DESIGNING A RANGELAND TO PRESERVE AFRICA'S MOST ENDANGERED MAINLAND BIRD AND A PEOPLE'S WAY OF LIFE

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Abstract

The Borana rangelands once had the highest grazing potential in East Africa and productive breed of cattle. Currently, the rangelands are severely degraded due to increase in human and cattle population, overgrazing, climate change and agricultural expansion. The Liben Plains, located 10 to 40 km from Negelle, is an area of rangeland known to be one of the last remaining stronghold of the Liben Lark (*Heteromirafra archeri)*. The species is currently listed as Critically Endangered, mainly due to habitat degradation, and with a tiny and rapidly declining global population. Research examining the abundance and habitat preferences of the species have been ongoing since 2007. Here I present an analysis of these and additional survey data from 2007 to 2013 regarding the species population size, density and habitat associations, and track changes in the patterns of land-use, habitat loss and degradation over the last 20 years. Distance sampling line-transect surveys were used to assess the density and distribution of the species. Measurements of structural habitat characteristics were also recorded using a standardised habitat recording method in use since 2007. Spatial data analysis revealed that the Liben Plains are experiencing significant and ongoing levels of habitat loss, primarily through the conversion of grassland habitat to cereal crops farming has been evident since 1994, but has accelerated since 2000, and alarmingly, has spread to include areas of red soil grasslands that were previously believed to be unsuitable for agriculture. Density estimates from 2007 to 2013 revealed that the Liben Lark population has declined dramatically across the Plains. The species is now extremely rare, numbering no more than 1 individual per km^2, and confined to just three tiny areas of 'density hotspots' covering an area of degraded grassland between $10km^2$ and $26km^2$ in size. Liben Larks were found to avoid areas of severe habitat degradation i.e. areas of the plains with high bare ground cover, short heavily disturbed grass, high cover of trees and invasive fennel, but preferred areas with medium to tall dense grass (least grazed areas), but patterns of habitat associations varied between differed survey seasons. Nest concealment is a large contributing factor for the survival of artificial lark nests containing artificial lark eggs, which experimental trials in this study reveal suffer extremely high nest failure rates due to predation by birds and mammals, and trampling by livestock. These factors may be restricting the Liben Lark population from breeding effectively. An integrated management system involving state, traditional and non-governmental bodies is crucial to balance grazing land for livestock and suitable habitat for the survival of the Liben Lark.

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INTRODUCTION

1.1. Rangelands and grassland ecosystems

Rangelands are often defined as any lands that are not considered arable or forest, and that are capable of supporting life for human and other animals from either the native or naturalized vegetation (SRM, 1989; Vavra & Brown, 2006). Estimates of the global extent of rangelands generally range from 60%-75% of total land area (Brown et al., 2008). Rangelands are composed of grasslands, shrublands, and savannas used as wildlife and livestock habitat (Follett et al., 2001; Hunt et al., 2003). Many grasslands are used as pastures or rangelands for livestock production (Azpiroz et al., 2012; Bleho et al., 2014) and thus, grasslands host an important part of the global economy with over 345 million ha of land worldwide being currently used as pastures or rangelands (Goldewijk, 2001).

Grassland ecosystems are found on every continent in the world except Antarctica, covering between 31 and 43% of the total land area of the world (Rosen, 2000). These ecosystems represent some of the most threatened terrestrial biomes in the world because they are under severe pressure on a global scale due to a variety of anthropogenic threats (Noss et al., 1995). The severe loss of grassland habitat has resulted in highly restricted remnant areas of grasslands which greatly limits any efforts to preserve these ecosystems and the unique grassland biodiversity they support (Hoekstra et al., 2005; Shepherd & Debinski 2005; Billeter et al., 2008; Henwood, 2010).

1.1.1. Grassland avian diversity and threats

Many grassland ecosystems also support unique grassland-dependent bird species, some of which are now facing dramatic population declines (Sauer & Link, 2011) primarily from habitat loss and degradation (Vickery et al., 2000; Donald et al., 2006) caused by agricultural intensification e.g. increased livestock production and cereal crop production (e.g. Bakker & Berendse, 1999; Walker et al., 2004). Intensive agriculture often increases the number of invasive generalist species, which can result in further adverse effects (McKinney & Lockwood, 1999). Due to these threats, the conservation and restoration of these grasslands and their unique species is now a global conservation priority (Cramer et al., 2008). Understanding relationships between livestock and grassland-dependent birds is therefore critical to designing and implementing grassland conservation strategies and sustainable livestock management practices (Derner et al., 2009). The abandonment of former crop fields and grazing pastures currently ongoing in some developing countries provides good opportunities for the conversion of former agricultural lands to grasslands (Deri et al., 2011). This leads to recreating new grassland patches or enlarging existing remnant patches for threatened grassland bird populations, and perhaps enhancing connectivity between neighbouring grassland areas (Hobbs & Cramer, 2007).

Vegetation structural characteristics are known to influence grassland bird species abundance (Winter et al., 2005). Understanding the influence of habitat quality on bird abundance is therefore a priority area of conservation research, particularly where the conversion of native grassland habitats to agricultural land uses, particularly livestock production, is thought to contribute toward such population declines (Vickery et al., 2000; Goldewijk, 2001). Whilst some studies have shown that livestock grazing benefits some grassland-dependent bird species through modification of grassland vegetation structure (e.g. Muchai et al., 2002; Fondell & Ball, 2004), other studies have highlighted the potential negative effects of such habitat modification (Bleho et al., 2014). Research has also revealed that declines in grassland bird abundance are also influenced by other factors including habitat loss, changes in local farming practices (Samson & Knopf 1994; Vickery et al., 1999; Askins et al., 2007) and increased woody vegetation encroachment (Coppedge et al., 2001; Scheiman et al., 2003; Grant et al., 2004).

1.1.2. Rangeland Management

Rangelands are human manipulated systems due to the fact that humans have heavy reliance on these types of habitats and due to their extensive use (Brown et al., 2008). Although rangelands are not intensively managed like croplands and forest, rangeland conditions are determined by how well humans can indirectly manage and/or impact ecological processes (Vavra & Brown, 2006). One of the major uses of rangelands in Africa is for livestock rearing (Pratt & Gwynne, 1977). In order to achieve the proper use of the rangelands in Sub-Saharan Africa, rangeland managers have suggested the severe reduction of livestock stocking rates, called the ‘destocking policy’. This policy is based on the carrying capacity (CC) of a given range, and defined as the maximum number of animals that can be supported in a particular space and feed supply. The destocking policy assumes that if stocked at the CC, range conservation and relatively high productivity could be achieved. However, this has not been the case for many rangelands and some argue that it has left the pastoral population and its ecosystem worse off than it was before. CC is usually expressed as the number of standardized 'Livestock Units' (LU) of 250 kg that can be held per unit of land area. The CC stocking rate is calculated by dividing the total amount of forage produced per unit area by the average yearly feed requirements of one LU (Hary et al., 1996). Thus, it assumes that the rangelands should respond by reducing grazing pressure but a major drawback of this concept is that it assumes that the grazing area is of homogenous forage growth and quality (Westoby et al., 1989). It assumes that the grazing systems are density-dependent and that range productivity decreases with increased stocking rates and vice-versa (Hary et al., 1996). However, in places with pronounced variation in climate, there will be periods of high plant growth and dormancy which is affected by the length of the growing season (Ellis & Swift, 1988). Plant quality is best at the peak of the growing season, then declines rapidly until the beginning of the dry season (Hary et al., 1996). Early plant growth is dominated by unpalatable species in some years and palatable species in other years. When the growth of palatable species is favoured, destocking could be effective in managing the rangeland, but destocking will not be effective during times when there are more unpalatable species (Westoby et al., 1989).

Forage quantity depends on the amount of rainfall, and so even though there may be sufficient biomass available during the dry season, the quality may be too low to satisfy the maintenance requirements of the livestock. Destocking rangelands would lead to a serious decline in the productivity of pastoral production systems and is not likely to halt rangeland degradation (Hary et al., 1996). Both stocking rate, rainfall and other environmental factors influence the cattle dynamics (Desta & Coppock, 2002). Hence, land use policy interventions should not only be focused on absolute livestock numbers but also on the optimal livestock distribution in space and time (Hary et al., 1996), the actual state of the land and vegetation (Westoby et al., 1989) and the effect of the human population dynamics in pastoral systems (Desta & Coppock, 2002).

1.2. The Borana rangelands of Ethiopia

Rangelands account for about 60 % of the total land area in Ethiopia out of which 7 – 12% is covered by the Borana rangelands (Angassa, 2002). The Borana rangelands were once known to have the highest grazing potential in East Africa and the highly productive breed of the Borana cattle (Care Ethiopia, 2010). The Borana cattle are capable of surviving in hot and sunny climates while drinking water only every third day. These breed are known to be very efficient converters of pasture forage into body fat even when consumed during times of drought (Bassi & Tachi, 2011).

1.2.1. *Gadda* system of land management

The Borana rangelands represent some of the most degraded rangeland habitats in Africa due largely to the disruption of the traditional '*gadda*' system of managing the rangelands (Dalle et al., 2005). The '*gadda*' system is the traditional sustainable administrative system practiced by the Oromo people in Ethiopia and that has existed since the 15th Century (Legesse, 1973). *Gadda* is a very strong symbol of the Oromo ethnicity and can manifests itself as social phenomena, prescriptive rules, ceremonies, rites, public offices and actual villages (Bassi, 1996). *Gadda* is recognized as a root feature of Oromo culture or as a symbol of a pan-Oromo national political identity that is distinct from the Ethiopia national identity (Baxter et al., 1994). The Borana are well known for being one of the few Oromo societies which have the Gadda system relatively still intact (Haberland, 1963; Legesse, 1973; Baxter, 1978). According to Baxter (1996), "the *gadda* system has served the Borana as (1) an organized way of ensuring that there is always a responsible segment of the nation responsible for maintaining proper relations with God, (2) as an organized way of ensuring that every man has the opportunity of a fulfilled ritual life while also fulfilling his obligations to the nation."

The Borana speak Oromifa with a distinct dialect that has an elaborate vocabulary which is difficult to understand by other Oromos populations in central and western Ethiopia (Kidane, 2002). Most of the Borana practice their indigenous religion which involves regularly pray for peace, fertility and rain and believe in one supreme God, Waaqa. Three Borana leaders (known as '*abba gadda*') are selected every eight years to assume responsibilities in Borana governance and cultural celebrations (Legesse, 1973). The Borana people classify rangelands into different functional land use units through discussion and agreements. Two of these are land for the largest families ('*Lafa Worra Guddaa*') which is further divided into land for calves ('*kallos*') settlement ('*Lafa Quftuma*') and for dry livestock ('*Lafa Fooraa*'). Villages are typically established so that settlements and grazing lands are located further away from each other. Studies have revealed that the pastoralists have indigenous knowledge not only about the forage type but also about the forage quality of plants in the area (e.g. Dalle et al., 2005).

There has been severe anthropogenic pressure on the rangelands in Ethiopia due to the increased number of cattle and human population (Homann, 2004). Currently there are about

1.5 million people living in the Guji zone and about 140,000 people living in the Liben district (FDRE 2008) which are composed of Borana Oromo, Guji Oromo and the Arsi people (Sherkite, 2006). Development programs in the southern pastoral areas in the 1970s and 1980s, resulted in larger and potentially less stable herds of cattle that had adverse effects on the rangelands and also led to further increases in the human population that is now heavily dependent on international famine relief. These programs were not complete failures in that the veterinary campaigns, ponds, roads and markets were beneficial to the Borana society (Coppock, 1994). Although the traditional *gadda* grazing practices were historically effective, they are currently disregarded by many in the pastoralist community due to the increase in human and livestock populations, poorly placed settlements and ponds and other development interventions (Dalle et al., 2005). Other reasons include a reduction in available grazing lands due to ranching, farming and bush encroachment (Angassa & Beyene, 2003).

1.2.2. The Liben Plain, Southern Ethiopia

The Liben Plain (24,000 ha), part of the Borana rangelands, once held the highest grazing potential in East Africa, and still significantly supports the Ethiopian livestock sector, the largest in Africa (Western et al., 2009). Approximately 12,000 people inhabit and communally own and manage the plain itself, with 85% of this rural population being dependent on pastoralism, and owning approximately 48,000 cattle. The plains are also home to unique livestock species such as the Boran Cattle and Wakka goat. However over four times more cattle are often brought from the larger surrounding regions in times of drought, as the plain provides 50% of the districts pasture. These plains are also important for biodiversity and have been designated as an Important Bird Area (IBA) and they also form part of the South Ethiopian Highlands Endemic Bird Area (EWNHS, 1996). The Liben Plain is located in the Liben District which is part of the Guji Zone (Fig 1.1). However, the Liben District used to be part of the Borena zone along with four other districts that were split off in 2003 to be part of the Guji Zone. The Liben Plain is mainly found within the boundries of the Siminto and Miesa Peasant Associations (PA) in the Liben District.

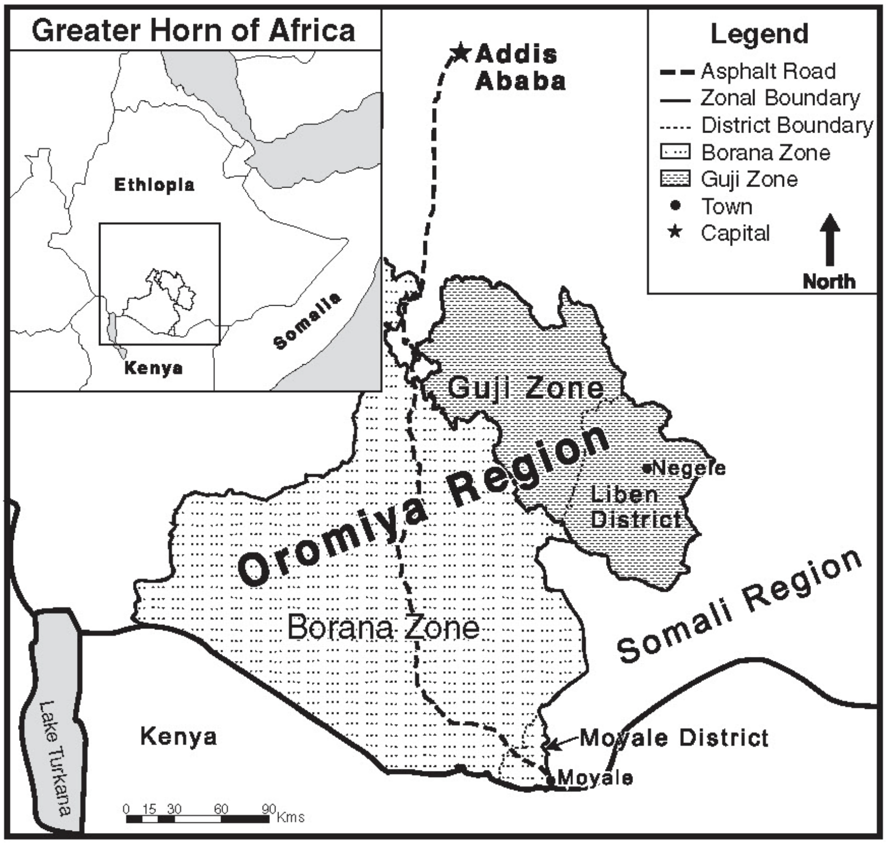

Figure 1.1 Map of the Liben District in the Guji Zone (Source Coppock et al., 2011)

1.2.3. Threats to the Liben Plain

Over the last 40 years, intensive overgrazing and a decline in nomadic pastoralist management, driven by settlement initiatives, has led to severe grassland degradation and reduction: only 7,500 ha of core grassland of the Liben Plain remains (Spottiswoode et al., 2009). Grassland productivity has declined due to changes in species composition, a decline in species richness and reduced sward height with degraded habitat supporting species of lower productivity and limited forage value (Donald et al., 2010b). Other negative impacts include increasing areas of bare ground, soil erosion, loss of soil nutrients, scrub encroachment and near complete loss of fauna. Climate change has increased the intensity and occurrence of droughts, having severe impacts on livestock productivity and food availability. In addition, Boran cattle populations and those of other livestock may be severely threatened due to poor breeding practices and forms of unsustainable grassland management (Angassa, 2002).

It is generally feared that the Liben Plains can no longer support populations of its unique grassland species or even the pastoralist livelihoods of the Borana people. An increasing proportion of the population (11%) are turning to crop cultivation, which has serious impacts on biodiversity and livelihoods, as it reduces grassland area, and is an unsustainable short-term strategy, due to poor quality soils and limited water. Historically there were no reports of cultivation on the Borana rangelands until Emperor Menelik II conquered the area in the late 19th Century. Settler soldiers and later immigrant farmers introduced the crop farming culture but oral historians in the area suggest that cultivation started in the early 1960s. However, it was not until the government's proclamation on land use in 1975 and the droughts in the 1970s that the majority of pastoralists began cultivation (Agassa & Oba, 2008).

1.2.3.1. Threats from bush encroachment

One of the main reasons for rangeland degradation in Ethiopia is the encroachment of invasive bush species. These grasslands typically have less than 10% bush cover and are considered to reach a bush climax when it exceeds 30%. This could take place due to the interaction between episodic rainfall, lack of fire, intensive grazing (Dalle et al., 2006) and loss of native browsing animals (Donald et al., 2010b). Nowadays it is generally agreed that the Borana lowlands have passed the critical threshold level to be considered healthy grasslands and entered the encroached condition of both density and cover of woody plants (Dalle et al., 2006). At least four of the seven villages in the area for this study have had invasive bush populations become firmly established within the lifetime of the village elders (Donald et al., 2010b).

Studies conducted in the Borana rangeland have revealed that its vegetation in the encroached areas had less plant diversity than non-encroached areas (Angassa, 2002). Severely encroached areas have been found to have lower carbon to nitrogen ratios than in less encroached areas (Dalle et al., 2006). One of the methods of controlling invasive bush encroachment is by clearing – recent findings from a number of studies have revealed that areas cleared of invasive scrub usually contain more desirable grass species and more seedlings of desirable grass species than those that have not been cleared. The removal of invasive scrub also improves the range condition by increasing the basal cover of grasses and improving the overall condition of the soil (see Angassa, 2002).

Herd diversification by introducing different species of browsing animals has also proved to be an efficient means of controlling bush encroachment (Trollope, 1980). The Borana pastoralists used to burn the grasslands more than thirty years ago with an interval of two to five years in order to control bush, ticks, and to improve the nutritional quality and accessibility of the grasslands. The use of fire was banned more than thirty years ago by the previous government to reduce forest loss, but this was done without considering its ecological management role on rangeland habitats (Agassa & Oba, 2008). The Borana pastoralists view the restriction of burning as a major management constraint that has affected the state of the rangelands (Coppock, 1994). Burning is also useful in providing open areas to serve as feeding ground and dense tall grass which could be used for some of the regions unique grassland ground nesting birds e.g. the Liben Lark *Heteromirafra archeri* (Donald et al., 2010a). Once invasive bush dominates and suppresses the grass across rangeland habitats, fire will not be effective in controlling the bush as the grass will not be sufficient to support intense fire. Even though fire is essential in maintaining and conserving African savanna grasslands, fire intensity is rarely measured and included in fire records. Fire intensity has effects on the vegetation and varies with seasons and fuel load which are factors that can be manipulated by rangeland managers (Trollope, 1980).

1.2.3.2. Threats from drought and climate change

Climate change can severely impact human health, availability of water resources, livestock and crop production and the energy sector of the country. About 70% of the land in Ethiopia consists of dry lands which are at high risk of desertification due to climate change. Ethiopia is also known for having one of the lowest water storage infrastructures in the world which makes it more dependable on the highly variable rainfall (Bewket, 2011). In previous years, drought used to occur in the area every five to eight years but more recently drought cycles have become more frequent, occurring every two to three years. Drought has prevailed in the years 1998/99, 2000/01, 2003/04, 2006/07 and 2007/08 resulting in pastoralists travelling on average 24 km a day in order to get access to good pasture and water for their livestock. According to the inhabitants in the southern lowlands including the Guji Zone, the climate induced changes have reduced the productivity of their cattle, making the cattle less resistant to diseases and increased cattle mortality (Amsalu & Adem, 2009). Each drought had resulted in the death of about half of all livestock. Some capacity building projects in the area have enabled the participants to get income from the livestock sales and to better cope with the droughts (Coppock et al., 2011).

1.2.3.3. Use of fenced enclosures and state ranches

Designating enclosures is an alternative and effective way of improving the quality of the rangelands by excluding livestock and allowing the vegetation to regenerate in terms of biomass and species diversity. Enclosures also helps reduce soil erosion and increases rain water infiltration (Aerts et al., 2009). However, care should be taken in their management as older enclosures tend to have lower species diversity and increased bush encroachment Angassa & Oba, 2010). State ranches in pastoral areas started in the 1970s during the socialist government of Ethiopia (Agassa & Oba, 2008). However studies have demonstrated that the herd productivity in traditional African pastoral systems equals or exceeds that of the ranches established in the same area. Ranching has not been found to be advantageous as the communal managed systems but they could be valuable to have as gene pool storage to be used to restock the pastoralists' herds after the drought seasons (Angassa & Oba, 2008).

1.2.4. Biodiversity on the Liben Plain

Ethiopia has designated 73 Important Bird Areas (IBAs) in the country. The Liben Plain and Negelle woodlands were designated as an IBA in 1996 because of two criteria namely having globally threatened and range restricted species, which is the Liben Lark (EWNHS, 1996). The Liben Plain is also situated within the southern highlands Endemic Bird Area (EBA) which contains six range restricted species: Nechisar Nightjar *Caprimulgus solala*, White-tailed Swallow *Hirundo megaensis*, Ethiopian Bush-crow *Zavattariornis stresemanni*, Salvadori's Serin *Serinus xantholaema*, Prince Ruspoli's Turaco *Tauraco ruspolii* and the Liben Lark (Spottiswoode et al., 2010). The plains also harbour other southern endemics such as the White-tailed Swallow (Gabremichael et al., 2009) and the Prince Ruspoli's Turaco. One of the lark species commonly found on the plain is the Somali Short-toed Lark *Alauda somalica*, which could sometimes be mistaken for the Liben Lark if not observed carefully. Other bird species characteristic of the plain are the Kori Bustard *Ardeotis kori*, White-crowned Starling *Spreo albicapillus*, Crowned Plover *Vanellus tectus*, Somali Crow *Corvus edithae*, Ethiopian Swallow *Hirundo aethiopica* and Temmick's Courser *Cursorius temminckii* (Spottiswoode et al., 2010). Currently 247 bird species have been recorded across the plain and the town of Negelle (Ash & Atkins, 2009).

1.3. The Liben Lark *Heteromirafra archeri*

1.3.1. Taxonomy and identification

Larks are passerine birds belonging to the family Alaudidae. Worldwide, there are currently 91 species of larks belonging to 19 different genera and all species (except one) occur in the Old World, and in northern and eastern Australia. The majority of lark species are distributed within Africa, where there are two centres of lark diversity within the continent: the north-eastern and southwestern arid zones (Ryan & Bloomer, 1999). In many aspects of their behaviour and physical appearance, most lark species resemble Pipits, Wagtails and Longspurs (which all belong to the family Motacillidae). Their colouration is cryptic, allowing them to blend in to their preferred habitat. Larks are predominantly terrestrial and tend to run rather than hop, and crouch to escape detection by predators or even sit out periods of bad weather (Elphick et al., 2001). The success of larks is attributed to their tolerance of heat, camouflage and their ability to survive on scare food resources. Those that depend more on grass seeds become nomadic as they have to follow the seeding season while the resident populations are more insectivorous (Kingdon, 1989).

Heteromirafra was originally considered to be the ancestral genus to other larks in the family. Species of this highly distinctive genus have a disjunct distribution in south-western and north-eastern Africa which they share with several other unrelated bird species (Cohen, 2011). Until very recently, the genus was thought to be comprised of three species: Rudd's Lark *H. ruddi* which occurs in South Africa, Archer's Lark *H. archeri* in north-western Somalia; and Liben (formerly Sidamo) Lark *H. sidamoensis* which was only known from southern Ethiopia. The ranges of *Heteromirafra* species are very small and fragmented which indicates that species within the genus may have had a much more widespread distribution (Spottiswoode et al., 2013).

The Rudd's Lark (*Heteromirafra ruddi*) is endemic to the highland grasslands of South Africa (Donald et al., 2010a). Archer's Lark (*Heteromirafra archeri*) which was first found in northwest Somalia, has not been seen in the wild since the 1920s and was presumed to be extinct. Within the last decade there were sightings of *Heteromirafra* larks about 50km south-west of the type locality near the town of Jijiga in Ethiopia, that were subsequently identified as being conspecific with Archer's Lark (Spottiswoode et al., 2013). Results of morphological, molecular and vocal data revealed that this population of *Heteromirafra* larks near Jijiga town was also conspecific to the Liben Lark and hence indicating that both the populations were in fact *Heteromirafra archeri*. The common English vernacular name has not been revised primarily to reflect the conservation status and plight of the Liben region (Spottiswoode et al., 2013). Species distribution models have revealed that an area east of Jijiga represents suitable habitat for occupancy of the species (Donald et al., 2010b). These two areas are currently the only known ranges of the Liben Lark (Fig 1.2).

The Liben Lark was first collected in 1968 by Christian Erard but was not formally described until 1975 (Erard, 1975). A second specimen was collected in 1974 but was not examined until 1978, by which time the species had already been described and named

Erard's Lark (Ash & Atkins, 2009). The type-specimen was collected from the grassland habitats of the Liben Plain, approximately 2 km east of the town of Negelle (Ash & Atkins, 2009). When first discovered, the Liben Lark's habitat was described as being found in tall grass, about waist height (Collar et al., 2008). The second specimen was collected in more open grassland with some *Acacia-Commiphora* bush (Vivero Pol, 2004). Some authors have suggested that the long hind claws of the Liben Lark is an indication of its adaptation to living in dense mats of tall grassland vegetation (Donald et al., 2010b). *Heteromirafra* species are morphologically different from other Larks in having long legs and neck and small, triangular-shaped heads (Donald et al., 2010a). The Liben Lark is short-billed with a long thin neck, relatively long legs with very long hind claws. The crown is finely streaked, with a creamy supercilium and pale buff hind crown and nape. The species has whitish underparts with small blackish streaks and buffy flanks (Redman et al., 2009; Sinclair & Ryan, 2010) and a scaly back with a short thin tail (Collar et al., 2008).

1.3.2. Behaviour and song

Liben Larks are terrestrial and very secretive (Collar et al., 2008) which makes detection during formal population surveys very difficult. They can move very quickly especially when they cross patches of bare ground (Abdu, 2012). On approach individual larks tend to run very quickly keeping hunched very low along the ground and continue out from view, rather than fly away (Redman et al., 2009; Collar et al., 2008; Spottiswoode, 2010). On occasion the species suddenly freezes on approach rather than fly away (Vivero Pol, 2004).

Liben Larks are known to sing during both the rainy and dry seasons of the year. Individuals which are thought to be males have a relatively short aerial song display during which they seem to be incapable of retracting their legs, which suggests that they may not be able to migrate or fly very far (Donald et al., 2010b). The Liben Lark tends to sing for longer periods in May, which is the main wet (rainy) season and one of the two breeding seasons for the species (Abdu, 2012). The display song consists of a series of continuous chirping whistles, undulating in pitch and delivered in a short (~20 secs) hovering display flight that that often stimulates other neighbouring males to display (Collar et al., 2008). Song duration varies from 3-47 seconds, with a mean of 11.6 seconds (Abdu, 2012) with individuals singing for longer periods during late afternoon (Abdu, 2012) and can often be heard from 300 to 400 m in good weather conditions (Collar et al., 2008). Displaying males usually fly directly upward to display up to a height of 10 m from the ground, whereby they then begin to glide or parachute slowly toward the ground whilst finishing their display song, landing close to where they had taken off to display (Collar et al., 2008; Redman et al., 2009). Some males have been also observed singing full songs and emitting other calls while on the ground (Collar et al., 2008).

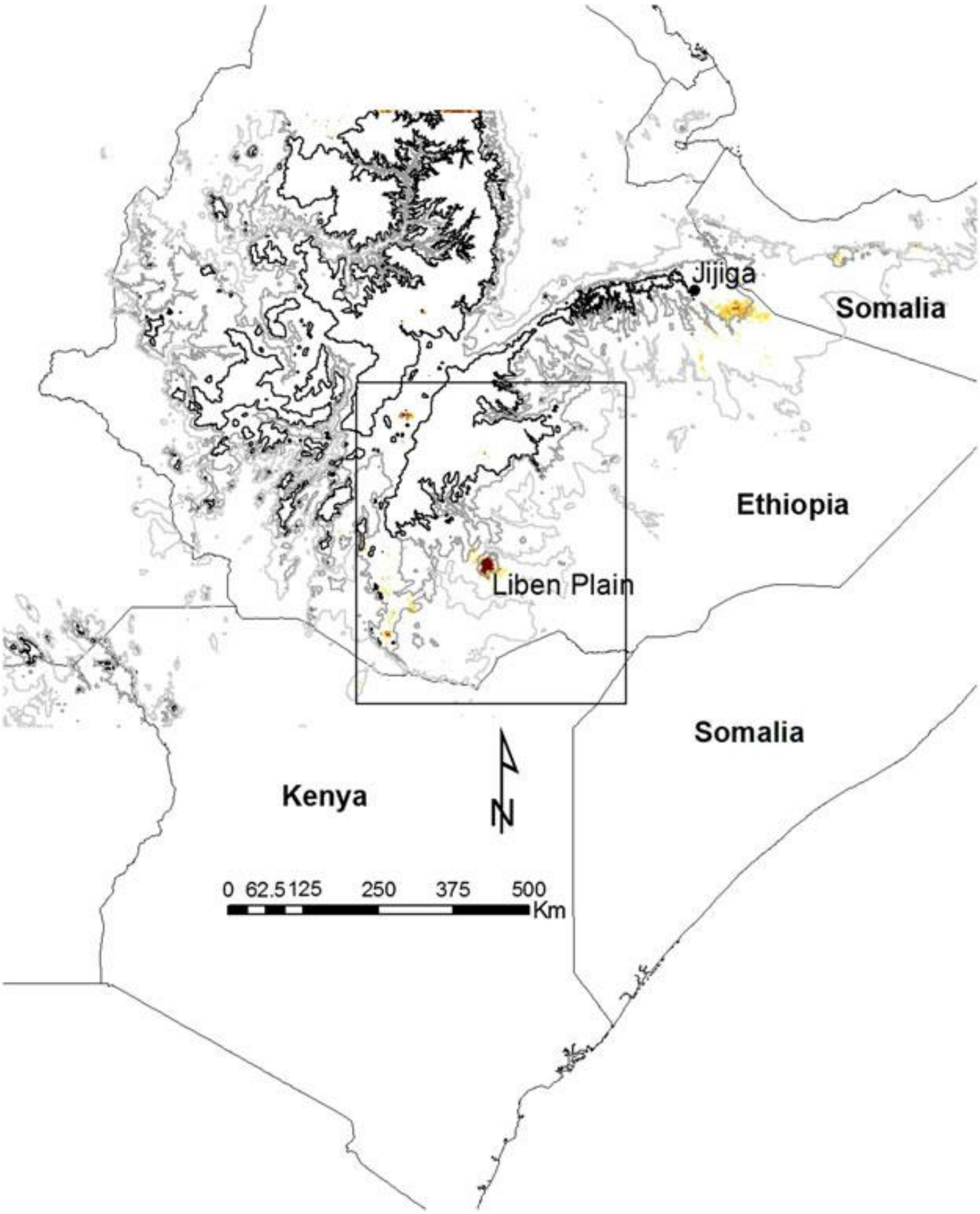

Figure 1.2 Distribution of potential Liben Lark habitat, based on NDVI and altitude using maximum entropy modelling. Darker browns indicate greater probability of habitat being suitable. The 1,000 m (light grey), 1,500 m (grey) and 2,000 m (dark grey) contours are shown, along with country borders. The box indicates the area over which the model was built (Source Donald et al., 2010b).

Liben Larks tend to feed by digging the ground with its bill or feeding on vegetation using quick pecks and gleans to feed on seeds and invertebrates such as small caterpillars and grasshoppers (Collar et al., 2008; Abdu, 2012). Liben Larks have also been seen chasing prey such as insects including small butterfly species (Abdu, 2012). Regarding its interaction with other bird species on the Liben Plain, the Liben Lark has been seen foraging in proximity to Somali Short-toed Lark and may be subordinate in interactions with other grassland generalist species including Plain-backed Pipit *Anthus leucophrys* and Isabelline Wheatear *Oenanthe isabellina*.

1.3.3. Habitat preferences of the Liben Lark

Identifying the habitat preferences of the Liben Lark has proven difficult in the few previous studies of the species. This is largely due to the species being very secretive and difficult to detect unless it is singing and displaying but also due to the fact that there may be so few individuals to detect. Evidence from observations made many decades ago suggested that areas of longer grass may have been important for the species (Collar et al., 2008). One recent modelling study revealed that males preferentially occurred in areas of grassland with greater cover of medium-height grass, some 5–15 cm in height, with less bare ground and fewer invasive bushes (Spottiswoode et al., 2009). Similarly in 2009, Liben Larks were associated with areas with greater than average grass cover and areas of taller grass. More importantly, the amount of bare ground and the number of invasive trees and bushes were significantly negatively correlated with lark presence (Donald et al., 2010b).

1.3.4. Nesting behaviour of Liben Lark

The first nest was found in June 2007 by a group of researchers from the Ethiopian Wildlife and Natural History Society (Birdlife partner in Ethiopia) and BirdLife International. The nest was woven by grass and placed under a small shrub (*Solanum tettense*) which had three whitish eggs that were brown-flecked. A second nest was found in June 2008 which contained three chicks (Collar et al., 2008). The two nests found were under isolated plant cover that was quite conspicuous in the midst of the degraded grasslands, thus was potentially much more exposed to predation risk, which was ultimately the cause of the failure of these nests (Donald et al., 2010b). Two other nests have been found, one in November 2012 which contained three young birds and another in November 2013 which also contained three young. During limited observations, the young birds in the nest were fed invertebrate prey by both parents (Collar, Donald and Lloyd *personal observation*). Both of these nests were located in very short, disturbed grass habitat. This suggests that the Liben Lark may have two 'peaks' in breeding each year – one during June and another in November each year. These periods follow the onset of the rains and that as grassland habitat quality continues to be eroded, thus Liben Larks are forced to nest in poorer and poorer quality habitat, which carries additional risks from increased rates of predation and trampling by cattle and other livestock.

Observations have recorded very few females compared to the number of males, whilst also taking into consideration that all the displaying individuals may have been males. Less than ten females were observed from 2007-2011 (Donald et al., 2010b; Abdu, 2012). Studies have shown sex ratio skewness to be a common phenomenon in wild bird populations with very small population sizes. Globally threatened species in particular have been found to have a heavily skewed population toward one sex, usually males (Donald, 2007). This suggests that their extinction risk is even higher and their reproductive potential lower than previously thought (Donald, 2007).

1.3.5. Threats and the conservation status of the Liben Lark

Not much was known about the status of the Liben Lark thus it was assigned in the category Indeterminate in 1985 based on John Ash's report in 1974 indicating the availability of sufficient good habitat for the species within its known range. In 1989, Ash observed that the habitat of the Lark was being impacted by increased human disturbance, which led to the species being listed as Endangered in 1994 (Collar, 1997). In 2000, the species conservation status was down-listed to Vulnerable, before being upgraded back to Endangered in 2007, and finally listed as Critically Endangered in 2009 following surveys conducted since 2007. The Liben Lark was placed in this category as it has an extremely small range which is decreasing and is confined to a single location (Spottiswoode et al., 2009).

The Liben Plains have lost huge areas of grassland habitat due to illegal conversion to cereal crops and increased grazing pressure (Spottiswoode et al., 2009; Donald et al., 2010b). The reduction in the amount of suitable breeding habitat for grassland birds and an increase in the abundance of more invasive generalist bird species across the Liben Plain have coincided with a dramatic population decline and range contraction for the Liben Lark (Donald et al., 2010b). Between 2007 and 2009 there was a significant decline in grass vegetation cover and height and bare ground cover increased more in areas where the species was recorded in 2007 suggesting a rapid degradation of the sites containing the best quality grassland habitat. There was also a loss of approximately 8% of good habitat to cereal crop agriculture between 2007 and 2009. Invasive fennel plants also increased in abundance (Donald et al., 2010b) across the plain. These changes were correlated with a 40% decline in the number of Liben larks recorded along survey transects (Donald et al., 2010b). The global range of the Liben Lark was previously estimated to be 760 km^2 but surveys in 2007 and 2008 have revealed that available habitat is less than 35 km^2, representing a dramatic reduction in suitable habitat (Spottiswoode et al., 2009), and a contraction of 38% of the area occupied by the species across the Liben Plain (Donald et al., 2010b).

The species global population was initially estimated to be around 2,000 individuals but following surveys in 2007-2008, the global population was empirically estimated to range from 90-256 individuals, with a possibly male biased ratio (Spottiswoode et al 2009). Now listed as Critically Endangered (BirdLife International, 2014), the Liben Lark currently occupies an extremely small range, and currently represents Africa's most threatened bird species, and is threatened with extinction in perhaps the next decade (Spottiswoode et al., 2009). The only way forward towards conserving the Liben Lark is to work closely with local Borana people to improve the quantity and quality of grassland habitat by reducing grazing pressure, agricultural expansion and scrub encroachment. The first step towards the conservation management of the plain is to gather ecological and socio-economic data to underpin future conservation management of the Liben Plain.

1.4. Overall Aim of the PhD and objectives of chapter

1.4.1. Academic Aim

The overall aim of the PhD is to produce an evidence-based conservation strategy, to find ways in which the plain can be managed in order to serve the dual purposes of reducing the extinction risk faced by Liben Lark primarily by increasing its population and area of occupancy while at the same time, managing the impacts on the livestock production and livelihoods of the Borana pastoralists who live on the plain.

1.4.2. Objectives

(1) To estimate the amount of grassland habitat remaining within the Liben Plain, identify areas of grassland converted to cereal crop farming, and quantify how such patterns of land-use change have varied in recent decades

(2) To estimate the distribution and density of the Liben Lark across the Liben Plain and determine how these have changed in recent years, related to temporal changes in land-use patterns.

(3) To determine the grassland structural characteristics that influence the abundance of the Liben Lark in areas of traditionally *Gadda* managed rangeland habitat or whether the species is tolerant of other habitats created through non-traditional agricultural land-use practices e.g. cereal crops.
(4) To understand the major institutions and forms of governance responsible for land management and decision-making regarding the Liben grasslands and livestock.
(5) To determine whether the use of a novel biological control measure can influence the survival rate of artificial lark nests from livestock trampling, and make some inferences as to how best to increase the reproductive capacity of Liben Lark.

1.4.3. Scope of analysis chapters

Chapter 2: Patterns of grassland habitat change across the Liben Plain

This chapter will describe and quantify the land use changes on the Liben Plain focussing around the core habitat of the Liben Lark. Several LandSat images will be used to quantify the extent of grassland habitat loss due to crop expansion in the area. The changes in grassland will also be examined by looking at NDVI values.

Chapter 3: Estimating the distribution, abundance and population size of Liben Lark

Population density of the Liben Lark was estimated using Program DISTANCE by examining the distribution and abundance of the species across the Liben Plain. Distinctive distributional patterns of density were examined by hotspots using Kernel Density Estimation.

Chapter 4: Temporal habitat associations of the Liben Lark

In this chapter I will characterise the grassland habitat using structural habitat variables recorded from survey transects and how these have varied over the years. Logistic regression analysis will be used to relate the presence/absence of Liben Lark to the measured habitat characteristics.

Chapter 5: Institutions and governance of the natural resources of the Liben Plain

There are gaps in knowledge in terms of institutions involved in land allocation and grazing management on the Liben Plain. New and existing data will be used to document the current and historic grazing systems by the Borana, perspectives on land use changes and how the different institutions responsible for the management of the rangelands interact. This understanding will help to make recommendations for well-coordinated and sustainable land use strategies both for the pastoralists as well as for the Liben Lark.

Chapter 6: Survival rates of artificial lark nests across the Liben Plain

In this chapter I will determine how best to increase the amount of breeding habitat and reproductive capacity of the Liben Lark through the use of artificial nest experiments and the use of a novel biological control measure (hyena dung) to prevent over-grazing/approach by livestock. Using artificial nests, I will first determine whether artificial nest survival is influenced by proximity to farmland or invasive scrub. Secondly, I will determine whether artificial nest survival is influenced by grassland vegetation structure by using hyena dung placed adjacent to nests to prevent overgrazing by livestock and also placing artificial nests in fenced enclosures, one newly created and one pre-existing enclosure with taller, regenerating grassland.

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Chapter Two

PATTERNS OF GRASSLAND HABITAT CHANGE ACROSS THE LIBEN PLAIN

2.1. Abstract

It is essential to quantify current land use practices within an area of interest in order to be able to make effective decisions on land utilization and biodiversity conservation. In this chapter, I use Geographical Information Systems (GIS) tools to assess changes in the extent of habitats across the Liben Plains grassland, Ethiopia. I used LandSat images to quantify the extent of grassland habitat loss and crop expansion from 1994-1995, and 2000-2105. Within the 399.3 km^2 selected study area of the Liben Plain, grassland habitat declined to 306 km^2 from 1994 to 2015. Concurrent with the reduction in grassland area has been the increase in land used for cereal crop production. Over the same period of time, 93 km^2 (just under 25%) of grassland was lost to crop cultivation without taking into account the extent of land taken over by bush encroachment and increased areas for settlement. Conversion to cereal crop cultivation occurred on both black soil and red soil grasslands, with a peak in the amount of black soils cultivated around 2008. Almost no areas of red soil grasslands (historically viewed as poorer quality soils) were cultivated until 2007 when there was a dramatic increase in their cultivation, which continued until 2015. A number of additional land use areas and habitats were distinguishable, which corresponded to areas encroached by invasive scrub, settlements, and regular paths used by residents and their livestock. Normalized Difference Vegetation Index (NDVI) analyses across four years (1998, 2003, 2008 and 2013) revealed pronounced seasonal patterns, with mean NDVI values peaking during both rainy seasons (May/June and November), and declining during the dry season months, mirroring regional rainfall patterns and revealing how dependent both grassland vegetation and crop cycles are on the biannual rainy seasons of the Liben Plain. Within the core area of the Liben Plain occupied by the Liben Lark, the majority of grassland has been converted to cereal crops. Grassland now covers just 23.76 km^2 of this core area, corresponding to remnant patches that range in size from 0.58 km^2 to 2.83 km^2. These patches and the immediate surrounding areas should be the focus of conservation efforts aimed at restoring the grassland vegetation.

