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The Ecology of Black Crowned Crane (*Pavonina pavonina ceciliae*) in relation to changes of land use at Lake Tana, Ethiopia

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A Thesis Submitted to the School of Graduate Studies of the Addis Ababa University in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Biology (Zoological Sciences Stream)

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School of Graduate Studies

This is to certify that the dissertation prepared by Shimelis Aynalem Zelelew, entitled: *The Ecology of Black Crowned Crane (Pavonina pavonina ceciliae) in relation to changes of land use at Lake Tana, Ethiopia* and submitted to in fulfillment of the requirements for the degree of Doctor of Philosophy in Biology (Zoological Sciences Stream) complies with the regulation of the university and meets the accepted standard with respect to originality and quality.

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ABSTRACT

The Ecology of Black Crowned Crane (*Pavonina pavonina ceciliae*) in relation to changes of land use at Lake Tana, Ethiopia

Shimelis Aynalem Zelelew

June, 2017

Black Crowned Crane is a resident species in Ethiopia. However, the available information on the breeding, feeding ecology and its status is in adequate. This study was carried out in Lake Tana area, from 2014-2016. The study aims to investigate the breeding and feeding ecology, distribution, abundance and habitat change of cranes. Different statistical tools were used to evaluate the different parameters. ANOVA and Shannon diversity index, a fixed GLM procedure and MANOVA were applied. A total of 74 and 56 transects in 2015 and 2016 was carried out to estimate the abundance and density of cranes. Multiple Covariate Distance sampling model was employed for distance analysis. Wetland habitat shrinkage was evaluated from the land use land cover change from 1986 to 2016. The result showed that all crane nests were located only in wetlands where water depth ranged 135-220 cm. The active nesting time was September to October. The inter-distance between nests did not vary from site to site. Cranes utilized nest materials collected from the nesting place. The mean vegetation height at which the nest constructed was variable. The nest morphology parameters were not different statistically. The nesting density was 6-7 /100 ha. The average clutch size of Black Crowned Crane was two (n=92). The mean length of eggs was 76.94±.22 mm, and width measured 54.05±.07 mm. The mean weight of eggs (n=92) were 111.99±.65g. There was a positive correlation between egg length and width, and were statistically significant. Hatchability was 91.3%, but the pre-fledged percentage was about 50%. Oryza longistaminata and Leersia hexandra were the dominant macrophytes. The distribution and biomass of macro-invertebrates were significantly different across study sites (P<.05). The most abundant and frequently occurring taxa were Libellulidae, Coenagrionidae, Hydrophilidae, and Culicidae. Grass seeds and crop seeds were major food sources of cranes. Fecal analysis of cranes revealed that the diet contained parts of plants, fragments of animal origin and small quantities of inorganic materials and shells at different proportion. There was spatial and seasonal variation in the distribution of cranes. Crane population was more abundant during the dry season. Chimba and Yiganda wetlands are identified as the main breeding and feeding sites; however, the habitats shrunk by 47% in Chimba and by 25% in Yiganda. Agricultural encroachment, livestock pressure and population growth are the main threats.

Keywords/phrases: Breeding, crane density, diet, egg and nest morphometry, land use land cover, nest

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DEDICATION

This Ph.D Dissertation is dedicated to Dr. George Archibald-co-founder of the International Crane Foundation, USA who have spent his entire life for the conservation of cranes and their habitats in the whole world.

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ACRONYMS

n	Number of observed cranes
L	Total length of transect line(s)
k	Number of samples
ER	Encounter Rate (n/L or n/K or n/T)
W	Width of line transect or radius of point transect
x(i)	Distance to i-th observation
s(i)	Cluster size of i-th observation
r-p	Probability for regression test
chi-p	Probability for chi-square goodness-of-fit test
m	Number of parameters in the model
A(I)	i-th parameter in the estimated probability density function(pdf)
f(0) - 1/u	value of pdf at zero for line transects
u - W*p =ESW	ESW, effective detection area for line transects
h(0)	2*PI/v
p	Probability of observing an object in defined area
ESW	for line transects, effective strip width = W*p
DS	Estimate of density of clusters
E(S)	Estimate of expected value of cluster size
D	Estimate of density of animals
N	Estimate of number of animals in specified area

DEFINITIONS

Species	*Balearica pavonina* (Linnaeus) 1758
Subspecies	*B. p. pavonina*: West African Crowned Crane. Resident north of the Congo Basin from Senegal east to Lake Chad, and south to Sierra Leone, Nigeria, and northern Cameroon. *B. p. ceciliae*: Sudan Crowned Crane. Resident in the Nile Valley from Malakal south to Nimule and east to Lake Rudolf and the Ethiopian lakes
Origins of scientific and vernacular names	Balearica: of the Balearic Islands, in the Mediterranean. *Pavonina:* from the Latin *pavo*, a peacock. *p. ceciliae:* after Lady William Cecil, who donated to the Zoological Society of London the live specimens on which the form's description was based.
Range	Resident in open country over most of Africa south of the Sahara, excepting the Congo Basin and the driest portions of southwestern Africa.
Weights	Walkinshaw (1973) lists a male and female of ceciliae as 3,628.8 grams each. Pomeroy (1980a) shows weights for four adults of gibbericeps ranging between 3 and 4 kilograms. Estimated egg weights are from 122 grams (regulorum) to 156 grams (pavonina).
Philopatry	Philopatry is the tendency of an organism to stay in or habitually return to a particular area. The causes of philopatry are numerous, but natal philopatry, where animals return to their birthplace to breed, may be the most common form

1. INTRODUCTION

Cranes have graced our planet's skies and stalked the grasslands and wetlands for at least 40 million years (Archibald and Lewis, 1996). Cranes constitute one of the world's most endangered families of birds. They are often serving as 'umbrella' and 'flagship' species in conserving wetlands and grasslands around the world. As such, they draw attention to, and provide protection for, a broad array of species and ecosystems (Schoff and Thompson, 1991). Because most cranes are highly visible at great distances and vulnerable to the loss and degradation of their wetland and grassland habitats, populations of most species have been reduced to a small fraction of their former numbers (Archibald and Lewis, 1996). Seven of the fifteen species are considered threatened at the species level, while several additional subspecies are also at risk of extinction.

Cranes are generally regarded as monogamous. The annual cycle of cranes can be divided into a 3-5 months nesting period and a longer non-breeding period. Successful breeding depends on securing a compatible mate and a breeding territory (Nesbitt, 1989). Even though the breeding season of birds is in Africa, though still imperfectly understood. Its onset is most likely to be affected by the alternation of wet and dry seasons rather than temperature and day length as in temperate regions (Fishpool and Evants, 2001). Therefore, the weather, particularly rainfall patterns, distribution and amount, could affect the breeding of cranes. Hence its effect has to be understood in order to design effective protection schemes.

Cranes are omnivorous and some species rely heavily on aquatic foods. In addition to taking grain crops, most cranes feed by probing the subsurface with their bills and take food from the soil surface or vegetation. The feeding habit of Black Crowned Crane differs between the breeding and non-breeding season. They are primarily feeding in uplands during the non-breeding season, but during the breeding season they use both uplands and wetlands. Their diet consists primarily of aquatic vegetation, but in drier habitats also include seeds, insects, and waste grain (Urban and Gichuki, 1991). Therefore, studying the food and foraging behavior provides the necessary background information to assess the management implication of the species.

Black Crowned Crane (*Balearica pavonina*) adult males and females are alike. Those of pavonina and ceciliae are generally darker than the two southern forms, and have smaller red chin wattles. In these two northern forms the bare cheek patches are white above, and a much larger lower portion is pinkish to reddish, while in the southern forms the cheek patches are almost entirely white, with a small upper portion bright red. A large, straw yellow crown covers the top of the head (paler in the southern forms), with each feather in the crest black-tipped and ringed with whitish or brownish. There are black velvety feathers around the bare cheek patches, which are bounded below with reddish skin areas of varying size, becoming large wattles in the southern forms. The neck feathers are pearl gray (southern forms) to slate gray (northern forms), becoming elongated and pointed toward the base of the neck and grading into body feathers of the same color. The primaries are black, as are the outermost one or two secondaries; the next two or three secondaries have black inner webs and chestnut on the exposed webs. The innermost secondaries are broad, long, and plume-like. The tail is black, and the upper and lower wing coverts are white, with the inner greater coverts becoming straw-colored and plume-like. The iris is grayish white to pale blue, the bill is black, and the legs and toes are black.

Juveniles are generally grayish, the upperpart feathers being edged with rufous, and those of the underparts with sandy buff. The crown and nape are brown, the face is feathered and buffy, and the crest is spiky and golden buff. The wing coverts are white, with buff tips or with varying amounts of gray and buff. The iris is brown, the legs and toes are pink initially, gradually changing to horn and finally to black. The throat wattle (which appears at about four months) is initially pink. The adult plumage is attained at about 12 months, but adult eye color and full development of the throat wattle and facial color may not occur for about another year (Pomeroy 1980).

Downy chicks (of regulorum) are pale buff, with the head pale ivory to light buff, and the back and dorsal stripe umber, and with dark flank spots, dark shoulders, and a dark caudal spot. The underparts are very pale buff, and the chest is a darker buff. The bill is gray, with a flesh color at the base of the lower mandible, and the base of the bill is light horn color. The iris is dark brown, the legs are flesh color, and the soles of the toes are pale yellow (Walkinshaw 1973)

Black Crowned Crane (*Balearica pavonina*) occurs in disjuncted sub-populations through the Sahel and Sudan-Guinea savanna zones of Africa, with records from as far south as the Democratic Republic of Congo**,** but was ones more numerous and widespread. The western sub-population (*B. pavonina pavonina*) is under alarming rate of decline (Beilfuss *et al.*, 2007). However, the status of the eastern sub-population (*B. pavonina ceciliae*) is less well-known, though the majority of the species are found in the Sudd flood plains, where the population is in decreasing trend from 65,000-90,000 individuals in 1985 and 65,000-77,500 individuals in 1994 to 28,000-55,000 individuals in 2004 (Beilfuss *et al.,* 2007).

The species is classified as globally threatened under the revised IUCN Red List criteria and population is decreasing (Meine and Archibald, 1996; IUCN, 2016). However, at present the available information in Ethiopia is insufficient.

In the last 300 years, the impacts of land use change have increased from significant to threatening proportions. At Lake Tana area, the advent of new agricultural systems, particularly irrigation, due to population pressure has resulted in land use changes, which is highly visible at present. Conversion of wetlands and grazing lands into permanent agricultural land, and draining of seasonal water reservoirs are now commonly observed. However, the real factors are not clearly set and documented. Therefore, description, explanation, prediction, prescription and evaluation of land use change in relation to the biology of Black Crowned Crane habitats are of paramount importance.

Black Crowned Cranes are known to be resident throughout the western highlands, the western part of the country and in the Rift Valley lakes and rivers of Ethiopia (Nowald *et al.*, 2007). However, 70% of the population occurs in Lake Tana area (Shimelis Aynalem *et al*., 2017). Different counts of Black Crowned Cranes have been made in different sites of Lake Tana area (Francis and Shimelis Aynalem, 2007; Nowald *et al.*, 2007). The area is also known for crane breeding and foraging site. In a survey in 2009, a non-breeding group of 154 and 500 Black Crowned Crane has been counted at Chimba wetland alone during the wet and dry seasons, respectively (Shimelis Aynalem *et al.*, 2011).

Limited information on the population status of *B. pavonina pavonina* along its distribution range, in Africa has been reported at different times (Meine and Archibald, 1996; Williams *et al.*, 2003). Some studies on the breeding biology of Black Crowned Crane have been conducted mainly in captivity (Walkinshaw, 1965). However, detailed information on the ecology of Black Crowned Crane has not been collected in the wild in area where the species is residing.

This study is important because it investigates aspects of the crane breeding ecology, diet and foraging behavior, and the threat facing them. Particularly, the study focuses on the nesting time, nest distribution, nesting material use, clutch size, fledging and hatchability of chicks, breeding performance, morphometric features of nests and eggs of the species; habitat use and preference, characteristics of the food; distribution, abundance and density of cranes and crane habitat change in relation to the land use land cover change in Lake Tana area.

1.1. Breeding biology of birds

The breeding ecology and behavior studies of birds provide essential information to both evolutionary biologists and conservation managers. For the evolutionary biologists, the breeding characteristics of a species provide insights into the selection pressures that individuals of that species have faced over time (Dowling, 2004). Additionally, as more data become available on the breeding ecology of previously unstudied species, it is possible to conduct more rigorous comparative tests to determine what factors are responsible for the differences in breeding parameters between species. For the conservation manager, realistic and effective modelling of risk management for a population requires that these breeding characteristics be accurately quantified (Dowling, 2004).

The reproductive biology of cranes is similar (Johnsgard, 1983a). All crane species are strictly monogamous, have long pair bonds and a prolonged period of juvenile dependency, and are highly territorial during the breeding season. All cranes also have an extremely limited reproductive potential, resulting from their deferred sexual maturity, low clutch size, and limited re-nesting tendencies following the loss of a clutch or hatched young (Johnsgard, 1983a). The breeding biology of all cranes is characterized by delayed maturity, long-term monogamy, annual breeding, small clutch size, and extensive pre- and post-fledging parental care (Tacha *et al.*, 1989; Drewien *et al.*, 1995). These demographic factors result in naturally low recruitment that limits the species' ability to recover from declines. Cranes lay clutches of 1-3 eggs, but 2 eggs is the normal clutch. Replacement clutches are laid if the first clutch is lost, after an interval of about 20 days (Nesbitt, 1988). Replacement clutches have been variously reported to often contain only one egg (Dwyer and Tanner, 1992), or to be no different from the first clutches (Nesbitt, 1988).

Nesting is a type of breeding behavior by which it involves selection of a site to construct a nest. Nest site selection in birds involves the choice of a particular location among the available habitats and sites, usually resulting in a nonrandom spatial distribution of nests (Burger and Gochfeld, 1990). Nest site selection is the final stage in a series of habitat choices, including colony, general habitat and territory selection (Burger and Gochfeld, 1990). In marsh nesting birds, it is usually performed just prior to egg laying (Clark and Shutler, 1999).

Birds select breeding habitats based on biotic and abiotic factors of the environment. This produces a nonrandom spatial distribution of nests. Nest sites influence avian ecology from the community level, where they affect species composition, to the level of the individual that can affect survival and reproductive performance. Many studies have demonstrated that nest sites are selected actively, such that microhabitat at nest sites differs from random sites. However, fewer studies have clearly demonstrated that such nest microhabitat preferences are adaptive; i.e., that individuals nesting in preferred microhabitats experience higher nest success in the long run (Clark and Shutler, 1999). Nest-site selection in water birds is influenced by a number of physical factors including elevation, substrate, slope, exposure to wind and waves, and cover (Rounds *et al.*, 2004). A good nesting site generally provides protection against predators, offers adequate stability and materials to support and construct the nest, and is located near adequate feeding areas (Hilaluddin *et al.*, 2003).

The main features of nesting behavior of cranes however are generally similar in all species of living cranes (Johnsgard, 1983a). Except Blue Crane (*Anthropoides paradisae*) and Demoiselle Crane (*Anthropoides virgo*), 13 of these species build nests in shallow wetlands with low emergent vegetation. The nest consists of a shallow platform built with dry material and supported from underneath by live plants. All the species of cranes are territorial during the breeding season. Territory sizes vary among species, but can range from two to several hundred hectares (Walkinshaw, 1973). The selection of marsh or wetland area could be due to the availability of nesting material and food. The levels of mortality of eggs and young due to extreme weather and predation may also be lower than in alternative habitats as long as there is enough depth of water in the nesting site (Nudds, 1983).

Lack (1954) proposed that "the clutch-size of each species of bird has been adapted by natural selection to correspond with the largest number of young for which the parents can, on the average, provide enough food." This theory may not work for all passerine and non-passerine birds equally, as it depends also on the complexity of nests. For example, nest predation in general, is much higher for open- than for hole-nesting species of birds (Ricklefs, 1969). It has been proposed that when the rate of nest predation is high, natural selection would favor small clutches (Snow, 1978; Slagsvold, 1981).

Unlike most other large water birds, cranes have a relatively small clutch size with the majority of species laying two eggs. The exceptions are the Crowned Crane, which lays two or three eggs and the Wattled Crane, which lays one or two eggs (Konrad, 1981). The duration of egg incubation in cranes as a group ranges from 28 to 36 days (Perrins and Middleton, 1987). The length of the incubation period varies among species and with the climatic regime. The Crowned Crane, which has a larger clutch size than the other species, usually starts incubation after laying the first or the second egg, but all the eggs hatch within a few hours of each other unlike other cranes that initiate incubation after laying the first egg (Walkinshaw, 1965; Urban *et al.*, 1986).

Nesting and fledging success rates of various crane population data showed that, there was a variable nesting and fledging success among species and from year to year in the same species. Such variability were largely dependent upon weather conditions and degrees of local disturbance or predation. However, in many cases the nesting success of wild crane populations is rather surprisingly high, occasionally with as many as 70 to 80 % of the nests that are initiated being successfully terminated (Johnsgard, 1983a). This remarkably high rate of nesting success is probably associated with effective nest defense by the combined efforts of the two adults, which are large enough to deter all but the most persistent predators. The percentage of eggs hatched is similar to that of the percentage of nests successfully terminated, suggesting a very low number of eggs that fail to hatch as a result of infertility, dead embryos, or other factors that might reduce hatchability. The rate of fledging success, however, is highly variable and is a difficult statistic to obtain with any degree of certainty. A certain study on fledging success suggested that anywhere from about 44 to 71% of the eggs laid may result in successfully fledged young under natural conditions. No more than one of the two crane young that normally hatch from a clutch will be fledged successfully, owing to inter-sibling strife (Johnsgard, 1983a).

In long-lived species with low reproductive rates and late age at first breeding, such as cranes, population parameters tend to change slowly and their effects on the reproductive success of individuals may be difficult to detect or measure in short duration of study (Gichuki, 1993). However, the breeding population of most bird species has a tendency to remain fairly constant unless unpredicted stochastic factor such as intentional extermination practice like poisoning or indefinite killing is happening (Lack, 1966).

Crowned Cranes are commonly seen in pairs, and are believed to retain mates throughout their life span (Walkinshaw, 1973). Birds of both sexes, occasionally gather on open sites, where adults engage in vigorous courtship displays and calls. Such aggregations are usually formed prior to breeding and on sites located away from the breeding sites. The species has elaborate courtship displays and calls (Archibald, 1977; Johnsgard, 1983a; Urban *et al.*, 1986). The pattern of mate competition, significance of courtship before and after pair bond formation and the influence of mate characteristics on the reproductive success of the species are still not well understood because the reproductive behavior of the species has not been studied in detail.

1.2. Food and foraging behavior

Food is the key regulator of populations, and of the individual breeding success of all wildfowl though predation, diseases, starvation and hunting are the many causes of mortality. As a group of closely related species sharing the same aquatic habitat, wildfowl show a remarkable adaptive ability to avoid competition for food, the most critical of all resources. Competition for the same resource can be avoided by resource partitioning, ensuring food is shared out equitably among all the closely related species living in the same habitat. Wildfowl are exemplary practitioners of this. Through adaptive radiation of bill structure and feeding habits, different wildfowl species are able to coexist, each exploiting its own food niche (Cabot, 2009). Food resources within wetlands can be diverse and vary temporally and spatially. Birds are unique among vertebrates in their ability to use wetlands dispersed over hundreds or thousands of kilometers in their annual range. However, they are most restricted in movement during the nesting and rearing season. Finding accurate information on foods used by birds seasonally and at various life cycle stages and ages is difficult (Weller, 1999).

To their foraging niches, few species of cranes have been studied intensively as and how these relate to those of other species of cranes or other possible competitors (Johnsgard, 1983a). As Walkinshaw (1973) has reported, cranes have been observed consuming a wide variety of foods, which makes them to have broad dietary requirements. For instance, the

African Blue Crane is apparently a ground-forager, with animal foods perhaps forming the majority of its diet, but it also at times eats grain or seeds and digs up and consumes roots. However, the Crowned Cranes consume grain and grass seeds, but do not seem to dig as much as do the longer-billed species (Walkinshaw, 1973).

Adults of Crowned Cranes are relatively diverse in their foraging activities, and consume not only a diversity of vegetable materials but also such animal life as lizards, grasshoppers, other insects, millipedes, and earthworms (Johnsgard, 1983b). Vegetable material consumed by crowned cranes includes the seed heads of sedges (*Cyprus* species) and such grasses as *Cynodon* species, and evidently long grasses growing around swamps that are in the process of seeding are preferred foods. They also have been observed pecking at old cobs of maize, and seem to prefer knocking seeds off heads of millet and maize cobs rather than picking up loose seeds. The birds often forage in croplands, especially of such types as soybeans and groundnuts, or consume the flowers and pods of bean plants. Damage to crops is sometimes indirect, as when the birds trample cotton crops while displaying, or dig up seedlings, apparently in search of insects (Pomeroy, 1980). A major part of the diet of *B. p. pavonina* is however, obtained from cereal crops such as millet, guinea-corn and rice (Bates, 1934) .

General categories of food resources used by water birds are diverse. Products of the diversity of vegetation and animals, which are themselves related to hydro periods, timing of biological and environmental events, and water depths in different wetland types (Weller, 1999). Vegetation structure is influenced by adaptations to water permanence, timing, current, and climatic and salinity regimes. This result in microhabitats with differing vegetation structures such as non-persistent emergent, persistent or robust emergent (Gaston, 1999). Aquatic vertebrates like amphibians and reptiles (herps), fish, or wetland mammals are major food of predaceous wetland birds and other vertebrates. But, as consumers, they also are linked directly to vegetation, invertebrates, or other smaller vertebrates for food. And directly to water for protection; and indirectly to water as the driving force for wetland plant and animal succession over time (Gaston, 1999).

How the bird feeds, what it eats, how efficient it is, and how it might compete with other species are strongly influenced by the nature of the wetland it chooses. Therefore, wetland choice, and the precise habitat or microhabitat within the wetland, and food needs for specific stages in the annual life cycle influence how the bird forages (Weller, 1999).

To maximize their feeding efficiency, birds must select plant species with highest nutrient content and least fiber (Livezey, 1997). We often assume that foods are abundant and unlimited for birds, but starvation and poor health condition are common, and many studies of food habits of birds have noted individuals that have spent long periods foraging but had near empty digestive tracts when collected. Birds follow the most efficient strategies and tactics that produce the needed food as *optimal foraging theory* suggests (Stephens and Krebs, 1986).

Few species of cranes have been studied intensively in their foraging niches and how these relate to those of other species of cranes or other possible competitors (Johnsgard, 1983a). Several observers have commented on the tendency of crowned cranes to stamp their feet while walking through grassy vegetation, apparently to disturb and thus expose insects (Walkinshaw, 1964; Pomeroy, 1980). These birds have also been seen walking among feeding cattle, much in the manner of cattle egrets (*Bubulcus ibis*), presumably catching the insects disturbed by the moving cattle. Birds are also attracted to freshly plowed fields, and they tend to feed in short grass rather than in long grassy cover to easily capture insects. They are sometimes attracted to rubbish dumps, where insects are associated with waste food (Pomeroy, 1980).

Separating strategies from tactics in patterns of gathering food is relative but perhaps worthwhile because it adds a temporal and evolutionary component (Ellis *et al.*, 1976). The term strategy represents a series of approaches or steps to accomplish a major goal incorporating various feeding, breeding, and mobility patterns that ensure security, health, and survival of the species during one or more life history stages, more in the sense of diet selection (Weller, 1999). Such patterns are not simply a matter of choice by the bird but may be fixed by traditional or genetic adaptations. Hence, there is a scale of foraging dictated by general foods and strategies. A fish eating cormorant, a duck diving for invertebrates, and a shorebird moving along the shore to opportunistically grab clams or worms, all have different scales and rates of movement as well as different anatomical specializations. These adaptations may be sufficiently unique to create species termed specialists, such as the snail kite of the everglades (Sykes Jr, 1987). Other species have been termed generalists: feeding on whatever is most available and using diverse nesting and resting sites. Such species have been able to fit into a variety of available habitats, perhaps through exposure to dynamic conditions over areas and time. Tactics and techniques of obtaining food are mechanistic but efficient actions that are still fairly consistent but do vary by food and microhabitat conditions (Weller, 1999). Cranes can be categorized as benthic probers; tubers can be one of their niches, and digging/ rooting is a tactic used to acquire the niche. Snow goose and magpie goose can share similar tactic; however several wetland birds show unique or distinct ways of foraging tactics, where competition can be minimized by resource partition (Weller, 1999).

The importance of timing of food is that maintenance needs must be met before energy can be directed to flight, migration, breeding and defense. High protein food for laying females or growing young is crucial (Arnold and Ankney, 1997). During nesting, the precocity of the young determines where foods are obtained (Weller, 1995).

Many factors influence where food resources are found within a wetland (i.e., spatial distribution): bottom substrate materials, vegetation at all levels (layers), water depth, tidal regimes, water temperature, or oxygen supply in the water. Water depth influences temperature and oxygen levels in water, and thereby fish or invertebrate species can thrive there. For example, large herons tend to eat larger fish than small herons; large ducks take larger maximum animal prey than small ones (Weller, 1972). Curlews take larger clams at greater depths than do oystercatchers, which take larger and older clams than do Sanderlings (Myers *et al.*, 1980). Depending on the kind of species the foraging sites are variable that can provide coexistence among themselves (Fig. 1).

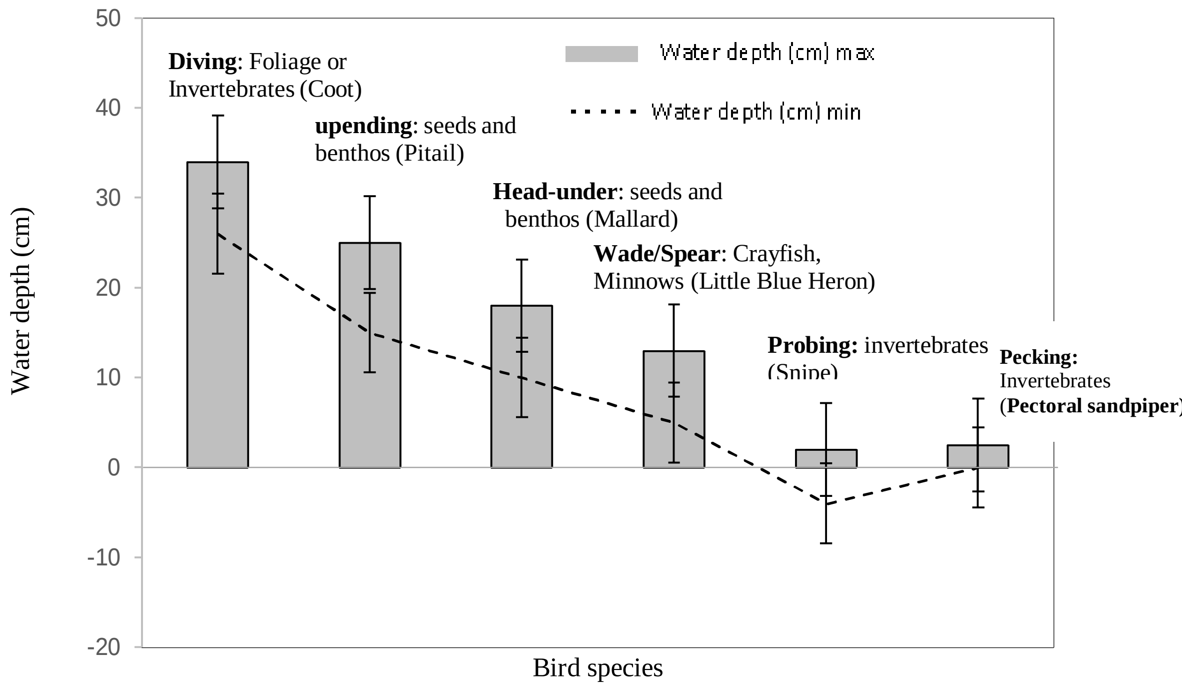


Figure 1. Tactics and possible food resources of common water birds in relation to the water depths (modified from Fredrickson and Taylor 1982).

1.3. Distribution of cranes

Cranes are found on five continents. There is no evidence that cranes ever inhabited South America. The current concentration of crane species in Asia and Africa suggests an Old World origin of Gruinae, with a more recent colonization of Australia and North America (Archibald, 1977). Most fossil species, however, have been found in North America (Witmer, 1990). This reflects both the proportionately greater amount of paleo-ornithological work in North America and the possible origins of cranes in the West (Archibald, 1977). Krajewski (1989) however believes that cranes originated in Europe near the end of the Paleocene Epoch.

The present-day species of the cranes of the world have generally been placed in four genera and 14 species, at least since the publication of Peters's (1934) as cited by Johnsgard (1983a) which the idea was widely adopted system. He recognized a single species of Balearica, two of Anthropoides, one of Bugeranus, and ten of Grus. Different scholars also had given different way of categorizing cranes (Tegetmeier, 1881; Blyth and Sharpe, 1894; Blaauw, 1897). However, Archibald (1976) reevaluated the Gruidae from a behavioral standpoint and proposed a classification very similar to that of Peters's, except that two species of Balearica were recognized *B. pavonina* and *B. regulorum*. They are distinguished from other species by their ability to roost on trees, and their loose plumage, straight trachea, elaborate crests, and colorful facial markings.

The inability to tolerate extended periods of freezing temperatures perhaps led to the extinction of Crowned Cranes on the northern continents during the Pliocene Epoch. At present, the two surviving species inhabit the wetlands and savannas of Africa. Paleontological, anatomical, behavioral, and DNA studies all indicate that Crowned Cranes are closest to the ancestral stock that gave rise to the more recent subfamily *Gruinae* that includes the other 13 species (Archibald, 1977; Krajewski, 1989). The 13 species of Gruinae were traditionally divided into three genera: *Bugeranus*, A*nthropoides*, and *Grus*. Recent DNA hybridization studies, however, suggest that *Anthropoides* and *Bugeranus* should be merged with *Grus* (Ingold *et al.*, 1987; Krajewski, 1989). *Grus* includes four distinct groups of closely related species the *Sarus* Species Group (White-naped, Sarus, Brolga); the Whooping Crane Species Group (Eurasian, Hooded, Black-necked, Red-crowned, Whooping Crane), and the Sandhill Crane and the Siberian Crane which each stand alone. The Sandhill Crane is probably most closely allied to the *Sarus* Group.

Etiology and anatomy hardly link the Siberian Crane to the Wattled Crane (Archibald, 1977). But DNA and recent behavior work suggest that the Wattled Crane and *Anthropoides* (Demoiselle and Blue Crane) are closely related and that the Siberian Crane is distinct from any of the other Gruinae species groups and should perhaps be placed in a separate genus (Krajewski, 1989). Except South America, Arctic and Antarctica cranes are distributed in the world; however, still the distribution and status of cranes is so different.

In Africa, six species and four genera of cranes occur in the continent, but two of them are wintering species. The resident ones: Wattled Crane (*Bugeranus carunculatus*) ranges across 11 countries, from Ethiopia to South Africa, the majority occurring in the extensive floodplain systems of southern Africa's large river basins (especially the Kafue, Okavango and Zambezi). The Blue Crane (*Anthropoides paradiseus*), has the most restricted distribution of any crane species, with most of the population occurring in South Africa and a small disjunct population near Etosha Pan in Namibia (Meine and Archibald, 1996). Grey Crowned Crane (*Balearica regulorum*), with a generally recognized biogeographical separation following the Zambezi River Valley. The East African subspecies *B. r. gibbericeps* has declined significantly across its range in recent years, including all nations within its range where surveys have been recently conducted. The Black Crowned Cranes (*B. pavonina*) main distribution area in Ethiopia is in the northwestern (Lake Tana area), southwestern (Jimma Boye area) and central Rift Valley areas (Archuma and Chuche wetlands) (Shimelis Aynalem *et al*., 2017b). Taking only the maximum number of *B. pavonina* recorded at different years, about 3000 *B. p. ceciliae* are supposed to live in Ethiopia. The Eurasian Crane (*Grus grus*), and the Demoiselle Crane (*Anthropoides virgo*) are the two Palearctic migrants which spends limited time in Africa, including Ethiopia (Meine and Archibald, 1996).

1.4. Significance of the study

- New knowledge and basic sciences on the breeding biology of the species, such as the breeding calendar, breeding performance, nesting site requirement, nesting materials and nesting material preference, morphometric measurements of nests and eggs, relationship of the biophysical measurements in the wetland with nesting requirements are determined.
- Basic knowledge on habitat availability, use and preference of cranes; seasonal abundance of potential food and characteristics of the food; principal foraging sites and foraging behavior of the species will help to design conservation projects for the species and its habitats to determine current and future population sustainability and survival of the species.
- Distribution and density of Black Crowned Cranes; and the status of the crane population identified in the Lake Tana area will be utilized as bench mark to understand the future trend of the species, and to intervene and implement any sustainable conservation measures.
- The dynamics of land use change mechanisms in relation to the survival of the Black Crowned Crane and the habitat in which cranes are nesting and foraging in Lake Tana area; the different land use practices and the land use change process over the last decades will help to propose any conservation measures for the existence of the species and the protection of wetland habitats.

1.5. Research questions

- Does the condition of vegetation cover, water depth and nesting site of the wetland habitat have influence on the nesting success of Black Crowned Cranes?
- Which time of the month is really appropriate for Black Crowned Crane nest initiation?
- How far crane nests are constructed from the main land, and is there any inter-nest distance difference among nests during nest construction?
- What type of nest materials are collected for nest construction, and how far from their nesting site?
- What is the vegetation height at which crane nests is constructed?
- What is the morphometric characteristics of crane nest, and there any difference?
- Is there any association or relation between nest height and water depth?
- What is the nesting density of cranes at Lake Tana area?
- Is there any nest sight fidelity in Black Crowned Cranes?
- What is the morphometric characteristics of Black Crowned eggs?
- Is there any variation on cranes eggs length, breadth and weight and egg shape index?
- What is the hatchability percentage of cranes egg in the wild, and what is the fledging percentage relative to egg laid?
- Which month of the breeding time has real impact on the breeding success of Black Crowned Cranes?
- Does nesting time has influence on breeding performance of cranes?
- What is the dominant macrophyte that cranes utilize for feeding and nesting?
- What type of macroinvertebrates are found in the breeding and feeding sites of cranes?
- What is the diversity and evenness of macroinvertebrates in crane feeding site?

- What is the potential and biomass of macroinvertebrates, grass seeds, and crop seeds at feeding sites of cranes?
- What is the diet characteristics and food composition of crane feces?
- Which type of habitat is more preferred by cranes for foraging?
- What is the distribution pattern and abundance of Black Crowned Crane at Lake Tana area?
- What is the density and cluster size of cranes in the wetland and farmland during the wet and dry season? And is there any significant difference?
- What is the dynamics of land use land cover change at Chimba and Yiganda watershed area?

1.6. Objectives

1.7. General objectives

The general aim of the study was to investigate the breeding and feeding ecology, distribution, and land use cover change impact on Black Crowned Cranes at Lake Tana area, Ethiopia.

1.8. Specific objectives

The specific objectives are the following:

- to study the distribution and location of nests at breeding sites;
- to determine the hatchability and fledging estimate of chicks of Black Crowned Cranes;
- to study the impact of time /season of nesting on breeding performance;
- to study the morphometric features of nests and eggs of the breeding species;

- to study the abundance of potential food;
- to determine the diet characteristics and food composition of cranes;
- to study the foraging behavior both in the wetland and farmland habitat;
- to study the distribution pattern, population size, and density of Black Crowned Crane in Lake Tana sub-basin;
- to detect and map patterns of land use change in relation to wetland shrinkage during the last 30 years at various spatial scales, and
- to evaluate the effect of land use on habitat availability of cranes foraging and breeding site

2. DESCRIPTION OF THE STUDY AREA

2.1. Study sites

The study sites were located in the northwestern Ethiopia, Lake Tana area with the geographical boundaries between 12°18'1.23" and 11°31'14.59" latitude; and 36°42'21.84" and 37°41'56.38" longitude, with an elevation of 1800±25 m asl (Fig. 2). Chimba (Bashadangela and Lamgebya area), Yiganda and Dirma and Infranz wetlands were the main sites selected to study the breeding and feeding ecology of cranes. However, additional some sites were also considered such as: Legdiya, Kunzila, Delghi, Shesher Wallala, and Wagtera areas

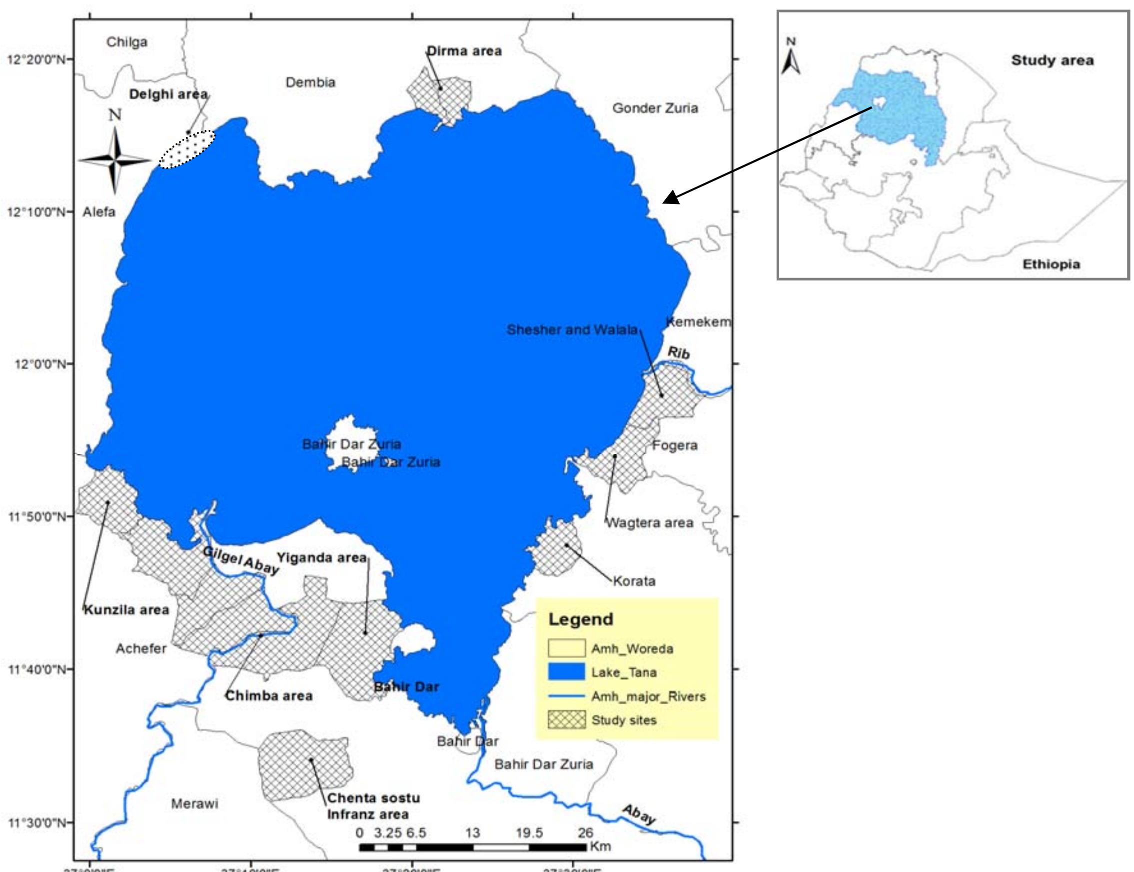


Figure 2. Map of the study area with the study sites, Lake Tana area.

The watershed of Chimba wetland locally known the Latamba Kebele, consists of Bashadangela and Lamgebeya wetland. These were the main sites where the breeding ecology, food and food characteristics study were specifically conducted. Chimba wetlands are situated along the Gilgel Abay River. It is bounded by 13 local administrative Kebeles. The wetland itself covers four Kebele: Latamba, Legdiya, Addis Amba, and Dehena Mesenta. Seasonal flooding occurs during the rainy season (June-August). However, the pick flooding occurs towards the end of August. Chimba wetlands harbor enormous number of resident and migratory bird populations. It is home to the largest Black Crowned Crane population. The extensive Papyrus bed is the only type that remains in the area at large.

Yiganda wetland is situated at Zegie Peninsula in the east bordering the Lake Tana. The area is known for Black Crowned Crane breeding and feeding sites. It is surrounded by Zegie forest, and there is papyrus bed in the middle and bordering the Lake. It is recognized as a core zone for Lake Tana Biosphere reserrve. The wetland is inundated by the outflow of the lake and also fed by Mina River, which disects the wetland and joins the lake.

Dirma wetland is situated in the northern part of Lake Tana. It is situated along Dirma River and also bounded by the lake to the south. Dirma River is one of the tributaries of Lake Tana. The watershed is very large; however, more than 95% of the area is already assigned for agriculture. The wetland is formed by the out flow of the lake and the Dirma River during the wet season. It is highly degraded due to intensive agriculture (irrigation) and overgrazing. But it is the only area still used by cranes for breeding in the northern part though patchy it is. Due to the watershed degradation, the area sediment load is high compared to other study sites. The area is highly infested by noxious weed water hyacinth (*Eichhornia crassipes*), and the currently introduced invasive woody species Balsa wood also *Hygrophila schulli* becoming dominant in the area.

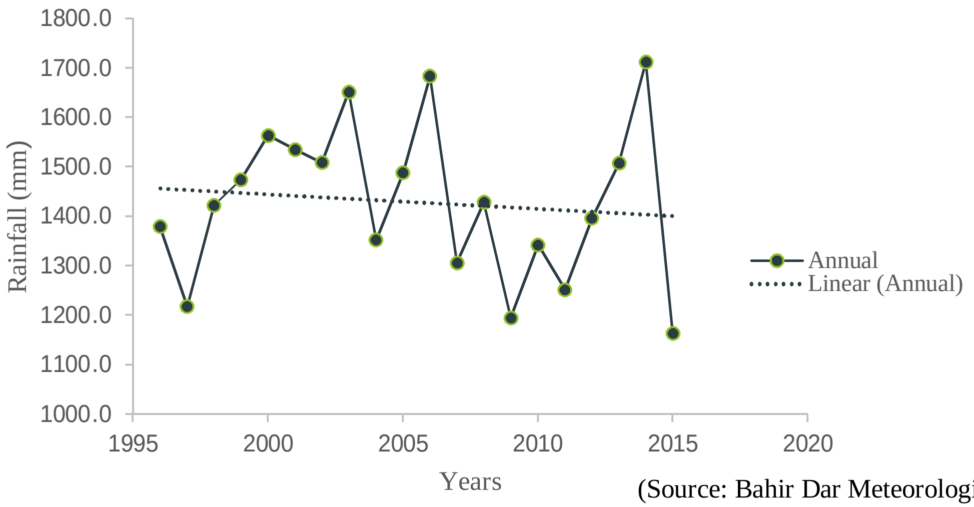
Chenta sostu is situated on the head of Infranz area. The area is patchy but still used for cranes breeding site. Indigenous trees and papyrus are found in small amount. However, the breeding area is highly exposed by locals, and therefore, juvenile cranes are dying before they are fledging. Irrigation, by draining water by motor pipe is becoming the most common practice, which the nesting site dries before the usual drying period.

2.2. Climate

The rainfall pattern is associated with the Intercontinental Convergence Zone (ITCZ). Dynamics of the moist air coming from Atlantic and Indian oceans following the north-south movement of the ITCZ produces inter-annually varying rainfall over Lake Tana basin (Mohamed *et al*., 2005). The northward movement resulting the major rainy season, whilst the southward movement of the ITCZ between October and May results in dry climatic condition. The annual climate in the region can be divided into distinct rainy and dry seasons. The rainy season can be subdivided into one minor and one major rainy season. The major rainy season (from June to September) bears about 70 to 90% of the annual rainfall (Uhlenbrook *et al.*, 2010).

