientific results support a fundamental shift or altered practice, adoption of that change may still be extremely slow or not take place at all.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The main objectives of my study were as follows:

- To determine whether Grey Crowned Cranes are responsible for crop damage to maize in the North Eastern Cape and quantify the damage caused by the birds
- To determine the age at which maize plants are most susceptible to crop damage
- To determine whether seed treatments used in the control of insect pests on maize may influence crane feeding behaviour
- To determine to what extent vegetation type and altitude (wetlands) may influence crane foraging
- To determine whether changes in land-use may have had any influence on the distribution and abundance of cranes within the study through the analysis of observer records recognizing the short comings of this method of data collection

Crop damage

Grey Crowned Cranes are responsible for crop damage on commercial farms within the North Eastern Cape of South Africa. Maize damage by Grey Crowned Crane, relative to other sources of loss, was quantified over two growing seasons and an economic value assigned to the damage caused. Crop damage by Grey Crowned Crane was not seen to be economically important relative to the losses that may be incurred as a result of possible insect damage.

Cranes select for young maize as soon as the plumule appears above the surface of the soil and feed on these seedlings up to 16 days after appearing. After this period the cranes no longer feed on the plants as the maize kernel has all been significantly reduced in size, and plants are no longer susceptible to crane damage.

Gaucho treated maize seed does act as a deterrent to crane feeding. It is unclear whether avoiding seeds treated with the chemical has or will become learned behaviour by the birds. Further toxicology tests will need to be undertaken to ascertain the extent to which this chemical may affect cranes. Feeding trials with captive Grey Crowned Crane, possibly in collaboration with zoo establishments, would clarify this aspect and could establish whether colour has any effect on feeding preferences by crowned cranes.

Crop damage by Grey Crowned Crane was not influenced by the distance to wetlands or the number of wetlands within a five kilometre buffer within the study area. This may however differ in areas where the altitude range of crop production differs. Vegetation type was also not considered an important variable in terms of determining crop damage.

A better understanding is needed of crowned crane breeding biology and habitat utilization in order to determine to what extent wetlands within plantations contribute towards maintaining crane population numbers within the North Eastern Cape.

Distribution and abundance of Grey Crowned Crane

Changes within the distribution and abundance of the Grey Crowned Crane were assessed through the analysis of four datasets. Due to the nature of the data sets used, it was not possible to draw any clear- cut conclusions, and therefore it was not possible to accept or reject the null hypothesis proposed. Although large scale afforestation has taken place in the Maclear area since 1990, it was not possible to determine to what extent this has had any effect on crane distribution within the area.

Traditionally, ecologists have conducted their studies at finer scales, partly due to limitations in data availability at broad scales, and a lack of analytic tools and methods appropriate for broad scale data. Research conducted only on fine spatial scales, in the habitat selection process, cannot resolve problems of population management, in particular the avoidance of potential conflicts between cranes and people. The information we gain at these levels can help us understand specific behaviours of the individuals or groups at a fine scale. The results, however, usually cannot be extrapolated to upper levels of the habitat selection process or to a broad spatial scale. Wildlife population management strategies need to address broad scale distribution and habitat use by birds (Su 2003).

Satellite tracking of individual Grey Crowned Crane and/ or an increase in the colour ringing effort would enable conclusions to be drawn about the population movements within the study area and provide vital information on population dynamics. The standardization of the methodology used in the collecting of sightings data would provide more reliable information on population trends and direct future conservation actions.

When viewed critically, the North Eastern Cape population of Grey Crowned Crane is vitally important when considering the unstable position of the species in the rest of Africa. Every effort should be made to secure the breeding areas of the species in the region.

Management recommendations

An avian bioenergetics study could estimate the number of birds of the depredating species feeding within the study area, the percentage of the crop in the birds‘ diet, the caloric value of the crop, and the daily caloric requirements of the bird species. A projection of the total biomass of crop removed by birds on a daily or seasonal basis could then be established based on these findings, which could confirm the limited economic impact deduced from my results.

In South Africa, political pressures for land reform and agricultural intensification may result in smaller farms and fields, increased human densities and anthropogenic disturbance, and the introduction of new crops. Studies from Europe demonstrate that certain forms of agriculture can benefit some threatened birds (Wolff *et al.* 2001) but that highly intensified agriculture has led to the collapse of farmland bird populations (Donald *et al.* 2001).

It would be important to determine to what extent Grey Crowned Crane are able to benefit from agricultural transformation and to determine the various drivers of the population. Establishing the benefits of cranes to agriculture would further support conservation efforts. The determination of the contribution of agricultural pest insects to crane diet, which include locusts and cut worms, could be viewed as such an example.

This report will be disseminated and used by conservation NGO's (particularly the Endangered Wildlife Trust) and statutory bodies for implementing management proposals and providing information on crop damage scenarios. This, together with the publication of scientific papers, will provide a better understanding of crop damage by Grey Crowned Crane, and hopefully reduce their persecution.

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REFERENCES

Agrisnet. 2010. Accessed on 10 December 2010.
http://www.sikkimagrisnet.org/General/en/Agriculture/Maize_Soil_Requirement.aspx

Allan, D and Ryan, P.1993. Morphometrics sex ratio, molt, and stomach contents of Blue Cranes in the Western Cape Province, South Africa. 325-327. *In:* Proceedings, African Crane and Wetland Training Workshop. Beilfuss, R.D, Tarboton, W.R, Gichuki, N.N. (Eds). International Crane Foundation: Wisconsin.

Allan, D.G; Harrison, J.A; Navarro, R.A; van Wilgen, B.W and Thompson, M.W. 1997. The impact of commercial afforestation on the bird populations in Mpumalanga province, South Africa: insights from bird-atlas data. Biological Conservation 79: 173-185.

Archibald, G. W. 1976. Crane taxonomy as revealed by the unison call. 225-251. *In:* Proceedings, International Crane Workshop. Lewis, J.C.(Ed). Oklahoma State University: Stillwater.

Armstrong, A.J. and van Hensbergen, H.J. 1996. Impacts of afforestation with pines on assemblages of native biota in South Africa. South African Forestry Journal 175: 35-42.

Armstrong, A.J. and van Hensbergen, H.J. 1998. Identification of priority regions for animal conservation in afforestable montane grasslands of the northern Eastern Cape Province, South Africa. Biological Conservation 87: 90-103.

Askham, L.R. 1992. Efficacy of methyl anthranilate as a bird repellent on cherries, blueberries and grapes.144-148. *In*:Proceedings, 15th Vertebrate Pest Management Conference. Marsh, R.E. (Ed). California.

Avery, M.L; Humphrey, J.S, and Decker, D.G. 1997. Feeding deterrence of anthraquinone, anthracene, and anthrone to rice-eating birds. Journal of Wildlife Management 61: 1359-1365.