2.2. Introduction

In order to be able to make decisions about effective land utilization, it is crucial that governments know the current land use of their countries. In recent times, the availability of satellite imagery, aerial photographs and various analytical tools have made this task much easier for land managers as well as for land conservationists. In particular, Geographical Information Systems (GIS) are becoming crucial for spatial analysis and, consequently, decision making (Foote & Lynche, 1996). GIS has facilitated the study of land use and land cover data to help determine the extent of various habitats and land use types (e.g. Schaich et al., 2015). Different soil mapping techniques can be used to identify potential areas for crop cultivation (Saleh et al., 2015) or to quantify the effects of certain soil types on crop productivity (e.g. Akinbile et al., 2015; Kumar et al., 2014). Satellite images can be combined with ground-truthed data to help land managers identify the type of crops planted in an area or identify gradual changes in the extent of the different types of crops (e.g. Zhong et al., 2015). GIS has also facilitated the study of habitat fragmentation and abandonment of farmlands over temporal scales to identify the drivers of these changes (e.g. Cheng et al., 2015; Bajocco et al., 2016) and for mapping risks that can lead to agricultural losses (e.g. Baizen & Sterk 2013; Kotikot & Onywere, 2015).

The continual increase in human population has driven up the demand for food production and this has resulted in the conversion of native habitats into vast areas of land for crop cultivation, especially in the tropics (Borras et al., 2011; Rulli et al., 2012). Due to the expansion of agriculture such as cattle grazing and cereal crop production, several ecosystems are becoming severely threatened (Phalan et al., 2013), particularly grassland ecosystems (Bakker & Berendse, 1999; Walker et al., 2004; Azpiroz et al., 2012; Bleho et al., 2014). An additional concern is that for many grassland ecosystems even areas that have historically been viewed as being very poor for agricultural land uses, such as cereal crop farming, are being converted to farmland as the situation faced by many rural poor becomes increasingly desperate. This further exacerbates the loss, fragmentation and degradation of the grassland ecosystem, and places a greater pressure on the populations of grassland-dependent species that remain, many of which experience further declines in their populations (Sauer & Link, 2011). Thus it is becoming increasingly important to use spatial data tools to examine changes in agricultural land-use and to quantify the ongoing conversion of native grassland habitats, including areas where poor soils (marginal habitats) are being converted to crop production, in order the determine what the implications could be for the many unique grassland-dependent species that are globally threatened (Vickery et al., 2000; Donald et al., 2006).

There has been severe anthropogenic pressure on the rangelands in Ethiopia due to the increasing numbers of cattle and human inhabitants (Homann, 2004). Many grasslands are used as pastures or rangelands for livestock production (see Chapter One) and thus hold a central role in the rural economy. Many of these grasslands also support unique grassland-dependent bird species, some of which are now undergoing severe population declines (Sauer & Link, 2011), primarily from habitat loss and degradation caused by the intensification of livestock grazing and the spread of cereal crop production (e.g. Bakker & Berendse, 1999; Walker et al., 2004). In southern Ethiopia, the Liben Plain represents one of the most threatened rangeland habitats and there are fears that it can no longer support populations of its unique grassland-dependent species, notably the critically endangered Liben Lark, or even the pastoralist livelihoods of the Borana people (Spottiswoode et al., 2009; Bennett et al., *in revision*). An increasing proportion of the rural Borana population (approximately 11%) are turning to crop cultivation, which reduces grassland area and is an unsustainable short-term strategy, due to poor quality soils and limited water (see Chapter One). Unpublished reports also reveal that even areas of the Liben Plain previously believed to be unsuitable for cereal crop farming are currently being converted for crop production (see Chapter One). This will probably lead to further degradation of the remaining area of grasslands. Consequently, this could well have knock-on effects for the Boran cattle productivity and thus, impact livelihoods for Borana pastoralists (Coppock, 1994; Oba, 1998; Bennett et al., *in revision*).

The type and extent of land use change and degradation on natural grassland habitats across the Liben Plain could be better understood, quantified and monitored using GIS tools to evaluate land-use changes from satellite imagery. This type of approach is essential to assist in decision making for the conservation and restoration of these habitats and the species dependent on them (Coppedge et al., 2001). Quantifying landscape changes can also help predict the effects of continued habitat loss and fragmentation on grassland bird species and help establish future monitoring programmes or even monitor the efficiency of conservation actions such as restoration activities and prescribed burning (Malmstorm et al., 2009).

One of the most widely used environmental indicators that is highly correlated to photosynthetic activity is the Normalized Difference Vegetation Index (NDVI) (Pettorelli et al., 2005). Different land cover classes such as grasslands, forests, waterbodies and barren land are quite different in the NDVI values that they display. The NDVI values of different habitats vary across the months of the year, revealing for example the most productive times for different types of crops (Zhong et al., 2015). The NDVI is mostly used for global vegetation monitoring as it helps to compensate for changing illumination conditions, surface slope, aspect and other factors (Lillesand, 2004). NDVI time series are thus a very powerful tool to help quantify the changes in vegetation cover (Levin, 2015). The NDVI values can also help to differentiate grasslands with higher and lower areas of productivity and thus help determine the extent of habitat available for certain species that prefer a particular extent or type of grassland.

The overall aim of this chapter is to describe and quantify the land use changes on the Liben Plain during recent decades. In order to do this I will be using different LandSat images to quantify the extent of grassland habitat loss and crop expansion in the area, which started to become visible in the mid-1990s. The change in grassland vegetation will also be examined by comparing NDVI values over the same time-scale. This will enable identification of the rate and pattern of deterioration of the grasslands.

2.3. Methods

2.3.1. Study Site

The Liben Plain is an extensive area of open, relatively level grassland that stretches east and south of Negelle town in southern Ethiopia, located at 05°15'N and 39°41'E. Negelle is 585 km south of Addis Ababa (EWNHS 1996). The plain is located in four Peasant Associations (PAs) of the Liben District. The Liben District is placed under the Guji Zone of the Oromia Region as shown in Fig 1.1 (see Chapter One). The Liben Plain has two rainy seasons: the main rainy season is between March and May, with the short rainy season occurring between September and November. Annual rainfall of the area is around 700 mm (EWNHS 1996). The average monthly temperature of the area is around 20°C with the maximum average temperature of 30.3°C recorded in February and the minimum average temperature of 14.7°C in July (National Meteorological Service Agency, 2014).

The Liben Plain is formed over an area of bedrock between the Genale and Dawa rivers, with Genale occurring at the Plain's eastern boundary and Dawa at its southern boundary. Except for some artificial ponds, there are no significant waterbodies in this area. Elevation varies from 1,000m at the edge of the Genale River gorge, to over 2,000m. Soils in the rangelands of East Africa are regarded as having low fertility mainly due to the old age of the component parent material. The main soil types found in the Borana rangelands consist of 53% red sandy loam soil (hereafter referred to as 'red soils'), and 30% black clay and volcanic light-coloured silty clay with 17% silt and vertisols (hereafter referred to as 'black soils') (Coppock, 1994). Historically, the red soils have never been farmed and are widely believed to be very poor for cereal crop farming, with black soils being the preferred areas for farming.

The Liben Plain is surrounded by dense *Acacia–Commiphora* thicket, and to the north-west intensive cultivation is practiced (Spottiswoode et al., 2009). Several plots of farmed areas occur in the area (e.g. maize, barley and beans). According to the inhabitants, the croplands have been expanding especially during the last 20 years. Some of the dominant grass species in the Liben District include Buffel Grass *Cenchrus ciliaris*, Bermuda Grass *Cynodon dactylon*, Switch Grass *Panicum spp*., and Love Grass *Eragrostis spp*. (Sherkite, 2006). Grass sward is typically 10 cm high (Spottiswoode et al., 2009), with shrubs like Whistling Thorn *Acacia drepanolobium* and *Solanum tettense* (Tefera et al., 2007). Several stands of Giant Fennel *Ferula communis* which are indicators of heavily grazed areas (Puff & Nemomissa, 2005) are also present. A high density of circular bare patches of ground created by Harvester Ants *Messor cephalotes* also occur on the plain (Spottiswoode et al., 2009).

The study site represents part of the Liben Plain, located in the Siminto and Meisa PAs of the Liben District, centred on a relatively flat area at 1,500-1,550m, 10-40 km south-east of Negelle town (EWNHS 1996). The site is traversed by the Negelle to Filtu road on the south-east, and a track to Arero on the south-west. At the junction of these two roads, there is a military base. Meisa PA is the area located to the north of the main road from Negelle to Filtu, while Siminto PA is found to the south of the road (Fig. 2.1). For this study, a rectangular area of 399.30 km^2 that corresponds to the known area inhabited by the remnant Liben Lark population was selected for analysis. The extent of black soil grassland, which covers an area of 103 km^2 is shown in Fig 2.1 and occurs from the Meisa PA and continues across a narrow band before reaching the main road where there is a waterhole called Fullo. The black soil grassland area continues into the Siminto PA with a wider base after an interruption by red soil for about one kilometre. The rest of the selected area corresponds to 296.30 km^2 of red soil grassland. In the eastern part, the study site is dominated by trees and scrubs. There are also two community enclosure (*kallos*) to the east, built on either side of the main road to serve as dry season forage reserves for near-by inhabitants of the Siminto and Meisa PAs.

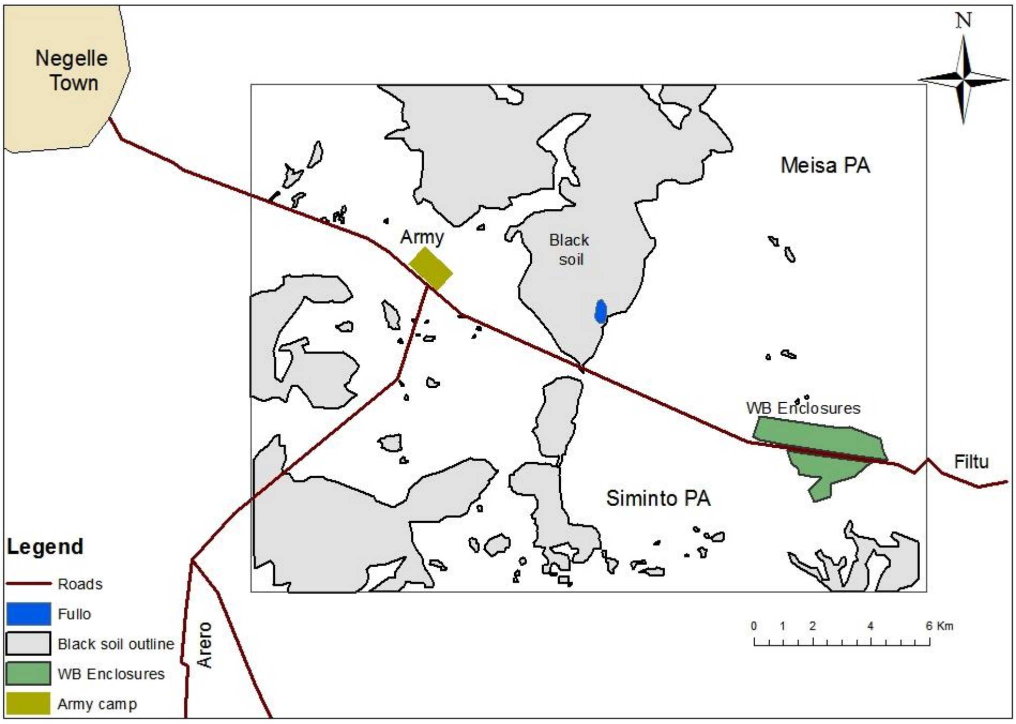

Figure 2.1 Map of the study site in reference to Negelle town and the main road to Filtu separating Meisa and Siminto PA. The area of analysis is shown in the inner rectangle with black soil extent in grey, red soil extent in white, Fullo waterhole, military base and the World Bank enclosures.

2.3.2. Data analysis

A total of 39 freely available satellite images of the study area were downloaded from the Global Visualization Viewer (GLOVIS) website. Images with less than 20% cloud cover were selected. Only ten images were downloaded from 1972 to 1995 due to availability. It was not possible to attain good LandSat images from 1995 – 2000 which led to a gap in the data analysis. From 2000 onwards it was possible to obtain one image per year and at least two images per year from 2007 to 2015. The images were transferred to ArcGIS Desktop version 10.2, to be stacked and clipped to the area of interest. In order to get a clearer picture of the different habitats on the images, I used band combinations that can easily help to differentiate croplands. A rectangular area was then marked on the map in order to digitize the cropping on the black and red soil grassland areas. Cultivation became visible on the images from 1994 onwards, thus one image per year was used from 2000 onwards as well as 1994 and 1995 images. Shape files were drawn manually and by eye around the cropped areas in the red and black soil separately for each year. The total area of the shape files for each year was then calculated in ArcMap using an equal area projection.

2.3.3. NDVI analysis

NDVI data were downloaded from the SPOT-VGT website in the form of 1km x 1km raster cells of the free 10-day synthesis or S10 products. The middle ten-day period or decad of all the months of the years 1998, 2003, 2008 and 2013 were used for the analyses on the grassland areas. These years were selected as five-year gaps to show the changes in NDVI and as the earliest year for the free data availability was 1998. VGT Extract was used to cut out the NDVI data corresponding to the study area of the Liben Plain. The NDVI data of all the years was then exported to ArcGIS. A total of 44 point shape files were placed in each 1km x 1km NDVI raster cells corresponding to the present grassland areas in the study site. The mean raster values of each 1km by 1km cell were then extracted to these points using the tool 'extract values to point' in ArcGIS. The values of each point for each month were then tabulated in ArcGIS and later exported to Microsoft Excel for analysis. The same S10 products were also used for cropland areas for the middle decad of all the months of the year 2013. A total of 39 point shape files were placed in the 1km x 1km NDVI raster cells corresponding to the currently cropped areas. These data were used to compare the NDVI values observed in grassland and cropland areas.

2.4. Results

2.4.1. General patterns of habitat loss and crop expansion across Liben Plain

Within the selected study area of the Liben Plain (399.30 km^2), the total area of grassland amounted to 396 km^2 in the year 1994 (Fig. 2.2), together with some areas of settlement, water ponds and other areas not used for cultivation that year. Since 2000, there has been an ongoing decline in the amount of grassland habitat. By 2001, the area of grassland had decreased in size to 390 km^2. From this period further declines were evident. In 2002, 383 km^2 of the area was considered grassland habitat, which largely remained unchanged until 2007, after which there was a decrease in the area of grassland, which continued to decline to 319 km^2 in 2013.

The area of grassland was further reduced to 306 km^2 in the year 2015 (Fig. 2.2). Thus since 1994 a total of 93 km^2 (just under 25%) of grassland was lost to crop cultivation without taking into account the extent of land taken over by bush encroachment and increased areas for settlement (see section 2.4.4). Concurrent with the reduction in grassland area has been the increase in land used for cereal crop production (Fig. 2.2). Over the same period of time, the increasing trend in land used for cereal crop production is almost a mirror reflection to the loss of grassland habitat, approaching 100 km^2 in total area (Fig. 2.2).

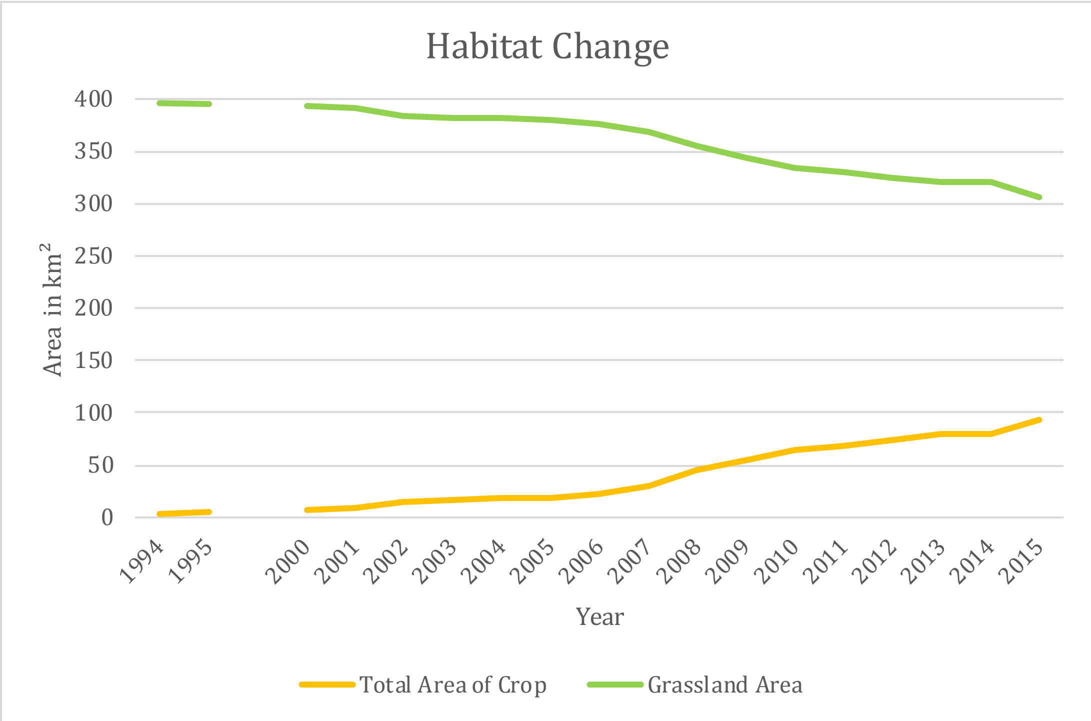

Figure 2.2 Change in areas of grassland and areas farmed for cereal crops across the Liben Plain from 1994-1995, and to 2000-2015

The trends for areas of black and red soils farmed for cereal crops also follow a similar trend to that of the total area of grassland converted to cereal crops (Fig. 2.3). The amount of black soils cultivated increased from 2000 and reached a peak around 2008. Between 2009 and 2013 there was a much lower increase in areas of farmed land on black soils followed by another peak between 2014 and 2015. In comparison, almost no areas of red soil grasslands were used for cereal crops until 2006, followed by a dramatic increase in the area of red soil grasslands cultivated for crops in 2007 (Fig. 2.3). Cropping on red soils increased dramatically from 2008 until 2015. Between 2009 and 2013 the rate and amount of red soils converted for crops was greater than that on black soils (Fig. 2.3).

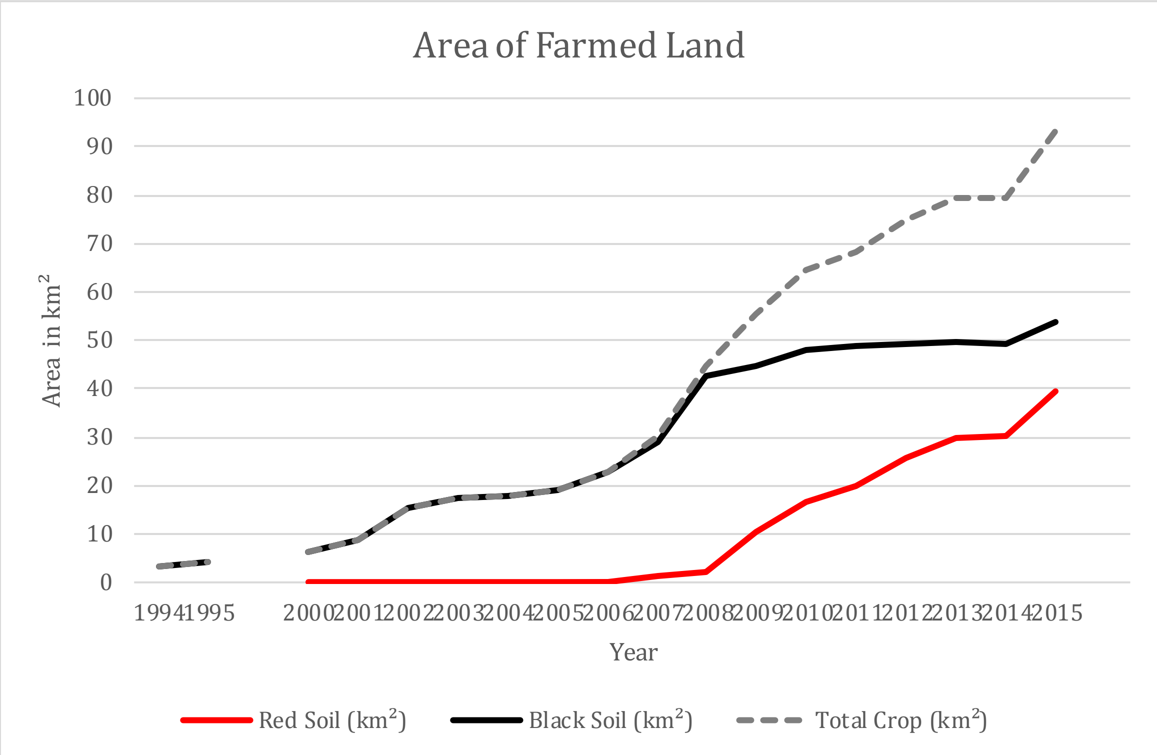

Figure 2.3 Amount of grassland on black soils, red soils and both soil types combined across the Liben Plain converted to arable cultivation from 1994-1995, and 2000-2015.

2.4.2. Detailed annual changes in grassland habitat and crop farming

In 1994, crops were clearly visible from the LandSat images, with cropped land appearing only on areas of black soil (see Appendix). All cropping was concentrated in a few areas in the northern part of the plain in the Meisa PA. In the southern Siminto PA, areas of crops were more diffuse. To the south of the main road and to Fullo, crop farming was confined to the edges of a region of black soil close to the road. The total area of black soil farmed during this year was 3.28 km^2. In 1995, 4.41 km^2 was cultivated for crop production (Fig. 2.4). During that year most of the crops were still located on black soil with increased crop cultivation seen mostly on the southern part of the plain, particularly towards the centre of the Siminto PA.

In 2000 the areas farmed for crops on black soil had increased to 6.28 km^2 (Fig. 2.5). In the Siminto PA, the area of crops spread from the centre of the PA more broadly to the north. In Meisa PA, the spread and increase of farmed land for crops on the black soils is more concentrated to a narrower section in comparison to the spread which occurred in Siminto PA. There was also an area of red soil corresponding to 0.05 km^2 converted to crops.

This was located at the narrower end of the black soil in the Meisa PA, very close to the main road and to the west of Fullo. A similar pattern was observed in 2001 (see Appendix) with some expansion of crop areas detected in both PAs. A total of 8.78 km^2 was farmed in the black soil, with the area of red soil grassland converted to crops remaining the same as the previous year.

By 2002, the area farmed for crops had reached 15.34 km^2. The expansion of crop cultivation was more pronounced in the narrower sections of black soil in both the southern and northern part of the main road. In 2003, crop cultivation had further expanded on the south-western part of the plain in the Siminto PA, especially at the narrower section of black soil, totaling 17.25 km^2 (see Appendix). During 2002 and 2003, the area of crops on red soil again did not show any noticeable increase from the previous years, but a further increase in crop cultivation on black soil occurred in 2005, amounting to a total of 18.99 km^2 (Fig. 2.6). The expansion was evident across all parts of the plain, with more changes detected in the south-western and northern part. In 2006, crop cultivation had spread across almost all parts of the black soil, corresponding to 22.73 km^2. There was a slight increase in red soil crop cultivation on the Meisa side located to the west of the black soil farms that surround Fullo, corresponding to 0.06 km^2. In 2007, crops had expanded to 28.96 km^2 on black soil (Fig. 2.7), with new plots of farms being distributed across all areas of black soil. New areas of cultivated land were also detected on red soils, to the west of the black soils near Fullo as well as to the north of the Army camp (located at the junction of the road going from Negelle to Yabello). A total of 30.12 km^2 of land was cultivated for crops for this year on both soils.

In 2008, most of the grassland on black soil had been converted to crops, corresponding to an area of 42.60 km^2. The rest of the areas with black soil were covered by settlements or set aside for traditional ceremonies of the Gadda system. The areas for crops to the south of the main road were more scattered compared to those found to the north of the road. The total amount of red soil farmed in 2008 was 2.19 km^2, all located in the north-western part of the study site. The majority of the cultivated land was located north of the main road, making the total area of farmed land 44.79 km^2. In 2009, crop cultivation on black soils had expanded a little, and the total area now covered 44.84 km^2. The farms on the red soil showed a dramatic increase to 10.58 km^2. These new areas were to the west of Fullo and surrounding the Army camp on the north side of the main road. New areas of crop cultivation in Siminto PA had also expanded to the east of the black soil to the south of Fullo.

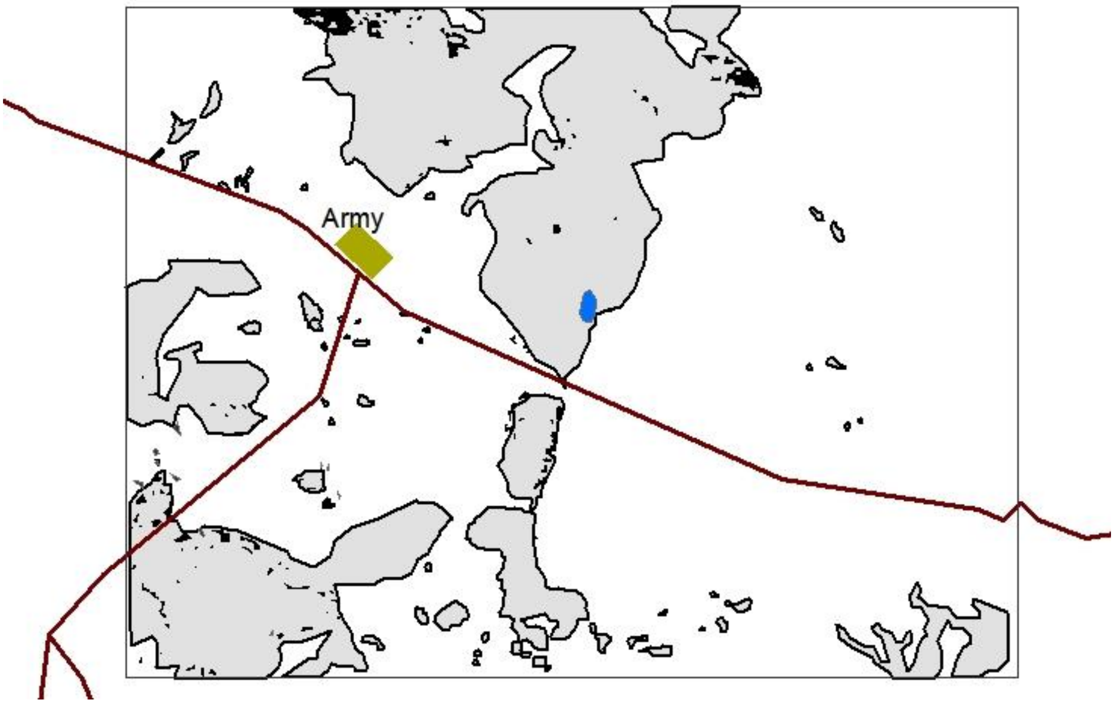

Figure 2.4 Map of the study site showing the amount of grassland converted to cereal crop farming on black soil (black shape files) in 1995.

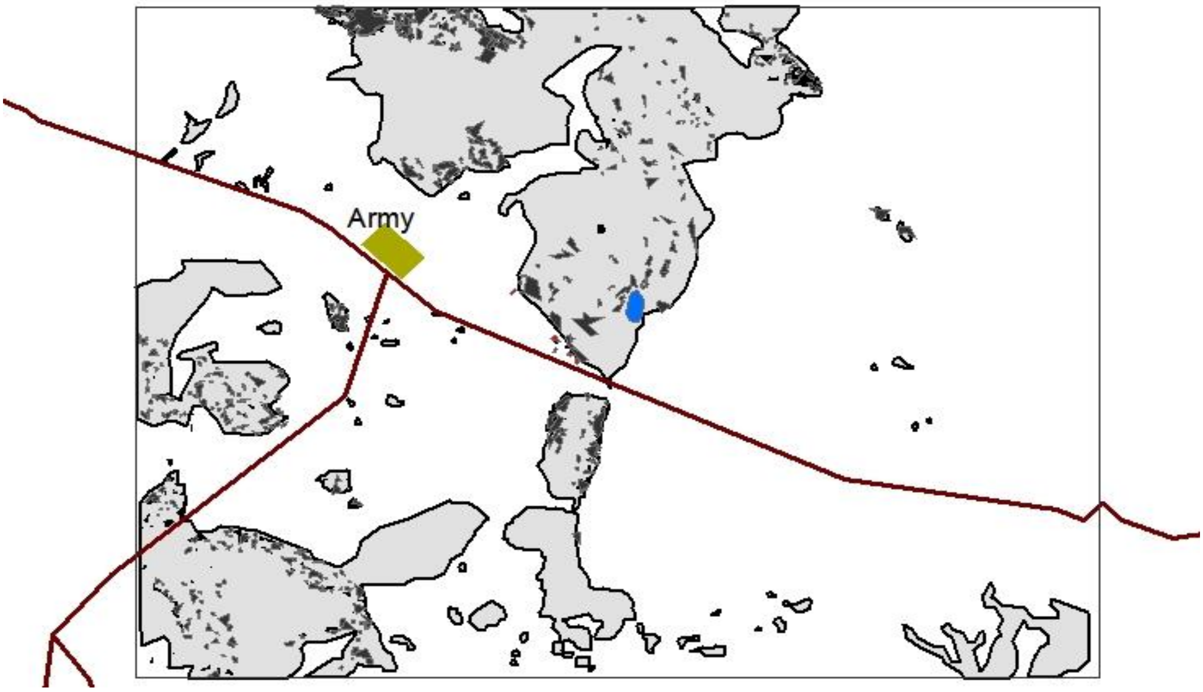

Figure 2.5 Map of the study site showing the amount of grassland converted to cereal crop farming on black soil (black shape files) and on red soil shown (red shape files) in 2000.

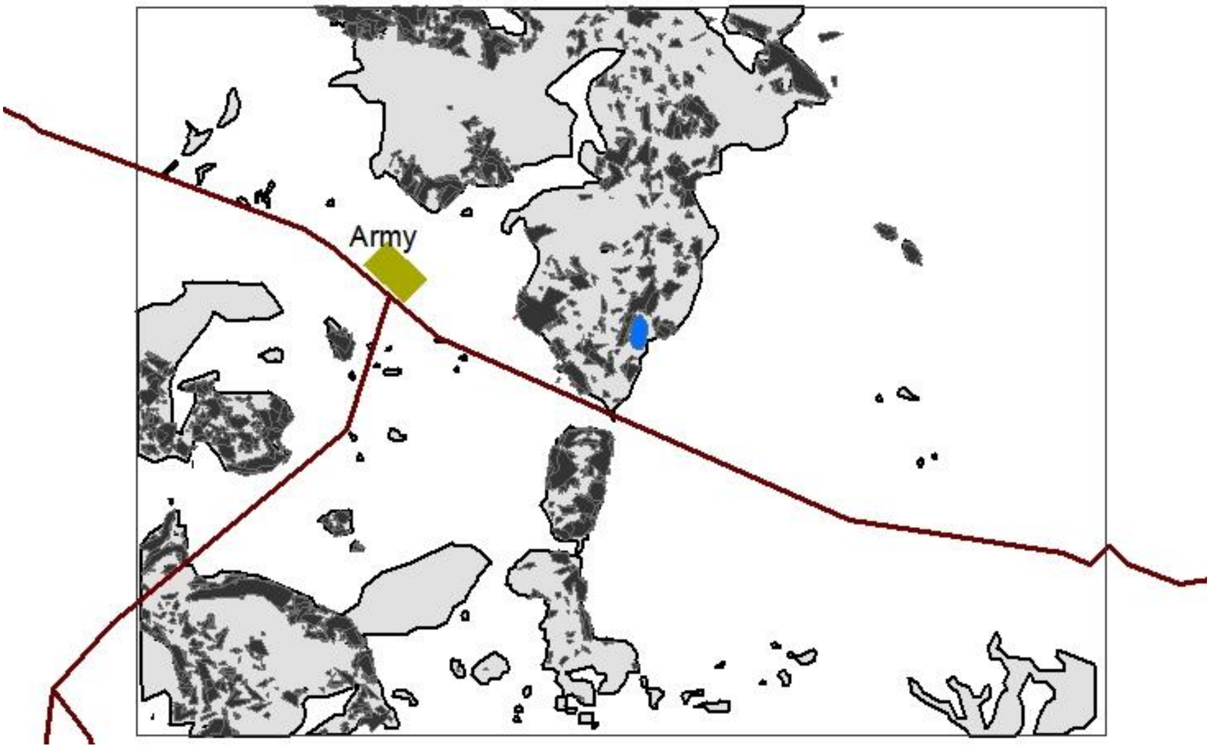

Figure 2.6 Map of the study site showing the amount of grassland converted to cereal crop farming on black soil (black shape files) and on red soil shown (red shape files) in 2005.

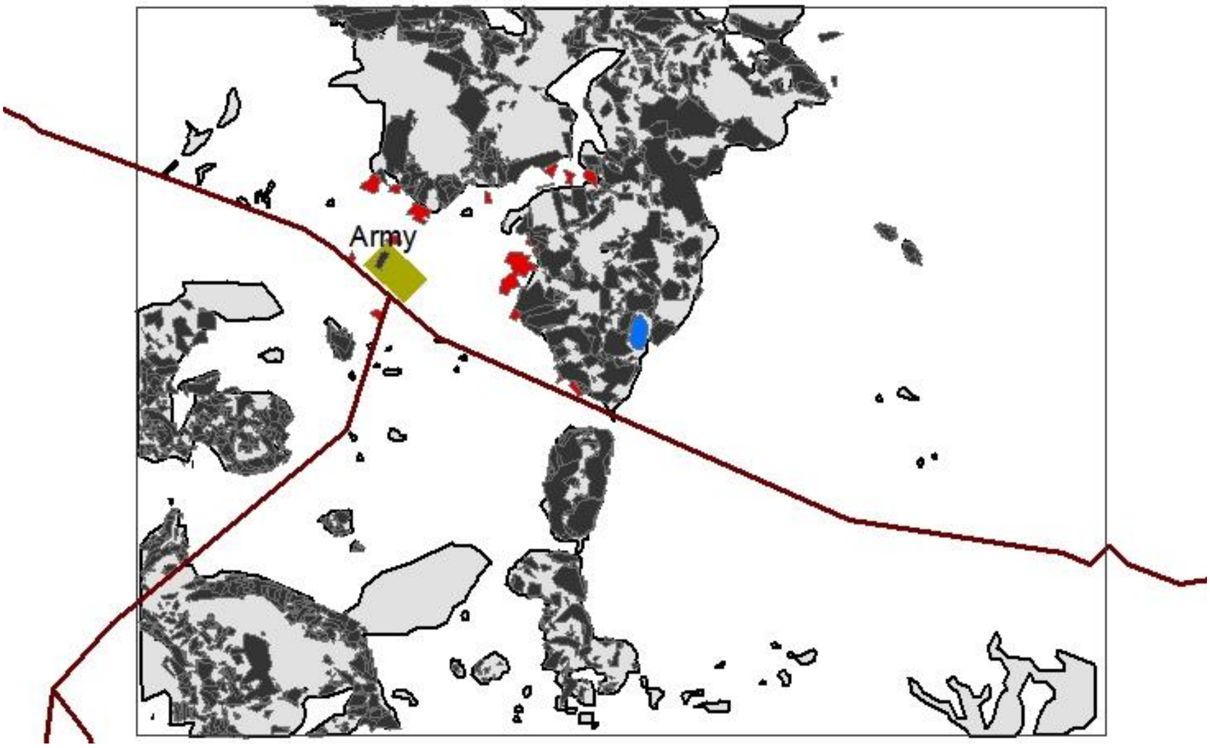

Figure 2.7 Map of the study site showing the amount of grassland converted to cereal crop farming on black soil (black shape files) and on red soil shown (red shape files) in 2007.

Further increases in red soil crop cultivation were evident in 2010 (Fig. 2.8), when there was expansion to the west of Fullo and extending to the west to the north of the main road. On the Siminto side, crop cultivation had expanded near the north-west and eastern part of the plain, with only a few new areas evident on the southern part of the plain. A total area of 16.72 km^2 was farmed on red soil during this time, with no change in crop cultivation on black soils from the previous year. In 2011 there were further increases in crop cultivation on red soils, but not on black soils. With an area corresponding to 19.81 km^2, red soil crop cultivation expanded on the western part of the Meisa PA to the north of the main road, and on the western part of Siminto close to existing crop fields. There were also increases in farms near the plots in the eastern and southern part of Siminto. Crop cultivation on black soils appears to have become saturated by 2012 (See Appendix). Cultivation on red soil areas had further expanded on the western part of Meisa as well as the eastern, southern and western part of Siminto PA. A total area of 25.81 km^2 was cultivated for crops on red soil by this year. By 2013 crop cultivation on red soil had expanded to 29.76 km^2 to areas near all existing farms, with more expansion seen in the south-western part of the plain while the area cultivated for crops on black soil remained the same.

By 2014 the total area of the plain cultivated for crops was 79.37 km^2, wherein 30.29 km^2 of red soil grassland was converted to cropland. The majority of land used for cultivation on red soil was concentrated on the north-western part of the plain, with crops located south of the main road positioned very close to black soil crop fields. Areas of red soil cultivated crops were not seen in the north of the main road to the east of the waterhole. However, areas cultivated for crops on black soil totaled 49.08 km^2 and remained concentrated on the northern part of the plain. By the year 2014, there were also considerable areas cultivated for crops located south of the main road. The only remaining un-cropped section of the black soil was located in the south-eastern part of the study area. This area is called Dalle-Malle and is considered to be sacred ground by the Borana pastoralists. In 2015, there have been further areas of grassland on red soils that were cultivated for crops in the Siminto PA, particularly in the south-western and eastern part of the plain (Fig. 2.9). Overall, 39.47 km^2 of red soil grassland and 53.79 km^2 of black soil grassland of the Liben Plain had been converted to crops by 2015.

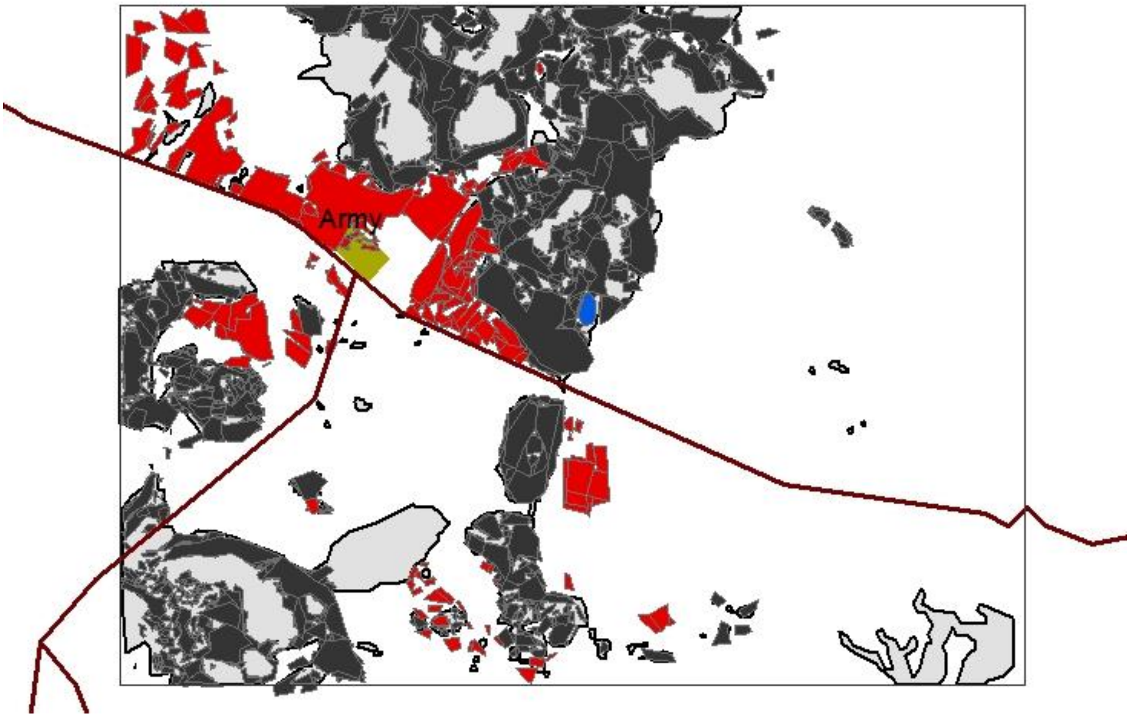

Figure 2.8 Map of the study site showing the amount of grassland converted to cereal crop farming on black soil (black shape files) and on red soil shown (red shape files) in 2010.