The rainfall distribution at Lake Tana area varies from place to place even along the lake borders. Full meteorological information was found only for Bahir Dar Station; however data in Chimba, Yiganda, and Zegie sites were very fragmented. With this information, data for Bahir Dar only were utilized to describe the climatic condition of Lake Tana area. The Lake

Tana area around Bahir Dar received mean average of 1428.87±35.36 mm rainfall annually during 1996-2015. The minimum and maximum annual rainfall was 1163 mm in 2015 and 1711.6 mm in 2014, respectively (Fig. 3). The amount of rainfall distribution was maximum during July and August at Lake Tana area. In July 418.15 mm and in August 394.67 mm monthly mean rainfall was recorded (1996-2015).



(Source: Bahir Dar Meteorological Station

Figure 3. Rainfall pattern and annual trend of Bahir Dar from 1996-2015.

Though Ethiopia is located in the tropics, the Lake Tana catchment tropical temperature is modified by its higher altitudes. The mean annual average air temperature of Lake Tana basin is 22 ^{0}C. Four different thermal zones could be distinguished in the Lake Tana Basin, namely: warm, tepid, cool, and cold. Calculations were based on mean annual air temperature during the growing period and their corresponding altitudes. Tepid zone represented the largest part of the basin area (91%), followed by cool (7.8%) and warm (0.64%) (Wubneh Belete *et al.*, 2017). However, at Lake Tana, Bahir Dar area the minimum range temperature was 10.33-13.80 and the maximum range was 26.75-28.77 ^{0}C from 1996-2015 years. However the average mean was 20 ±.14 ^{0}C (Fig. 4).

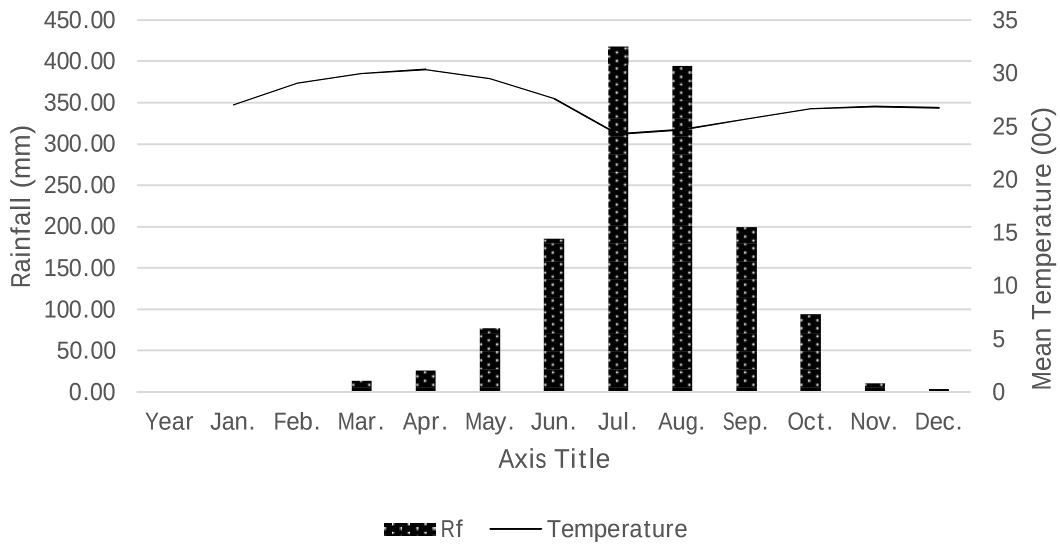


Figure 4. Mean monthly distribution of rainfall (mm) and Temperature (^{0}C) from 1996-2015, Bahir Dar area. (Source: Bahir Dar Meteorological Station)

2.3. Hydrological characteristics

The Lake Tana Basin is located in the northwest part of Ethiopia, and is one of the tributaries of the Blue Nile River. The rainfall over the Upper Blue Nile in general, originates from moist air coming from the Atlantic and Indian oceans following the north-south movement of the Inter Tropical Convergence Zone. The southern portion of Tana basin receives the highest rainfall (~ 1,600 mm) with a decreasing trend from south to north (~ 1200 mm). The basin has four main rivers: the Gilgel Abay, Gumara, Rib and Megech. Gilgel Abay River alone contributes 60% of the flow into Lake Tana. Lake Tana is the largest lake in the country but is relatively shallow; historically, lake levels have fluctuated within the range of 1,784.26 to 1,787.81 m asl. The hydrological process of the basin is poorly understood and only 42% of the basin is gauged. Recently, efforts have been made to identify the processes by different scientists (Elias Sime and Biazenlegn Solomon, 2017).

2.4. Agriculture and farming practice

Agriculture is the mainstay of the Ethiopian economy in general and Lake Tana sub-basin in particular. The crop diversity in the sub-basin is high and the crop categories include cereals, legumes, root crops, oil crops, vegetables, fruit crops and other cash crops. The cropping pattern includes rain-fed, irrigation, residual moisture and minor recession cropping. More than 80% the cultivated land during the base-year is under rain-fed system and the remaining land is cultivated using irrigation and residual moisture. The farming system is characterized by crop-livestock mixed production system. Crop production is the focus of farmers both for food and cash income. In recent years, agriculture has shown a sustained increase in the use of improved inputs notably seed varieties and chemical fertilizer, pesticides and farm credit. In the sub-basin areas, horticultural crop production is a relatively new activity which is mainly triggered by the commencement of small scale irrigation scheme. Studies in the area revealed that insect pests and diseases were, and still are one of the major production constraints. Farmers also ranked pest problems as the major production constraints in the area (Merkuz Abera, 2017).

Farming practice in Lake Tana area mainly were crop rotation, mixture, intercropping and double cropping when there is black soil to utilize the residual moisture. Sometimes it is supported by supplementary irrigation (Taddesse Amsalu, 2006). Almost all farmers in the Tana Sub-basin areas practice crop rotation to restore the fertility status of the soil as well as to minimize the buildup of weeds, insect pests and plant diseases. The most common crop rotations are cereal-legume-cereal, cereal-cereal-legume, oil crop-cereal-pulses, horticultural crops-cereal-pulse and cereal-cereal-pulse (Taddesse Amsalu, 2006). The average landholding per household of the Amhara Region where Lake Tana belongs to is 1.10 ha and the average per capita holding is 0.24 ha, which is much lower than the national average (CSA, 2003). And hence, the cropping pattern and the type of crop farmers are cultivating are also diverse, in such a fragmented land holding system. However, finger millet (*Eleusine coracana*), maize (*Zea mays*) and tef (*Eragrostis tef*) are the major crops that are grown in Chimba and Yiganda area.

Livestock contributes 19% of the national GDP, 45% of agricultural GDP and 20% of the export earnings in Ethiopia. They are also contributing to people’s livelihoods as source of food, cash income, liquid asset, diversification of risk, inputs to crop production, cultural value and fuelwood. Livestock is also very important to nutritional and food security, income and livelihood of people around Lake Tana sub-basin. The livestock production systems in Lake Tana sub-basin are mainly mixed crop-livestock. Despite the important contribution made by livestock to the people’s livelihood in the sub-basin, the productivity of livestock is low due to various challenges. The challenges include land use change, limited access and low use of feed technology, inadequate veterinary service provision, genetic limitation of the indigenous livestock breeds, limited access and high cost of improved breeds, market inefficiency/failure, inadequate research/technology generation, weak linkages among stakeholders, limited access to credit, and climate change (Kefyalew Alemayehu and Asaminew Tassew, 2017).

2.5. Land use land cover

The characteristic changes of land use and cover of the Lake Tana sub-basin, after the mid-1980s, was found dominated by the conversion of more lands to urban areas, forests and croplands largely at the expense of shrubs and grasslands. Despite being relatively small in sizes, the rates of expansion of forest cover and urban lands were found to be about 50 to 100%, respectively. However, land area converted into rural settlement is difficult to indicate on a map, since the settlement pattern of the rural Ethiopia is known for being dispersed and family-based. Nonetheless, the land area that has been used for rural settlement is thought to have doubled along with the doubling population in the last twenty years. Thus, based on the population size during the 1980s and 2004, land area that has been used for rural settlement was estimated to have risen from about 32 to 61 km^2, respectively (Biru Yitaferu, 2007).

The expansion of croplands has still continued unabated. On the other hand, in the mountainous and cooler areas of the basin, expansion of crop cultivation surpassed the arable land areas and mounted to the non-arable mountains long years ago. Thus, the recent expansion has to be in the lower plains and foot-slope areas where the landscapes have been considered problematic due to poor drainage, malaria infestation and slope factors. Similarly, much of the swamplands were converted to fields for rice production, even though the biophysical characteristics of the class make it difficult to determine whether the water submerged fields could be used for crop cultivation or not. Some expansions are also observed on the water body; this might be mainly attributed to floods retained in some swamplands and lakeshore areas that had not dried up.

2.6. Wetlands

The Lake Tana watershed wetlands are distributed along the Lake Tana tributaries of Gilgel Abay, Rib-Gumara and Megech and Dirma rivers. The floodplains of Dembia and Fogera areas also hold wetlands. The wetlands of Lake Tana area are home of globally threatened species as well as also the world recognized migratory wintering sites. The total wetland area of Lake Tana area watershed is estimated to be 32157 ha. These wetlands have different physical and hydrological, chemical and water quality, and biological and habitat functions. The wetlands in the Lake Tana watershed extend from the headwaters of Guna and Gishe-Abay to Fogera and the Dembia floodplains. The river mouths of the Gumara, Megech, Dirma, and Gilgel Abay are the major delta wetland ecosystems. Yiganda wetland is of the lacustrine wetland type formed by the lake water while Chimba and Infranz wetlands are the common riverine wetlands. Several other wetlands are formed from cold and hot springs. There are also man-made wetlands such as the Koga Dam area and other constructed small water bodies. Lake Tana watershed wetlands provide habitat for globally threatened and endangered species. However, wetland loss is evident wherever major developments such as dams, irrigation schemes and conversion projects are present in the developing world. Humans usually and very dramatically accelerate natural processes. In the Lake Tana watershed, human induced threats such as conversion of wetlands into agriculture, draining of wetlands and lack of defined ownership of the resource is the main threats (Shimelis Aynalem *et al.*, 2017b).

2.7. Fauna and flora

The vegetation characteristics of Lake Tana area is so variable and consists of different habitat types. Different patches of forest land situated inside monasteries, and along some boarders of the lake; farmlands, wetlands, outcrops, *acacia* woodland can be some of them. According to Friis (1992) and Friis *et al.* (2010) the potential natural vegetation of the Lake Tana area consists of Dry Evergreen Afromontane forest and Grassland Complexes, freshwater lake, freshwater marshes and swamps, floodplains and lake shore vegetation and Combretum-

Terminalia woodland and wooded grassland. In addition, Hughes and Hughes (1992) mentioned that emergent macrophyte fringe the flat swampy parts of the shoreline, with dominant species being *Cyperus papyrus, Echinochloa pyramidalis, Echinochloa stagnina, Polygonum barbatum, Polygonum senegalense* and *Typha domingensis*. Floating leaved species such as *Nymphaea caerulea, Nymphaea lotus* and *Pistia stratiotes*. *Ceratophyllum demersum* and *Vallisneria spiralis* are noted as the most important submerging plants that occur in the lake area.

The fishes of Lake Tana show impressive diversity and unprecedented uniqueness. The lake harbors the only species flock of large cyprinids in the world, and of the 28 known species, approximately 75% are endemic to the lake (Abebe Getahun and Eshete Dejen, 2012). Most of the habitats harboring the ichthyofaunal diversity of this lake are relatively intact, and still naturally attractive. Fast increase in human population of the Lake Tana sub-basin and associated human-induced impacts are degrading the natural habitats and negatively affecting the fish and the fisheries. The impact on the fishes occurs indiscriminately and does not appear taxon-specific. However, endemic taxa such as the Large African barbs of the lake can be more prone than other widely distributed species (Abebe Amha *et al.*, 2017).

Birds play a vital role in keeping the balance of nature. Most of the wetlands situated along the rivers and Lake Tana shore support several thousand birds. Taking previous work in the area into consideration, the Lake Tana sub-basin possesses six globally threatened species, 35 highland biome species and four Sudan-Guinea Savanna biome species. The sub-basin area is particularly important for wetland and water birds. The total population of birds counted during the winter season exceeds 150,000 seasonally, in Lake Tana area alone. Shesher-

Wallala area contributes the largest winter population. The Lake Tana sub-basin consists of 78 families of 437 birds; the most dominant is Accipitridae with 39 species. The distribution of birds in the area is changeable. However, Lake Tana area and associated wetlands hold the largest bird populations compared to forest, farmland and bushland habitats. The Fogera and Dembia flood plain provide suitable feeding and roosting sites for winter birds, and is also known as a congregation site. Both Palearctic (112) and Afrotropical migrants (7) occur. In addition, the Lake Tana sub-basin holds 15 species of endemic birds, some of which are shared with Eritrea. Degradation of the wetlands is underway, with overgrazing, vegetation removal, cultivation, deforestation, occurrence of invasive weeds, wetland drainage, flooding, continuing sedimentation and major water resources (Shimelis Aynalem, 2013; Shimelis Aynalem 2017).

Of the 64 known amphibian species of Ethiopia, the Lake Tana Sub-basin is believed to contain 19 species of amphibian belonging to 12 genera and 9 families. All of these species are grouped under Order Anura. Most of the species found in the area appear to be those that are tolerant to changed habitats. Fourteen species of lizards, 20 species of snakes and one species of freshwater turtle, a total of 35 reptile species occur in the area. In addition, a total of 27 species of mammals that belongs to 16 families are known to reside in the area (Shimelis Aynalem and Abebe Amha, 2017).

3. MATERIALS AND METHODS

3.1. Materials

AWS-250 Digital Pocket Scale were used to measure eggs at nest site. Adjustment of the weighing scale was performed with a 200 g stone. A six inch 150 mm Carbon Fiber Composite Vernier Digital Electronic Caliper Ruler US with accuracy ±.2 mm were used to measure the length and width of eggs.

Dissecting microscope, glass petri dishes, Forceps, jars, 75% ethanol alcohol, D-frame dip nets with 500 micrometer large and small plastic pans were used for invertebrate and fecal sample collection and identification. GPS Map (12 model), digital Camera (Sony x16 optical zoom lens), telescope (25-60x Swarovski model), binoculars (10*50 Nikon), sample collection bag, pressing materials, measuring tape, wader and rubber shoes were utilized. Portable pH/EC/TDS and Temperature Meter with CAL Check™-HI98130 was used to measure physicochemical properties of water in the wetland habitat.

3.2. Methods

3.2.1. Breeding biology

Intensive nest searching in the study sites was carried out using a spotting scope and binoculars, starting from August 2014 (wet season). Nests constructed in different sites were measured since the initiation of nesting in September. The dimension in terms of length, breadth, height from water surface to the ground, and height at one meter distance from the nest rim was measured using measuring tape. Presence, type and height of the vegetation was also noted. Plants used as the nesting material were collected and identified using the Flora of

Ethiopia (Hedberg and Edwards, 1989; Phillips, 1995 ; Edwards *et al*., 1997; Hedberg *et al.*, 2003). Simple correlation analyses as well as multivariate models were used to explain variation in nest architecture and location.

The length and breadth and weight of the egg found in the nest was measured using a Carbon Fiber Composite Vernier Digital Electronic Caliper Ruler US and Digital Pocket Scale, respectively. For each egg, egg shape index (ESI) and volume (V) were calculated according to Hoyt (Hoyt, 1979; Mukherjee, 1999).

$$ESI = \frac{B}{L} * 100$$

Where ESI = Egg Shape Index, B= breadth or width of egg, and L= Length of the egg

$$V = 0.51 * LB^2$$

Where V= egg volume, 0.05= scaling constant, L= length, and B= breadth of egg

The egg measurement was adjusted with the correction factor of 199.7/200, which every egg weigh measurement in the field was multiplied by 0.9985 to get the correct weight of egg.

The parameters like breeding season, nest site selection, nest site fidelity and clutch size were evaluated by taking data during the study time. The distribution of nests were also recorded at each study site. The density of breeding nests at each breeding site was determined and compared. The inter-distance between nest in 2014 and 2015 of the same habitat were compared. For comparison only randomly selected 17 nests were compared. A One-way ANOVA was run at 5% level of significance. The association of nests constructed with the vegetation height and type were evaluated.

The association of nest site: water depth, year of construction and study site were tested using a non-parametric Kruskal-Wallis test, after a Shapiro-Wilk's Test performed to see the normality of the data.

During nest location a geographical coordinate was taken then the distance from the closest mainland and the inter-distance between nests were calculated using ArcGIS 10.2.1 for Desktop version; 10.2.1.3497 ©1999-2013 Esri Inc. and the Google Earth Data SIO. NOAA, US. Navy. GNA. G3BCO @2016 Google. Nests that are isolated by barriers were excluded from analysis even though we have recorded 25 nests, only 18 pair of nests were taken for comparison in 2014. The maximum and the minimum distance that nests are established were analyzed by simple descriptive statistics. The location of nests from the mainland and the inter-distance between the closest nests were scrutinized. To see the relationship of nest location in the study site, statistical test was carried out.

The dependent variable in this case was the nest location distance from the mainland which was not normally distributed for each category of the independent variable (site) as there were unequal sample size and unequal variance. However, a normality test was run to see the normality distribution of dependent variables. A Shapiro-Wilk's test ($P > .05$) (Shapiro and Wilk, 1965; Razali and Wah, 2011) were used to see normality of nest location from the mainland of each study site, and the inter-distances of nests of each site. But the data were not normally distributed. The level of skewness and kurtosis were also evaluated (Cramer, 1998; Cramer and Howitt, 2004; Doane and Seward, 2011). For the non-parametric test of these data, a Kruskal-Wallis Test was applied and run to see the significance level of nest location and nest inter-distance between nests in the study area. To meet the requirement of Kruskal-

Wallis test those sites that had data records below five were excluded for the analysis; since the independent data of the two seasons 2014 and 2015 did not meet for analysis, the overall data of the two seasons however, were considered. Then Mann-Whitney Test was run further for Kruskal-Wallis test that showed a significant difference ($P < 0.05$) to see which site category has real significance.

For nest morphology, the length (l), width (w), nest height (H) which is the height from the surface of water where the nest was established and the depth (D) of water at which the nest was constructed were taken. A normality test for all were carried out and all the numerical data of l, w, H and D were approximately normally distributed.

To analyze the nest morphometry of cranes the following parameters were considered: nest length, width, and nest height. Descriptive statistics, for the mean average, and Shapiro-Wilk Test to evaluate the normal distribution of data of the morphometric measurements of nest (Table 1). Then a One-way ANOVA was used to evaluate whether there was a significant difference for nest morphology parameters at .05 level.

Table 1. Normality test of nest morphometry in Chimba and Yiganda, 2014-2015.

Parameters	Study site	Shapiro-Wilk		
Variables		Statistic	df	Sig.
Nest length	Infranz	.947	16	.446
	Yiganda	.889	10	.166
	Chimba Lamgebya	.931	9	.486
	Chimba Bashadangela	.844	17	.009
Nest width	Others	.943	16	.387
	Yiganda	.866	10	.089
	Chimba Lamgebya	.899	9	.245
	Chimba Bashadangela	.896	17	.058
Nest height above water	Others	.927	16	.220
	Yiganda	.951	10	.679
	Chimba Lamgebya	.843	9	.062
	Chimba Bashadangela	.940	17	.322
Water depth	Others	.881	16	.040
	Yiganda	.895	10	.191
	Chimba Lamgebya	.961	9	.808
	Chimba Bashadangela	.951	17	.467

To see the relationship between nest height and water depth at each site, Pearson Correlation was used. Since the correlation coefficient tells about only the strength and the existence and the direction of the relationship.

When the regression was predicted the nest height value when the water depth is known.

$$Y = a + b * x + e$$

Where: Y= Dependent variable, a= intercept (constant), b= slope (regression coefficient), x= independent variable, e= error

The vegetation height at which the nest established was estimated when the first clutch at each nesting site was observed. A Shapiro-Wilk Test of Normality was run, then a One-way ANOVA was run to test the significance at 0.05 level. Nest height from water surface (H1), height from the ground (H2) at one meter distance from the nest rim was measured using measuring tape. Presence, type and height of the vegetation were noted.

The total watershed area of study sites (Chimba, Yiganda and Dirma wetlands) covers 11,250.12 ha. However, surveyed nesting sites were 463 ha (4%). Of which Yiganda (lacustrine) covers 454.23 ha (4%), Chimba (riverine wetland) covers 1142.16 ha (10%), and Dirma (flood plain) covers 9653.73 (86%) of which, Yiganda covered 68 ha (15%), Chimba Bashadangela and Chimba Lamgebya covered 315 (145+170) (28%) and Dirma covered 80 ha (1%). The nesting density was calculated by dividing the total pairs of cranes that had eggs with the sampled study area.

The laid eggs were numbered using permanent marker to indicate first laid, second laid, and third laid if there are three clutches. Measurements such as length, breadth, and weight of each egg were taken; so that each clutch will have separate measurements for comparison. Student t-test and One-way ANOVA were employed to see the significance difference between all measurements within and between year, and study sites. The age of the clutch size was determined based on the time of eggs laid. It was assigned ‘new’, ‘old’, and ‘older’ stages. For clutch two, it has ‘new’ and ‘old’ stage; whereas for clutch three ‘new’, ‘old’, and ‘older’ stage was assigned. But clutch one could be either ‘new’ or ‘old’ depending on the time of recording. Nest searching was carried out on weekly bases interval. If nest construction was found to be completed during the time of visit and were found with no egg but found one in the next visit, it was recorded as ‘old’ for clutch one nest. However, if two or three clutches were found within a week, the egg stages were assigned based on the size of the egg. The color condition of the egg, length and weight tells the different stages. The dirtier the egg was assigned old / older depending on the clutch size; and the whiter was assigned newer laid egg (Plate 1).

Plate 1. Eggs and nest measurement at nesting sites, Chimba and Yiganda wetland, in 2014. (Source: © Shimelis Aynalem, 2014)

To see which egg stage/age has really a significant effect, Post Hoc Test was run. Tukey HSD was used to carry out multiple comparison of egg ages /stages. The harmonic mean of the group sizes was used since the group sizes were unequal. Pearson correlation coefficient for egg measurements were run to see the significance level 5% two-tailed.

Breeding performance was evaluated starting from nest initiation to pre-fledging time. During the study period at Lake Tana area, 90 days of pre-fledging time of Black Crowned Cranes were considered while estimating the pre-fledge success. The pre-fledged cranes were followed up since the time during the first egg-hatched and before fledging (Plate 2). Breeding pairs are territorial, and usually stick to their specific site which made it easy for follow up. A paired samples t-test was run to see the association between egg laid and hatched. Nest initiation time, egg laid time and egg hatching and pre-fledged time was estimated. The expected and observed fledging percentage was assessed.

Plate 2. Breeding performance follow up in the study sites, Lake Tana area, 2014-2015. (Source: © Shimelis Aynalem, 2014)

3.2.2. Food resource and foraging behavior

During the study period the total area of Dirma wetland was estimated to be 303.3 ha, which is excluding the most intensive cultivated area. With an interval of 50 meter transect length, a total of 10 quadrats (one meter by one meter) that represents 60 ha of wetland were laid. However, in Yiganda wetland since there was extensive and inaccessible area to lay quadrats, excluding 18 hectare of Papyrus and Typha bed, only nine quadrats were laid along the border of the wetland. Regarding Chimba area, the total area of the watershed which was put for Lake Tana Biosphere Reserve is estimated 2,378.2 ha. However, for our purpose only 20 quadrats of macrophyte sampling were performed. The dominant macrophyte at each site was investigated and simple descriptive analysis was performed just to evaluate the proportion of macrophytes at each wetland area.

The sample sites for physicochemical and macroinvertebrate sampling was performed. Sampling were performed twice during the active breeding time of Cranes in December 2014 and 2015 to investigate the abundance and diversity of macroinvertebrate population. The samples were taken at an interval of 100 meter transect length. A total of 34 samples were collected during the entire study period. In 2014, 14 samples (six from Chimba and eight from Yiganda); where as in 2015 a total of 20 samples (10 from Chimba and 10 from Yiganda) were collected. During sample collection time (8:00 AM to 10:00 AM), water depth, water quality measurements (pH, TDS, EC, and T), vegetation height and type, and photographs were taken at site. Study site selection, invertebrate sampling plan, field sampling and sample processing and analysis were performed using U.S. EPA protocol (EPA, 2002). Descriptive statistics, and One-way ANOVA were performed to evaluate the mean variations of physicochemical parameters.

The abundance of potential food for cranes was assessed in areas where cranes were found feeding during the study period. In Lake Tana area, the grazing pasture land is the wetland itself, therefore, assessments of food abundance were carried out in wetlands and crop fields only. In the wetlands both macroinvertebrate abundance and grass panicle seeds were collected. During the breeding period, cranes mostly spend their time foraging in the wetland. During hatching time, parents were busy tramping the wetland to feed chicks with the nutritious or protein rich food that were arthropods larvae and the adults. The adult cranes (parents) and the grown unfledged cranes also feed on grass panicles. Hence it was pertinent to assess the abundance of food in the wetland, macroinvertebrates and grass seeds in the macrophyte studied area.

Sampling of macroinvertebrates was performed one by one meter quadrat. The Dip Net D-frame was held perpendicular to the ground, pushing down against the wetland bottom; then sweep up to bring out the macroinvertebrates (Plate 3). The effort was repeated three to five times to cover all quadrat area before dislodging of macroinvertebrates. The sample collection was performed from 8:00 Am to 10:00 Am. The time taken was 3-5 seconds for each sweeping. Then the collected material was sieved through the 500 µm and put in a plastic collection tube. The net was inspected often to make sure the macroinvertebrates that were being dislodged are washed into the net. All samples were preserved with 75% Alcohol to avoid invertebrate brittle if the concentration is higher. Within 24 hours, fresh alcohol was used. All the organisms in the sample were counted and identified to the lowest possible taxonomic level (family level) using a dissecting microscope and standard keys (Brown, 1994; Gooderham and Tsyrlin, 2002). Standard key for invertebrate identification was used as there is no key developed in Ethiopia (Brown, 1994; Gooderham and Tsyrlin, 2002; Thorp and Rogers, 2011).

Plate 3. Macroinvertebrate sample collection in Chimba and Yiganda wetlands, 2015.

A total of 34 macroinvertebrate samples were collected during 2014 and 2015 (14 samples in 2014, and 20 samples in 2015). The dried matter was weighed using AWS-250 Digital Pocket Scale. All biomass measurements in gram (g) of 34 samples were analyzed using SPSS to test the variance of mean in Yiganda and Chimba sites and the study years. Before any analysis, data normality was tested. A Shapiro-Wilk's test was performed Shapiro and Wilk (1965) and Razali and Wah (2011) and the data was not normally distribute. Mann-Whitney Test was performed because it was a numerical data, to test the mean variation mean biomass across study sites and years at 0.05 level.

The number of individuals and the frequency of occurrence of macroinvertebrate taxa or the proportion of potential macroinvertebrates in the quadrat samples was evaluated using the Shannon diversity index (H′).

$$H' = -\sum_{i=1}^{n}(piln(pi))$$

Where pi is the proportion of individual taxa (ni/N) of the i^{th} taxa, *ni* = number of individuals in the taxa *i* and N = total number of individuals in all families.

A transect line with 50 meter interval, and 10 quadrats in each areas with every two month interval (November, January and March) for a year were taken. Thirty samples in each site making a total of 90 samples were collected in one cropping season. A 0.5 by 0.5 m quadrat was applied. However, the data were converted into g/m^2 for analysis. The samples were taken during 2015/2016 cropping season Simple random sampling technique was applied, but with due consideration of cranes foraging sites; inaccessible and areas that are not preferred by 85cranes was avoided during sampling. Measurements such as height of vegetation (grass) and water depth were recorded. The collected panicles were put in a plastic bag, then oven-dried and the dried weight of seeds was taken for analysis (Plate 4). The mean biomass weight of grass panicles were compared using Two-way ANOVA to see effect of seasons on food abundance in the wetlands, and their interaction. A post hock test was performed to find out which factor was more contributing for significant difference.

Plate 4. Grass panicle collection, and cranes foraging grass seeds, in Chimba wetland, 2016.

To estimate the abundance of crop seeds, the study was conducted in Chimba area, specifically Latamba Kebele administration area. The sampled sites were systematically assigned within the radius of one km from the edge of Chimba wetlands (Lamgebeya and Bashadangela) since cranes usually do not go far away from the main wetland during foraging time in the crop fields. Johnsgard (1983b) reported that feeding of Crowned Cranes usually occurred from 0.8 to 1.6 km from the nest site, and the birds would either walk or fly to their foraging grounds from the nesting site. Finger millet, tef and maize crops were selected for this study purpose. Since tef and finger millet are minute seed to quantify ones sown and even during stubble time, the abundance of these crops were therefore estimated by taking the damaged erected seeds spikes from the farmland (the quadrat could consists of damaged and intact spike of tef and finger millet). And hence three methods was used to estimate the abundance of crops seeds. These were sown, stubble and erected matured crop. Sown and stubble crops of maize (n=60); twice in one cropping season, but assessing damaged erected matured tef and finger millet by cranes were only ones.

For tef and finger millet crop seeds, biomass estimation, quadrat sampling size of 0.5 x 0.5 m were randomly laid in the damaged area (Plate 5); then all the crop panicles were cut, threshed and oven dried to estimate the amount of productivity per sampled quadrat. The amount of crop damaged in the sample quadrat tef (n=42), finger millet (n=42) was then compared with the amount of productivity-with the controlled sample, to find out the amount of loss (biomass) in each quadrat due to cranes. The biomass result then multiplied with the number of sample quadrats and converted into g/m^2 to estimate the total seed biomass utilized by cranes. The total loss of that crop (here after the biomass of crop seed) was taken as abundance of crop seed available for cranes.

Plate 5. Finger millet cropland undamaged (left photo) and damaged ones by cranes (right photo), in Chimba area, 2016.

In the case of maize crop, abundance of maize seeds of crops and fallen seeds was assessed in Chimba area. Quadrat sampling of size 0.5 x 0.5 meter was applied to count the matured seed of crops following Gichuki procedure (Gichuki, 1993). In the crop fields, cranes foraged on seeds found on the soil surface although they sometimes dug out buried seeds, including those planted by farmers. Quadrat was placed at random in sown and stubble crops of maize. Since the farming practice in Ethiopia is oxen ploughing, and considering the anatomical bill structure of Black Crowned Cranes, all the seeds on the soil surface were collected and those buried within the first 5 cm of the soil were removed by sieving. The seeds were oven-dried and their dry weights measured. A total of 60 samples, 30 during sowing time and 30 from stubble maize were taken during 2015/2016 cropping season. In all cases, the mean of the seed biomass of 84 samples of tef and finger millet, and 60 samples for maize crop seed was used to analyze the mean variance using One-way ANOVA.

Fecal sample were collected in Chimba wetland during the post-rainy period (November-December) and dry season (February-March). The droppings were collected specially for mixed flocks in the middle of the wetland during the resting time (Plate 6). None-fragmented fresh and old fecal samples were collected in the survey site. The smaller sizes were assigned to sub-adult and juveniles. The collected samples were put in plastic jar, labeled for further diet composition analysis. The dried weight of individual droppings were measured using AWS-250 Digital Pocket Scale in the laboratory to estimate the biomass.

The composition and diversity of diet were determined from the analysis of 172 pellets, 62% of which were from adults, 38% from sub adults and juveniles. Fecal sample analysis of adult and sub-adult cranes was carried out to determine diet composition. Dissecting low power binocular microscope was used to identify the composition of the dry matter of the diet at major food items level, such as grass seeds, crop seeds, non-seed plant materials and fragments of animal origin. It was not possible to undertake further analysis on the genera or species of plants and animals because of the highly fragmented state of the food item, and the difficulty identifying since it may require the use of specialized bibliography and assistance from specialists (Chaves and Alves, 2013). However, in order to obtain the composition of the diet, the weight of each type of fragments was expressed as a percentage of the total weight of all the fragments in the sample (Ralph *et al*., 1985). Comparison between the food composition (% by weight) of sub-adult and adult Black Crowned Cranes as revealed by fecal analyses were made by Kruskal-Wallis of Chi-square test.

Plate 6. Fecal sample collection during cranes resting time, Chimba 2016.

The study of foraging behavior of cranes was conducted in the wetland and farmland habitats. It was Chimba area during the wet (June-November) and dry seasons (December-May) during 2015/2016 cropping season. The study sites and sampled areas were areas where the abundance of crop seeds were studied. There was one km average distance between the transect lines of farmland and the wetland habitat. A 500 m band length was used to record cranes in left and right direction of farmland transect lines, but in the wetland habitat only one side direction was applied since the transect were laid along the edge of the wetland. A total transect length of 25 km (10 km in wetland, 15 km in farmland) were laid. In the farmland, the transect lines were laid in opposite direction of Chimba wetlands, because in between there was Gilgel Abay River. To the western side, there were seven transects, whereas in the eastern side it was eight. In the wetland habitat Bashadangela and Lamgebeya were selected, 4 and 6 transects were applied, respectively. The sampling techniques and the count period was considered following (Bibby *et al.,* 1998). The occurrence of foraging cranes only along the transect line in both habitats were registered.

Sitting, preening, fighting behaviors were not included when the observation was performed in both habitats. Juvenile non-fledged cranes that were foraging with parents were excluded, but breeding adults were considered when they are in the farmland because there is a likely chance for one of the breeding pair to forage in the farmland during the breeding time. The effort of data collection was 6:00 A.M to 6:00 P.M during the day time for each habitat and once at each study time. This procedure was repeated during the wet and dry seasons. The average number of crane occurrence in both wetland and farmland transects was taken to analyze percent cranes day spent feeding in each habitat of day time category. In order to determine the influence of time of day on habitat use, the locations of birds in different habitats was classified into 4 (three-hour time) blocks: 06.01-09.00 h, 09.01-12.00 h, 12.01-15.00 hand 15.01-1 (Gichuki, 1993). Every time when a cluster of cranes occuring within the time block was asigned within that time block and the average number of cranes was taken for analyaia. A Shapiro-Wilk test for normal data and MANOVA was used to analyze the data. The overall interaction effect was performed using N-ways ANOVA. Differences were considered statistically significant at .05 level. A post hock test of Tucky HSD. Multiple mean comparisons were made for crane foraging time blocks which F-values were declared as a significant difference.

3.2.3. Distribution and population

The spatial and seasonal distribution of the species was studied around Lake Tana area. Survey was conducted in the surrounding the lake where cranes were supposed to be distributed based on the local information and previous knowledge of the researcher. Both the foraging, resting and nesting sites were assessed. To identify the seasonal distributional pattern, data were collected on quarter bases. September to November; December to February; March to May; and June to August at five study categories: Yiganda area (Yiganda and Infranz together), Chimba (Bashadangela and Lamgebeya), and Legdiya-Kunzila, Delghi-Dirma, and Shesher-Wagtera area. Each category has a wetland and farmland habitats.

Data collection points at each site were set prior to data collection. A grid square of 0.5 x 0.5 km (0.25 km^2) was taken on digitized Google Earth Map (©2014-2015 Google). Ten grid square for one site category, for one type of habitat, and for one season (quarter) was assigned. Then (10*0.25*2 (wetland + farmland) = 5 km^2 was covered in one study site. At four season and at five study sites, a total of 100 km^2, which is 10,000 ha of wetland and farmland was visited in 2015-2016. A total of 400 observations was performed for the year 2015-2016 cropping season; however, the number of observation varied in the wetland and farmland habitats. Two individuals involved in wetland and farmland habitats data collection.

The data were organized into dependent and independent variables. The dependent variable was the number of Black Crowned Cranes that occur in each study sites, habitats and seasons.

Therefore, the study site categories (five), habitats (two) and seasons (four) were assigned. All dependent variables were assigned to each independent variables. The sample sizes were equal across each habitat and sites; however, each quadrat was assigned at each study and habitat sites systematically randomized.

The General Linear Model (GLM) was used to assess the effects of habitat, study sites and seasons on the distribution of Black Crowned Cranes using the GLM model.

$$Yijk = \mu + \alpha i + \beta j + \gamma k + eijk$$

Where: $Yijk$ = the individual observation of cranes is a factor of the i^{th} habitat, j^{th} site, and the k^{th} season

μ = the population mean of cranes

αi = effect of the the i^{th} habitat

βj=effect of the j^{th} site

γk= effect of the k^{th} season

$eijk$= effect of the error term

Shapiro-Wilk test for normal data was run, and the data is normally distributed at $P > 0.05$ (Table 2**)**. Test for equality of covariance matrix of 41 group means, assuming homogeneity were performed using Wilks' lambda, Pillai's trace test using MANOVA was tested (Appendix 1). Besides the main effect (habitat, site and season), the interaction of the three factors with each other and the overall interaction effect was performed using N-ANOVA in Stata. Differences were considered statistically significant at 0.05 level. A post hock test was run to analyze the least square of variance using Tucky HSD. Multiple mean comparisons were made for variables which's F-values declared a significant difference. However, post hock test was not performed for habitat because there were fewer than three groups.

Table 2. Shapiro-Wilk test for normal data.

Variable	Observation	W	V	z	Prob>z
Habitat	400	0.99565	1.197	0.427	0.33468
Site	400	0.99404	1.641	1.178	0.11940
Season	400	0.99709	0.802	-0.524	0.69988

Species are often much more abundant in one habitat than another. If census points are selected at random, then the number of points falling in each habitat will greatly influence the mean and thus the estimate of total population. It is usually preferable to sample each habitat independently to give a population estimate for each habitat. These are combined to estimate the total population. Such stratified sampling is almost always preferable to random sampling (Sutherland, 2000). There are systematic variations in population density across the study area, or one may suspect that densities are likely to differ in different habitats. If so, then it is usually valuable to divide the study into subareas that differ in density or habitat and to sample randomly within each. Such subareas are strata (Sutherland, 2006).

For this study *Line transect systematic random sampling design* was employed in which the samples were collected in a stratified sample arranged based on the size and type of habitat. As the crane distribution in the study area was fairly estimated, the number of samples put for each stratum was determined based on the area of the sampled site and the occurrence of cranes. The sampling techniques, location of census stations and the count period was logically considered following "Bird survey expedition techniques" (Bibby *et al.*, 1998).

Distance sampling is a widely-used group of closely related methods for estimating the density and/or abundance of biological populations. In the line-transect sampling, a series of straight lines (track lines) is traversed by an observer (Thomas *et al*., 2002). While, estimation perpendicular distances "x" are measured from the line to each detected object of interest. The distance sampling techniques were utilized to estimate the abundance and density of cranes during the study period (Thomas *et al*., 2002; Buckland *et al*., 2004). The population/density estimation was conducted in two strata (wetland and farmland) habitats in the northern, southern, southeastern, and southwestern part of Lake Tana area. A total of 74 transects (80 km) in 14,764 ha was conducted in 2015. However, in the wetland habitat the count was performed within 6764 ha of area, 34 transect line and 114 observation with a maximum width of 500 m. In the farmland; however, it was conducted in 8000 ha (selected sites), with a total of 40 transect and 104 observations performed. But, in 2016, a total of 56 transect (50.67 km) in 14,764 ha was conducted. The wetland habitat consisted of a total of 6764 ha, 32 transect (26.6 km), and a total of 107 observations with a maximum width of 400 m was performed. In the farmland, similar size of area was visited, but the study was performed in 24 transects (24 km), where 99 observations were performed. The sampling sites were categorized into five sites: Yiganda area wetlands include (Yiganda and Infranz), Chimba area (Bashadangela and Lamgebeya), Legdiya area (Tiloma and Kunzila), Dirma (Gorgora and Delghi) and Fogera plain (Shesher-Wallala and Wagtera).

Distance 6.2 software (source: http://distancesampling.org/) were used to analyze the abundance and density of cranes (Buckland *et al.*, 2001; Thomas *et al*., 2010). For this purpose, Multiple Covariate Distance Sampling (MCDS) model with hazard-rate key function and Simple polynomial series adjustment / expansion was employed, primarily to estimate density of cranes in the stratified study area. Analysis of distance sampling data where covariates in addition to distance were used to model the detection function. MCDS model was selected because of its robustness and shape criteria in terms of estimating g(x) (probability detection function) and applicable for stratified sampling (Buckland *et al.,* 2001).

The encounter rate, detection probability, expected cluster size and density for each stratum (wetland and farmland) data individual were the parameter estimation specification that was performed during the data analysis. The analysis was performed using exact distances estimated in the field with some violation, taking the advantage of transect count in which transects are probably more accurate than point counts. This is because the most likely violation of assumptions concern between bird and observer. Their impact rises linearly for transects and by square for point counts (Bibby *et al.*, 1998).

Hazard rate key (σ = 0.3), where g(x) the detection probability is calculated using this formula in distance program:

$$g(x) = 1 - exp\left[-\left(\frac{x}{\sigma}\right)^{-\beta}\right], x \leq w$$

Where g(x) = relationship between detection probability and distance, x = perpendicular distance in a line transect, and w= truncation distance for x, and σ and β = the parameter, sigma and beta, which made ‘hazard rate’ to have two parameters. This enables this model more flexible to take on wide variety of shape than ‘half normal’ ‘uniform’ and ‘negative exponential’ key functions.

Cluster analysis based on exact sizes is expected value of cluster size computed by regression of log(s(i)) on g(x(i)). The following estimators such as term selection mode: Sequential; term selection criterion: Akaike Information Criterion (AIC); and distances scaled by: auto W (right truncation distance) were used. However, among the models used, the minimum AIC was chosen during estimator selection. In addition, variance of n: Empirical estimate from sample, and Variance of - f(0): MLE (Maximum Likelihood Estimation) estimate were utilized. The Goodness of fit (Chi-squared test) based on grouped distance interval was estimated by Cut points chosen by distance program. The Chi-squared test measured the observed and expected frequencies when we have our perpendicular distance data we have the number of siting we had in bin number one and we compare that against the number of siting our model predicts ought to be in bin one, so the distribution of that statistic is assumed to be Chi-squared test.

3.2.4. Evaluation of land cover-use change

The land use cover change of Chimba specifically Bashadangela and Lamgebeya and Yiganda wetland watershed were selected only for this purpose, because these areas are the most important breeding and feeding sites of the largest population of Black Crowned Cranes, and the area is registered by UNESCO as Biosphere Reserve (UNESCO, 2014).

By analyzing satellite images (land sat images -ETM+ from USGS website), land use units was classified according to their area coverage as forest, cultivated land, grazing land, wetland, bushland, etc. The integration of GIS and remote sensing is a good approach for analyzing the aerial photographs and satellite images. GIS and remote sensing using ArcGIS and ERDAS IMAGINE software was employed to evaluate the temporal and spatial changes in land use with 30 years' time period gap.

The study area was divided into different habitats. Percentage of various land uses was calculated with the ArcGIS environment. The land use dynamics showed the possible changes in spatial pattern of land use. This will predict future changes projected from the current land use under growth pressure within the Lake Tana watershed by relating population pressure with destruction of ecological habitat of Black Crowned Cranes. Hence the consecutive negative impacts on bird habitats were stated.

Land use change patterns in relation to wetland shrinkage was mapped and analyzed at two spatial scales; at specific watershed level on the basis of classified LANDSAT-Imagery through the application of ERDAS IMAGINE software (1986 and present). Time series of aerial photographs (1986 - 2016) was used. Ground truthing and signatures were collected in the field during 2015-2016. These signatures were synchronized with satellite images. Following selection and classification of images, validation of compiled land use maps were achieved. Bio-physical data from land use land cover analysis, satellite images, and actual ground survey observation were collected. Then the effect of land use change on crane habitat availability was evaluated.

The wetland habitat shrinkage in particular was evaluated from the LULC change from 1986 to 2016. The proportion of wetland changed into other LULC was evaluated and how much wetland was left for nesting and foraging of cranes was determined. The available wetland due to LULC change for territorial cranes (breeding cranes) was discussed; and future prospect of cranes habitat was argued.