Baker, N and Baker, L. 2004. Tanzania bird atlas: distribution and seasonality. www.tanzaniabirdatlas.com

Barnes, K.N. (Ed) 2000. The Eskom red data book of birds of South Africa, Lesotho and Swaziland. BirdLife South Africa: Johannesburg.

Basili, G.D. and Temple, S.A. 1999. Dickcissels and crop damage in Venezuela: defining the problem with ecological models. Ecology 9: 732- 739.

Bayer Crop Science. 2008. Accessed on 12 October 2008. http://www.bayercropscienceus.com/products_and_seeds/seed_treatments/ gaucho.html

Bean, N.J. and Mason, J.R. 1987. Dimethyl anthranilite repellency to Mallard Ducks *Anas platyrhynchos* and Ring-necked Pheasants *Phasianus colchicus*. Unpublished bird damage research report. USDA-APHIS. Denver Wildlife Research Centre: Ohio.

Beilfuss, R.D; Dodman, T and Urban, E.K. 2007. The status of cranes in Africa in 2005.*In*: Proceedings, 11th Pan-African Ornithological Congress, 2004. Ostrich 78: 175- 184.

Belant, J.L; Tyson, L.A. Seamans, T.W. and Ickes, S.K. 1997. Evaluation of lime as an avian feeding repellent. Journal of Wildlife Management 61: 917-924.

Berliner, D and Desmet, P. 2007. Eastern Cape biodiversity conservation plan. Department of Water Affairs and Forestry (DWAF): Pretoria.

BirdLife International 2009. *Balearica regulorum*. *In*: IUCN Red List of Threatened Species. Version 2010.4. Accessed on 15 November 2010 www.iucnredlist.org .

Bigalke, R. C. 1980. Plantation forests as wildlife habitats in southern Africa. 5-11. *In*: Proceedings, Joint Symposium on Plantation Forests as Wildlife Habitats and Problems of Damage. IUFRO: Athens.

Blackwell, B. F; Helon, D. A. and Dolbeer, R. A. 2001. Repelling sandhill cranes from corn: whole-kernel experiments with captive birds. Crop Protection 20:65-68.

Bouffard, S.H. 1993. Crop depredation by Sandhill Cranes. 545-552. *In*: Proceedings, African Crane and Wetland Training Workshop. Beilfuss, R.D, Tarboton, W.R and Gichuki, N.N. (Eds) International Crane Foundation: Wisconsin.

Carswell, M; Pomeroy, D; Reynolds, J and Tushabe, H. 2005. The bird atlas of Uganda. British Ornithologists‘ Club and British Ornithologists‘ Union: Oxford.

Cherret, J.M; Ford, J.B; Herbett, I.V. and Probert, A.J. 1971. The control of injurious animals. The English Universities Press: London.

Cohen, M. 2005. Environmental impact assessment for the construction of a particle board plant, door plant and saw mill at Ugie, North Eastern Cape. CEN Integrated Environmental Management Unit: Port Elizabeth.

Coppedge, B.R; Engle, D.M; Masters, R.E. and Gregory, M.S. 2001. Avian response to landscape change in fragmented Southern Great Plains grasslands. Ecological Applications 1: 47-59.

De Grazio, J.W. 1978. World bird damage problems. 9-24. *In*: Proceedings, 8th Vertebrate Pest Conference. University of Nebraska: Lincoln.

Dolbeer, R.A.1975. A comparison of two methods to estimating bird damage to sunflowers. Journal of Wildlife Management 39: 802-806.

Dolbeer, R.A; Holler, N.R. and Hawthorne, D.W. 1994. Identification and assessment of wildlife damage: an overview. A1- 18. *In*: The handbook: prevention and control of wildlife damage. University of Nebraska: Lincoln.

Dolbeer, R.A. and Ickes, S.K. 1994. Red-winged Blackbirds feeding preferences and response to wild rice treated with Portland cement or plaster. 279-282. *In:* Proceedings, 16th Vertebrate Pest Conference. Halverson, W.S and Crabb, A.C (Eds). University of California:Davis.

Dolbeer, R. A.; Seamans, T.W; Blackwell, B.F. and Belant. J.L. 1998. Anthraquinone formulation (Flight Control™) shows promise as avian feeding repellent. Journal of Wildlife Management 62: 1558-1564.

Donald P.F; Green R.Eand Heath, M.F. 2001. Agricultural intensification and the collapse of Europe‘s farmland bird populations.. *In:* Proceedings, Royal Society of London Series B 268: 25-29.

Dowsett, R.J; Aspinwall, D.R. and Dowsett- Lemaire, F. 2008. The birds of Zambia. An atlas and handbook. Tauraco Press and Aves: Liège.

Dowsett- Lemaire, F. and Dowset, R.J. 2006. The birds of Malawi. An atlas and handbook. Tauraco Press & Aves: Liège .

Du Toit, A.S; Prinsloo, M.A; Durand, W. and Kiker, G. 2000. Vulnerability of maize production to climate change and adaptation assessment in South Africa.12- 17. *In*: Climate change impacts in South Africa. Report to the national climate change committee. Kiker, G (Ed). Department of Environmental Affairs: Pretoria. www.sanbi.org/countrystudy

DWAF / Ukhahlamba District Municipality. 2005. Ukhahlamba Orthophotography Land Resources International (Pty) Ltd: Pietermaritzburg.

Fain, M.G; Krajewski, C. and Houde, P. 2007. Phylogeny of ‗core Gruiforms' (Aves: Grues) and resolution of the Limpkin- Sungrebe problem. Molecular Phylogenetics and Evolution 43: 515-529.

Fey, M.A. 2005. The soils of South Africa. Cambridge University Press: Cambridge.

Filmer, R. and Holtshausen, G. 1992. Results of the southern African crane census 1985/1986. 132-153. *In:* Proceedings, 1st Southern African Crane Conference. Porter, D.J; Craven, H.S.; Johnson D.N and Porter, M.J.(Eds) Southern African Crane Foundation: Durban.

Forsyth, G.G; Versveld, D.B; Chapman, R.A. and Fowles, B.K.1997. The hydrological implications of afforestation in the North-Eastern Cape: A survey of resources and assessment of the impacts of land-use change. WRC report No.511.Department of Water Affairs: Pretoria.

Gillespie, G.D. 1985. Feeding behaviour and impact of ducks on ripening barley crops grown in Otago, New Zealand. Journal of Applied Ecology 22: 347-356.

Goldammer, J.G. & de Ronde, C. (Eds.) 2004. Wildland fire management handbook for Sub-Sahara Africa. Global Fire Monitoring Centre. Oneworld Books: Oxford.

Griffin, D-L. 2006. Frontier Heartland: Analysing the impact of forestry and tourism on ―white identity" in Maclear. Unpublished MA Dissertation. Rhodes University: Grahamstown.