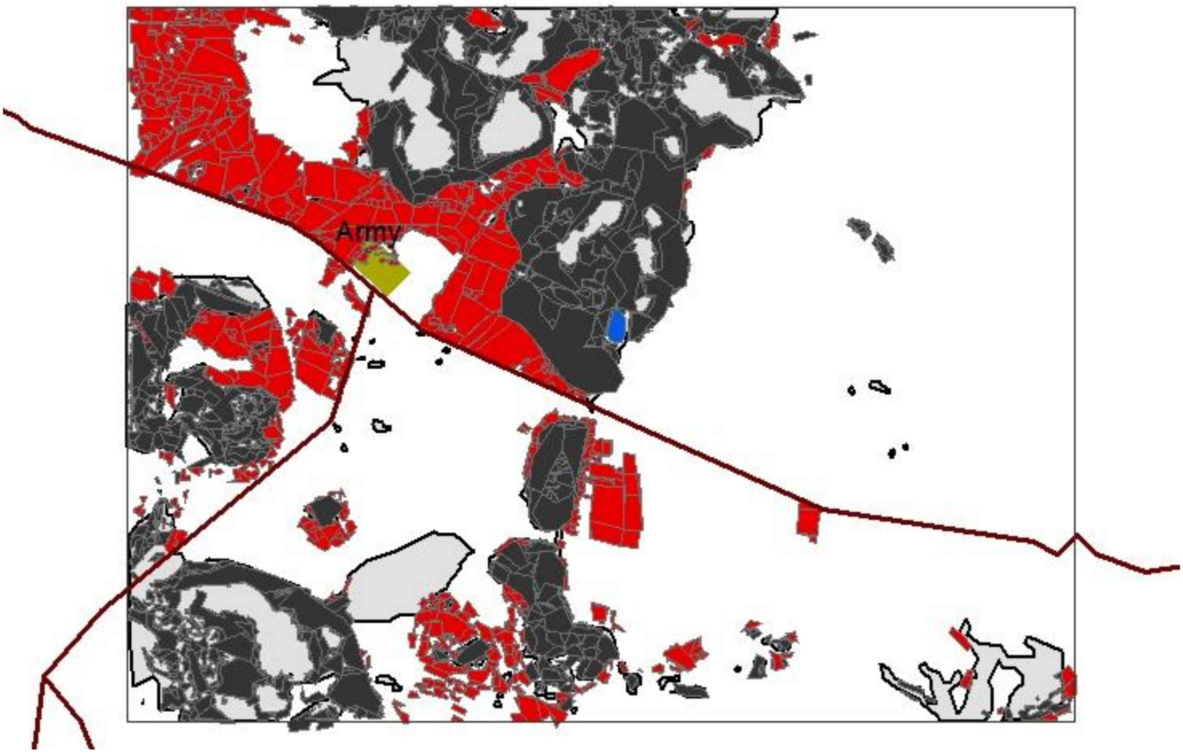

Figure 2.9 Map of the study site showing the amount of grassland converted to cereal crop farming on black soil (black shape files) and on red soil shown (red shape files) in 2015.

2.4.3. NDVI analyses of vegetation across the Liben Plain

Across all four years analysed, mean NDVI values across the Liben Plain show marked variation primarily around both rainy seasons (May/June and November) and the intervening dry season from June to October (Fig. 2.10). Peaks in mean NDVI values were obvious during the main rainy season for all years, which follows a decline in NDVI from the preceding February and March period (Fig. 2.10). Mean NDVI values decline immediately after the primary rainy season, either from May until August, or from June to August. NDVI values then increase from September onwards with another sharp increase during the secondary rains from October to November (Fig 2.10). Across all years analysed, there are very low mean NDVI values in the months immediately following the primary rains from June to July in 1998, June until August in 2003, and from May until August in both 2008 and 2013. Mean NDVI values for cereal crop vegetation in 2013 show significant peaks between March and May and from August to November for that year, with declines immediately following those periods (Fig 2.10). These patterns mirror those of rainfall patterns for the same years (Fig. 2.11), which show clearly marked peaks in rainfall between March and June, and September and November, for each year.

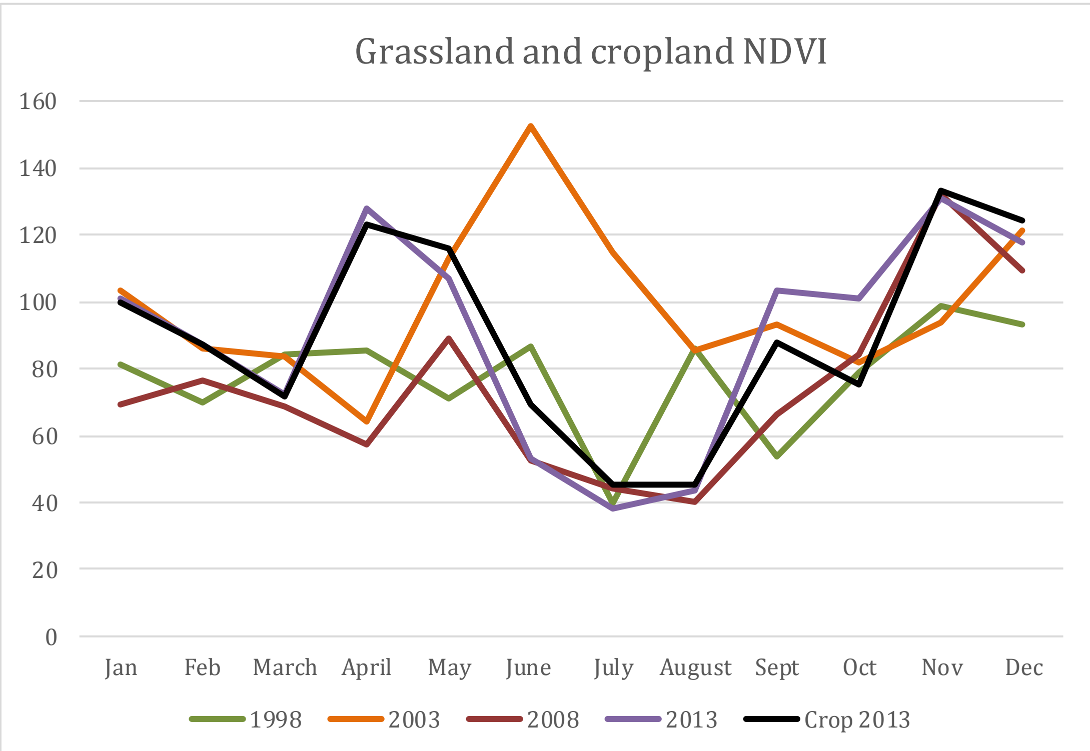

Figure 2.10 Showing mean NDVI values of the grassland vegetation from across the Liben Plain analysed from 1998, 2003, 2008 and 2013, and also for crop vegetation in 2013

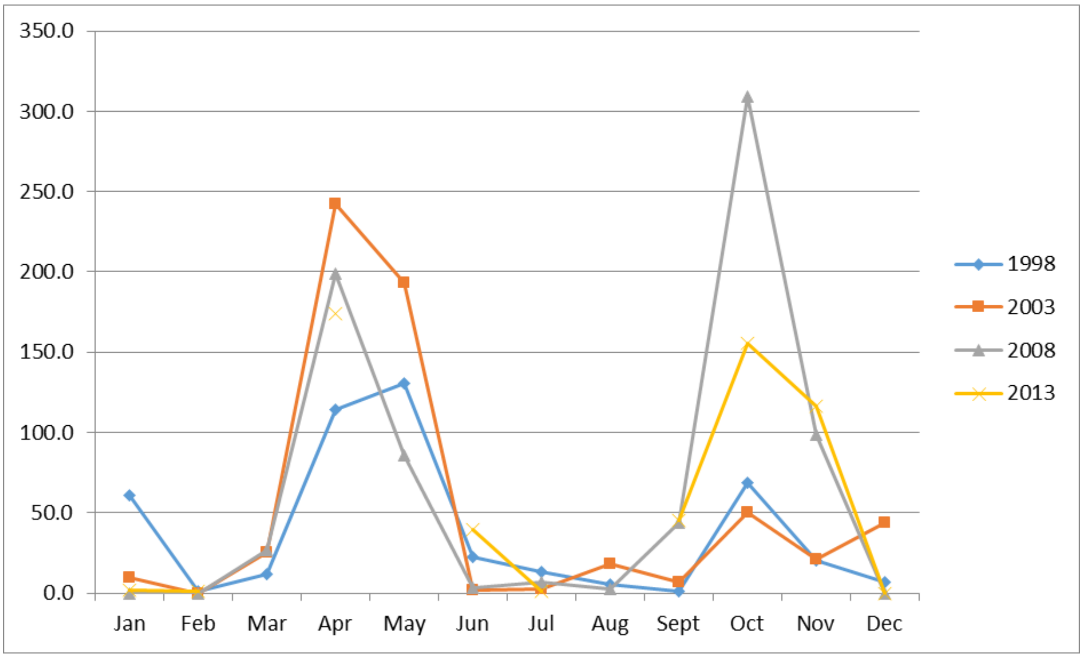

Figure 2.11 Showing the patterns of rainfall across the Liben Plain for 1998, 2003, 2008 and 2013

2.4.4. Areas of remaining grassland and other land uses

A number of additional land use areas and habitats were distinguishable from the 2015 image of the study site (Fig. 2.12). These primarily corresponded to areas encroached by scrub, settlement, and regular paths being used by the residents and their livestock. Areas of settlement in Siminto PA were more concentrated close to the main road from Negelle to Filtu, with other settlements in Siminto situated near the PA itself on the road from the military base to Arero. In Meisa PA settlements were situated close to the main road that connects Negelle to Filtu. (Fig. 2.12). Other scattered settlements were evident near Fullo on predominantly black soil areas. Settlements were very scarce in the eastern part of the plain which is further from water sources and dominated by scrub and woodland. Numerous paths traversed by pastoralists and livestock connected different settlement areas across the plain, and also to the main watering point at Fullo. The remainder of the plain has been converted to cereal crops. The extent of remnant grassland habitat across the plain was 23.76 km^2 (Fig 2.12), with areas ranging from a minimum size of 0.58 km^2 to a maximum of 2.83 km^2 (mean = 1.69 km^2).

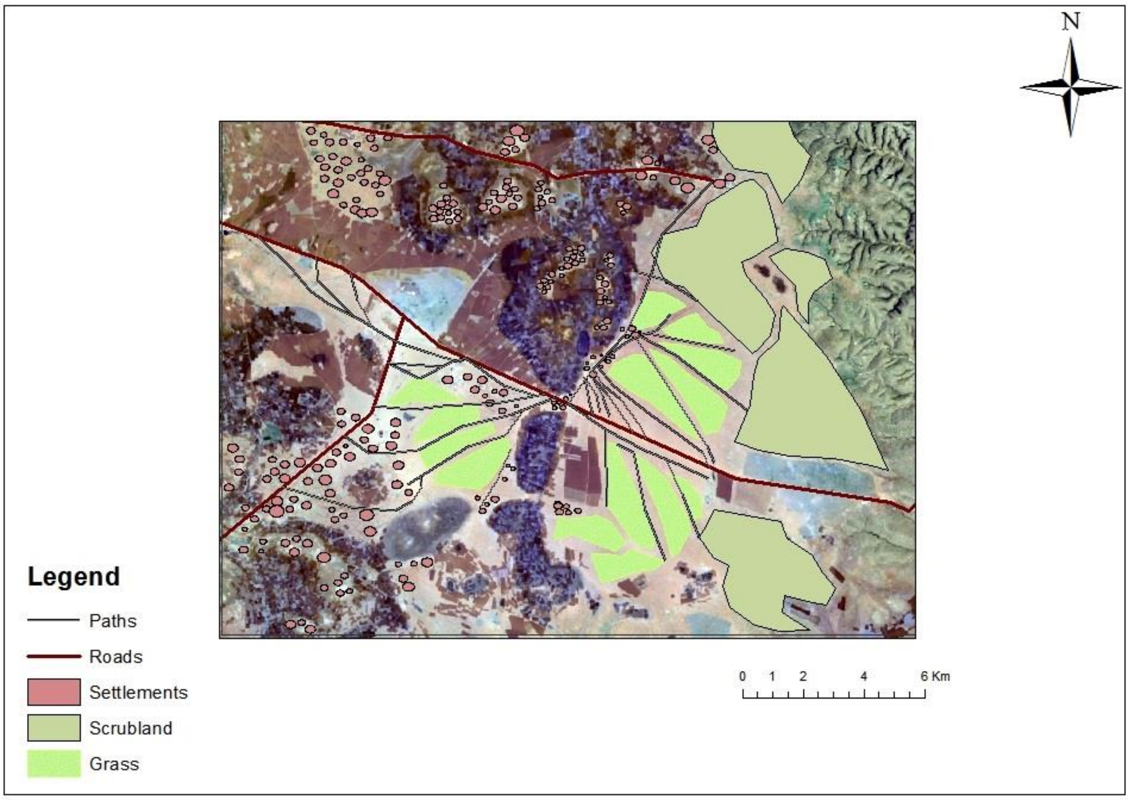

Figure 2.12 Map of the study area showing settlement, areas of scrubland, network of roads and paths, and the remaining patches of remnant grassland on the Liben Plain in 2015

2.5. Discussion

2.5.1. Loss of grassland habitat and expansion of cereal crops

Understanding the impacts of grazing pressure and agricultural expansion across rangeland habitats requires long-term data, as these effects can often be influenced through combined actions of episodic rainfall, drought, and periodic fires (Skarpe, 1991; Oba, 2000; Bennett et al., *in revision*). My study uses GIS and NDVI analyses of a long-term data set to identify changes in land-use patterns across the Liben Plain, the expansion of cereal crop farms, and the loss of grassland habitat. From this I am able to suggest possible factors leading land-use changes across the plain, how they are influenced through patterns of rainfall, and what this means for conservation strategies that help to conserve the Liben Lark.

In this study the loss of grassland habitat has been ongoing across the Liben Plain, primarily due to conversion of grass to cereal crops. In total, 23.5% of the core area of the Liben Plain has been converted to crops since 1994. In addition to that, other land use types such as settlement, expansion of scrubland and usage of paths for human and livestock have led to further decrease of the available grassland to about 23 km^2 in the study area, situated in

14 remnant patches (see Fig.2.12). Previous studies by Coppock et al., (2006) found that across the Borana Plateau, there were dramatic declines in grassland habitat quality and extent, with cropland increasing by five times the previous amounts. In the Yabello district (located in the Borana zone), the total amount of grassland declined from 173 km^2 to just 24 km^2 from 1974 to 2003, and grassland now covers just 6% of the region's landscape, compared with 43% in 1974 (Coppock et al., 2006). Other studies of Ethiopian rangelands have also reported similar losses of grassland habitat and increases in bare ground cover due to heavy grazing pressure (e.g. Oba et al., 2000). In some Ethiopian rangelands, the area of cultivated crops are reported to be larger, almost double the size, of grazing lands (e.g. Ősterle et al., 2012), and in some lowland areas crops constitute 60% of areas, with 40% remaining for grazing (e.g. Sisay, 2000). Amsalu & Addisu (2014) report that cultivated land has rapidly increased by up to 12% in the Amhara Region of the country, with up to 34.5% of grazing land being converted into croplands. Biazin & Sterk (2013) report that the amount of agriculture in the dry lands of the Rift valley increased from 10% in 1965 to 29% in 2010. Studies of other Ethiopian dry bush habitats also report a steady rate of conversion from native habitats to arable crops during the last four decades (e.g. Dessie & Kleman, 2007; Tsegaye et al., 2010), with some areas reporting an increase of land being converted to agriculture by up to 126% (e.g. Garedew et al., 2009). My results from the Liben Plain match those of other studies, and confirm that within Ethiopia, there is now an ongoing general trend for rangeland conversion to cereal crops (Ősterle et al., 2012). Conservation strategies for biodiversity and grasslands of the Liben Plain must focus on reversing this loss.

2.5.2. Grassland soil types and cropping cycles in the Liben Plains

The suitability of rangeland areas for either livestock or crop production and the type of livestock species or crop species to be produced in that region depends on the agro-ecological conditions of that rangeland (Tolera & Abebe, 2007). Elsewhere in Ethiopia, there is a clear association between soil type, land-use class and crop production system (Nyssen et al., 2007). Typically, there is a very sharp contrast between the preferred locations for cereal crop farms and rangeland based on soil type in other African countries. The soil in the region is predominantly Chromic Cambisol according to the FAO/UNESCO system and these soil types are used for cereal crop farming in sub-Saharan African countries (Yusuf et al., 2015). The black soils across the Liben Plain are these types of soils and have been primarily cropped and used up by 2008. The remaining areas of black soil in the selected study site have already been taken up for settlement or for traditional ceremonies. The red soils are widely believed to be poor for cereal crops and it could be that these soil types consist of a different type of heavy clay soil, such as Vertisols (perhaps Chromic Vertisols). Since these areas have limited agricultural potential, the preparation of the grassland for cereal crop farming is quite difficult. Nevertheless, these grasslands on red soils are rapidly being converted to cropland as the more productive black soils have all been converted to cropping in the study site.

Crop farming is a recent livelihood diversification in the last 20 years or so for Borana pastoralists (e.g. Coppock, 1994). The cause of switching from livestock production to crop farming on black soils was simply food security during poor livestock production years (Coppock, 1994). This strategy is advocated by some to be a good strategy for coping with unpredictable weather patterns (e.g. PFE, 2010). The GIS analyses in this chapter reveals that crop farming has reduced the amount of grassland habitat across the Liben Plain by almost 24% so that there only remains 23 km^2 of grassland deemed suitable for the Liben Lark. This has also reduced the amount of suitable dry season grazing areas for pastoralists. This loss of extent and quality of suitable dry season grazing areas in recent decades across the Borana Plateau is well known to the pastoralist communities (Coppock, 1994). The Liben Plain was historically used as a wet season grazing area but changed through time to an all year round grazing area (Bennet et al., *in revision*). This loss of grazing areas consequently concentrates more intense grazing pressure into smaller and smaller areas across the plain, leading to over-grazing and possibly soil erosion, further deteriorating the grassland habitat.

The conversion of red soil grassland areas to crops across the Liben Plain should be a significant cause for concern as this breaks the more recent approach to crop farming in the region. This study has shown that prior to 2008, crop farming was conducted primarily on the more fertile black soils but farming on red soils has increased dramatically since 2008, as the black soils have become entirely covered by cropping. In 2007 people began illegally 'grabbing land' and also using tractors to farm larger areas. These activities brought a change in attitude amongst local residents who realize that it was possible to use the red soil grasslands for agriculture and to prevent losing further land to non-residents by farming areas themselves. Consequently, between 2009 and 2013 the rate and amount of red soils converted and farmed for crops was greater than that on the more fertile black soils. The use of the less-fertile red soil grasslands since 2008 is almost certainly the result of the drought and the food production emergency of August 2008. In fact, the use of such marginal grassland for crop production probably reflects the necessity of pastoralists to divert to cereal crops after the culmination of successive droughts on 2003-2004, 2006-2007 and 2007-2008, rather than the response to just one drought in 2007/8. Coping with severe and successive droughts and unpredictable rainfall by cereal crop expansion has been reported elsewhere in Sub-Saharan Africa (e.g. Fleuret, 1986; Cooper et al., 2008) including Ethiopia (e.g. Biazin & Sterk, 2013). However the use of red soil grasslands only reduces the amount of dry season grazing areas further still, and adds further pressure on the population of the Liben Lark, in terms of the amount of suitable breeding habitat available for the species.

The NDVI values have revealed how dependent both grassland vegetation and crop cycles are on the biannual rainy seasons of the Liben Plain, and how fragile the grassland ecosystem is to changes in those rainfall levels. Distinctive patterns of grassland growth during the annual periods of rain from May/June and around November each year (Figs 2.10 and 2.11) follow periods of less grassland vegetation during the dryer months. The NDVI analyses also revealed that cereal crop farming is also dependent on both rainy seasons, with greater crop vegetation recorded from March to May and from August through until December. Tolera & Abebe (2007) found similar patterns in the main cropping season in Southern Ethiopian rangelands, which ranged from mid-February to mid-May during the rainy season, whereas the smaller rainy season cropping extends from mid-September to mid-November. These authors also report that crop failure is a common feature of the area due to unreliable rainfall and frequent drought, with crop failure apparent every 4-5 years, and successful harvests occurring perhaps every 2-3 years. On a more optimistic note, the sites for cereal crop farms in Liben are likely to have deep soils and residual soil characteristics of former grassland habitats (e.g. Tolera & Abebe, 2007) and could have the potential to be restored to the former native grassland habitat. Crop field abandonment following crop failures could present conservation biologists with an opportunity to restore smaller patches of the Liben Plain to suitable areas for dry season grazing, and perhaps, suitable habitat for the Liben Lark. What is required though is collection of more data on the distribution and abundance of the Liben Lark, to determine how the species has responded to land-use changes across the Plain in light of the reduction of grassland habitat and cereal crop expansion on both black and red soils.

As grassland area declines, grassland dependent bird species are known to be negatively affected in terms of reduced distribution and abundance (e.g. Herkert, 1994, Hezler & Jelinski, 1999) and also reduced nesting success (e.g. Winter & Faaborg, 1999). However the influence of grassland habitat extent may vary among different years or seasons (Winter et al., 2006). In the next chapter, I estimate the distribution and abundance of the Liben Lark across the Liben Plain across a seven-year period, producing density estimates and density hotspots for the species, and relate these data to changes in grassland habitat and cereal crop expansion.

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Chapter Three

ESTIMATING THE DISTRIBUTION AND DENSITY OF THE LIBEN LARK

3.1. Abstract

Estimating densities of species through time helps to detect the reaction of species to various land use changes. Distance Sampling is known to be a very reliable and robust means to estimate density. The collection of long-term Distance Sampling data of the Liben Lark, together with new data on its current distribution, is crucial to understand the current status and trajectory of the Liben Lark population and to propose evidence-based conservation management strategies for the species in one of its last remaining strongholds – the grasslands of the Liben Plain. Distance sampling line transect surveys were conducted from 2007, and 2009-2013. Twenty transects with 252 corresponding waypoints were used to survey the Liben Lark population. Spatial analytical tools were used to map density hotspots for the species, for each survey season. A total of 217 individual Liben Larks were recorded within 300 m of the line transects. More males were detected than females, and significantly fewer males were detected during the two dry season surveys. Surveys conducted during the main wet season (May/June) also produced greater sample sizes and more robust density estimates than those conducted in the shorter (November) wet season surveys. Density estimates of the Liben Lark varied markedly from 2007 and 2009–2013, but declined from a high of 3.2 individuals per km^2 of grassland habitat in 2007, to approximately one individual per km^2 of grassland habitat in November 2013. Liben Larks were concentrated in highly conspicuous hotspots, which ranged in size from 26.38 km^2 to 3.87 km^2 and the location of these shifted slightly throughout the different years due to changes in the extent of grassland habitat and loss to croplands. Liben Lark population persistence is incompatible with continued cereal crop farming and the cessation of grassland conversion to croplands will be critical for the survival of the species. The density estimates and hotspot locations provide conservation managers with suitable, realistic population recovery goals and priority areas for strategic citing of habitat restoration efforts through the creation of communal *kallos*.

3.2. Introduction

Reliable estimates of abundance are very important in monitoring the population trends of species (Cahill et al., 2006), particularly as the IUCN criteria for categorizing the degree of threat to any species are highly quantitative (Mace et al., 2008, Lloyd, 2008). Density estimates enable conservation biologists to detect the reactions of the species to various land use changes (Marsden, 1998) or the responses to direct persecution (Lambert, 1993). Reliable density estimates are also crucial in order to identify important areas for species conservation particularly regarding the numbers of birds in unsurveyed or highly disturbed areas (e.g. Buckland et al., 1993, Jones et al., 1995), and also for establishing population recovery goals for habitat restoration programmes (Rivera-Milan et al., 2015; Lloyd, 2008). They are also useful for extrapolating population sizes, which is important in relation to the IUCN criteria, which in turn relate indirectly to levels of genetic variability.

Some of the most widely used methods for estimating density and abundance of birds and other taxa including amphibians, reptiles, and mammals are Distance Sampling methods (Buckland et al, 2004; Thomas et al., 2010). Numerous studies have shown that surveys conducted using Distance Sampling produce reliable and robust density estimates (Somershoe et al., 2006; Ronconi & Burger, 2009). Compared to other more traditional bird survey methods such as territory mapping (sometimes called 'spot mapping'), distance sampling is more beneficial because it takes less time to carry out, and allows coverage of a larger area (Thomas et al., 2010). Typically, Distance Sampling surveys are based on either line transect or point count methods (Buckland et al., 2001) and involve observers estimating distance from the position of the bird to the centre of the point count site or to the actual route of the line transect (Buckland et al., 1993; Bibby et al., 1999). These data are used to calculate the density of the species being recorded (Buckland et al., 1993; Bibby et al., 1999). Crucially, these distances take into account the fact that different bird species differ in their detectability over different distances, or that a species may be more easily detected in one habitat type compared to another (Buckland et al., 1993, Buckland et al., 2001; Thomas et al., 2010). Collecting Distance data therefore enables conservation biologists to directly compare the densities of the same species in different habitat types such as undisturbed versus disturbed habitats (Buckland et al., 2001; Bibby et al., 2000).

Few studies have generated reliable density estimates for threatened grassland-dependent bird species, and even fewer studies have specifically employed Distance Sampling methods for their surveys. Grassland ecosystems represent one of the most threatened ecosystems in the world (Noss et al., 1995) and many support unique grassland-dependent bird species (see Chapter One). Many of these species are suspected of undergoing dramatic population declines (Sauer & Link, 2011), primarily from habitat loss and degradation (Vickery et al., 2000). For many grassland species, particularly species of grassland-dependent larks (family Alaudidae) there remains a serious lack of empirical data concerning their density and population size. This makes it difficult to predict with any certainty the consequences of ongoing habitat loss and degradation or even set targets for population recovery goals for more highly threatened lark species. Some grassland-dependent bird species occur at low densities in some habitats (e.g. Johnson & Igl, 2001) and similar findings have been made of grassland-dependent lark species.

Whether occurring at low density is typical of other grassland-dependent lark species such as the Critically Endangered Liben Lark *H. archeri*, which is the sister species to Rudd's Lark and the only other member of the *Heteromirafra* genus, remains unknown. This lack of empirical data is hindering any applied conservation recommendations for Africa's most threatened bird species (see Chapter One). The collection of long-term Distance Sampling data of the Liben Lark, together with new data on its current distribution, is now crucial in order to understand the current status and trajectory of the Liben Lark population and to propose evidence-based conservation management strategies for the species. The aim of this chapter is to estimate the distribution, density and population size of the Liben Lark in one of its last remaining strongholds – the grasslands of the Liben Plain. More specifically, this chapter looks at population changes across a series of years.

Specifically, for this chapter, I have the following research objectives: (1) Estimating the current density of the Liben Lark across the Liben Plain (2) Looking at changes in Liben Lark density since 2007 (3) Estimating the population size of the Liben Lark (4) Examining the distributional patterns of density (e.g. clusters or hotspots of density) of the Liben Lark population and looking at possible temporal variability. (5) Looking at changes in distribution, density and/or population size in relation to land use changes and habitat quality (habitat association will be covered in chapter 4) and what the implications are for population recovery goals.

3.3. Methods

3.3.1. Study site

A full description of study site and the whole Liben Plain is given in Chapter 2. The study site is located in a smaller area than that shown in Chapter 2. The location of the transect waypoints (Fig 3.1) and relative location from the study area is shown in Fig 3.2.

3.3.2. Bird survey method

The Liben Lark population was surveyed using an adaptation of a Distance Sampling line transect method established by Spottiswoode et al., (2009). The data were collected by several different observers across the different seasons including myself since 2010, and I was the primary data recorder for all surveys from 2012. The data collectors in 2007, who set the techniques for bird and habitat data collection, later on trained the primary data collectors of other years. Data collected from 2007 to 2013 are referred to as follows: Main Wet Season June 2007; Main Wet Season June 2009; Main Wet Season June 2010; Main Season May 2011; Dr Season August 2012; Short Wet Season November 2012; Dry Season January 2013; Main Wet Season May 2013; and Short Wet Season November 2013. Only one visit was made to each transect for each survey period and the direction of survey along the transect was alternated to minimize any bias of lark activity throughout the day.

Since 2007, twenty transects with 252 survey waypoints placed 250 m apart along each transect have been used to survey the Liben Lark population in the core area occupied by the species' population. The transects, approximately 63 km in total length, were situated at least 1 km apart, and the waypoints used as habitat data collection points (Spottiswoode et al., 2009). Transects were surveyed from 06:30 to 11:00 and only on days of suitable weather conditions, i.e. not during rain or in strong windy conditions (Bibby et al., 2000). Along each transect, observers recorded the number, presumed sex and behaviour of individuals seen or heard. However it was difficult to differentiate between the sexes unless they show distinctive behaviours such as the display flight which is assumed to be only in the adult males. GPS coordinates of each observation of Liben Larks were taken from the position where the individual was first sighted. For each record of Liben Lark observers also estimated the perpendicular distance to the bird from the transect line (Buckland et al., 2001).

There are four basic assumptions of distance sampling that must be met by observers if an unbiased density estimate is to be obtained. These assumptions are as follows and are from Bibby et al., (1999), Buckland et al., (2001) and Thomas et al., (2010): (1) Transects or points are representatively placed with respect to bird density; (2) Objects (birds) directly on the line or at each point are always detected; (3) Objects are detected at their initial location prior to natural movement or movement in response to the observer's presence; (4) Distances should be accurately measured (or at least estimated with small and random error). Distance data are then analysed by fitting a detection function which will help estimate the proportion of objects (e.g. individual birds) missed by the survey and thus estimate the density of the target bird species. Ideally >100 records of individuals are needed for a reliable and precise density estimate (Buckland et al., 2001; Thomas et al., 2010). However, this makes Distance Sampling particularly difficult to estimate densities for species that are intrinsically (naturally) rare and/or highly threatened (Marsden 1999). However, some authors have found that 60–80 records of individuals of the target species is around the ideal minimum that can be used to get reliable density estimates (Bibby et al., 1998). Alternatively, for rare or threatened species with very small sample sizes, data can be pooled across different habitats or different years, in order to increase precision (Marsden, 1999). In extreme cases, approximate data from other studies or similar species can be used to estimate densities or to estimate a detection curve (Gottschalk & Huettmann, 2011).

3.3.3. Data Analysis – Distance data and density estimates

Distance data were analysed using the Conventional Distance Sampling (CDS) engine of Distance version 6.2 release software (Thomas et al., 2010). Density was expressed as number of individuals per km^2 of grassland. Exact distances were used for bird records that were entered as single records rather than as clusters, since the larks were recorded individually. The shape criteria of distance histograms were examined for heaping or cluster bias and where necessary any outliers were right-hand truncated (Buckland et al., 2001; Thomas et al., 2010). Generally, up to 10% of outliers are truncated, but to determine the actual values for truncation and subsequent grouping of records into distance bands the detection histograms were visually inspected (Thomas et al., 2010). Data were then truncated to 300 m to minimize any bias that could be caused with the very few data that were recorded beyond this distance. Distance intervals were then set at 50 m and entered manually for each analysis. Four key functions (uniform, half-normal, hazard rate and negative exponential, all with cosine series adjustment) were considered for each analysis (Buckland et al., 2001). Key function selection was evaluated using Akaike's Information Criteria (AIC) and a chi-square statistic was used to assess the 'goodness of fit' of each function (Buckland et al., 2001). Density estimates were created for all survey seasons combined and also for individual survey seasons (stratified by season) with a global detection function. All data were analysed with separate detection functions in order to be able to get better density estimates as well as Estimated Strip Width (ESW). Reliability of density estimates was provided using the percentage coefficient of variation (% CV) and 95% confidence intervals (95% CI).

3.3.4. Data analysis: density contour maps

ArcMap 10.2.2 was used to map all the Liben Lark locations from data recorded in 2007 and 2009–2013 on the Liben Plain. I used the Kernel density tool in the spatial analyst toolbox to create 'hotspot maps' of the Liben Lark population across the Liben Plain. The hotspot analysis identifies spatial clusters of high Liben Lark occurrence (i.e. 'hotspots') and areas of low lark occurrence. Kernel estimators were used because these are generally considered to be good for identifying and visualizing general trends or areas for the abundance of target species (Nelson et al., 2007). Kernel density estimation (KDE) is a local density technique that identifies clusters by searching for dense concentrations of point data (Gitman & Levine, 1970). KDE involves dividing the entire study area into a predetermined number of cells and placing a smooth, symmetrical surface over each lark data point across a map image of the Liben Plain and evaluating the distance from the point to a reference location based on a mathematical function (Silverman, 1986). KDE then sums all the value for all the surfaces for that reference location. This procedure is then repeated for successive point records of larks. This allows placement of a kernel over each lark observation, and summing these individual kernels results in the density estimate for the distribution of lark records (Fotheringham et al., 2000). Hotspot maps therefore hold an advantage over 'heat maps' because the areas visualized are statistically significant and therefore less subjective than the latter.

All the GPS coordinates of the Liben Larks sighted across all the years (2007 and 2009–2013) were used to produce one kernel density map. Each year was then analysed separately in order to produce a kernel density map for each survey season. The KDE density function created rasters showing the frequency of points (records of Liben Larks) within a given search radius. For these analyses, the default setting for the search radius (or bandwidth) which uses the following formula:

$$SearchRadius = 0.9 * \min\left(SD, \sqrt{\frac{1}{\ln(2)}} * D_m\right) * n^{-0.2}$$

Where SD is the standard distance calculated from the distances of the mean centre for all the points, D_m is the median distance, n represents the number of points if no population field is supplied, and min = whichever of the two options that results with a smaller value will be used (Silverman, 1986).

Kernel density maps normally include records that are usually placed up to the outermost records of birds, but often this is problematic as it can result in the exclusion of the furthest birds in the hotspots. In order to avoid this problem four false lark records were positioned more than 2 km from all 'real' lark records in all four compass directions. This enabled the program to include all 'real' Liben Lark locations and build a more appropriate hotspot map. Raster cells were then rendered with a red colour map. The first three lower valued classes were discoloured in order to focus on the classes that had higher density. Lark locations which were further apart were then represented by pale colours that change from light green to yellow and become darker orange and red when the records (and density) of Liben Larks become greater, i.e. records of larks which are closer and closer together. A shape file was then drawn around each polygon and the area of these density hotspots was then calculated using ArcGIS.

An NDVI map was extracted from a LandSat image of June 2009 in order to examine the cause for the localisation of the Liben Lark population during that year. This resulted in a 30m x 30m NDVI cover map depicting the high and low values of NDVI in the study area.

3.4. Results

3.4.1. Distribution and abundance of Liben Lark

From 2007 to 2013, a total of 227 individual larks were recorded during all surveys. Most individuals recorded were displaying males, with only ten records of either females or non-displaying males. The majority of records were recorded within a 300m distance either side of the transects during 06.30hrs - 11.30hrs. The highest number of individuals (n=67) were recorded during the main rainy season of June 2007 with the smallest number of individuals recorded during the short wet season of November 2013 (Table 3.1). In June 2009, less than half the number of larks were recorded but this number increased in June 2010 increased, although the total was still less than the June 2007 total. There was a 70% decline in number recorded along transects in May 2011 and another obvious decline in the numbers recorded in November 2013 (Table 3.1). Most individuals were recorded from points located along three transects in the central-west part of the plain (transects three, four and seven) and one in the south-eastern part of the plain (transect eleven) (see Fig. 3.1). High numbers of larks were also recorded from two transects situated in the central-east part of the plain (transects 14 and 16). Larks were never recorded from transects located in the easternmost edges of the survey area (transects eighteen and twenty - see Fig. 3.1). Because of the very low number of individuals recorded during these two survey seasons, they were omitted from the Distance Sampling analysis.

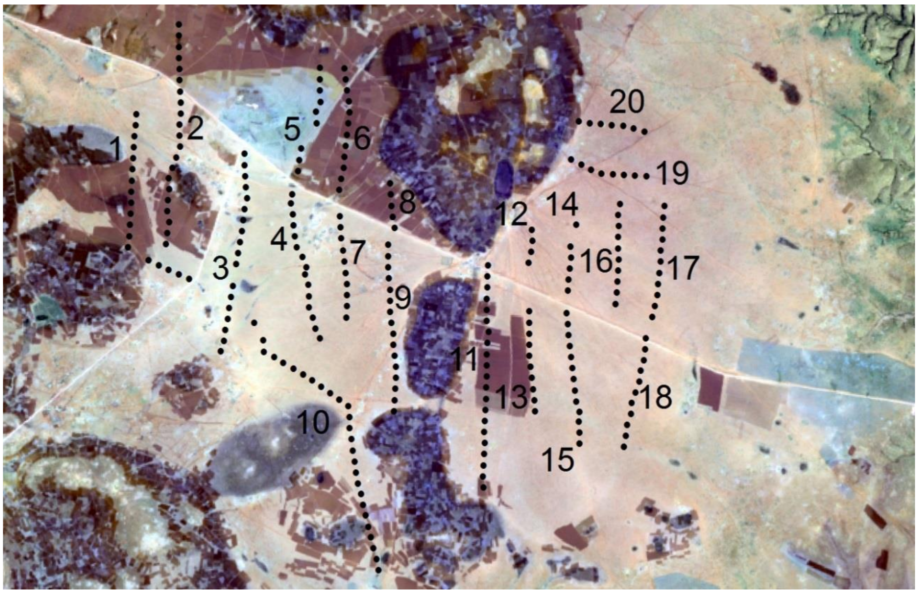

Figure 3.1 Satellite image from March 2015 of the survey area on the Liben plain showing the locations of the 20 line transects used for the surveys.

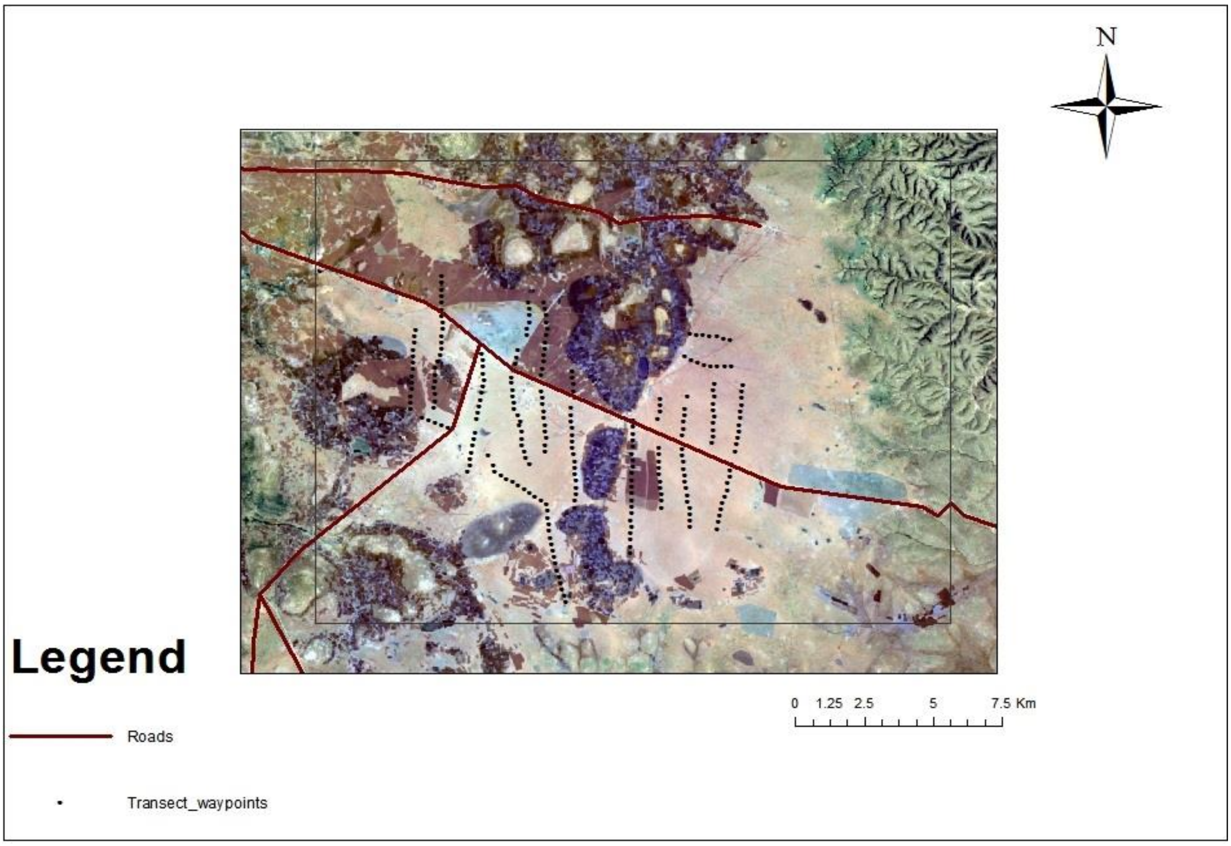

Figure 3.2 The Liben Lark survey area (with transect waypoints as black dots) shown with regards to the location of the study site examined in chapter two

Table 3-1 Density estimates (DE), coefficient of variation (%CV), 95% confidence intervals (CI), Estimated Strip Width (ESW) and other model parameters for the Liben Lark. Records from August 2012 and January 2013 were excluded from analyses due to small sample sizes. Density is expressed as the number of individuals km^{-2} grassland habitat. Estimates for Global Detection Function are stratified per season using a global detection function

Season	Key function selection with series adjustments	Number displaying males (total number)	Seen within 50 m (seen within 300 m)	DE ± %CV (95% CI) Global Detection Function	DE ± %CV (95% CI) Separate Survey Detection Functions	ESW (m)
All seasons combined	Half normal, hermite polynomial	217 (n=227)	66 (n=202)	1.4 ± 15.2 (1.0–1.9)		173
June 2007	Half normal, hermite polynomial	67 (n=67)	18 (n=66)	3.2 ± 21.6 (2.1 – 5.0)	3.1 ± 11.1 (1.9 – 4.5)	183
June 2009	Uniform, cosine	31 (n=31)	8 (n=20)	0.9 ± 56.4 (0.3 – 2.9)	0.9 ± 15.1 (0.3 – 2.8)	183
June 2010	Half normal, hermite polynomial	53 (n=53)	10 (n=47)	2.3 ± 29.8 (1.3 – 4.2)	2.0 ± 13.7 (1.1 – 3.9)	197
May 2011	Hazard rate, simple polynomial	16 (n=22)	8 (n=20)	0.9 ± 41.5 (0.4 – 2.2)	1.4 ± 26.7 (0.5 – 3.6)	120
Nov 2012	Uniform, cosine	20 (n=21)	9 (n=19)	0.9 ± 36.8 (0.4 –1.9)	1.1 ± 15.2 (0.5 – 2.2)	150
May 2013	Negative exponential, cosine	17 (n=18)	5 (n=16)	0.8 ± 36.1 (0.4 – 1.6)	1.1 ± 29.5 (0.4 – 2.5)	130
Nov 2013	Negative exponential, cosine	13 (n=15)	8 (n=14)	0.7 ± 54.7 (0.2 – 2.0)	1.6 ± 29.0 (0.5 – 5.1)	72

3.4.2. Density estimates of the Liben Lark

Density estimates calculated using either the global detection function or separate survey season detection functions revealed that the Liben Lark was extremely rare, occurring at an extremely low density per unit area of grassland habitat (Table 3.1). The highest density of Liben Larks estimated using the global detection function was estimated for June 2007 (Table 3.1). Density estimates for 2009 were much lower, at one individual per km^2, followed by a doubling in the estimate for June 2010. Density estimates declined again in 2011 to a similar estimate to that of 2009, after which there was a consistent decline density until the final survey in November 2013, at which the estimate reached a low of 0.7 individuals per km^2 of grassland (Table 3.1).