The threats in each study site, habitat and season for Black Crowned Crane distribution, food and foraging behavior and breeding biology during the study period 2013-2016 were assessed by observation at site and communicating with the people on farm. Secondary information for threats, opportunities and policies, treaties at national and international level were also reviewed from published literatures (Frances and Shimelis Aynalem, 2007; Nowald *et al*., 2007; Shimelis Aynalem *et al*., 2011; Shimelis Aynalem *et al*., 2017a; Shimelis Aynalem *et al*., 2017b).

3.2.5. Data analyses

The data collected were organized in the excel sheet for statistical analyses. Data normality were checked using a Shapiro-Wilk's test, the Kolmogorov-Smirnov test (K-S) and Cramer-von Mises family test (C-von M-test). For those data that had satisfied the standard normal distribution criteria were subjected to ANOVA, t-test, Pearson Correlation, MANOVA and GLM model for analyses. However, the data that were not normally distributed, a non-parametric test such as Kruskal-Wallis test, Independent Sample Mann-Whitney Test, Chi-square test (χ^2), and Spearman's ratio were utilized. Mean comparisons were made using Tucky HSD for variables whose F-values declared a significant difference. Two tailed significance, and differences were considered statistically significant at 5% level.

Besides others statistical analysis such as descriptive statistics; Egg Shape Index (ESI), and Egg volume (V), probability density function (pdf) for distance sampling were used. Simple regression model and diversity indices were employed to assess the macroinvertebrate food potential. During data analysis SPSS version 21, Stata/SE 11.0, Distance Sampling (beta 6.2), ArcGis and ERDAS IMAGINE soft wares were used.

4. RESULTS

4.1. Breeding biology of Black Crowned Cranes

4.1.1. Nest location and characteristics

All of the nests of Black Crowned Cranes were located only in wetlands where there is enough water depth and open vegetation to construct nests. The nesting were constructed at variable distance from the main terrestrial land. Depending on the proximity of the mainland to the nest, the depth of water where the nests were built and the disturbance induced by humans and livestock were main factors for cranes to establish nests. Constructed nests were located away from high grazing pressure or where there was minimum and little disturbance during the nesting time. Cranes prefer places that have short grasses than long grasses. They do not establish nests just adjacent to long papyrus reed or in the middle of a patchy area where there is papyrus reed as it blocks crane observations. They need open wetland which enable them to scrutinize and scan to defend their territory.

During the field study period a total of 52 nests (25 in 2014 and 27 in 2015) were identified and recorded. In Yiganda, the water depth where nests were built ranged from 202- 210 cm however in Chimba it ranged from 135-220 cm. The active nesting period was September-October. In 2015 similarly, the water depth in Yiganda ranged from 155-180 cm, whereas in Chimba, it was 135-202 cm. The vegetation cover where the nests were built ranged from 30-50 cm long for Yiganda wetland. But the vegetation height 2014/2015 for the study sites were ranged from 20-90 cm (44.83± 2.397, N=48). However, in Dirma area because of the water hyacinth (*Eichhornia crassipes*) dominancy, the nest was built on the top of water hyacinth.

The closest nest in Yiganda was built 195 m away from the main land, while in Chimba, it was 117 m (Table 3).

Table 3. Nest site, water depth and distance from the main land, 2014-2015.

No.	2014			2015		
	Nest recorded in 2014	Water depth in cm	Nest distance from closest mainland (m)	Nest recorded in 2015	Water depth in cm	Nest distance from closest mainland (m)
1	I_n1	205	60.83	I_n1	170	48.97
2	I_n2	170	68	I_n2	120	107
3	Cht_1	190	172	Cht_1	145	621.51
4	Cht_2	190	170	Cht_2	170	221.25
5	Cht_3	185	91	Cht_3	172	153.86
6	D_n1	150	121.2	D_n1	120	121.2
7	D_n2	80	221.2	D_n2	80	221.2
8	D_n3	80	227	D_n3	85	227
9	Y_n1	210	195.6	Y_n1	175	147.6
10	Y_n2	208	357.26	Y_n2	160	334.3
11	Y_n3	220	351.6	Y_n3	150	351.6
12	Y_n4	215	411.6	Y_n4	155	411.6
13	Y_n5	202	302.8	Y_n5	180	302.8
14	C_n1	135	117.5	C_n1	140	117.5
15	C_n2	165	137.8	C_n2	135	137.8
16	C_n3	180	267.1	C_n3	155	267.1
17	C_n4	170	299.6	C_n4	160	299.6
18	C_n5	150	314.7	C_n5	145	314.7
19	C_n6	154	402	C_n6	142	402
20	C_n7	189	330.2	C_n7	175	330.2
21	C_n8	203	465	C_n8	180	465
22	C_n9	220	613.8	C_n9	194	613.8
23	C_n10	180	629.2	C_n10	170	629.2
24	C_n11	185	588.11	C_n11	190	588.11
25	C_n12	180		C_n12	202	632
26	-	-		C_n13	195	566
27	-	-		C_n14	196	421

Note: C = Chimba, Cht= Chenta sostu, Y = Yiganda wetland, D= Dirma wetland, I= Infranz wetland, n= nest

The nest characteristics of cranes are similar. They build nests above the water surface where there is vegetation (grass). Initially they turn or bend down the available grass and then pile up cut grasses taken close to the nest. The cleared grasses around the nest could be different based on the type of nest material and height of grasses used. At the base, the nest was broad but in the middle it was cup-like in structure. On top of it, soft grass leaves and down feathers were observed. Every time cranes pull out grasses around and add to the nest until they hatch the egg. As the height of the nest increases against the water level, it keeps the nest dry. The length and breadth of the nest differs from nest to nest.

The closest distance where the Black Crowned Crane nest located was 48.97 m in Infranz Chenta sostu area, but the maximum was 795.01 m in Chimba Lamgebya area. The mean distance was 321.32±191.93 m (Table 4).

Table 4. Distribution of nests and location in the study sites.

Total nest	Site name	Nest Id	Nest distance from closest mainland (m)	The nearest nest pairs	Inter-distance between nests (m)
2014					
1	Chenta sostu	I_n1	60.83	-	-
2		I_n2	68	-	-
3		Cht_1	172	Cht_1and 2	108.2
4		Cht_2	170	Cht_2 and 3	165.23
5		Cht_3	91	-	-
6	Dirma	D_n1	99.13	D_n1 and 2	730.18
7		D_n2	251	D_n2 and 3	726.23
8		D_n3	493.81	-	-
9	Yiganda	Y_n1	152.6	Y_n1 and 5	306.94
10		Y_n2	357.26	Y_n3 and 5	107.64
11		Y_n3	376.78	Y_n3 and 4	64.49
12		Y_n4	394.6	Y_n4 and 2	92.13
13		Y_n5	302.8	-	-
14	Chimba Bashadangela	C_n1	171.12	C_n1 and 2	56.95
15		C_n2	142.04	C_n1 and 3	86.39
16		C_n3	265.15	C_n3 and 4	68.71
17		C_n4	276.31	C_n4 and 6	83.54
18		C_n5	258.84	C_n3 and 5	63.14
19		C_n6	359.18	C_n7 and 8	127.5

Total nest	Site name	Nest Id	Nest distance from closest mainland (m)	The nearest nest pairs	Inter-distance between nests (m)
20		C_n7	290.57	C_n6 and 8	275.82
21		C_n8	489.05	-	-
22	Chimba Lamgebya	C_n9	647.97	C_n9 and 10	165.75
23		C_n10	579.71	C_n10 and 11	226.42
24		C_n11	798.01	C_n11 and 12	199.7
25		C_n12	680.12	-	-
2015					
1	Chenta sostu	I2_n1	48.97		
2		I2_n2	107		
3		Cht2_1	621.51	Cht2_1 and 2	1875
4		Cht2_2	221.25	Cht2_2 and 3	120.73
5		Cht2_3	153.86		
6		D2_n1	120.87	D2_n1 and 2	682.71
7		D2_n2	270.21	D2_n2 and 3	5.84
8		D2_n3	266.24		
9	Yiganda	Y2_n1	153.14	Y2_n1 and 5	279.62
10		Y2_n2	290.39	Y2_n2 and 3	65.32
11		Y2_n3	356.07	Y2_n2 and 5	96.37
12		Y2_n4	431.24	Y2_n3 and 4	96.42
13		Y2_n5	271.17		
14	Chimba Bashadangela	C2_n1	183.41	C2_n1 and 2	40.42
15		C2_n2	153.5	C2_n1 and 3	100.21
16		C2_n3	274.84	C2_n3 and 4	69.45
17		C2_n4	336.24	C2_n4 and 6	108.34
18		C2_n5	255.27	C2_n1 and 5	85.2
19		C2_n6	367.63	C2_n5 and 7	82.33
20		C2_n7	288.13	C2_n6 and 8	234.72
21		C2_n8	578.89	C2_n7 and 10	919.6
22		C2_n9	281.86	C2_n9 and 10	321.16
23		C2_n10	176.3		
24	Chimba Lamgebya	C2_n11	722.34	C2_n11 and 12	183.92
25		C2_n12	672.14	C2_n11 and 14	251.89
26		C2_n13	572.26	C2_n12 and 13	182.89
27		C2_n14	586.06		

Note: C2, Cht2, Y2, I2 and D2 = the number ‘2’ indicates the data collection year (2015)

A Shapiro-Wilk's Test showed that nest location from the mainland and inter-distance between nests were not normally distributed for each sites, with a skewness of 2.526

(SE=.687), -.734 (SE=.687), -.415 (SE=1.334), 1.151 (SE=.586), .640 (SE=.750), .946 (SE=.845) and Kurtosis 7.064 (SE=1.334), -.415 (SE=1.334), 1.642 (SE=1.038), -.176 (SE=1.481) and 1.382 (SE=1.741) for Chenta, Yiganda, Chimba Bashadangela, Chimba Lamgebya and Dirma, respectively.

There was a significant difference in nest location in the study sites ($\chi^2 = 26.613$, d.f. = 4, $P < .05$). Independent Sample Mann-Whitney Test showed that there was a significant difference in nest location in Chenta and Yiganda (U =18, d.f. 1, P = .016, $P < .05$), Chenta and Chimba Bashadangela (U = 30, d.f. 1, P = .004, $P < .05$), Chenta and Chimba Lamgebeya (U =3, d.f. 1, P = .001, $P < .05$), and Chimba Lamgebeya and Chimba Bashadangela (U=1, d.f. 1, P= .000, $P < .05$). However the inter-distance between nests in all sites did not show any significant difference ($\chi^2 = 5.435$, d.f.4, $P > 0.05$).

4.1.2. Nest materials, vegetation height and nest morphometry

Cranes utilized nest materials collected from the nesting place just around the nest. The kind of nest material is dependent on the type of vegetation near in the nesting area. During 2014, five nesting materials were identified for 20 nests from Yiganda, Chimba and Dirma (Table 5). *Leersia hexandra* (44%), *Oryza ongistaminata* (41%), *Cyprus rotundus* (9%), *Sacciolepsis Africana* (4%t) and *Ludwigia stolonifera* (3%). Only one nest utilized *L. stolonifera* because this species was dominant in the area. Similarly, only two nests utilized *C. rotundus*. However, *L. hexandra* and *O. longistaminata* accounted 85% of the nesting material utilized.

Table 5. Nest materials utilized and its proportion in percentage for Black Crowned Cranes, 2014.

Site name	Nest Id	Vegetation height near nesting area average (cm)	Plant materials used for nest construction (Scientific name)	Proportion in (%)	Cleared area (m^2)
Infranz	I_n1	76	*Ludwigia stolonifera*	60	7.07
			Oryza longistaminata	40	
	I_n2	55	*Cyprus rotundus*	65	6.58
			Oryza longistaminata	35	
Yiganda	Y_n1	59	*Oryza longistaminata*	95	3.14
			Leersia hexandra	5	
	Y_n2	65	*Oryza longistaminata*	99	4.52
			Leersia hexandra	1	
	Y_n3	60	*Leersia hexandra*	45	0.79
			Oryza longistaminata	55	
	Y_n4	50	*Leersia hexandra*	50	0.50
			Oryza longistaminata	50	
	Y_n5	55	*Leersia hexandra*	55	0.82
			Oryza longistaminata	45	
Chimba	C_n1	30	*Oryza longistaminata*	60	2.27
			Leersia hexandra	40	
	C_n2	25	*Leersia hexandra*	80	1.91
			Oryza longistaminata	20	
	C_n3	30	*Leersia hexandra*	90	0.05
			Oryza longistaminata	10	
	C_n4	33	*Leersia hexandra*	85	10.86
			Oryza longistaminata	15	
	C_n5	25	*Leersia hexandra*	80	8.04
			Oryza longistaminata	20	
	C_n6	30	*Oryza longistaminata*	75	1.54
			Leersia hexandra	25	
	C_n7	45	*Oryza longistaminata*	70	1.54
			Leersia hexandra	30	
	C_n8	55	*Leersia hexandra*	90	1.54
			Leersia hexandra	10	
	C_n9	50	*Sacciolepsis africana*	85	1.54
			Leersia hexandra	15	
	C_n10	60	*Cyprus rotundus*	85	4.52
			Leersia hexandra	15	
	C_n11	40	*Cyprus rotundus*	85	1.54
			Leersia hexandra	15	

Site name	Nest Id	Vegetation height near nesting area average (cm)	Plant materials used for nest construction (Scientific name)	Proportion in (%)	Cleared area (m^2)
Dirma	D_n1	90	*Leersia hexandra*	80	2.01
			Oryza longistaminata	20	
	D_n2	62	*Oryza longistaminata*	70	1.13
			Leersia hexandra	30	
	D_n3	60	*Oryza longistaminata*	70	1.54
			Leersia hexandra	30	

But during 2015, five nesting materials were identified for 22 nests in Yiganda and Chimba (Table 6). *Leersia hexandra* (43%), *Oryza longistaminata* (31%), *Cyprus rotundus* (19%), *Sacciolepsis Africana* (4%) and *Eichhornia crassipes* (3%). Due to the high infestation rate with water hyacinth in Dirma wetland, *E. crassipes* dominated the natural grass. Even though the previous nesting sites were being invaded by this alien species; still *L. hexandra* and *O. longistaminata* accounted 74% of the total nest material used.

Table 6. Nest materials utilized and its proportion in percentage for Black Crowned Cranes, 2015.

Site name	Nest Id	Vegetation height near nesting area (cm)	Plant materials used for nest construction (Scientific name)	Proportion in (%)	Cleared area (m^2)
Yiganda	Y2_n1	40	*Oryza longistaminata*	90	7.07
			Leersia hexandra	10	
	Y2_n2	35	*Oryza longistaminata*	90	12.56
			Leersia hexandra	10	
	Y2_n3	30	*Leersia hexandra*	70	5.31
			Oryza longistaminata	30	
	Y2_n4	35	*Leersia hexandra*	65	6.15
			Oryza longistaminata	35	
	Y2_n5	60	*Leersia hexandra*	60	7.25
			Oryza longistaminata	40	
Chimba	C2_n1	40	*Oryza longistaminata*	80	3.14
			Leersia hexandra	20	
	C2_n2	30	*Leersia hexandra*	75	2.54

Site name	Nest Id	Vegetation height near nesting area (cm)	Plant materials used for nest construction (Scientific name)	Proportion in (%)	Cleared area (m^2)
			Oryza longistaminata	25	
	C2_n3	35	*Leersia hexandra*	90	1.54
			Oryza longistaminata	10	
	C2_n4	33	*Leersia hexandra*	70	1.13
			Oryza longistaminata	30	
	C2_n5	20	*Leersia hexandra*	75	2.01
			Oryza longistaminata	25	
	C2_n6	40	*Oryza longistaminata*	70	0.50
			Leersia hexandra	30	
	C2_n7	50	*Oryza longistaminata*	80	1.54
			Leersia hexandra	20	
	C2_n8	60	*Leersia hexandra*	80	1.13
			Oryza longistaminata	20	
	C2_n9	52	*Sacciolepsis africana*	85	0.79
			Oryza longistaminata	15	
	C2_n10	45	*Cyprus rotundus*	80	4.52
			Leersia hexandra	20	
	C2_n11	60	*Cyprus rotundus*	75	13.85
			Leersia hexandra	25	
	C2_n12	40	*Cyprus rotundus*	90	0.28
			Leersia hexandra	15	
			Oryza longistaminata	5	
	C2_n13	35	*Cyprus rotundus*	90	0.38
			Leersia hexandra	10	
	C2_n14	30	*Cyprus rotundus*	80	0.50
			Leersia hexandra	20	
Dirma	D2_n1	80	*Leersia hexandra*	50	3.14
			Oryza longistaminata	50	
	D2_n2	20	*Eichhornia crassipes*	30	2.01
			Leersia hexandra	70	
	D2_n3	22	*Eichhornia crassipes*	40	1.54
			Leersia hexandra	60	

A total of 48 nests were observed and a Shapiro-Wilk Test of Normality showed that the variables (vegetation height) were approximately normally distributed. Yiganda (n =10, d.f. = 10, P = .430) Chimba Bashadangela (n = 17, d.f.=.17, P =.178) Chimba Lamgebya (n = 8, 82d.f.= 8, P = .73) and other sites Dirma, Chenta sostu (n = 13, d.f.= 13, P = .430). The mean vegetation height (cm) of the constructed nest was 44.83±4. However, the mean height at each site was 51.54±6.59 (Infranz), 12.78±4 (Yiganda), 36.65 ± 10.83 (Chimba Bashadangela), and 46.25± 11.57 (Chimba Lamgebya). 95% Confidence Interval for mean lower boundary and upper boundary for total =40.01-49.66 but for sites 37.18-65.9, 39.76-58.04, 31.08-42.21, and 36.57-55.93 were the lower boundary and upper boundary of Dirma and Chenta sostu, Yiganda, Chimba Bashadangela and Chimba Lamgebya, respectively. The One-way ANOVA was F= 2.527, d.f. = 3, P = .070. The vegetation height at each site did not show significant difference, P > 0.05. However, the mean vegetation height of sites in 2014 and 2015 showed significant difference at .05 level. In 2014 (n = 21, 50.24±3.77), in 2015 (n = 27, mean 40.63±9.90) (F = 4.226, d.f. = 1, P = .046).

The shape of the nest is usually elongated or oblong. Nests that had eggs showed depressed shape in the central part of the nest (Plate 7).

Plate 7. Nest locations in Yiganda, Chimba, and Dirma areas, 2014-2015.

A total of 52 nests were used to analyze the morphometry of Black Craned Crane nests. The nest length range was 50-110 cm. (n = 52, mean = 69.53±15.26 cm), nest width 49-100 cm (n = 52, mean = 63.84±11.26 cm), nest height from the surface of water ranged 10-30 cm (n = 52, mean= 18.54±4.88 cm). Nests were constructed in the wetland where the water depth ranged 80-220 cm (n = 52, mean = 166.86±34.97 cm). The smallest nest length was recorded in all sites, except in Chimba Bashadangela. Whereas the smallest nest width was recorded in Yiganda wetland in 2014, 49 cm. The largest was in Chimba Lamgebya during the same year, 100 cm. The smallest and largest nest height measured in Yiganda, in 2014 was 10 and 30 cm, respectively. In Chimba Lamgebya the smallest in 2014 and the largest in 2015 were also recorded. However, the nest morphology parameters: length (F = 1.77, d.f. = 3, P = 0.1649), width (F = 2.68, d.f. =3, P = 0.057), and height (F = 0.04, d.f. = 3, P = 0.989) did not show significant difference at $\alpha_2 = .05$ in all study sites.

Nest height and water depth relationship were observed using a Pearson Correlation (Table 7). There was a weak positive correlation between water depth and nest height (R = 0.205, d.f. = 28, P > 0.05). The R square adjusted ($R^2 = .042$) shows the relationship percentage, in that the water depth accounted only 4.2% the variation in nest height. So 95.8% of the variation are explained by other factors (Fig. 5). The significance of the two tailed gave the P value =.145, P > .05. There is no significant correlation between water depth and nest height.

The P value of ANOVA for regression (the slope) (P = .145, P > .05) are not statistically significant. There is no supported relationship between water depth and nest height (b = 0). Therefore the regression equation regarding the null hypothesis based on the application of Regression model with equation is:

$H_i = 13.77 + .03WDi$

Where H_{i} = nest height of the i[tch] observation, WD_i=*water depth* of the i[tch] observation

Table 7. Correlation and Regression coefficients for nest height and water depth relationship.

Model Summary

Model	R	R^2	Adjusted R^2	SE of the estimate
1	.205[a]	.042	.023	4.82492

a. Predictors: (Constant), Water depth

Coefficients[b]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	Constant	13.771	3.292		4.184	.000
	Water depth	.029	.019	.205	1.479	.145

b. Dependent Variable: Nest height above water

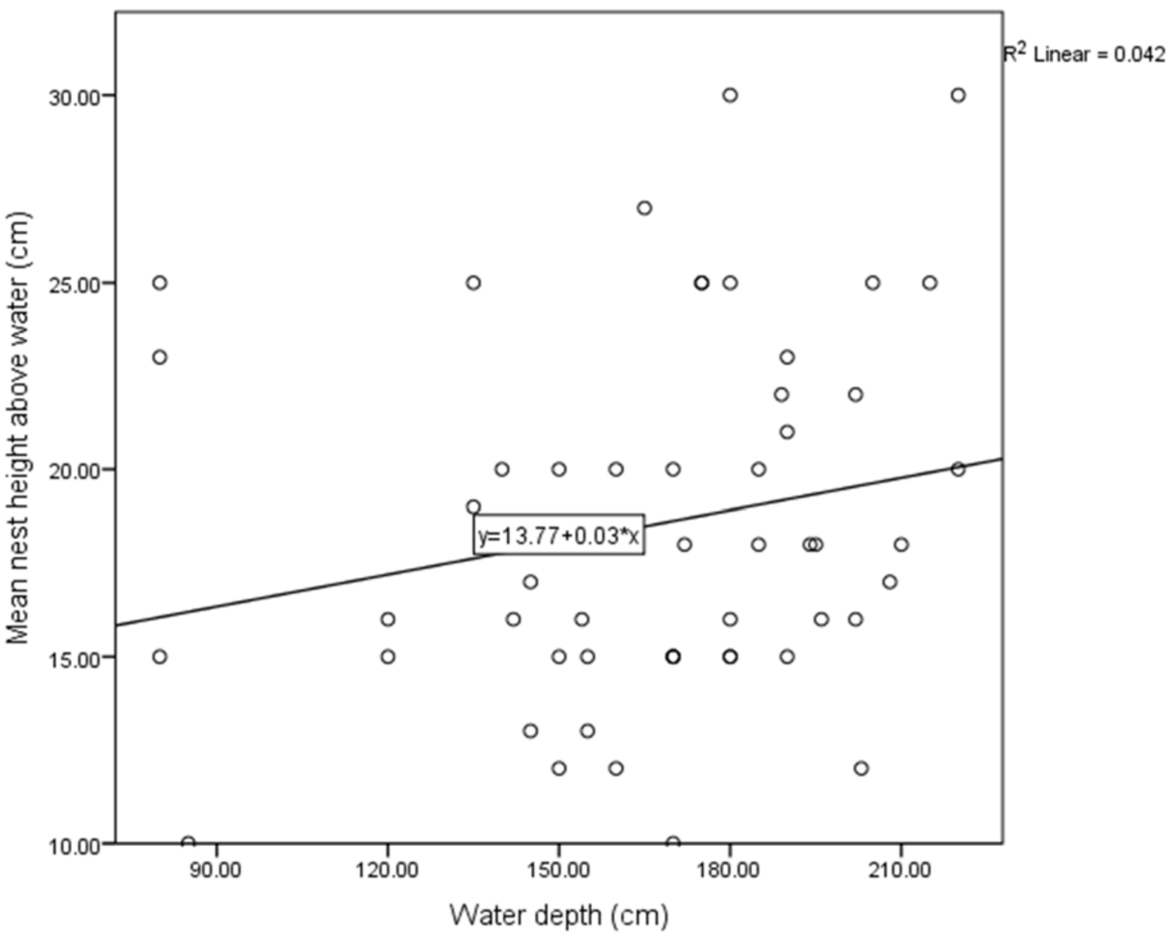


Figure 5. Regression equation adjusted for water depth and the mean nest height.

4.1.3. Nesting density and nest sight fidelity

In 2014, a total of 16 breeding pairs with eggs were recorded: four in Yiganda, six, in Chimba Bashadangela, three pairs in Dirma and Chimba Lamgebya area; whereas in 2015 the record showed five pairs with eggs in Yiganda, 10 pairs in Chimba Bashadangela, and three each in Chimba Lamgebya and Dirma wetland.

Nesting density of Black Crowned Cranes in Yiganda wetland was six, in 2014 and seven, in 2015 per 100 ha. In Chimba Bashadangela four and seven pairs per 100 ha was in 2014 and 2015, respectively; but in Chimba Lamgebya, it was two pairs per 100 ha in 2014 and 2015, respectively. In Dirma wetland areas, it was four in 2014, and three pairs per 100 ha.

Cranes were observed to use similar nesting area during 2014 and 2015 though not sure similar breeding pairs were using the same area since birds had no ring. The mean inter-nest distance (m) in the study sites were: 63.27±16.19 in Dirma and Chenta sostu; 22.69±6.96 in Yiganda, and 35.59±14.49 in Chimba area. There was no significant different between nests constructed in 2014 and 2015 ($F = 1.663$, $d.f = 2$, $P = .225$). Therefore nest sight fidelity was observed in all sites with overall mean distance between nests of the study site 38.31±8.49.

4.1.4. Eggs and morphometric measurements

A total of 52 nests was constructed in September 23 (55%), October 15 (36%), November 10 (24%) and in December 4(10%). However, only 46 nests had eggs, the first clutch of eggs was recorded in September 18, and 20 in 2014 and 2015, respectively, which lasted until November 1, 2014 in 2014 and December 10, 2015. So, the duration of nest construction and initiation of the first clutch of egg in Black Crowned Cranes at Lake Tana, area was September to December. No record was seen in August and January (Fig. 6).

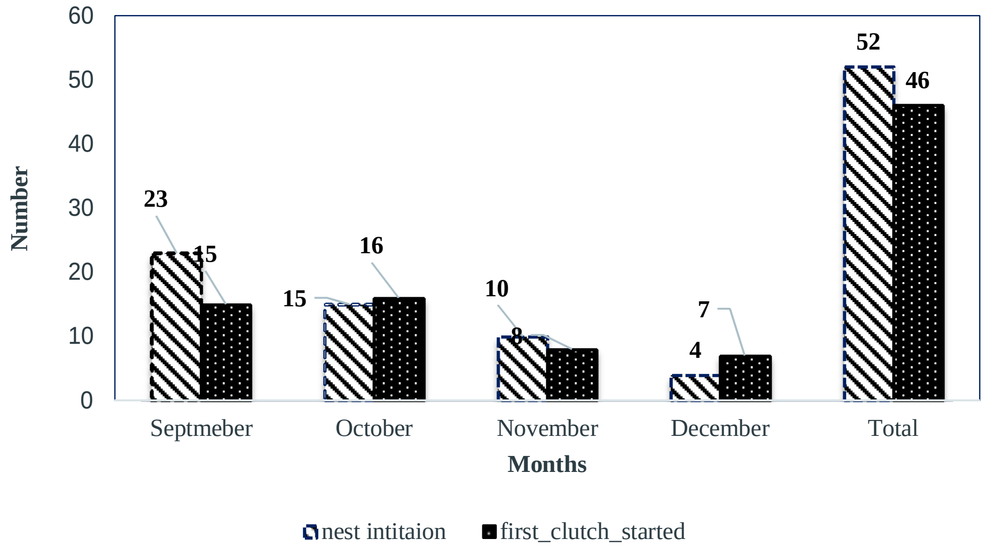


Figure 6. Nest initiation and constructed and the first clutch of egg recorded.

Among 46 breeding pairs that had eggs, a total of 92 eggs were recorded in 2014 and 2015. These were 44, in 2014 and 48 in 2015. The average clutch size during the breeding season (2014 and 2015) was two. Clutch one had seven nests, clutch two had 32 nests, and clutch three had seven nests. The mean weigh to clutch one was 109.88±2.04 g, clutch two 226.22±2.00 g, and clutch three 327.9±6.84 g (Fig. 7).

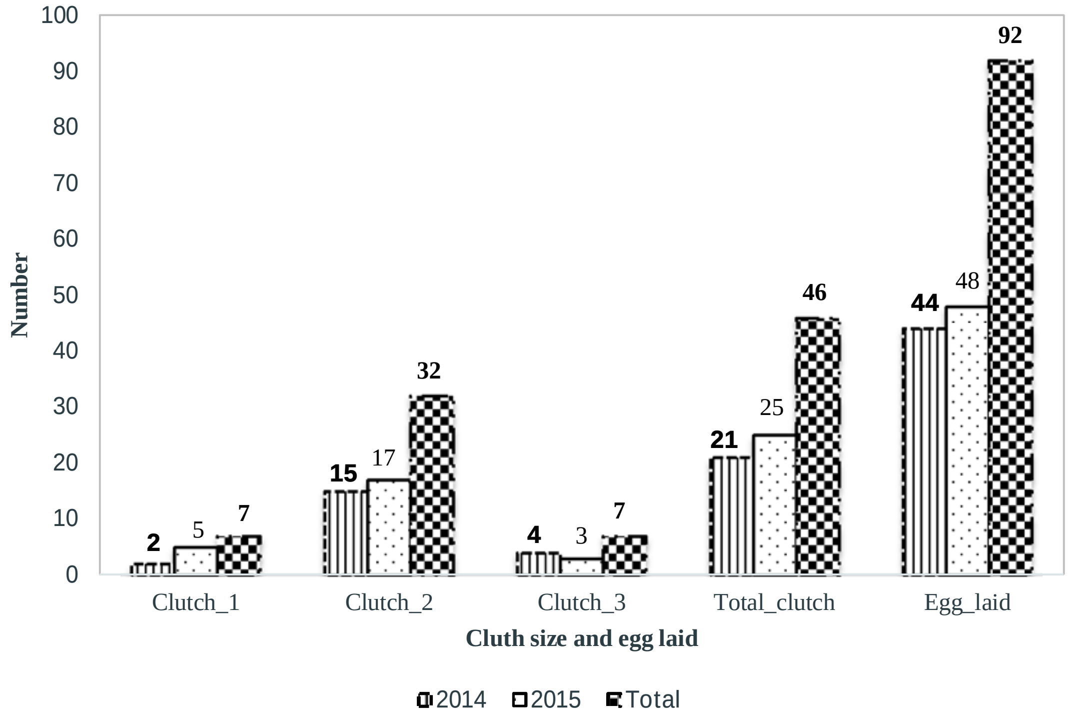


Figure 7. Clutch size and egg laid in the study area.

Egg measurements showed that the mean length of 92 eggs was 76.94±.22 mm with minimum length of 74.00 mm and maximum 82.20 mm. The mean width was 54.05±.07 mm with minimum length of 51.50 mm and maximum 55.80 mm, and the mean weight of all eggs was 111.99±.65g, with minimum of 101.05 and maximum 128.61g. Therefore there was no significant difference in all measurements at 5% level of significance (length, n = 92, d.f. = 1, F = .02, P >.05; breadth, n = 92, d.f. = 1, F = .048, P > .05; weight, n = 92, d.f. = 1, P > .05) Table 8).

Table 8. One-way ANOVA and mean length, breadth and weight of eggs of Black Crowned Crane.

Variables all season	Egg measurements mean (±S.E)	d.f.	F	Sig.
Egg length (mm)	76.94±.22	1	.020	.887
Egg breadth (mm)	54.05±.07	1	.048	.827
Egg weight (g)	111.99±.65	1	2.052	.155

However, the result of all eggs at a time analysis could not be a representation of the stages/ages of all eggs. The first clutch, the second clutch and the third clutch had different measurements. To see whether there is a statistical variation on the mean length, breadth, and weight of eggs, all eggs were categorized into stages: 'new', 'old' and 'older' ages. The mean length of first laid egg (older), second laid egg (old), and third laid egg (Table 9).

Table 9. Mean length, width and weight of 1^{st}, 2^{nd} and 3^{rd} laid eggs.

Measurements	Egg stage/age	N	Egg measurements Mean (±S.E)
Egg length	new	40	77.55±0.32
	old	45	76.60±0.34
	older	7	75.64±0.51
Egg width	new	40	54.39±0.07
	old	45	53.83±0.11
	older	7	53.50±0.11
Egg weight	new	40	114.27±0.94
	old	45	110.86±0.86
	older	7	106.21±2.35

However, there was a significant difference between the stages/ages of eggs (Table 10).

Table 10. One-way ANOVA for egg length, breadth and weight, based on egg stages (1st, 2nd, and 3rd laid).

	Sum of Squares	d.f.	Mean Square	F	Sig.
Egg length between egg stages	31.607	2	15.804	3.604	0.031
Egg width between egg stages	9.054	2	4.527	12.8	0.000
Egg weight between egg stages	499.506	2	249.753	7.212	0.001

Mean difference of egg length, breadth, and weight using a Post Hock test (Table 11). There was a positive correlation between egg length and egg width and statistically significant (R = .219, P = .036, P < .05, n = 92). But there was no correlation between egg length and weight and statistically not significant (R = -.019, P = .857, P > .05). There was also no significance difference between egg width and egg weight (R = .04, P = .694, P > .05, n = 92).

Table 11. Multiple comparison of egg stages/ages for egg length, breadth, and weight using Tukey HSD test.

Dependent Variable	(I) egg stage	(J) egg stage	Mean Difference (I-J)	Std. Error	Sig.
Egg length	new	old	0.943	0.455	0.101
		older	1.905	0.858	0.073
	old	new	-0.943	0.455	0.101
		older	0.962	0.851	0.498
	older	new	-1.905	0.858	0.073
		old	-0.962	0.851	0.498
Egg width	new	old	.56583*	0.129	0.000
		older	.89250*	0.244	0.001
	old	new	-.56583*	0.129	0.000
		older	0.327	0.242	0.371
	older	new	-.89250*	0.244	0.001
		old	-0.327	0.242	0.371
Egg weight	new	old	3.41136*	1.279	0.024
		older	8.06139*	2.411	0.003
	old	new	-3.41136*	1.279	0.024
		older	4.650	2.391	0.132
	older	new	-8.06139*	2.411	0.003
		old	-4.650	2.391	0.13

The mean length of egg at Chenta Sostu and Dirma area was 77.12±.42 (n = 30), Yiganda 77.22±.62 (n = 18), Chimba Bashadangela 76.91±.35 (n = 32) and Chimba Lamgebya were 76.17±.37 (n = 12). For egg breadth, the mean width of egg at (Chenta sostu and Dirma area) was 54.18±.08 (n = 30), Yiganda 53.73±.15 (n = 18), Chimba Bashadangela 54.03±.14 (n = 32) and Chimba Lamgebya were 54.25±.17 (n = 12). The mean egg weight at Chenta sostu and Dirma area was 112.94±1.26 (n = 30), Yiganda 113.51±1.50 (n = 18), Chimba Bashadangela 54.03±.14 (n = 32) and Chimba Lamgebya were 54.25±.17 (n = 12) (Table 12).

Table 12. The mean length (mm), width (mm) and weight (g) of laid eggs in the study sites.

Egg measurements	Study sites	Sample size (N)	Mean egg length, width and weight (± S.E)
Egg length	Infranz	30	77.12±0.42
	Yiganda	18	77.22±0.62
	Chimba Bashadangela	32	76.91±0.35
	Chimba Lamgebya	12	76.17±0.37
	Total	92	76.94±0.22
Egg width	Infranz	30	54.18±0.08
	Yiganda	18	53.73±0.15
	Chimba Bashadangela	32	54.03±0.14
	Chimba Lamgebya	12	54.25±0.17
	Total	92	54.05±0.07
Egg weight	Infranz	30	112.94±1.26
	Yiganda	18	113.51±1.50
	Chimba Bashadangela	32	111.54±1.08
	Chimba Lamgebya	12	108.55±0.99
	Total	92	111.99±0.65

However, there was no statistically significant different between the study sites of eggs at 5%, d.f. = 3, $P > .05$ when $F = .68$, 2.21 and 1.89 for length, breadth and weight, respectively (Table 13).

Table 13. One-way ANOVA For egg length (mm), breadth (mm) and weight (g), based on study sites.

	Sum of Squares	d.f.	Mean Square	F	Sig.
Egg length between sites	9.556	3	3.185	0.680	0.567
Egg width between sites	37.689	3	0.947	2.211	0.092
Egg weight between sites	217.546	3	72.515	1.897	0.136

The egg shape index and egg volume were analyzed using fresh laid eggs. The mean difference of egg length (cm), egg breadth (cm), ESI and egg volume in 2014 and 2015 were length: 7.76±0.04 and 7.75±0.05; width: 5.44±0.01 and 5.44±0.01; ESI: 70.18±0.39 and 70.19±0.42; and volume: 117.08±0.92 and 116.97±0.77, respectively. The mean difference between the egg parameters of the fresh laid egg length, width, ESI, and volume were not significantly different, $P > .05$ (n=40) (Table 14).

Table 14. Independent Sample t-test for equality of means between 2014 and 2015 fresh laid eggs.

Variables	t	d.f.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Length	0.031	38	0.975	0.002	0.064	-0.128	0.131
Breadth	0.097	38	0.923	0.001	0.015	-0.028	0.031
ESI	-0.016	38	0.987	-0.009	0.58	-1.184	1.165
Volume	0.09	38	0.929	0.107	1.192	-2.306	2.52

4.1.5. Breeding performance

From the total of 92 eggs, only 84 eggs were hatched (39/44 in 2014 and 45/48 in 2015). Therefore, the hatchability percentage was 89% and 94% in 2014 and 2015, respectively. However, the total hatchability percentage was about 91.3%. The hatching success was not significantly different between 2014 and 2015 ($t = 4$, $df = 1$, $P = .156$). The destroyed eggs were mainly from Chimba area (C_n3, n4, n5, and n11), and one egg from Chenta sostu (n3). In 2015, three eggs were destroyed from Chimba area (n4 and n10), and from Chenta (n3).

Only 23 cranes were pre-fledged in 2014 and 19 in 2015. The distribution of pre-fledged cranes in the study sites was different. Only 58.79% of juveniles were pre-fledged in 2014, and 42.22% in 2015. Taking the entire study time into account, the pre-fledging percentage was about 50% (Fig. 8)

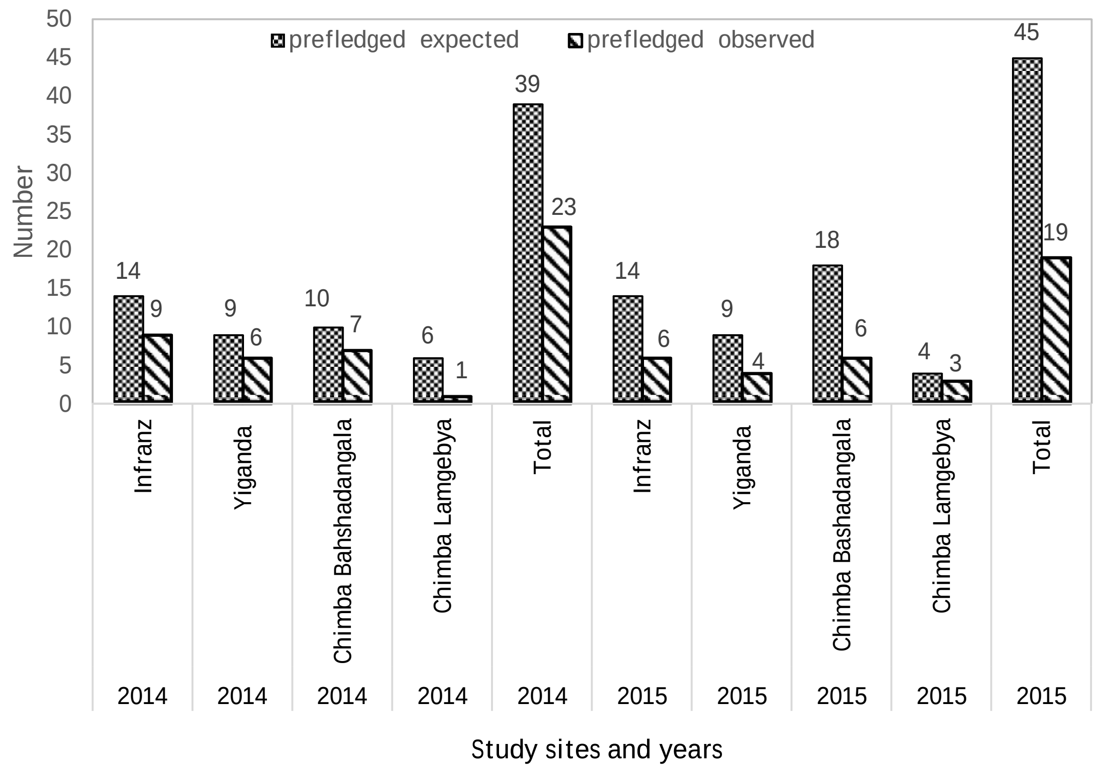


Figure 8. Expected and observed pre-fledged cranes in the study sites.

Nest initiation time, egg laid time, egg hatching and pre-fledged time was estimated. The nesting time observation was at weekly bases. The two weeks pooled to 15 days interval for descriptive analysis. The first early nest was initiated in September 14-15, in 2014 and lasted in the first two weeks of December, in 2015. The duration of egg laying was from the 3rd and 4th week of September to the second week of December; however the last hatched egg were stayed up to second week of January. Those cranes that had late nest initiation had poor breeding performance (Fig. 9).

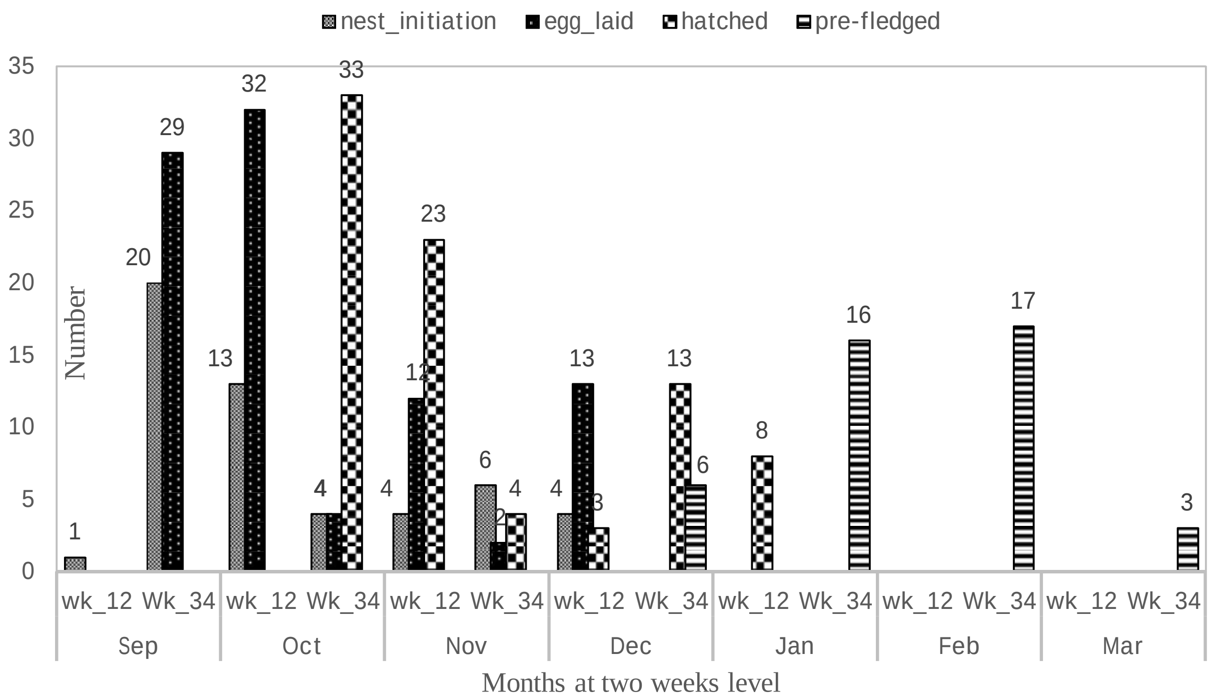


Figure 9. Breeding performance of cranes in Lake Tana area.