Harrison, J.A; Allan, D.G; Underhill, L.G; Herremans, M; Tree, A.J; Parker, V. and Brown, C.J. (Eds) 1997. The Atlas of Southern African Birds. Volume 1: Non-passerines. 316-317. BirdLife South Africa: Johannesburg.

Harris, J. 1994. Cranes, people and nature: preserving the balance.1-14. *In:* Proceedings of the International Symposium: The future of cranes and wetlands. Higuchi, H and Minton, J. (Eds) Wild Bird Society of Japan: Tokyo.

Hockey, P.A.R; Dean, W.R.J and Ryan, P.G. (Eds) 2005. Roberts Birds of Southern Africa, 7th edition. Trustees of the John Voelcker Bird Book Fund: Cape Town.

Hunt, H.E and Slack, R.D. 1989. Winter diets of whooping and sandhill cranes in South Texas. Journal of Wildlife Management 53: 1150-1154.

Ingold, J.L; Guttman, S.I. and Osborne, D.R. 1987. Biochemical systematics and evolution of the cranes (Aves: Gruidae) 575-584*. In*: Proceedings, 1983 International Crane Workshop. Archibald, G. W. and Pasquier, R. F. (Eds). International Crane Foundation: Wisconsin.

Ingold, J.L; Vaugh, J.C; Guttman, S.I. and Maxon, L.R. 1989. Phylogeny of the cranes (Aves: Gruidae) as deduced from DNA-DNA hybridization and albumin micro-complement fixation analyses. Auk 106: 595- 602.

Iverson, G.C; Vohs, P.A. and Tacha, T.C. 1987. Habitat use by mid-continent sandhill cranes during spring migration. Journal of Wildlife Management 51: 448-458.

Johnsgard, P.A. 1983. Cranes of the World. Indiana University Press: Indiana.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Jongman, E; Selby, E; Barnett, J; Fisher, P. and Temby, I. 2000. Feeding preferences in captive corellas for green-dyed and plain oats. Corella 24: 62-64.

Jenkins, A; Smallie J. J and Diamond, M. 2010. Avian collisions with power lines: a global review of causes and mitigation with a South African perspective. Bird Conservation International 20: 263-278.

Karpeta, W.P. and Johnson, M.R. 1979. The geology of the Umtata area. Geological survey. Department of Mines: Pretoria.

Krajewski, C. 1989. Phylogenetic relationships among cranes Gruiformes: Gruidae based on DNA hybridization. Auk 106: 603-618.

Krajewski, C; Sipiorski, J.T. and Anderson, F.E. 2010. Complete mitochondrial genome sequences and the phylogeny of cranes Gruiformes:Gruidae. Auk 127: 440-452.

Lacy, A.E. and Barzen, J.E. 2005. Evaluating crop damage and deterrence by Sandhill Cranes at two geographical scales of habitat selection. Unpublished report. International Crane Foundation: Wisconsin.

Lewis, A. and Pomeroy, D. 1989. A bird atlas of Kenya. A.A. Balkema: Rotterdam.

Lockman, D.C; Serdiuk, L. and Drewien, R. 1987. An experimental greater sandhill crane and Canada goose hunt in Wyoming. 47-57. *In*: Proceedings, North American Crane Workshop: Wisconsin.

Mace, G; Masundire, H. and Bailie, J. (Eds). 2000. Millennium Assessment, Chapter 4: Biodiversity. UNEP: Geneva.

Mackworth-Praed, C.W. and Grant, Captain C.H.B. 1955. Birds of eastern and north eastern Africa. Vol 1. Longmans, Green and Co: London:

Macdonald, I. A. W. 1989. Man's role in changing the face of southern Africa. 51-77 *In:* Biotic diversity in southern Africa: concepts and conservation. Huntley. B.J. (Ed) Oxford University Press: Cape Town.

Manikowski, S. and Da Camara-Smeets, M. 1979. Estimating bird damage to sorghum and millet in Chad. Journal of Wildlife Management. 43: 540-544.

Mafabi, P.G. 1991. The ecology and conservation of the Grey Crowned Crane in Uganda. 363-367.*In:* Proceedings, 1987 International Crane Workshop. Harris, J. (Ed) International Crane Foundation: Wisconsin.

McIvor, D.E and Conover, M.R. 1994. Impact of greater sandhill cranes foraging on corn and barley crops. Agriculture, Ecosystems and Environment. 49: 223-237.

McCann, J.C. 2005. Maize and grace: Africa's encounter with a New World crop. 1500-2000. Harvard University Press: Cambridge, Massachusetts.

Meilgaard, M; Civille, G.V. and Can, B.T. 1987. 47-51. Sensory evaluation techniques. CRC Press: Florida.

Meine, C.D. and Archibald, G.W.(Eds) 1996. The cranes: - status survey and conservation action plan. IUCN: Gland, Switzerland.

Mitchell, A. 1999. The ESRI guide to GIS analysis. Esri Press: California.

Mmari, E.D.J. 1993. The effects of pastoralism on Grey Crowned Cranes at West Kilimanjaro Ranch, Tanzania. 209 -211. *In*: Proceedings, African Crane and Wetland Training Workshop. Beilfuss, R.D, Tarboton, W.R, and Gichuki, N.N.(Eds). International Crane Foundation: Wisconsin.

Morrison, K. L. 1998. Habitat utilization and the population ecology of cranes in the Dullstroom area of the Mpumalanga province. Unpublished MSc Thesis. University of Pretoria: Pretoria.

Motulsky, H. 2005. Prism 4 Statistics guide-statistical analyses for laboratory and clinical researchers. GraphPad Software Inc.: San Diego.

Mucina, L. and Rutherford, M.C. (Eds) 2006. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia19. South African National Biodiversity Institute: Pretoria.

Muheebwa, J.M. 2004. Assessing the status of the Grey Crowned Crane *Balearica regulorum* in Uganda. Unpublished MSc Thesis. Makerere University: Kampala.

Mullins, W.H. and Bizeau E.G., 1978. Summer food of sandhill cranes in Idaho. Auk 95: 175-178.

Murray, B.R; Dickman, C.R; Robson, T; Haythornthwaite, A; Cantlay, A.J; Dowsett, N and Hills, N. 2007. Effects of exotic plants in native vegetation on species richness and abundance of birds and mammals. 216 – 221. *In:* Pest or Guest: the zoology of overabundance. Lunney,D; Eby,P ; Hutchings, P. and Burgin, S.(Eds). Royal Zoological Society of New South Wales: Mosman.

Myburgh, A.C. (Ed). 1989. Crop pests in Southern Africa. Vol 4. Plant protection research unit. Department of Agriculture: Pretoria.