Density estimates calculated from separate detection functions yielded the highest estimate for the main wet season of June 2007. In 2009, the estimate was almost three-times lower than in 2007. Nevertheless, both these estimates were very similar to those calculated using the global detection function. In 2010, Liben Lark density estimate was higher at 2.0 individuals per km^2 and individuals were recorded at a greater ESW of 197 m. From 2011 until the end of the surveys, density estimates were higher than those estimated using the global detection function. Liben Lark density declined from November 2012 and May 2013 to almost one individual per km^2 at an ESW of < 150 m. Liben Lark density increased slightly in November 2013 but the ESW was much smaller.

3.4.3. Distribution of Liben Lark density hotspots

The hotspot maps reveal a distinctive spatial and temporal pattern of Liben Lark distribution across the Liben Plain over the survey period (Figs 3.3-10). In 2007, there were four hotspot clusters of Liben Lark density evident across the Liben Plain, all were located on red soil grassland and close to the centre of the study area (Fig 3.3). Areas with the higher densities of Liben Larks, were located in the central-east and central-west region of the plain, with two other hotspot clusters apparent just north-west and south-east of the central area of the plain. Collectively these areas correspond to an area of 26.4 km^2 of red soil grassland habitat. In 2009, there were four hotspots of Liben Lark density and all were much smaller than the 2007 hotspots (Fig 3.4). These were situated west of the central region of the plain, on red soils. The largest hotspot cluster was located west of the centre of the plain, measuring 3.87 km^2 in extent and situated to a smaller hotspot area from 2007. The area hosting the 4.4 km^2 hotspot which was located in the north-western part of the plain in 2007 (Table 3.2) experienced significant habitat conversion to cereal crops from 2008 onwards, and the area was fully converted to cropland by 2011 and the hotspot was not registered on the plain after 2011. Three red soil grassland density hotspots were evident in June 2010, corresponding to an area of 19.2 km^2 (Fig 3.5) with the most prominent being just northwest of the centre of the study site. Two of the hotspots represented a noticeable 'shift' for the species density distribution toward the east and south of the plain due to a dramatic increase in red soil cereal crop farming in the area, but all three hotspots represented larger concentrations of density than the hotspots in 2009.

Further shifts in hotspot distribution were evident in May 2011 (Fig 3.6). Two of the hotspots located to the south of the road were in a very similar location to those of 2010. Collectively these hotspots covered an area of 10.54 km^2 with the prominent eastern hotspot cluster for the species in 2010 no longer present. In November 2012, three hotspots corresponding to an area of 17.98 km^2 were recorded, and having a similar distribution to those present in 2010 (Fig 3.7). The first eastern-most cluster located to the south of the road was the largest, and covered a larger area, and represented an eastern-ward shift in important areas for the species when compared to previous years. Three hotspots were evident for the species during May 2013 in similar locations to those in 2010 (Fig 3.8). The easternmost hotspot to the south of the road was the largest of the three and was bigger than previous years. The second hotspot situated south of the road represented a shift for the species density distribution further south on the plain compared to 2010 and 2011. The third hotspot was located north of the road and collectively these three hotspots covered an area of 25.93 km^2. The similarity of the density hotspots would account for the higher percentages in the area of overlap of these years (see Table 3.2).

In November 2013, three hotspots were identified in similar locations to those of 2010 (Fig 3.9). The easternmost hotspot to the south of the road had a similar size to that of 2010, and overall these hotspots revealed more suitable areas for the Liben Larks were located in the east and south-east region of the plain - a pattern similar to that found in November the previous year. The hotspots in this final survey covered a total area of 10.65 km^2 of the Liben Plain, encompassing 0.51 km^2 of cropland (approximately 13% of its total area) and representing a shift of more than 2 km further south when compared to the distribution of hotspots in 2007 (Fig 3.11). The extent of cropland in 2015 covered an estimated 55% of the Liben Lark density hotspot distribution from 2007, which is an area of 2.03 km^2 (Table 3.2). Examination of all lark records and all years combined resulted in four hotspots that largely resembled the distributional patterns from surveys conducted in 2010 (Fig 3.10), but covered an area of approximately 13 km^2. The largest of these hotspots was located in the western part of the plain south of the main road, with a second hotspot located south-east of the centre, that was much smaller than the 2010 hotspot. The third, easternmost hotspot, north of the road, was slightly smaller than those found in individual years. The fourth hotspot was located to the west and north of the road and was very small.

Table 3-2 Summary of the size (km^2) and approximate location (region) of Liben Lark density hotspots across the Liben Plain from 2007 and 2009–2013.

Seasons	Central-west	Central-east	South-east	North-west	Total (km^2)
June 2007	13.22	5.6	3.71	4.4	26.38
June 2009	3.6	0	0	0.27	3.87
June 2010	11.33	3.82	4.02	0	19.17
May 2011	6.13	0	3.04	1.37	10.54
Nov 2012	4.21	4.63	9.14	0	17.98
May 2013	16.94	5.87	3.12	0	25.93
Nov 2013	2.59	4.02	4.04	0	10.65
All seasons combined	8.21	2.4	2.26	0.11	12.98
Average	8.29	4.79	3.87	2.01	16.36

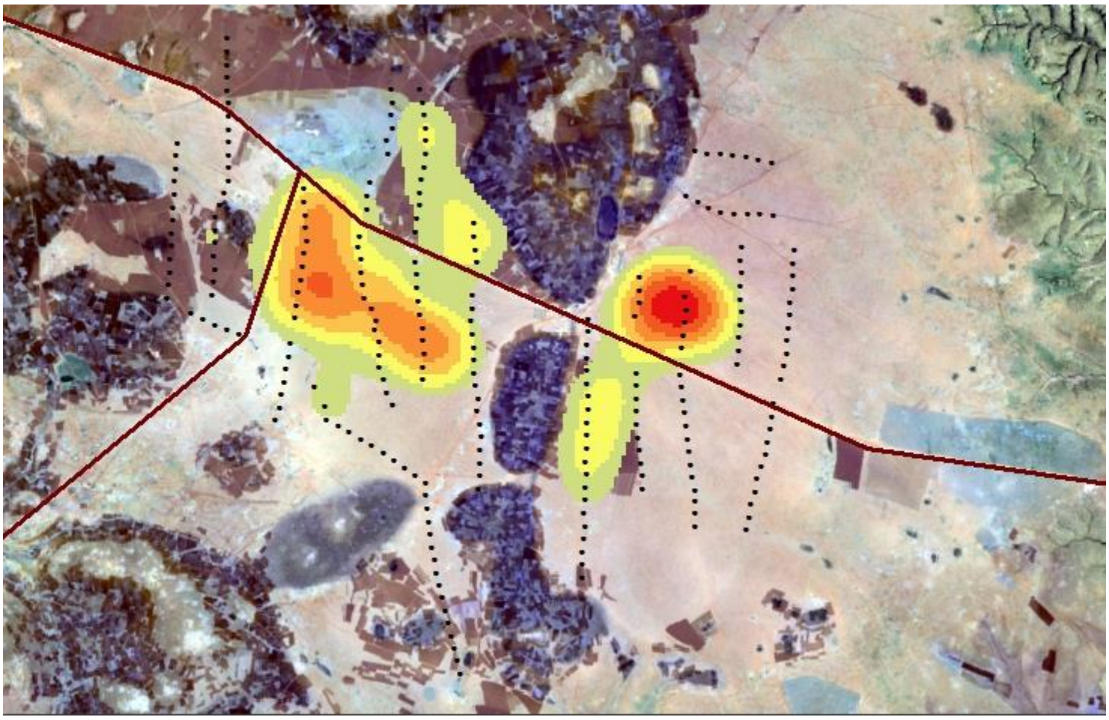

Figure 3.3 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for June 2007.

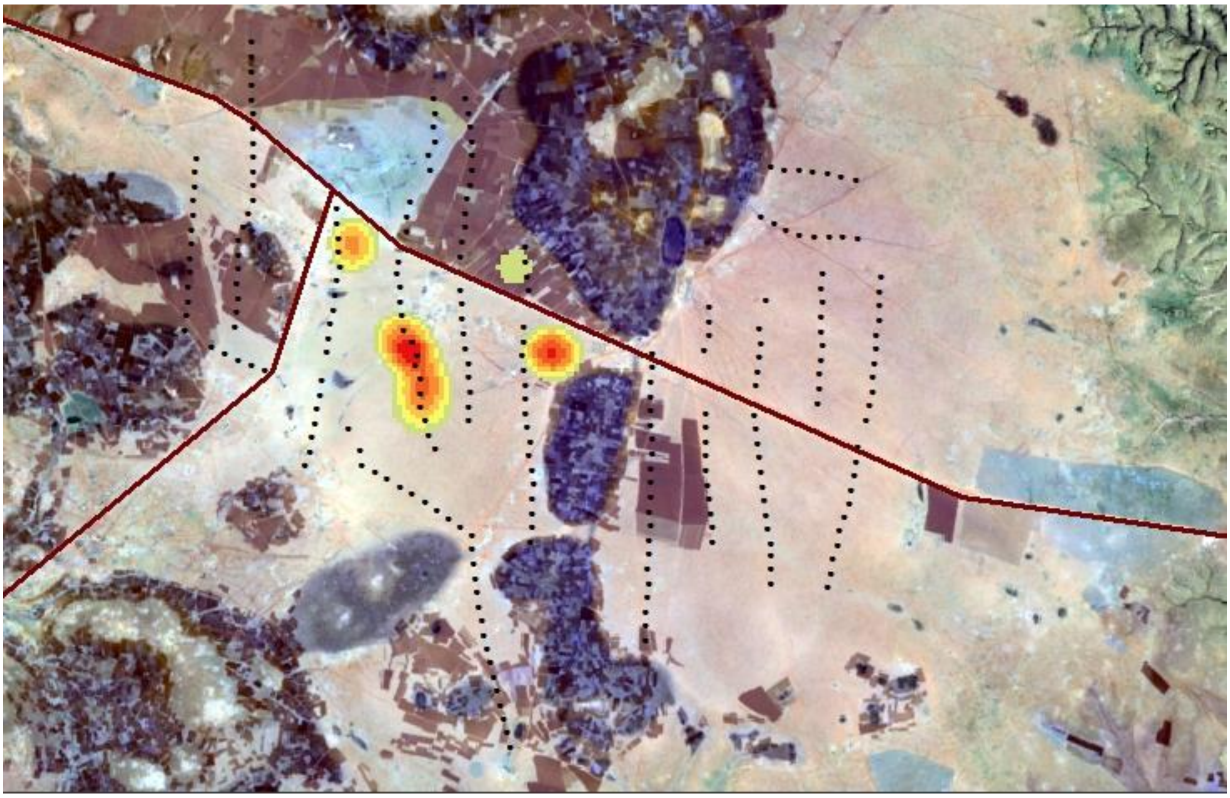

Figure 3.4 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for June 2009.

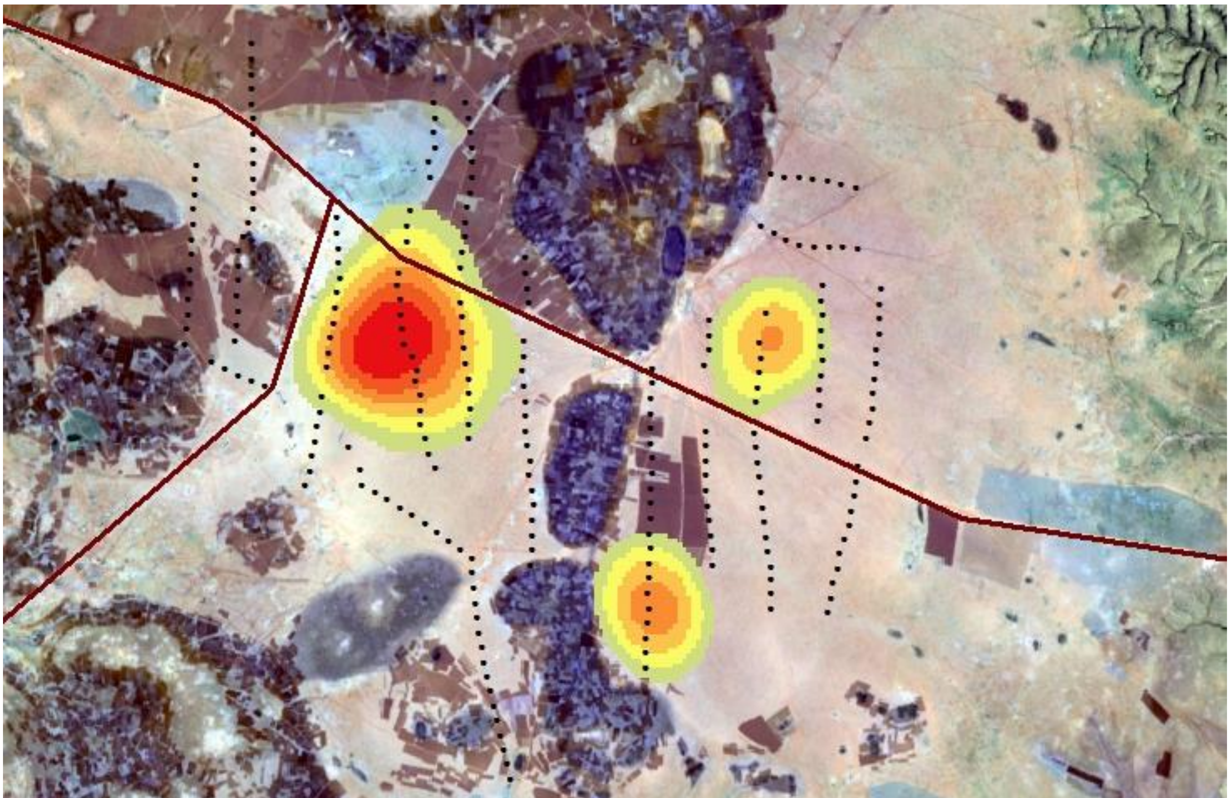

Figure 3.5 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for June 2010.

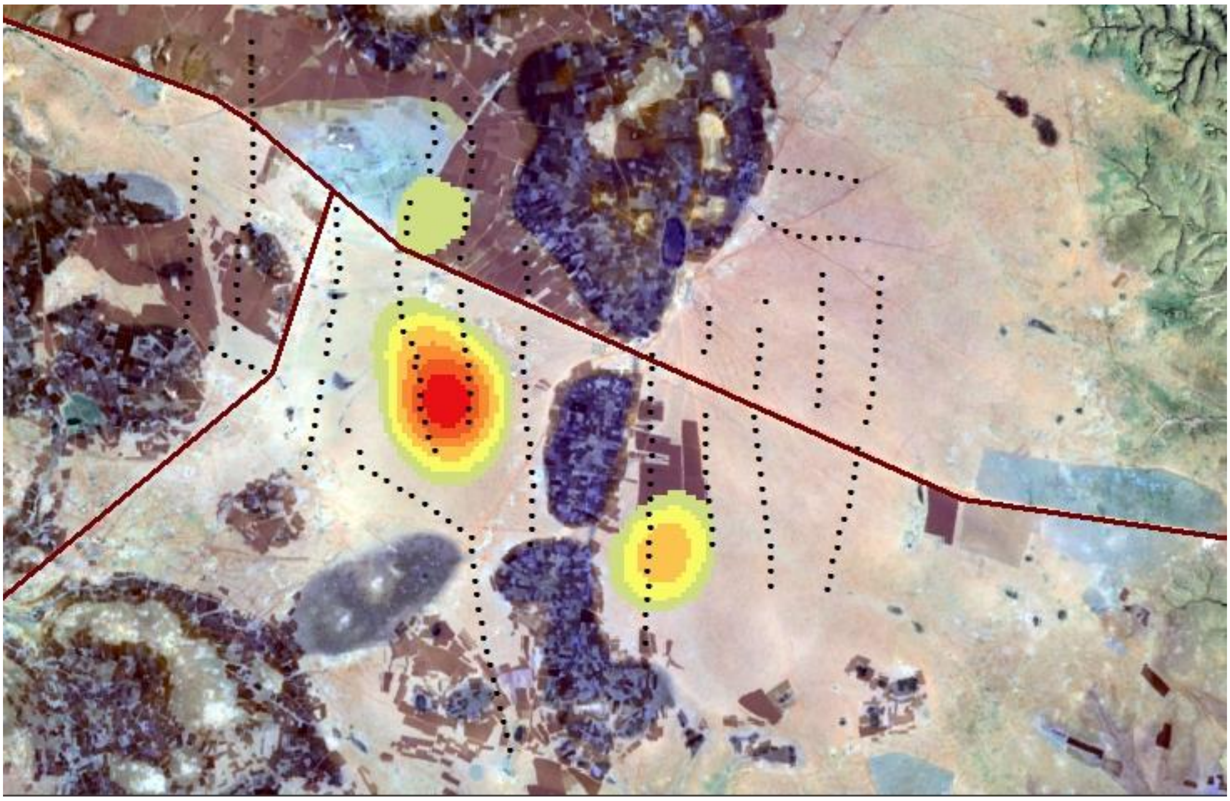

Figure 3.6 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for May 2011.

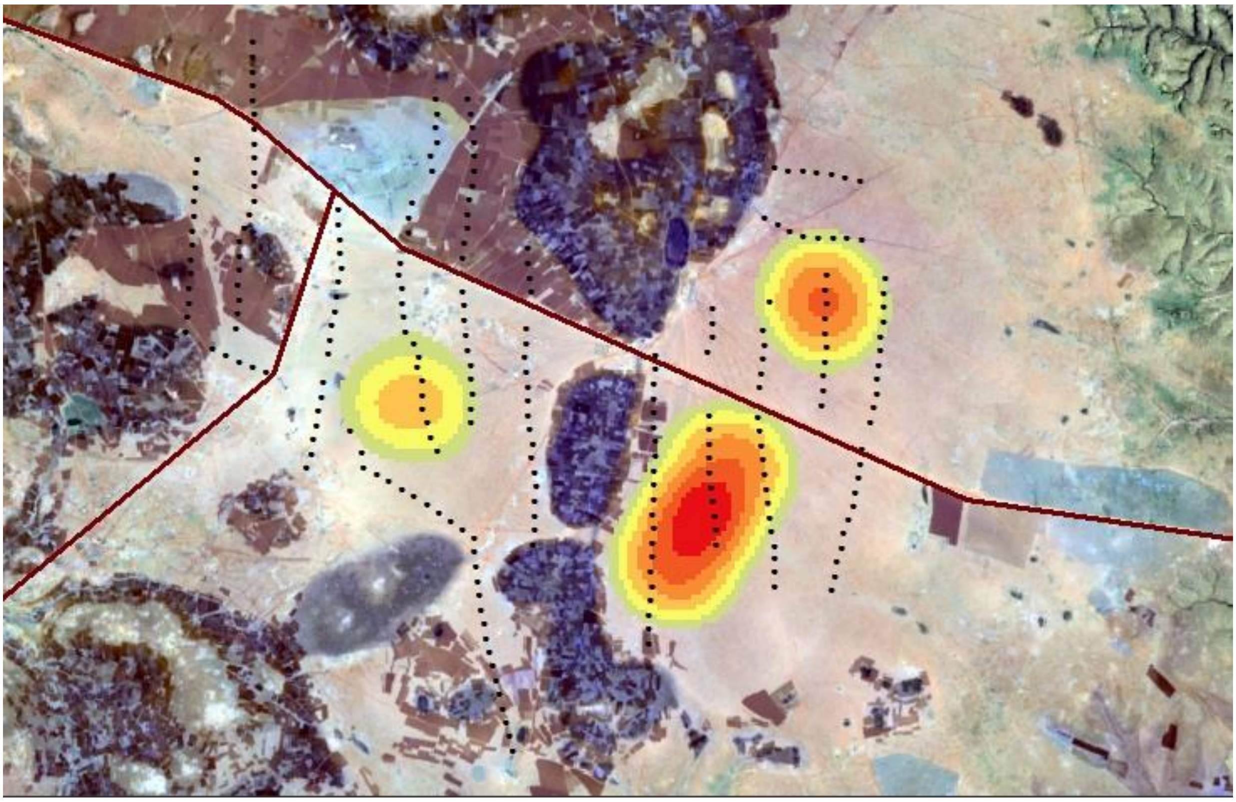

Figure 3.7 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for November 2012.

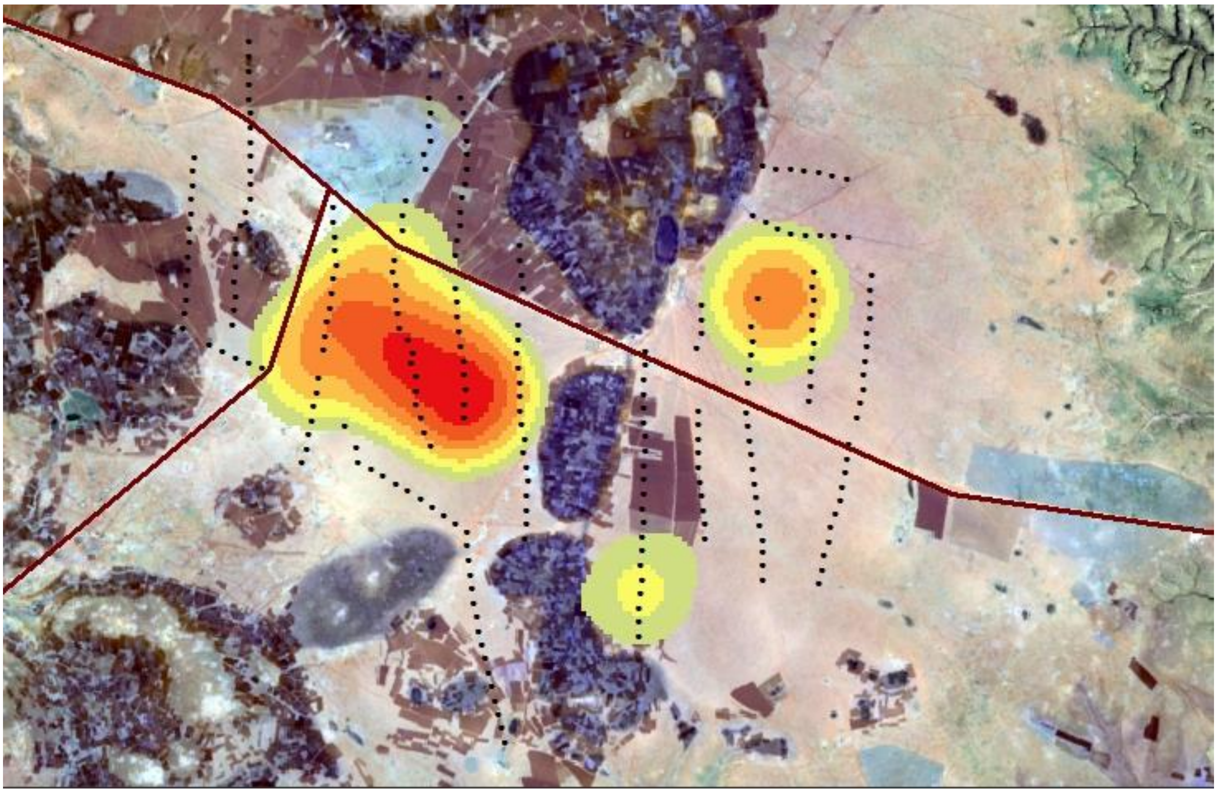

Figure 3.8 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for May 2013.

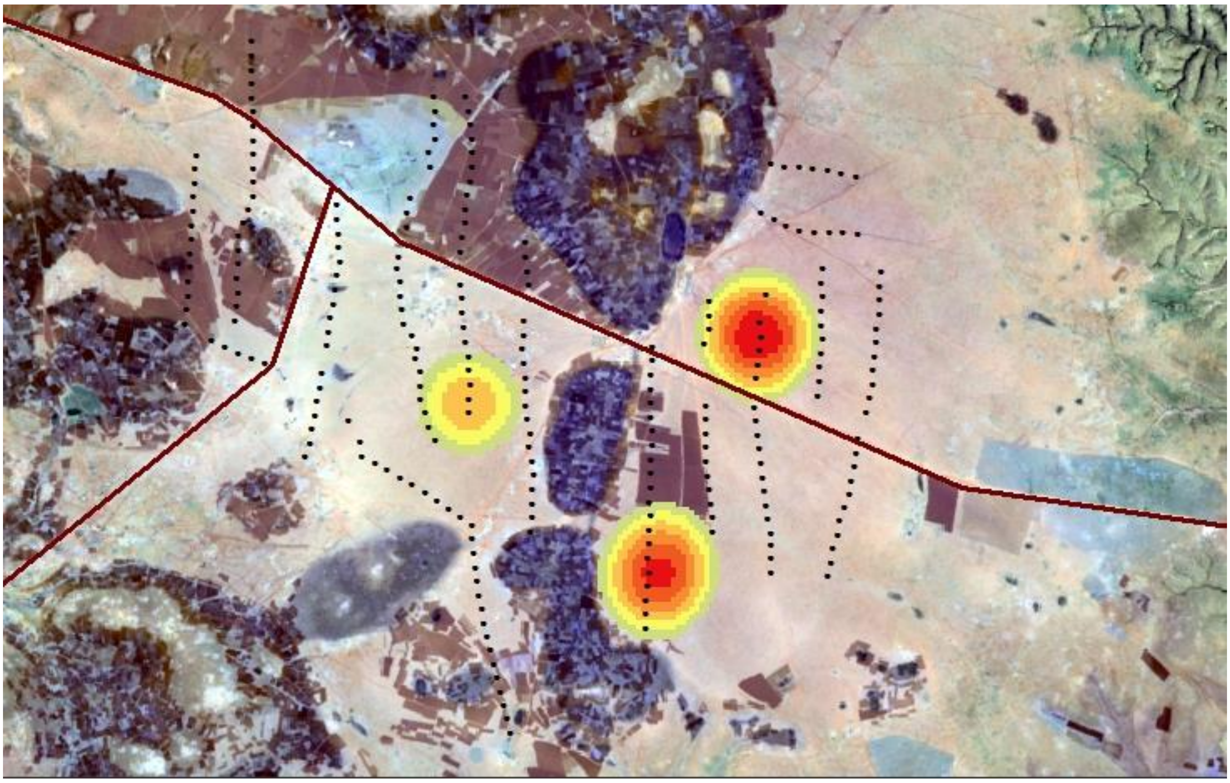

Figure 3.9 Showing the number, location and extent of Liben Lark density hotspots in relation to the transect routes (in black dots) across the Liben Plain for November 2013

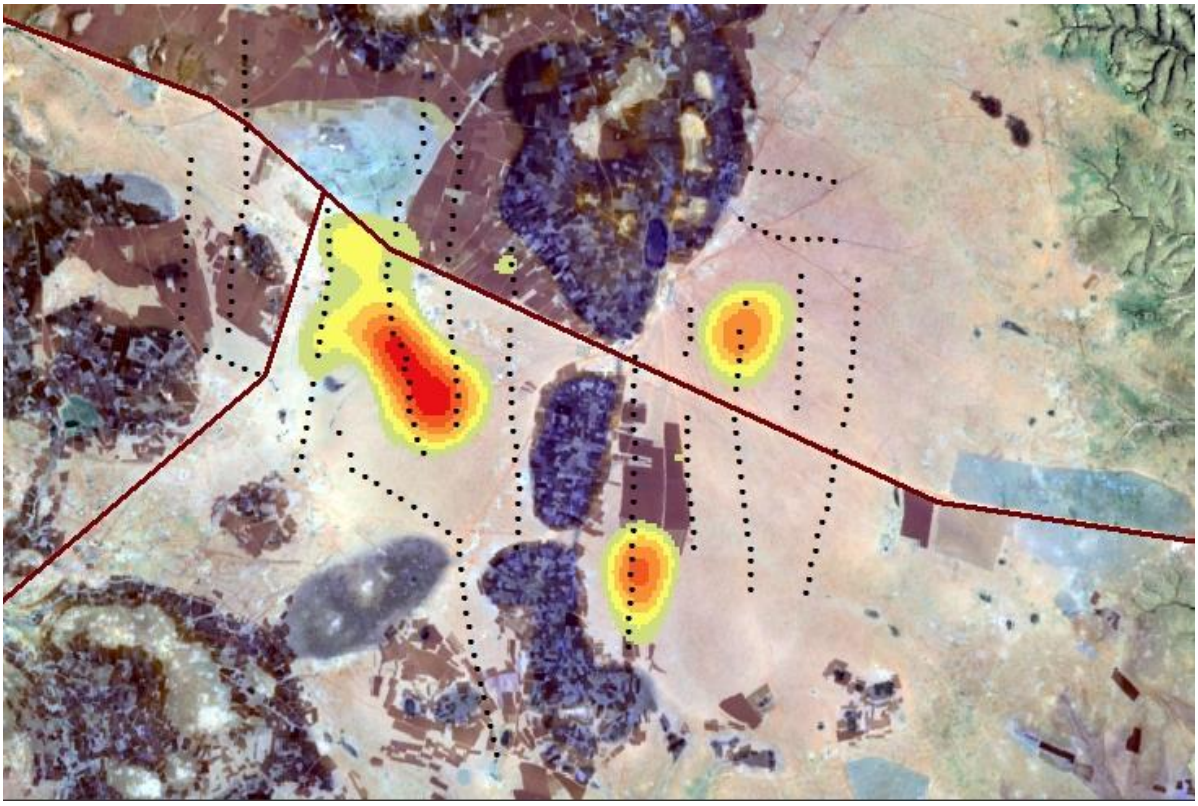

Figure 3.10 The number, location and extent of Liben Lark density hotspots in relation to the transect routes (black dots) for all surveys combined on a satellite image of the Liben Plain from 2013.

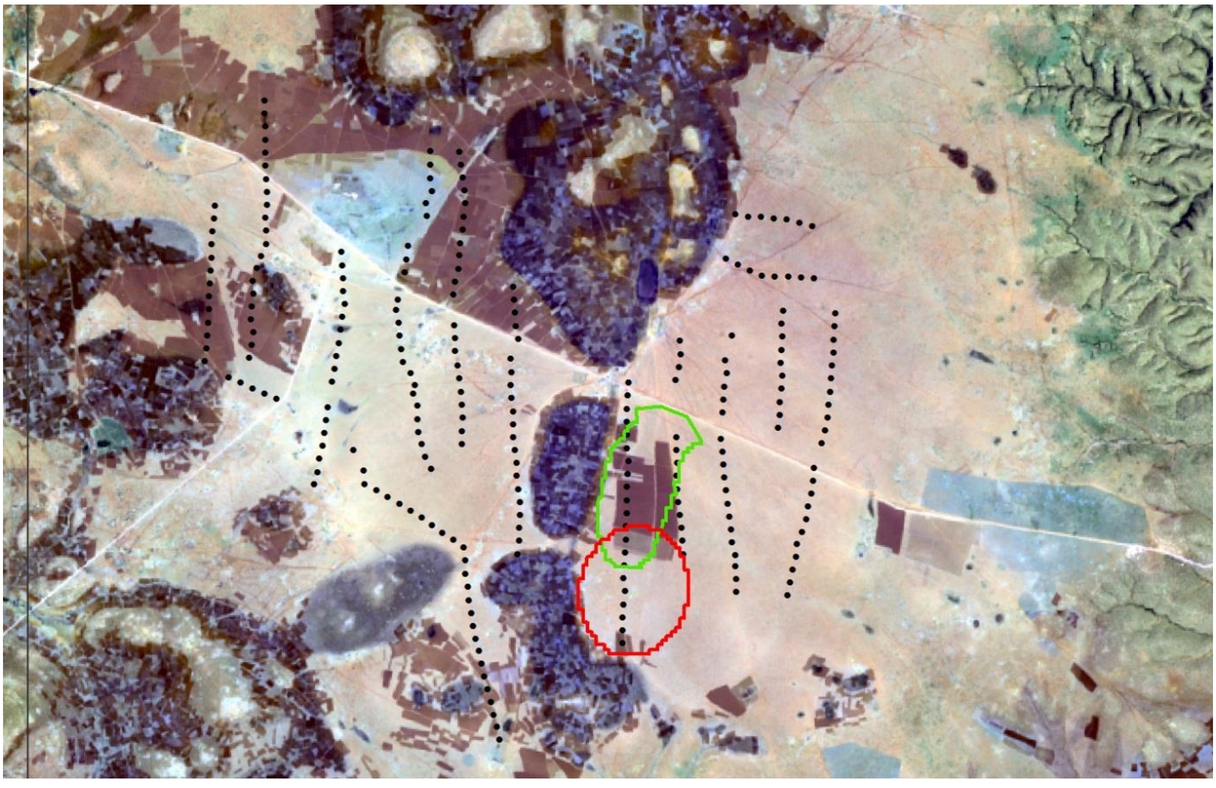

Figure 3.11 Showing the general location of Liben Lark density hotspots in the south-eastern region of the plain. Green polygon shows the location of the 2007 hotspots, red polygon shows the November 2013 hotspots, overlaid on a satellite image taken in March 2015.

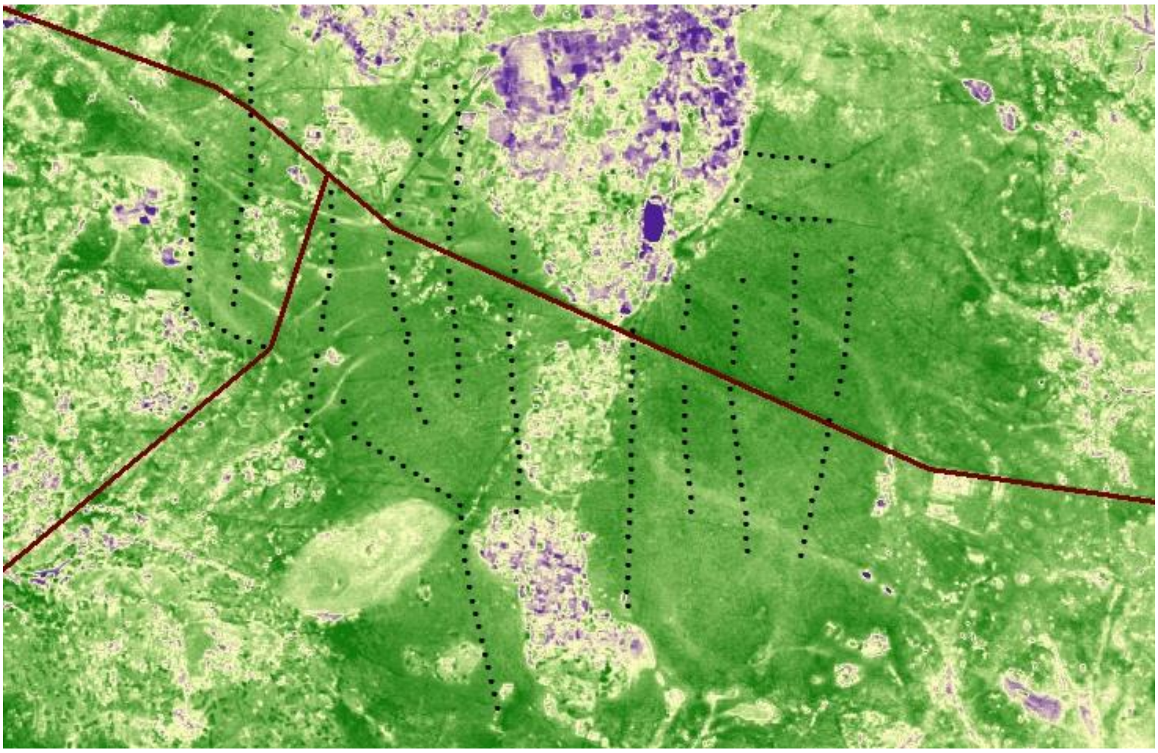

Figure 3.12 Map showing NDVI of the study area with higher values shown in green to lower values in white and least values in blue.

The hotspot which was located in the north-western part of the plain in 2007 had a size of 4.4 km^2 (Table 3.2). The hotspot area started decreasing due to the rapid conversion to farmland after 2008. The whole area was taken over by crops after 2011 and so the hotspot completely disappeared after that time. In 2007, the south-eastern hotspot was located further north. After 2010, farming dramatically increased in this area, which resulted in the shift of this hotspot to the south. At the end of the last survey in 2013, there was a shift in the hotspot position by more than 2 km further south as compared to that of 2007 (Fig 3.11). Considering the extent of cropland in 2015, it would have covered about 55% of the hotspot in 2007, which is about an area of 2.03 km^2. The latest hotspot has shifted to the edge of the crop field as shown in Fig 3.10. The hotspot of November 2013 has currently about 0.51 km^2 of its area in cropland, which is about 13% of its total area.

Table 3.3 shows that there were four hotspots in 2007. This was the time that the highest number of birds was recorded as well as the largest area of hotspots. The numbers had declined in 2009 with an area that was about a sixth of that of 2007. Although there were four hotspots during this year the areas were much smaller and were located within the areas of the two westernmost hotspots of the previous survey year (see Fig 3.4). In order to determine the dramatic shift and localization of hotspots in 2009, an NDVI map of that duration was examined (Fig 3.12). According to the NDVI map, there was no distinct colour difference seen in the NDVI of the grassland area on the eastern and western part of the core area. This suggests that the unusual distribution of the Liben Lark in 2009 may not have been caused as a result of variable NDVI. In 2009, agriculture in the north-western part of the plain was gradually expanding, leading to a decrease in the area of the hotspot there. This area had a hotspot again only in 2011 (Fig 3.6). This appears to be due to the remaining patches of grass in-between the crop fields and the longer grass in the army camp, which is near one of the transects.

From November 2012 onwards, the three locations for the hotspots were similar to those of 2010 and 2007, which were also seen in the hotspot for all the years combined (Fig 3.10). This is the reason for the higher percentages in the area of overlap of these particular years. The percentages of areas of overlap of the hotspots during November 2012 and November 2013 were lower as the larger patches of hotspots were located in the south-eastern part of the plain in contrast to being located in the central-west part during the main rainy season. Hence the overlap of hotspot areas of the separate years with the hotspot of all the years combined (Fig 3.10) was larger during the years 2007, 2010 and May 2013 with percentages of about 81, 90 and 94 respectively (Table 3.3).

The percentage of Liben Larks outside the hotspot areas fluctuated widely across the years, with values as high as 33.3% in November 2012 and as low as 7.7% in November 2013 (Table 3.3). The density of the Liben Larks inside the area of their corresponding hotspots, had values with an average of 2 individuals per km^2 until 2011 with an exception of about 7 individuals per km^2 in 2009. The values started decreasing after November 2012, with density being as low as 0.5 individuals per km^2 during May 2013.

Table 3-3 Showing the number of Liben Lark density hotspots, area of extent of hotspots, number of cluster within each hotspot and number of individuals recorded within and outside each hotspot for all survey seasons. Area of extent = km^2. Density = number individuals per km^2 of hotspot area.

Survey Season	Area of extent (number of hotspot clusters)	% area of overlap with 2007 hotspot	% area overlap with hotspot all years combined	Number individuals recorded outside hotspot (% total)	Number individuals recorded inside hotspot	Density of larks inside hotspot
June 2007	26.38 (4)	NA	81.6	11 (20)	55	2.1
June 2009	3.87 (4)	11.2	21.9	4 (14.8)	27	6.9
June 2010	19.17 (3)	53.2	90.6	9 (20.9)	43	2.2
May 2011	10.54 (3)	23.4	50.9	5 (26.3)	19	1.8
November 2012	17.98 (3)	29.1	47.6	5 (33.3)	15	0.8
May 2013	25.93 (3)	57.3	94.5	2 (14.3)	14	0.5
November 2013	10.65 (3)	24.9	50.2	1 (7.7)	13	1.2

3.5. Discussion

3.5.1. Variation in Liben Lark density estimates

The density estimates of the Liben Lark varied markedly from 2007 and 2009–2013, but taken collectively, the overall pattern could be interpreted as one of decline. From a high of 3.2 individuals per km^2 of grassland habitat in 2007, the Liben Lark is now an extremely rare, low-density species, averaging approximately one individual per km^2 of grassland habitat. As a consequence of this rarity, fewer individuals (i.e. smaller sample sizes) were recorded during subsequent survey seasons, resulting in wider confidence intervals and larger % CVs in subsequent density estimates (Table 3.1). The 2013 density estimates are lower than those obtained from a previous study, which generated an estimate of 3.8 individuals per km^2 of grassland (Spottiswoode et al., 2009). Interestingly, the density estimates from 2007 are quite similar to those estimated for its closest relative, Rudd's Lark *H. ruddi*. Hockey et al., (1988) estimated Rudd's Lark densities of 3.8 individuals per km^2 of natural grassland in one of the strongholds, which represented the highest density estimate for that species since the 1970s (see Hockey et al., 1988). What these data suggest is that the Liben Lark did occur at a much higher density estimate prior to the further loss of grassland habitat to cereal crop farming, and continued overgrazing, and that a density estimates of three or four individuals per km^2 grassland habitat are possible and should be the target for population recovery goals through an evidence-based conservation strategy, for the short term.