The pre-fledged time was estimated based on the hatching time. Since cranes are territorial during the nesting period, after hatching cranes spent most of the time around the nesting site during feeding. The fledging period was scrutinized since hatching time. Therefore, before juveniles are fledged and move from place to place, the pre-fledged time was estimated. When juvenile cranes start trial flight within the nesting place and spend few seconds flying in the air, the plumage color and growth, particularly the flight feathers, and also the body conformation show the growth condition of the bird to determine the pre-fledged age. Hence, the expected time at which the cranes pre-fledged were recorded based on time the scale (weeks then pooled to a month). The total number of pre-fledged cranes from 2014 to 2015 were only 42. The proportion of pre-fledged cranes decreases as time advances from

December to April. The death rate of cranes increases from 33.33% in December to 100% in April. So late initiation of nesting, egg laying and hatching time increases the risk of chick mortality. The mortality and pre-fledged proportion was equivalent, which indicates that the overall breeding performance of cranes in the study area is very poor (Fig. 10).

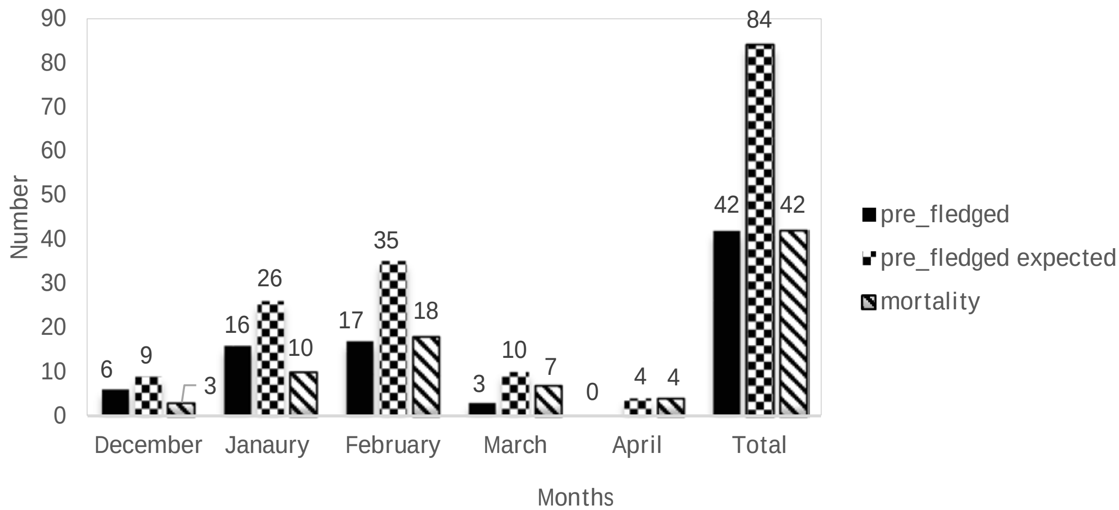


Figure 10. The number of pre-fledged expected, pre-fledged and mortality of juveniles on monthly basis.

When we see the seasonal effect of chick mortality, the expected pre-fledged and the actual pre-fledged cranes were six (actual) out of nine (expected) in December, 16 out of 26 in January. 17/35 in February, 3/10 in March and none out of four, were pre-fledged in April. The proportion of death rate in the months were 33.33%, 38.46%, 51.43%, 70%, and 100% (Fig. 11). Spearman's rho was performed to see the season (months) effect on chick mortality rate. The months and pre-fledged juvenile mortality were strongly positively correlated. Correlation was significant at the 0.01 level (2-tailed) (Spearman's rho =1, months=5, P < .01). The mean death proportion of months (December, January, February, and April) was 0.59±.12. A one-sample test was also performed to compare the mean death proportion of cranes during the pre-fledging time, and there was a significant difference on the mortality rate of cranes between months at which cranes were supposed to be fledged ($t = 4.84$, $df = 4$, $P = .008$).

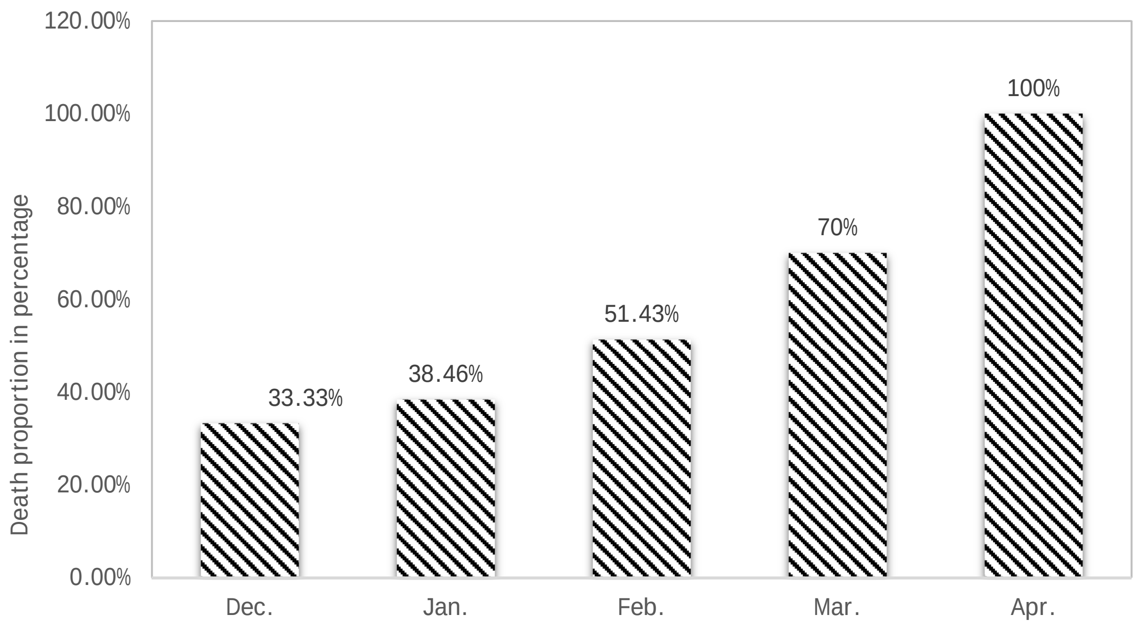


Figure 11. Proportion of crane deaths from December to April (%).

4.2. Food resource, diet and foraging behavior

4.2.1. Macrophyte, descriptions and their ecological significance

Nine macrophyte species were recorded in the sampled area. At Dirma, the total proportion of species cover during the study was *Oryza longistaminata* accounted 27%, *Hygrophila schulli,* 20%, *Ludwigia stolonifera,* 13% *Nymphaea nouchae,* 9%, *Leersia hexandra,* 9% and *Eichhornia crassipes,* 15, *Cyperus dives* (4%), *Perscaria senegalensis* (2%), *Typha latifolia* (1%). A total of 18 macrophyte species that belong to 11 family were recorded (Appendix 2). *Poacea* family consisted of eight species, which was the dominant of all family, *Menyanthaceae* and *Onagraceae* had two species, but the rest: *Acanthaceae, Ceratophyllaceae, Convolvulaceae,* and *Cyperaceae, Onagraceae* has only one type of species each.

At Yiganda, 14 species that belong to 13 families were recorded. These species were: *Andropogon gayana, Cheilanthes sp, Cyperus rotundus, Cyperus papyrus, Echinochloa stagina, Hygrophila schulli, Hyperrhenia rufa, Ipomoea aquatic, Leersia hexandra, Legume (UI), Ludwigia stolonifera, Nymphaea nouchali, Oryza longistaminata* and *Typha latifolia. C. rotundus cover* 10.7%, *C. papyrus* (13.3%), *E. stagina* (7.8%), *H. schulli (*4.2%), *I. aquatic* (3.3%), *L. hexandra* (18.2%), *N. nouchali* (4.4%), *O. longistaminata* (7.8%) and *T. latifolia* (4.4%). The edge of the wetland area also consists of 12 indigenous tree species belonging to nine family: *Cordia Africana, Juniperus procera, Millettia ferruginea, Apodytus dimidiata var. acutifolia, Ficus sur, Ficus sycomorus, Ficus vasta, Sizygium guineense, Podocarpus falcatus, Rothmannia urcelliformis, Mimusops kummel, and Celtis afaricana*. However the most dominant tree species bordering Monzi area, which is part of Yiganda watershed are:

Sizygium guineense and *Mimusops kummel*. These trees serve as a resting site for Black Crowned Cranes next to Zegie forest (Table 15).

Table 15. Tree species at Yiganda wetland, Monzi area, 2013.

Scientific name	n	Mean	D (density)	No=D*61ha	proportion	Remark
Millettia ferruginea	2	0.4	1	61	1.31	Endemic
Diospros mespiliformis	7	1.4	3.5	213.5	4.58	Tree
Cordia africana	7	1.4	3.5	213.5	4.58	Fruit tree
Ficus sycomorus	5	1	2.5	152.5	3.27	Fruit tree
Ficus vasta	3	0.6	1.5	91.5	1.96	Fruit tree
Keff (LN)	1	0.2	0.5	30.5	0.65	Tree
Mimusops kummel	100	20	50	3050	65.36	Fruit tree
Sizygium guineense	27	5.4	13.5	823.5	17.65	Fruit tree
Albezia schimperiana	1	0.2	0.5	30.5	0.65	Threatened

Plate 8. Forest patch in Yiganda wetland around Monzi, Yiganda, 2013.

Note: LN: Local Name

At Chimba, several species macrophytes were recorded. However, the major macrophytes are: *Cyperus rotundus, Cyprus papyrus, Echinochloa colona, Echinochloa stagnina, Hygrophila schulli, Ipomoea aquatic, Leersia hexandra, Ludwigia stolonifera, Nymphaea nouchali, Oryza longistamina, Perscaria senegalensis, Potamogeton thunbergii* and *Sacciolepis africana* (Fig.12).

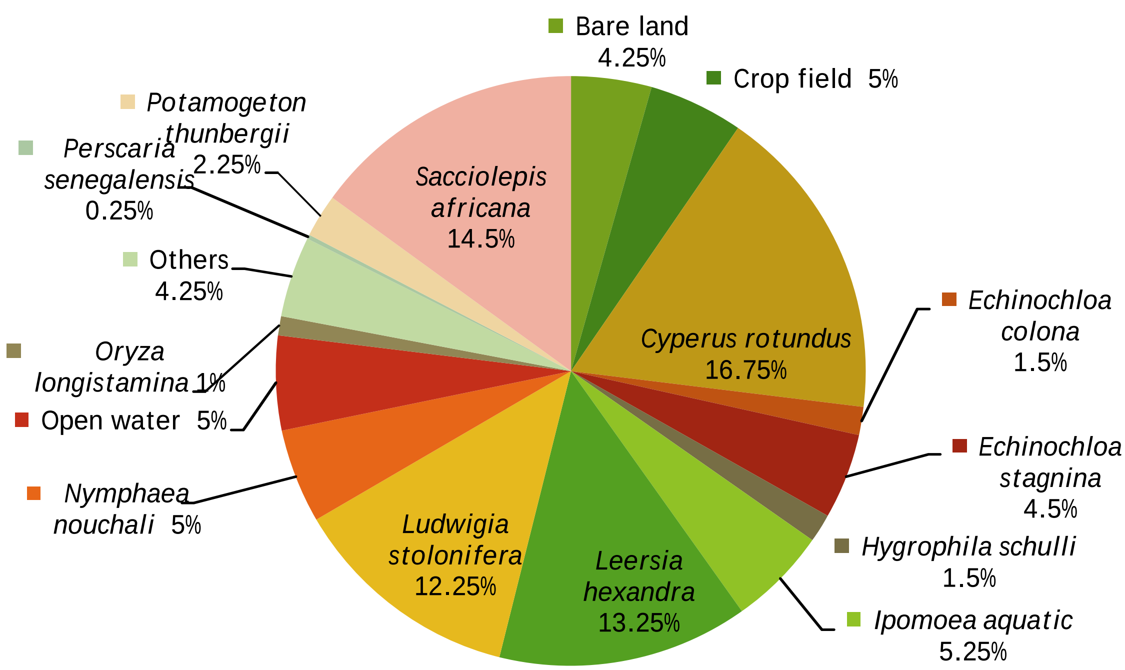


Figure 12. Proportion of macrophyte in Chimba wetlands.

During the study period some macrophytes that are ecologically important for the wetland ecosystem in relation to cranes are described. The macrophytes could be good or bad when ecologically important.

Cyperus dives is the most confusing species since the family *Cyperus* is a large genus of about 600 species of sedges. At Lake Tana wetlands in the study sites, it is proportionately distributed in Dirma, Yiganda and Chimba wetlands. *Cyperus* species are eaten by the larvae of some Lepidoptera species, which they are important feed components of birds in general and cranes in particular. The seeds and tubers are also important food for cranes and other birds that depend mostly on tuber, seed and insects such as rails and gallinules.

Eichhornia crassipes is the second largest species that covers the wetland area (about 15% during the 2013 preliminary data collection period). In 2016, the wetland is almost dominated by this invasive species. It is rare to find other plants ones the water hyacinth is established (Plate 9). Black Crowned Cranes used the plant for nest construction since there was no any chance for them. Although juvenile cranes can walk easily, but there was little food to forage. They were observed moving very fast during observation period as cranes were two to three weeks old in 2016.

Plate 9. Water hyacinth in Dirma wetland, 2013.

At Dirma, the occurrence of *Hygrophila schulli* species was rare during the past 10 years, but recently the weed has invaded the farmland and the wetland habitat. The local people tried to eradicate it by weeding mechanically, but has shown increment from time to time. The weed seed is transported from the upper course of Dirma River, Dembia area during the rainy season. The study revealed that 20% of the study site was invaded with this noxious weed. It outcompetes the important indigenous macrophyte that are used as feed source for cranes. It is hard to find any herbaceous plant grown under the shade of this weed. The weed is encroaching the wetland area the water level is reduced. It is absent at high water depth (Plate 10).

Plate 10. Weed infestation (*H. schulli*), Dirma wetland (2013).

Leersia hexandra is one of the dominant grass species and produces seed throughout the year where there is ample amount of soil moisture. The seed of this macrophyte is the most important feed source for Black Crowned Crane. It is also important for nest construction.

Oryza longistaminata is the dominant one in the area which accounts 27%. It is most important feed for cranes. It produces seeds which look like oat seed. Without which really life could have been very difficult in Chimba, Yiganda and other wetlands around Lake Tana area.

Cyperus papyrus is one of the largest emergent aquatic sedges in Yiganda (Plate 11). It forms a bed in the middle of the wetland and extends to the edge of Lake Tana. About 15 ha of the area is covered with this plant. In Chimba wetlands, *C. papyrus* is more extensive than all the other wetlands. Ecologically, papyrus is very important for hydrological cycle, pollution control, food and shelter of several birds, invertebrates, fish, amphibians and reptiles. Chimba wetland is one of the few places where Wattled Crane breeds in Ethiopia. Ecologically this plat supports several aquatic organism for shelter, food and nesting place for birds. Black

Crake, Allen's Gallinule and Black Crowned Crane depend on this plant. Papyrus swamps are important habitats supporting a wide diversity of species, African python *Python sebae,* also occur at Chimba area, Papyrus is useful in preventing pollution and sedimentation. Thus, in turn it prevents the accumulation of heavy metals in the biota through the food web.

Plate 11. Papyrus bed in Yiganda wetland (2013).

Typha latifolia is distributed bordering the lake in the area. However, the proportion of cover relative to the other species is about one percent. It mostly occurs more in Yiganda than Chimba and Dirma. A number of water birds and fish breed around the plant. It is also used as shelter and buffer zone. It traps sediments and filters pollutants. The nests of Black Crowned Cranes are sometimes located adjacent to it.

Potamogeton thunbergii is mainly distributed in Chimba wetland. It is a short plant. It has submerged and floating leaves found at Chimba mainly at Bashadangela area. The edge of the specified wetland is important site for the distribution of this macrophyte. Ecologically, could be important for macroinvertebrate breeding.

Nymphaea nouchae is distributed in the freshwater of all wetlands in Lake Tana area. Besides to aesthetic value, the plant could provide breeding ground for macroinvertebrates that are important feed components of cranes during the breeding period.

About one ha of pristine forest patch is located adjacent to Chimba wetland Lamgebeya area (Plate 12). The dominant trees are: *Mimusops kummel* and *Sizygium guineense.* However, extensive *acacia* wood land is located between Lamgebeya (north) and Dehena-Mariam (south) area. The presence of these tree patches are very important for sheltering, feeding and resting sites of cranes and other birds of prey. *Mimusops kummel* is an ever green tree that produces fruit. It grows usually where there is water body. This species supports a number of wild animals. Particularly birds of highland biome species such as White checked Turaco, Bruce's green Pigeon, Plantain Eater and several fruit eating birds are entirely dependent on this species. Grivet monkey and squirrels also depend on this plant fruit. Cranes also use as resting site when they are departing to their roosting sites. *Sizygium guineense* supports several wild animals for shelter, resting place and source of food. Cranes also use this tree as *Mimusops kummel*. *Millettia ferruginea*. It produces pod seeds. Locally used for medicine; however, this species is extensive located at Zegie peninsula. It is ecologically significant for many birds as a shelter, and also resting site of African Fish Eagle and cranes as well.

Plate 12. Forest patch at Chimba area.

4.2.2. *Physicochemical characteristics of Chimba and Yiganda wetlands*

The physicochemical characteristics of crane feeding sites wetlands were analyzed for Chimba and Yiganda habitats (Table 16). The mean water depth were (n=20) (31.88±3.33, 27±2.35), pH (7.22±.08, 7.22±.08), TDS (.23±.03, .13±.01), EC (.4±.03, .31±.05), and temperature (24.21±.68, 23.10±.61) at Chimba and Yiganda in 2014 and 2015, respectively.

Table 16. The physicochemical characteristics of crane feeding sites.

Parameters and sites		N	Mean	Std. Error	Minimum	Maximum
Water depth	Chimba	20	31.88	3.33	12.00	60.00
	Yiganda	20	27.00	2.35	10.00	50.00
	Total	40	29.44	2.05	10.00	60.00
pH	Chimba	20	7.22	0.08	6.80	8.00
	Yiganda	20	6.84	0.08	6.50	8.10
	Total	40	7.03	0.06	6.50	8.10
TDS (ppt.)	Chimba	20	0.23	0.03	.11	.69
	Yiganda	20	0.13	0.01	.07	.18
	Total	40	0.18	0.02	.07	.69
EC (ms/l)	Chimba	20	0.40	0.03	.22	.70
	Yiganda	20	0.31	0.05	.15	1.22
	Total	40	0.36	0.03	.15	1.22
Temperature	Chimba	20	24.21	0.68	19.50	29.00
	Yiganda	20	23.10	0.61	18.20	27.10
	Total	40	23.6525	0.46	18.20	29.00

The mean physicochemical parameters of Chimba and Yiganda feeding sites in 2014 and 2015 were compared to see their significance difference at 0.05 level. There was no significant difference between physicochemical parameters except pH and TDS ($F = 11.92$, $df = 1$, $P < .05$; $F = 9.99$, $df = 1$, $P < .05$), respectively (Table 17).

Table 17. Physicochemical parameters of Chimba and Yiganda wetlands 2014-2015 (One-way ANOVA test).

Parameters		Sum of squares	df	F	Sig.
Water depth	Between Groups	237.656	1	1.432	0.239
	Within Groups	6307.938	38		
	Total	6545.594	39		
pH	Between Groups	1.505	1	11.923	0.001
	Within Groups	4.798	38		
	Total	6.303	39		
TDS (ppt.)	Between Groups	0.087	1	9.989	0.003
	Within Groups	0.333	38		
	Total	0.42	39		
EC (ms/l)	Between Groups	0.076	1	2.267	0.14
	Within Groups		38		
	Total		39		
Temperature	Between Groups		1	1.474	0.232
	Within Groups		38		
	Total		39		

4.2.3. Composition and abundance of potential foods of cranes

A total of 31 taxa, 1374 individuals of macroinvertebrates were recorded. The most abundant and frequently occurring taxa were *Libellulidae* (F=38, 21%), *Coenagrionidae* (F=34, 12%), *Hydrophilidae* (F=30, 12%), and *Culicidae* (F= 23, 8%), respectively. However, based on their proportion, other taxa are listed accordingly (Fig. 13). But 12 taxa had the lowest proportion <1% and recorded only ones during the entire study period.

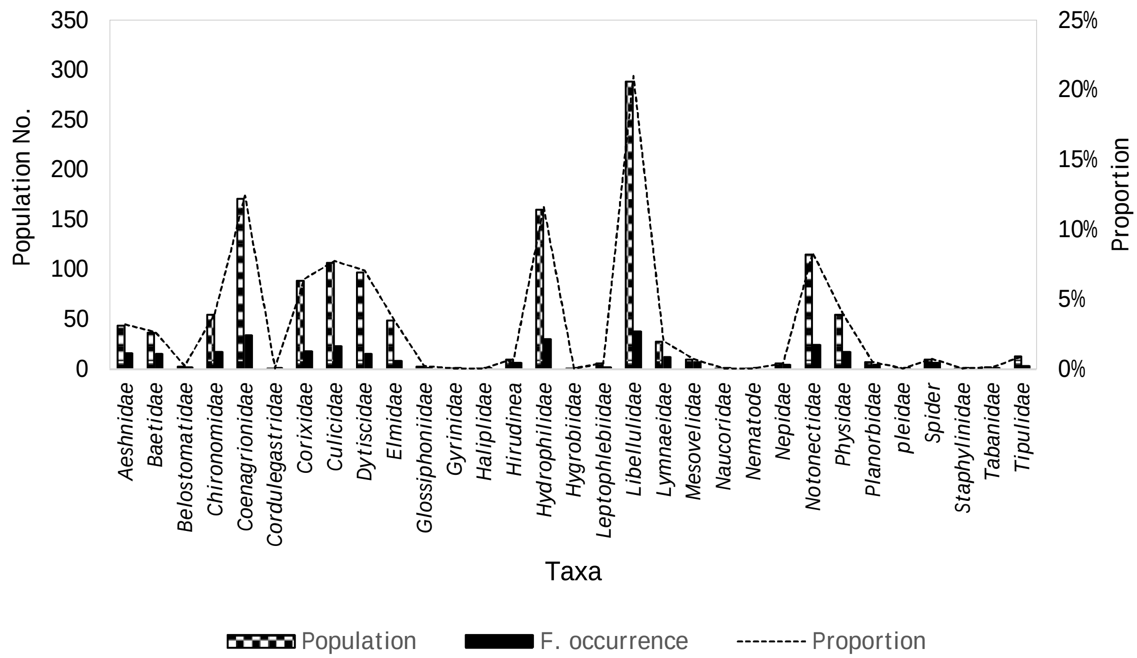


Figure 13. Composition, population and frequency of occurrence and the proportion of each macroinvertebrate taxa in the study site.

A total of 664 macroinvertebrates comprising 21 taxa were recorded in 2014. In Chimba 16 taxa and 281individuals, and in Yiganda 19 taxa and 383 individuals were recorded. The most abundant taxa were: *Notonectidae* (27%, F=8), *Libellulidae* (24%, F=8), and Hydrophilidae (16%, F=9); however, *Hirudinidae*, *Limnaeidae* and *Nepidae* were the least taxa recorded during the season (Fig. 14)**.**

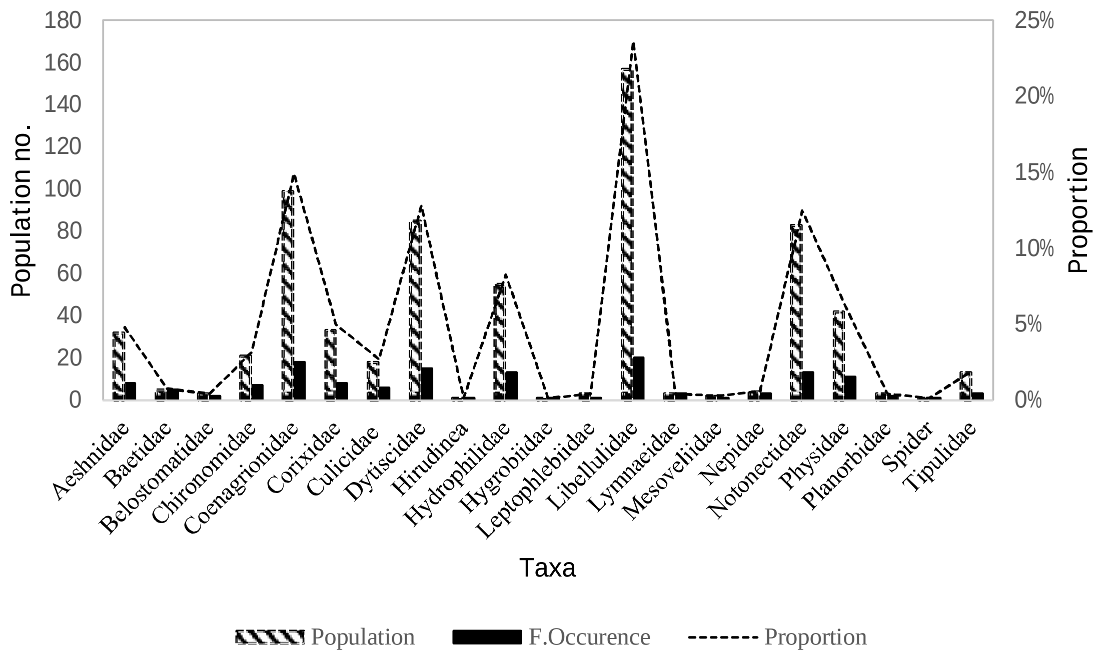


Figure 14. Composition, population and frequency of occurrence and the proportion of each macroinvertebrate taxa in Chimba and Yiganda wetland, 2014.

In 2015, a total of 709 individuals comprising 29 taxa were recorded. In Chimba 22 taxa and 331 individuals, and in Yiganda 23 taxa and 378 individuals were recorded. However, the most abundant of macroinvertebrates in the study sites were: *Libellulidae* (19%, F=18), *Hydrophilidae* (15%, F=17), *Dytiscidae*, 12%, F= 10), *Coenagrionidae* (10%, F=16). Whereas 11 taxa had lowest proportion (Fig. 15)

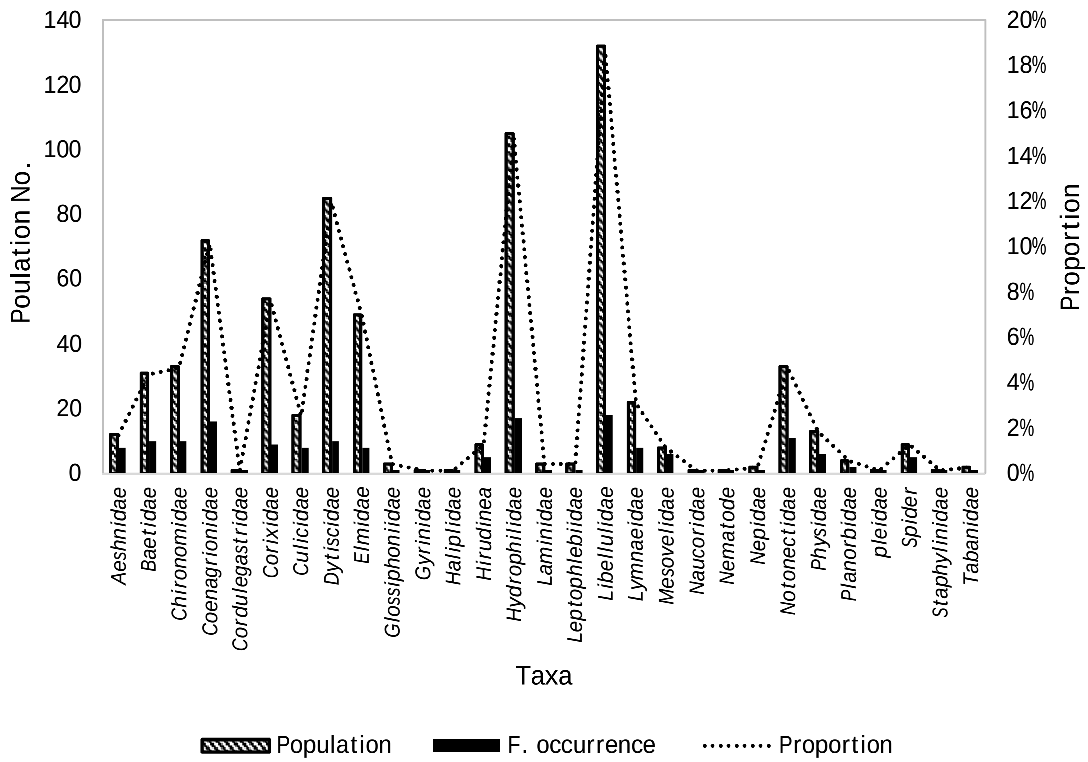


Figure 15. Composition, population and frequency of occurrence and the proportion of each macroinvertebrate taxa in Chimba and Yiganda wetland, 2015.

The mean biomass of macroinvertebrates (g) at study sites were Chimba (n = 16, 0.16±.05) and Yiganda (n = 18, 0.51±.13) and during the study period 2014 (n = 14, 0.49±.17); and 2015 (n = 20, 0.24±.05) (Table 18). However, Independent Mann-Whitney U test showed the distribution of macroinvertebrates biomass is the same across categories of year 2014 and 2015, $P > .05$. But the distribution of macroinvertebrates biomass was not similar across categories of site ($P < .05$).

Table 18. Biomass of macroinvertebrates obtained in Chimba and Yiganda wetland, 2014-2015.

Sites	N	Mean	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Chimba	16	0.155	0.04548	0.0581	0.2519	0.01	0.5
Yiganda	18	0.515	0.12715	0.2467	0.7833	0.01	2.1
2014	14	0.49	0.1664	0.1305	0.8495	0.01	2.1
2015	20	0.2445	0.05144	0.1368	0.3522	0.01	0.8

The Shannon diversity index and the evenness (Shannon equitability) in both cases are high. We can see from the results that the diversity and evenness in this site from Yiganda wetland during 2014 data is higher than in Chimba wetland (2.18 > 2.07) (Table 19).

Table 19. Diversity index of macroinvertebrates in Chimba and Yiganda in 2014.

Habitat Type	Number of taxa	Abundance	D	H´	E_{H*}=H´/H´max	H'max=lnsi
Chimba	16	284-2*	0.82	2.070	0.747	2.773
Yiganda	19	387-4*	0.85	2.180	0.740	2.944

H´= Shannon diversity index (Shannon diversity index; E_H=H´/H´max= Evenness or Shannon Equitability; D= Diversity Index; H'max= ln(S_i), * individuals added to avoid 'zero" result of lni (natural log of the i^{th} number of species) applies for the next three tables; *Equitability assumes a value between 0 and 1 with 1 being complete evenness.

The Shannon diversity index and the evenness in both case is good; however, we can see from the results that the diversity and evenness in this site from Chimba wetland are higher than in Yiganda wetland (H´) (2.56 > 2.38). In Chimba wetland, the individuals in the community are distributed more equitably than Yiganda. In the Yiganda wetland, there is one more species higher than Chimba wetland (Table 20).

Table 20. Diversity index of macroinvertebrates in Chimba and Yiganda in 2015.

Habitat Type	Number of taxa	Abundance	D	H´	H´/H´max	H'max=lnsi
Chimba	22	336*	0.9	2.560	0.828	3.091
Yiganda	23	382**	0.87	2.380	0.759	3.135

H´= Shannon diversity index; H´/H´max= Evenness; D= Diversity Index; H’max= ln(S_i); * 5 individuals, and ** 4 individuals were added to avoid undefined result during ln of i^{th} computation.

Generally, the Shannon diversity index and the evenness in 2014 and 2015 were very worthy. However, the results show that the diversity and evenness of macroinvertebrates in 2015 was higher than in 2014 (Table 21).

Table 21. Diversity index of macroinvertebrates in 2014 and 2015, in the study sites.

Habitat Type	Number of taxa	Abundance	D	H´	H´/H´max	H'max=lnsi
2014	21	667**	0.87	2.340	0.769	3.045
2015	29	716**	0.90	2.620	0.778	3.367

H´= Shannon diversity index; H´/H´max= Evenness; D= Diversity Index; H’max= ln(S_i); **nine individuals were added during lni calculation to avoid “zero” result.

The most abundant and occurring grass species were *Leersia hexandra*, *Oryza longistaminata*, *Echinochloa stagina*, and *Eleusine africana.* These grasses produce seeds as long as there is enough moisture in the wetland, and if there is less grazing intensity. The mean biomass of grass panicles in Chimba (8.8±1.19), Yiganda (9.3±.87) and Dirma (6.5±.71) during the study seasons were variable (Table 22).

Table 22. Biomass of grass panicles in study sites 2015-2016.

Sites	N	Mean	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Chimba	30	8.7733	1.18983	6.3399	11.2068	0.8	25.2
Yiganda	30	9.3467	.86654	7.5744	11.1189	1.60	20.80
Dirma	30	6.4800	.70659	5.0349	7.9251	1.60	16.00

In addition, during the post-rainy, dry and pre-rainy time, the mean biomass of grass panicles during the post and dry season period were productive than during the pre-rainy time (Table 23).

Table 23. Biomass of grass panicles during study seasons 2015-2016.

Season/ months	N	Mean	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
November	30	11.2800	.96168	9.3131	13.2469	3.2	25.2
January	30	8.8400	.88499	7.0300	10.6500	1.60	23.20
March	30	4.4800	.54597	3.3634	5.5966	.80	12.00

Statistically, the mean biomass of grass seeds varied significantly between the study sites ($F = 5.92$, $df = 2$, $P < 0.05$). A post-hock test revealed that Chimba and Yiganda showed more a significant difference in the productivity of grass panicles than Dirma wetland. The seasonal variation in the productivity of grass panicles was shown that the mean biomass productivity varied among post-rainy, dry and pre-rainy period significantly ($F = 18.6$, $df = 2$, $P < 0.05$) (Table 24). Spatial and seasonal differences in seed biomass could be related to differences in soil moisture, status of the wetland degradation nature (occurrence of invasive species in Dirma, overgrazing and human pressure) and phenology of various grass species.

Table 24. Two-way ANOVA, the mean biomass of all species of grass seeds (g/m^2) at three study sites in Lake Tana area.

Source	Partial SS	df	MS	F	Prob > F
Model	907.008	8	113.376	5.92	0.0000
Site	138.059	2	69.029	3.61	0.0316
Season	712.032	2	356.016	18.60	0.0000
Site * Season	56.917	4	14.229	0.74	0.5652
Residual	1550.352	81	19.140		
Total	2457.36	89	27.611		

Number of observations = 90, R- squared = 0.3691; Root MSE = 4.37495; Adjusted R-squared = 0.3068, * interaction

The availability of crop seeds changes according to the farming cycle and the types of crops grown in the Lake Tana area. The main cover types that are available to cranes were sown and stubble crops of maize. The biomass of crop seeds varied significantly with maize crop cover type (One-way Anova, F = 738.183, df = 1, P < 0.001). The mean biomass in g/m^2 of sown maize seed was 0.131±.004; whereas the stubble one was 15.823±.578 (Table 25). Pair wise comparisons of seed biomass between cover types of maize was not performed because there were fewer than three groups. Maize was the most widely grown crop and its seeds were more abundant in stubble fields than sown. Cranes picked up seeds from the soil surface or dug out planted seeds from sown fields in May and June. Biomass of maize seed was higher in crop stubble than in sown fields, since the sowing rate per ha is a very small amount. Cranes could have less opportunity to pick sown seed. Maize seeds were also available from crop stubble between November and December, since the productivity is much higher than the sown amount of maize, seeds can be found in the farmland while threshing. The threshing mechanism (oxen) itself can contribute for seed occurrence and abundance. In addition, rodents and birds, during harvesting season can contribute to the loss of seeds in the ground for cranes.

Table 25. The mean biomass (g/m^2) of crop seeds obtained from cultivated fields that were used for foraging by Black Crowned Cranes in Chimba 2015/2016 cropping season.

Cover type	Sample size	Mean biomass of seeds collected (g±S.E)	Period when seeds were available	Current farm activity
Maize				
- Sown field	30	0.131±.004	May-June	Seed sowing
-Stubble field	30	15.823±.578	Nov.-Dec	Crop harvest
Finger millet				
-Erected stand	42	0.579±0.268	December	Standing crop
Tef				
-Erected stand	42	0.969±0.118	November	Standing crop

The biomass of tef and finger millet seeds were treated differently from the maize one. Live matured crop stand foraging as erected before harvesting was estimated in 84 sample quadrats. The biomass of crop seeds varied significantly (One-way Anova, F = 104.85, df = 1, P < 0.001). The mean biomass of tef was 0.969±0.118 g/m^2, and finger millet it was 0.579±0.0268. Total tef productivity for 42 samples was estimated to be 630 g/m^2, but the amount of tef produced from predated samples was 588.18 g/m^2. The biomass of tef crop consumed by cranes was estimated to be 41.82 g/m^2, which means 7%. In the case of finger millet, the abundance of crop seeds consumed by cranes was estimated to be 24.31 g/m^2 (546 g/m^2 - 521.69 g/m^2). This estimate accounted 4.45% lower than tef seed biomass.

Cranes prefer tef crop seed first to finger millet. The edge of crop fields was more susceptible for foraging than the middle. During foraging, cranes do not prefer the middle side of crop field particularly they avoid it if the crop stand is higher than their height. Maize and sorghum prohibit observation; therefore the shorter crops are more preferred ones. Cranes prefer the local tef variety than the improved variety known as "Kuncho" tef because of the weak resistant tiller (spike).

4.2.4. *Diet characteristics and foraging behavior*

The analyses of feces revealed that the diet of Crowned Crane contains parts of plants including grass seeds, crop seeds and roots, rhizomes and stems (69.05%), fragments of animal origin (24.64%) and small quantities of inorganic material and shells (dirt, grits and shells) (6.31 %) (Table 26). The mean dried fecal weight of cranes is sub-adult 0.66±.03g, with 95% Confidence Interval for mean Lower Boundary (LB) and Upper Boundary (UB) was 0.59 and 0.72 g, respectively; whereas for adults, it was 1.97±0.16 g, with 95% Confidence Interval for mean LB and UB (1.64 and 2.29), respectively.

Table 26. Mean diet compositions (% by weight) of sub-adult and adult Black Crowned Cranes during post-rainy and dry season.

Mean comparison between season and Cranes		Fecal biomass (g)	Food items mean proportion in feces (%)				
			Grass seeds	Crop seeds	Roots, rhizomes and stems	Fragments of animal origin	Others including grit
Post-rainy	Sub adult	0.75	12.02	5.58	44.98	31.72	5.70
	Adult	2.01	14.77	10.23	40.84	27.16	6.77
dry	Sub adult	0.57	11.74	16.28	46.02	20.49	5.70
	Adult	1.92	15.12	16.4	42.67	19.19	7.09
Cranes	Sub-adult	0.66	11.88	10.93	45.50	26.10	5.70
	Adult	1.97	14.94	13.31	41.76	23.17	6.93
Season	Post-rainy	1.38	13.40	7.905	42.91	29.44	6.23
	dry	1.25	13.43	16.34	44.35	19.84	6.40
Total		1.31	13.41	12.12	43.63	24.64	6.31

The distribution of food items composition in proportion (percentage by weight) for carne category (sub-adult and adult) was observed. The distribution of grass seeds and crop seeds proportion percentage by weight were statistically significant at 0.05 level. However, the distribution of other food items in the diet was not statistically different at .05 level (Table 27). The mean proportion of food items for sub-adult cranes was: grass seeds (11.89±.68), crop seeds (10.93±.89), roots (45.50±1.27), animal fragments (26.10±1.50) and other materials (5.70±.45); whereas for adult cranes it was 4.94±1.09, 13.31±.80, 41.75±1.65, 23.17±1.53 and 6.93±.48, respectively.

Table 27. Mean comparison between the food composition (% by weight) of sub-adult and adult Black Crowned Cranes as revealed by fecal analyses; comparisons were made by Kruskal-Wallis of Chi-square test.

Test Statistics[a,b]	Grass seeds	Crop seeds	Roots rhizomes and stems	Animal fragments	Others grit including
Chi-Square	4.828	4.603	3.493	2.613	3.125
df	1	1	1	1	1
Asymp. Sig.	.028	.032	.062	.106	.077

a. Kruskal Wallis Test; b. Grouping Variable: Cranes,

The distribution of food item composition in proportion (percentage by weight) for cranes during the study period/season category (post-rain and dry) was recorded. The distribution of crop seeds and animal fragments proportion percentage by weight were statistically significant at 0.05 level (χ^2 =55.50, df =1, P = .000; χ^2 =19.27, df =1, P = 0.000, respectively). However, the distribution of other food items in the diet was not statistically different at .05 level (28). The mean proportion of food items for cranes during the post-rainy period was: grass seeds (13.40±1.05), crop seeds (7.91±0.88), roots (42.91±1.84), animal fragments (29.44±1.92) and other materials (6.23±0.47); whereas for adult cranes it was 13.43±0.78, 16.34±0.53, 44.35±1.01, 19.84±0.64 and, 6.40±0.48, respectively.

Table 28. Seasonal comparison between the food composition (% by weight) of Black Crowned Cranes as revealed by fecal analyses; comparisons were made by Kruskal-Wallis of Chi-square test.

Test Statistics[a,b]	Grass-seeds	Crop seeds	Roots rhizomes and stems	Animal fragments	Others grit including
Chi-Square	.286	55.570	.024	19.269	.113
df	1	1	1	1	1
Asymp. Sig.	.593	.000	.877	.000	.737

a. Kruskal Wallis Test; b. Grouping Variable: Season

Most of the food items of cranes is plant, in which grass seeds, crop seeds, and variable type of roots, rhizomes and stems constitute the diet of cranes. The grass seeds mostly occur in the wetlands of Lake Tana area. The most dominant grass seeds that cranes utilize during foraging and analyzed in the feces as well were *L hexandra*, *O. longistaminata*, *E. stagina*, and *S. africana*. It was clear to see the cellulose part of seed cover of these plants though difficult to quantify each in terms of biomass. Similarly, cranes forage throughout the year these grass panicles. The regeneration of these plants particularly *O. longistaminata* and *L. hexandra* is very promising unless intensive grazing devastates the area in which cranes usually do not prefer it or abandon the area. The sub-adult cranes utilize the grass seeds more in the wetland than crop seeds in the farm. The reason could be that the unfledged juvenile cranes spend more in wetlands during the post-rainy time than the non-breeding adults. The mean proportion of grass seeds in the feces was 12.02%, but crop seeds, 5.58%. The fledged cranes and sub-adults can be accounted for crop seed foraging in the crop field. However, the use of crop seeds during the dry season increase to 10.23% because certain number of juveniles during the post-rainy season can fledge and join the adult group in the crop field. Nevertheless, there was little change in the composition of roots, rhizomes and stem diets during the post-rainy and dry period 42.91% and 44.35%, respectively. Sub-adult and adult crane diet consisted of 45.5% and 41.76%, respectively. This indicates that cranes are still dependent on wetland plant food resources, which make the major proportion of food items throughout the year.

Significant amount of crop seeds, finger millet in particular was observed in the feces. Some of them were undigested. However, it was difficult to find other crop seeds such as ‘tef’ crop that might be completely digested in the digestive tract. Cranes were observed feeding on finger millet and tef stands in the crop field before harvesting period, and also other fallen crops such as maize, rice and sorghum. Adult cranes use more crop seeds than sub-adult cranes; where the mean proportion of the diet characteristics was 13.31% and 10.93%, respectively. During the dry season mean proportion of crop seeds in the fecal analysis was statistically significant. The grazing pressure in the wetlands, human interference and draining of wetlands make cranes move to crop fields. The breeding and non-breeding adults could join together during the dry season contributing to the proportion of crop seed diet composition higher than during the post-rainy period. However, during the post-rainy period cranes still utilize the wetland resource.