Ohsaka, Y. 1994. Analysis of Crane population change, habitat selection and human disturbance in Japan. 107-113. *In:* The Future of Cranes and Wetlands: Proceedings of the International Symposium. Higuchi, H. and Minton, J. (Eds).Wild Bird Society of Japan: Tokyo.

Otis, D.L; Holler, N.R; Lefebvre, P.W. and Mott, D.F. 1983. Estimating bird damage to sprouting rice. 76-89. *In*: Proceedings, 4th Vertebrate Pest Control and Management Materials Symposium. Kaukeinen, D.E. (Ed). American Society for Testing and Materials: Philadelphia.

Parker, V. 1999. The atlas of the birds of Sul do Save, Southern Mozambique. Avian Demography Unit: Cape Town and the Endangered Wildlife Trust: Johannesburg.

Parker, V. 2005. The atlas of the birds of Central Mozambique. Avian Demography Unit: Cape Town and the Endangered Wildlife Trust: Johannesburg.

PG Bison, 2007. Unpublished rainfall data 2002 – 2006. North Eastern Cape Forests. Wildebeest Estate: Ugie.

Quinn, G.P and Keough,M.J. 2002. Experimental design and data analysis for biologists. Cambridge University Press: Cambridge.

Pomeroy, D.E. 1980. Aspects of the ecology of the crowned crane, *Balearica regulorum* in Uganda. Scopus 4: 29-35.

Reinecke, K.J., Krapu, G.L. 1986. Feeding ecology of sandhill cranes during spring migration in Nebraska. Journal of Wildlife Management 50: 71-79.

Shaw, J.M; Jenkins, A.R; Ryan, P.G. and Smallie, J.J. 2010. A preliminary survey of avian mortality on power lines in the Overberg, South Africa. Ostrich 81:109-113.

South African Grain Laboratory.(SAGC) 2008. Accessed on 12 October 2008. http://www.sagl.co.za/pdf/MaizeReport2006-2007_11.pdf

South African Bird Atlas Project 2 (SABAP 2), 2010. Accessed November 2010 http://sabap2.adu.org.za/species_maps.php?Spp=214

SAFEX Commodity derivatives 2010. Accessed Nov 2010. http://www.jse.co.za/Markets/Commodity-Derivatives-Market/Commodity-Derivatives-Price-History.aspx#whitemaize

Snow, D.W. 1978. An atlas of the speciation in African non- passerine birds. British Museum of Natural History: London.

Sokal, R.R. and Rohlf, J. F. 1995. Biometry: the principles and practice of statistics in biological research. 3rd Edition. W.H. Freeman and Company: New York.

Somers, C. M. and Morris, R.D. 2002. Birds and wine grapes: foraging activity causes small –scale damage patterns in single vineyards. Journal of Applied Ecology 39: 511-523.

Su, L. 2003. Habitat selection by Sandhill cranes, *Grus canadensis tabida*, at multiple geographic scales in Wisconsin. Unpublished PhD Dissertation, University of Wisconsin: Wisconsin.

Sugden, L. G; Clark, R. G; Woodsworth, E. J. and Greenwood, H. 1988. Use of cereal fields by foraging sandhill cranes in Saskatchewan. Journal of Applied Ecology 25: 111-124.

Sykes, J.M; Lowe, V.P.W and Briggs, D.R. 1989. Some effects of afforestation on the flora and fauna of an upland sheepwalk during 12 years after planting. Journal of Applied Ecology 26: 299- 320.

Tacha, T.C.; Jorgenson, C. and Taylor, P.S., 1985. Harvest, migration, and condition of sandhill cranes in Saskatchewan.Journal of Wildlife Management 49: 476-480.

Tyson, P.D; Preston-Whyte, R.A. and Schultz, R.E. 1976. The climate of the Drakensberg. Natal town and regional planning report. Volume 31: Pietermaritzburg.

Tyson, P.D. 1986. Climate change and variablity in Southern Africa. Oxford University Press: Cape Town.

Urban, E.K; Hilary Fry, C. and Keith, S. 1986. The Birds of Africa, Volume 2. Academic Press: London.

Walter, G.H. 2003. Insect pest management and ecological research. Cambridge University Press: Cambridge.

Walkinshaw, L.H. 1964. The African Crowned Cranes. Wilson Bulletin. 76: 355-377

Walkinshaw, L.H. 1973. Cranes of the world. Winchester Press: New York.

Weatherhead, P.J; Tinker, S. and Greenwood, H. 1982. Indirect assessment of avian damage to agriculture. Journal of Applied Ecology 19: 773-782

Wojtaszekova, K. 2008. Habitat requirements for breeding of the endangered Wattled Crane (*Grus carunculatus*) in KwaZulu-Natal, South Africa. Unpublished MSc Thesis. Faculty of Biological Sciences Graduate School. University of Leeds: Leeds.

Wolff, A; Paul, J.P; Martin, J.L. and Bretagnolle, V. 2001. The benefits of extensive agriculture to birds: the case of the little bustard. Journal of Applied Ecology 38:963-975.

Young, D.J.; Harrison, J.A;, Navarro, R.A.; Anderson, M.D. and Colahan, B.D. (eds), 2003. Big birds on farms: Mazda CAR report 1993-2001. Avian Demography Unit: Cape Town.

Wood, D.S. 1979. Phenetic relationships within the Family Gruidae. Wilson Bulletin 91: 384-399.

APPENDIX 1

Table 3: Maize crop damage monitoring for Fairbridge Farm (2005).

Subfarm	Gaucho(Treated)	Germination date	Quadrat	Original plants	Crane Damage	Other feeding	Crow Feeding	Trampling	Unknown	Total plants
Farm 1	Treated	11-Nov-05	1	519	0	4	0	3	0	512
Farm 1	Treated	11-Nov-05	2	488	0	7	0	1	0	480
Farm 1	Treated	11-Nov-05	3	424	0	8	1	0	5	410
Farm 1	Treated	11-Nov-05	4	561	4	3	10	0	0	544
Farm 1	Treated	11-Nov-05	5	515	0	4	0	0	0	511
Farm 1	Treated	11-Nov-05	6	511	0	1	0	0	0	510
Farm 1	Treated	11-Nov-05	7	472	0	14	0	1	0	457
Farm 1	Treated	11-Nov-05	8	522	15	2	2	0	3	500
Farm 1	Treated	11-Nov-05	9	522	0	3	0	0	0	519
Farm 1	Treated	11-Nov-05	10	482	0	1	0	0	3	478
Farm 2	Untreated	11-Nov-05	1	561	11	10	0	0	2	538
Farm 2	Untreated	11-Nov-05	2	583	0	6	0	0	0	577
Farm 2	Untreated	11-Nov-05	3	612	0	42	0	1	0	569
Farm 2	Untreated	11-Nov-05	4	583	0	4	0	0	0	579
Farm 2	Untreated	11-Nov-05	5	577	0	4	0	0	0	573
Farm 2	Untreated	11-Nov-05	6	569	5	0	0	0	0	564
Farm 2	Untreated	11-Nov-05	7	480	0	16	0	1	0	463
Farm 2	Untreated	11-Nov-05	8	571	1	12	0	0	7	551
Farm 2	Untreated	11-Nov-05	9	596	0	7	0	0	32	557
Farm 2	Untreated	11-Nov-05	10	530	0	3	0	0	12	515

Table 4: Maize crop damage monitoring for Mondamin Farm (2005).