Density estimates generated using the global and separate season detection functions were very similar. Comparing across all main wet seasons, short wet seasons, or all seasons, density estimates follow the same trend in fluctuation and decline (and a similar magnitude of decline) with the exception of the final November 2013 shorter wet season survey, which showed an increase under a separate season detection function (Table 3.1). Analytically, this study has also revealed that the density estimates obtained using separate detection functions rather than those generated using a stratified global detection function were more reliable on average owing to the smaller confidence intervals (Table 3.1). Future studies should also consider this consensus approach of using both global and separate detection functions to determine the most reliable density estimates for the species.

The patterns of Liben Lark density estimates are related, in part at least, to the conversion of grassland habitat to croplands which is related to how the Liben Plain is managed. Across the Liben Plain the area of grassland used for farming cereal crops has dramatically increased since the early 2000s (see Chapter 2), and since 2008 this change has been highly significant for grassland habitat situated on red soils. The majority of observations of Liben Larks since 2007 come from areas of red soil grassland habitat. Thus, the lower density estimates can be attributed to the loss of grassland habitat on the red soils through cereal crop cultivation. In other grassland ecosystems, declines in lark density estimates have been strongly linked to the loss and degradation of their grassland habitat, and some of these declines have occurred over a similar 6-year period to that observed across the Liben Plain. The density of Crested Larks *Galerida cristata* in open grassland areas on the outskirts of Warsaw has declined from 5.7 pairs per km^2 in 1980 to 0.11 pairs per km^2 in 1986 (Lesinski, 2009). Different agricultural management practices are also known to influence grassland-dependent lark density. Skylark and Black Lark *Melanocorypha yeltoniensis* densities were estimated at 45 individuals per km^2 and 144 individuals per km^2 of fodder grass fields and old abandoned wheat fields, which are preferred habitats for these species (Kamp et al., 2012). Densities of Calandra Lark *M. calandra* are also known to be almost double (36 compared to 95 birds per km^2) in grassland areas subject to less intensive forms of agricultural management (Sanza et al., 2012). Other studies of grassland-dependent birds, including those of other lark species, have found that densities of these species are influenced by cereal crop farming (e.g. Kamp et al., 2012) or grassland burning practices (e.g. Holmes & Robinson 2013; Cox et al., 2014). The density of grassland dependent lark species such as Calandra Lark, Black Lark, Short-toed Lark and Skylark decrease dramatically under scenarios based on significant expansion of cereal crop yield production (see Kamp et al., 2016). Thus, it appears that cereal crop farming is incompatible with the preservation of many grassland-dependent lark populations. Halting the conversion of grassland habitat to croplands will therefore form the critical part of an evidence-based conservation strategy aiming at recovering the population of the Liben Lark.

3.5.2. Surveying the Liben Lark population using Distance Sampling

Population surveys of Critically Endangered bird species usually face the problem of small sample sizes, often therefore resulting in wide confidence intervals of density estimates (e.g. Lloyd, 2008). This is precisely the case with the Liben Lark, and this has implications for data analyses for future surveys on the Liben Plain and also at another site named Jijiga in eastern Ethiopia, where the species has recently been found (see Chapter 1). The variation in densities and sample sizes show that greater efforts need to be made to increase the likelihood of detecting Liben Larks during future Distance Sampling surveys. During this study, greater number of Liben Larks were detected during surveys conducted during the main wet season in May/June and also during the shorter wet season around November, with the least during the dry seasons, resulting in those data being omitted from the analyses. Thus, future surveys must first use the same transects and methods used in this study, and be conducted primarily during the main and shorter wet seasons. Surveys that are conducted only during the dry season months, when males are assumed to be singing much less frequently or not at all, are likely to detect very few individuals and thus will result in largely biased and less reliable density estimates (i.e. estimates with very large confidence intervals).

Most Liben Larks were detected within 200 m of each side of each survey transect (Table 3.1). However, there remains the likelihood that not all individuals were recorded during the surveys, particularly females. During a field trial in November 2012, a number of individual Liben Larks were detected using a simple playback technique, using recordings made of those individuals (Lloyd, *personal communication*). Individuals that were initially concealed from view, responded to playback of a male's display song, with both male and presumed females responded to playback. In some cases, individuals reacted by either displaying (males) or by emitting a low audible soft song from the ground (presumed females) or flying toward and beyond the location of playback over distances of +300 m (presumed both sexes). The use of playback may therefore hold some potential for increasing the number of individuals detected during population surveys and its use in conjunction with Distance Sampling line transect methods should be explored.

3.5.3. Density hotspots and implications for grassland habitat restoration

The long-term (multiple-year or survey season) data has revealed an interesting temporal pattern in the number, extent and location of hotspots of Liben Lark density that would not have been apparent from just a single season survey. There are now only four locations that can be deemed hotspots for the species within a very small core area of between 10 km^2 and 26 km^2 of the Liben Plain. Individual hotspot clusters generally range in size from 4.42 and 8.29 km^2 in extent. Of greater concern is the loss in 2011 of the 4.4 km^2 hotspot that was located in the north-western part of the plain in 2007, and that a total of 0.51 km^2 of the November 2013 density hotspot has been converted to farming for cereal crops. Conservation strategies designed to boost the Liben Lark population must therefore capture the spatial configuration and temporal patterns in density hotspots. My analyses reveals three grassland areas as being immediate priorities for the survival of the species, all of which are very small and average between 4 km^2 to 8 km^2 of grassland habitat. I suggest that these areas require immediate conservation action via the protection and restoration of the habitat within them.

According to the area of overlap of the different survey seasons as compared to the hotspot of all the years combined, these three areas are repeatedly used by the Liben Larks. Cereal crop farming is negatively impacting the extent and location of hotspots in the core area of the species. These cropland areas should also be targeted for conversion to grassland by immediate habitat restoration as cropping is not productive in these areas. Following restoration of these areas, subsequent targets should be protection and restoration of the remaining grassland within the 26 km^2 core area. The 2007 density estimates should be the target for population recovery goals in the short term.

The question remains however, is how best to restore the grassland habitat? The creation of traditional communal enclosures or *kallos* would be a critical component of the grassland restoration scheme, provided this approach is led by the local community. *Kallos* have the potential to recreate and restore grassland to a quality that may be able to provide the Liben Lark with good feeding and nesting habitat and thus achieve the population recovery goals mentioned above. In 2010, a two hectare *kallo* was set up at the edge of one of the known Liben Lark hotspots (central-west) and although a single Liben Lark male was seen displaying from the habitat within the *kallos* in June 2010, the *kallos* was soon disbanded. Newly restored grass within the *kallos* can also be cut after the Liben Lark breeding season and used for livestock fodder by the Borana pastoralists. Post-establishment surveys for grassland habitat quality and *kallos* use by Liben Larks must also form part of the habitat restoration strategy.

In the next chapter I will examine the influence of grassland habitat quality and other habitat features on the presence/absence of the Liben Lark to determine how these characteristics may further influence the design of habitat restoration strategies for the recovery of the species.

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Chapter Four

HABITAT ASSOCIATIONS OF THE LIBEN LARK

4.1. Abstract

Understanding the influence of habitat quality on bird abundance is important in order to be able to prioritize conservation works. I used presence/absence data of Liben Lark from bird surveys conducted from 2007 and 2009-2013 and related these data to structural habitat characteristics from the same period. Habitat surveys revealed that >21% of the grasslands covered by the transect surveys had been converted to crops by the end of 2013. There was considerable temporal variation in the mean habitat characteristics of the Liben Plain. Multiple logistic regression analyses generated minimum adequate models that identified the key habitat features that influence the presence or absence of the Liben Lark during 2007–2013. Key grassland habitat features were readily identified during the main and short wet seasons, but dry season surveys did not reveal any significant habitat associations, in part due to the extremely low number of larks detected during these dry seasons. Liben Lark presence was positively influenced by more medium-height grassland quality (ranging from 5cm to 40cm) but they avoided areas of very tall grasslands. Trees, areas of bare ground, short degraded grass (<5cm height) and invasive scrub all had negative effects. These findings help conservation practitioners to set realistic restoration goals that would help restore suitable habitat for the Liben Lark and good areas of grazing pasture for livestock.

4.2. Introduction

Anthropogenic activity has greatly altered natural grassland ecosystems across the globe. These ecosystems are currently recognized as one of the most threatened ecosystems in many countries around the world (e.g. Noss et al., 1995). Many of these grasslands support unique grassland-dependent bird species, many of which are now facing dramatic population declines as a consequence of both reductions on grassland quantity and of deterioration in grassland quality (Sauer & Link, 2011). Vegetation structural characteristics are known to influence grassland bird species abundance (Winter et al., 2005). Therefore, understanding the influence of habitat quality on bird abundance is a priority area of conservation research, particularly where the conversion of native grassland habitats to agricultural uses is thought to contribute toward such population declines (Vickery et al., 2000).Many of these threatened grasslands are used as pasture for livestock grazing (Goldewijk, 2001). Whilst some studies have shown that livestock grazing benefits some grassland-dependent bird species through modification of grassland vegetation structure (e.g. Muchai et al., 2002; Fondell & Ball, 2004), others have highlighted the negative effects of such habitat modification (Belho et al., 2014). Research has also revealed that declines in grassland bird abundance is also influenced by vegetation changes caused by shifting local farming practices (Samson & Knopf, 1994; Vickery et al., 1999; Donald et al., 2006; Askins et al., 2007) and increased woody vegetation encroachment (Coppedge et al., 2001; Scheiman et al., 2003; Grant et al., 2004).

The Liben Plain represents 24,000 ha of the Borana rangelands and still significantly supports the Ethiopian livestock sector (see Chapter One). Approximately 12,000 people inhabit and communally manage the plain. Some 85% of this rural population being dependent on pastoralism, owning approximately 48,000 cattle (Chapter One). These plains are also important for biodiversity and have been designated as an Important Bird Area and form part of the South Ethiopian Highlands Endemic Bird Area. Over the last 40 years, intensive overgrazing and a decline in nomadic pastoralist management, driven by settlement initiatives, has led to severe grassland degradation and reduction on the Liben Plain (see Chapter Two). The Liben Plain has lost significant areas of grassland habitat due to illegal conversion to cereal crops (Spottiswoode et al., 2009), whilst other areas are subject to increased levels of unsustainable grazing pressure (Donald et al., 2010). Between 2007 and 2009 there was a significant decline in grass vegetation cover and height, and the proportion of bare ground increased more in areas where the species was recorded in 2007, suggesting a rapid degradation of the sites containing the best quality grassland habitat (Donald et al., 2010). Fennel plants *Ferula communis*, which proliferate when grass is overgrazed, have also increased in abundance across the plain. There was also a loss of approximately 8% of good habitat to cereal crop agriculture between 2007 and 2009 (Donald et al., 2010).

These changes in vegetation structure and land use were correlated with a 40% decline in the number of Liben Larks recorded along survey transects (Donald et al., 2010). Now listed as Critically Endangered (BirdLife International, 2014), the Liben Lark currently represents Africa's most threatened bird species (see Chapter One); without intervention, its extinction was once predicted as likely to occur as early as 2020 (Spottiswoode et al., 2009). When first discovered, the Liben Lark's habitat was noted as being composed of longer grass, about waist-high, which is not the case now (Collar et al., 2008). Identifying the habitat preferences of the Liben Lark has proved difficult, largely due to the species being very secretive and difficult to detect unless it is singing and displaying, but also because there may be so few individuals to detect. Another reason for the difficulty in identifying habitat preferences is because the remaining habitat is extremely uniform, owing to such close grazing by so many cattle. Observations from decades ago suggest that areas of longer grass may have been important for the species (Collar et al., 2008). Recent logistic regression models based on two survey seasons in 2007 and 2009 have revealed that males preferentially occurred in areas of grassland with greater cover of medium-length grass (5–15 cm in height) with less bare ground cover and fewer woody bushes (Spottiswode et al., 2009). Similarly in 2009, Liben Larks were associated with areas with greater than average grass cover and areas of taller grass (Donald et al., 2010). More importantly, the amount of bare ground and the number of invasive trees and bushes were significantly negatively correlated with the presence of the Liben Lark along survey transects (Donald et al., 2010).

In this Chapter, I build on these earlier investigations by examining the influence of habitat characteristics on the presence/absence of Liben Lark using presence/absence data collected from dry and wet season bird surveys conducted from 2007 and 2009–2013. I then relate these data to structural habitat characteristics from the same period. Specifically, I was interested in the following research questions: (1) what are the primary grassland habitat characteristics across the Liben Plain and how have these changed across different surveys? (2) Has there been significant deterioration in habitat quality since the first empirical surveys in 2007? (3) Which features of the habitat best predict the presence/absence of Liben Lark and are these predictors consistent across different seasons? (4) What are the implications for the design of grassland habitat restoration strategies aimed at boosting the Liben Lark population that also incorporate livestock grazing?

4.3. Methods

4.3.1. Study site

A full description of the study site and the Liben Plain is given in Chapter Two.

4.3.2. Bird survey method

The Liben Lark population was surveyed using an adaptation of a Distance Sampling line transect method (see Spottiswoode et al. 2009). Data were collected by several different observers across the different seasons including myself since 2010, but I was the primary data recorder for all surveys since 2012. Twenty transects with 252 survey waypoints placed 250 m apart along each transect were established in a 30-km^2 area of the Plain corresponding to the core area occupied by the remnant Liben Lark population. Transect length totalled 63 km and were situated approximately 1 km apart, and have been used to survey the population since 2007. Transects were surveyed from 06:30 a.m. to 11:00 a.m. and observers recorded the number of individuals, distance from transect, and whether the individuals were either male or female assuming that only the males were making display calls. GPS coordinates of each observation were recorded from where individual birds were first sighted. Data collected from 2007 to 2013 are referred to as follows: Survey One - Main Wet Season June 2007; Survey Two – Main Wet Season June 2009); Survey Three – Main Wet Season June 2010; Survey Four – Main Wet Season May 2011; Survey Five – Dry Season August 2012; Survey Six – Short Wet Season November 2012; Survey Seven – Dry Season January 2013; Survey Eight – Main Wet Season May 2013; Survey Nine - Short Wet Season November 2013.

4.3.3. Grassland habitat surveys

Grassland habitat variables were recorded from the same transect waypoints along the same line transects used for the Liben Lark population surveys and using the same methods as Spottiswoode et al., (2009) and Donald et al., (2010). Observers recorded the number of trees, fennel plants, paths/tracks and the number of harvester ant nests (indicated by large, roughly circular patches of bare ground) within a 25 m radius of each waypoint. The two latter measurements were taken because the number of animal tracks and ant nests are also expected to influence grass height. Within two 5-m radius circles, located on both sides of the way point and perpendicular to the axis of the transect, the number of bushes and cowpats were counted and the percentage of bare ground was estimated. The height of the grass in these areas was also estimated as the percentage cover of grass less than 5 cm tall, 5–15 cm tall, 15–40 cm tall and grass over 40 cm tall (Spottiswoode et al., 2009).

4.3.4. Statistical analysis

Univariate statistical analyses were conducted using SPSS for Windows Release 20.0.1 (SPSS Inc., 2013). Habitat variables were examined for normality using a combination of Kolmogorov–Smirnov tests and visual inspection of histograms. I examined differences between the habitat variables recorded in different survey seasons using non-parametric Kruskal–Wallis tests. Associations between the presence and absence of Liben Lark from survey waypoints and all possible explanatory habitat variables were examined using univariate binomial logistic regression analysis with logit-link function and backward elimination (Cox & Snell, 1981). To test for spatial autocorrelation, I examined the correlation coefficients for all habitat variables and retained all variables that were <0.9

(following Lipsey et al., 2015). Nagelkerke R^2 was used as a measure of the variation explained by each logistic model (Nagelkerke, 1991) and model fit was assessed using the Hosmer & Lemenshow chi-square (χ^2) goodness of fit test.

4.4. Results

4.4.1. Changes in areas of Liben grassland during 2007-2013

Out of all the 252 waypoints that were located in grassland when the surveys started in 2007, more than 21% had been converted to crops by the end of 2013 (Figure 4.1). The increase in crop fields in the survey area started slowly after 2007, with 7.5% (n=19) of grassland waypoints being converted to crop by the beginning of 2009. The largest crop expansion took place between 2009 and 2010, corresponding to 20% (n=52) of grassland waypoints in the Liben Plain. After this, net conversion to cropland appeared to have slowed with a total of 54 grassland waypoints were as cropland by the end of 2013. From 2011 onwards conversion appears to have largely been compensated for by abandonment of cropped areas such that by the end of 2013, 5% (n=12) of waypoints previously in crop fields had reverted back to grassland habitat through regeneration.

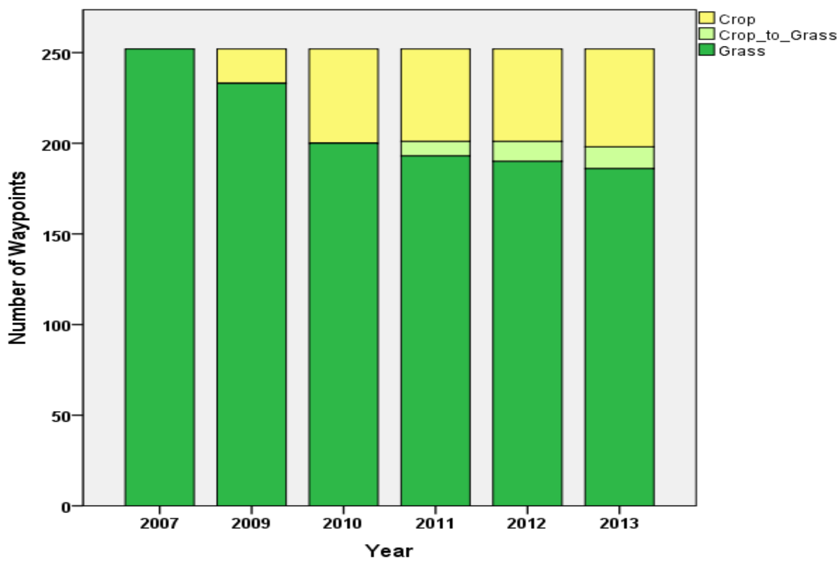

Figure 4.1 Showing the number of waypoints located in grassland, crop fields and areas of crop field that have recently been reconverted to grassland during 2007 – 2013

4.4.2. Temporal patterns in rangeland habitat characteristics

Across all surveys there was considerable temporal variation in the mean habitat characteristics of the Liben Plain. The number of trees differed significantly across surveys (H= 144.2; df = 8; P<0.05) with most trees being recorded in June 2009. However, since May

2011 the mean number of trees has noticeably decreased to its lowest levels. The mean number of ant nests also showed some variation (H= 60.4; df = 8; P<0.05), with numbers increasing from November 2012 onwards and reaching the highest numbers in May and November 2013. The number of paths fluctuated seasonally (H= 137.3; df = 8; P<0.05) with a peak in May 2011. Both the mean number of bushes (H= 21.8; df = 8; P<0.05) and cowpats (H= 241.7; df = 8; P<0.05) differed significantly, with bush numbers peaking in May 2011 and cowpat volume peaking in August 2012 and November 2013.

There was also significant seasonal variation (H= 156.0; df = 8; P<0.05) in the amount of fennel recorded from survey plots. Higher numbers were recorded in the wet seasons, with the highest means in May 2011 and May 2013. The mean percentage bare ground cover fluctuated across sampling times (H= 604.6; df = 8; P<0.05), reaching peaks in June 2009 and May 2011. Estimates of all grass height categories showed significant variation across seasons. The proportion of grass in the shortest (<5cm) grass height category (H= 972.0; df = 8; P<0.05) showed a sharp decrease in June 2010 following the highest mean value recorded in June 2009. The lowest and highest mean percentage cover in the 5–15cm height category (H= 854.7; df = 8; P<0.05) was recorded in June 2009 and June 2010 respectively, with mean values steadily increasing until May 2013. Significant differences were also recorded for medium-height (15–40 cm) grass category (H= 887.6; df = 8; P<0.05), with the highest and lowest percentages recorded in November 2012 and May 2011 respectively. The mean percentage of the tallest, least disturbed grass (>40 cm height) showed significant variation (H= 925.5; df = 8; P<0.05) between surveys, with peaks in grass height being recorded in November 2012 and May 2013. Taller grass was recorded during 2007 but grass height was much lower in 2009. From August 2012, although grass height remained relatively low, there was more medium and taller grass, suggesting that as a whole the grassland habitat was experiencing a greater degree of natural regeneration and reduced grazing. Variation in all habitat characteristics was significantly different between dry season surveys (Mann-Whitney U tests, P<0.001), shorter wet seasons (Mann-Whitney U tests, P<0.05) and the main wet season surveys (Kruskal-Wallis tests, P<0.05).

4.4.3. Influence of habitat factors on presence/absence of Liben Lark

Results of the multiple logistic regression analyses generated models that identified they key habitat features influencing the presence or absence of the Liben Lark during the years 2007–2013 (Table 4.2). Across all surveys the number of variables in each minimum adequate model that had a significant influence on Liben Lark presence/ or absence varied as did the type of variable (Table 4.2). Generally, factors influencing Liben Lark presence or absence were more commonly identified during the wet season surveys, particularly the main wet seasons, than during surveys conducted at other seasons of the year. Surveys conducted during the two dry seasons (August 2012 and January 2013) identified the least number of variables and none of these were significant in the minimum adequate models. Across three of the main wet seasons, the abundance of trees had a significant negative influence on lark presence, with increasing areas of bare ground cover having a significant negative influence across two main wet seasons and one shorter wet season (Table 4.2). Short heavily grazed grass (<5 cm in height) had a significant negative effect on lark presence during only the main wet seasons (May) and shorter wet season (November) of the 2013 surveys. Number of paths, ant-nests and invasive scrub also had a significant negative effect on lark presence at waypoints during only the main wet season surveys of 2007 and 2011 respectively.

Short-to-medium height grass (5cm-15cm) and medium height grass (15cm-40cm) had significant or near significant positive influence on lark presence across the majority of main wet season surveys and one short wet season. Tall grass (>40cm in height) was only included in one model (main wet season June 2009) and did not exert any significant influence on lark presence or absence. Interestingly, invasive fennel had a positive influence on lark presence during the short wet season on 2012 and main wet season of 2013.

4.5. Discussion

4.5.1. Changes in areas of grassland 2007–2013

Loss of grassland to crops is still occurring across the Liben Plain and currently 21% of all grassland survey transect waypoints have been converted to cereal crops. There was a dramatic increase in the amount of grassland converted to cereal crops from 2007 to 2010. This was due primarily to the illegal acquisition of land by some residents of Negelle. These residents illegally obtained an identity card from the peasant associations which enabled

Table 4-1 Showing binary logistic regression models (using backward elimination) of presence/absence of Liben Lark recorded from all transect waypoints during 2007–2013 surveys and all habitat variables. Model fit χ^2 = Hosmer & Lemenshow chi-square (χ^2) goodness of fit test.

Survey	**Minimum Adequate Model**	**Coefficient (± SE coefficient)**	***Z***	***P***	**Model Summary**
June 2007 (Main wet season)	Number of trees	-1.074 ± 0.518	4.303	**0.038**	-2 Log-likelihood = 278.8
	Number ant nests	0.300 ± 0.149	4.021	**0.045**	Nagelkerke R^2 = 0.233
	Mean number of bushes	-2.089 ± 0.826	6.396	**0.011**	χ^2_8 = 4.8, P = 0.778
	Mean % Bare ground	-0.040 ± 0.012	11.800	**0.001**	
	Mean % Grass 5cm-15cm	0.021 ± 0.008	6.208	**0.013**	
June 2009 (Main wet season)	Number of trees	-1.313 ± 0.573	5.257	**0.022**	-2 Log-likelihood = 186.9
	Mean number of bushes	-2.816 ± 1.936	2.116	0.146	Nagelkerke R^2 = 0.224
	Mean % Bare ground	-0.050 ± 0.015	10.717	**0.001**	χ^2_8 = 10.3, P = 0.241
	Mean % Grass >40cm	-31.448 ± 5327.1	0.000	0.995	
June 2010 (Main wet season)	Number of trees	-1.174 ± 0.568	4.274	**0.039**	-2 Log-likelihood = 220.6
	Mean % Grass <5cm	0.277 ± 0.179	2.402	0.121	Nagelkerke R^2 = 0.191
	Mean % Grass 5cm-15cm	0.350 ± 0.181	3.754	**0.049**	χ^2_8 = 11.8, P = 0.160
	Mean % Grass 15cm-40cm	0.377 ± 0.196	3.690	0.055	
May 2011 (Main wet season)	Number of trees	-15.681 ± 1351.9	0.000	0.991	-2 Log-likelihood = 104.4
	Number of paths	-1.015 ± 0.371	7.503	**0.006**	Nagelkerke R^2 = 0.338
	Number of bushes	-2.491 ± 1.884	1.748	0.186	χ^2_8 = 8.4, P = 0.391
	Mean % Grass 5cm-15cm	0.050 ± 0.014	12.218	**0.000**	
August 2012 (Dry season)	Number of fennel	0.051 ± 0.031	2.802	0.094	-2 Log-likelihood = 12.2
	Number of paths	-15.075 ± 1903.6	0.000	0.994	Nagelkerke R^2 = 0.631
	Mean number of bushes	-62.850 ± 3255.2	0.000	0.985	χ^2_8 = 0.8, P = 0.998
	Mean % Bare ground	-0.110 ± 0.088	1.560	0.212	
	Mean % Grass <5cm	-0.498 ± 0.278	3.219	0.073	
	Mean % Grass 5cm-15cm	-0.379 ± 0.234	2.620	0.106	
	Mean % Grass 15cm-40cm	-1.522 ± 0.902	2.846	0.092	

Table 4-2 (continued) showing binary logistic regression models (using backward elimination) of presence/absence of Liben Lark recorded from all transect waypoints during 2007–2013 surveys and all habitat variables. Model fit χ^2 = Hosmer & Lemeshow chi-square (χ^2) goodness of fit test

Survey	**Minimum Adequate Model**	**Coefficient (± SE coefficient)**	***Z***	***P***	**Model Summary**
November 2012 (Short wet season)	Number of Fennel	0.035 ± 0.016	4.448	**0.035**	-2 Log-likelihood = 120.5
	Number of bushes	-2.350 ± 1.959	1.668	0.196	Nagelkerke R^2 = 0.143
	Mean % Bare ground	-0.035 ± 0.021	2.958	0.085	χ^2_8 = 8.6, P = 0.374
	Mean % Grass 5cm-15cm	0.031 ± 0.015	4.187	**0.041**	
January 2013 (Dry season)	Mean % Grass 5cm-15cm	0.071 ± 0.048	2.255	0.133	-2 Log-likelihood = 28.7
					Nagelkerke R^2 = 0.089
					χ^2_8 = 7.5, P = 0.479
May 2013 (Main wet season)	Number of Fennel	0.010 ± 0.005	5.026	**0.025**	-2 Log-likelihood = 108.2
	Number of paths	-0.921 ± 0.524	3.084	0.079	Nagelkerke R^2 = 0.170
	Mean % Grass <5cm	-0.057 ± 0.025	5.152	**0.023**	χ^2_8 = 8.1, P = 0.431
	Mean % Grass 15cm-40cm	0.105 ± 0.050	4.451	**0.035**	
November 2013 (Short wet season)	Number of trees	-17.914 ± 3438.0	0.000	0.996	-2 Log-likelihood = 65.8
	Number of Fennel	-0.700 ± 0.619	1.277	0.258	Nagelkerke R^2 = 0.382
	Number of cowpats	-0.298 ± 0.188	2.524	0.112	χ^2_8 = 3.6, P = 0.889
	Mean % Bare ground	-0.111 ± 0.037	9.022	**0.003**	
	Mean % Grass <5cm	-0.328 ± 0.168	3.813	**0.051**	
	Mean % Grass 5cm-15cm	0.311 ± 0.169	3.383	0.066	
	Mean % Grass 15cm-40cm	0.384 ± 0.215	3.184	0.074	

them to get permission from the Liben District Land Use Office to farm on the Liben Plain. The Land Use Office does not have the budget to travel to the site or the expertise to be able to determine the extent of land allocated to residents for farming, thus allowing existing farmers to gradually expand their farms. However, whilst the percentage is high, the amount of land currently being utilized for cereal crop production has remained fairly constant since 2010. This finding is encouraging but one possible cause of this could be the drought that took place from the end of 2010 until May 2011 during which many cattle died and where most of the crops on the Liben Plains failed (Liben Pastoralist Development Office, *personal communication*). The lack of an irrigation system and an outbreak of African army -worms (*Spodoptera exempta*) which tend to occur at very high densities during the rainy season, especially after periods of prolonged drought (Haggis, 1984) as was the situation in 2011, could have also contributed to the low cereal crop yields (Liben Pastoralist Development Office, *personal communication*).

4.5.2. Temporal changes in rangeland habitat characteristics

Surveys conducted across the Liben Plain between 2007 and 2013 reveal that the structural characteristics of the grassland habitat do not remain static but change across different sampling times. Other studies have shown that grassland vegetation structure varies significantly over time when there are significant changes to land-use practices such as the abandonment of agriculture and with changing grazing pressure (Kamp et al., 2012). A variety of factors could explain the temporal change in Liben grassland structural characteristics noted during this study. For example, the numbers of trees and bushes have shown a decline since 2011, which coincides with the beginning of a programme of tree/scrub removal and clearing led by the Ethiopian Wildlife and Natural History Society. This NGO has cleared an area of about ten square kilometres along some of the survey transects (Transect 16 and 18). The Borana pastoralists are also known to occasionally clear bushes in order to build fences for grass enclosures near their houses.

Patterns of variation in grass structural characteristics are very interesting. On average, despite there being some fluctuation, the grass across the Liben Plain was getting marginally taller during the more recent surveys in 2012 and 2013 until November 2013 when there was a sharp decrease in amount of tall grass and a large increase in the percentage short grass. This could be attributed, in part, to the low levels of precipitation during the short rainy season of 2013, since rainfall data reveals that the amount of rainfall in November 2011 was more than twice than that of November 2013. Unfortunately, the data for November

2012 is not available and hence it is difficult to be certain. What is apparent is that to understand fully, the factors that may influence the abundance of the Liben Lark across the Liben Plain, more surveys across several consecutive seasons are required to explain the variation in grassland quality as this varies within and across years.

4.5.3. Influence of habitat factors on presence/absence of Liben Lark

These results are largely in agreement with previous studies that suggest a high influence at the local patch-level, of vegetation characteristics such as grassland vegetation height and grass cover on lark presence or absence, and the detrimental effects of shorter, sparse grassland cover and exposed areas of bare ground (Kamp et al., 2012). Research in 2007 suggested that the Liben Lark was dependent on taller grass (Spottiswoode et al., 2009) but that was not found to be the case in 2009 because the grass across the plain was almost uniformly short (Donald et al., 2010). Furthermore, in 2007, Liben Larks avoided areas of woody vegetation, areas with very short grass and bare ground and they were never recorded in areas of cereal crops (Spottiswoode et al., 2009). This study can reveal that since 2007, the habitat characteristics that best predict the presence/absence of Liben Lark in one season or year may not be suitable predictors of Liben Lark presence/absence in subsequent seasons or years. Donald et al., (2010) also suggest that significant habitat predictors of Liben Lark presence/absence may vary across different years.

From 2007 to 2013, short-to-medium and medium height grass, ranging from 5cm to 40cm was an important factor influencing the presence of Liben Larks along survey waypoints. Unexpectedly the tallest grass, over 40cm in height, and an indicator of the least disturbed, less grazed areas of grassland, was not significant (Table 4.2). Differences in grazing pressure and grassland vegetation characteristics have been used by studies to explain differences in lark species distribution and abundance at smaller, local-level (patch-level) scales (Kamp et al. 2012). Calandra Lark *Melanocorypha calandra* abundance in grassland steppe habitats is higher in areas with less grazing pressure from livestock (Fedosov, 2010), with densities gradually increasing with increasing grassland vegetation height (Morgado et al., 2010). Skylark *Alauda arvensis* density reaches a maximum at an intermediate grassland height of around 55cm to 60cm (Donald et al., 2001; Kamp et al., 2012). Black Lark *M. yeltoniensis* are known to prefer denser, taller grass and avoid areas of bare ground and sparser cover (Kamp et al., 2012). Short-toed Lark *Calandrella brachydactyla* presence in grassland steppe habitats in Spain is positively correlated with low livestock grazing pressure, but interestingly not related to grassland vegetation height (Suárez et al., 2002).

More interesting perhaps is the known absence of Rudd's Lark *H. ruddi*—the only other member of the genus - from areas of dense and very tall stands of grass in the Highland grasslands of South Africa (Hockey et al., 1988). These grassland habitats are used for the grazing of sheep and cattle, but are also experiencing an increasing amount of arable agricultural land-use (Hockey et al., 1988). In these highlands, some grassland areas are left ungrazed for long periods, resulting in dense tall stands of grass dominated by *Themeda triandra* with other areas cultivated for monocultures of tall dense stands of pasture grasses (e.g. *Eragrostis curvula*) used largely for winter fodder. Both of these habitats are avoided by Rudd's Lark, which seems to prefer moderately grazed grasslands (Hockey et al., 1988). Furthermore, intensive livestock grazing does not necessarily adversely affect Rudd's Lark, provided such grazing does not lead to invasion of the area by plants other than grasses (Hockey et al., 1988). Indeed, during the breeding season Rudd's Lark selects areas of grassland for nesting that are shorter than average, particularly favouring areas that have been burned shortly before the start of the breeding season (Maphisa et al., 2009). Thus, *Heteromirafra* larks may not prefer the tallest, densest, least disturbed grassland areas but actually benefit from the vegetation characteristics maintained through low-to-moderate grazing practices and, in some instances, moderate burning practices. Therefore, maintaining the grassland as mosaic of different sward structures might facilitate different areas of foraging and nesting for the species.

Woody habitat and invasive woody scrub had a negative influence on Liben Lark presence in some surveys. Several studies have documented the negative effects of increased levels of woody vegetation on the abundance of obligate grassland bird species (e.g. Coppedge et al., 2001; Scheiman et al., 2003; Grant et al., 2004, Hill & Deifenbach, 2014). Some studies have even found a negative influence of tree cover on the abundance of grassland-dependent lark species (e.g. Ambarli & Bilgin, 2014). Bare ground was also a negative influence on Liben Lark presence. This is very similar to previous findings (see Spottiswoode et al., 2009 and Donald et al., 2010) and suggests that the Liben Lark population is negatively affected by disturbed, overgrazed areas with very short grass, degraded bare ground and woody invasive shrubs or trees. Bare ground and other vegetation characteristics such as forbs and dead vegetation are also unsuitable areas for nesting habitat by Rudd's Lark (see Maphisa et al., 2009).

Fennel abundance showed a significant increase in 2009 from 2007 (Donald et al., 2010). In addition, fennel abundance was much greater during surveys conducted in the main rainy season (May–June) than in the other, dryer sampling times. Fennel usually dries out during the dry season (August and January) and beginning of the second short wet season (November) with regeneration starting after getting adequate rain. In addition, the number of cowpats, which is presumed to be a reliable indirect measure of cattle abundance and an indicator of grazing pressure, was also higher in the dry seasons as well as in the beginning of the rainy seasons. One reason could be the lack of adequate rain that would normally break-up cowpats, rather than there being a significant difference in cattle numbers or grazing pressure between wet and dry seasons. Thus drawing conclusions about invasive fennel and the volume of cowpats, and their potential impact on the grassland of the Borana rangeland must take into account the seasonal variation in relation to wet or dry seasons.

The predictive accuracy was low for all logistic regression models across all survey seasons with Nagelkerkes R^2 values ranging from 8% to 38%, with the exception of the August 2012 Dry Season model (Table 4.2). Previous studies of grassland-dependent lark species have also found similar ranges of variation explained using regression models (see Kamp et al., 2012 for more details). Although the R^2 value for this was 63% there were far fewer individual Liben Larks recorded during this season, and consequently, this model perhaps is the least reliable due to the low sample size of presence records. In addition, key habitat characteristics that have either a positive or negative influence on Liben Lark presence were only identified during wet season surveys, and more during the main wet season of May/June rather than the shorter secondary season in November (Table 4.2). No significant influences were detected during the two dry season surveys, and part of the reason for this was the differences in detecting individual larks between wet and dry seasons. The majority of contacts during surveys were thought to be singing males, who tend to sing more and thus are more conspicuous during the wet seasons (Abdu, 2012) although it is equally difficult to detect non-singing males and females during any season. Variation in the number of significant influences during the main and shorter wet seasons could be attributed to having lower detectability due to the timing of survey, as males of other lark species tend to sing less frequently during incubation and brooding time (Donald et al., 2010). Future surveys need to consider using an additional methods, such as playback techniques, in conjunction with the current line transect method. During the surveys in November 2012, playback of the display song was trialled at different males over a short two-day period. Both males and near-by females responded vocally and with aggressive behaviours e.g. flight toward and beyond the playback, agitated calls from perched birds, alarmed posture on the ground by perched birds, display songs. This technique holds some promise for future surveys, particularly if they are trialed during the dry season to increase the chance of detecting larks.

4.5.4. Implications for habitat restoration strategies on the Liben Plain

These results have some important implications for any future proposed restoration strategies for the Liben Lark's habitat. First, habitat restoration efforts should focus on activities that restore areas of the Liben Plain to recreate areas of medium height grass, ranging from 5cm to 40cm in height (Table 4.2). These activities could be driven by encouraging more traditional grazing practices in these areas and working closely with the Borana people as well as other relevant stakeholders across the Liben Plain. These activities should be made together with efforts to enhance the growth of existing short grass areas (<5cm in height) so that they become taller and better in quality (Table 4.2), possibly through the use of communal enclosures, known locally as *kallos* (see Chapter One) or other means of cattle rotational grazing practices. The restoration of traditional burning regimes across the Plain could also be encouraged once the grassland habitat has recovered to sufficient quality and quantity. Burning could help create suitable nesting grounds for the Liben Lark as has been observed with the congeneric Rudd's Lark (Maphisa et al., 2009), as well as help control bush encroachment and maintain good quality grass for cattle (Angassa & Oba, 2008). Other important restoration goals should be to reduce the amount of degraded bare ground cover and paths through perhaps areas set aside as communal *kallos* to permit natural regeneration, and the removal of invasive trees or bushes, which have a significant negative influence on Liben Lark abundance during the wet seasons (see Table 4.2). Thompson et al., (2014) showed that reducing the amount of trees and bushes in an area is more effective in increasing the density of grassland birds in an area than actually trying to improve the grass quality and quantity.

These data reveal that cereal croplands do not represent good habitat for the species for either feeding or breeding. Areas of crops abandoned for just two or three years have also shown a degree of natural regeneration (Fig. 4.1) without specific management interventions, whilst other small areas of degraded grassland habitat are also showing signs of natural regeneration. This could be due to the increased rainfall amount in recent years and also because of a decrease in bush and tree cover in some parts of the Plain. Hence, it is very likely that suitable areas of grassland habitat can be restored from abandoned crop fields and current degraded bare ground areas. Other studies have found that grassland-dependent larks largely avoid cereal cropland habitat (e.g. Kamp et al., 2011; Ambarli & Bilgin, 2014) although some grassland lark species do utilize former cropland habitat for feeding and nesting but only after abandonment for several years (e.g. Lameris et al., 2016). Increases in cereal crop yields also has detrimental effects on the densities of grassland-dependent lark species such as Calandra Lark, Black Lark, Short-toed Lark and Skylark (Kamp et al., 2016). Thus the continued loss of grassland and conversion to cereal crops will not benefit the Liben Lark. Coupled with inconsistent crop yields across the plain, the future of these farming activities and realistic restoration plans to fulfil the pressures for grazing livestock and for creating new habitat for the Liben Lark need to be fully evaluated under a newly revised Participatory Rangeland Resource Assessment that includes all stakeholders in the region. In order to be able to do that it is essential to understand what the current land management practices are and which institutions have mandates to influence the land management at the study site. This will be the focus of the next Chapter of this PhD.

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Chapter Five

INSTITUTIONS AND GOVERNANCE OF THE NATURAL RESOURCES OF THE LIBEN PLAIN

5.1. Abstract

Pastoralism in Africa is mainly based on rearing livestock and strategic movement in order to access grazing resources. Pastoralism in Ethiopia has not been given the necessary attention and focus in order to be able to be a primary management tool for sustainable rangeland use. Borana pastoralists are known to have utilised rangelands in southern Ethiopia for centuries and are governed by the traditional *gadda* system. Their system of land management divides the grazing resources into different sections to be well utilized, sometimes even utilizing wet and dry season grazing reserves, permitting the grassland habitat to be restored and used sustainably. However, there remain significant gaps in our documented knowledge in terms of the institutions involved in land allocation and grazing management on the Liben Plain. For this research, Focus Group Discussion and Semi-structured interviews were used to gather data from the community members in the Siminto and Meisa Peasant Association of the Liben Plain. There have been adverse changes in the rangeland habitat, mostly involving expansion of agricultural fields. Access to land for either cropping or for private enclosures is handled mostly by government institutions and does not involve the traditional institutions. Members of the traditional institutes such as the *Abba Dheedaas* still demand that people go elsewhere for their wet season forages which is not followed through by most inhabitants. Therefore a well-coordinated management approach is necessary to ensure the sustainable use of the rangelands on the Liben Plain.