Cyprus and *Typha* species such as *C. rotundus, C. papyrus* and *T. latifolia* and other wetland grass species could be accounted for this occurrence in the diet. The crop stems of finger millet in particular was also observed in the diet. During the entire season the proportion of roots, rhizomes and stems in the diet remain constant or stable. This also indicates that how cranes are more dependent on wetlands than agricultural fields for foraging. This could be the reason why there was no significant difference among the mean proportion of diet composition across seasons and between sub-adult and adult cranes.

Macroinvertebrates are important sources of food for cranes to meet the protein requirements especially during growth. During the breeding period, parents were busy feeding on animal feeds by tramping the wetland and running and picking insects most of the time. The duty of feeding lied upon entirely on the parents, particularly during the first three weeks of hatching period. However, sub-adult and adult cranes both utilize animal origin foods during all seasons. The proportion of animal origin foods in the diet analysis was about one third. The mean proportion in sub-adults was 26.1% and adults 23.17%. Fragments of arthropod legs, wings, and remnant of gastropod species such as *Planorbidae* and *Physidae* were observed. The occurrence of fragments of animal origin during pot-rainy and dry season were significantly different; it was, 29.44% and 19.84%, respectively. The vegetation cover and presence of water, and little disturbance during the post-rainy season can account for this variation where cattle invade the wetland during the dry season. Because it is the only pastureland for cattle in which degradation of soil and tramping of vegetation and removal are a common phenomenon that destroys arthropod habitats. However, cranes can dig and probe the wetland to utilize the source even during the dry season if a little soil moisture is available.

During probing in the wetland, cranes could take mud, and deliberately consume grit to digest foods in the alimentary canal. Though the gizzard is responsible for digestion, the presence of considerable amount of shells of gastropods in the diet indicates how cranes consume animal origin foods. However, the proportion of these materials was similar across seasons and between cranes, 6.23% for sub-adult and 6.4% for adults. The time spent foraging in wetlands and farmlands, during wet and dry seasons was significantly different with the time blocks of foraging time at .05 level (Table 29).

Table 29. ANOVA for total number of cranes foraging time observation due to habitat, season and foraging time blocks effect on cranes location.

Source	Partial SS	df	MS	F	Prob > F
Model	10896.6883	15	726.445889	36.98	0.0000
Season	387.603333	1	387.603333	19.73	0.0000
Habitat	4158.96333	1	4158.96333	211.74	0.0000
Season*Habitat	790.563333	1	790.563333	40.25	0.0000
Time	2536.09667	3	845.365556	43.04	0.0000
Season*Time	437.91	3	145.97	7.43	0.0001
Habitat*Time	3556.41667	3	1185.47222	60.35	0.0000
Season*Habitat*Time	260.07	3	86.69	4.41	0.0050
Residual	3614.06667	184	19.6416667		
Total	14510.755	199	72.9183668		

Note: N=200, Root MSE=4.43189, R-squared =0.7509, and adjusted R-squared =0.7306, * interaction

The mean comparison of Tukey HSD for time block variables showed that the overall means of cranes 6:00AM-9:00AM (T1), 9:1AM-12:00AM (T2), 12:01PM-3:00 PM (T3), and 3:01PM-12:00PM (T4) time blocks was 4.50±0.438, 4.66±0.604, 10.48±2.046, 3.22±0.733, and 5.72±0.604, respectively. The mean of Black Crowned Cranes counted in T1 with T2, T1 with T4, did not vary. Also, there was no variation existed between T2 with T4. But there was a high significant difference between T3 and T1, T3 withT2 and T3 with T4 (Table 30).

Table 30. Tukey HSD, Multiple Comparisons of foraging time blocks of Black Crowned Cranes frequently forage in wetland and farmlands during the wet and dry seasons.

(I) Time of the day	(J) Time of the day	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	-0.16	1.625	1	-4.37	4.05
	T3	-5.980a*	1.625	0.002	-10.19	-1.77
	T4	1.28	1.625	0.86	-2.93	5.49
T2	T1	0.16	1.625	1	-4.05	4.37
	T3	-5.820ab*	1.625	0.002	-10.03	-1.61
	T4	1.44	1.625	0.812	-2.77	5.65
T3	T1	5.980a*	1.625	0.002	1.77	10.19
	T2	5.820b*	1.625	0.002	1.61	10.03
	T4	7.260c*	1.625	0	3.05	11.47
T4	T1	-1.28	1.625	0.86	-5.49	2.93
	T2	-1.44	1.625	0.812	-5.65	2.77
	T3	-7.260c*	1.625	0	-11.47	-3.05

*The mean difference is significant at the 0.05 level.

The breeding and non-breeding adults and sub-adults usually roost in the wetland except during the end of the dry season when water level reduced and when there is little vegetation. In the wetland habitat, cranes utilize different sources of food as mentioned in the characteristics of food. Breeding pair usually come to the edge of the wetland before sunrise. The edge of the wetland could be rich in terms of food source for juveniles to forage around but they return to the wetland when people and cattle approach to the wetland. Breeding cranes have been observed fighting with cranes of the same species and others. This phenomenon was intensive in smaller wetland areas (Infranz) than bigger ones (Chimba and Yiganda). However, in all wetlands breeding pairs have been observed chasing Egyptian Goose (*Alopochen aegyptiacus*) and Spur-winged Geese (*Plectropterus gambensis*) that were foraging with their chicks. Parents were responsible to feed the juveniles until they are fledged on shift basis.

In the farmland, cranes utilize specific food items such as tef, maize, finger millet, rice, and sorghum. They were observed to feed on sorghum crops that have thin stem and scattered panicles. The gathering takes place usually at the edge of the crop field. They bend and break the stock during feeding. In the north and eastern part of Lake Tana, there is high production of rice. Rice by nature is very easy to shatter when it gets matured. Cranes however, feed on fallen seeds and erected ones with precaution from the local attendants.

4.3. Distribution of Black Crowned Crane along Lake Tana area

4.3.1. Spatial and seasonal distribution

The distribution of cranes in the study area was assessed during cropping season (2015-2016). Four hundred observations were made in five study sites. There was spatial and seasonal variation in the distribution of cranes. The adjusted R-squared (=0.2614) tells us, above 26% of the variation in the distribution of cranes was brought by the predictor variables such as study habitats, sites and seasons. The GLM model showed that the habitats and study sites have affected the distribution of cranes across the study area significantly (Table 31).

Table 31. N-way ANOVA for total number of observation due to habitat, site and seasons effect on crane distribution.

Source	Partial SS	df	MS	F	Prob > F
Model	87879.5375	39	2253.32147	4.62	0.0000
Habitat (n=2)	21311.7033	1	10655.8517	21.85	0.0000
Site (n=5)	12034.7654	4	3008.69136	6.17	0.0001
Habitat*Site	16306.9467	4	2038.36833	4.18	0.0001
Season (n=4)	10240.1733	3	3413.39111	7.00	0.0001
Habitat*Season	8210.80667	3	4105.40333	8.42	0.0003
Site*Season	9110.39333	12	759.199444	1.56	0.1023
Habitat*Site*Season	6490.99333	12	811.374167	1.66	0.1059
Residual	175571.9	360	487.699722		
Total	263451.438	399	660.279292		

Root MSE=22.0839, R-squared =.3336, and adjusted R-squared =.2614

It is more common to find large number of cranes during the dry season than the wet, post-rainy and pre-rainy season (Fig. 16). The total number of cranes recorded during each season and the mean number of cranes were: during Post-rainy time (8.63±1.38, n=863), dry season (17.27±4.41, n = 1727), pre-rainy (3.91±.96, n = 391) and wet season (7.54±1.85, n = 754).

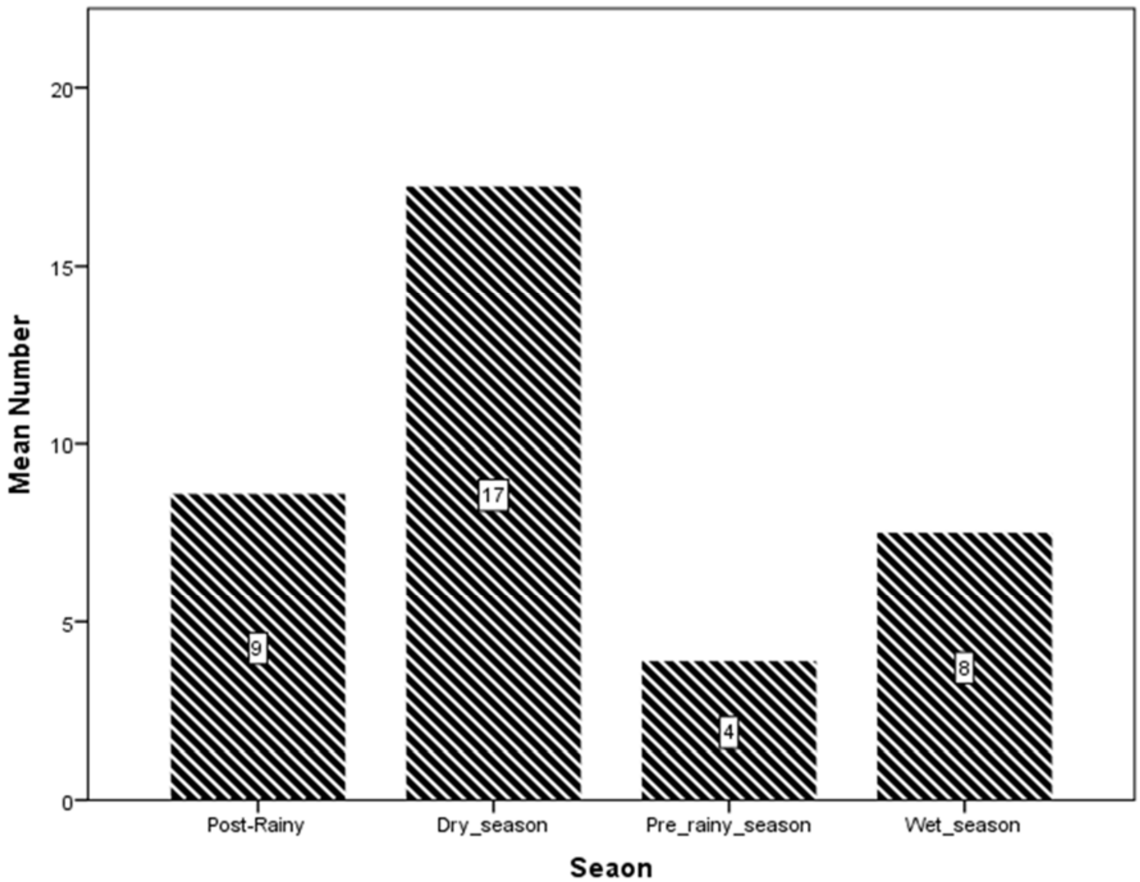


Figure 16. Mean number of cranes distributed during cropping season.

A One-way ANOVA showed that there was a significant difference on the observation of cranes during the study seasons at 0.05 level of significance ($F = 4.98$, $df = 3$, $P < .05$) (Table 32).

Table 32. One-way ANOVA effect of season on the abundance and distribution of cranes (2015-2016).

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9611.388	3	3203.796	4.998	.002
Within Groups	253840.050	396	641.010		
Total	263451.438	399			

A post hock test was run to show which season has really effect on the observation of cranes. It showed that there was a significant difference in the distribution of cranes particularly during the dry-season and pre-rainy season (Table 33).

Table 33. Tukey HSD multiple comparison of study sites on the number of observation of cranes.

(I) Season	(J) Season	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Post-rainy	Dry	-8.640	3.581	.076	-17.88	.60
	Pre-rainy	4.720	3.581	.552	-4.52	13.96
	Wet season	1.090	3.581	.990	-8.15	10.33
Dry	Post-rainy	8.640	3.581	.076	-.60	17.88
	Pre-rainy	13.360*	3.581	.001	4.12	22.60
	Wet	9.730*	3.581	.035	.49	18.97
Pre-rainy	Post-rainy	-4.720	3.581	.552	-13.96	4.52
	Dry	-13.360*	3.581	.001	-22.60	-4.12
	Wet	-3.630	3.581	.741	-12.87	5.61
Wet	Post-rainy	-1.090	3.581	.990	-10.33	8.15
	Dry	-9.730*	3.581	.035	-18.97	-.49
	Pre-rainy	3.630	3.581	.741	-5.61	12.87

* The mean difference is significant at the 0.05 level.

The availability of food in the wetland and farmland during dry season was abundant, as well as the space occupied by crop field was available for cranes foraging. In addition, during the wet (rainy time) the wetlands are inundated. During this time cranes are forced to leave or move somewhere outside the study area, dispersed. Besides to availability of food and space during the dry season, new recruited fledged cranes, non-breeding birds as well as adults were more in number. More than 98% of crop cultivation especially cereals is based on rain fed agriculture. In the area maize, finger millet, rice, wheat and sorghum that are important food source of cranes are harvested during the dry period. The cropping pattern itself has influence on the distribution of cranes. However, towards to the end of the dry season, most wetlands were overgrazed, large number of livestock are kept in the wetland as there is little private grazing land in the area. The grazing pressure in the wetlands, and human disturbance by removing grasses, motor pump irrigation and scaring have been observed. Therefore the occurrence of cranes during the pre-rainy period was less. Due to these factors cranes disperse where the density of crane population is minimum. During the wet (rainy) period, cranes start to gather or congregate where there is water around the wetland; however, the water level increases since the vegetation is grazed, cranes avoid to be in the wetland. But several cranes have been observed around river delta area. Since the breeding time starts towards of the end of the rainy season; breeding pairs segregate from the floaters and more to dominate the nesting site area. Since the farmland is covered by crop, cranes were not in a position to prefer or to be in the middle of crop farm.

Black Crowned Cranes were more distributed in the wetland habitat than in the farmlands. The Chimba wetlands are the most suitable area where a large number of cranes occur. The total number of cranes recorded in wetlands and farmlands in each study sites were: in Yiganda (8.13±2.14), Chimba (20.81±3.781), Kunzila-Legdiya (1.71±.23), Dirma-Delghi (12.01±4.38), and Shesher-Wagtera (4.03±.82) where n = 80 (Fig. 17).

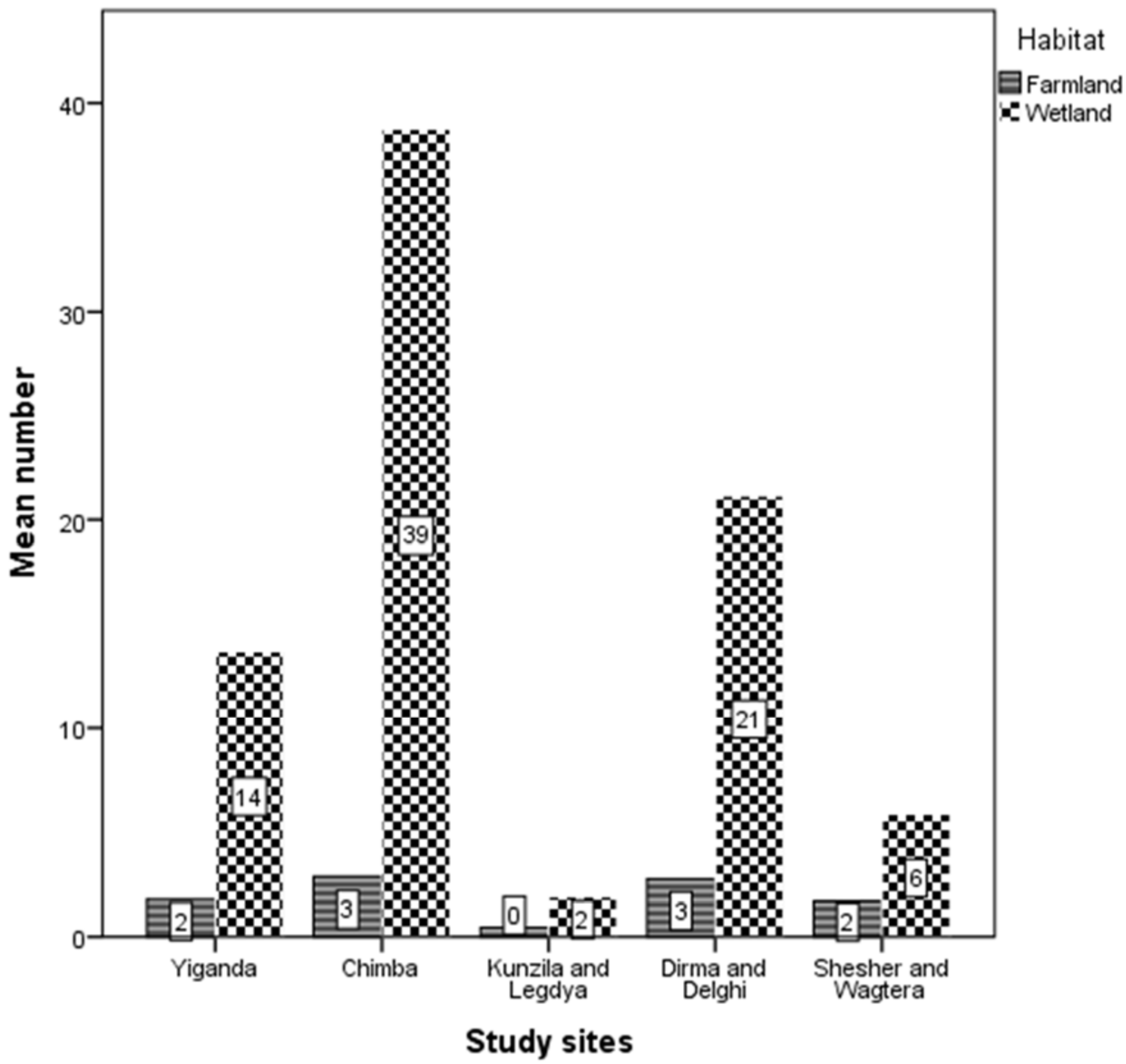


Figure 17. Mean number of cranes observed in study sites.

A One-way ANOVA showed that there was a significant difference on the observation of cranes in study sites at 0.05 level of significance (F = 7.30, df = 4, P < .05) (Table 34).

Table 34. One-way ANOVA effect of study sites on the distribution of cranes (2015-2016).

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18133.175	4	4533.294	7.3	.000
Within Groups	245318.263	395	621.059		
Total	263451.438	399			

Post hock test was run to show which study site has really effect on the observation of cranes. It showed that there was a significant difference in the distribution of cranes particularly Yiganda with Chimba, Chimba with Kunzila-Legdiya and Shesher Wagtera (Table 35).

Table 35. Tukey HSD multiple comparison of study sites on the number of observation of cranes.

(I) Study sites	(J) Study sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Yiganda	Chimba	-12.688*	3.940	.012	-23.49	-1.89
	Kunzila-Legdiya	6.413	3.940	.481	-4.39	17.21
	Dirma Delghi	-3.888	3.940	.861	-14.69	6.91
	Shesher Wagtera	4.100	3.940	.836	-6.70	14.90
Chimba	Yiganda	12.688*	3.940	.012	1.89	23.49
	Kunzila-Legdiya	19.100*	3.940	.000	8.30	29.90
	Dirma Delghi	8.800	3.940	.170	-2.00	19.60
	Shesher Wagtera	16.788*	3.940	.000	5.99	27.59
Kunzila-Legdiya	Yiganda	-6.413	3.940	.481	-17.21	4.39
	Chimba	-19.100*	3.940	.000	-29.90	-8.30
	Dirma Delghi	-10.300	3.940	.070	-21.10	.50
	Shesher-Wagtera	-2.313	3.940	.977	-13.11	8.49
Dirma Delghi	Yiganda	3.888	3.940	.861	-6.91	14.69
	Chimba	-8.800	3.940	.170	-19.60	2.00
	Kunzila-Legdiya	10.300	3.940	.070	-.50	21.10
	Shesher Wagtera	7.988	3.940	.255	-2.81	18.79
Shesher Wagtera	Yiganda	-4.100	3.940	.836	-14.90	6.70
	Chimba	-16.788*	3.940	.000	-27.59	-5.99
	Kunzila-Legdiya	2.313	3.940	.977	-8.49	13.11
	Dirma Delghi	-7.988	3.940	.255	-18.79	2.81

*The mean difference is significant at the 0.05 level.

The distribution of cranes in the wetland and farmland habitats were assessed. In all seasons and study sites, wetland habitats are the most important places where cranes are spending most of the time for foraging, resting, watering and breeding. However, cranes were also located in farmlands though the farmlands are not far from wetlands or water bodies (Fig. 18).

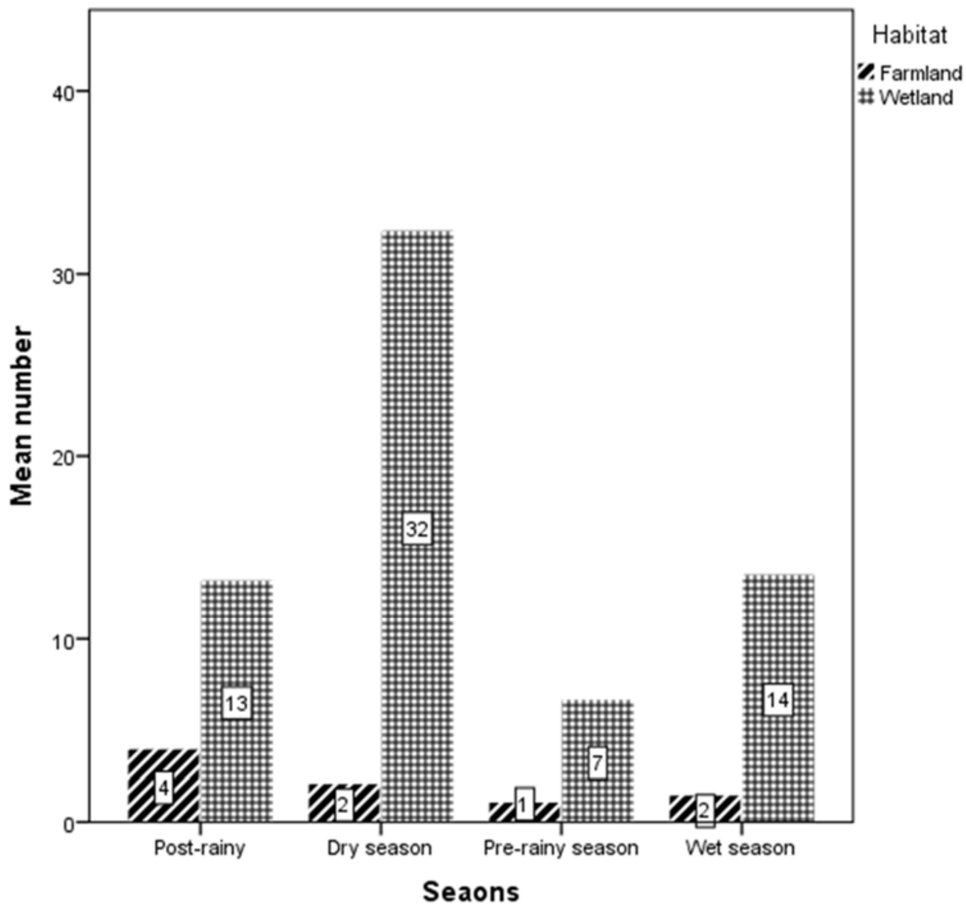


Figure 18. Mean number of cranes observed based on season and habitats.

The mean distribution of cranes in wetlands (16.49±2.46) and farmland (2.19±.23) were statistically significant ($F = 33.52$, $df = 1$, $P < .05$) (Table 36).

Table 36. One-way ANOVA effect of habitat on the distribution of cranes (2015-2016).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20463.302	1	20463.302	33.518	.000
Within Groups	242988.135	398	610.523		
Total	263451.437	399			

4.3.2. Detection function, cluster size and density

The detection function of cranes in wetland habitat showed that the Hazard rate Key function model parameters A(1) and A(2) were positively correlated (r=.761). The model took the lowest AIC value for wetland habitat only and it was 1364.3245 (Table 37). The AIC value gives us the relative measure of fit or model performance.

Model: Hazard Rate key, k(y) = 1 – Exp (-(y/A(1))**-A(2))

Table 37. Detection function wetland habitat parameter estimates, 2015.

Parameter	Point Estimate	Standard Error	% Coefficient of Variation	95 % Confidence Interval	
A(1)	180.7	32.56			
A(2)	2.279	0.5806			
f(0)	0.40209E-02	0.43374E-03	10.79	0.32491E-02	0.49760E-02
p	0.49740	0.53656E-01	10.79	0.40193	0.61555
ESW	248.70	26.828	10.79	200.97	307.77

The QQ-plot, rather a depiction which can tell us to see the spacing within those bins to find out if the speed which we are moving through our data is equivalent to the speed which we moving through our predicted probability density function (pdf). When those things are equivalent, then the points on this QQ-plot will fall along the 45 degree line. So the QQ-plot is our own expectation when we have a model that fits our data. The Empirical Distribution

Function (EDF), from the data collected, and the Fitted Cumulative Distribution Function (CDF), from the model showed relatively fitted (Fig. 19).

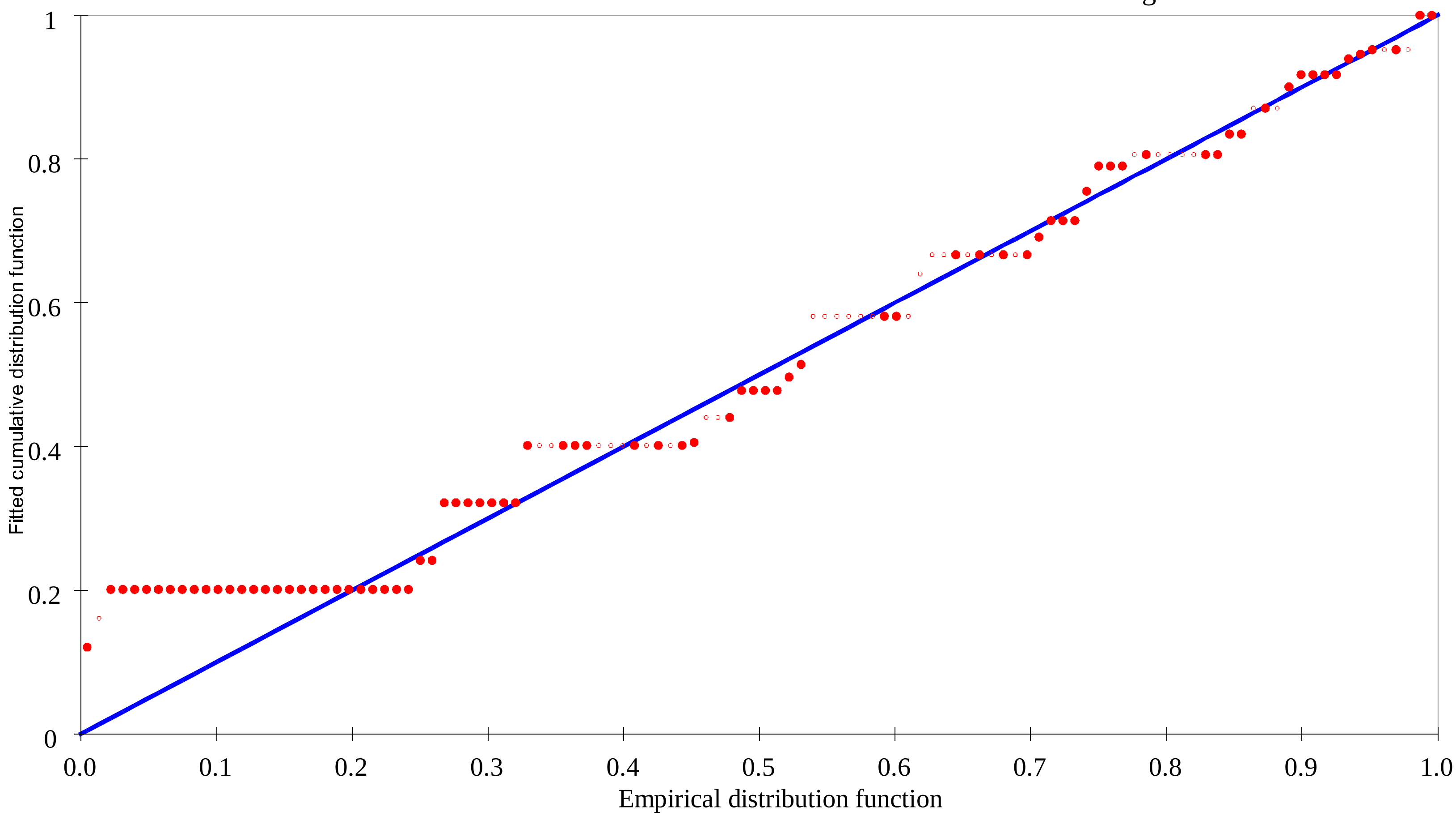


Figure 19. Detection function Black Crowned Crane QQ-plot in the wetland habitat during the wet season.

The Kolmogorov-Smirnov test (K-S) looks at QQ-plot detection function and asks where the discrepancy is the collected data from the 45 degree line where they belong if there is a good fit of our model. How big is that the discrepancy? It tabulates some statistics with associated P-value. The Cramer-von Mises family test (C-von M-test) does the same and it looks the QQ-plot and transforms the location of those points into a statistic that allows assessment the various hypothesis that the model fits the data. In this case both tests showed the P-value showed that had little evidence to suggest that our model is consistent to the data we have collected. In other words the model fitted to our data which was inadequate (Table 38). However, the data collected was subjected to the necessity of inducing cut-points to apply a Chi-square test.

Table 38. Detection function wetland habitat/ K-S GOF Test, 2015.

Kolmogorov-Smirnov test			Cramer-von Mises family tests	
D_n	= 0.1835	p = 0.0009	W-sq (uniform weighting) = 0.3310	0.100 < p <= 0.150
			Relevant critical values:	
			W-sq crit(alpha=0.150) = 0.2836	
			W-sq crit(alpha=0.100) = 0.3472	
			C-sq (cosine weighting) = 0.3045	0.050 < p <= 0.100
			Relevant critical values:	
			C-sq crit(alpha=0.100) = 0.2353	
			C-sq crit(alpha=0.050) = 0.315	

Three detection probability was run; however, the first detection probability test that had seven cut-points for this data was selected (Fig. 20). The Chi-squared test showed that there is little evidence to reject the null hypothesis that the detection function fitted to the model selected (Chi-square= 1.4082, df = 4, $P > 0.05$) (Table 39). Total Chi-square value = 1.4082, df = 4.00; Probability of a greater chi-square value, $P = 0.84278$.

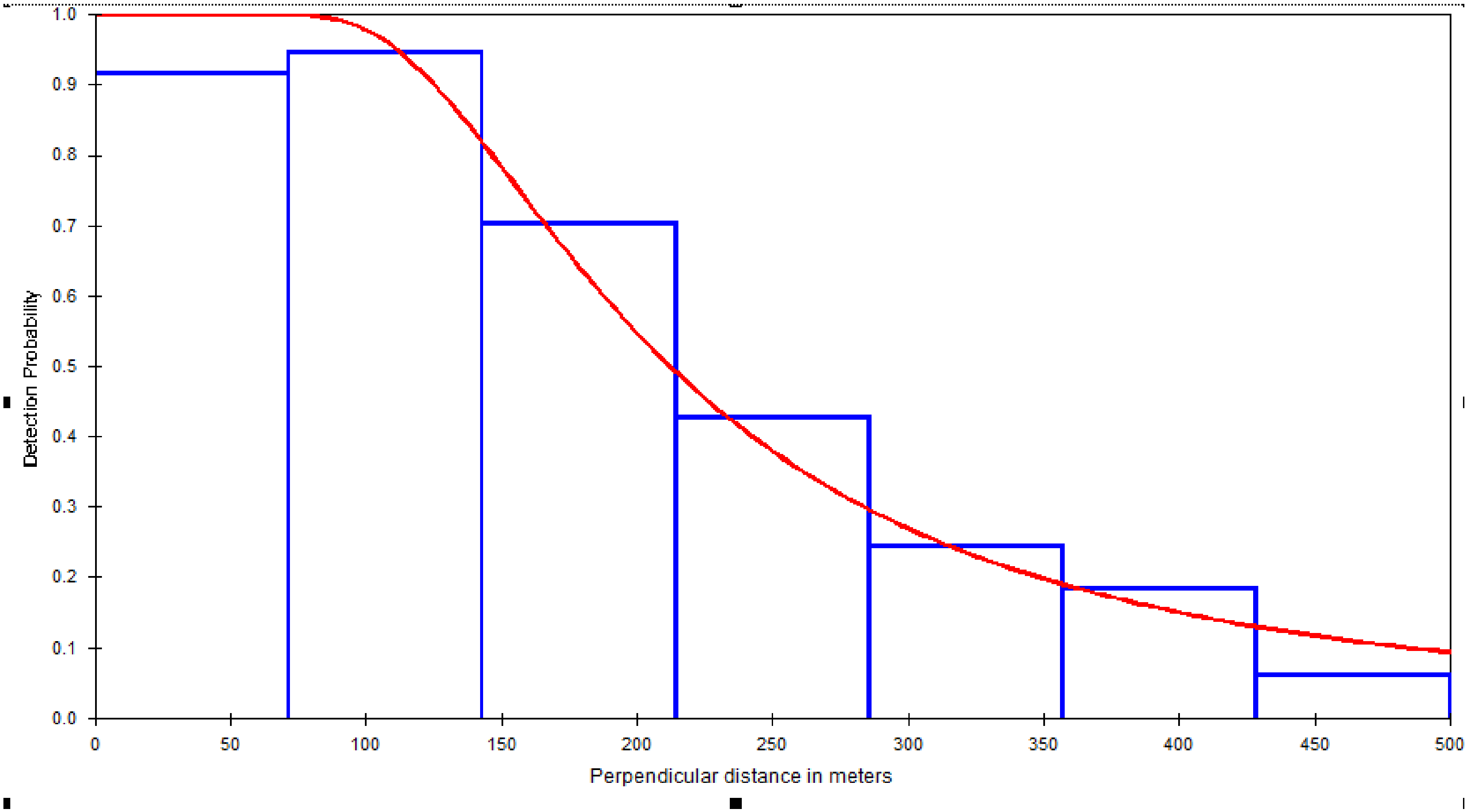


Figure 20. Detection probability plot in the wetland habitat during the wet season.

Table 39. Detection Function of wetland habitat, Chi-sq GOF, 2015.

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	71.4	30	32.74	0.230
2	71.4	143.	31	30.89	0.000
3	143.	214.	23	21.18	0.157
4	214.	286.	14	12.59	0.158
5	286.	357.	8	7.81	0.005
6	357.	429.	6	5.17	0.133
7	429.	500.	2	3.62	0.726

Detection function of cranes in farmlands during wet season revealed that the Hazard rate Key function model, parameters A(3) and A(4) were positively correlated (R=.738). The model took the lowest AIC value for farmland habitat and it was 1236.9219 (Table 40).

Table 40. Detection function farmland habitat parameter estimates, 2015.

Parameter	Point Estimate	Standard Error	% Coefficient of Variation	95 % Confidence Interval	
A(3)	214.7	27.44			
A(4)	3.344	0.8899			
f(0)	0.37605E-02	0.31853E-03	8.47	0.31799E-02	0.44472E-02
p	0.53184	0.45049E-01	8.47	0.44972	0.62895
ESW	265.92	22.524	8.47	224.86	314.47

The QQ-plot for farmland was also drawn (Fig. 21). The K-S test and the C-von M-test P-value were subjected to the necessity of inducing cut-points. Then a detection probability test that had seven cut-points for this data was selected (Fig. 22). The Chi-squared test showed that the detection probability test fitted to the model selected, which we accept the Ho (Chi-square = 9.2913, df = 4, P > 0.05) (Table 41).

Table 41. Detection Function farmland habitat, Chi-sq GOF, 2015.

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	71.4	22	27.94	1.261
2	71.4	143.	33	27.87	0.945
3	143.	214.	24	23.22	0.026
4	214.	286.	10	12.86	0.637
5	286.	357.	12	6.52	4.608
6	357.	429.	1	3.53	1.813
7	429.	500.	2	2.07	0.002

Total Chi-square value = 9.2913, Degrees of Freedom = 4.00, Probability of a greater chi-square value, P = 0.05422.

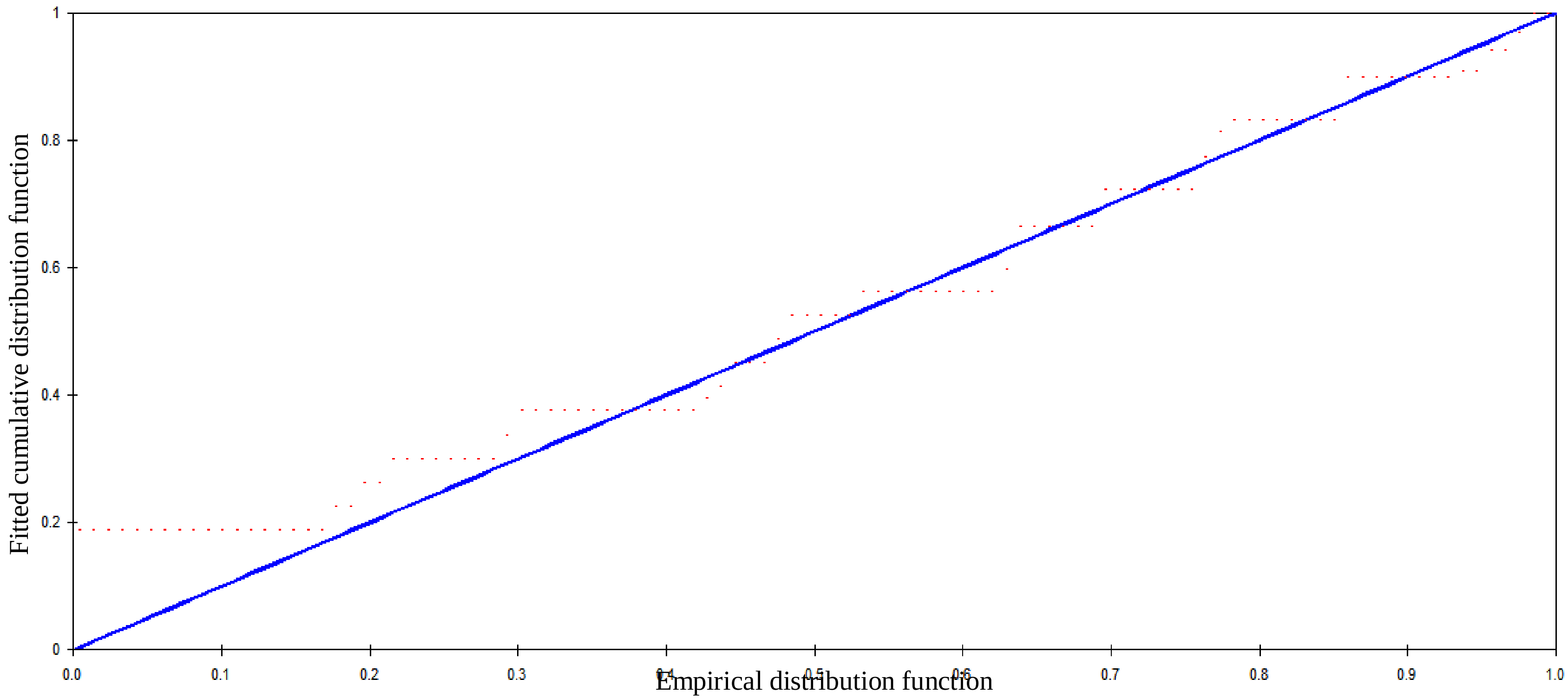


Figure 21. Detection function QQ-plot in farmland habitat during the wet season.

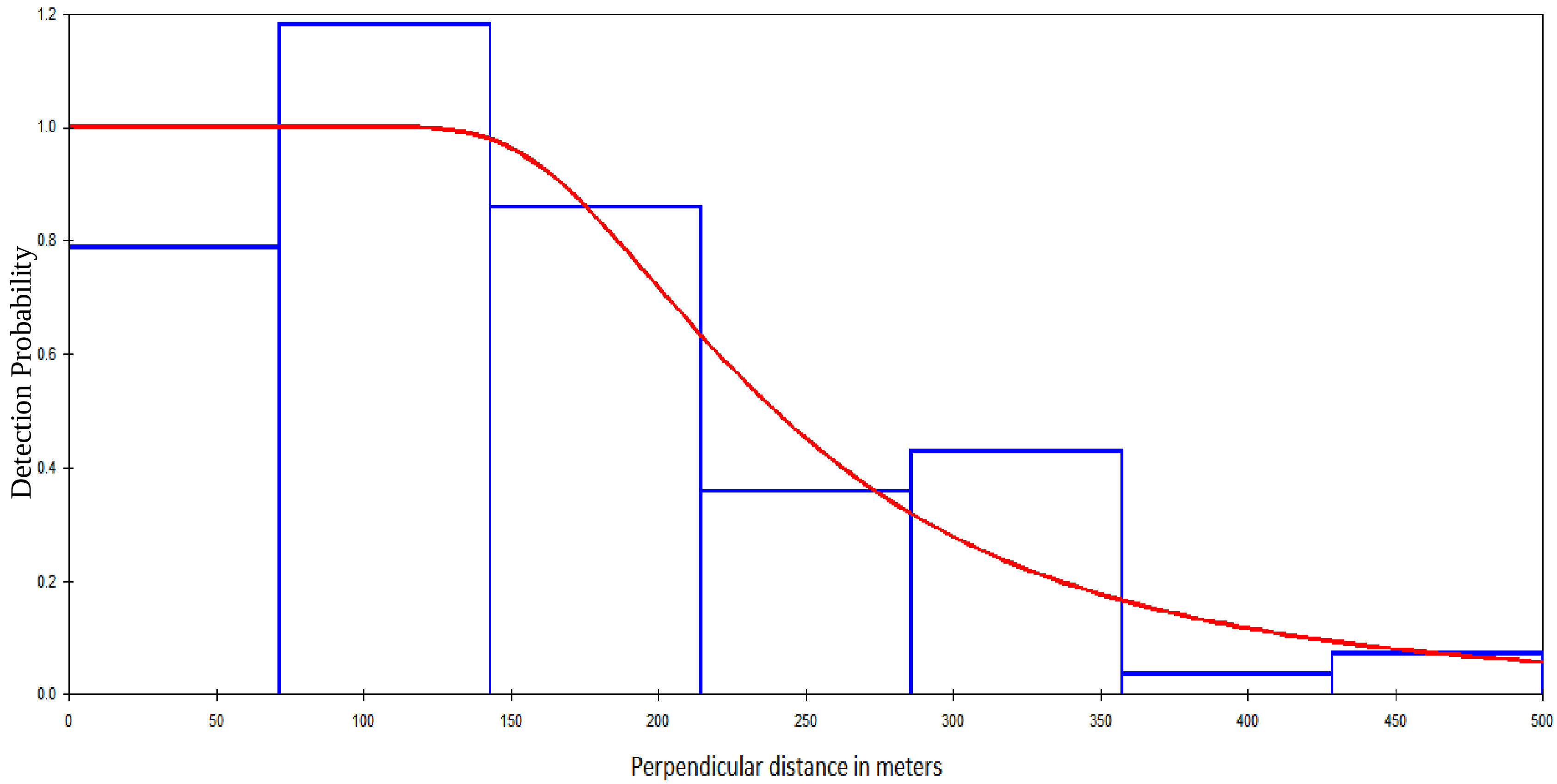


Figure 22. Detection probability plot in farmland habitat during the wet season.

The cluster size of cranes during the wet season in wetland and farmland habitats were analyzed based on regression of: log (s(i)) on g(x(i)). The regression estimates of wetland habitat was: slope = .155832, intercept = .733145. Then the regression predicted the log (s(i)) value when the log (x((i)) is known. The P value of Students-t test for regression or the p value of the slope (p>.05) are not statistically significant, we fail to reject the null hypotheses of no relationship. There is no supported relationship between cluster size and distance (b=0). Therefore, the regression equation regarding the null hypothesis based on the application of Regression model with equation is:

$$Cw_i = 0.733 + .156 * xi$$

Where C_i = cluster size of the i[tch] observation in wetland, x_i=distance to the i[tch] observation

Cluster size and distance relationship were seen using a Pearson Correlation. There was a weak positive correlation between cluster size and distance (R= 0.0513, d.f. = 112, P > 0.05). Students-t test was performed (t= .543379, df = 2, Pr (T<t) = .706026).