Subfarm	Gaucho	Germination date	Quadrat	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total plants
Farm 1	Untreated	14-Nov	1	388	16	9	0	0	3	360
Farm 1	Untreated	14-Nov	2	435	0	16	0	0	15	404
Farm 1	Untreated	14-Nov	3	443	25	1	0	0	17	400
Farm 1	Untreated	14-Nov	4	396	14	1	0	0	3	378
Farm 1	Untreated	14-Nov	5	490	71	1	0	2	28	388
Farm 1	Untreated	14-Nov	6	466	91	1	0	0	14	360
Farm 1	Untreated	14-Nov	7	504	49	2	0	0	12	441
Farm 1	Untreated	14-Nov	8	518	42	0	0	1	23	452
Farm 1	Untreated	14-Nov	9	495	49	0	0	0	11	435
Farm 1	Untreated	14-Nov	10	581	111	2	2	2	13	451
Farm 2	Untreated	14-Nov	1	365	0	1	0	0	2	362
Farm 2	Untreated	14-Nov	2	552	13	13	5	0	11	510
Farm 2	Untreated	14-Nov	3	523	18	0	0	0	5	500
Farm 2	Untreated	14-Nov	4	504	51	2	0	0	3	448
Farm 2	Untreated	14-Nov	5	535	39	3	0	0	13	480
Farm 2	Untreated	14-Nov	6	530	18	0	0	0	2	510
Farm 2	Untreated	14-Nov	7	434	0	0	0	0	0	434
Farm 2	Untreated	14-Nov	8	486	0	0	0	0	5	481
Farm 2	Untreated	14-Nov	9	460	0	0	0	0	2	458
Farm 2	Untreated	14-Nov	10	456	0	0	0	0	1	455

Table 5: Maize crop damage monitoring for Orpen Farm (2005).

Subfarm	Gaucho	Germination date	Quadrat	Original plants	Crane Damage	Other feed	Crow Feed	Trampling	Unknown	Total plants
Farm 1	Treated	11-Nov-05	1	480	0	0	0	0	1	479
Farm 1	Treated	11-Nov-05	2	496	0	0	0	0	0	496
Farm 1	Treated	11-Nov-05	3	527	1	0	0	0	0	526
Farm 1	Treated	11-Nov-05	4	536	0	0	0	0	0	536
Farm 1	Treated	11-Nov-05	5	523	0	0	0	0	0	523
Farm 1	Treated	11-Nov-05	6	510	1	0	0	0	0	509
Farm 1	Treated	11-Nov-05	7	480	4	0	0	0	0	476
Farm 1	Treated	11-Nov-05	8	527	0	0	0	0	0	527
Farm 1	Treated	11-Nov-05	9	421	1	0	0	0	0	420
Farm 1	Treated	11-Nov-05	10	531	0	0	0	0	0	531
Farm 2	Treated	11-Nov-05	1	485	0	0	0	0	0	485
Farm 2	Treated	11-Nov-05	2	428	0	0	0	0	0	428
Farm 2	Treated	11-Nov-05	3	453	0	0	0	0	0	453
Farm 2	Treated	11-Nov-05	4	502	0	0	0	0	0	502
Farm 2	Treated	11-Nov-05	5	466	0	0	0	0	3	463
Farm 2	Treated	11-Nov-05	6	485	0	0	0	0	1	484
Farm 2	Treated	11-Nov-05	7	499	0	0	0	0	0	499
Farm 2	Treated	11-Nov-05	8	380	3	0	0	60	2	315
Farm 2	Treated	11-Nov-05	9	462	0	0	0	0	1	461
Farm 2	Treated	11-Nov-05	10	518	5	2	0	0	0	511

Table 6 : Maize crop damage monitoring for Esperando Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Remaining plants
Farm 1	Untreated	24-Oct-06	1	90	0	1	0	0	0	89
Farm 1	Untreated	24-Oct-06	2	65	0	0	0	0	0	65
Farm 1	Untreated	24-Oct-06	3	84	0	3	0	0	0	81
Farm 1	Untreated	24-Oct-06	4	77	0	1	0	0	0	76
Farm 1	Untreated	24-Oct-06	5	85	1	1	0	0	1	82
Farm 1	Untreated	24-Oct-06	6	80	0	0	0	0	0	80
Farm 1	Untreated	24-Oct-06	7	78	0	3	0	0	2	73
Farm 1	Untreated	24-Oct-06	8	72	0	0	0	0	0	72
Farm 1	Untreated	24-Oct-06	9	73	0	1	0	0	3	69
Farm 1	Untreated	24-Oct-06	10	78	0	0	0	0	0	78
Farm 1	Untreated	24-Oct-06	11	88	0	0	0	0	0	88
Farm 1	Untreated	24-Oct-06	12	78	0	0	0	0	0	78
Farm 1	Untreated	24-Oct-06	13	126	0	1	0	0	1	124
Farm 1	Untreated	24-Oct-06	14	77	0	3	0	0	0	74
Farm 1	Untreated	24-Oct-06	15	75	0	0	0	0	0	75
Farm 1	Untreated	24-Oct-06	16	78	0	2	0	0	0	76
Farm 1	Untreated	24-Oct-06	17	69	0	0	0	0	0	69
Farm 1	Untreated	24-Oct-06	18	87	0	1	0	0	0	86
Farm 1	Untreated	24-Oct-06	19	85	0	0	0	0	0	85
Farm 1	Untreated	24-Oct-06	20	69	0	0	0	0	0	69
Farm 2	Untreated	02-Dec-06	1	93	10	0	0	0	0	83
Farm 2	Untreated	02-Dec-06	2	69	0	1	1	0	0	67
Farm 2	Untreated	02-Dec-06	3	89	0	0	0	0	0	89
Farm 2	Untreated	02-Dec-06	4	79	8	0	2	0	0	69
Farm 2	Untreated	02-Dec-06	5	70	7	1	0	0	0	62
Farm 2	Untreated	02-Dec-06	6	86	6	2	0	0	0	78
Farm 2	Untreated	02-Dec-06	7	74	6	2	0	0	0	66
Farm 2	Untreated	02-Dec-06	8	91	12	2	1	0	0	76
Farm 2	Untreated	02-Dec-06	9	102	27	0	0	0	0	75
Farm 2	Untreated	02-Dec-06	10	34	19	0	0	0	0	15
Farm 2	Untreated	02-Dec-06	11	32	27	0	5	0	0	0
Farm 2	Untreated	02-Dec-06	12	46	17	0	22	0	0	7
Farm 2	Untreated	02-Dec-06	13	18	0	0	13	0	0	5
Farm 2	Untreated	02-Dec-06	14	69	4	1	58	0	0	6
Farm 2	Untreated	02-Dec-06	15	71	0	0	55	0	0	16
Farm 2	Untreated	02-Dec-06	16	70	0	1	10	0	0	59
Farm 2	Untreated	02-Dec-06	17	102	0	0	52	0	0	50
Farm 2	Untreated	02-Dec-06	18	99	4	2	9	0	0	84
Farm 2	Untreated	02-Dec-06	19	83	26	4	4	0	0	49
Farm 2	Untreated	02-Dec-06	20	96	7	3	0	0	0	86