5.2. Introduction

Pastoralism is a way of life and production system that involves about 268 million people in Africa who mostly inhabit the arid and semi-arid regions (African Union, 2010). Pastoral areas are found in three major natural zones in Africa which are characterised by low and highly variable rainfall. These are the Mediterranean and Saharan zone in North Africa, the sub-Saharan tropical and equatorial zone, and the Southern zone (African Union, 2010). Pastoralism in Africa is based on rearing livestock using strategic mobility in order to efficiently access and use grazing resources (Niamir-Fuller, 1999). These movements are seasonal and traditionally governed and, having been developed over centuries, are very well adapted to the environment as well as the type of livestock reared. The culture of pastoralists is at the heart of Africa's history, culture and heritage which is reflected in the various traditions and languages, including an indigenous social support system where poorer households who have lost livestock are supported (Coppock, 1994). Pastoralists are known to reside on about 43% of the land in the continent (African Union, 2010). Pastoralism contributes 10–44% to the gross domestic product (GDP) of African countries. The pastoral livestock and meat trade in the Horn of Africa alone reached a value of US$ 1 billion in the year 2010 (Behnke & Muthami, 2011). Other African countries such as Ethiopia, which has one of the largest livestock populations in Africa (UN OCHA-PCI, 2007), livestock numbers have been estimated to be about 53 million cattle, 25 million sheep, 22 million goats, 2 million horses, 6 million donkeys, 400,000 mules and around 1 million camels (CSA, 2011). The leather industry which is dependent on the country's livestock production is Ethiopia's second largest source of foreign currency after coffee (Kassahun, 2003; ICPALD, 2013).

5.2.1. Borana pastoralism in southern Ethiopia

In Ethiopia, pastoralists belong to at least 29 different ethnic groups with the majority being of Somali, Afar and Oromo ethnicity (PFE et al., 2010). According to the Ethiopian Agricultural Research Organization, pastoralism has occurred on more than 62% of the land categorized as arid and semi-arid rangelands in Ethiopia (Amaha Kassahun, 2003).The Borana are part of the Oroma pastoral sub-group living in the semi-arid areas of southern Ethiopia and northern Kenya. In Ethiopia, Borana territory used to correspond with the southern part of the Sidamo Region—a demarcation used during the imperial and socialist periods of the country's history (Bassi & Tache, 2011). However, the Borana rangelands are now located in the Borana and Guji Zones. Formerly, the Borana pastoralists were administered by a form of indigenous governance based on the '*Gadda*' system of generation classes that has existed since the 15thCentury (Legesse, 1973). Every eight years, a new generation class, which represents the elected leaders from the major clans, becomes the new leadership (Baxter, 1978).

The key natural resources in Borana rangelands are water, pasture and forests, which used to be managed as communal property under the *gadda* system (Tache & Irwin, 2003). Traditionally, property rights are usually divided into four regimes: namely the communal (common) property, open access, private property and state property (Berkes et al., 1989). A communal property regime has a well-defined user group, a well-defined resource that the group manages as well as a set of institutional arrangements that define the group and resource to be used. Resources are managed on a consensus basis for the benefit of the community, and this arrangement provides an incentive to help ensure their productivity for the future (Bromley & Cernea, 1989). Disruption of communal property regimes often results in open access regimes (Ostrom et al., 1990), in which users have privileges of using resources since there are no authoritative figures with a legal right to actually exclude them. Typically, the users as well as the resources to be used, are not well defined in this regime, and the management decisions are taken at the individual level, which will only benefit the individual concerned. Consequently, there is little or no incentive, in terms of the long-term sustainable use of the resources in question .

Most natural resources in Africa such as forests, rangelands and water bodies are traditionally viewed and utilized as communal property. With the relatively low human population and relatively low pressure on land-use, the communal system of pastoralism functioned very efficiently until around the 1960s (Coppock, 1994). In recent decades, the rise in human population, coupled with land degradation due to increased and largely unsustainable land-use pressures, began disrupting the *gadda* system. Consequently, the communal management system were viewed as largely inefficient by some academics and policy makers (Kamara et al., 2004). This was based largely on western notions of individual property rights as being most efficient for production (the 'Tragedy of the commons' paradigm - Hardin, 1968). Mobile livestock keeping was considered by decision makers to be unproductive and impracticable given that Ethiopian rangelands in the south of the country are exposed to unpredictable patterns of rainfall and severe droughts (Benhke & Kerven, 2013). Subsequently, there were further modifications of the Borana management system by adapting new policy reforms, but these reforms were not able to influence the patterns of unsustainable land-uses by pastoralists. Instead of understanding the traditional *gadda* management system and adapting it to the situation faced by the Borana pastoralists, the new reforms were more focused on actually replacing this communal management system (Kamara et al., 2004).

5.2.2. Pastoralist land ownership issues in Ethiopia

In Ethiopia, land tenure policy and legal frameworks on the rights of pastoralists within the country have not been adequately addressed. During Emperor Haile Selassie's regime, all communal lands, including rangelands, were considered to be the property of the state. Article 131 of the constitution of the Imperial Ethiopian government in 1955 stated that '*All property not held and possessed in the name of any person, natural or judicial as well as all* *products of the sub-soil, all forests and grazing lands, water-courses, lakes and territorial waters, are state domain*' (Imperial Ethiopian Government, 1955). This gave no recognition of pastoral rights to access key resources and to move freely between resources in seasons of need. Afar and Kereyou pastoralists in eastern Ethiopia were even forcibly relocated from their customary land without any form of compensation, so that the land could be used for commercial farming and protected areas. Then in 1968, a radical policy was initiated by the Imperial Government to push pastoralists into sedentary agriculture (Mulatu & Bekure, 2013). In 1974, the new socialist (Derg) regime nationalized all lands, but, according to the Rural Lands Nationalization Proclamation in 1975, pastoral land rights were recognized. Article 24 of this proclamation stated that 'nomadic people shall have the possessory rights over the lands they customarily use for grazing or other purposes related to agriculture'. However, Article 24 also removed any authoritative power and decision making of the traditional leaders to administer and manage the grazing lands. This required pastoralists to form associations with chairpersons and executive committees, which, under Article 10 of the same document, were then granted powers to 'induce the nomads to cooperate in the use of grazing and water rights and to carry out the functions of applying land use directives of the government, administer and conserve public property; establish judicial tribunals etc. within their locality' (PMAC, 1975).

Greater policy and legal recognition of pastoral land rights under the current ruling government (EPDRF) came into power in 1990. The 1994 constitution guaranteed that pastoralists cannot be displaced from their land under Article 40(5) (FDRE, 1995). This protection, however, was not translated into federal law. The Federal Lands Expropriation and Compensation Proclamation No. 255 from 2005 stated that compensation will not be provided in situations where communal lands have been expropriated. Furthermore, the 2003 Poverty Reduction Strategy paper (FDRE, 2003) and the 2005 five-year plan for Accelerated and Sustained Development to End Poverty (2005) actively promoting settled agriculture as an alternative to pastoralism. This was further supported in a 2010 draft document on the Growth and Transformation Program (2011-2015; FDRE, 2010), the purpose of which was to seek domestic and foreign investment to expand cultivation in the lowlands, and to settle pastoralists (Mulatu & Bekure, 2013).

In the traditional pastoralist system used to manage the land sustainably for livestock production, rangelands were divided into grazing areas around water points (*maddas*) and into areas having several villages (*ardas*) (Kamara et al., 2004). Typically, herds are divided into settled home herds or *warra*, and the mobile herd, known locally as *fora*. The *warra* consist of milking cows and calves, whereas *fora* consist of dry cows, bulls, immature males and oxen. The traditional grazing system used to subdivide the grazing reserve for the *warra* and the *fora* herds that were sent elsewhere when the forage became scarce (Oba, 1998). Access to grazing lands or '*Dheedaas*' was regulated by elders who were locally known as '*Abba Dheedaas*' or heads of grazing lands (PFE et al., 2010). In order to enhance the growth of calves and protect milking cows and sick animals some areas were set aside and was called *Seera Yabbii*. This was a type of traditional enclosure which was not physically fenced off. Communal and/or private enclosures (*kallos*) are areas of the grazing land that are mostly physically fenced off (usually with *Acacia drepanalobium*) and set aside for grazing by all types and ages of cattle. These types of *kallos* were not traditional practice. Nevertheless the communal *kallos* were first tried in the 1970s and started expanding in the 1980s. Community kallos could be built through the initiative of the community, the government or NGOs. These types of *kallos* benefitted large number of households with forage provision especially during the drought seasons (Tache, 2013).

Private *kallos* also have physical fences but they are used by the cattle of usually one household owner. Private *kallos* are much smaller than community kallos and started expanding after 2001 (Kamara et al., 2004; Napier & Desta, 2011). The traditional *warra* grazing areas have mostly been lost either to be used as communal *kallos*, which are restricted communities, or as private holdings in the form of farms or *kallos* (Kamara et al., 2004). Under this *gadda* system the Borana rangelands were sustainably managed as a communal property resource (Cossins & Upton, 1987). However, from the 1970s onwards major land use changes took place on these rangelands which limited herd mobility and increased use of cereal crop agriculture. The situation further deteriorated after the change in government in 1991 (Bassi & Tache, 2011).

5.2.3. Governing institutions and Borana pastoralists

The rangelands on the Liben plain are currently governed by different types of institutions. Institutions are defined as the structures of power that shape what can be made possible in a particular situation (O'Riordan & Jordan, 1996). These institutions can be fluid and dynamic, and can be altered with changing ideas and balances of power (Watson, 2003) through the active investment of the people that are governed by them (Berry, 1989). On the Liben Plain, three types of institutions currently co-exist. State institutions are all the different levels of government organizations and administrations operating at the zonal, district, and PA level, since they could influence the land management at the site. The zonal and district offices are based in Negelle town, which is the Guji zone capital and about 20 km from the Liben Plain. However, the state institution located at the site would be the Meisa and Siminto Peasant Associations. Traditional institutions are the different local actors and rules that exist as part of the *gadda* system. The third type of institution is represented by non-governmental organizations, some of which have a role in resource utilization in the area such as SOS Sahel, Save the Children, Mercy Corps and the Ethiopian Wildlife and Natural History Society (EWNHS). Collectively these institutions have played a significant role in management of the unique biodiversity in the area, including threatened species such as the Liben Lark. However, to date, there remain large gaps in our knowledge concerning the continuing ability traditional authority has to make and enforce collective grazing management decisions on the Liben Plain and the implications of this for biodiversity.

5.2.4. Aim and objectives

The purpose of this chapter is to identify the current state of knowledge and gaps in our knowledge in terms of the institutions involved in land allocation and grazing management on the Liben Plain. I use new and existing data to document the historic and current grazing systems employed by the Borana, perspectives on land-use changes and the institutions responsible for the management of the rangelands, and how traditional leaders and state actors (and potentially NGOs) interact in decisions around the management of rangeland resources on the Liben Plain, especially *kallos*. Understanding these relationships will be crucial for development of grounded and meaningful recommendations regarding alternative land management strategies that benefit the globally threatened Liben Lark, and which are tenable within the current socio-political environment of the Liben rangelands.

5.3. Methods

5.3.1. Study Site

The Liben Plain currently comes within the political jurisdiction of Liben Woreda (District) under the Guji Zone of the Oromia region and it is located between the Genale and Dawa rivers. The Liben Plain is known to include the Meisa, Siminto, Hadhessa and Korati Peasant Associations (PAs) under the Liben district. However, for this study, only Meisa and Siminto PAs were selected, as they are known to encompass the habitat range of the Liben Lark (Spottiswoode et al., 2009). The site also has two enclosure built by the World Bank on the eastern side close to the edge of the main road from Negelle to Filtu (for details on the location, see Chapters 1-3). Each PA has in turn three zones within it. Fig. 5.1 (below) shows the existing structure from the household to the PA level.

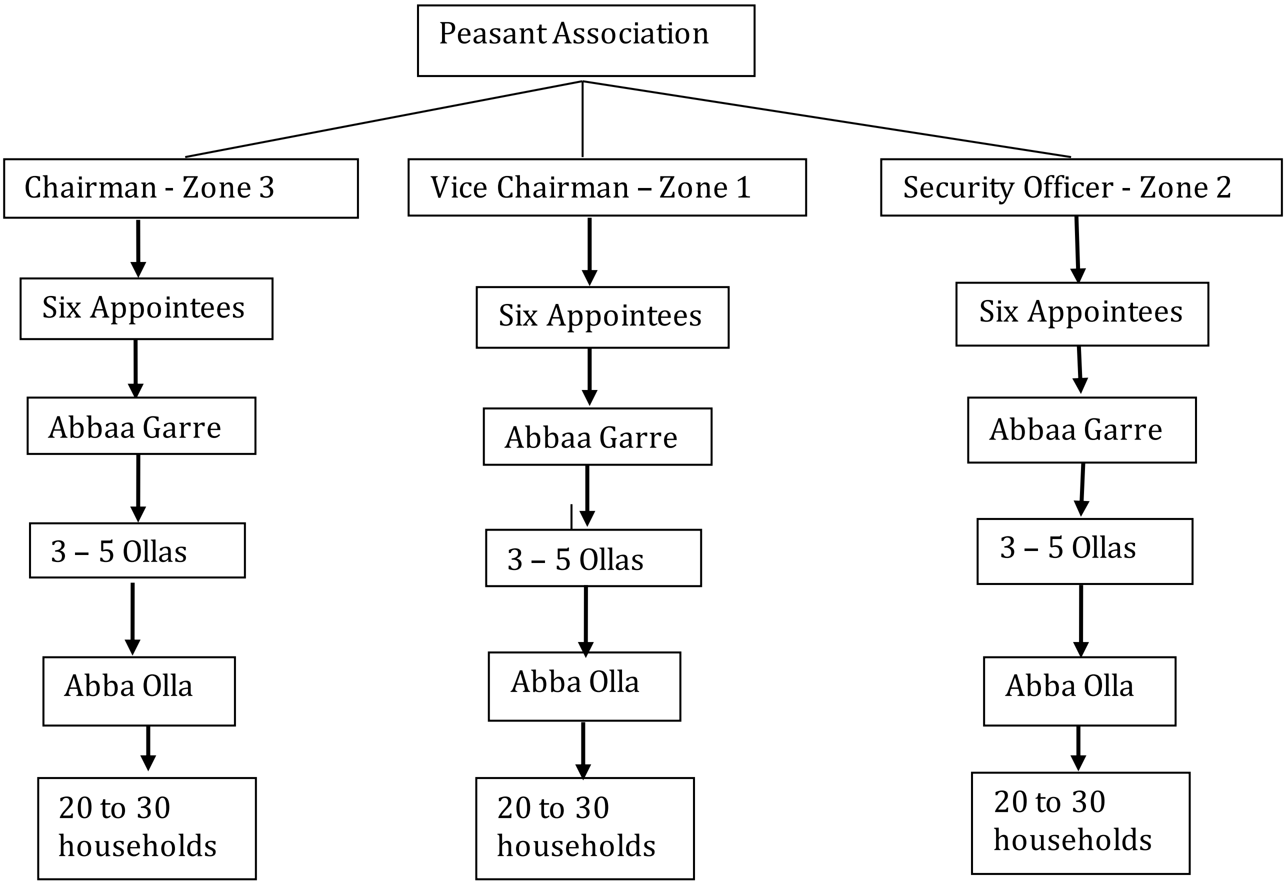

Figure 5.1Organizational structure from the Peasant Association to the household level

5.3.2. Focal Group Discussions and Interviews

Focus Group Discussions (FGDs) were used to collect information on how Borana and other stakeholders perceive the historical and current state of the grazing lands, to understand the current rules and regulations governing grazing management, how access is gained to arable land and what the existing interactions are between the different institutions. FGDs are a method of collecting qualitative data in which a group can convey their perceptions, opinions and beliefs on a certain issue in an interactive manner (Krueger, 1988). During an FGD, participants are guided by a facilitator who introduces topics for discussion and ensures that the participants interact well (Stewart & Shamdasani, 1990). Semi-structured interviews were held with key informants to complement the FGDs. Semi-structured interviews have a framework of themes and are open ended which can enable incorporation of new ideas and information (DiCicco-Bloom & Crabtree, 2006.). Key informants that were directly relevant for managing the land, such as the PA and zone leaders and the *Abba Dheedaas*, were selected in order to conduct these interviews. This was done in order to understand in more detail the mandates of the different institutions and the constraints on the effective operation of the current system. The necessary clearance on ethics was obtained from MMU to be able to conduct these discussions and interviews with local communities as well as representatives from local government. The project officer of the Ethiopian Wildlife and Natural History Society (EWNHS), who is also a local resident, helped to collect the data by acting as a facilitator for the FGDs. EWNHS is an Ethiopian NGO which is the Birdlife partner in Ethiopia that is working on conserving the Liben Lark (see Chapter 1). I was involved in all data recording and administering the discussions which could have had some influence in the data due to my gender and lack of knowledge of the local language.

FGDs were used in order to collect data in the two PAs. Each PA is further divided into three zones and the FGDs were held with participants from the three zones. Permission was obtained from the PA leaders to conduct these discussions. In order to be able to hold them, different villages ('*Ollas*' in the local language) were identified along with the PA leaders. A total of 61 people were involved in the FGDs in Siminto. Data collection was slightly different in Meisa PA as it was difficult to make an appointment with the PA leaders, who were mostly engaged with meetings in the villages where there are no mobile telephone networks, and access to these areas was difficult during the rainy season. Thus, we took the opportunity to take part in meetings where most *Abba Ollas* (head of the villages) and some inhabitants were required to attend.

The total number of people involved in the FGDs in Miesa was 28. Compensation for this smaller sample size was attempted by involving people from a greater number of *garres* (areas which include 3-4 *Ollas*) in the three zones. The group sizes in Siminto had an average of 7 people with total group sizes ranging from 4 to 12 individuals. In Meisa, the number of people representing a *garre* ranged from 2 to 4 individuals. Figure 5.2 shows the locations of different *garres* where the participants of the focus groups reside in the three zones of the Siminto and Meisa Peasant Association (PA). Table 5.1 shows the number of *garres* found in each zone of both Siminto and Meisa PAs, the number of *garres* that participated in the FGDs and the number of people who were involved in the study from each zone of the PA. A total of 89 people participated in 7 FGDs in Siminto PA and 5 FGDs in Meisa PA. Key informants were interviewed in order to have a better understanding of how the natural resources are utilized and who has the authority to give access to these resources. For this purpose, an *Abba Olla*, zone leaders in the PAs, and PA leaders from both Siminto and Meisa

PAs were interviewed. We also held discussions with two *Abba Dheedas* to see how effectively the traditional system of grazing is currently being utilized.

Table 5.1 showing the number of participants involved in the focus group discussions from the Garres in the different zones of the Siminto and Meisa Peasant Associations

Peasant Association (PA)	Zone	Total number of Garres in the zone	Garres elected for the FGDs	People involved in the FGDs in each zone
Siminto	1	14	3	27
	2	11	2	15
	3	12	3	19
Meisa	1	26	4	9
	2	14	5	14
	3	12	2	5

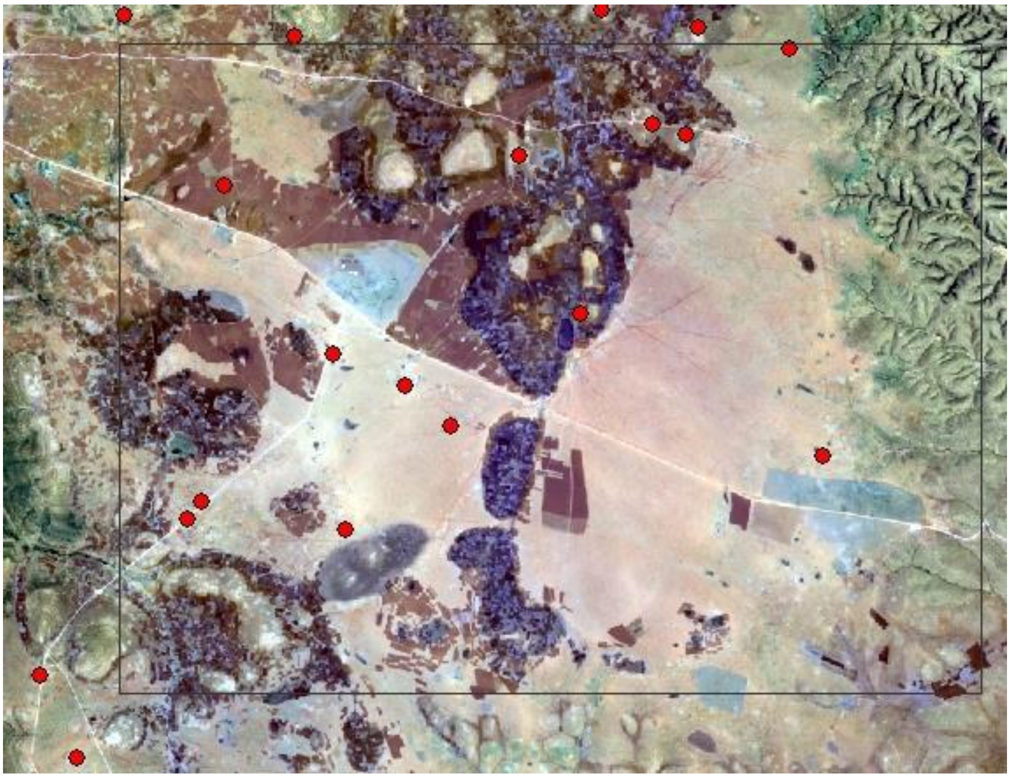

Figure 5.2 Locations of the different garres where the participants of the focus groups reside in (shown in red dots) the Siminto and Meisa Peasant Association with a landsat image of 2015.

5.4. Results

5.4.1. Historical and current condition of rangelands

All participants in all the FGDs in the PAs agreed that the condition of the grasslands and other natural resources was considerably better historically than at present. According to the respondents, the rains were also previously very good. The grass quality used to be very different and more beneficial for the cattle. Some groups mentioned that the grass used to be so dense and tall that it was possible for children to play games such as 'hide and seek'. One group mentioned that a person could lose a spear if thrown into the grass. Others mentioned that the rangelands were in such good condition that there were few bare paths and little soil erosion, with running water like the present day. In one of the FGD groups in Siminto PA, two respondents mentioned that they had to abandon their farmlands due to the severe levels of soil erosion. They also pointed out that the main road from Negelle to Filtu is a very rough gravel road and has not been maintained, and as a consequence many vehicles now prefer to drive on the grasslands, which has led to further erosion of the land. In addition to this, all respondents felt that farming has reduced the area of rangeland available for grazing. There are now many more people both within the community and outside who are using the rangelands which has contributed to its degradation. Nowadays, respondents stated that there were times when the cattle return without getting enough forage.

5.4.2. Grazing practices on the Liben Plain

The Liben Plain was historically used only as a wet season grazing area (see also PFE et al., 2010). Thus, all livestock stayed at other dry season grazing areas and were brought back to the plain only during the wet season. This used to be very beneficial as it would decrease the pressure on the grasslands caused by overgrazing and trampling and thus provide sufficient forage resource for the livestock as well as the wildlife in the area. The Liben Plain is currently used for grazing by milking cows and other livestock throughout the year. The dry cattle are sometimes taken elsewhere during the dry season and herded back to the Liben Plain during the wet season. (Bennett unpublished research findings).

All the respondents in both PAs agreed that there is currently no functional delineation of the dry and wet season grazing areas. Moreover, the participants mentioned that there are no paths that their cattle regularly use when going to drink water in different areas of the plain. This leads to the further degradation of the rangelands. All the FGDs mentioned that it has become increasingly difficult for them to be able to sustain the needs of their families during periods of drought. This is mainly due to the very low productivity of their livestock and the mortality of some of their livestock during these times. The low productivity of their livestock was in turn the result of very poor grass availability owing to long-term degradation and overuse of the forage available locally by high concentrations of livestock.

All the participants in the FGDs mentioned that there were no set rules to determine the exact areas where the livestock of different villages can graze. Therefore, any resident can let their livestock graze anywhere. This was indicated to be the case even when other communities like the Somalis come to the area during drought season, which indicates a shift to an open access system. However, all the respondents in the near-by zones of both PAs mentioned that they sometimes use the grass from the World Bank communal enclosures (which is a government built communal *kallos*) for their dry cattle. This indicates that there is still a functioning management system for accessing these enclosures collectively.

About 30% of the respondents from zone 1 of Siminto PA had a different response due to the fact that these individuals had already built a private *kallos* (private enclosure) which they were using for their calves and milking cows. Private *kallos* are not allowed by *Abbaa Dheedaas*. Private *kallos* are considered illegal in the traditional Borana system; however, the *Abba Dheedaas* are not informed when land is given out as private *kallos*. The *Abbaa Dheedaas* have delineated the dry and wet season grazing areas across the Liben region. Dry season pastures contain permanent water points, whereas wet season pastures are areas of good grass but are only accessible during and immediately after the rains (Bassi & Tache, 2011). As much as possible, the maximum use of wet season pastures is practiced so that pressure is minimized on the most intensely used rangelands near to the permanent water points (Bassi & Tache, 2011).

Currently the *Abba Dheedaas* instruct that cattle go to Elele *tika* (the smaller part of Elele grazing area) and Elele *guddaa* (larger part of Elele) some 37 km further away, and both have very good grass,during the wet season, and remained on plain during the dry season, but this judgement has not been followed. Some 3,000–5,000 cattle went to Elele during late 2014 but these pastoralists came back before the end of the wet season mainly because not everyone followed the rules, or other tribes had already settled there. Respondents in the FGDs generally felt that the *Abbaa Dheedaas*' capacity is weak in enforcing any traditional by-laws. In 2014, the short rains were insufficient so pastoralists did not move to Elele, and Somali pastoralists came to graze livestock on the Liben Plain.

Controlled fire on rangelands is very important in maintaining the quality of pasture, to control the expansion of bush and ticks as well as to facilitate the movement of livestock. Controlled burning used to be conducted every two to five years in different villages in the Borana rangelands. However, fires were banned by the government and were last said to be conducted in the early 1970s (Angassa & Oba, 2008). The ban was enacted in order to protect forests in the Ethiopian highlands, but this was done without considering the impacts it would have on the neighbouring rangelands (Reid et al, 2000). The ban later resulted in change to vegetation composition, into bush-encroached areas across the Borana rangelands (Angassa & Oba, 2008). In the 1980s the percentage of bush in the Borana rangelands was less than 40%, while by the early 2000s it had surpassed 50% (Homann et al., 2008).

5.4.3. Farming activities on the Liben Plain

The majority of the respondents (~ 85%) stated that farming on the Liben Plain first started on the black soils around 1990 and that the cultivation on the red soils began in 2008. There are some groups of respondents who said that farming on black soils actually started around 1978, but only began to expand rapidly during the 1990s. Farming might have been adopted from traditional farming like the kind practiced in the Southern Highlands of Ethiopia (Watson, 2004), but these activities were severely punished as they were prohibited by the *Gadda* laws. In the late nineteenth century, during the reign of Menelik II, immigrant farmers introduced farming in the Borana rangelands in southern Ethiopia. The humid areas that were reserved as dry season forage were soon farmed by the settlers (Oba, 1998). This contributed to the disruption of the traditional management system of the area. Following the droughts in the 1970s and the military government's Land Proclamation of 1975, many pastoralists started to get involved in farming (Angassa & Oba, 2008). Most of the recent land-grabbing for agriculture is due to private investors (Oba, 1998). This in turn has led to further land-grabs for cultivation by local people. Today, it is the relatively poorer members of the Borana communities who increasingly rely on cultivation in order to survive. In addition to this, wealthier individuals from within and outside the region also got involved in cultivation in order to increase their means of income. The FGDs also identified that the *Abbaa Dheedaas* are actually not informed when land is given out as farmlands as well as private kallos and that they do not support it.

Currently, Meisa PA has large areas converted to farmland, which may have been influenced by the availability of larger amounts of black soil as compared to the Siminto PA. Most respondents claim that they only farm their lands during the long rainy season (April – June), as it is usually more reliable. All participants said that they use the products from the farms for their own sustenance rather than for making profit, although a few mentioned that they may make a profit from selling their produce during times of very good rains. Some informants mentioned that the relatively wealthier pastoralists actually cultivate in order to sell their produce not for sustenance.

Regarding fertilizers, the majority of the FGDs said that they use urea and DAP (Diammonium phosphate) to increase the productivity of their crops. However, they indicated that they use a much lower amount than that used by the investors in the area. Furthermore, these investors use tractors for ploughing while oxen are used by the local people. The majority of the respondents in Meisa PA mentioned that the health of many local people has been deteriorating in recent times. They seemed to connect this to a change in diet that coincided with people starting to grow their own crops.

According to a key informant working at the Liben pastoralist District Office, Siminto and Meisa Peasant Associations are grouped as being 'agro-pastoralist' PAs. The PAs that are currently considered purely pastoralist within Liben district are Melka Guba, Hadhesa, Korati, Algee, Bulbul and Buba. This key informant also mentioned that it was in 2004 that the last pure pastoralist in Siminto PA converted to agro-pastoralism. This has, in turn, encouraged the district land use office to allocate more areas of land as being suitable for farming in Siminto PA. Furthermore, the edges of these two PAs are bordered by the main road from Negelle to Filtu. This has had a major influence in attracting large number of investors who can easily finance further cultivation and transport the produce to Negelle town. Some of these investors have started farming on the grasslands that were at the edge of the main road, which were dominated by native grasses, thus making it easier to cultivate (plough) compared to the invasive bush-encroached areas. These sites were also areas that some Liben Larks used to occupy (see also Chapter 3).

5.4.4. Current and future perceptions of land use changes

One of the primary concerns of the pastoralists who live on the Siminto side of the Liben Plain is the expansion of cereal crop farms in their rangeland areas. Most of the inhabitants of Siminto PA are also concerned that perhaps all of the grasslands will eventually succumb to conversion to cereal crop farmland in the future. However, some respondents think that currently some of the land is unsuitable for cultivation, as it is currently covered with a high proportion of bushes and trees which makes it more difficult to clear and cultivate. All the groups that were involved in the discussion were very concerned about the rapid rates of land-grabs in the area for cultivation. The way things are progressing, the participants of the FGDs perceive that all the areas will be converted to farmlands in less than ten years. This will threaten their existence as a pastoralist society. A previous study of Borana pastoralism has shown that communal grazing lands are continually being threatened by privatisation for crop cultivation and enclosure through the building of private *kallos* (Kamara et al., 2004).

Current circumstances are pushing pastoralists to engage more in agriculture in order to obtain food, as well as to secure some land for the longer term, even though the area is not suitable for agriculture due to marginal (for rain-fed agriculture) and irregular rainfall (Berhanu & Colman, 2007; Bassi & Tache, 2011).

5.4.5. Access to resources

When a member of the local community wants to create a private *kallos* (grassland enclosure) near their house, they discuss their plan with the *Abba Olla,* who then gives them the permission to do so. Some respondents during the FGDs mentioned that the size of the *kallos* that the person is allowed to have depends on the number of livestock the person has, which indirectly indicates the importance of that person in the community. One key informant mentioned that the size of the *kallos* is simply determined by the interest and capacity of the owner. Thus, so long as the individual can find the means to fence off the land with *Acacia drepanalobium*, the *Abba Olla* will permit them up to 2 hectares. However, this information, and the size of the land enclosed is not always transferred to the PA leaders, nor included in the land use data that the PA or the district possess. A key informant at the FGDs, who also had a private *kallos*, mentioned that a person can build his own private *kallos* and may or may not inform the *Abba Olla* about it. The use of land as private *kallos* has recently started increasing in zone 1 of the Siminto PA, as it is judged to be more suited to the creation of *kallos* as it has a greater amount of open grassland remaining.

Alternatively, when local people want to farm, they have to inform the head of the zone within the PA who in turn selects the exact location of the farm (as it can be in any zone regardless of where the person resides). The person then has to start paying tax for the land – up to 1 ha is taxed at 40 birr (1.86 USD), with 2ha taxed at 65 birr (3.02 USD), and 3ha at 100 birr (4.64 USD) per year. If a bigger area is required, then it is jointly decided by the PA leaders. It usually does not matter if the person requesting land has enough resources to farm it or not; it is just the declaration of intent and the tax payment that is required. The Development Agents then estimate the land farmed and report to the Liben district every year. This estimation is done without the help of a GPS or any assistance from the Liben district land use office.

There is currently much about the cropland accessibility that is not transparent and it is unclear, for example, how people outside the PAs get access to farmland. According to the Oromia Regional National State Rural Land Administration and Use regulation, a person who applies for land acquisition should be a resident of that PA. Squatting on rural land by constructing houses or fences and cultivating is forbidden, and may be punishable with 1-5 years imprisonment. Two key informants indicated however, that some of the farmlands in Meisa and Siminto PAs belong to people residing in Negelle town who have illegally acquired residence identity cards from the PAs. When Government and Non-government Organizations wish to acquire land for enclosures they have to request this from the District rural land and environmental protection office. If some of the grazing land is to be given out for investment, it is not specified that compensation will be given to the affected land users, especially those that do not have titles to support land ownership and access.

5.4.6. Mandates of institutions on land use

The Rural Land and Environment Protection Bureau is responsible for preparing and providing a rural land map for land users. It also gives information about investment lands to the Oromia Investment Commission and its offices at different administration levels. The bureau also issues land-holding certificates to persons for whom it is permitted and has the responsibility to follow up, control and protect government and communal lands. The bureau can issue corrective measures to be taken against individuals who illegally occupied land or cause it to be occupied. The Zonal Administration Office supports the correct implementation of rural land laws and can also provide the necessary support regarding the preparation of land use plans and investment. The District Administration Office is responsible for rural land administration and the implementation of land use laws. The office is also mandated to provide support for land demarcation for different land uses, and is responsible for follow up and control of the rural land uses to prevent illegal occupation and can take legal measures. At the district level there is the Liben Pastoralist Development Office, which provides support to the community.

The Peasant Association Administration is responsible for strengthening the awareness of local people and to enable the rural land administration and use laws to be implemented. However, this area of responsibility does not extend to the regulation of communal lands such as grazing lands (which is the responsibility of traditional institutions), but only communal lands such as market places, cemeteries and religious lands. A committee of five members is established, all of whom are accountable to the PA administration, and they keep a registered data of land and ensure that landholders obtain land holding certificates. The five members then send this information to the district administration office.

One of the major drawbacks of enforcing the land use plans is not having enough human resource capacity to map out the currently cultivated areas. The PA leaders therefore estimate the amount of land given out for individuals for cultivation with the help of the Development Agents. This information is then passed on to the district land use office, which similarly, does not have the capacity to go out to the various PAs to measure the extent of the different land uses. In addition to this, the different offices working at the district level are not well coordinated. The land use office may assign land for farming without consulting other offices such as the tourism office and the Liben Lark Conservation Committee, which is a working group established by the Ethiopian Wildlife and Natural History Society (EWNHS) in 2009, and which was functioning at the zonal, district and the PA levels.

An association with the name Siminto and Meisa Pastoralist Associations (PAs) joint Participatory Rangeland/*Kallos* Management (PRM) was set up in 2015. The main purpose for the establishment was to set up *kallos* to ensure the effective management of about 150 ha of reclaimed rangeland on communal land located in the Meisa and Siminto PA. These enclosures were built in collaboration with the Site Support Group (SSG) that was also established by the initiation of the EWNHS. The SSG members are local youths who mainly work as local bird guides for tourists who visit the area, and who also worked on setting up and protecting the enclosures. Setting up of these *kallos* was started due to grants acquired through a Darwin project to the EWNHS and SOS Sahel to work on rangeland restoration and Liben Lark conservation. A new regional bylaw was established through the association in order to manage the *kallos*. The need for a bylaw to manage these *kallos* was to ensure the availability of sufficient palatable pasture for livestock especially during periods of extreme drought or other environmental or social pressures. The other reason for having the *kallos* was to be able to integrate biodiversity conservation and to increase the survival chance of the Liben Lark by creating suitable habitat for the species to breed. The association is membership based and any resident from the Meisa and Siminto PAs can become members on a voluntary basis as long as they support and enforce the objectives of the association. The association is structurally composed of a general assembly, and three committees: the rangeland management committee; the pasture utilization committee; and a controlling committee. The general assembly overlooks the general direction of the association including the ongoing work of the three committees.

The rangeland management committee is responsible in dealing with challenges such as rangeland degradation especially due to agricultural activities and settlements by working closely with the Site Support Group. The Committee is also responsible in ensuring that the reclaimed rangeland is protected and constitutes suitable habitat for the Liben Lark. The pasture utilization committee is directly accountable to the rangeland management committee, and to ensure the use of the *kallos* for animal feed through grazing or cut and carry does not take place during the breeding season of the Liben Lark. The committee also makes sure that any utilization does not in any means seriously disturb the Liben Lark or affect its habitat. The committee is also responsible for recording the maturity of the grass and vegetation change in the *kallos*, and where necessary, to recommend any appropriate measures for the *kallos* habitat management. Punishments or penalties for violations such as extension of croplands and settlements in the *kallos* as well as for cutting grass or allowing cattle inside the *kallos* without the consent of the association members have been identified and highlighted within the bylaw document.

5.5. Discussion

5.5.1. Resource utilization and status

The data collected from FGDs and semi-structured interviews confirm what was been reported elsewhere in the literature regarding the grassland habitat across the Borana rangelands. The vegetation structure of the Liben plain has declined within the past few decades (see also Chapter 2). The bush cover in the area has gradually increased, leading to a decrease in the quality of forage (Angassa & Oba, 2008) and a decline in good quality grass on the rangelands. The increase in agriculture has further led to rangeland deterioration by decreasing the total area of grasslands (Homann, 2004), subsequently restricting the mobility of livestock, resulting in increased grazing pressure (overgrazing) on the remaining grassland areas. The decrease in vegetation cover itself has further resulted in the erosion of soil, and gully erosion in some areas of the plain is fairly conspicuous.

Even though there is still a designation of dry and wet season grazing lands by the *Abba Dheedas*, it is not followed by most of the inhabitants on the Liben Plain nor is it supported or endorsed by the local government officials. This results in a lack of mobility between seasons which means large numbers of livestock are now on the Liben Plain throughout the year. This in turn leads to increased pressure on the remaining areas of grassland on the Liben Plain, which would mean insufficient forage for the livestock especially during the dry seasons and droughts. Droughts are known to severely increase livestock mortality (Coppock, 1994), and their impact is intensified when mobility and access to key resources is restricted (Scoones, 1993).

The amount of land suitable for agriculture in the whole of the Borana rangeland was previously estimated to range from 9 to 12% (Coppock, 1994). However, more recent estimates place it at more than 16% (Boru et al., 2015). Areas of cultivation are usually closer to towns as it is easier to transport the products to market and due to the availability of government extension services. In Liben district, the Peasant Associations (PAs) such as Siminto and Meisa that are closer to Negelle are heavily cultivated. Siminto is said to have 60% of its area under cultivation (Boru et al., 2015).

According to Boru et al., (2015), pastoralists in neighbouring PAs to Siminto indicated that the land in Siminto is more desirable for farming and that some have acquired land there for that purpose. However, this has recently become difficult to do as there is an unofficial fee for purchasing land in Siminto, along with annual tax (which is not applicable in Hadhessa and Qorati PAs). The amount of land cultivated in Siminto was positively related to wealth (Boruet al., 2015). Pure pastoral activity has been seen more in older people and comparatively less in larger household sizes. Some younger household heads that were relatively skilled and literate were found to have a more diversified means of income.

The building of private *kallos* in the Siminto PA is mostly supported by the *Abba Ollas*, which are part of the traditional institution. By building private *kallos*, the local inhabitants can temporarily ensure that the land that they enclosed will not be cultivated by other individuals in the near future. It will also provide sufficient forage for their livestock especially during the dry season. Nonetheless, the increase in private *kallos* will result in decreased area of communal grazing land with additional grazing pressure. When the communal grazing land on the Liben Plain is allocated for farming or enclosed as private *kallos*, the state institution at the site level like the PA leaders are made aware especially if it is to be used for croplands. However, representatives of the traditional institutions such as the *Abba Dheedaas* are not informed when portions of the communal grazing areas are given off for these purposes. Moreover, the *Abba Dheedaas* are in direct opposition of such practices which will lead to further degradation of the remaining grasslands. The *gadda* leaders from 2009 onwards even asked the government officials to dismantle these private kallos which did not actually happen (Napier & Desta, 2011). This clearly indicates that there is conflict and lack of coordination between the traditional and state institutions with regards to resource use and allocation. It also shows that there is lack of connection, even at the different levels of the traditional institutions where the *Abba Ollas* do not inform the *Abba Dheedaas* about the private *kallos* and they have opposing views on the matter. Therefore, there is lack of coordination of the institutions at two levels: at the state and traditional level and at the different levels within the traditional institution itself.

Although the mandates of the different government bodies are clearly stated in several government documents, the activities are not fully executed for several reasons. The traditional institutes are becoming increasingly unable to cope with the different government policies on development and resettlement (Bassi & Tache, 2011), which has led to further degradation of the rangelands. The process of land acquisition is unclear and needs to be investigated in detail in order to be able to halt the uncoordinated land-grabs on the Liben Plain and thereby help to increase the likelihood of the Liben Lark's survival. It will also help ensure grazing lands for the local community which can be managed in collaboration with the existing institutions in the area.

Since the 1970s, several development projects have been undertaken in the Borana region (Coppock, 1994). Most efforts have focused on developing infrastructure and making veterinary services available for the Borana pastoralists. The main aim of these development interventions was to boost the production of livestock, aiming to result in livestock commercialization. The construction of new ponds increased the utilization of other grazing lands (Coppock, 1994). With the availability of veterinary services and water resources, the livestock population increased as predicted. However, the human population also increased, and as most people were not willing to sell off their cattle this resulted in further pressure on the available grazing resources. Traditionally, the Borana pastoralists depended on milk for food and traded some of it for grains, coffee and other materials that they may need (Coppock, 1994). Hence, it was not always important for them to go to markets to sell their cattle. Moreover, cattle are viewed more as accumulated assets rather than as a cash crop (Coppock, 1994). Hence, the aim to increase livestock commercialization by western-trained advisors did not go as planned because they did not have a complete understanding of the pastoralist's social values and production system. Collectively, these programmes gradually contributed to further degradation of the rangelands and the dependence of most of the Borana people on food aid (Coppock, 1994).