Whereas, the regression estimates of farmland habitat was: slope = -0.2122, intercept =0.520876. Then the regression predicted the log (s(i)) value when the log (x((i)) is known. There is no supported relationship between cluster size and distance (b = 0). Therefore the regression equation regarding the null hypothesis based on the application of Regression model with equation is:

$$Cf_i = 0.5208 + -0.2122 * xi$$

Where Cf_{i} = cluster size of the i^{tch} observation in the farmland, x_i = distance to the i^{tch} observation

Cluster size and distance relationship were seen using a Pearson Correlation. There was a weak negative correlation between cluster size and distance ($R = -0.1028$, d.f. = 102, $P > 0.05$). Students-t test was performed ($t = -1.0434$, df = 2, $Pr(T<t) = 0.1496$).

Hence, the mean cluster size of cranes in the wetland habitat was 5.2719±1.2812; but in the farmland habitat, it was 1.875±0.23851.

The Black Crowned Crane population and density during the wet season were estimated both in the wetland and farmland habitats separately, during the wet season (2015). During the wet season in the wetland habitat, the crane density was estimated 0.21768±0.82 per hectare, and the total population (N) was estimated to be 1472±554.62. However, the estimate of density of clusters of cranes (DS) was 0.57283E-01±0.20705E-01. The estimate of expected value of cluster size is 5.2719. In the farmland, crane density was estimated 0.79921 E-01±0.13370E-01 per hectare, and the total population (N) was estimated to be 639. However, the estimate of density of clusters of cranes (DS) was 0.48887E-01± 0.75460E-02. The estimate of expected value of cluster size is 1.875. The encounter rate (n/L) in wetland and farmland habitats were 2.8493 (% CV=34.5, df = 33, 95% CI = 1.4403-CI-5.6367) and 2.6000 (% CV = 12.9, df = 39, 95%CI = 2.0049-CI-3.3718).

The total density and abundance of Black Crowned Cranes during the wet season in 2015 was estimated. The pooled estimates of density was 0.14304 cranes per hectare with (%

CV = 26.75, df = 50.2, 95%CI= 0.84355E-01=CI = 0.24254) and the population was estimated to be 2112 cranes with (% CV = 26.75, df = 50.2, 95%CI = 1245=CI = 3581).

The detection function of cranes in wetlands during dry season showed that the Hazard rate Key function model parameters A*3*) and A(4) were positively strongly correlated (R=.817). The model took the lowest AIC value for wetland habitat only and it was 1197.8406 (Table 42). The AIC value gives us the relative measure of fit or model performance.

Model: Hazard Rate key, k(y) = 1 – Exp (-(y/A(3))**-A(4))

Table 42. Detection function wetland habitat parameter estimates, 2016.

Parameter	Point Estimate	Standard Error	% Coefficient of Variation	95 % Confidence Interval	
A(*3*)	90.46	20.80			
A(4)	2.008	0.4182			
f(0)	0.71518E-02	0.98195E-03	13.73	0.54543E-02	0.93778E-02
p	0.34956	0.47995E-01	13.73	0.26659	0.45836
ESW	139.82	19.198	13.73	106.64	183.34

The QQ-plot for the wetland habitat was also drawn (Fig. 23). The K-S test and the C-von M-test P-value were subjected to the necessity of inducing cut-points. Then a detection probability test that had seven cut-points for this data was selected (Fig. 24). The Chi-squared test showed that the detection probability test fitted to the model selected, which we accept the Ho (Chi-square= 2.1167, df = 3, P = 0.5485) (Table 43).

Table 43. Detection Function wetland habitat, Chi-sq GOF, 2016.

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	66.7	54	49.69	0.374
2	66.7	133.	24	29.35	0.974
3	133.	200.	15	13.33	0.209
4	200.	267.	8	7.19	0.091
5	267.	333.	3	4.44	0.468
6	333.	400.	3	3.00	0.000

Total Chi-square value = 2.1167; Degrees of Freedom = 3.00; Probability of a greater chi-square value, P = 0.54854

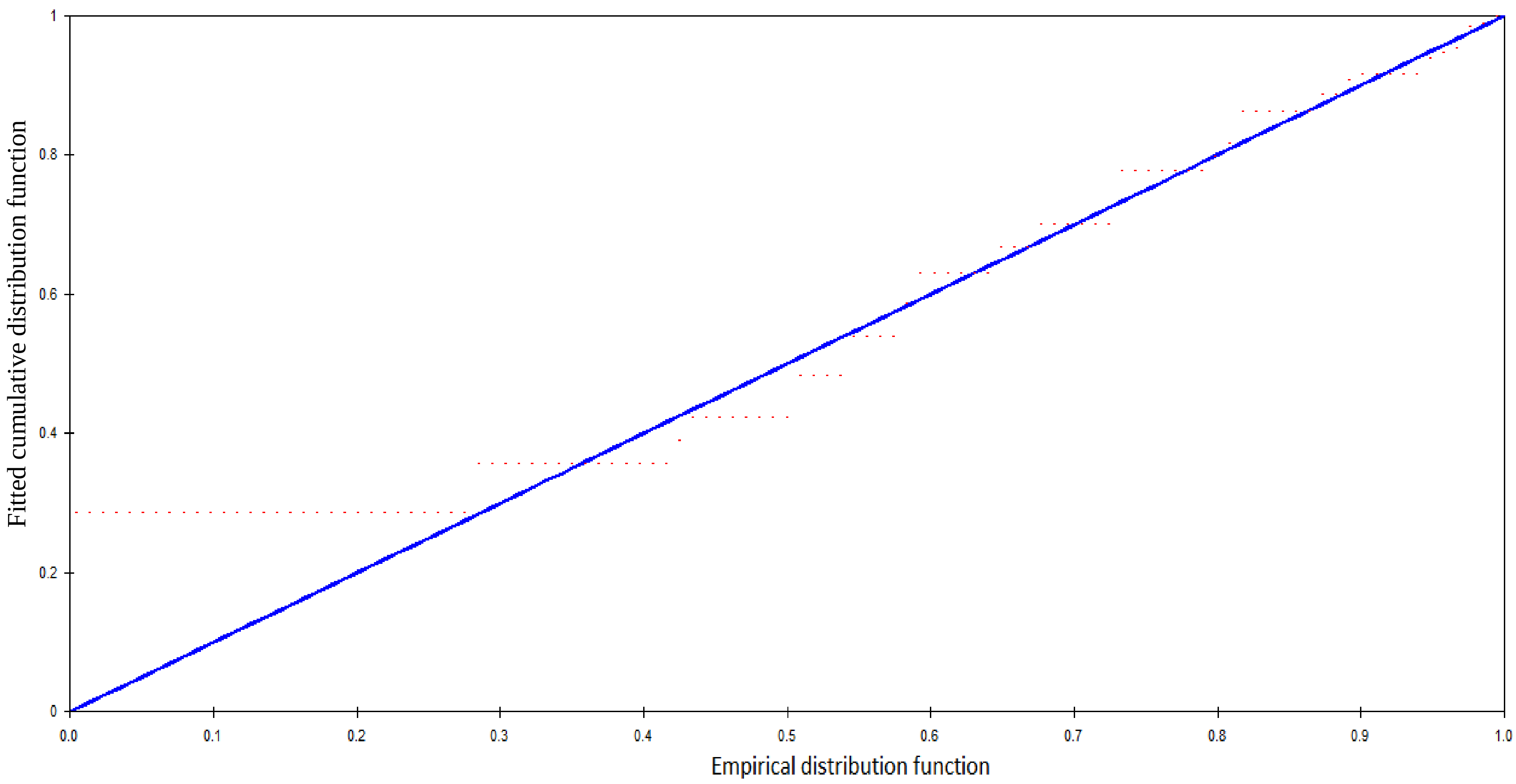


Figure 23. Detection function QQ-plot in the wetland habitat during the dry season.

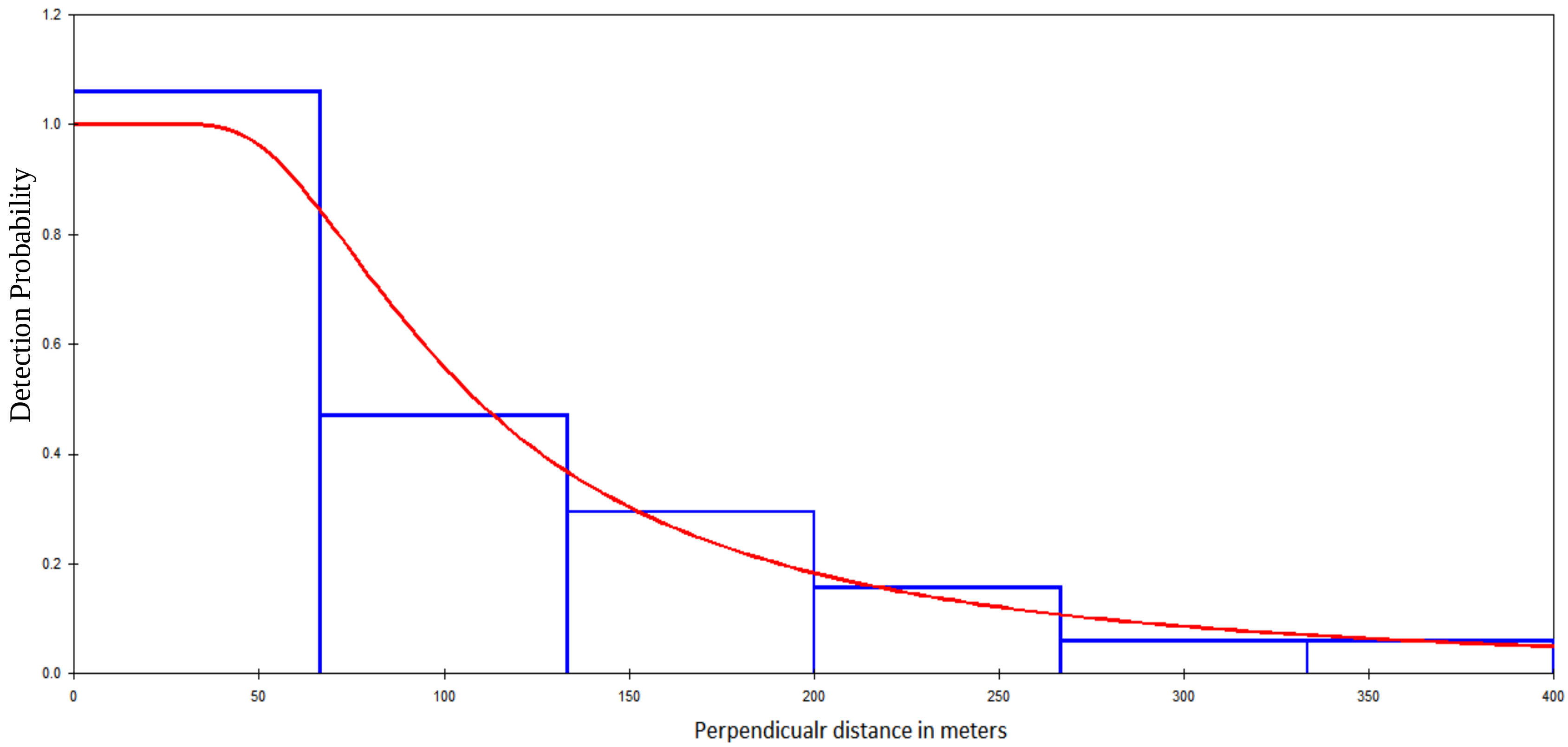


Figure 24. Detection probability of cranes in wetland habitat during the dry season.

Detection function of cranes in farmlands during dry season showed that the Hazard rate Key function model (3.5), parameters A (3) and A (4) were strongly positively correlated (R=.740). The model took the lowest AIC value for farmland habitat and it was 1160.8372 (Table 44).

Table 44. Detection function farmland habitat parameter estimates, 2016.

Parameter	Point Estimate	Standard Error	% Coefficient of Variation	95 % Confidence Interval	
A(3)	264.7	23.40			
A(4)	6.134	2.903			
f(0)	0.34274E-02	0.20207E-03	5.90	0.30492E-02	0.38525E-02
p	0.72942	0.430049E-01	5.90	0.64893	0.81988
ESW	291.77	17.202	5.90	259.57	327.95

The QQ-plot for farmland habitat data collected looks fitted (Fig. 25). The K-S test and the C-von M-test P-value suggested that in all three instances we had little evidence to suggest that our model is not consistent to the data that we have collected. The model fitted to the data is adequate, and therefore we can leave the necessity of inducing subjectivity. The detection probability test with a broader shoulder for the data was selected (Fig. 26). The Chi-squared test showed that the detection probability test was fitted to the model selected, which we accept the Ho (Chi-square= 3.4663, df = 3, P = 0.032516) (Table 45).

Table 45. Detection Function of farmland habitat, Chi-sq GOF, 2016.

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	66.7	29	22.62	1.799
2	66.7	133.	24	22.62	0.084
3	133.	200.	18	22.61	0.942
4	200.	267.	17	19.39	0.294
5	267.	333.	9	8.74	0.008
6	333.	400.	2	3.01	0.340

Total Chi-square value = 3.4663; Degrees of Freedom = 3.00; Probability of a greater chi-square value, P = 0.32516

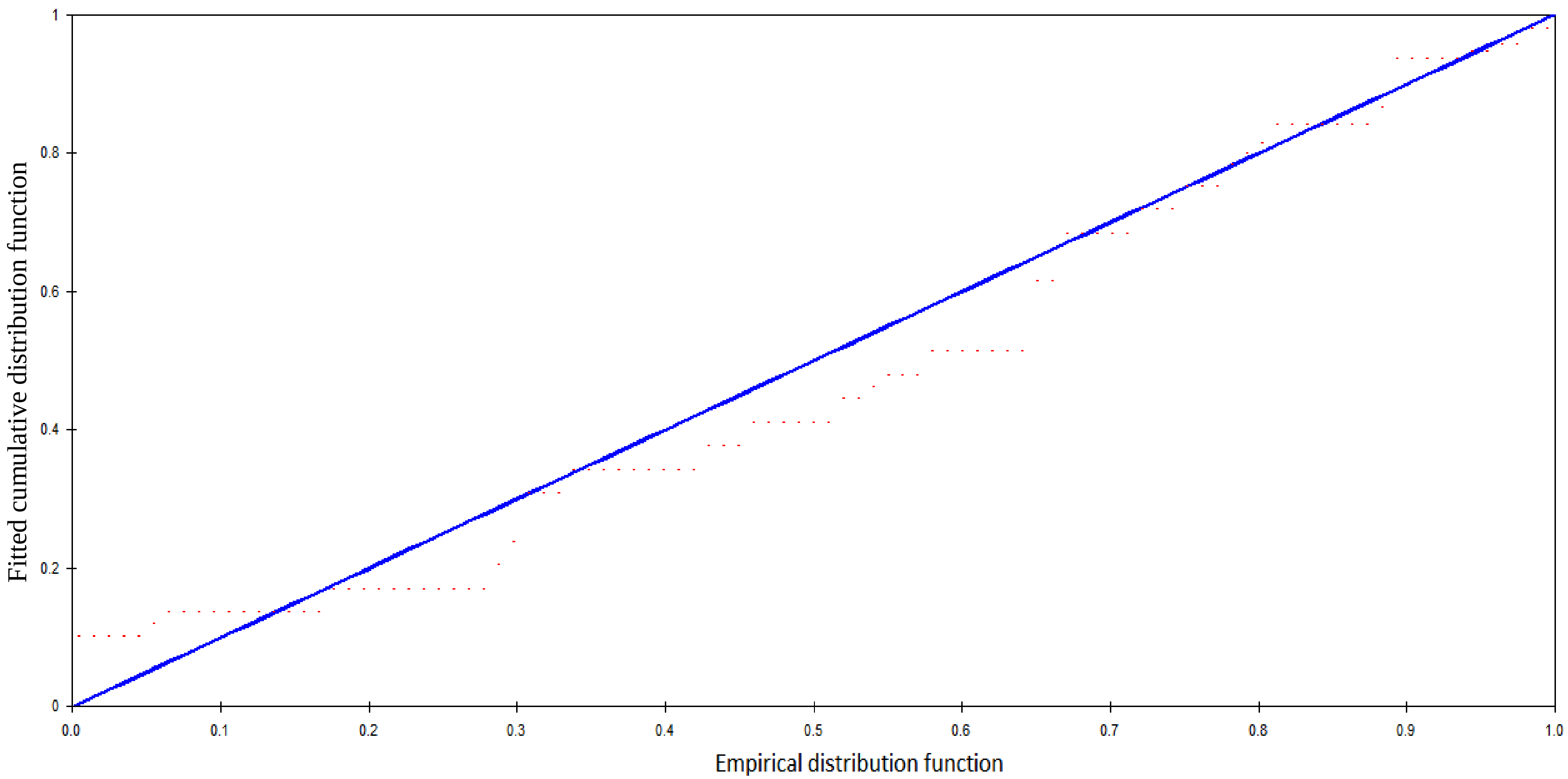


Figure 25, Detection function QQ-plot in farmland habitat during the dry season.

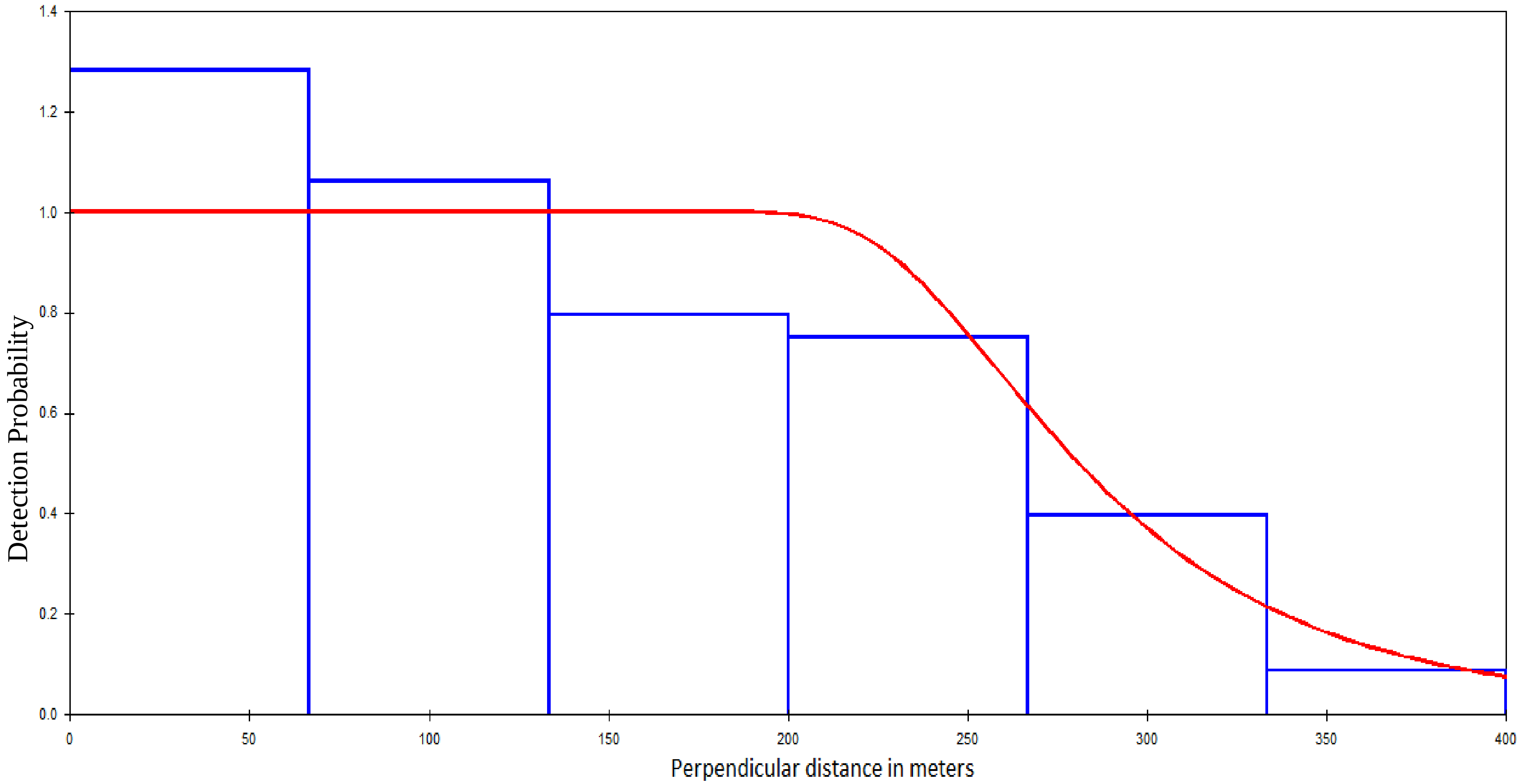


Figure 26. Detection probability of farmland habitat during the dry season.

The cluster size of cranes during the dry season, in the wetland and farmland habitats was analyzed based on regression of: log (s(i)) on g(x(i)). The regression estimates of wetland habitat was: slope = 0.154974, intercept = 0.564469. Then the regression predicted the log (s(i)) value when the log (x((i)) is known. The P value of Students-t test for regression or the p value of the slope p>.05, which we fail to reject the null hypotheses of no relationship. There is no supported relationship between cluster size and distance (b=0). Therefore the regression equation regarding the null hypothesis based on the application of the Regression model with equation is:

$Cw_i = 0.15549 + .5645 * xi$

Where Cw_i = cluster size of the i^{tch} observation in the wetland, x_i=distance to the i^{tch} observation

Cluster size and distance relationship was observed using a Pearson Correlation. There was a weak positive correlation between cluster size and distance (R = 0.0840, d.f. = 105, P > 0.05). Students-t test was performed (t = .864151, df = 2, Pr (T<t) = .805263).

Whereas, the regression estimates of farmland habitat were: slope = 0.2013, intercept =0.3392. Then the regression is predicted the log (s(i)) value when the log (x((i)) is known. There is no supported relationship between cluster size and distance (b=0). Therefore the regression equation regarding the null hypothesis based on the application of Regression model with equation is:

$Cf_i = 0.2013 + -0.3392 * xi$

Where Cf_i = cluster size of the i^{tch} observation in the farmland, x_i=distance to the i^{tch} observation

Cluster size and distance relationship was observed using a Pearson Correlation. There was a weak negative correlation between cluster size and distance (R= 0.0869, d.f. = 97, P > 0.05). Students-t test was performed (t = 0.8593, df = 2, Pr (T<t) = 0.8038). Hence, the mean cluster size of cranes in the wetland habitat was 2.4486±0.19707; but in the farmland habitat, it was 1.9293±0.10769.

The Black Crowned Cranes population and density during the dry season was estimated both in the wetland and farmland habitats during the dry period in 2016. The crane density was estimated 0.3625±0.6958E-01 per hectare, and the total population (N) was estimated to be 2452±470.65. However, the estimate of density of clusters of cranes (DS) was 0.143471±0.25728E-01, and estimate of expected value of cluster size 2.5267±0.17291. In the farmland, the cranes density was estimated 0.13904±0.14809E-01 per hectare, and the total population (N) was estimated to be 1112±118.44. However, the estimate of density of clusters of cranes (DS) was 0.70690E-01± 0.64118E-02, and estimate of expected value of cluster size 1.9669±0.10983. The encounter rate (n/L) in the wetland and farmland habitats were 4.012 (%CV=11.54, df = 31, 95%CI = 3.1733-CI-5.0723) and 4.1250 (%CV = 6.89, df = 23, 95%CI = 3.5774-CI-4.7564). The total density and abundance of Black Crowned Cranes during the dry season in 2016 was estimated. The pooled estimates of density was 0.24142 cranes per hectare with (%CV=13.62, df = 164.02, 95%CI = 0.18473=CI= 0.31550) and the population was estimated to be 3564 cranes with (%CV=13.62, df = 164.02, 95%CI = 2727=CI = 4658).

4.4. Evaluation of land cover-use change in Lake Tana area

4.4.1. Wetland land use dynamics of Chimba and Yiganda wetlands

Chimba area is one of the most important wetland areas for Black Crowned Cranes. The location of the area adjacent to Gilgel Abay River gives Chimba wetlands to be preferred by several wintering and resident birds. The most important breeding sites for resident cranes occur here. However, the area is under pressure. The human pressure can have impact on the future existence of this pristine wetland ecosystem. Land use land cover (LULC) is changing from time to time. Agricultural encroachment, sedimentation due to the outflow of the river and erosion in the upper catchment, and high livestock pressure and population growth for demand of more land are the main factors for the change.

During 1986, the Chimba wetland area covered a total of 15,134,974.6 m^2 (7.4%) from the total watershed area of 203,312,456.3 m^2. Others such as cultivated land, 100,036,956.9 m^2 (49.2%); farm village with trees and cultivation, 88,025,623.2 (43.3%); and natural forest area 114,901.6 (0.1%) (Fig. 27).

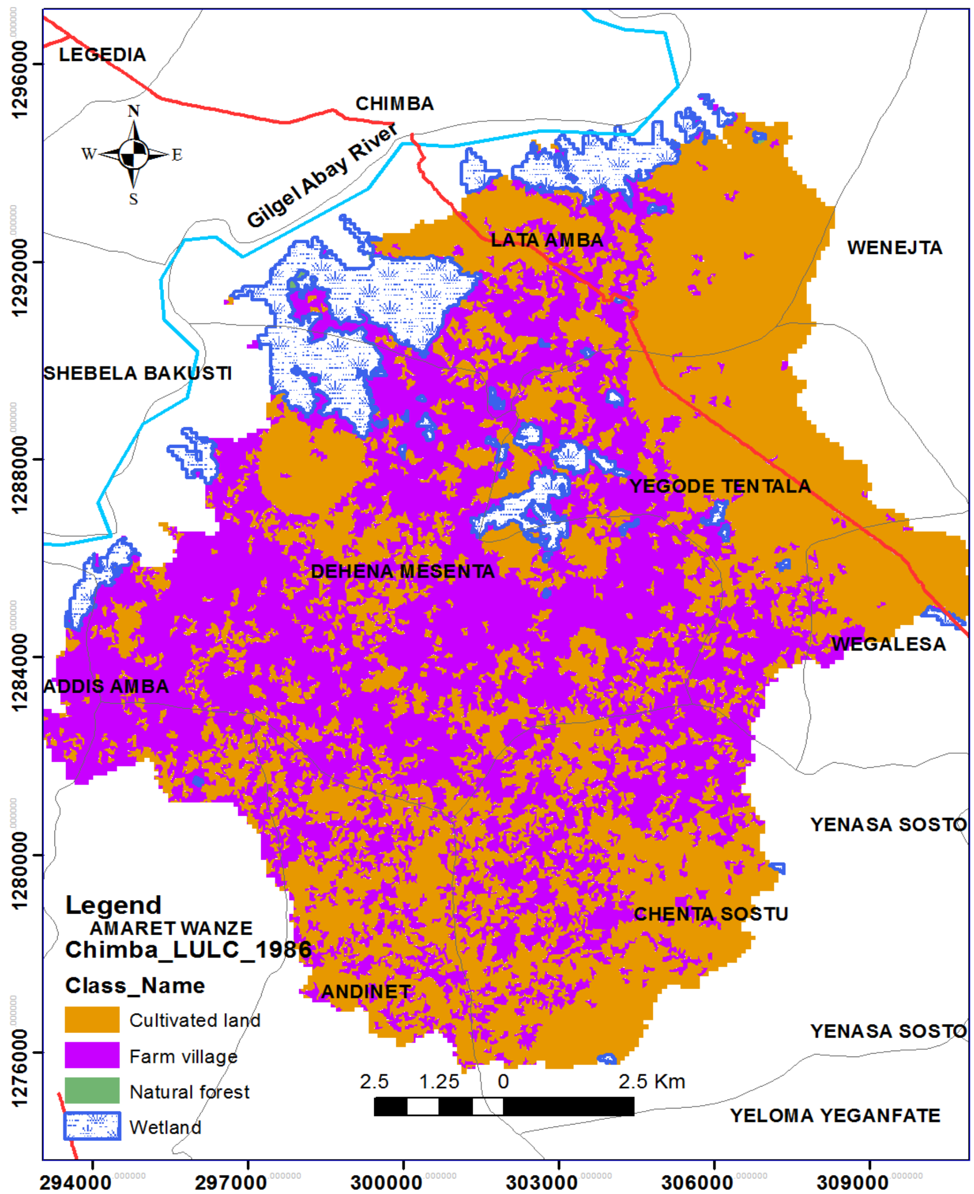


Figure 27. Chimba (Lamgebeya and Basha-Dangela) Wetland Watershed and LULC 1986.

Note: most of the area classified as farm village shall be considered to be high natural trees coverage in scattered tukuls; or most of the villages scattered all over the watershed are collected by villageization program in 1987 to 1990 in the Dergue regime were converted to intensively cultivated land.

The existing LULC in 2016 showed that the wetland coverage was changed and shrunk to 11,421,574.2 m^2 (5.24%) (Table 46). The change in 30 years period is shown in the map (Fig. 28).

Table 46. Existing Land Use and Land Cover of Chimba wetlands watershed.

S.N.	LULC Type	Area, m^2	%
1	Farm villages with trees and cultivation	56511599.6	25.91
2	Grass land	49599750.2	22.74
3	Intensively cultivated land	9737199.5	4.46
4	Marshland (wetland)	11,421,574.2	5.24
5	Moderately cultivated land	52864.2	0.02
6	Natural forest	483758.7	0.22
7	Plantation forest	1621248.5	0.74
8	Shrub land	5120681.7	2.35
9	Water body	1170332.1	0.54
10	Woodland	82374872.6	37.77
	Sum	218093881.4	100.00

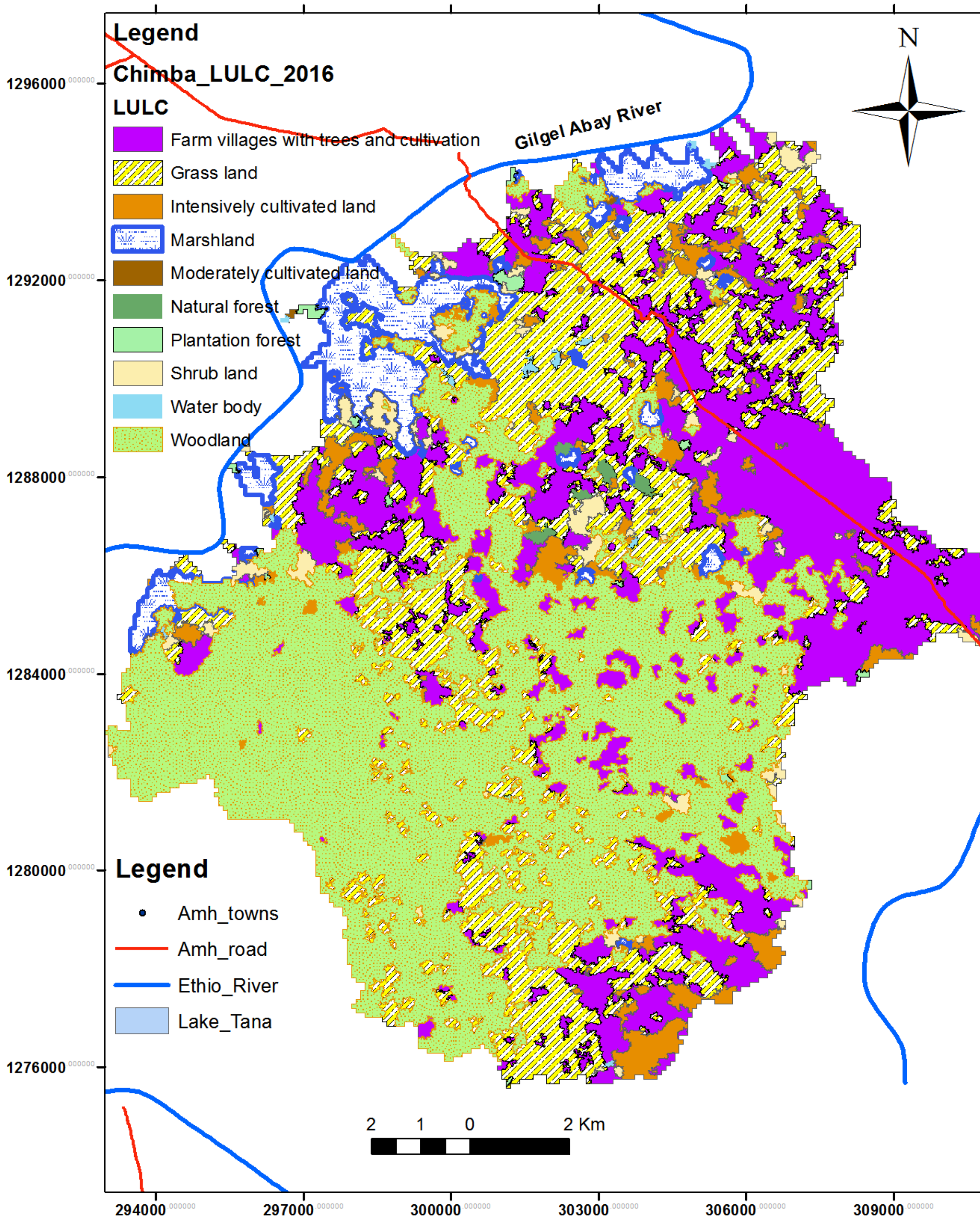


Figure 28. Existing LULC and watershed of Chimba (Lamgebeya and Basha-Dangela) wetland 2016.

A tremendous change had been occurred with 30 years' time. The Chimba (Lamgebeya and Basha-Dangela) watershed wetlands covered about 1540.6 ha of land in 1986. The mainland use land cover in 1986 has changed into different land use practices in 2016 (Table 47).

Table 47. Change detection between 1986 and 2016.

S.N.	LULC 1986	LULC 2016	Area (m^2)	%
1	Cultivated land	Farm villages with trees and cultivation	38751228.8	38.74
2	Cultivated land	Grass land	28228364.5	28.22
3	Cultivated land	Intensively cultivated land	6404861.8	6.40
4	Cultivated land	Marshland	697240.7	0.70
5	Cultivated land	Moderately cultivated land	5926.4	0.01
6	Cultivated land	Natural forest	11269.4	0.01
7	Cultivated land	Plantation forest	452225.2	0.45
8	Cultivated land	Shrub land	1568628.1	1.57
9	Cultivated land	Water body	347797.8	0.35
10	Cultivated land	Woodland	26690088.5	26.68
11	Farm village	Farm villages with trees and cultivation	16636559.5	18.90
12	Farm village	Grass land	20198101.1	22.95
13	Farm village	Intensively cultivated land	2716797.5	3.09
14	Farm village	Marshland	2174284.4	2.47
15	Farm village	Moderately cultivated land	10319.9	0.01
16	Farm village	Natural forest	93018.1	0.11
17	Farm village	Plantation forest	898569.6	1.02
18	Farm village	Shrub land	2327692.0	2.64
19	Farm village	Water body	737692.3	0.84
20	Farm village	Woodland	53622393.8	60.92
21	Natural forest	Grass land	20840.4	18.14
22	Natural forest	Intensively cultivated land	21706.8	18.89
23	Natural forest	Marshland	56104.8	48.83
24	Natural forest	Shrub land	13808.3	12.02
25	Natural forest	Woodland	2441.4	2.12
26	Wetland	Farm villages with trees and cultivation	1123811.2	7.43
27	Wetland	Grass land	1152444.3	7.61
28	Wetland	Intensively cultivated land	593833.5	3.92
29	Wetland	Marshland	8493944.3	56.12
30	Wetland	Moderately cultivated land	36617.9	0.24
31	Wetland	Natural forest	379471.2	2.51
32	Wetland	Plantation forest	270453.7	1.79
33	Wetland	Shrub land	1210553.3	8.00

S.N.	LULC 1986	LULC 2016	Area (m^2)	%
34	Wetland	Water body	84842.0	0.56
35	Wetland	Woodland	2059948.9	13.61

Only 55% of the wetland as marshland was remained in 2016, which means 45% of the wetlands has been changed (Fig. 29). Therefore currently the existing land use in the wetland boundary of Chimba area showed that the available wetland for cranes is only about 808 ha (Table 48).

Table 48. Chimba (Lamgebeya and Basha-Dangela) wetlands land use conversion.

LULC	Area, m^2	%	Remark
Farm villages with trees and cultivation	704642.3	5.7	Converted part of the wetland
Grass land	539265.0	4.4	Converted part of the wetland
Intensively cultivated land	328092.5	2.7	Converted part of the wetland
Marshland	8081742.9	65.5	Being grazed
Moderately cultivated land	44132.6	0.4	Converted part of the wetland
Plantation forest	206064.7	1.7	Converted part of the wetland
Shrub land	711453.2	5.8	Converted part of the wetland
Water body	35609.8	0.3	Converted part of the wetland
Woodland	1693204.6	13.7	Converted part of the wetland
Sum total	12344207.5	100.0	

Chimba (Lam Gebeya and Basha-Dangela) wetland is a marsh type of wetland covering about 1234.4 ha of land. Based on the January 2016 image classification (SPOT5, 2.5 m resolution), 5.7% of the wetland is converted completely to farm villages where most of its part is covered with Eucalyptus trees and cultivated land, 4.4% grassland being grazed by cattle, about 15.4% vegetation and the rest, 3.1% of the wetland part is being cultivated. The wetland has a little area to recede.

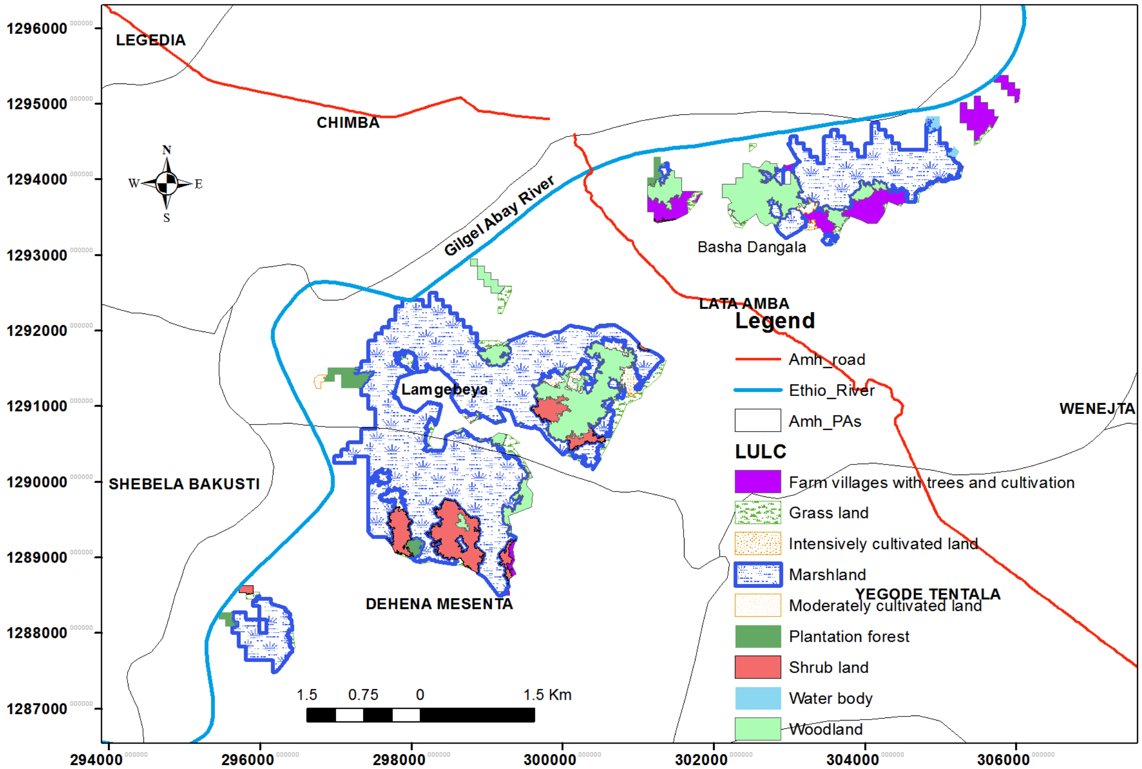


Figure 29. Existing LULC of Chimba wetland, 2016.

The LULC of Yiganda wetland watershed in 1986 from the total area of 28,075,506.2 m^2 area were: farm village with trees and cultivation, 10 078 414.0 (35.90%); cultivated land, 9920522.9 (35.34%); grass land, 6102.8 (0.02%); natural forest, 2580806.1 (9.19%); water body, 138018.7 (0.49%); and the wetland area covers 5,351,641.7 m^2, which was (19.06%) (Fig. 30).

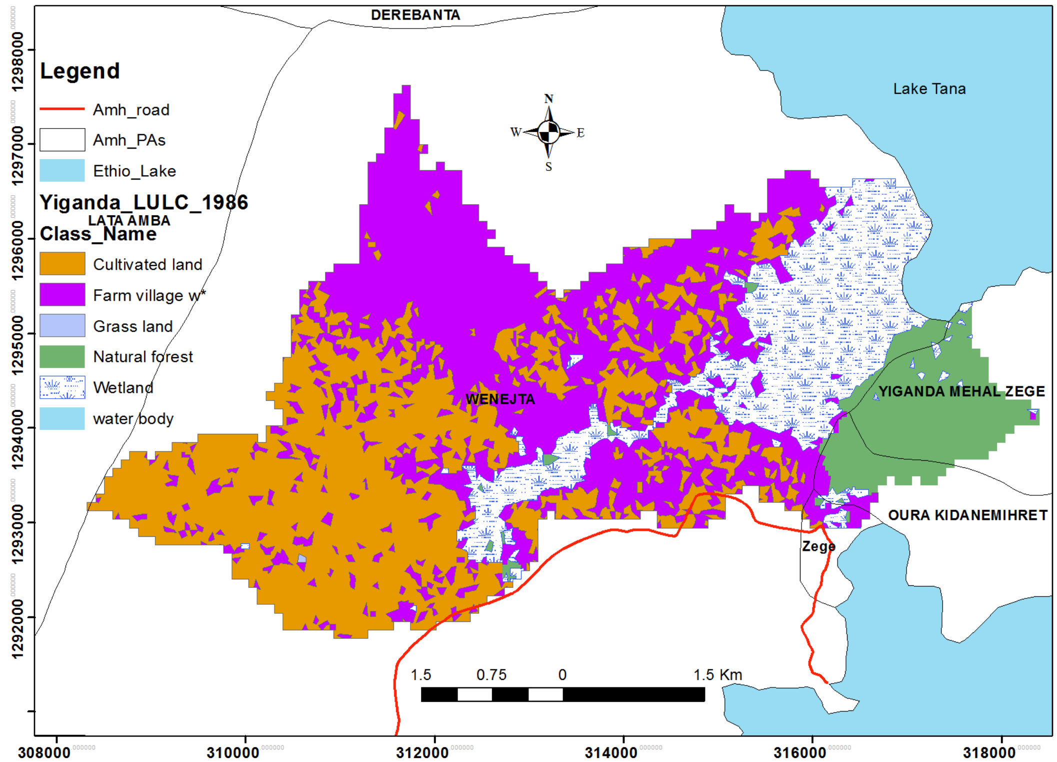


Figure 30. Yiganda wetland watershed and LULC 1986.

Note: most of the area classified as farm village shall be considered to be high natural trees coverage in scattered tukuls; or most of the villages scattered all over the watershed are collected by villagisation from 1987 to 1990 during the Dergue regime converted to intensively cultivated land.

The existing LULC in 2016 showed that the wetland coverage was changed and shrunk to 4542297.99m ^{2} (16.2%). Others were: farm village with trees and cultivation, 4617336.92 (16.4%); grass land, 2594487.95 (9.2%); intensively cultivated land, 11914903.57 (42.4%); natural forest, 3707209.05 (13.2%); shrub land, 411753.01 (1.5%); water body, 251938.95 (0.9%); woodland, 35578.81 (0.1%) from the total 28075506.25m ^{2} (Fig. 31).