Table 7 : Maize crop damage monitoring for Fairbridge Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total Plants
Farm 2	Treated	19-Nov-06	1	56	3	4	0	0	0	49
Farm 2	Treated	19-Nov-06	2	48	2	2	0	0	0	44
Farm 2	Treated	19-Nov-06	3	58	0	0	0	0	1	57
Farm 2	Treated	19-Nov-06	4	58	0	3	0	0	0	55
Farm 2	Treated	19-Nov-06	5	68	0	1	0	0	0	67
Farm 2	Treated	19-Nov-06	6	67	0	8	0	1	0	58
Farm 2	Treated	19-Nov-06	7	68	0	0	0	0	0	68
Farm 2	Treated	19-Nov-06	8	72	0	0	0	0	0	72
Farm 2	Treated	19-Nov-06	9	56	0	0	0	0	0	56
Farm 2	Treated	19-Nov-06	10	51	0	0	0	0	0	51
Farm 2	Treated	19-Nov-06	11	62	0	0	0	0	0	62
Farm 2	Treated	19-Nov-06	12	56	0	0	0	0	0	56
Farm 2	Treated	19-Nov-06	13	66	0	2	1	0	0	63
Farm 2	Treated	19-Nov-06	14	70	0	1	0	0	0	69
Farm 2	Treated	19-Nov-06	15	47	0	2	0	0	0	45
Farm 2	Treated	19-Nov-06	16	82	2	1	0	0	0	79
Farm 2	Treated	19-Nov-06	17	53	0	1	0	0	0	52
Farm 2	Treated	19-Nov-06	18	71	0	0	0	0	0	71
Farm 2	Treated	19-Nov-06	19	48	0	1	0	4	0	43
Farm 2	Treated	19-Nov-06	20	83	0	1	0	4	0	78
Farm 1	Treated	09-Nov-06	1	42	0	1	0	0	1	40
Farm 1	Treated	09-Nov-06	2	27	0	1	0	0	0	26
Farm 1	Treated	09-Nov-06	3	28	0	1	0	0	0	27
Farm 1	Treated	09-Nov-06	4	49	0	0	0	0	1	48
Farm 1	Treated	09-Nov-06	5	21	0	2	0	0	1	18
Farm 1	Treated	09-Nov-06	6	44	0	0	0	0	0	44
Farm 1	Treated	09-Nov-06	7	43	0	4	0	1	0	38
Farm 1	Treated	09-Nov-06	8	44	0	1	0	0	0	43
Farm 1	Treated	09-Nov-06	9	26	0	4	0	0	0	22
Farm 1	Treated	09-Nov-06	10	30	0	2	1	0	0	27
Farm 1	Untreate	09-Nov-06	11	62	0	0	0	3	0	59
Farm 1	Untreate	09-Nov-06	12	51	0	7	0	0	0	44
Farm 1	Untreate	09-Nov-06	13	60	1	1	0	0	5	53
Farm 1	Untreate	09-Nov-06	14	63	1	1	0	0	0	61
Farm 1	Untreate	09-Nov-06	15	69	8	2	0	0	0	59
Farm 1	Untreate	09-Nov-06	16	53	0	1	0	0	0	52
Farm 1	Untreate	09-Nov-06	17	42	0	0	0	0	1	41
Farm 1	Untreate	09-Nov-06	18	66	2	0	0	0	0	64
Farm 1	Untreate	09-Nov-06	19	65	0	0	0	0	0	65
Farm 1	Untreate	09-Nov-06	20	64	2	1	0	0	1	60

Table 8: Maize crop damage monitoring for Frankskead Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total Plants
Farm 1	Treated	04-Nov-06	1	78	0	0	0	0	0	78
Farm 1	Treated	04-Nov-06	2	78	0	1	2	0	0	75
Farm 1	Treated	04-Nov-06	3	92	0	0	0	0	0	92
Farm 1	Treated	04-Nov-06	4	97	0	0	0	0	0	97
Farm 1	Treated	04-Nov-06	5	92	0	3	0	0	0	89
Farm 1	Treated	04-Nov-06	6	85	1	1	0	1	0	82
Farm 1	Treated	04-Nov-06	7	89	0	0	0	0	0	89
Farm 1	Treated	04-Nov-06	8	91	0	0	0	0	0	91
Farm 1	Treated	04-Nov-06	9	90	0	0	1	0	0	89
Farm 1	Treated	04-Nov-06	10	94	0	8	0	0	0	86
Farm 1	Treated	04-Nov-06	11	87	6	0	0	0	0	81
Farm 1	Treated	04-Nov-06	12	85	0	1	0	0	0	84
Farm 1	Treated	04-Nov-06	13	87	0	10	0	0	0	77
Farm 1	Treated	04-Nov-06	14	82	0	14	0	0	0	68
Farm 1	Treated	04-Nov-06	15	93	1	3	0	0	0	89
Farm 1	Treated	04-Nov-06	16	96	0	1	0	1	0	94
Farm 1	Treated	04-Nov-06	17	89	0	0	16	0	0	73
Farm 1	Treated	04-Nov-06	18	98	0	9	0	0	0	89
Farm 1	Treated	04-Nov-06	19	94	0	0	0	0	0	94
Farm 1	Treated	04-Nov-06	20	91	0	1	1	0	0	89
Farm 2	Treated	27-Nov-06	1	77	2	0	0	1	0	74
Farm 2	Treated	27-Nov-06	2	74	5	0	0	0	0	69
Farm 2	Treated	27-Nov-06	3	81	2	2	0	0	0	77
Farm 2	Treated	27-Nov-06	4	85	0	0	0	0	0	85
Farm 2	Treated	27-Nov-06	5	74	0	0	0	0	0	74
Farm 2	Treated	27-Nov-06	6	72	0	0	0	0	0	72
Farm 2	Treated	27-Nov-06	7	87	0	0	0	0	1	86
Farm 2	Treated	27-Nov-06	8	88	0	0	0	0	0	88
Farm 2	Treated	27-Nov-06	9	81	0	0	0	0	0	81
Farm 2	Treated	27-Nov-06	10	67	0	0	0	0	0	67
Farm 2	Treated	27-Nov-06	11	84	0	0	0	0	0	84
Farm 2	Treated	27-Nov-06	12	81	9	0	0	0	0	72
Farm 2	Treated	27-Nov-06	13	77	7	2	0	0	0	68
Farm 2	Treated	27-Nov-06	14	77	0	0	0	0	1	76
Farm 2	Treated	27-Nov-06	15	51	4	0	0	0	0	47
Farm 2	Treated	27-Nov-06	16	76	3	5	0	0	0	68
Farm 2	Treated	27-Nov-06	17	70	0	1	0	0	0	69
Farm 2	Treated	27-Nov-06	18	86	0	2	1	0	0	83
Farm 2	Treated	27-Nov-06	19	78	0	0	1	0	0	77
Farm 2	Treated	27-Nov-06	20	73	1	0	0	0	0	72