The association that is set up to manage the *kallos* is essential and encouraging, but lacks an actual mandate or link to work formally with other organizations. They may be able to communicate or share information about issues in the area but not having a formal link could affect the success of the activities. The documentation does not mention how the schedule and mechanism for the harvesting and utilization of the forage will be undertaken. Although the pasture utilization committee is linked to the Site Support Group, it is not clear how they should coordinate their activities together to efficiently manage *kallos*. The bylaw does not explain if the vegetation change actually quantified and if there is any baseline data taken and how often the vegetation should be surveyed. References to the sharing of resources are also vague and it is not clear whether these opportunities will be available for members of the association only, or for residents located near the *kallos*. It would also be extremely beneficial to enforce the penalty mentioned on the document and to be able to use the money to sustain the activities of the association. There is general acknowledgement throughout the region that the establishment of *kallos* will be very helpful to provide nesting and feeding habitat for the Liben Lark. Furthermore, it will provide forage for the livestock and help them cope even during times of drought.

The Borana pastoral system has been repeatedly hit by major external shocks of catastrophic proportions during the last four decades. Some of the major factors that led to this are recurrent droughts, violent conflicts, bad governance, shrinking grazing area and high population growth rates (Tache, 1996; Taye, 2002). The annual human population growth rate increased from 1.3% in the 1960s to 2.5% in the late 1980s (Helland, 2006; Lindtjort et al., 1993), which is often attributed to the deterioration of the traditional population control mechanisms of the *Gadda* system (Lindtjort et al., 1993; Coppock, 1994)

5.5.2. Conclusion

The communal property regime that used to exist on the Liben Plain has deteriorated, and now exists almost entirely as an open access property regime. The rangelands of Borana and the Liben Plain in particular have become highly degraded in the past few decades. This has occurred due to a combination of factors including the push by successive governments for settling pastoralists, poorly researched development works by NGOs, the banning of fire management techniques, the introduction and expansion of cereal crop agriculture, recurrent droughts and most importantly the deterioration of the traditional *gadda* system of managing the rangelands. In addition to this, the absence of clear federal policies and provisions in law ensuring pastoralists the access to key resources has exacerbated the situation. Communal lands of pastoralists are not given adequate attention, especially when compared to the focus that has been given to lands used for agriculture. As a consequence, the deterioration of rangelands is severely affecting the survival chance of the Liben Lark as well as the pastoralist way of life of the local community on the Liben Plain.

The land use regulation of 2012 states that the common holdings of pastoralists, semi-pastoralists or farmers like grazing lands, forests and water points shall be certified by the name of the users. However, the local residents have not made use of this right. Thus, it would be highly beneficial if the residents can obtain legal certification of these lands in order to ensure that these areas will not be cultivated by investors. The recent development of large communal enclosures (*kallos*) has helped ensure forage for the livestock of local communities especially during the dry season. Promoting and expanding the use of these types of enclosures will be a promising way to produce enough livestock forage and prevent the expansion of cultivation which is neither suitable nor productive on the Liben Plain. Designating and using different areas for dry and wet season grazing is very crucial to reduce pressure on the Liben Plain as well as for long-term drought resilience. Clearing bushes and regularly monitoring controlling the re-growth is very essential for opening new areas of grasslands. However, this activity should be managed by the local community in order to ensure its sustainability.

There are still some gaps in knowledge about how land is illegally being acquired for farming. Having an integrated management approach for rangeland on the Liben Plain involving institutions from state and traditional and non-government bodies is essential in order to balance grazing land for livestock with key biodiversity objectives such as saving the Liben Lark from extinction. It is essential to resolve the current problems of coordination between the traditional and state actors as well as between different actors within the traditional institution itself. The by-laws formulated by the community elders and other members to manage the enclosures is a useful starting point for the integration of the different existing institutions in the area. However, a formal link of the association with the relevant district offices as well as the Site Support Group is essential to be able to properly manage the *kallos*. On the whole, a long-term plan for rangeland management which is coherent, fully supported and clearly structured can prevent further illegal agriculture and ensure the sustainability of the pastoralist way of life while also directly addressing the significant biodiversity needs of the area.

5.6. References

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Chapter Six

SURVIVAL RATES OF ARTIFICIAL LARK NESTS ACROSS THE LIBEN PLAIN

6.1. Abstract

Nest predation and trampling of nests by livestock are some of the major factors affecting reproductive success of grassland birds. Due to the difficulty of finding and monitoring nests of threatened grassland birds, many authors advocate the use of artificial nest trials. In this Chapter, experiments using artificial nests and plasticine eggs were conducted to determine the causes of nest failure, to see if distances to habitat edges, changes in grassland vegetation height, nest visibility (concealment) and presence/absence of hyena faeces influenced the daily survival rates (DSR) of artificial nests. A total of 141 artificial nests, resembling the same material and dimensions as real Liben Lark nests were used in two 14 day trials in November 2012 and June 2013. Nests which were arranged in experimental triplets at 5 m, 30 m, 70 m and 100 m from edges of crop fields and bush or scrub area. A third artificial nest trial was conducted in November 2014 using 120 nests in three different experimental 'blocks' over a 20-day period. Grassland habitat variables were also recorded at each next location in November 2014. Predation and trampling were found to be the main causes of nest failure. No significant changes in grass height due to the effects of hyena faeces were detected within the duration of the 2014 experiment. There was no obvious trend of increasing DSR with increasing distance either from the edge of cereal crop fields or invasive bush in 2012 and 2013. In 2014 the overall effect of grass height change on nest DSR was independent of hyena faecal treatment but artificial nest DSR was higher with the provision of hyena faeces and where grass height increases during a 20-day exposure period. Across the Liben Plain, artificial nest failure seemed to be a random chance event but hyena faeces may have some value as a novel biological control agent. Taller grass vegetation should be a habitat restoration goal for the recovery of the Liben Lark breeding population.

6.2. Introduction

Nest predation is the major factor limiting reproductive success in grassland-dependent bird species (Martin, 1993; Martin, 1995) and contributing to recent population declines (Robbins et al., 1989; Askins et al., 1990). Nest predation rates also have implications for the spatial distribution of grassland birds (Martin, 1988; Andrèn, 1995) and overall bird community structure (Martin, 1988; Marini, 1997). Various agricultural management practices such as burning, intensive grazing by livestock and trampling caused by high stocking levels of cattle can alter the structural characteristics ('quality') of the grassland habitat as well as reduce grassland cover and area of extent (Johnson et al., 2012). This in turn may have impacts on the response of populations of predators in grassland ecosystems (Ricklefs, 1969; Sandercock et al., 2008). Research has shown that increased encounters between predators and nests occur by increases to predator abundance or by changes in nest concealment that make nests easier for predators to locate (e.g. Blouin-Demers & Weatherhead, 2001). Unsurprisingly, many grassland-dependent bird species have higher nesting success in areas with taller and better-quality grass vegetation (Winter, 1999; Davis, 2005).

Owing to the difficulty in finding and making regular observations of real grassland-dependent bird species' nests, and/or because of the vulnerability of the species under observation, nest predation risk has traditionally been investigated by means of experiments with artificial nests . These experiments have been conducted using either real quail or hen eggs (e.g. Haskell, 1995; Butler & Hamilton, 2000) or by using artificial eggs made of plasticine (e.g. Maier & Degraaf, 2001). The use of artificial nests also has the advantage in that the number, position and contents of the nests (e.g. number and pattern/colouration of eggs) can be predetermined and manipulated (Major & Kendell, 1996). Studies with artificial nests have revealed important insights into how nest survival rates may vary in relation to threats such as habitat fragmentation (e.g. Langen et al., 1991; Donovan et al., 1997), habitat degradation (e.g. With et al., 2008) and edge effects (e.g. Andrèn, 1995; Hartley & Hunter, 1998). Nest predation is however, predominantly determined by the abundance and foraging ecology of potential nest predators within the grassland ecosystem, but these data are lacking for many grassland ecosystems (Ricklefs, 1969). Consequently, some researchers have voiced concerns about the reliability of artificial nest experiments (e.g. Roper, 1992; Major & Kendell, 1996) and whether they do actually provide an index of or any real insight into predation rates for real nests (King et al., 1999; Davison & Bollinger, 2000; Zanette, 2002).

The Liben Plain of southern Ethiopia has lost large areas of grassland habitat owing to conversion to cereal crops and increased grazing pressure (Spottiswoode et al., 2009; Donald et al., 2010). The reduction in the amount of good breeding habitat for grassland-dependent birds across the Liben Plain has coincided with a dramatic population decline and range contraction in the Liben Lark (Donald et al., 2010). Declines in grass vegetation cover and height, and increases in degraded bare ground cover, suggest that the Liben Plain has undergone a rapid degradation of its habitat quality (Chapter Four), coupled with increasing cereal crop farming (see Chapter Two) and encroachment of invasive fennel and acacia scrub (see Chapter Four). The impact of these changes on the breeding biology and nest survival rates of the Liben Lark remains unknown. Few nests of the Liben Lark have ever been found. The nest was first described from observations of a nest discovered in June 2007, which was constructed of grass woven together in an open-cup shape and placed under small *Solanum tettense* shrub, and contained three brown-flecked whitish eggs (Collar et al., 2008). A second nest found in June 2008 contained three young birds (Collar et al., 2008). Both these nests were situated under isolated plant cover that was quite conspicuous in the midst of degraded grassland areas, and both nests failed due to predation (Donald et al., 2010). Only three other nests of Liben Lark have been found, these were in June 2010 (two nestlings), November 2012 (three nestlings) and November 2013 (three nestlings). These nests were found in short disturbed grass habitat, generally believed to be atypical for Liben Lark nesting habitat. These observations suggests that the Liben Lark has two 'peaks' in breeding each year – one during June and another in November each year, each period following the onset of the rains and when Liben Larks are more conspicuous (Chapter Four). More worryingly, it suggests perhaps Liben Larks are increasingly being forced to breed in poorer and poorer quality habitat, leaving their nests at ever-increasing risk from predation and trampling by livestock. The severe predicament of the species, with so few nests having been discovered, its rarity (see Chapter Three) and the risks associated with making direct observations from a small number of real nests (if found) all make examining the survival and threats of real nests impractical.

Measures to reduce the impacts of overgrazing by livestock and other large mammals generally involved one of two main strategies: (1) fencing-off critical areas for ground-nesting birds to enable them to breed without disturbance whilst also allowing some natural regeneration of the habitat; or (2) the use of non-lethal deterrents (repellents) such as the odours (e.g. urine or faeces) of natural predators. Designating enclosures is an alternative and effective way of improving the quality of the rangelands by excluding livestock and allowing the vegetation to regenerate in terms of biomass and species diversity. Creation of such enclosures, which are communally owned by the Borana pastoralists and known as *kallos*, also helps reduce soil erosion and increases rainwater infiltration (Aerts et al., 2009). However, there are many practical difficulties in creating and managing communal *kallos* across the Liben plain as most of it is considered a communal grazing area. A more novel approach to reduce grazing activity by cattle could be to use and apply a form of non-lethal repellent to deter cattle from feeding in close proximity to Liben Lark nesting areas (assuming these could be found). A suitable repellent would potentially, not only deter cattle from grazing in close proximity to the nest, but also reduce the risk of trampling, thus increasing nest success. Over time, the repellent may actually have some impact in improving breeding vegetation quality: grass height and density around the nests may increase, thus improving the concealment of the nest.

Natural and artificially produced predator odours from felid or canid predators have been used to reduce ungulate feeding damage in woodland plantations (e.g. Melchiors & Leslie, 1985; Conover, 1987; Andelt et al., 1991; Swihart et al., 1991) and Snowshoe Hare *Lepus americanus* grazing impacts (e.g. Sullivan et al., 1985) or simply for keeping other game species away from roads to reduce road accidents . Other studies have found that domestic goats avoid feeding in areas that are treated with predator faeces such as Lion *Panthera leo* . Around the Liben Plain, Spotted Hyena *Crocuta crocuta* are one of the most common carnivore predators of grazing livestock in Ethiopia and have lived in an anthropogenic context with Borana pastoralists and their livestock for centuries. Throughout the Horn of Africa, Spotted Hyena hunt livestock mainly at night particularly in the rainy season. Before the start of this research, patches of longer grass found in the midst of shorter grass across the Liben Plain were often noted to contain hyena dung (M. Wondafrash *personal communication*) and observers postulated whether cattle were avoiding these areas. These observations became the basis for this next chapter of experimental research.

In this chapter, Spotted Hyena faeces were used in conjunction with a series of artificial nests and eggs to examine whether it can act as a non-lethal biological repellent to grazing by Boran cattle and to other predators around artificial lark nests. Owing to the plight of the Liben Lark and the lack of observations of real nests, I used artificial nests and plasticine eggs made to resemble real Liben Lark nests. Moreover, artificial nest trials could also shed light on potential sources of predation of this and other ground-nesting birds across the Liben Plain. Specifically, I wanted to determine the following: (1) What are the main causes of artificial nest failure across the Liben Plain, e.g. predation or trampling by cattle?

(2) Do daily survival rates of artificial nests differ in relation to distance to edges of invasive scrub or cereal crop fields? (3) Are the survival rates of artificial nests that are treated with hyena faeces greater than those without? (4) Are there any immediate improvements in vegetation height (and thus nest concealment) in the vicinity of nests treated with hyena faeces? I had a number of *a priori* predictions concerning the outcomes of these artificial nest trials: (1) Artificial lark nests treated with hyena faeces will have higher daily survival rates and higher percentage 'nesting success' than those without hyena faeces; (2) artificial nests treated with hyena faeces will have smaller percentage of 'failures' caused by livestock trampling; (3) artificial nests positioned closer to edges will experience higher predation rates; (4) vegetation in close proximity to artificial lark nests treated with hyena faeces will be taller and more dense than the vegetation around untreated artificial nests.

6.3. Methods

6.3.1. Study site

Artificial nest trials were conducted across the Liben Plain in the core area occupied by the remnant population of the Liben Lark. Further details on the study site are presented in Chapters Two and Three.

6.3.2 Artificial nest trial experiments

Three artificial nest trials were conducted in this study. Artificial Liben Lark nests were constructed using native grasses, to resemble as closely as possible the known materials and dimensions of nests of the Liben Lark. Nests were bowl-shaped with the hole measuring approximately 6 cm in diameter. Artificial lark eggs were constructed using plasticine, and measuring 3cm × 2cm, similar to the real dimensions of Liben Lark eggs (Collar et al., 2008). Artificial eggs were also spotted with brown paint, to increase their resemblance to real eggs of the species. Two eggs were placed in each artificial nest. The eggs had strings in them which were then tied through the nests to avoid loss by predation (Nour et al., 1993).

For the first two trials, in November 2012 and June 2013, artificial nests were positioned across the Liben Plain in a triplet arrangement. Each nest was placed 50 m apart (Martin & Geupel, 1993) in order to reduce the probability of a predator locating another nest placed close by, since one study found systematic predation by a single predator on nests placed 20 m apart (Bayne & Hobson, 1997). Nests were placed in sets of triplets as follows: (1) Hyena faeces (one or two pieces with roughly the same biomass; see section 6.2.3 for sourcing) were placed at the proposed artificial nest location one month prior to the actual placement of the artificial nest. This was done to examine the effectiveness of the hyena faeces odour in deterring cattle and thus grazing. We assumed that these areas would have longer grass than the surrounding area. (2) Another, second artificial nest was placed in grass 50 m from the first one but without any hyena faeces. (3) A third artificial nest was placed 50 m from the second nest but with fresh hyena faeces (i.e. the faeces were deployed at the same time as the nest was placed). This was done to examine if the fresh odour would help to prevent trampling of the nest by cattle and/or deter potential nest predators. Stones (10–20 cm in length) were collected from the roadside and placed approximately 10 m north of the first nests so that they could easily be re-located. Nests were marked with a GPS and a brief description of the site made (Martin & Geupel, 1993).

A total of 141 artificial nests with artificial eggs were placed in these triplet arrangements in three different habitat locations: (1) at 5 m, 30 m, 70 m and 100 m from the edge (Nour et al., 1993) of crop fields; (2) same distances from the edge of invasive scrubland; and (3) random areas of grassland habitat within the Liben Plain (more than 200 m away from edges). The edge of scrublands was determined by finding an area where the bushes thin out so much that only one or two bushes were present. Nests were then placed at that edge with subsequent nests placed further into the open grasslands. Artificial nests were left for 12–14 days, which corresponds to the incubation period of other larks and were classified as having failed and were removed if found out of place, missing, trampled or predated. An egg was considered predated if it had bird bites, teeth marks and other damages which are made by other animals or even humans. Nests were examined twice during November 2012, with the first check taking place 3 to 10 days following nest placement, and the second 11 to 14 days following initial placement. Nests were not checked regular during the first experiment because it took longer than anticipated to place the nests and due to the need to find other appropriate methods to relocate the nests. In June 2013, all the artificial nests were placed on the same day and all were checked in total, three times at 5, 9 and 12 days after initial placement.

In the third trial, conducted in November 2014, I used 120 artificial nests of the same design and dimensions as the previous trials, again with two plasticine eggs each. Nests were placed in three experimental block arrangements measuring 350 × 400m in size. Each block contained 40 artificial nests. The first two blocks were placed in an area of degraded grassland with very few invasive scrub bushes on the central north-eastern and south-eastern region of the plain, inside the core area of the Liben Lark (see Fig. 3.8, Chapter 3). This was in a similar area to that used for the first two experimental trials. The third block was positioned in an area of acacia woodland scrub with a relatively high density of trees, in a region further east than the core area of Liben Lark density hotspots (see Chapter 3).

For each experimental block, I placed eight nests in five different rows, with each nest positioned 50 m apart, and each row separated by a distance of 100 m. The nests alternated in having hyena faeces and no faeces across the rows of artificial nests. The nests were left for a duration of 20 days and checked after 10 days and on the final 20th day when evidence of failure (e.g. predation, trampling by livestock) or survival were recorded. Grass vegetation height measurements were taken at each nest location at the start (Day 0) and end (Day 20) of the experimental trial. Grass height was measured using a sward stick and a plastic disc with a diameter of 29.5 cm. This measurement was made at three locations in the proximity of the nest: (1) at the nest itself (which is also where the hyena dung was placed); (2) one metre to the north of the nest, and; (3) one metre to the south of the nest.

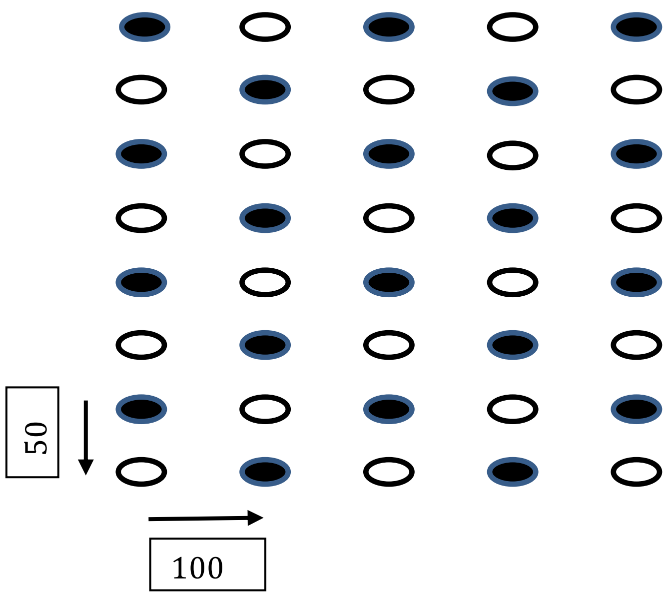

Figure 6.1 Showing the design layout of the nest experiment in November 2014. Five columns separated with nests placed 100 m apart and eight rows of nests placed 50 m apart. Black ovals are nests without hyena faeces and white ovals are nests with hyena faeces.

6.3.3. Hyena faeces collection

Hyena faeces were collected from the town of Harrar, located 371km east of the capital Addis Ababa. Here Spotted Hyenas have been fed by local people for many years and the history of people with the resident hyena population is well documented (e.g. Gade, 2006). During October 2012 fresh hyena faeces were collected by local guides in Harar. The faeces were wrapped and placed in air-sealed plastic bags and transported to Negelle for use on the Liben Plain. For the next two nest experiments, fresh hyena faeces were sent to Addis Ababa by established contacts in Harrar prior to my departure to the Liben Plain. Total time between collection and placement on the Liben Plain was about 5 to 6 days.

6.3.4. Data analysis – daily survival rates of artificial lark nests

Daily survival rates (DSR) of artificial lark nests were calculated using two similar techniques. First, for November 2012 and June 2013 I used Program MARK (White & Burnham, 1999). Daily survival rates are the probability that a nest will survive from one day to the next (Mayfield, 1961; Mayfield, 1975). Program MARK uses the maximum likelihood estimator approach of Bart & Robson (1982) to model DSR (Dinsmore et al., 2002) using binary data of nest fate where nest failure = 0 and nest success = 1 (Dinsmore & Dinsmore, 2002). Nests were judged to have failed when a nest showed signs of: (1) predation, i.e. loss of one or both eggs, presence of teeth or beak marks in any remaining plasticine eggs, nest removed with remains found/unfound; or (2) signs of trampling, i.e. eggs had been squashed while in the nests or outside the nests due to cattle, other livestock or humans treading on them. Program MARK estimates DSR using a general linear modelling framework with a binomial error distribution and a logit-link function (Dinsmore et al., 2002; Rotella et al., 2004). For the artificial nest trials in November 2012 and June 2013, the percentages of nests that survived were calculated and the different causes of nest failures were represented as a percentage of the total nest failures. To estimate DSR for artificial nests placed at different distance intervals from edges, all data were pooled from each distance category (e.g. 5m, 30m, 70m, 100m and no edge) from both November 2012 and June 2013 trials to improve sample sizes (e.g. Butler & Hamilton, 2000; Li et al., 2015). Similarly, to estimate DSR of artificial nests with no or different hyena faeces treatments, data were pooled from both November 2012 and June 2013 trials.

6.3.5. Data analysis – influence of vegetation and faecal treatment on DSR

For the November 2014 trails, differences in mean vegetation height around each artificial nest with and without hyena faecal treatment were examined at the start and end of the experiment using two-sample t-tests following examination of the data for normality, in SPSS Statistics v.22 software (SPSS Inc, 2015). Modelling predation and trampling rates separately could be problematic because trampling and predation may not be independent i.e. some of the trampled nests may be predated if they are not trampled, others would not have, and vice versa. Therefore, for the November 2014 nest trials, I modelled predation rates and trampling rates as a function of grass height, grass height change, visibility (calculated as 100 – estimated percentage vegetation cover concealing the nest), and presence or absence of hyena faeces. I first calculated an overall survival rate (OSR) using a generalised linear model (GLM) with a logit-link function and binomial error distribution (Aebischer, 1999) using package lme4 (Bates et al., 2015) and analysed in R version 3.2.3 software (R Core Development Team, 2015). Both grass height variables (before and after next placement) were strongly correlated (Pearson correlation: $r > 0.7$) so I created a new grass vegetation height variable named grass height change, which consisted of grass height measurement after 20 days minus the grass height measurement made on the first day of nest placement. To generate an overall artificial nest survival rate (OSR), I first ran a GLM using all data. I used the estimate of the intercept (i.e. the overall average) from this model and converted this to a daily failure rate (DFR) using the exponential value and the formulae: 1/1+(1/exponential). The DSR was then calculated as 1- DFR. For the OSR, I raised the DSR to the power 20 (DSR^{20}) since this represented the total number of days nests were left for the trial. Confidence intervals (95%) for this global model were calculated by adding and subtracting the intercept coefficient with its standard error and back transforming. Confidence intervals (95%) for models with single factors were calculated by adding and subtracting the intercept coefficient with the variable coefficient and back transforming.

For the GLM examining grass height change (again using a binomial error and logit link function), I saved the predicted values from this model and used the highest negative (-3.67) and positive (4.5) values to estimate DSR for each of these extremes, and used a zero (0) value to calculate a DSR for when there was no grass height change. Finally, I ran a separate GLM to examine the interaction between grass height change and nest treatment to determine whether the relationship between grass height change and DSR differs between nests with dung and nests with no dung.

6.4. Results

6.4.1. Survival, causes of nest failure and DSR of all artificial lark nests

The nesting success of artificial lark nests varied across all three trials (Table 6.1). Overall, nesting success was less than 50% for all three trials, and ranged from a low of 36% in June 2013, to a high of 45% in both November trials (Table 6.1). Predation and trampling by livestock were the main causes of nest failure, whilst up to 20% of artificial nests in each trial failed for unknown reasons (Table 6.1). Predation was the primary cause of nest failure in November 2012 and June 2013 whilst most nests failed in November 2014 due to trampling by livestock. Predation of artificial nests varied from 36% in November 2014 to a high of 68% in June 2013. Trampling of artificial nests varied from 8% in June 2013 to almost 55% in November 2014 (Table 6.1).

6.4.2. DSR of artificial nests and different hyena faecal treatments

Pooled datasets from November 2012 and June 2013 show that the observed nesting success of artificial nests was low, varying from 29.8% to 51% (Table 6.2). Predation was again the primary cause of nest failure of nests under different faecal treatments, causing up to 55% to 65% of all nest failures during these two trials (Table 6.2). Predation rates were greatest for nests with the older hyena faecal treatment (65.2%) and lowest for nests with fresh hyena faeces (55.2%). Trampling by livestock caused 13% to almost 28% of all artificial nest failures. The fewest nest failures caused by trampling were the nests with the older hyena faecal treatment, and unexpectedly highest (28%) for nests with the fresher, newest hyena faeces (Table 6.2). DSR were low for all three treatments, with the highest DSR recorded for artificial nests treated with older hyena faeces, and the lowest DSR, which was almost half the previous DSR, recorded for the nests treated with new hyena faeces (Table 6.2).

6.4.3. DSR of artificial nests and distance from edge

Similarly, pooled datasets from November 2012 and June 2013 show that the success of artificial nests at different distance intervals from cereal crop or invasive bush edges was again low, ranging from 29% to a high of only 46% (Table 6.3). Nest success rates were lowest at 30m from the edge, but increased at 70m and again at 100m from the edge (Table 6.3). Nesting success was similar at 5m from the edge to success rates of artificial nests placed in the interior of the Liben grassland (no edge – see Table 6.3). Predation was the main cause of artificial nest failure but there was no obvious gradient of increasing predation rate and greater proximity of artificial nests to an edge. Predation rates were highest at 70m and 100m from the edge (Table 6.3) and lowest at 5m and 30m from the edge. Similarly, no obvious gradient was found in the nest failure rates caused by trampling or in DSR and proximity of the artificial nests to edges (Table 6.3). Trampling by livestock caused 15% to 29% of all nest failures and was greater at 5m and 30m from the edge (Table 6.3). DSR was greatest at 100m from the edge and 5m from the edge (Table 6.3).

6.4.4. Influence of vegetation and faecal treatment on artificial nest survival

There was an increase in mean vegetation height around nests after 20 days following the faecal treatment (mean = 6.76 cm ± 2.13 cm SD) when compared to the mean vegetation height at the start of the trial (mean = 6.4 cm ± 1.98 cm SD) but these differences were not significantly different (t = –0.96; df = 237; P=0.337). There was only slight increase in the mean vegetation height across the locations where there were no faecal treatments (mean = 6.12 cm ± 1.78 cm at day 0) and (mean = 6.24 cm ± 1.76 cm at day 20). The change in grass height in the faecal treated areas had a mean of 0.36, while it had a mean of 0.11 in the untreated areas. T-tests revealed that there was no significant difference (P=0.183) in grass height changes brought about in areas with faecal treatment as compared to the areas with no treatment.

Across all three experimental blocks in November 2014, trampling caused the highest percentage of observed nest failures (Block 1 = 65.5%; Block 2 = 50%; Block 3 =43.5%) with predation also causing a high percentage of observed failures (Block 1 = 30.8%; Block 2 = 43.8%; Block 3 = 39.1%). The remaining nests failed due to unknown reasons. When running GLM models with covariates, faecal treatment and grass height change were retained, but not visibility. The overall DSR for artificial nests in November 2014 was 46% (Table 6.4). DSR for nests with hyena faeces was higher (58%) than artificial nests without faecal treatment (35.4%). DSR for negative changes in grass height (17%) was much lower than where there were increases (positive) changes in grass height (74.5%) and where there was no change (45% - Table 6.4). In other words, artificial nests were more likely to survive if the grass became taller over the 20-day exposure period, but were more likely to fail if there was a reduction in grass height. The GLM without interaction between faecal treatment and change in grass height (see Table 6.4) performed better than the model with interaction (GLM interaction faeces*grass height change: β = 0.1460, SE = 0.2842, Z = 0.514, P = 0.607) suggesting that the effect of grass height change on nest DSR was independent of hyena faecal treatment.

Table 6-1 Daily survival rates (DSR) and 95% confidence intervals (CI) of artificial lark nests placed across the Liben Plain in three separate experimental trials. n = number of artificial nests used for each trial.

Month (trial)	**Nesting success % (n)**	**Causes of failure % (n)**	**DSR (95% CI)**
November 2012 (n=63)	44.4% (n=28)	Predation = 48.6% (n=17) Trampling = 40% (n=14) Unknown = 11.4% (n=4)	0.936 (0.912–0.954)
June 2013 (n=78)	35.9% (n=28)	Predation = 68% (n=34) Trampling = 8% (n=4) Unknown = 24% (n=12)	0.924 (0.901–0.942)

Table 6-2 Daily survival rates (DSR) and 95% confidence intervals (CI) of artificial lark nests placed across the Liben Plain with different treatments of Spotted Hyena faeces. n = number of artificial nests used for each trial.

Treatment (n)	**Nesting success %(n)**	**Causes of failure % (n)**	**DSR (95% CI)**
Old hyena faeces (n=47)	51.1% (n=24)	Predation = 65.2% (n=15) Trampling = 13.0% (n=3) Unknown = 21.7% (n=5)	0.473 (0.334–0.616)
No hyena faeces (n=47)	29.8% (n=14)	Predation = 60.6% (n=20) Trampling = 21.2% (n=7) Unknown = 18.2% (n=6)	0.258 (0.120–0.468)
New hyena faeces (n=47)	38.3% (n=18)	Predation = 55.2% (n=16) Trampling = 27.6% (n=8) Unknown = 17.2% (n=5)	0.256 (0.096–0.529)

Table 6-3 Daily survival rates (DSR) and 95% confidence intervals (CI) of artificial lark nests placed across the Liben Plain at different distance intervals from two different edges (cereal crop farm and invasive bush scrub); n = number of artificial nests used in each trial.

Treatment (n)	**Nesting success % (n)**	**Causes of failure % (n)**	**DSR (95% CI)**
Grass no edge (n=45)	42.2% (n=19)	Predation = 57.7% (n=15) Trampling = 15.4% (n=4) Unknown = 26.9% (n=7)	0.376 (0.247–0.525)
5 m from edge (n=24)	41.7% (n=10)	Predation = 50% (n=7) Trampling = 28.6% (n=4) Unknown = 21.4% (n=3)	0.403 (0.227–0.608)
30 m from edge (n=24)	29.2% (n=7)	Predation = 52.9% (n=9) Trampling = 29.4% (n=5) Unknown = 17.7% (n=3)	0.292 (0.146–0.498)
70 m from edge (n=24)	37.5% (n=9)	Predation = 73.3% (n=11) Trampling = 20% (n=3) Unknown = 6.7% (n=1)	0.321 (0.124–0.614)
100 m from edge (n=24)	45.8% (n=11)	Predation = 69.2% (n=9) Trampling = 15.4% (n=2) Unknown = 15.4% (n=2)	0.443 (0.190–0.730)

Table 6-4 Showing Generalised Linear Models of predation rates and trampling rates of artificial nests modelled as a function of grass height change and presence or absence of hyena faeces. DSR = Daily Survival Rate (with 95% CI). See main text for description of DSR calculation.

Model	**Variables**	**Estimate**	**SE**	***Z***	**Significance**	**Daily Survival Rate (DSR) (with 95% CI)**
No covariates	*Intercept*	- 3.2416	0.1784	-18.17	*P*<0.0001	Overall DSR = 0.464 (0.040 – 0.519)
Single factor Hyena faeces	*Intercept* Hyena faeces	-2.9304 0.6604	0.2132 0.2566	-13.75 -2.57	*P*<0.0001 *P*<0.01	DSR with faeces = 0.580 (0.533 - 0.889) DSR without faeces = 0.354 (0.079 - 0.367)
Single factor Grass height change	*Intercept* Grass height change	-3.20276 -0.22440	0.1744 0.0851	-18.36 -2.63	*P*<0.0001 *P*<0.001	DSR negative grass change = 0.170 (0.040 – 0.818) DSR positive grass change = 0.745 (0.092 - 0.916) DSR no grass change = 0.450 (0.359 – 0.827)

6.5. Discussion

6.5.1. Predation of artificial nests

Clearly, the two major causes of artificial nest failure are predation and trampling by cattle (Tables 6.1 to 6.4). Predation is known to be a critical factor in the nesting success of many ground-nesting bird species (e.g. Robbins et al., 1989 ; Davis, 2005) and from field trials using artificial nests (e.g. Nour et al., 1993; Huhta et al., 1996). Intensification of certain agricultural practices often results in increased predator abundance across agricultural landscapes (Klug et al., 2009) which has consequences for ground-nesting grassland-dependent bird species (Pita et al., 2009). Increased predator abundance can lead to reductions in bird population size by reducing breeding success (Yanes & Suarez, 1996; Fletcher et al., 2010). Across Ethiopian rangelands there has been documented increases in the number of Boran cattle and the resident human population (Homann, 2004). On the Liben Plain there has been intensive overgrazing and a decline in nomadic pastoralist management (see Chapter One). The effects on populations of native nest predators such as the Somali Crow and the Kori Bustard and mammal predators like the White-tailed Mongoose *Ichneumia albicauda* remain unknown and should be the focus of future research.

Despite the fact that an artificial nest trial modelled on a single target species has the greatest likelihood of resembling a natural situation (Major & Kendell, 1996), the artificial nest predation rates and the DSRs in this study may not resemble the predation rates or DSRs of real Liben Lark nests for several reasons (Green, 2004; Ludwig et al., 2012). First, predation rates could have been affected by nest placement and thus degree of concealment (see also section 6.4.3. below), although for this study I made every effort to minimise any risks associated with placement by recreating the conditions of natural nest placement based on what is known of the Liben Lark nesting behaviour (see Collar et al., 2008). Second, other studies have suggested that natural nest placement may impact artificial (and natural) nest survival rates (e.g. Salonen & Penttinen, 1988; Reitsma, 1992; Kelly, 1993, Major et al., 1994). Third, predators may be attracted or deterred by certain features of the artificial eggs (Janzen, 1978; Maier & DeGraaf, 2001) such as the scent of the plasticine (Green, 2004); predators may use different cues such as the presence of an incubating adult bird to find real nests (Green, 2004). Fourth, adult birds may in some instances be able to deter predators from the nest, thus influencing nest survival (Schaefer, 2004; Trnka et al., 2008). Other studies have used arbitrary exposure periods (Major & Kendell, 1996) or have exposure times determined by the logistics of the field trial (e.g. Loiselle & Hoppes, 1983). However in this study, I attempted to approximate the exposure time and all aspects of nest design, egg design and nest placement to something similar of the known incubation period of other lark species.

Some studies have shown that predation rates of artificial nests are much higher than those of real nests (e.g. Reitsma, 1992; Roper, 1992), whereas other studies have found the opposite (e.g. George, 1987; Willebrand & Marcstrom, 1988) and still others have failed to find any difference in predation rates between the two types (e.g. Gottfried & Thompson, 1978; Crabtree et al., 1989). Making inferences about real predation rates from the use of artificial nests for the Liben Lark is therefore problematic, but this does not lessen the importance of using artificial nest trials. I recommend that future studies should target the further use of artificial nest trials in conjunction with camera traps (e.g. Thompson et al., 1999; Butler & Hamilton, 2000; Pietz & Granfors, 2000) in order to identify and perhaps estimate relative abundance of the different predators of the artificial nests. Understanding the role of different predators of artificial nests will lead to a more accurate assessment of predation on real Liben Lark nests across the Liben Plain (e.g. Thompson et al., 1999; Renfrew & Ribic, 2003).

6.5.2. Livestock trampling of artificial nests

Trampling by livestock (cattle) also plays a key role in the breeding success of ground-nesting grassland birds (Beja et al., 2014). There has been intensive overgrazing and a decline in nomadic pastoralist management across the Liben Plain, driven by settlement initiatives, causing severe grassland degradation and reduction (see Chapter One). Whether this has caused a decline in the real nesting success for the Liben Lark remains unknown. However, if these data are used as an index for real nest survival rates (e.g. Major & Kendell, 1996; Lind, 1997) then trampling could be another important factor affecting lark nest survival. Less is known about any differences in trampling rates between artificial and real nests (Beja et al., 2014) but one study has suggested that the difference in trampling rates between nest types may be smaller than those of predation rates (Mandema et al., 2013). These authors report that cattle movements across grazing fields are largely independent of the breeding bird activity or patterns of nest concealment, so any differences between real or artificial nests should be minimal (see Mandema et al., 2013).

Heavy grazing pressure by increasing numbers of cattle alters the vegetation characteristics of the grassland (Johnson et al., 2012), changing both the height and structure (quality) of the grass, and could therefore modify the exposure of nesting birds and their nests to predators (Dion et al., 2000; Van der Wal & Palmer, 2008). Variability in stocking rates of cattle across the Liben Plain (Bennett et al., *in revision*) could therefore potentially have strong direct and indirect effects on Liben Lark nest success. However, livestock grazing is a complex spatiotemporal form of disturbance (Johnson et al., 2012), and factors such as stocking rates have to be considered in future studies of Liben Lark nesting behaviour or the use of artificial nest trials across the plain. Stocking rates could influence nesting success because they can determine the amount and distribution of vegetation available for use by grassland-dependent birds (Fuhlendorf & Engle, 2001), as well as the length of time either real or artificial nests are exposed to potential trampling by the cattle (Johnson et al., 2012).

6.5.3. Influence of habitat edges on DSR

I found no obvious trend of increasing nest survival (increasing DSR) with increasing distance from the edge of cereal crop fields or invasive bush encroachment (Table 6.3). DSRs of artificial lark nests were different at different distance intervals but an increasing trend was only apparent from 30 to 100m. In fact, the DSR at 100 m was more similar to that of artificial nests placed only 5 m from the edge habitat (Table 6.3). Some studies have shown that nesting success of grassland birds declines with increasing proximity to woodland edge habitats (e.g. Bollinger & Gavin, 2004) but not towards roads or agricultural fields (Winter et al., 2000). Other studies however have shown that nesting success between grasslands and woodland edges and those bordering crop fields are very similar (e.g. Jensen & Finck, 2004; Renfrew et al., 2005).

The pooling of Liben nest data due to small sample sizes from both habitat types may have masked any continuous trend from the edge to 100 m to the interior of the grassland habitat. Alternatively, the small sample sizes, distance intervals and artificial nest density may not have been adequate and may have affected the DSRs. Nevertheless, the distance intervals used in this study were similar to that used in other studies of grassland bird species (e.g. Winter et al., 2000), which showed that most predation of artificial nests occurs within 50m of the grassland–woodland boundary. However, it could be the case that on the Liben Plain too few nests were placed within 50 m of enough different types of edges to account for a more obvious trend in DSRs. Or it may be the case that both invasive bush habitat and cereal crop fields may not represent a sharp contrast between grassland and the other habitats, i.e. they do not represent ‘hard edges’ and future studies using artificial nest trials should determine this.

6.5.4. Modelling predation and trampling rates

The GLM models did not explain much of the variation in DSRs of the artificial nests (Table 6.4). In fact, artificial nest failure seemed to be a random chance event across the three experimental blocks in November 2014. Previous studies have found that trampling by livestock is a spatially random process, where chance plays a significant role on the DSR of artificial nests (e.g. Jensen et al., 1990; Pavel, 2004). Other studies have even found that predation and trampling are independent influences on nest survival (e.g. Beintema & Müskens, 1987). Perhaps more importantly, the GLMs do suggest that artificial nest DSR is higher with the provision of hyena faeces and is significantly higher where grass height increases over the 20-day exposure period (Table 6.4). These results suggest that hyena faeces may have some value as a novel biological control agent and that taller grass vegetation should be a habitat restoration goal for the recovery of the Liben Lark breeding population. Taller, denser grass vegetation could help promote greater nest concealment and reduce the likelihood of predation. However, it is worth remembering that these trails were conducted using artificial nests and the DSR of real nests may be very different. For example, Johnson et al., (2012) found no relationship between grassland vegetation structure and real nest failure rates of Horned Lark (*Eremophila alpestris*) due to predation. Other studies have found that increased vegetation height is associated with reduced artificial nest trampling rates (e.g. Paine et al., 1996). Grassland height can change even throughout the brief 20-day window of the November 2014 trials (see Results). The cause of the changes to vegetation quality should be examined further to determine whether the increases are caused by reduced grazing, caused by hyena faeces treatment or by other, natural levels of grass growth during the breeding season. These data could permit a more accurate assessment of the use of hyena faeces as a novel biological control agent to prevent overgrazing around real nests.

In this chapter I have shown that field trials using artificial nests constructed and placed resembling natural nests can make a significant contribution to our understanding of the threats faced by ground-nesting grassland-dependent bird species, and more specifically, to a better understanding of the nesting ecology of Africa's most threatened bird species. These trials have also provided important insights into how future conservation strategies should focus on restoring tall, dense grass vegetation for suitable breeding habitat. In the final chapter I will use summarise the major findings of Chapter's Two to Six, and use these findings to develop an evidence-based conservation strategy to prevent the extinction of the Liben Lark and help restore Borana pastoralism.