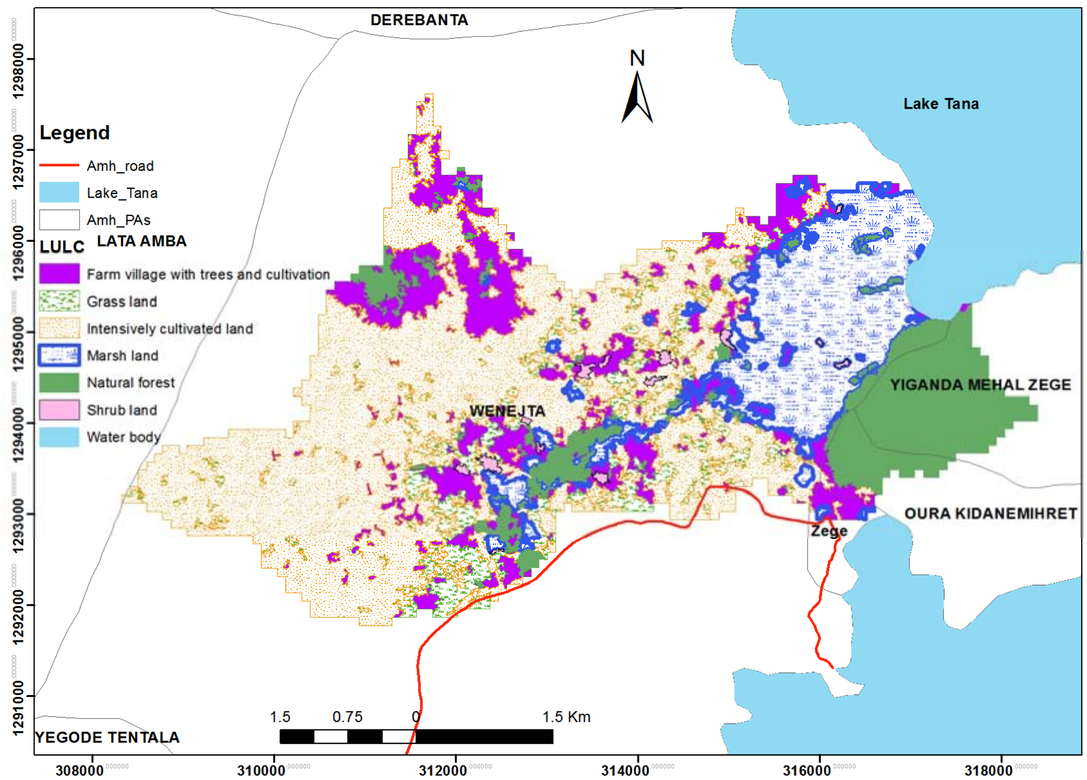


Figure 31. Existing LULC and watershed of Yiganda wetland, 2016.

The Yiganda watershed wetlands covered about 535.2 ha of land in 1986. Based on the January 2016 image classification (SPOT5, 2.5 m resolution), it is found that 397.85 ha (74.3%) are left to be wetlands or marshland. The land use land cover change between 1986 and 2013 has indicated that about 50.7 ha (9.5%) is converted to farm villages with trees and cultivation, 2.9 ha (0.5%) is converted to grazing land; 7.5 ha (1.4%) is converted to intensively cultivated land; 59.7 ha (11.2%) is converted to natural forest (this could be trees in swamps); about 12.3 ha (2.3%) is converted to water body (this cloud be the Lake water being regulated by Chara-Chara weir) and about 4.2 ha (0.8%) is converted to shrub land (Appendix 4). Therefore, currently the existing land use in the wetland boundary showed that the available wetland for cranes is only about 402 ha (Table 49) (Fig. 32).

Table 49. Yiganda wetland land use conversion, 1986-2016.

LULC	Area, m^2	%	Remark
Farm village with trees and cultivation	463096.2	9.90	Converted part of the wetland
Grass land	48334.6	1.03	Converted part of the wetland
Intensively cultivated land	26614.2	0.57	Converted part of the wetland
Marsh land	4,029,177.8	86.14	Papyrus taken by cut and carry
Natural forest	88537.0	1.89	Converted part of the wetland
Shrub land	21732.6	0.46	Converted part of the wetland
Sum total	4677492.5	100.00	

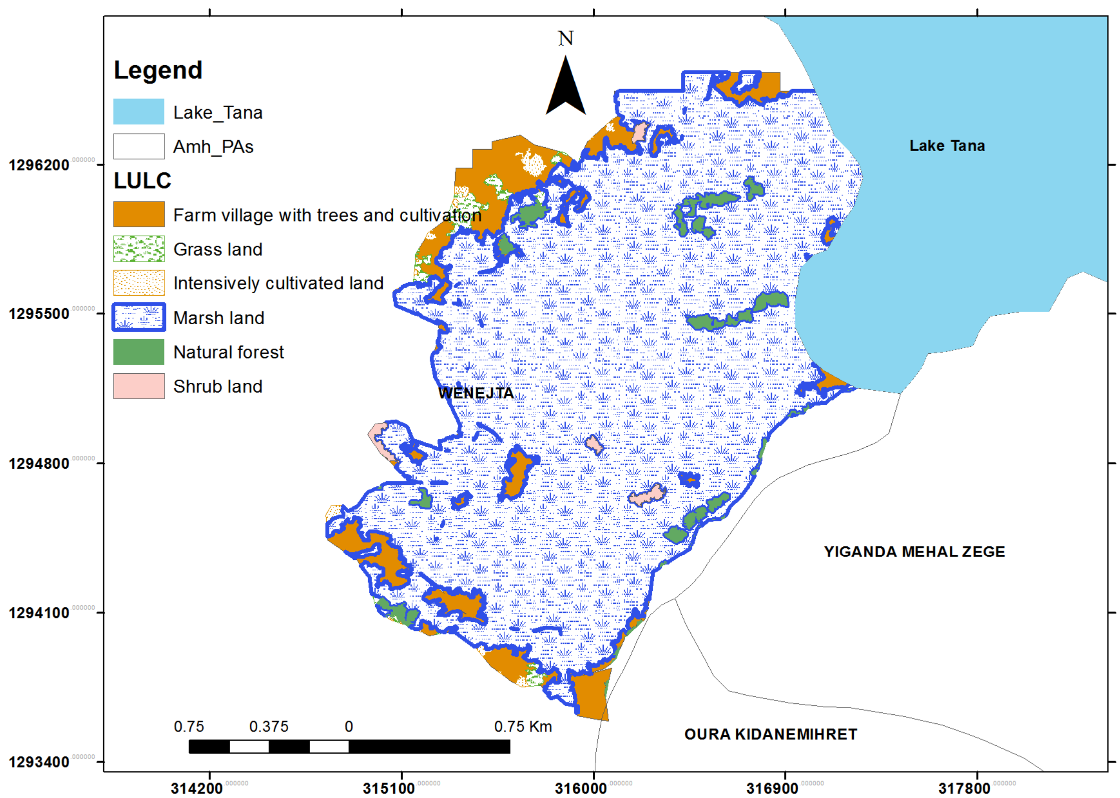


Figure 32. Existing land use of Yiganda wetland.

Yiganda wetland is a marsh type of wetland covering about 468 ha of land; excluding other wetlands in the upper part of the watershed. Based on the Jan. 2013 image classification (SPOT5, 2.5 m resolution), it is found that 9.9% of the wetland is converted completely to farm villages where most of its part is covered with Eucalyptus trees and cultivated land, 1.03% grassland being grazed by cattle, about 2.3% of the vegetation and the rest, 0.57% of the wetland part is being cultivated. The wetland has a little area to recede where there is no cultivation following the recession. It is the most conserved wetland among the five wetlands under consideration in this study around Lake Tana; except, a few erosion risk where the upper catchment is very flat; a little erosive flood risk.

4.4.2. Effects of land use on crane habitats

When we compare the wetland change in 1986 to 2016. Chimba wetland was more affected in which 705.33 ha was changed into other land use land cover (1513.5 ha-808.17ha); where as in Yiganda 130.24 ha was changed during the last 30 years (535.16-404.92). When we see the exponential trend change of LULC it could affect crane ecology by reducing the habitat availability for cranes.

The population pressure created more land for cultivation during 30 years. As cranes are territorial, the breeding territory has decreased by 47% in Chimba and by 25% in Yiganda. If this scenario continues for next 30 years, the wetlands of crane habitats availability in both wetlands will be affected at a significant level. Only 100 ha for Chimba and about 250 ha in Yiganda will only be available for crane breeding and foraging activity in these wetland areas. The intensity of human interference will aggravate and affect the breeding ecology of cranes.

The grazing pressure could also affect crane ecology in many ways. The agricultural practice in the area is mixed crop and livestock farming. However, there is no private pasture land that is devoted for their cattle. The only feed source option for their livestock is the wetland resource and the crop residue. Unless the rainy season comes and inundates the wetland during the wet season, cattle are confined in the Chimba, Yiganda and other wetlands. As there is no protection and regulation how to utilize the resource anyone anywhere can come and enjoy the resource. Hence the pressure on the wetland increases from time to time. The young ones did not have farmland, but cattle production and fattening activities is the only option. Only during the rainy season particularly starting from August and until the post-rainy time November, cattle are kept near home vicinity utilizing the poor food quality crop residue preserved for this purpose. So, as the number of young individuals encroach the wetland for agriculture and remove the vegetation without sustainable management, the nesting and foraging site of cranes will be affected.

4.4.3. Threats and challenges of crane conservation

Papyrus is removed for commercial purpose. The spikes are being removed and transported to Bahir Dar. More disturbance is observed on organisms that depend on for shelter, nesting and resting. The forest patches in Yiganda and Chimba belongs to the Ethiopian Orthodox Church. However, still there is illegal removal of old and big trees at Zegie Peninsula.

However, deforestation is being aggravated in the wetland watersheds of the study sites, which is the main cause of run off and siltation in Dirma and Chimba wetlands.

The water in the wetland is being drained for' chat' cultivation in Yiganda and Chimba (Plate 13). Expansion of this activity would affect the wetland ecosystem as the wetland dries fast before the next rain is coming.

Plate 13. Pumping wetland water for chat cultivation at Chimba wetland, Lamgebeya area, 2013.

People proceed to cultivate as the water level recedes like the other areas in the eastern shore of the Lake. In Dirma, rice production is being practiced recently; however, after harvesting sequential farming follows, leading to degradation and nutrient loss of the area. In Yiganda and Chimba wetland conversion into agriculture is becoming prominent. The border of wetlands is given to the local young group. They cultivate different cash crops, 'Chat' (*Catha edulis*) and onion are the commonest. In addition, there is no clear border of the wetland, as a result encroachment is observed. Some wetland vegetation are being rooted out due to intensive cultivation. Agricultural inputs (herbicides and pesticides) are increasing from time to time the blooming of invasive species in the northern part of Lake Tana can be a prominent example.

Cranes are being threatened and killed by people who live around. Even though the crop foraging rate is minimum as the study suggests in section 4.3 (7% for tef and 4.5% for finger millet) crop foraging was recorded. The bad perception of the community on Cranes is increasing. Kids kill juveniles by taking out from the wetland deliberately.

Due to human pressure, most of the agricultural lands are cultivated from year to year without fallowing. Private grazing lands are not common; however, the Dirma wetland is the only grazing place for enormous number of cattle are also seen in Yiganda and Chimba. Since the wetland is not owned by anyone, it is free for anyone to exploit the resource. Livestock pressure can be the main cause for the degradation of the wetland. Unmanaged way of utilization could destroy the vegetation, and also increase the weed in the area. Due to overgrazing at Chimba particularly in Lamgebeya wetland, about 4.25% of the sample area vegetation was changed to bare land (Plate 14).

Plate 14. Sediment covers in Chimba wetland that borders Gilgel Abay River, 2013.

The Dirma area is being highly infested with invasive species. Water hyacinth (*E. crassipes*), *H. schulli,* and the currently propagation of Balsa wood tree (*Aeschynomene elaphroxylon*) are the common ones. The propagation and dissemination of water hyacinth in the area is dreadful. Even though weed eradication campaign has begun since 2012, the management techniques was so poor to make the weed not to revive during the next wet season. The weeds accumulate at the edge of wetlands where there is enough moisture. In addition, use of fertilizer at the shore of the lake would aggravate the situation since it is an input for the growth and multiplication of the weed. The Balsa wood tree became prominent from time to time with 300 trees counted in 2013 and at present (2016) it tripled.

The establishment of flower farms, hotels and camps at the edge of the lake without a treatment plant is dangerous. The construction of the China camp at the verge of Dirma wetland is at risk, because the wastes from the camp are being drained to the wetland without any treatment.

The absence of legal or illegal Crane trade in Ethiopia in general, and Lake Tana in particular can make the chance of building the crane population promising In addition, the registration of the Lake Tana Area by UNESCO is also another opportunity. The Biosphere Reserves is being administered by ANRS Bureau of Culture, Tourism and Parks Development, under the authority of the Ethiopian Ministry of Science and Technology.

Ethiopia has not ratified the Ramsar Convention yet. However, as reported by Shewaye Deribe (2007), the country has gone some steps to sign or ratify the Convention. In spite of the delay of signing and/or ratifying the Ramsar Convention, Ethiopia has signed and/or ratified some important Multilateral Environmental Agreements (MEA) that are relevant to environmental resource conservation including wetland. These were: The United Nations Framework Convention on Climate Change (1994), the Convention on Biological Diversity (1994), the United Nations Convention to Combat Desertification (1994), the Cartagena Protocol on Bio-safety to the Convention on Biological Diversity (2000), African Eurasian Water Bird Agreement (AEWA), Convention concerning the protection of world cultural and natural heritage (6 July 1977), and Convention on International Trade in Endangered Species of Fauna and Flora (5 April 1989). Those treaties, legislations and polices are unless put into practice, they cannot be a guarantee to conserve cranes and its habitats.

The Government of Ethiopian has developed and implemented a wide range of policies, laws and programs on environment, water, forests, climate change, and biodiversity over the last two decades. Some of these policies, laws and programs that are relevant to environmental resource conservation are: The Constitution of the Federal Democratic Republic of Ethiopia; Environmental Policy of Ethiopia; Conservation strategy; Environmental Management Proclamations; Agricultural and Rural Development Strategy; Sustainable Development and Poverty Reduction Programs; The National Biodiversity Conservation Policy; Science and Technology Policy; Water Resource Management Policy and Proclamations; Wildlife Policy; Land use and land administration Proclamation; Forest Policy; and Climate Resilient Green Economy (CRGE) Strategy (EPA, 2012; MoFED, 2006; IBC, 1998).

The poor implementations practice of rules and regulations in Lake Tana wetlands; the inadequate and absence of environmental education on the community; the inactive participations of stakeholders to make the Lake Tana Biosphere Reserve; the weak bylaws of the community designed to utilize the wetland resource sustainably in the area; absence of job opportunities of the landless young people are the main challenges that will last long unless action is taken.

5. DISCUSSION

The breeding ecology of Black Crowned Crane regarding nest initiation, nest site selection, nesting characteristics, nest materials utilized, nest and egg morphometry, water depth at which nest is constructed, and their breeding performances were discussed. The type of food and abundance, diet characteristics, and the foraging behavior of cranes were are also studied. In addition, the distribution, abundance and density of Black Crowned Crane, and land use land cover change of the wetland habitat were also covered.

In the Okefenokee Swamp, Florida Sandhill Cranes exclusively depended upon wetlands (Bennett and Bennett, 1992). Similarly, the nests of Black Crowned Cranes at Lake Tana area were located only in natural wetlands where there is enough water depth and open vegetation to construct nests. This is in contrary to the Grey Crowned Crane and Sarus Crane that utilized both agricultural land and man-made wetlands (Gichuki, 1993, 2000; Mukherjee *et al*., 2000). Even though there is marshy area in the rice paddy agricultural fields in Dirma and Fogera area, Black Crowned Cranes did not prefer to nest in the rice paddy field. The high risk of predation and disturbance by the people could be accounted for the restriction of nesting only in the wetlands. This nesting site selection behavior was also reported by Brown (1969), and Burger and Gochfeld (1990) in which nest site selection resulted a nonrandom spatial distribution. Clark and Shutler (1999) also reported that nest site selection is associated to territorial factor. During nesting time, nesting sites were situated far from the main land away from disturbance induced by humans and livestock. This result was in contrary to the finding of Nesbit (1989), Winter (1991) and

Mukherjee *et al*. (2000) where Sarus, Demoiselle and Sandhill Cranes nested in agricultural fields unlike Black Crowned Cranes that required secure nesting site.

Nests of Black Crowned Cranes were constructed at places where there was short vegetation cover. This result is similar to Johnsgard (1983a), who reported that all crane species except Blue and Demoiselle Cranes build nests in shallow wetlands with low emergent vegetation. In South Africa, nesting habitats of Crowned Cranes were reported to consist of open marshes, knee-high to shoulder-high stands of sedges and grasses (Johnsgard, 1983b). The preference of open wetland by Black Crowned Cranes during nesting enables them to scrutinize and scan the area. This could be related to the territoriality defense behavior of the bird; besides it can enable them to escape if there is any danger around the nest or the individual. Similar result was reported by Clark and Shutler (1999) where openness of nesting sites is important to defend the territory of the breeding site. Walkinshaw (1950) and Bennett (1978) have reported similarly that Sandhill Cranes also prefer to have cover with a structure and density that allowed them a clear view while incubating and free movement when walking to and from the nest.

The Black Crowned Cranes display a call when they leave the nest and return back to their nest but should be after and before at least some distances away from their nest. This behavior could be related to "distraction display behavior of birds" as reported by several scholars. Barrows (2001), Armstrong (2008) and Wang *et al*. (2013) explained that a call can help to distract the enemy or to keep the territorial integrity by warning opponents to be away. This form of behavior is common in many birds as distraction display used to attract the attention of an enemy away from the nest or young. Similarly, the Red Crowned

Crane has also been observed to perform such kind of distraction practice. Walkinshaw (1964) and Johnsgard (1983a) have also reported that in crowned cranes, when approached by cattle, or snakes, distraction display is typical. This includes dancing on the part of one or both birds. Head-bobbing is done frequently, and birds will sometimes spread their wings, run around the intruder, or jump up and down. At times, they pick up objects from the ground and toss them into the air.

Depending on the type of site, Black Crowned Cranes nest in wetlands where at least there is water and matted vegetation. The water depth ranges from 135 - 220 cm during the active nesting time September to October. This finding was similar with the study conducted in 2008 in Yiganda wetland (Shimelis Aynalem *et al.*, 2011). The result also agrees with Mukherjee *et al*. (2000), who reported the presence of certain water depth level as a prerequisite for the nest site selection in Sarus Cranes. The selection of marsh or wetland area could be due to the ease availability of nesting material, food and to avoid predator. In addition, Nudds (1983) reported that the levels of mortality of eggs and young due to inclement weather and predation may also be low due to enough depth of water in the nesting site.

Nesting characteristics of all crane species are similar, except a few species like Blue Crane and Demoiselle Crane (Johngard, 1983b). Black Crowned Cranes however build nests above the water surface where there is matted vegetation (grass), turn or bend down the available grass and then pile up cut grasses taken close to the nest. At the base, the nest was broad but in the middle, it is a cup-like structure. On top of it, soft grass leaves and down feathers were observed. This type of nest architecture is also followed by Crowned

Cranes and Sarus Cranes (Gichuki, 1993; Mukherjee *et al*., 2000; Borad *et al.*, 2001). Crowned cranes pull out grasses around and add to the nest until the eggs are hatched. As the height of the nest increases against the water level, it keeps the nest dry and fungus growth can be inhibited. Similar result was also reported by Mukherjee *et al*. (2000). The location of nests from the edge of the wetland varied. The territorial integrality among nesting cranes could be related with the genetic behavior of cranes and environmental factors. Hinde (1958) and Brown (1969) pointed that territoriality in birds is often centered more on spatial habitat requirements than genetic factors.

Black Crowned Cranes utilized nest materials collected from the nesting place just around the nest. For Sarus Crane, the material was always collected within 16 m radius of the nest (Mukherjee *et al*., 2000). Even though there were other vegetation types, crane nesting locations were dominated by a few emergent macrophytes. During the study period in 2014, nests were located where five species of macrophytes were located. It was similar to 2015. The preference of cranes to build their nest from grasses could be because these macrophytes (grass) produce seeds that are utilized as feed by cranes during their breeding period. Nests close to these grass species could be related to the feeding behavior of Black Crowned Cranes, and it provides adequate feeding ground close to their nest. This result coincides with the nest site selection behavior by Cattle Egret (Hilaluddin *et al*., 2003). In addition, these macrophytes provide cover and protection against predators and exposure to wind which the nest site selection behavior is associated with (Rounds *et al*., 2004). The choice of low emergent vegetation during nest construction by Black Crowned Cranes is associated with a clear view and to defend their territory, as Sandhill Cranes do (Walkinshaw, 1950; Bennett, 1978; Johnsgard, 1983a,b; Clark and Shutler, 1999).

The nests of Black Crowned Crane are usually oblong shape. Nests that have eggs showed depressed shape in the central part of the nest, but not for nests without eggs. This nest architecture is similar across wetland nesting cranes (Johnsgard, 1983a, Johnsgard, 1983b; Mukherjee *et al.*, 2000). The nest measurement of Black Crowned Cranes is closer to the report of Walkinshaw (1973). The West African crane nests were larger than the South African nests, and ranged from 70 to 140 cm across (Walkinshaw, 1973).The variation in nest breadth of this similar species of West African Black Crowned Crane and the East African cranes at Lake Tana area could be due to the difference in nesting site location, habitat, land use type and altitudinal variation.

The nest height above water surface during the study period ranged from 10 to 30 cm. This could be associated with the nesting behavior of the species, water depth level, the availability of nesting material and type used, and the location of nests where the nests are constructed. However, these factors do not affect the morphometric measurements of crane nests significantly. This observation disagrees with the report of Mukherjee *et al.* (2000). The use of different microhabitats in the case of Sarus Crane could account for the variation in water depth and nest height significantly.

Since cranes have retained "ground nesting" habit of their ancestors, all the species of cranes are territorial during the breeding season. Territory sizes vary among species, but can range from two to several hundred hectares (Walkinshaw, 1973). During the study period, nesting density of Black Crowned Cranes was 4 pair/100 ha in 2014 and 5 pair/100 ha in 2015. These results were far from nesting densities of crowned cranes recorded in Kitale area in Kenya. It was 54 pairs/100 ha. The area in Kitale was mostly a protected area unlike the Lake Tana nesting sites. The free use nature of wetlands in Lake Tana area besides to agricultural encroachment, unmanaged way of vegetation removal, destruction of nests and nesting habitats could account for the less number of breeding pairs to be observed. Though the breeding pairs at Lake Tana area had larger territory, the nests constructed at each wetland were concentrated at specific locations. These locations were mostly inaccessible to humans and cattle. The mean inter-nest distance in the study sites tells about how nests were localized in specific sites. However, there was variation in nest inter-distance during the study periods. The presence of deep water at the nesting site, the size of the wetland, edge effect, vegetation cover and type could be the main factors for nest concentration at specific locations. In the vast expanses of papyrus in Yiganda and Chimba, and in Dirma where there was high water hyacinth cover, it might have decreased the nesting density of cranes, because no nesting pairs were recorded in this micro-habitat.

Site fidelity in cranes could be due to successful breeding in the previous seasons or because of mate preferences. Site philopatry, however, can reduce reproductive success if the site is degraded. This behavior can offset the reproductive advantages of breeding experience in old birds (Gichuki, 1993). Cranes were observed to use similar nesting area during 2014 and 2015 though not sure whether similar breeding pairs were using the same place. Similar observation was recorded in 2008/2009 at Lake Tana area (Shimelis Aynalem *et al*., 2011). Nest sight fidelity was observed in all sites with overall mean distance between nests constructed in 2014 and 2015 of the same study site, but were variable. Nesting site disturbance or degradation, water depth variability during the seasons and unsuccessful breeding experience could be accounted for infidelity. Wattled Crane nesting site consistency has been reported by Bento *et al.* (2007) in the Marromeu complex of the Zambezi Delta, unless they are disturbed. Nevertheless, still Crowned Cranes utilize similar nesting place with a small variation of nest placement distance at Lake Tana area.

The periods of nesting in crowned cranes varied in different parts of Africa (Johnsgard, 1983b). At Lake Tana area, Black Crowned Cranes nest from September to December. Nest initiation and egg laying was synchronized with the post-rainy season. Breeding records in Uganda, however, extend throughout the year for the East African race, with peaks in the breeding activity associated with drier periods (Pomeroy, 1980b). According to Brown and Britton (1980a), Crowned Cranes generally breed during the rainy season in most areas of East Africa, but the dry period seems to be preferred. In Ethiopia, particularly in Lake Tana area, the nesting period is restricted to the specified time. This synchronization at Lake Tana could be related to the availability of cover, water level, security and less disturbance by humans and cattle during the nesting period.

Cranes need undisturbed nesting sites except the Indian race (Sarus Crane) which is highly tolerant of human activity. Wild cranes generally nest in isolated places where the risk of predation is minimal (Archibald and Meine, 1996; Claire *et al.*, 1996; Bento *et al.*, 2007; Gopi, 2009; Shimelis Aynalem *et al.*, 2011). But studies carried out in nest success of Greater Sandhill Cranes at Malheur National Wildlife Refuge, Oregon showed that nest concealment has no relationship with nest success (Ivey, 2007). However, the breeding grounds of cranes at Lake Tana, as observed, all nests were built in secure and inaccessible places, which support the above findings except Ivey (Ivey, 2007).

It is doubtful that significant differences in clutch sizes exist in different Crowned Cranes (Jonsgard, 1980b). Pomeroy (1980a) noted, however, that clutch seems to vary with altitude; in that 12 nests from areas of generally below 1,500 meters averaged 2.17 eggs, while 29 nests from highland areas above 1,500 meters averaged 2.72 eggs. Records of 17 West African Crane nests provided by Walkinshaw (1973) indicate an average clutch size of 2.47 eggs. At Lake Tana area, however, average clutch sizes of 2 eggs were recorded. This result was similar with the finding of Shimelis Aynalem *et al*. (2011), but different to the findings of Gichuki (1993) which was 2.4 eggs (89 nests) for Crowned Cranes in Kitale area, Kenya. This variation could be due to the species specific genetic character, because Grey and Black Crowned Cranes are different species, and/or could be due to age/maturity of cranes during their breeding period.

The size of bird eggs may be important in determining body size and condition of fledglings, their probability of survival and, ultimately, their reproductive success (Schifferli, 1973; Williams, 1994). In addition, it was reported that egg dimensions affect the size of nestlings and thus may have an influence on their survival (Smith and Bruun, 1998; Ricsch and Rohwer, 2000). The egg measurements of Black Crowned Cranes showed, there were low variations in egg breadth than length and weight. This variation might be due to the constrained by the female oviduct diameter (van Noordwijk *et al*., 1981). Romanoff and Romanoff (1963) have also reported that eggs originate in an oviduct whose cross sectional area has a limited extensibility and the egg width was the most constant of all the parameters. Similarly, in Sarus Crane egg, width was found to be the most consistent parameter (Mukherjee *et al*., 2000). The variation observed in egg diameter within a clutch was very small compared to the variation noted between clutches in Black Crowned Cranes. This is also reported in Sarus Crane as well (Mukherjee *et al*., 2000).

Variation in egg dimension results from both genetic determination and impact of environmental conditions on these features (Surmacki et al., 2003). Pomeroy (1980a) shows egg weights from 122 g (regulorum) to 156 g (pavonina), but at Lake Tana it was 128 (112 ± .65).

Egg measurements can differ in their within-clutch variation (Surmacki et al., 2003). In the Black Crowned Cranes, the variation was observed in egg width (new with old stage, and new with older eggs stage). In addition, egg weight variation existed between new with old, and new with older egg stages. The variations noted in egg weight may be attributed to the date of observation after egg laying and also to its sequence error within the clutch during data collection. However, this observation seems to represent a more general rule and has been reported as variable for many bird species (Ojanen, 1983; Tryjanowski *et al*., 2001).

In captivity the hatchability percentage of the West African Crowned Cranes was reported 100% (Johnsgard, 1983a). In the wild, the hatchability percentage of cranes at Lake Tana was by far greater than a study of Crowned Cranes in Kenya, which was 83.6% (Guchiki, 1993). The destroyed eggs were mainly because of human factors. The attitudes towards cranes is becoming negative, they sometimes associate with crop foraging. The absence of environmental education for local people could be accounted for the nesting site and eggs loss.

Pomeroy (1980a) estimated that fledging occurred at about 100 days of age, and Walkinshaw (1973) stated that hand-reared West African cranes may not fly until they are 4 months old. However, Steel (1977) estimated that hand-reared East African birds were virtually fledged at 8 weeks of age, and Archibald and Viess (1979) reported fledging in hand-reared birds at only 63 days after hatching. Clearly, these wide divergences in estimated fledging times must indicate an unknown source of considerable variation, perhaps in the amounts of food available to the young cranes. The pre-fledged cranes at Lake Tana however, was almost half way from the number of hatched ones. The late nest initiation time, disturbance, competition of resources, predation of juveniles and sibling strife could be accounted for low breeding performance. Besides to predation, Fox (2011) reported that specifically, if a colt was one of a pair and had a living sibling, the probability of fledging was 50.87%.

The proportion of pre-fledged cranes decreases as time advances from December to April, because the crane death rate increased from 33.33% in December to 100% in April. The fledging time and pre-fledged juvenile mortality were strongly positively correlated. Late initiation of nesting, egg laying and hatching time increases the risk of chick mortality. Experienced breeders nest early in larger wetland habitats (Fox, 2011). Nesbitt (1988) and Ivey and Dugger (2008) have also reported that increased breeding experience has been correlated with early nesting, selection of larger wetland habitats, and greater nesting and fledging success. Therefore, the fledging success of Black Crowned Cranes at Lake Tana area can be associated with breeding experience of the crane pairs, late nest initiation time, disturbance, deliberate killing, wetland shrinkage, and poor environmental education and poor awareness towards cranes.

Poacea was the dominant macrophyte family that occur in the study area. In all study sites, *L. hexandra* and *O. longistaminata* were the major feed source and nesting material of Cranes. The occurrence of these macrophytes are quite different from the Kitale area in Kenya and Southern Africa wetlands where crowned cranes are distributed. The variation could be due to altitudinal, latitudinal and climate variations, and the hydrology regime in all these specified areas (Gichuki, 2000; Collins, 2005). The presence of emergent aquatic macrophytes at Lake Tana area provides several ecological values and functions. Westlake (1966) and Brix (1997) reported that emergent macrophytes are the most productive of all aquatic macrophytes. Rao *et al*. (2003) had also reported, the net yield of emergent macrophytes ranges from 35 to 85 tones/ha/year in fertile ponds.

Macrophytes have different ecological significance and characteristics (Westlake 1966; Brix, 1997). *Cyperus* species are eaten by the larvae of some *Lepidoptera* species. The seeds and tubers are also an important food source for many small birds and mammals (Westlake, 1966). Cranes, rails, and gallinules at Lake Tana area have been observed to utilize *Cyperus* species too. Brix (1997) has also reported, the wetland vegetation may support a diverse wildlife including birds and reptiles.

According to Brix (1997), water hyacinth (*E. crassipes*) is known to reduce nutrient load (approx. 350 kg P and 200 kg N uptake capacities /ha/year) if used for water treatment purposes. However, the presence of water hyacinth in the Dirma wetland could decrease phytoplankton productivity which can lead to decrease in dissolved oxygen with negative consequences for fish and other water bird prey under these mats, as reported by Meerhoff *et al*. (2003) and Toft, (2003). The occurrence of *H. schulli* at Dirma recently, has also invaded grazing lands. The weed seed might be transported from the upper coarse river of Dirma River during the rainy season. The invasive nature and that can occur in the terrestrial and fresh water body was reported by Kumar *et al*. (2011).

*L. hexandra*is a perennial grass growing from rhizomes and stolon. The erect stem parts may float in water, can grow densely in aquatic habitat and become matted, forming what are often referred to as "carpets", used to construct crane nest on it. This plant grows in shallow freshwater habitat and on wet and moist land. It can persist for a time in drier conditions during drought. In all wetlands, the seed of this macrophyte is the most important feed source for Black Crowned Crane. The *O. longistaminata*, also share the same ecological characteristics of *L. hexandra.*

Papyrus bed is found in Chimba and Yiganda wetland. Ecologically, it is very important for hydrological cycle, pollution control, food and shelter for birds, invertebrates, fish, amphibians and reptiles (Owino and Ryan, 2006; Shimelis Aynalem and Abebe Amha, 2017). At Lake Tana area, *C. papyrus* L. found to support Black Crowned Crane and others birds like Black Crake and Allen’s Gallinule for food, nest and shelter. The African python (*Python sebae*) was also reported to shelter in the Cyperus bed of Yiganda and Chimba (Shimelis Aynalem and Abebe Amha, 2017). The identified aquatic macro-invertebrates play an important role in the food webs because they are an important component of the trophic structure of freshwater ecosystems as reported by Grubh and Mitsch (2004), and they are stimulate nutrient cycling by reducing the size of organic particles (Callisto *et al.*, 2001).

The physicochemical parameters were within the range of WHO standard. However, temperature was higher than 23^{o} C, which could be critical for fish survival; the variation could be due to time of the day and air temperature when the measurement was taken. This finding was similar to Tenagne Addisu (2009). In addition, the variation in TDS, could be due to organic sources, silt, and plankton, other sources from runoff, fertilizers and pesticides used on farms.

Even though most of macroinvertebrate studies focuses on rivers and streams mainly, wetlands still support diverse range of macroinvertebrates though smaller in occurrence than streams and rivers (Gooderham and Tsyrlin, 2002). Black Crowned Cranes feed on macroinvertebrates in the study sites. The abundant and frequently occurring taxa of *Libellulidae*, *Coenagrionidae*, *Hydrophilidae*, and *Culicidae* during the study period could be due to physiological adaptation of the taxa. Hilsenhoff (1988) reported that the pollution or disturbance tolerance nature of macroinvertebrate might contribute for the abundance of these taxa. Similarly, these taxa were also recorded as abundant in Infranz wetland though it was mainly reported in the streams (Abrhet Kehasay *et al.*, 2014). There was mean biomass variation of macroinvertebrates between study sites. Vegetation cover, the variation on the physicochemical properties of the wetland habitat, human pressure, grazing and runoff could account for this variability (Hilsenhoff, 1988; Masese*et al.*, 2013).

Yiganda and Chimba wetlands are diverse in terms of macroinvertebrate resources. The individuals in the community were also distributed more equitably. This indicates that both sites still can support crowed cranes as a feed resource during their breeding time. The quality of the wetland, in terms of physicochemical parameter, vegetation cover, and presence of adequate water level might contribute for the area to have diverse macroinvertebrate resource compared to polluted Dirma wetland in the northern part of Lake Tana (Banchiamlak Getnet, 2014).

The mean biomass of grass panicles in Chimba, Yiganda and Dirma vary depending upon seasons. Even though the estimation of grass panicles was in different micro-habitats and vegetation cover, Gichuki (1993) reported that the mean biomass of grass seeds in Kitale area were different in the absence of grazing. So, the difference in the results could be due to way of land management practice, type of vegetation, rainfall variability, and human-livestock pressure (Gichuki, 2000; Collins, 2005).

The mean biomass of grass panicles during the post-rainy and dry season time were more productive than during the pre-rainy time. Particularly Chimba and Yiganda were more different in the productivity of grass panicles than Dirma wetland. The degradation effect (siltation, occurrence of water hyacinth and Balsa wood) in Dirma wetland could account for less productivity of grass seeds that are available to Cranes. There was also seasonal variation in the productivity of grass seeds during the study period. Seed production continues as long as there is enough moisture and less grazing intensity.

The availability of crop seeds changed according to the farming cycle and the types of crops grown in the Lake Tana area (ANRS_BoA, 2013; Merkuz Abera, 2017). The biomass of crop seeds varied significantly with maize cover type. Maize was the most widely grown crop and the seeds were more abundant in stubble fields than sown. Cranes picked up seeds from the soil surface or dug out planted seeds from sown fields in May and June. Biomass of maize seed was higher in crop stubble than in sown fields, since the sowing rate per ha is very small amount, the cranes could have less opportunity to pick sown seed. Maize seeds were also available from crop stubble between November and December, since the productivity is much higher than the sown amount, seeds can be found in the farmland while threshing. This result is far from Gichuki (1993). In addition to the cultivation difference during sowing and harvesting, the threshing mechanism (oxen) itself can contribute for seed occurrence and abundance in the stubble field. Loss of crops during harvesting in Lake Tana sub-basin is high due to traditional practice, pests and diseases (Fentahun Tesfa *et al*., 2014; Merkuz Abera, 2017). In addition, rodents and birds, during harvesting period can contribute for the loss of seeds to the ground, making it ideal for cranes.

The first priority for cranes to consume crop seed is tef, then finger millet. The biophysical nature of the crop and the anatomical structure of the Crowned Crane beak could account for this preference. The edge of crop fields was more susceptible for foraging than the middle. Black Crowned Cranes do not prefer to forage in the middle of crop field usually if the crop stand is higher than their height, because high crop stand such as maize and sorghum prohibits observation. So, short crops are more preferable, because it helps cranes to scan, and to escape from any danger.

Based on the report of Ralph *et al*. (1985), the analyses of feces revealed that the diet of Crowned Crane contained parts of plants, fragments of animal origin and small quantities of inorganic material and shells. This result is comparable to fecal analysis of crowned Cranes in the Kitale area, but the animal origin and inorganic materials were lower than that of cranes in Lake Tana. Foraging behavior, availability of food resources could account for this difference. In Kitale area, cranes spend more time in crop fields for foraging than wetlands unlike in Lake Tana area (Gichuki, 1993).

Grass and crop seed proportion percentage by weight for crane category (sub-adult and adult) were statistically significant. However, the distribution of other food items in the diet was not statistically different. Sub-adult cranes utilize more grass seeds in the wetland than crop seeds in the farm. The reason could be the unfledged juvenile cranes spend mostly in wetlands during the post-rainy time than non-breeding adults that indicate adult cranes mostly account for crop foraging. However, the use of crop seeds during the dry season increased because certain number of juveniles during the post-rainy season fledge and associate the adult group in the crop field. Nevertheless, there was little change in the composition of roots, rhizomes and stem diets during the post-rainy and dry periods. This indicates that cranes are still dependent on wetland plant food resources that made up the major proportion of food items throughout the year.

The time spent foraging in wetlands and farmlands during the wet and dry seasons were significantly different with the time blocks of foraging time at 0.05 level. Particularly, the occurrence of high mean number of cranes during 12:01-3:01 (T3) could be related with watering time, warm temperature, resting time and less disturbance in the area.

Black Crowned Cranes in Lake Tana area are more attached with wetlands than farmlands; however, the Crowned Cranes in Kenya are more attached in the farmlands (Gichuki, 2000). The farm plots at Lake Tana area are fragmented and usually supervised by the owners; this might contribute for less use of croplands. The breeding and non-breeding adult and sub-adult usually roost in the wetland except during the end of the dry season where the water level is reduced with less vegetation (Walkinshaw, 1964; Pomeroy, 1980b). Breeding pairs usually move to the edge of the wetland before sunrise to forage. The edge of the wetland could be rich in food source and cranes might come to consume grits for digestion.

It is more common to find large number of cranes during the dry season than the wet, post-rainy and pre-rainy seasons. This could be due to the food availability during the dry time. The crop fields were available for cattle due to crop harvesting time, then fallen crops in the soil will be more abundant than during the rainy and pre-rainy time. This result coincides with Gichuki (2000) and Shimelis Aynalem (2017). But during the pre-rainy period, less number of cranes was observed. Gichuki (2000) reported that cranes are more dispersed during the pre-rainy or towards the end of dry season due to competition of resources due to food scarcity.

There was a significant difference on the observation of cranes in study sites. Black Crowned Cranes were more distributed in the wetland habitat than in the farmlands. The Chimba wetlands were the most suitable area where most cranes occurred. The suitability of the site in terms of vegetation cover, food availability, less disturbance and size could account for the higher number. Pomery (1980b) reported that there is less competition of resources in larger areas than smaller ones. Gichuki (1993) also found the density of cranes high where there is abundant food resources. He also reported that the location of feeding sites in relation to roosting sites influence the foraging ranges of individual cranes.

Detection function decreases with increase of the perpendicular distance from the line transect (Buckland *et al*., 2001; Thomas *et al*., 2010). However, detection probability does not depend on distance where the cranes are located from the observer only. It may depend on the ability of the surveyor, the characteristics of the individual animals, environmental or weather conditions, and other factors (Buckland *et al*., 2001). Nevertheless, it is sometimes useful to model the detection probability as a function of variables other than distance, because detection probability can be influenced as density is correlated with detection probability; or a large component of the variance of the abundance estimate is due to estimation of the detection function, and this variance can be 'explained' by variables other than distance. Detection probability changes across strata but there are inadequate detections in some strata to allow separate estimation of detection probability within each stratum (Burnham *et al*., 1980; Buckland *et al*., 2001).

The cluster size of cranes in wetland and farmland habitats at which cranes were observed had no supported relationship, and statistically did not vary. The behavior, availability of food, competition of individuals with and across bird species could be accounted for weak relationship. However, the cluster size of cranes in the wetland habitat was found more than in the farmland habitat.

Breeding populations of most bird species tend to remain fairly constant over time (Lack, 1966). In long-lived species with low reproductive rates and late age at first breeding, such as cranes, population parameters tend to change slowly and their effects on the reproductive success of individuals may be difficult to detect or measure. Because of the short duration of the present study, it was not possible to demonstrate the effects of each month on the density of Black Crowned Cranes. However, the data generated were important for understanding the population ecology of cranes in the Lake Tana area.

During the wet season in 2015, crane density in the wetland was estimated at 0.2 /ha while in the farmland, it was 0.08 /ha. This result is more than 10 times smaller than cranes that occur in Kenya area averaging 200/ha (Gichuki, 1993). Since farmlands are occupied by crops during the wet season, only wetlands are available for cranes. As a result, cranes might be located in several places. The total population of Black Crowned Crane at Lake Tana was estimated at 1472 in the wetland and 639 in the farmland. This is higher than Kitale, Kenya (Gichuki, 1993). The possible reason for this abundance in Lake Tana area could be the size of the area, presence of different pocket wetlands, availability of sparsely distributed feed resources and presence of inter and intra-specific competition of bird species when cranes were forced to disperse everywhere in the Lake Tana area.

During the dry season, there was no supported relationship of distance with cluster size of cranes. The mean cluster size of cranes in the wetland and farmland habitat did not vary, but far from the wet season. The availability of feed sources in the wetland could be accounted for high cluster size during the dry season. However, in all cases the cluster size during the wet season was higher than the dry season in the wetland habitat. The concentration of cranes in the wetland habitat during the study period could be accounted for this difference.

During the dry season in 2016, crane density in the wetland habitat was estimated to be 0.36/ha, while in the farmland, it was, 0.14/ha. Still the density of cranes is very small compared to the reports of Gichuki (1993). The available area is larger so that cranes can disperse reducing the density. The small food resource could also account for high area occupancy per individuals or clusters of cranes.

There was variation in density and population during the wet and dry seasons. The difference could be due to variation in effort, weather condition, and movement of cranes and feed availability. In both cases, the density of cranes at Lake Tana area is far from the report obtained by Shimelis Aynalem *et al*. (2011) and Shimelis Aynalem *et al*. (2017). However, the result of this study can be taken as a bench mark since the study has addressed several sites, habitats, seasons and took tremendous time of study in the field.

Chimba and Yiganda watershed area are the best places to harbor the most important wetland area in Lake Tana sub-basin for Black Crowned Cranes. The location of Chimba adjacent to Gilgel Abay River and Yiganda wetland to the shore of the lake gives both wetlands to be preferred by several wintering and resident birds. Important breeding sites for cranes occur here. But these sites, because of their location to the water source are under human pressure. The human pressure can impact on the future existence of this pristine wetland ecosystem due to the land use land cover (LULC) change from time to time. Agricultural encroachment, sedimentation due to the outflow of the river and erosion in the upper catchment, and high livestock pressure and population growth for more land are the main factors for the change.