Table 9 : Maize crop damage monitoring for Mondamin Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total Plants
Farm 1	Untreated	06-Nov-06	1	77	0	0	0	0	0	77
Farm 1	Untreated	06-Nov-06	2	82	0	1	0	0	0	81
Farm 1	Untreated	06-Nov-06	3	63	2	2	0	0	0	59
Farm 1	Untreated	06-Nov-06	4	69	1	1	0	0	0	67
Farm 1	Untreated	06-Nov-06	5	54	5	0	0	0	0	49
Farm 1	Untreated	06-Nov-06	6	74	0	0	0	0	0	74
Farm 1	Untreated	06-Nov-06	7	54	8	1	1	0	0	44
Farm 1	Untreated	06-Nov-06	8	78	4	0	1	0	0	73
Farm 1	Untreated	06-Nov-06	9	48	7	0	0	0	0	41
Farm 1	Untreated	06-Nov-06	10	49	0	0	0	0	0	49
Farm 1	Untreated	06-Nov-06	11	82	0	0	0	0	0	82
Farm 1	Untreated	06-Nov-06	12	69	6	0	0	0	0	63
Farm 1	Untreated	06-Nov-06	13	74	1	2	0	0	0	71
Farm 1	Untreated	06-Nov-06	14	76	0	4	0	0	0	72
Farm 1	Untreated	06-Nov-06	15	82	0	0	0	0	0	82
Farm 1	Untreated	06-Nov-06	16	78	0	0	0	0	0	78
Farm 1	Untreated	06-Nov-06	17	79	0	5	0	0	0	74
Farm 1	Untreated	06-Nov-06	18	80	0	0	0	0	0	80
Farm 1	Untreated	06-Nov-06	19	55	0	0	0	0	0	55
Farm 1	Untreated	06-Nov-06	20	76	0	0	0	0	0	76
Farm 2	Treated	04-Dec-06	1	78	0	2	0	0	0	76
Farm 2	Treated	04-Dec-06	2	81	0	1	0	0	0	80
Farm 2	Treated	04-Dec-06	3	64	0	1	0	0	0	63
Farm 2	Treated	04-Dec-06	4	80	0	1	0	0	0	79
Farm 2	Treated	04-Dec-06	5	75	0	3	0	0	0	72
Farm 2	Treated	04-Dec-06	6	53	0	0	0	0	0	53
Farm 2	Treated	04-Dec-06	7	60	0	1	0	0	0	59
Farm 2	Treated	04-Dec-06	8	79	0	3	0	0	0	76
Farm 2	Treated	04-Dec-06	9	72	0	2	0	0	0	70
Farm 2	Treated	04-Dec-06	10	64	0	1	0	0	1	62
Farm 2	Untreated	04-Dec-06	11	62	0	1	0	0	0	61
Farm 2	Untreated	04-Dec-06	12	78	0	1	0	0	0	77
Farm 2	Untreated	04-Dec-06	13	82	0	1	0	0	0	81
Farm 2	Untreated	04-Dec-06	14	87	0	2	1	0	0	84
Farm 2	Untreated	04-Dec-06	15	76	0	0	2	0	0	74
Farm 2	Untreated	04-Dec-06	16	75	0	1	0	0	0	74
Farm 2	Untreated	04-Dec-06	17	70	0	1	0	0	0	69
Farm 2	Untreated	04-Dec-06	18	73	0	3	2	0	0	68
Farm 2	Untreated	04-Dec-06	19	71	0	1	0	0	0	70
Farm 2	Untreated	04-Dec-06	20	78	0	1	4	0	0	73

Table 10 : Maize crop damage monitoring for Orpen Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total Plants
Farm 1	Treated	08-Nov-06	1	97	0	0	0	0	0	97
Farm 1	Treated	08-Nov-06	2	90	0	0	0	0	0	90
Farm 1	Treated	08-Nov-06	3	97	0	0	0	0	0	97
Farm 1	Treated	08-Nov-06	4	93	0	0	5	0	0	88
Farm 1	Treated	08-Nov-06	5	107	0	0	0	0	0	107
Farm 1	Treated	08-Nov-06	6	107	0	0	0	0	0	107
Farm 1	Treated	08-Nov-06	7	97	0	0	0	1	0	96
Farm 1	Treated	08-Nov-06	8	92	0	0	0	0	0	92
Farm 1	Treated	08-Nov-06	9	104	0	0	0	0	0	104
Farm 1	Treated	08-Nov-06	10	106	0	0	0	0	0	106
Farm 1	Treated	08-Nov-06	11	99	0	0	0	0	0	99
Farm 1	Treated	08-Nov-06	12	96	0	0	0	0	0	96
Farm 1	Treated	08-Nov-06	13	82	0	0	0	0	0	82
Farm 1	Treated	08-Nov-06	14	77	0	0	0	0	0	77
Farm 1	Treated	08-Nov-06	15	66	0	1	0	0	0	65
Farm 1	Treated	08-Nov-06	16	81	0	0	0	0	0	81
Farm 1	Treated	08-Nov-06	17	85	0	0	0	0	0	85
Farm 1	Treated	08-Nov-06	18	93	0	1	0	0	0	92
Farm 1	Treated	08-Nov-06	19	98	0	2	0	0	0	96
Farm 1	Treated	08-Nov-06	20	92	0	0	0	0	0	92
Farm 2	Treated	16-Nov-06	1	90	0	1	2	0	0	87
Farm 2	Treated	16-Nov-06	2	103	1	0	0	0	0	102
Farm 2	Treated	16-Nov-06	3	91	0	1	0	0	0	90
Farm 2	Treated	16-Nov-06	4	79	4	1	0	0	0	74
Farm 2	Treated	16-Nov-06	5	91	5	0	0	0	0	86
Farm 2	Treated	16-Nov-06	6	96	0	0	0	0	0	96
Farm 2	Treated	16-Nov-06	7	85	2	1	0	0	0	82
Farm 2	Treated	16-Nov-06	8	83	0	2	0	0	0	81
Farm 2	Treated	16-Nov-06	9	83	0	2	0	0	0	81
Farm 2	Treated	16-Nov-06	10	83	10	1	0	0	0	72
Farm 2	Treated	16-Nov-06	11	101	11	0	3	0	0	87
Farm 2	Treated	16-Nov-06	12	95	0	0	9	0	0	86
Farm 2	Treated	16-Nov-06	13	111	0	2	5	0	0	104
Farm 2	Treated	16-Nov-06	14	88	8	1	4	0	0	75
Farm 2	Treated	16-Nov-06	15	93	1	1	3	0	0	88
Farm 2	Treated	16-Nov-06	16	87	0	4	3	0	0	80
Farm 2	Treated	16-Nov-06	17	89	0	1	9	0	0	79
Farm 2	Treated	16-Nov-06	18	100	1	1	2	0	0	96
Farm 2	Treated	16-Nov-06	19	100	2	0	0	0	0	98
Farm 2	Treated	16-Nov-06	20	95	1	1	1	0	1	91