6.6. References

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Chapter Seven

AN EVIDENCE-BASED CONSERVATION STRATEGY FOR THE LIBEN LARK

7.1. Meeting the main aim of the PhD

The overall aim of the PhD was to produce an evidence-based conservation strategy, to find ways in which the plain can be managed in order to serve the dual purposes of reducing the extinction risk faced by Liben Lark primarily by increasing its population and area of occupancy while at the same time maximizing the yield of the plain. Below I outline the main findings of each chapter, and then detail how each of these main findings contribute toward a new five-point evidence-based conservation strategy to prevent the extinction of the Liben Lark.

7.2. Summaries of analysis

7.2.1. Chapter Two.

Analysing LandSat data using Geographical Information Systems (GIS) revealed changes in the extent of habitats across the Liben Plain. During 1994-2015 grassland habitat declined by 25% due to crop cultivation, with some losses due to bush encroachment and settlement. Conversion to cereal crop cultivation occurred on both black soil and red soil grasslands, with the poorer red soil grassland conversion rate increasing dramatically from 2008. Grassland vegetation and crop cycles were highly dependent on the biannual rainy seasons of the Liben Plain. Within the core area of the Liben Plain occupied by the Liben Lark, the majority of grassland now covers just 23.76 km^2 corresponding to only fourteen remnant patches.

7.2.2. Chapter Three.

Distance sampling line transect surveys were conducted from 2007, and 2009-2013. A total of 217 individual Liben Larks were recorded, the majority of which were males. Surveys conducted during the main wet season (May/June) produced greater sample sizes and more robust density estimates than those conducted in the shorter (November) wet season. Density estimates of the Liben Lark varied markedly and declined from a high of 3.2 individuals per km^2 of grassland habitat in 2007, to one individual per km^2 by November 2013. Liben Larks were concentrated in highly conspicuous hotspots, which ranged in size from 26.38 km^2 to

3.87 km^2 and the location of these shifted slightly throughout the different years due to changes in the extent of grassland habitat and loss to croplands.

7.2.3. Chapter Four.

Grassland habitat surveys revealed that >21% of the grasslands covered by transect surveys had been converted to crops by the end of 2013. Multiple logistic regression analyses identified key habitat characteristics influencing the presence/absence of Liben Larks during the main or shorter wet seasons, but not dry season surveys due to extremely low detection of larks. Liben Lark presence was positively influenced by more medium-height grassland quality (ranging from 5cm to 40cm) but they avoided areas of very tall grasslands. Trees, areas of bare ground, short degraded grass (<5cm height) and invasive scrub all had negative effects on the Liben Lark population.

7.2.4. Chapter Five.

Focus Group Discussion and Semi-structured interviews with the community members in the Siminto and Meisa Peasant Association of the Liben Plain revealed that there have been adverse changes in the rangeland habitat, mostly involving expansion of agricultural fields leading to the degradation of the grassland habitat. Access to land for either cereal crop farming or for private enclosures is determined primarily by government institutions and does not involve traditional Borana institutions. Members of these institutions (e.g. the *Abba Dheedaas*) insist that people go elsewhere for their wet season forage, but this is largely ignored by most residents. The building of private *kallos* in the Siminto PA is mostly supported by the traditional *Abba Ollas* but could result in reducing the overall area of communal grazing land. Representatives of the traditional institutions such as the *Abba Dheedaas* are not informed when portions of the communal grazing areas are allocated for cereal crop farming, and tend to be in direct opposition of such practices. There is conflict and lack of coordination between the traditional and state institutions with regards to resource use and allocation across the Liben Plain to the extent that traditional institutes are becoming increasingly unable to cope with the different government policies on development and resettlement.

7.2.5. Chapter Six.

Predation and trampling were found to be the main causes of artificial lark nest failure. No significant changes in grass height due to hyena faecal treatment were detected and there was no obvious trend of increasing daily survival rates (DSR) of artificial nests with increasing distance either from the edge of cereal crop fields or invasive bush. The effect of grass height change on artificial nest DSR was independent of hyena faecal treatment but artificial nest DSR was higher with the provision of hyena faeces and where grass height increased over a 20-day exposure period. Across the Liben Plain, artificial nest failure seemed to be a random chance event but hyena faeces may have some value as a novel biological control agent.

7.3. An evidence-based conservation strategy to prevent the extinction of the Liben Lark and help preserve Borana pastoralism

7.3.1. Restore grassland habitat and remove invasive scrub

First and foremost, in order to prevent the extinction of the Liben Lark and to maintain good grazing grounds to sustain the livestock of the Borana families, conservation efforts must focus on restoring suitable grassland habitat for the species and the pastoralists, whilst halting the loss of grassland habitat to cereal farming. Habitat restoration should take the form of creating communal kallos – fenced enclosures. Communal kallos are a recent development for rangeland habitat management in Eastern Africa, but have gained rapid support by many Borana because of the increasing grassland degradation and drought frequency throughout Borana rangelands and are now recognised as essential to preserving pastoralism. These kallos will provide Borana households with hay in the dry season, enabling cattle to produce milk for people, so closing the dry season hunger gap they currently experience.

Evidence from Chapter Five reveals that NGOs can play a role in promoting and supporting the creation of kallos and following Borana custom, the hay grown from the kallos could be distributed preferentially to female-headed and/or poorest households, who are recognised as being the most vulnerable. Evidence from Chapters Three and Four reveal that the Liben Lark breeds in May/June and also November each year. The use of kallos to create suitable tall dense grassland should increase the breeding productivity of the Liben Lark, thus leading to a rapidly detectable population increase. Importantly, hay cutting from the kallos for the Borana should be conducted after the breeding seasons of the Liben Lark in case the species breeds within the newly created kallos.

Evidence from Chapter Four shows that the Liben Lark avoids wooded habitat whilst evidence from Chapter Two shows that the amount of suitable grazing areas has been lost across the Liben Plain. Conservation efforts should therefore also focus of removing invasive Acacia scrub to extend the open grassland area for livestock foraging. The cut acacia can then be transported to construct kallos fences and subsequently under-planted with non–invasive euphorbia, which grows into permanent 'living fences' as the acacia biodegrades.

7.3.2. Target habitat restoration efforts in remaining stronghold of Liben Lark

Evidence from Chapter Two suggests that cereal crop farming has expanded dramatically from black soil grasslands to red soil grasslands. Evidence from Chapters Three and Four shows that the remnant Liben Lark population is highly aggregated around areas of red soil and avoids areas converted to cereal crops. Conservation efforts should focus on the strategic siting of *kallos* on red soil grassland areas that correspond to known density hotspots for the Liben Lark and areas immediately adjacent to them. Newly created *kallos* should aim to encompass most of the known 23km^2 area occupied by the Liben Lark.

7.3.3. Set realistic population recovery goals for the Liben Lark

Evidence from Chapter Three suggests that in 2007, the Liben Lark occurred at a density of almost quadruple of what was estimated in 2013. Conservation efforts should aim to help the Liben Lark population to recover to a level of four individuals per km^2 of grassland habitat in the next four years. Annual surveys of vegetation and lark bird density should be conducted both inside and outside the *kallos* to monitor grass growth and Liben Lark population.

7.3.4. Enhance and maintain grassland habitat quality for Liben Lark

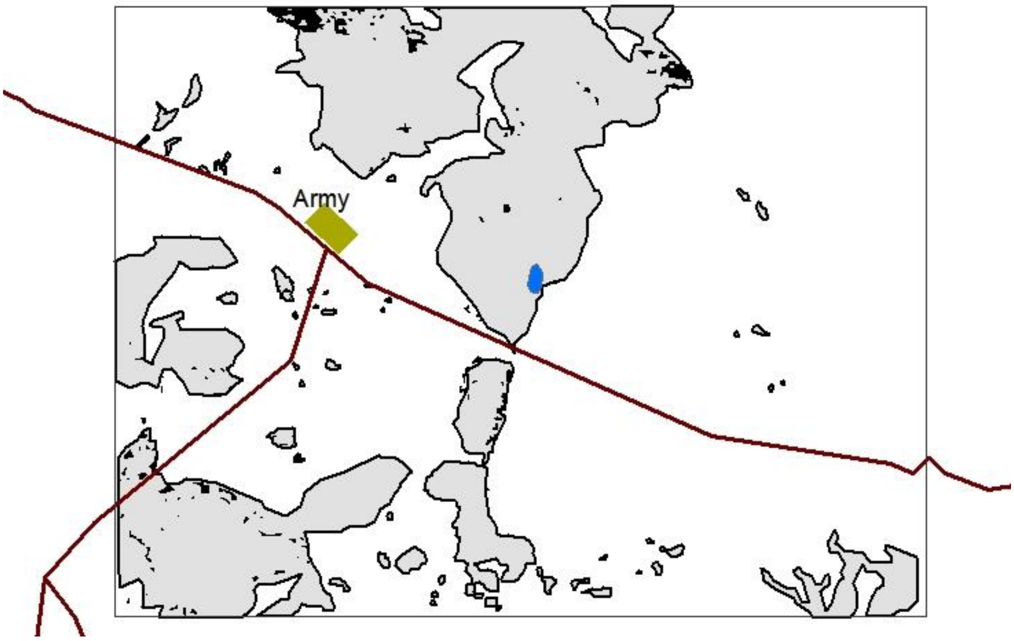
Evidence from Chapter Two shows that May/June and November coincide with the rains and greatest growth of new grass across the plains. Evidence from Chapter Four suggests that the Liben Lark avoids areas of cereal crops, instead preferring areas of taller, lesser disturbed grassland, that are subject to less grazing pressure, with less invasive tress and fennel plants, and few areas of bare, exposed ground. Conservation efforts on the Liben Plains should therefore focus on restoring the grasslands to such a condition that is beneficial for the lark. *Kallos* should therefore aim to restore grassland habitat at the onset of both wet seasons, to recreate extensive tall, dense grass vegetation (15cm-40 cm in height), thus increasing the chances of lark breeding success through increased vegetation cover for greater nest concealment (see Chapter Six) and reducing the amount of bare ground cover. All invasive plants should be removed from the proposed *kallos* sites and livestock prohibited from grazing within them. Density hotspots for the Liben Lark situated on black soil grasslands outside of communal *kallos* should be treated with hyena faeces to act as a biological deterrent to cattle grazing, to help minimize the risk of nest failure caused by livestock trampling and improve nest concealment.

7.3.5. Empower local institutions and improve governance for habitat restoration

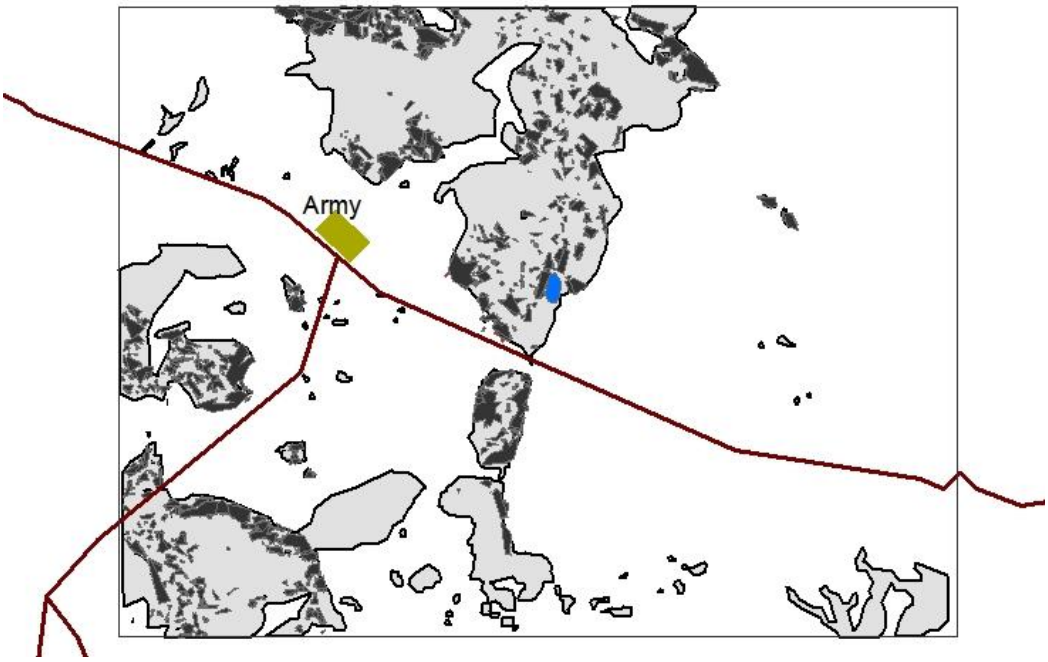
Evidence from Chapter Three shows that several areas in Siminto and Meisa Peasant Association (PA) represent core habitat areas of the Liben Lark. Evidence from Chapter Five suggests that promoting and expanding the use of *kallos* represents a realistic strategy identified by the Borana, for producing enough livestock forage for pastoralists and may prevent further expansion of cultivation. Institutions such as the Oromia Forestry and Wildlife Enterprise (OFWE) and conservation organisations could play a lead role in the demarcation of *kallos* for these areas. Current problems of coordination between the traditional and state actors (e.g. pasture utilization committee and Site Support Group) and between different actors within traditional institutions must be resolved by reforming by-laws formulated by community elders. This would help create more formal links between traditional institutions with relevant district offices and permit effective conservation management of *kallos*. Revised by-laws would also clarify the process of land acquisition to prevent uncoordinated 'land-grabs' on the Liben Plain. Local institutions should be empowered to enforce penalties for extension of croplands and settlements in the *kallos*, or for cutting grass or allowing cattle inside *kallos* without the consent of the association members. Finally, to help reduce the need to take up cereal crop farming, non-governmental organisations and other international conservation organisations should consider the establishment of local community-based organisations (CBOs) to benefit the most vulnerable households and help diversify their livelihood options.

Appendix

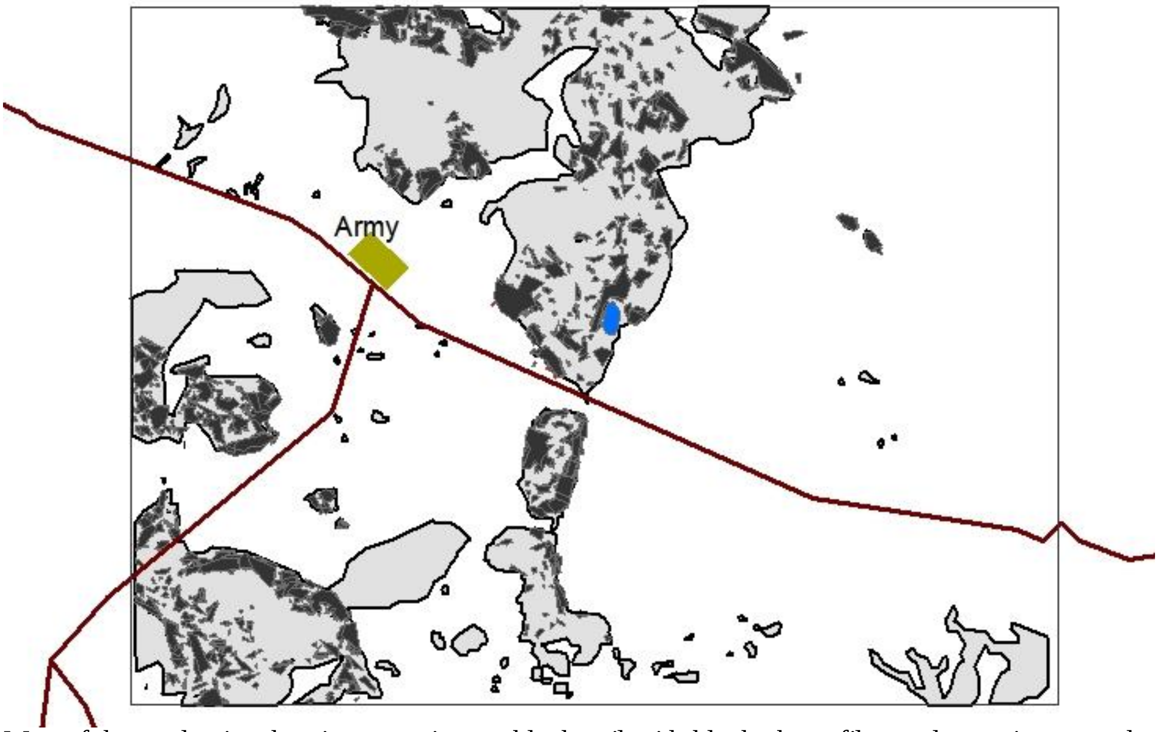
Chapter Two – images showing the annual conversion of grassland habitat to cereal crop farming across the Liben Plain



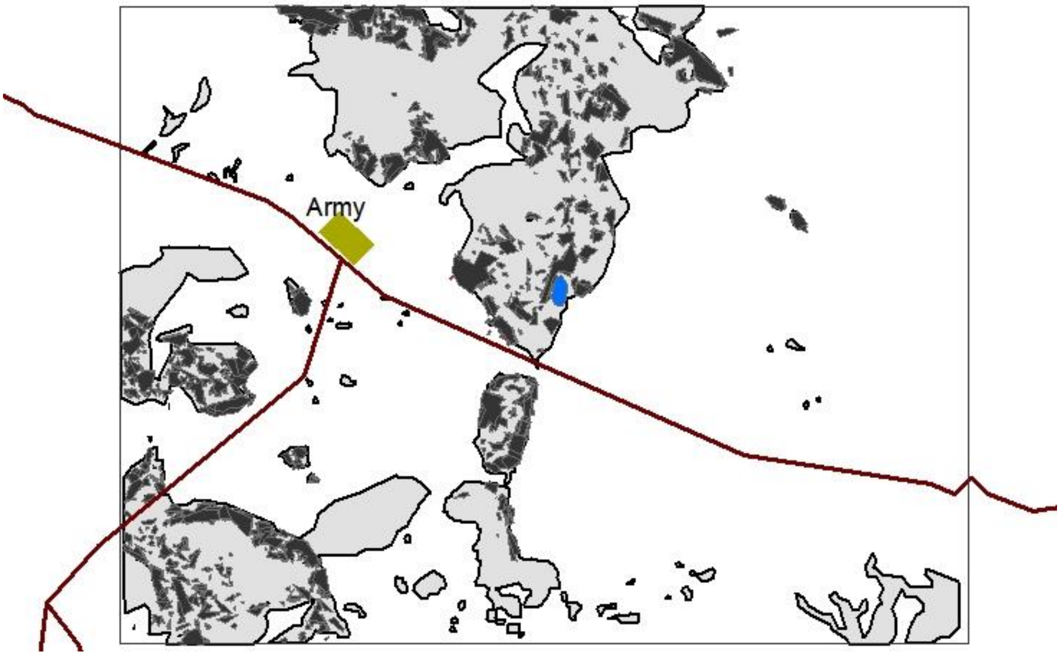
Map of the study site showing cropping on black soil with black shape files in 1994



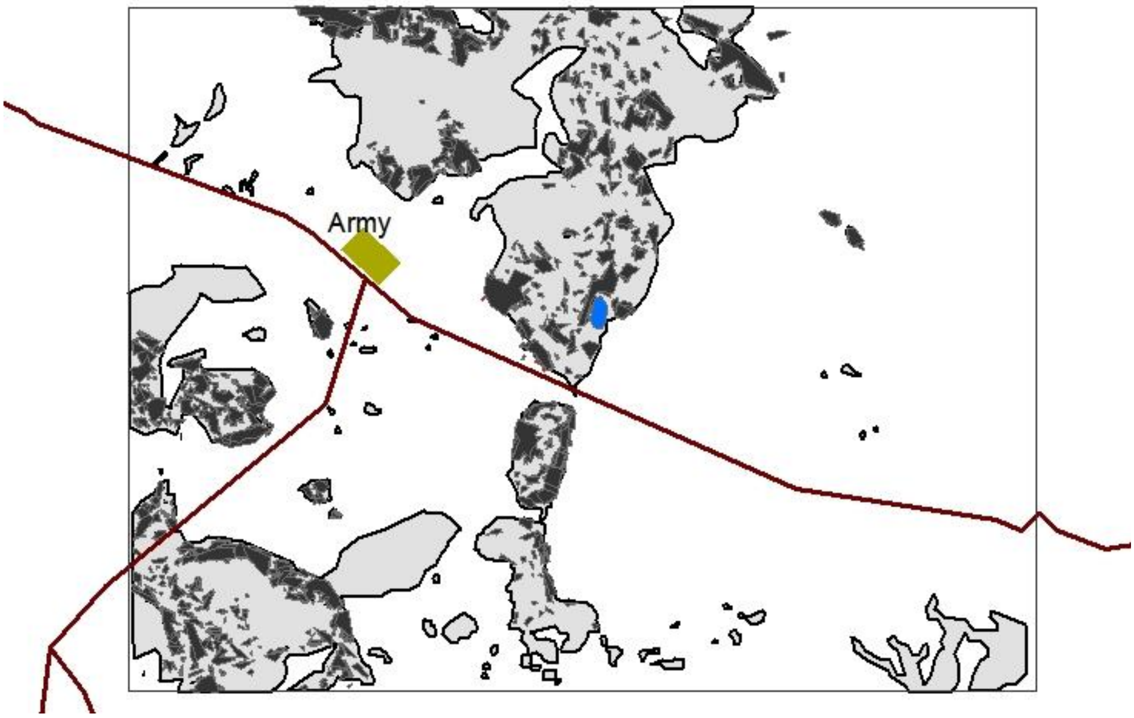
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2001



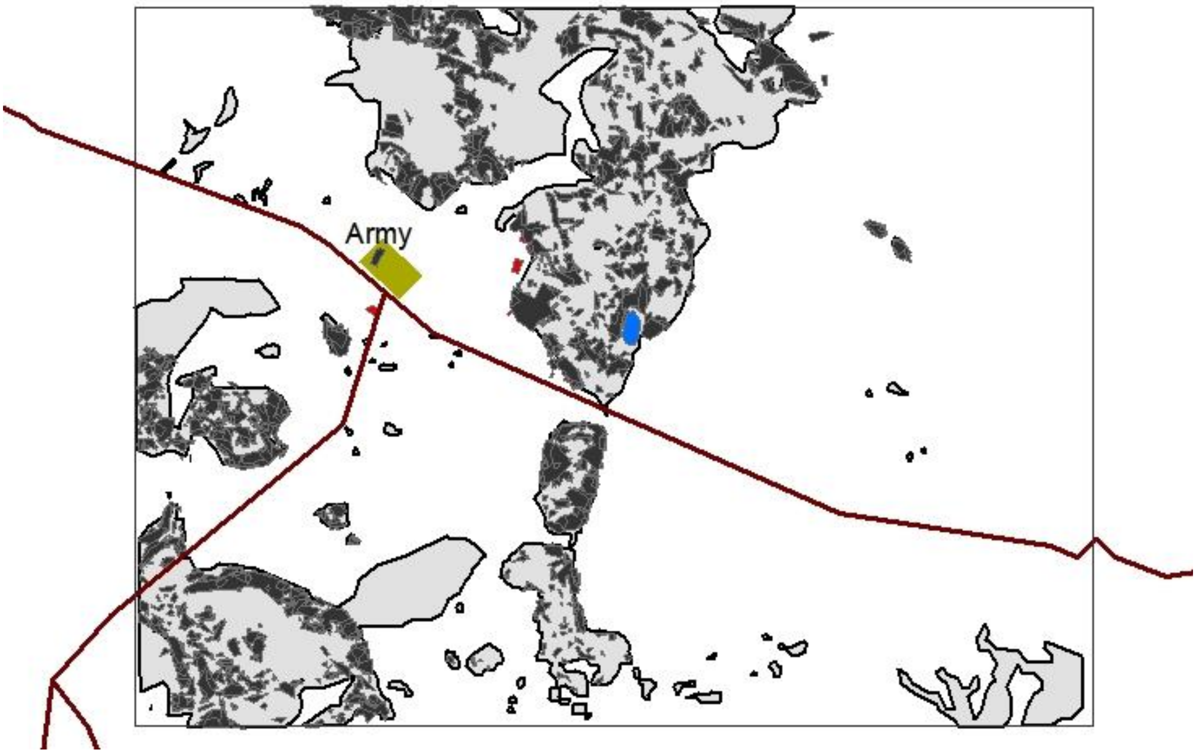
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2002



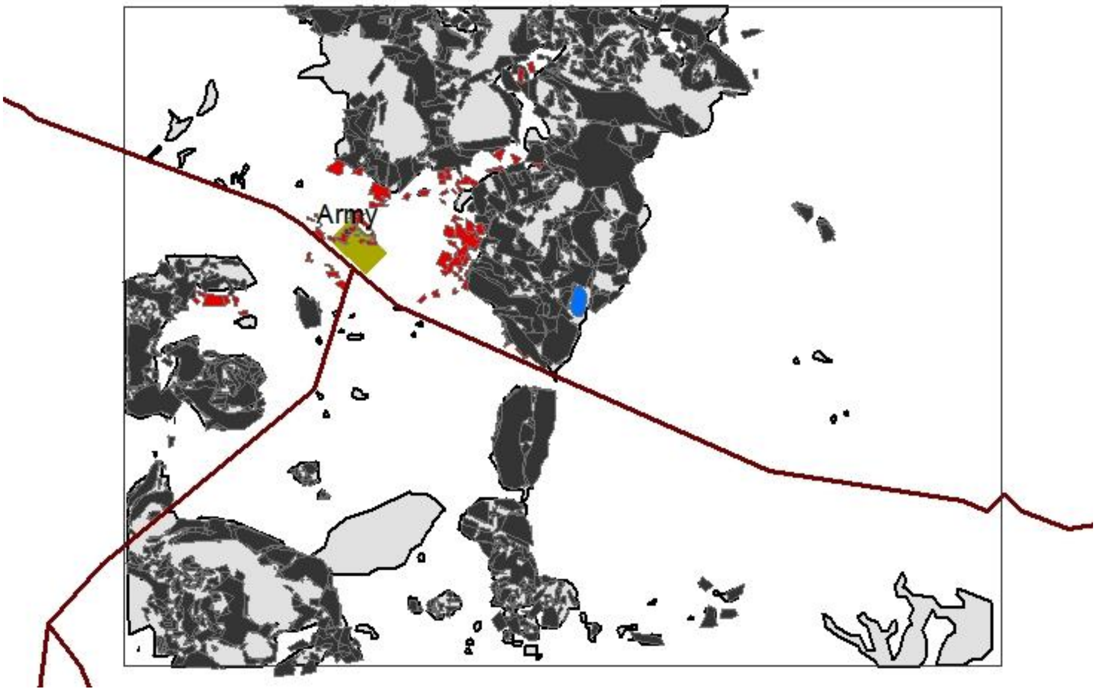
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2003



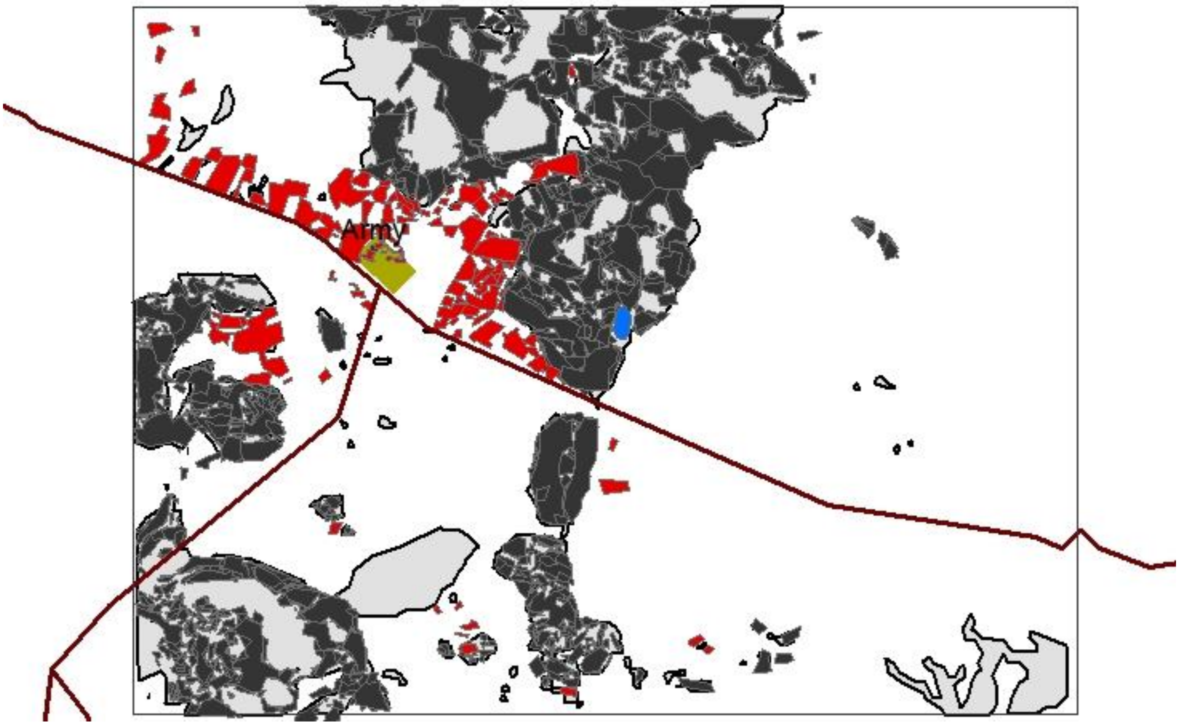
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2004.



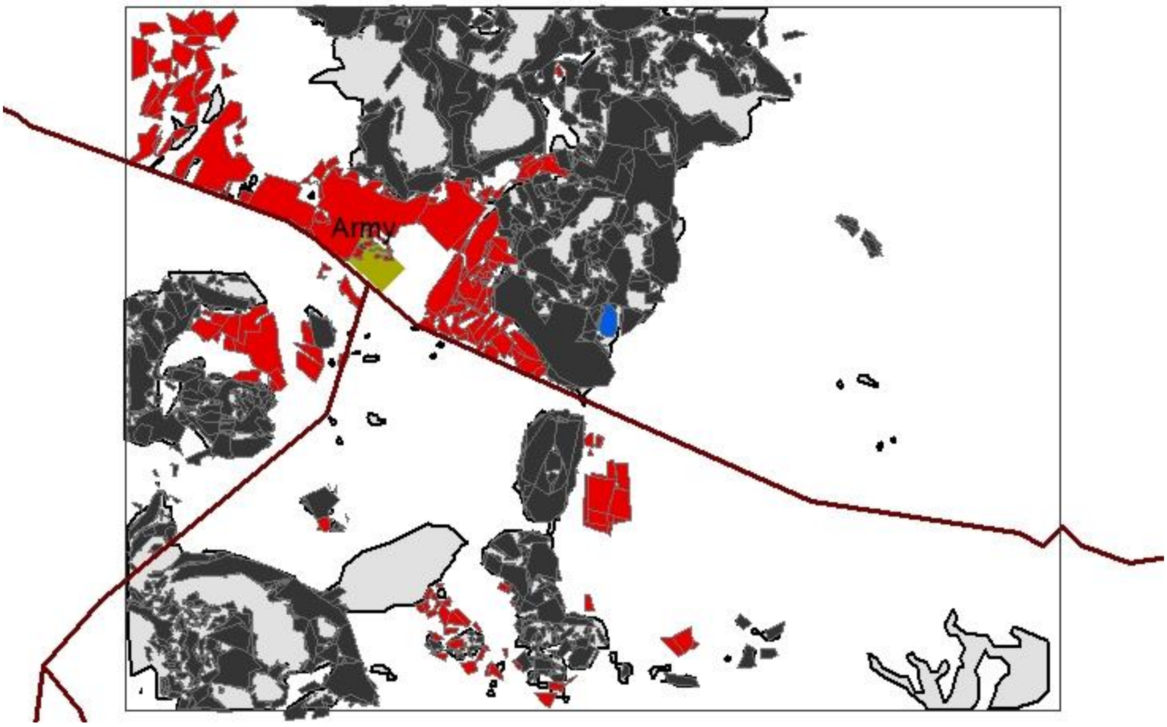
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2006.



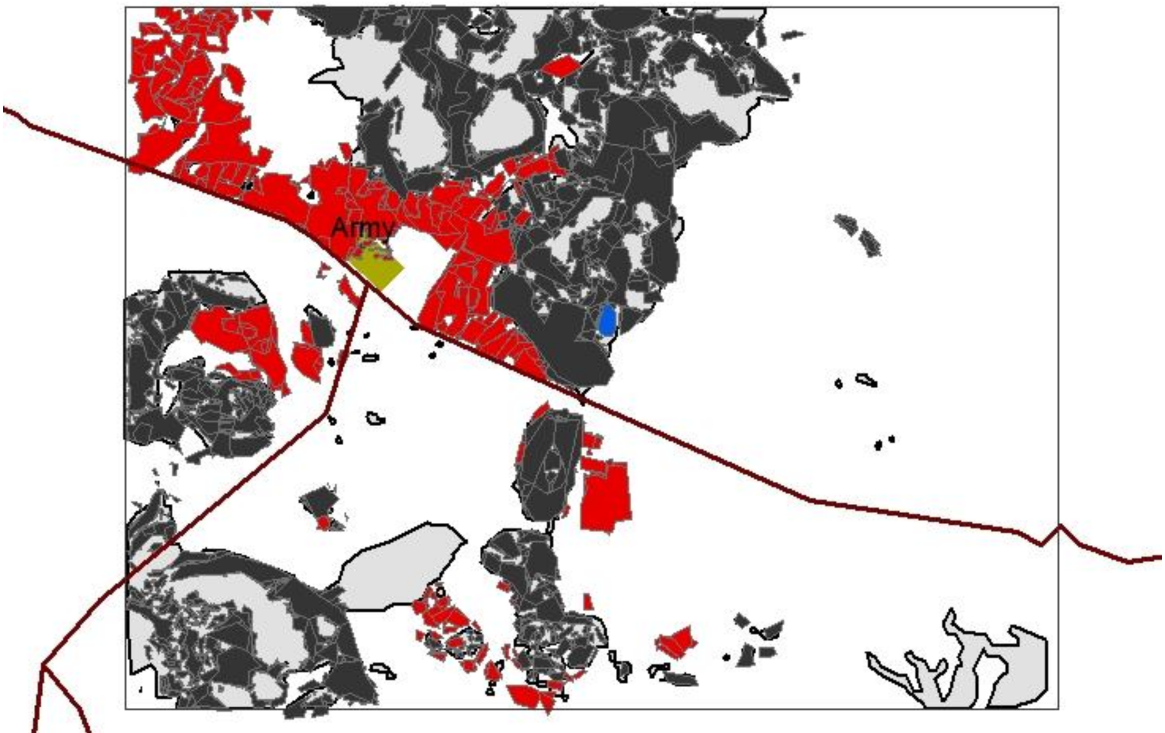
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2008.



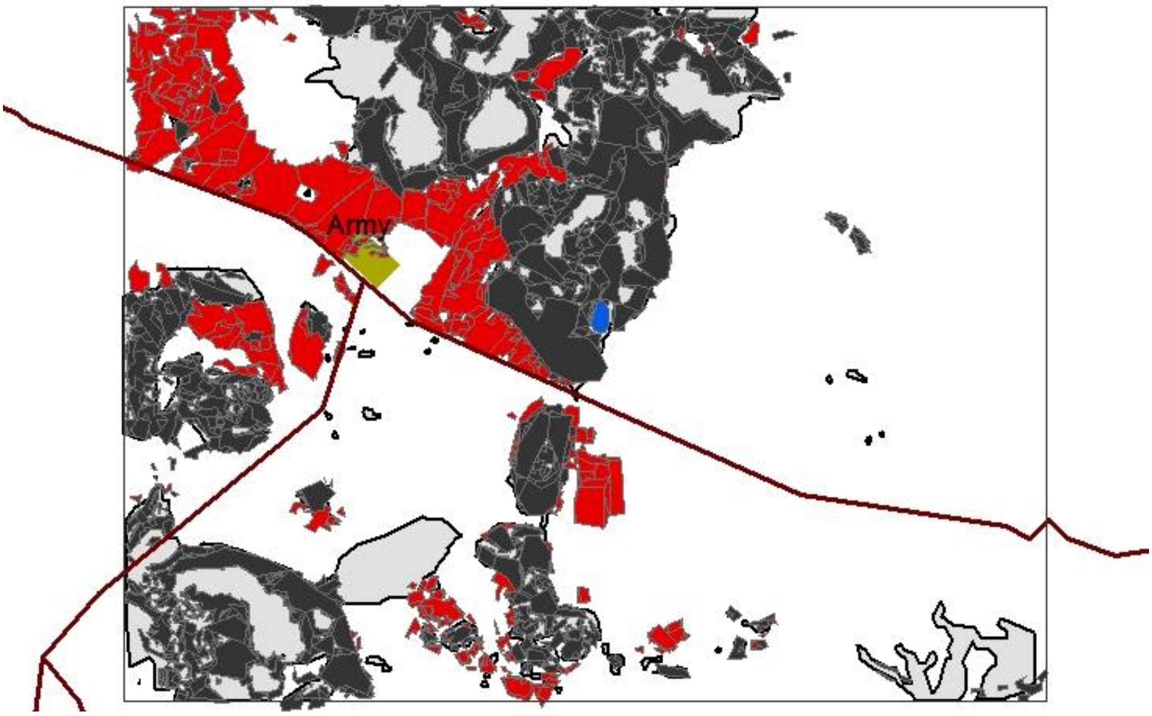
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2009.



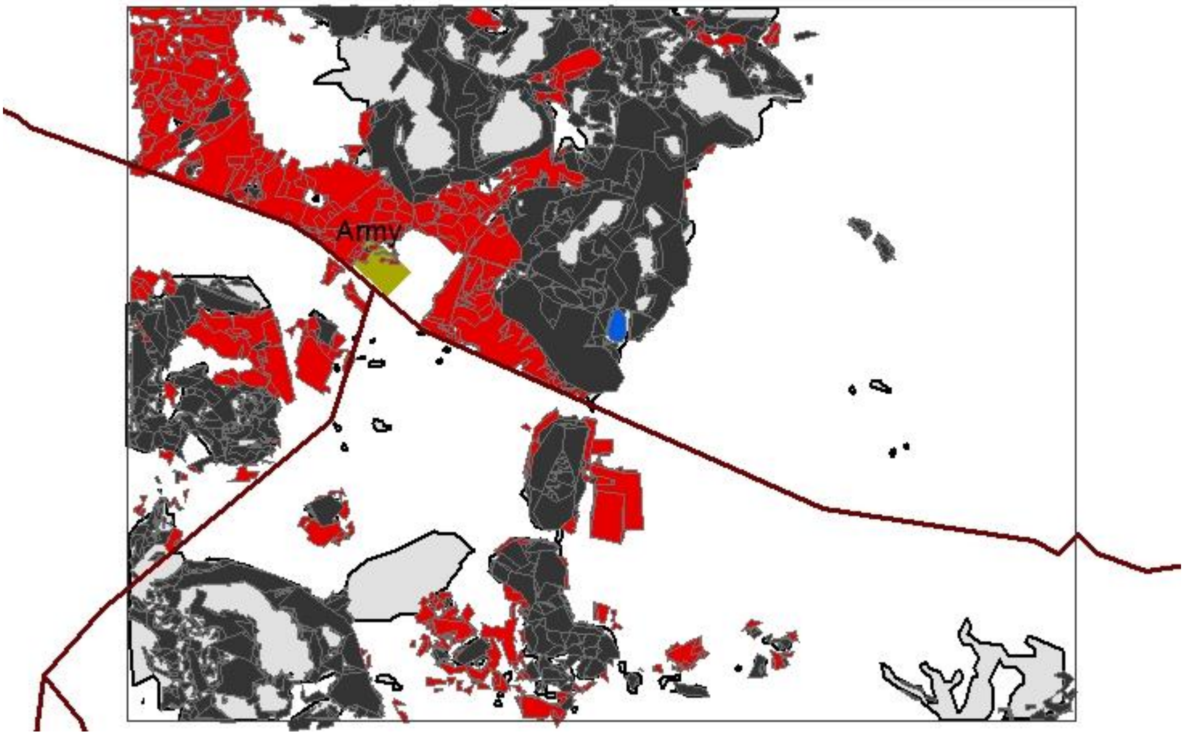
Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2011



Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2012.



Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2013.



Map of the study site showing cropping on black soil with black shape files and cropping on red soil shown in red coloured shape files in 2014.

Chapter Six - artificial Liben Lark nest experiment

Artificial nest with two plasticine eggs, categorised as failed due to predation

Artificial nest with plasticine eggs categorised as failed due to livestock trampling

Chapter Five - Focus group discussions

Focussed Group Discussions being held in the Meisa PA

Focussed Group Discussions held at the Siminto PA

Chapter Five – example of the Questionnaire

Questionnaire survey format for socio- economic impact assessment at Borena Negele.

Kebele/ Zone/ Ola ________________________

Number of household in the Ola ____________

Agropastoralists or pure pastoralists

No. of people present in the group discussion / household

____

1. How was the plain in previous times and how has it changed over the years? Describe the similarities/differences.
2. Is it good or bad for you?
   why/how
3. How are grazing lands managed? and who decides who grazes where?
4. Where do cows, calves and/or dry livestock graze?
5. How many of the respondents had private kalos?
6. Do you use different grazing areas in dry and wet seasons
7. Where do cattle go for drinking water and which paths do they use?
8. When did farming start in this area i.e.
   on red soil and on black soil
9. Is your crop yield good? Do you plant during both the rainy seasons? Do you use it for self-sustenance or you have surplus to sell?
10. What chemicals do you use as fertilizers and/or pesticides?
11. Why were some crop fields abandoned?
12. What is the biggest problem for you due to the change?
13. What solutions do you recommend for the stated problems?
14. If the problem is grass shortage during dry season
    a) How has shortage of forage during dry season affected your family?
    b) How many litres of milk/cow do you get during dry season?
    c) Do any of your milking cows die during the dry season?
15. How do you think the plain will change after ten years?
16. How would you like the plain to change after 10 years?
17. Have you heard about the Liben lark? What do you know about it?