Table 11: Maize crop damage monitoring for Pot Luck Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total Plants
Farm 1	Untreated	22-Oct-06	1	65	0	0	0	0	0	65
Farm 1	Untreated	22-Oct-06	2	53	0	0	0	0	0	53
Farm 1	Untreated	22-Oct-06	3	88	0	0	0	0	0	88
Farm 1	Untreated	22-Oct-06	4	76	0	0	0	0	0	76
Farm 1	Untreated	22-Oct-06	5	80	0	0	0	0	0	80
Farm 1	Untreated	22-Oct-06	6	68	0	2	0	0	1	65
Farm 1	Untreated	22-Oct-06	7	80	1	1	0	0	0	78
Farm 1	Untreated	22-Oct-06	8	59	0	0	0	0	0	59
Farm 1	Untreated	22-Oct-06	9	75	0	6	0	0	0	69
Farm 1	Untreated	22-Oct-06	10	88	0	0	0	0	0	88
Farm 1	Untreated	22-Oct-06	11	73	0	0	0	0	0	73
Farm 1	Untreated	22-Oct-06	12	75	27	11	1	0	0	36
Farm 1	Untreated	22-Oct-06	13	59	0	1	2	0	0	56
Farm 1	Untreated	22-Oct-06	14	39	3	1	1	0	0	34
Farm 1	Untreated	22-Oct-06	15	83	0	6	0	0	0	77
Farm 1	Untreated	22-Oct-06	16	45	7	2	2	0	0	34
Farm 1	Untreated	22-Oct-06	17	71	0	2	8	0	0	61
Farm 1	Untreated	22-Oct-06	18	53	0	3	1	0	0	49
Farm 1	Untreated	22-Oct-06	19	103	0	0	0	0	0	103
Farm 1	Untreated	22-Oct-06	20	82	2	0	0	0	0	80
Farm 2	Treated	21-Nov-06	1	91	0	0	0	0	0	91
Farm 2	Treated	21-Nov-06	2	92	0	0	0	0	0	92
Farm 2	Treated	21-Nov-06	3	95	0	1	0	0	0	94
Farm 2	Treated	21-Nov-06	4	82	0	0	0	0	0	82
Farm 2	Treated	21-Nov-06	5	82	0	0	5	0	0	77
Farm 2	Treated	21-Nov-06	6	79	0	0	0	0	0	79
Farm 2	Treated	21-Nov-06	7	82	0	0	0	0	0	82
Farm 2	Treated	21-Nov-06	8	87	0	0	0	0	0	87
Farm 2	Treated	21-Nov-06	9	90	0	0	0	0	0	90
Farm 2	Treated	21-Nov-06	10	109	0	1	0	0	0	108
Farm 2	Treated	21-Nov-06	11	94	0	0	0	0	0	94
Farm 2	Untreated	21-Nov-06	12	97	0	0	0	0	0	97
Farm 2	Untreated	21-Nov-06	13	104	0	0	0	0	0	104
Farm 2	Untreated	21-Nov-06	14	101	0	1	0	0	0	100
Farm 2	Untreated	21-Nov-06	15	105	0	0	0	0	0	105
Farm 2	Untreated	21-Nov-06	16	95	0	0	0	3	0	92
Farm 2	Untreated	21-Nov-06	17	95	0	0	0	0	0	95
Farm 2	Untreated	21-Nov-06	18	98	0	0	0	0	0	98
Farm 2	Untreated	21-Nov-06	19	93	0	0	0	0	0	93
Farm 2	Untreated	21-Nov-06	20	103	0	0	0	0	0	103

Table 12: Maize crop damage monitoring for Strathmore Farm (2006).

Sub-farm	Gaucho (Treated)	Germination Date	Quadrant	Original plants	Crane Damage	Other Feed	Crow Feed	Trampling	Unknown	Total Plants
Farm 1	Untreated	29-Oct-06	1	61	1	0	0	0	0	60
Farm 1	Untreated	29-Oct-06	2	66	0	1	0	0	0	65
Farm 1	Untreated	29-Oct-06	3	71	0	0	0	0	0	71
Farm 1	Untreated	29-Oct-06	4	78	0	0	0	0	0	78
Farm 1	Untreated	29-Oct-06	5	83	0	0	0	0	0	83
Farm 1	Untreated	29-Oct-06	6	96	0	0	0	0	0	96
Farm 1	Untreated	29-Oct-06	7	90	0	0	0	0	0	90
Farm 1	Untreated	29-Oct-06	8	73	0	1	0	0	0	72
Farm 1	Untreated	29-Oct-06	9	69	0	2	0	0	0	67
Farm 1	Untreated	29-Oct-06	10	79	0	0	2	0	1	76
Farm 1	Untreated	29-Oct-06	11	63	0	1	0	0	0	62
Farm 1	Untreated	29-Oct-06	12	79	0	3	1	0	1	74
Farm 1	Untreated	29-Oct-06	13	83	0	0	0	0	0	83
Farm 1	Untreated	29-Oct-06	14	83	0	1	0	0	0	82
Farm 1	Untreated	29-Oct-06	15	86	0	2	0	0	0	84
Farm 1	Untreated	29-Oct-06	16	89	0	2	0	0	0	87
Farm 1	Untreated	29-Oct-06	17	71	23	1	0	0	0	47
Farm 1	Untreated	29-Oct-06	18	66	0	0	0	0	0	66
Farm 1	Untreated	29-Oct-06	19	61	3	1	0	0	0	57
Farm 1	Untreated	29-Oct-06	20	80	0	0	0	0	0	80