During the 1986 and 2016 periods, a tremendous change had occurred. When we compare the wetland change in 1986 to 2016, Chimba wetland was more affected in which 705.33 ha was changed into other LULC; whereas in Yiganda 130.24 ha was changed during the last 30 years. When we see the linear trend, change of LULC could affect crane ecology by reducing the habitat availability for cranes.

Intensive agriculture, persecution of cranes during foraging in crop fields, overgrazing, invasive species and pollution are the most threats of cranes at Lake Tana. This observation has been reported in various ways (Shimelis Aynalem and Afework Bekele, 2008; Shimelis Aynalem *et al*., 2008; Shimelis Aynalem and Afework Bekele, 2009; Shimelis Aynalem *et al*., 2011; Shimelis Aynalem, 2013; Shimelis Aynalem *et al.*, 2017a and b). Freshwater ecosystems generally have been altered by human disturbances such as agriculture, urban development, impoundment, channelization, mining, road construction and species introduction (LaBonte *et al.*, 2001). These led to severe degradation and loss of biodiversity (Vinson and Hawkins, 1998) and as a result, these ecosystems have become one of the most endangered ecosystems on the planet (Dudgeon *et al.*, 2006).

The ratification of Multilateral Environmental Agreements (MEA) are relevant to environmental resource conservation including wetland such as "The United Nations Framework Convention on Climate Change" (1994), the Convention on Biological Diversity (1994), the United Nations Convention to Combat Desertification (1994), the Cartagena Protocol on Bio-safety to the Convention on Biological Diversity (2000), African Eurasian Water Bird Agreement (AEWA), Convention concerning the protection of World Cultural and Natural Heritage (6 July 1977), and Convention on International Trade in Endangered Species of Fauna and Flora (5 April 1989). Those treaties, legislations and polices are unless practiced, cannot be a guarantee to conserve cranes and their habitats. However, the treaties, legislations and policies could be helpful when designing a certain conservation based project.

The poor implementation practice of rules and regulations in Lake Tana wetlands; the inadequate and absence of environmental education for the community; the inactive participation of stakeholders to make Lake Tana Biosphere Reserve into reality; the weak bylaws of the community designed to utilize the wetland resource sustainably in the area; absence of job opportunities for the landless locals will remain to be the main challenges in conserving cranes and their habitats in the future.

6. CONCLUSION AND RECOMMENDATIONS

Black Crowned Cranes occur in disjuncted sub-populations through the Sahel and Sudan-Guinea savanna zones of Africa. The western sub-population (*B. pavonina pavonina*) is under alarming rate of decline. The ecology of the eastern sub-population (*B. pavonina ceciliae*) is less well-known. Studying the breeding and feeding ecology, the distribution and the habitat characteristics where the species lives will provide essential information to both evolutionary biologists and conservation managers.

The results suggest that the time of nesting influences the breeding performance of Black Crowned Cranes in a range of different ways. Early initiation of nest construction, egg laying and hatching in a secure breeding site during the post-rainy time particularly September to October result in the highest pre-fledging success of cranes than cranes initiated nest construction lately during December. The presence of adequate vegetation cover, water depth, availability of food for juveniles, and less chance of human disturbance due to water level around the nest account the success history of cranes during the specified season. Therefore, protection and conservation of cranes and their habitats should be synchronized and associated with the peak nesting time during the post-rainy time.

Cranes utilize nest materials collected from the nesting place just around the nest. This might decrease the energy expenditure during nest material searching. Therefore, nest material selection or preference is not a matter of species specificity rather becomes a matter of availability around the nest area. The morphometric measurement of eggs and clutch size for Black Crowned Crane could be genetically species specific. But, the mean weight of eggs could vary depending on the size of clutch. However, there was no variation seen in the overall mean of egg weight, egg length and width. Food is the key regulator of populations. The type of feed resource distributed in an area could vary spatially and seasonally. The type of food preference by cranes could be associated with the foraging behavior as the anatomical structure of a bird can impact on the type of food utilized. At Lake Tana area, the wetland and farmland areas were the sole places where cranes forage. During the breeding time, the wetlands are more important places because the juveniles are entirely dependent on it to get all the requirements until they fledge. The abundance and the type of food available, and the characteristics of food in the diet were estimated and determined in the field. The habitats, study sites and seasons have affected the distribution of cranes across the study area significantly. It is more common to find large number of cranes during the dry season than the wet, post-rainy and pre-rainy season. The availability of food, the addition of newly recruited fledged cranes to the adult crane population play a significant role.

The cluster size of cranes in wetland and farmland habitat during the dry season showed that Black Crowed Crane consisted of a small number of cranes per family. However, the wetland habitat was more suitable than the farmland in consisting larger cluster size. This factor accounted for the occurrence of large population of Black Crowned Cranes during the dry season.

The loss of wetlands worldwide, particularly in developing countries has been exacerbated from time to time. As agricultural activities have expanded and intensified over the past decades, landscapes have been substantially altered in nearly all regions. Chimba and

Yiganda wetlands are main breeding and feeding sites of cranes. During the 30 years period, more than 700 ha of wetland in Chimba and 130 ha in Yiganda have been converted in to other land forms. As a result, the crane habitats have shrunk down to a level that requires recovery and protection to save the remaining patch of wetland. If this scenario continues, the crane habitat can be extinct in the near future together with the cranes.

The following recommendations are proposed for habitat conservation of cranes*:*

- Clear demarcation of private land that is situated adjacent to the wetlands should be carried out to prevent encroachment to wetlands.
- Agricultural inputs (herbicides and pesticides) are increasing from time to time. Organic farming should be promoted, and application of agricultural input should be used wisely and professionally.
- The bad perception of the community on cranes is increasing, as cranes are damaging some crops, therefore, environmental education should be strengthened in schools, and at community level where cranes forage and nest.
- Community based utilization of the wetland resource should be properly designed.
- The propagation and dissemination of invasive species in the wetlands should be controlled manually or mechanically than using chemicals and biological methods.
- Generally, the pollution level on Lake Tana wetlands is minimal. However, the new advent of flower farms, hotels and camps at the edge of the lake and without a treatment plant is dangerous. Proper EIA must be implemented to avoid further damage on the ecosystem, and to restore it.

Research gaps that should be carried out in the future:

- Habitat suitability index should be studied for cranes in Ethiopia;
- The reproductive performance and behavior of cranes should be studied using ringed birds;
- The social and breeding behavior of cranes should be studied in detail;
- Satellite tracking should be carried out in order to determine the home range and movements pattern of cranes seasonally;
- Population ecology of crane sex ratio, social structure and age structure in particular should be researched out;
- Detailed fecal diet analysis should be carried out;
- Potential diseases of cranes and mortality factors in the wild should be studied in detail;
- Human and crane conflict, and the impact of cranes in the agricultural fields should be widely investigated.
- Strengthen communication of the network.
- Regularly monitoring the population should be practical
- Annual census or systematic count of cranes all over the country should be carried out to know the status of crane population.

7. REFERENCES

Abebe Ameha, Chalachew Aragaw Zeleke, Minwyelet Mengist Zerihun and Goraw Goshu Yemer (2017). The fish and the fisheries of Lake Tana. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 157 – 178 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

Abebe Getahun and Eshete Dejen (2012). *Fishes of Lake Tana. A guide Book.* Addis Ababa University Press. Addis Ababa.

Abrhet Kehasay, Ayalew Wondie, Minwuyelt Mengistand Vijverberg, J. (2014). Spatial and seasonal variation in the macro-invertebrates and physicochemical parameters of the Infranz River, Lake Tana sub-basin (Ethiopia). *Ecohydrology and Hydrobiology* **14:** 304 **-** 312.

An, S., Harbin, L., Baohua G., Changfang Z., Zhongsheng W., Zifa, D., Yingbiao, Z.,Yuhong, L., Chi, X. and Shubo, F. (2007). China's natural wetlands: past problems, current status, and future challenges. AMBIO: *Journal of the Human Environment* **36:** 335 **-** 342.

ANRS BoA (Amhara National Regional State Bureau of Agriculture) (2013). Community-Based Integrated Natural Resources Management Project in Lake Tana Sub-Basin, Volume 8 Baseline Report on Crop Production, (TCS), Bahir Dar.

Archibald, G. W. (1977). The unison call of cranes as a useful taxonomic tool. PhD dissertation. Cornell University, Ithaca, NY.

Archibald, G. W. and Lewis, J. C. (1996). Crane Biology. **In:** *Cranes: Their Biology, Husbandry, and Conservation*, pp 1-30 (Ellis, D. H., Gee, G. F. and Mirande, C. M. eds.). Department of the Interior, National Biological Service, Washington, DC.

Archibald, G. W. and Meine, C. (1996). Ecology, status, and conservation. **In:** *Cranes: Their Biology, Husbandry, and Conservation*, pp 263-292 (Ellis, D. H., Gee, G. H. and Mirande, M. C. eds.). Published by the Department of the Interior, National Biological Service and Washington, DC, and the International Crane Foundation, Baraboo, Wisconsin.

Archibald, G. W. and Viess, D. L. (1979). Captive propagation at the International Crane Foundation, 1973-78, pp. 51 – 74 (Lewis, J. C. ed.). Proceedings 1978 Crane Workshop, Dec. 6-8, Rockport, Colorado State University and National Audubon Society, Texas.

Armstrong, E. A. (2008). Diversionary Display. *Ibis* **91:** 179.

Arnold, T. W. and Ankney, C. D. (1997). The adaptive significance of nutrient reserves breeding American coots: a reassessment. *The Condor* **99:** 91 **-** 103.

Banchiamlak Getnet (2014). Impact of water hyacinth (*Eichhornia crassipes*) on water quality in the north-eastern part of Lake Tana, Ethiopia. Fisheries Wetlands and Wildlife Management, MSc. Thesis, Bahir Dar University.

Barrows, E. M. (2011). *Animal behavior desk reference: a dictionary of animal behavior, ecology, and evolution.* 3rd ed. CRC press, London.

Bates, G. L. (1934). Birds of the southern Sahara and adjoining countries in French West Africa. Part 5. *Ibis* **75:** 685 **-** 717.

Beilfuss, R. D., Tim D. and Urban, E. K. (2007). The status of cranes in Africa in 2005. *Ostrich: Journal of African Ornithology* **78:** 175 **-** 184.

Bennett, A. J. (1978). Ecology and status of Greater Sandhill Cranes in southeastern Wisconsin. M.S. Thesis, University of Wisconsin, Stevens Point.

Bennett, L. A. and A. J. Bennett (1992). Territorial behavior of Florida Sandhill Cranes in the Okefenokee Swamp. **In:** *Proceedings 1988 North American Crane Workshop, Feb. 22–24, 1988* (Wood D. A. ed.). *Lake Wales, Florida* (Tallahassee, F. L. : State of Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report #12, 1992), pp. 177 **-** 184.

Bento, C. B., Beilfuss, R. D. and Hockey, P. A. R. (2007). Distribution, structure and simulation modeling of the Wattled Crane population in the Marromeu Complex of the Zambezi Delta, Mozambique. *Ostrich* **78:** 185 **-** 193.

Bibby, C. J., Stuart, M. and Martin, J. (1998). Bird surveys, Expedition Advisory Centre.

Biru Yitaferu (2007). Land Degradation and Options for Sustainable Land Management in the Lake Tana Basin (LTB), Amhara Region, Ethiopia. Ph.D Thesis. Universität Bern, Bern.

Borad, C. K., Aeshita, M. and Parasharya, B. M. (2001). Nest site selection by the Indian Sarus Crane in the paddy crop agro-ecosystem. *Biological Conservation* **98:** 89 **-** 96.

Brix, H. (1997). Do macrophytes play a role in constructed treatment wetlands? *Water Science and Technology* **35:** 11 **-** 17.

Brooke, M. and Birkhead, B. (1991). The Cambridge Encyclopedia: Ornithology. Cambridge, Cambridge University Press, Cambridge.

Brown, D. S. (1994). Freshwater Snails of Africa and their Medical Importance, 2nd ed. Taylor and Francis Ltd, UK.

Brown, J. H. (1984). On the relationship between abundance and distribution of species. American Naturalist **124:** 255 **-** 279.

Brown, J. L. (1969). Territorial behavior and population regulation in birds: a review and re-evaluation. *The Wilson Bull.* **81:** 293 **-** 329.

Brown, L. H., and Britton, P. L. (1980). The breeding seasons of East African birds. Nairobi: East Africa Natural History Society, Addis Ababa.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. and Thomas, L. (2001). Introduction to distance sampling estimating abundance of biological populations. Oxford University Press, London.

Burger, J. and Gochfeld, M. (1990). Nest site Selection in Least Terns (*Sterna antillarum*) in New Jersey and New York. *Colonial Waterbirds* **13:** 31 **-** 40.

Burnham, K. P., Anderson, D. R. and Laake, J. L. (1980). Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* **72:** 3 **-** 202.

Cabot, D. (2009). *Wildfowl*. Harper Collins Publishers, London.

Callisto, M., Moreno, P. and Barbosa, F. A. R. (2001). Habitat diversity and benthic functional trophic groups at Serra Do Cipo, Southeast Brazil. *Revue Brasilia Biol*. **61:** 259 **-** 266.

Chaves, F. G. and Alves, M. A. S. (2013). Gender-related diet composition and morphometry of the Restinga Antwren, *Formicivora littoralis* (Aves. *Thamnophillidae*). *Zoologia* **30:** 601 **-** 606.

Claire, M. M., George, F. G., Ann, B. and Peter, W. (1996). Egg and semen production. **In:** Cranes: Their Biology, Husbandry, and Conservation, pp 45-58 (Ellis, D. H., Gee, G. H. and Mirande, M. C. eds.). Published by the Department of the Interior, National Biological Service and Washington, DC, and the International Crane Foundation, Baraboo, Wisconsin.

Clark, R. G. and Shutler, D. (1999). Avian habitat selection: pattern from process in nest-site use by ducks? *Ecology* **80:** 272 **-** 287.

Collins, N. B. (2005). Wetlands: The basics and some more. Free State Department of Tourism, Environmental and Economic Affairs. Free State.

Cramer, D. (1998). Fundamental statistics for social research. Routledge, London.

Cramer, D. and Howitt, D. (2004). The SAGE dictionary of statistics. SAGE, London.

CSA (2013). Area and production of major crops. The Federal Democratic Republic of Ethiopia Central Statistical Agency, Agricultural Sample Survey. *Statistical Bulletin* **532:** 124.

Doane, D. P. and Seward, L. E. (2011). Measuring Skewness. *Journal of Statistics Education* **19:** 1 **-** 8.

Dowling, D. K. (2004). Breeding biology of the red-capped robin. *Australian Journal of Zoology* **51:** 533 **-** 549.

Drewien, R. C., Brown, W. M. and Kendall, W. L. (1995). Recruitment in Rocky Mountain Greater Sandhill Cranes and comparison with other crane populations. *The Journal of Wildlife Management* **59:** 339 **-** 356.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z., Knowler, D. J., Leveque, C., Naiman, R. J., Prieur-Richard, A., Soto, D., Stiassny, M. L. J. and Sullivan, C.

A. (2006). Freshwater biodiversity: importance threats, status and conservation challenges. *Biological Reviews* **81:** 163 **-** 182.

Dugan, P. (1993). *Wetland in danger: a world conservation atlas*. Oxford University Press, Oxford.

Dwyer, N. C. and G. W. Tanner (1992). Sand Hill Crane. *The Wilson Bulletin* **104:** 22 **-** 31.

Edwards, S., Sebsebe Demissew and Hedberg, I. (eds.) (1997). *Flora of Ethiopia and Eritrea*. *Vol. 6: Hydrocharitaceae* to *Arecaceae*. EMPDA. The National Herbarium, Addis Ababa.

Elias Sime and Biazenlegn Solomon (2017). Hydrology of Lake Tana Basin. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 117 **-** 126 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

Ellis, J. E., Wiens, J. A., Rodell, C. F. and Anway, J. C. (1976). A conceptual model of diet selection as an ecosystem process. *Journal of Theoretical Biology* **60:** 93 **-** 108.

EPA (2012). National Report of Ethiopia, the United Nations Conference on Sustainable Development (Rio+20). Federal Democratic Republic of Ethiopia, Addis Ababa.

EPA, U. S. (2002). Methods for Evaluating Wetland Condition: Introduction to Wetland Biological Assessment. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

Fentahun Tesfa, Dagninet Amare, Merkuz Abera (2014). Evaluation of single yoke implement, harnessed and drawn by horse for cultivation of farmlands in north-western Ethiopia. *Journal of Agricultural Research* **2:** 38 **-** 46.

Finlayson, C. M., Davidson, N. C., Spiers, A. G. and Stevenson, N. J. (1999). Global wetland inventory–current status and future priorities. *Marine and Freshwater Research* **50:** 717 **-** 727.

Fishpool, L. D. C. and Evans, M. I., eds. (2001) Important Bird Areas in Africa and associated islands: Priority sites for conservation. Pisces Publications and BirdLife International (BirdLife Conservation Series No. 11). Newbury and Cambridge, UK.

Fox, J. M. (2011). Survival of Sandhill Crane colts in northeastern Illinois: the role of age and significance of land cover in an urbanized landscape. Ph.D. Dissertation. University of Illinois at Urbana-Champaign. Chicago.

Francis, I. and Shimelis Aynalem (2007). Bird surveys around Bahir Dar-Lake Tana IBA. Filed Report, RSPB International Division, UK.

Friis, E. M., Pedersen, K. R. and Crane, P. R. (2010). Diversity in obscurity: fossil flowers and the early history of angiosperms. Philosophical Transactions of the Royal Society of London B: *Biological Sciences* **365:** 369 **-** 382.

Friis, I. (1992). Forests and forest trees of northeast tropical Africa: their natural habitats and distribution patterns in Ethiopia, Djibouti and Somalia. Royal Botanic Gardens, Kew Bulletin, Her Majestry's Stationery Office, London.

Gaston, G. R. (1999). Wetland birds. Habitat resources and conservation Implications. Estuaries **22:** 1110 **-** 1111.

Gichuki, N. (2000). Influence of breeding on foraging behavior and diet of crowned cranes. *Ostrich* **71:** 74 **-** 79.

Gichuki, N. (1993). Factors affecting the reproductive success of the Grey Crowned Crane. Ph.D Thesis. Department of Zoology, University of Cambridge.

Gooderham, J. and Tsyrlin, E. (2002). *The Waterbug Book*: a guide to the freshwater macroinvertebrates of temperate Australia. CSIRO Publishing, Collingwood.

Gopi, S. K. (2009). Are rice paddies suboptimal breeding habitat for Sarus Cranes in Uttar Pradesh, India? *The Condor* **111:** 611 **-** 623.

Grubh, A. R. and Mitsch, W. J. (2004). Distribution and abundance of macro-invertebrates in created wetland ecosystems. **In:** Olentangy River Wetland Research Park Annual Report 2003, pp 105-116 (Mitsch, W. J., Zhang, L. and Tuttle, C. eds.). The Ohio State University, Columbus, Ohio.

Harris, J. (2012). Cranes, Agriculture and Climate Change. Proceedings of a workshop organized by the International Crane Foundation and Muraviovka Park for Sustainable Land Use. Printed in China by Beijing Foundart Colour Printing Co., Ltd.

Hedberg, I. and Edwards, S. (eds.) (1989). *Flora of Ethiopia. Vol. 3: Pitosporaceae to Araliaceae.* EMPDA. The National Herbarium, Addis Ababa.

Hedberg, I., Edwards, S. and Sileshi Nemomissa eds. (2003). *Flora of Ethiopia and Eritrea*. Volume 4, Part 1. *Apiaceae* to *Dipsacaceae*. Addis Ababa: The National Herbarium Biology Department, Science Faculty, Addis Ababa University.

Hilaluddin, J. N. S. and Tahir, A. S. (2003). Nest site selection and breeding success by Cattle Egret and Little Egret in Amroha, Uttar Pradesh, India. *Waterbirds* **26:** 444 **-** 448.

Hilsenhoff, W. L. (1988). Rapid field assessment of organic pollution with a family-level biotic index. *Journal North Amer. Bentholog. Soc*. **7:** 65 **-** 68.

Hinde, R. A. (1956). The biological significance of the territories of birds. *Ibis* **98:** 340 **-** 369.

Hoyt, D. F. (1979). Practical methods of estimating volume and fresh weight of bird eggs. *The Auk* **96:** 73 **-** 77.

Hughes, R. and Hughes, J. (1992). A directory of African wetlands. IUCN, Gland, Switzerland and Cambridge, UK/ UNEP, Nairobi / WCMC, Cambridge.

IBC (1998). Proclamation No. 120/1998 Institute of Biodiversity Conservation and Research, Addis Ababa.

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

IUCN (2016). The IUCN Red List of Threatened Species. Version 2016-3. www.iucnredlist.org . Downloaded on 03 February 2017.

Ivey, G. L. (2007). Factors influencing nest success of Greater Sandhill Cranes at Malheur National Wildlife Refuge, Oregon. M.Sc. Thesis. Oregon State University, Oregon.

Ivey, G. L. and Dugger, B. D. (2008). Factors Influencing Nest Success of Greater Sandhill Cranes at Malheur National Wildlife Refuge, Oregon. *Waterbirds* **31:** 52 **-** 61.

Johnsgard, P. A. (1983a). *Cranes of the World*. University of Nebraska, Lincoln.

Johnsgard, P. A. (1983b). Cranes of the World: Crowned Crane (*Balearica pavonina*). Cranes of the World, by Paul Johnsgard. Paper 12. http://digitalcommons.unl.edu/bioscicranes/12

Kefyalew Alemayehu and Asaminew Tassew (2017). Challenges and opportunities for increased farm animal productivity in Lake Tana Sub-basin. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 399 **-** 416 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

Konrad, P. (1981). Status and ecology of Wattled Crane in Africa. **In:** *Crane Research around the World*, pp 220 **-** 237 (Lewis, J. C. and Masatomi, H. eds.). Robinson Press, Fort Collins, Colorado.

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

Kumar, R. B., Anitha, K., Watve, A., Mani, S., Rehel, S., and Arisdason, W. (2011). The status and distribution of aquatic plants of the Western Ghats. **In:** *The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India*, pp 49 **-** 62 (Molur, S., Smith, K. G., Daniel, B. A. and Darwall, W. R. T. eds.). IUCN, Cambridge.

LaBonte, J. R., Scott, D. W., McIver, J. D. and Hayes, J. L. (2001). Threatened, endangered and sensitive insects in Eastern Oregon and Washington forests and adjacent lands. *Northwest Sci*.**75:** 185 **-** 198.

Lack, D. (1954). *The natural regulation of animal numbers*. Oxford: Clarendon Press. London. pp. viii + 343 pp.

Lack, D. L. (1966). *Population Studies of Birds*. Clarendon Press, Oxford.

Li, A., Deng, W., Kong, B., Song, M., Feng, W., Lu, X., Lei, G. and Bai, J. (2010). A comparative analysis on spatial patterns and processes of three typical wetland ecosystems in 3H area, China. *Procedia Environmental Sciences* **2:** 315 **-** 332.

Livezey, B. C. (1997). A phylogenetic classification of waterfowl (Aves: Anseriformes), including selected fossil species. *Annals of Carnegie Museum* **66:** 457 **-** 496.

Masese, F. O., Muchiri, M.and Raburu, P. O. (2009). Macroinvertebrate assemblages as biological indicators of water quality in the Moiben River, Kenya. *Afr. Journal of Aquatic Sci*. **34:** 15 **-** 26.

Masese, F. O., Omukoto, J. O. and Nyakeya, K. (2013). Biomonitoring as a pre-requisite for sustainable water resources: a review of current status, opportunities and challenges to scaling up in East Africa. *Ecohydro. Hydrobiology* **13:** 173 **-** 191.

Meerhoff, M., Mazzeo, N., Moss, B. and Rodriguez-Gallego. L. (2003). The structuring role of free-floating versus submerged plants in a subtropical shallow lake. *Aquatic Ecology* **37:** 377 **-** 391.

Meine, C. D. and Archibald, G. W. (1996). The Cranes: Status Survey and Conservation Action Plan. IUCN, Gland, Switzerland, and Cambridge, 294pp. Northern Prairie Wildlife Research Center, Version.

Merkuz Abera (2017). Agriculture in the Lake Tana Sub-Basin of Ethiopia. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 375 **-** 398 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

MoFED 2006. Ethiopia: Building on Progress- A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10), Volume I: Main Text. Ministry of Finance and Economic Development (MoFED), FDRE, Addis Ababa.

Morrison K, Beall F, Friedmann Y, Gichuki C, Gichuki N, Jordan M, Kaita M, Ndang'ang'a P, Muheebwa J. (2007). African Crane Trade Project: Trade Mitigation Planning Workshop. Workshop report. Conservation Breeding Specialist Group (SSC/IUCN)/CBSG Southern Africa, International Crane Foundation/Endangered Wildlife Trust Partnership Johannesburg.

Mukherjee, A. (1999). Ecological Study on the Sarus Crane (*Grus antigone*) in the central Gujarat, Saurashtra. Ph.D. Thesis. University of Saurashtra, Rajkot.

Mukherjee, A., Soniya, V. C., Borad, C. K. and Parasharya, B. M. (2000). Nest and eggs of Sarus Crane (*Grus antigone antigone* Linn.). *Zoos' Print Journal* **15:** 375 **-** 385.

Myers, J. P. l., Williams, S. L. and Pitelka, F. A. (1980). An experimental analysis of prey availability for sanderlings (Aves: Scolopacidae) feeding on sandy beach crustaceans. *Canadian Journal of Zoology* **58:** 1564 **-** 1574.

Nesbitt, S. A. (1988). Nesting, Re-nesting, and Manipulating Nesting of Florida Sandhill Cranes. *Journal of Wildlife Management* **52:** 758 **-** 763.

Nesbitt, S. A. (1989). The significance of mate loss in Florida Sandhill Cranes. *The Wilson Bulletin* **101:** 648 **-** 651.

Nowald, G., Schröder, W. and Wilhelmi, F. (2007). First Survey of Eurasian Cranes (*Grus grus*) in Ethiopia. Unpublished Report by Crane Conservation Germany Crane Information Center GroßMohrdorf, Mohrdorf.

Nudds, T. D. (1983). Niche Dynamics and Organization of Waterfowl Guilds in Variable Environments. *Ecology* **64:** 319 **-** 330.

Ojanen, M. (1983). Significance of variation in egg traits in birds, with special reference to Passerines. *Acta Univ. Oulu. Biol*. **20:** 1 **-** 61.

Owino, A. O. and Ryan, P. G. (2006). Habitat associations of papyrus specialist birds at three papyrus swamps in western Kenya. *African Journal of Ecology* **44:** 438 **-** 443.

Perrins, C. M. and Middleton, A. L. A. (1987). *Cranes and rails*. *Encyclopedia of Birds*. C. M. Perrins and A. L. Middleton., Equinox (Oxford) Ltd. New York.

Phillips, S. (1995). *Flora of Ethiopia and Eritrea*: *volume 7. Poaceae (Gramineae).* Addis Ababa, Uppsala: The National Herbarium, Biology Department, Science Faculty, Addis Ababa University.

Pomeroy, D. (1980a). Aspects of the ecology of Crowned Cranes (*Balearica regulorum*) in Uganda. *Scopus* **4:** 29 **-** 35.

Pomeroy, D. (1980b). Growth and plumage changes of the Grey Crowned Crane (*Balearica regulorum gibbericeps*). *Bull. Brit. Ornith. Club* **100:** 219 **-** 223.

Prasanth, J. J., Rao, V. V. and Nagulu, V. (1994). Nesting, egg size, incubation and factors affecting clutch size in Little Egret (*Egretta garzetta*) at Nellore Andhra Pradesh. *Pavo* **32:** 67 **-** 72.

Ralph, C. P., Nagata, S. E. and Ralph, C. J. (1985). Analysis of droppings to describe diets of small birds. *Journal of Field Ecology* **56:**165 **-** 174.

Rao, V. V. S. G., Nandakishore P., Reddy, K. S. and Sankaran, S. (2003). Solid Waste Disposal Practices: Implications on Groundwater Pollution. **In:** *Recent Advances in Environmental Science,* pp 214 **-** 218 (Hiremath, K. G. ed.). Discovery Publishing House, New Delhi.

Razail, N. M. and Wah, Y. B. (2011). Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *Journal of Statistical Modeling and Analytics* **2:** 21 **-** 33.

Ricklefs, R. E. (1969). *An Analysis of Nesting Mortality in Birds*. Smithsonian Institution Press, District of Colombia, Ohio.

Risch T. S. and Rohwer F. C. (2000). Effects of parental quality and egg size on growth and survival of herring gull chicks. *Canadian Journal of Zoology* **78:** 967 **-** 973.

Romanoff, A. L. and Romanoff, A. J. (1963). *The Avian Egg*. John Wiley and Sons, Inc., New York.

Rounds, R. A., Erwin, R. M. and Porter, J. H. (2004). Nest-site selection and hatching success of waterbirds in coastal Virginia: some results of habitat manipulation. *Journal of Field Ornithology* **75:** 317 **-** 329.

Schifferli, L. (1973). The effects of egg weight on the subsequent growth of nestling Great Tits (*Parus major*). *Ibis* **138:** 2 **-** 15.

Schoff, G. H. and Thompson, D. H. (1991). Reflections, the Story of Cranes, International Crane Foundation. Wisconsin.

Shapiro, S. S. and Wilk, M. B. (1965). An Analysis of Variance Test for Normality (Complete Samples). *Biometrika* **52:**591 **-** 611.

Shewaye Deribe (2007). Wichi Integrated Wetland-Watershed Management Project. Presentation prepared for the international conference on Population, Health, and environment: integrated Development for east Africa. Addis Ababa.

Shimelis Aynalem (2017). Birds of Lake Tana Sub-Basin. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 179 **-** 206 (Stave, K., Goraw. Goshu and Shimelis Aynalem eds.). Springer.

Shimelis Aynalem and Abebe Amha (2017). Herpetofauna and Mammals. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 207 **-** 230 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

Shimelis Aynalem and Afework Bekele (2008). Species composition, relative abundance and distribution of bird fauna of riverine and wetland habitats of Infranz and Yiganda at southern tip of Lake Tana, Ethiopia. *Tropical Ecology* **49:** 199 **-** 209.

Shimelis Aynalem and Afework Bekele (2009). Species composition, relative abundance and habitat association of the bird fauna of montane forest of Zegie peninsula and nearby islands, Lake Tana, Ethiopia. *SINET: Ethiop. J. Sci*. **32:** 45 **-** 56.

Shimelis Aynalem Zelelew (2013). *Birds of Lake Tana Area, Ethiopia: A photographic Field Guide*. View Graphics and Printers, Addis Ababa.

Shimelis Aynalem, Afework Bekele and Abebe Getahun (2008). Species Diversity, Distribution, Relative Abundance and Habitat Association of the Avian Fauna of Modified Habitat of Bahir Dar and Debre Mariam Island, Lake Tana, Ethiopia. *International Journal of Ecology and Environmental Science* **34:** 259 **-** 267.

Shimelis Aynalem, Goraw Goshu and Ayalew Wondie (2017a). Wetlands of the Lake Tana watershed. **In:** *Social and Ecological System Dynamics: Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia*, pp. 245 **-** 256 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

Shimelis Aynalem, Nowald, G. and Schroder, W. (2011). Observation on the biology and ecology of cranes: Wattled Cranes (*Bugeranus carunculatus*), Black Crowned Cranes (*Balearica pavonina*), and Eurasian Cranes (*Grus grus*) at Lake Tana, Ethiopia. *Journal of African Crane Research and Conservation* **1:** 1 **-** 12.

Shimelis Aynalem, Nowald, G., Archibald, G., Hadis Tadele, Abebayehu Aticho, Tariku Mekonen, and Morrison, K (2017b). Cranes, Wetlands, their Conservation Status and Threats in Ethiopia. *Ostrich* in Press.

Slagsvold, T. (1981). Clutch size and population stability in birds: a test of hypotheses. *Oecologia* **49:** 213 - 217.

Smith H. G. and Bruun M. (1998). The effect of egg size and habitat on starling nestling growth and survival. *Oecologia* **115:** 59 - 63.

Snow, D. W. (1978). An atlas of speciation in African non-passerine birds, British Museum Press.

Souttou. K., Baziz, B., Doumandji, S., Denys C. and Brahimi, R. (2006). Analysis of pellets from a suburban Common Kestrel (*Falco tinnunculus*) nest in El Harrach, Algiers, Algeria. *Ostrich* **77:** 175 - 178.

Steel, N. R. (1977). Breeding the Grey-necked Crowned Crane. *Avicultural Magazine* **83:** 63 - 68.

Stephens, D. W. and Krebs, J. R. (1986). *Foraging theory*. Princeton University Press.

Surmacki, A., Stępniewski, J. and Zduniak, P. (2003). Repeatability of egg dimensions within the clutches of Bearded Tit (*Panurus biarmicus*). *Acta Ornithologica* **38:** 123 - 127.

Sutherland, W. J. (2000). *The Conservation Handbook*: *Research, Management and Policy*. Blackwell Publishing Company.

Sutherland, W. J. (2006). *Ecological Census Techniques*. UK, Cambridge University Press.

Sykes Jr, P. W. (1987). The feeding habits of the snail kite in Florida, USA. *Colonial Waterbirds* **10:** 84 **-** 92.

Tacha, T. C., Haley, D. E., and Vohs, P. A. (1989). Age of sexual maturity of Sandhill cranes from mid-continental North America. *The Journal of wildlife management* **53:** 43 **-** 46.

Taddesse Amsalu (2006). Current land management in Lake Tana watersheds: Future challenges and opportunities for sustainable land management. In: Proceedings of the national consultative and promotional workshop on Lake Tana and its environs: Conservation, utilization, development and threats, EPLAUA, Bair Dar, 6-7 November, 2006

Tenagne Addisu (2009). The impact of urban storm water runoff and domestic waste effluent on water quality of Lake Tana and local Groundwater near the city of Bahir Dar, Ethiopia. M.Sc. Thesis, Faculty of the Graduate School of Cornell University.

Thomas, L., Buckland, S. T, Burnham, K. P., Anderson, D. R., Laake, j. L., Borchers, D. L. and Strindberg, S. (2002). Distance sampling. **In:** *Encyclopedia of Environmetrics* (ISBN 0471 899976). Volume 1, pp 544 **-** 552, (El-Shaarawi, A H. and Piegorsch, W. W. eds.). John Wiley and Sons, Ltd, Chichester.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bisho, P. J. R., Marquest, T. A. and Burnham, K. P. (2010). Distance software: design and analysis of distance sampling survey for estimating population size. *Journal of Applied Ecology* **47:** 5 **-** 14.

Thorp, J. H. and Rogers, D. C. eds. (2011). *Field guide to freshwater invertebrates of North America*. Elsevier Inc. Amsterdam.

Toft, J. D., Simenstad, C. A., Cordell, J. R. and Grimaldo. L. F. (2003). The effects of introduced water hyacinth on habitat structure, invertebrate assemblages, and fish diets. *Estuaries* **26:** 746 **-** 758.

Tryjanowski, P., Kuczyński, L., Antczak, M., Skoracki, M. and Hromada, M. (2001). Within-clutch repeatability of egg dimensions in the jackdaw (*Corvusmonedula*): a study based on a museum collection. *Biologia Bratislava* **56:** 211 **-** 215.

Uhlenbrook, S., Mohamed, Y. and Gragne, A. S. (2010). Analyzing catchment behavior through catchment modeling in the Gilgel Abay, upper Blue Nile River basin, Ethiopia. *Hydrology and Earth System Sciences* **14:** 2153 **-** 2165.

UNESCO (2014). Lake Tana Biosphere Reserve, Ethiopia. Source: http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/africa/ethiopia/lake-tana/) accessed 1/31/2017.

Urban, E. K. and N. Gichuki (1991). Recent research and conservation activities with cranes in Africa. (Harris, J. T. ed.). Proceedings 1987 International Crane

Workshop Qiqihar, Heilongjiang Prov. China. Baraboo, Wisconsin: International Crane Foundation. 351 pp.

Urban, E. K., Fry, C. H. and Keith, S. (1986). *The birds of Africa*. Volume II, Gamebirds to pigeons. Academic Press, London.

Van Noordvijk, A. J. (1987). Quantitative ecological genetics of great tits. **In:** *Avian genetics*, pp. 363 **-** 380 (Cooke, F. and Buckley, P. A. eds.). Academic Press, London.

Vinson, M. R.and Hawkins, C. P. (1998). Biodiversity of stream insects: variation at local, basin and regional scales. *Annu. Rev. Entomol*. **43:** 193 **-** 271.

Walkinshaw, L. H. (1950). The Sandhill Crane in the Bernard W. Baker Sanctuary Michigan. *Auk* **67:** 38 **-** 51.

Walkinshaw, L. H. (1964). The African crowned cranes. *The Wilson Bulletin* **76:** 355 **-** 377.

Walkinshaw, L. H. (1965). One hundred thirty-three Michigan Sandhill Crane nests. *Jack-Pine Warbler* **43:** 136 **-** 143.

Walkinshaw, L. H. (1973). *Cranes of the world*. Winchester Press, New York.

Wang, Q., Zhou, X. and Lu, X. (2013). The ‘Injury Feigning’ Displays of the Red-Crowned Crane. *Wilson Journal of Ornithology* **125:** 415 **-** 417.

Weller, M. W. (1972). Ecological studies of Falkland Islands' waterfowl. *Wildfowl* **23:** 25 - 44.

Weller, M. W. (1995). Use of two waterbird guilds as evaluation tools for the Kissimmee River restoration. *Restoration Ecology* **3:** 211 - 224.

Weller, M. W. (1999). *Wetland Birds*: *Habitat Resources and Conservation Implications*. Cambridge University Press, Cambridge.

Westlake, D. F. (1966). Some basic data for investigations of the productivity of aquatic macrophytes. **In:** *Primary productivity in aquatic environments*, pp 231 - 248 (Goldman, C. R. ed.) University of California press, California.

Williams T. D. (1994). Intraspecific variation in egg size and egg composition in birds: effects on offspring fitness. *Biol. Rev*. **68:** 35 - 59.

Williams, E. T. C., Beilfuss, R. D. and Dodman, T. (2003). Status survey and conservation action plan for the Black Crowned Crane (*Balearica pavonina*), Wetlands International, Bern.

Witmer, L. M. (1990). The craniofacial air sac system of Mesozoic birds (Aves). *Zoological Journal of the Linnean Society* **100:** 327 - 378.

Wubneh Belete, Tesfahun G/Michael, Elias Sime, Biaznelign Solomon and Fenta Negate (2017). Climate of Lake Tana Basin. **In:** Social and Ecological System Dynamics:

Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia, pp. 51 - 58 (Stave, K., Goraw Goshu and Shimelis Aynalem eds.). Springer.

8. APPENDICES

Appendix 1. MANOVA factor interaction (Habitat*Site* Season), where N=400.

Source	Statistic	df	F(df1,df2)	F	Prob>F
Model	W 0.6664	39	39.0 360.0	4.62	0.0000 e
	P 0.3336	360	39.0 360.0	4.62	0.0000 e
Residual					
Habitat	W 0.8918	2	2.0 360.0	21.85	0.0000 e
	P 0.1082		2.0 360.0	21.85	0.0000 e
Site	W 0.9359	4	4.0 360.0	6.17	0.0001 e
	P 0.0641		4.0 360.0	6.17	0.0001 e
Habitat*Site	W 0.9150	8	8.0 360.0	4.18	0.0001 e
	P 0.0850		8.0 360.0	4.18	0.0001 e
Season	W 0.9449	3	3.0 360.0	7.00	0.0001 e
	P 0.0551		3.0 360.0	7.00	0.0001 e
Habitat*Season	W 0.9553	2	2.0 360.0	8.42	0.0003 e
	P 0.0447		2.0 360.0	8.42	0.0003 e
Site*Season	W 0.9507	12	12.0 360.0	1.56	0.1023 e
	P 0.0493		12.0 360.0	1.56	0.1023 e
Habitat*Site*Season	W 0.9643	8	8.0 360.0	1.66	0.1059 e
	P 0.0357		8.0 360.0	1.66	0.1059 e
Residual		360			
Total		399			

W = Wilks' lambda, P = Pillai's trace, e = exact,* interaction

Appendix 2. List of Macrophytes Lake Tana wetlands, 2013.

Botanical Name	Family Name	Growth habit	Status	Dirma	Yiganda	Chimba	Remark
Acanthaceae	*Dyschoriste radicans* Nees	Herb	LC		✔	✔	weed
	Dyschoriste sp.	Herb	LC		✔	✔	
	Hygrophila schulli (Hamilt.) MR. and S.M Almeida	Herb	LC	✔	✔	✔	weed
Ceratophyllaceae	*Ceratophyllum demersum*	submerged		✔		✔	
Commelinaceae	*Floscopa glomerata* (Wild.ex JA. Schult.and JH. Schult.) Hassk				✔		
Convolvulaceae	*Ipomoea aquatic* Forssk.			✔	✔		Aquatic floater
Cyperaceae	*Cyperus rotundus* L.				✔		
	Cyperus articulates L.				✔		
	Cyperus papyrus L.				✔	✔	
	Cyperus longus L.				✔	✔	

Botanical Name	Family Name	Growth habit	Status	Dirma	Yiganda	Chimba	Remark
	Cyperus macrostachyos	Sedge	LC/2013		✔	✔	
	Cyperus dives			✔	✔	✔	
Menyanthaceae	*Nymphoides indica* (L.) O.Kunze	Water herb		✔			Float leaves
	Nymphaea lotus						
	Nymphaea nouchali var. caerulea			✔	✔	✔	
Onagraceae	*Ludwigia stolonifera* (Guilt L. and Perl'.) Raven			✔	✔	✔ ✔ ✔	
	Ludwigia sp.			✔	✔		
Poaceae	*Hyperrhenia rufa* Staps	Grass			✔		
	Andropogon gayanus Kunth.	Grass			✔		
	Snowdenia polystachya Pilg	Grass			?	?	

Botanical Name	Family Name	Growth habit	Status	Dirma	Yiganda	Chimba	Remark
	Echinochloa colona (L.)Link	Aqu.Grass		✔	✔ ✔		Aquatic
	Echinochloa crus-galli	Aqu.Grass		✔	✔	✔	Aquatic
	Echinochloa pyramidalis	Aqu.Grass			✔		Aquatic
	Echinochloa stagnina (Retz.) P. Beauv.	Aqu.Grass		✔			Aquatic
	Leersia hexandra SW.			✔	✔		
	Pennisetum sphacelatum (Nees) Th. Dur. and Schinz			✔			
	Sacciolepis Africana CE. Hubb.and Snowden			✔	✔		
	Pennisetum sp.						
	Oryza longistaminata			✔	✔ ✔		

Botanical Name	Family Name	Growth habit	Status	Dirma	Yiganda	Chimba	Remark
	A. Chev. and Roehr.						
	Eleusine africana *Phragmites australis et karka* *Vossia cuspidate*	Akirma like		✔			edge part w
Pollygonaceae	*Persicaria senegalensis* (Meisn.) Sojak		LC	✔ ✔	✔		
Pontederiaceae	*Eichhornia crassipes*			✔			
Potamogetonanceae	*Potamogeton thunbergii* Cham. and Schlecht.	Submeregent				✔	
Sinopteridaceae	Cheilanthes sp.				✔		
Typhaceae	Typha latifolia			✔	✔ ✔ ✔		

Appendix 3. List of trees and shrubs Lake Tana wetlands, 2013.

No	Family Name	Botanical Name	Growth habit	Status	Dirma	Yiganda	Chimba
1	Acanthacea	*Acanthus sennii* Chiov.	Kosheshla	Shrub	✔	✔	✔
2	Boraginaceae	*Cordia africana* Lam.	Wanza	Tree		✔	✔
3	Celastraceae	*Catha edulis (Vahl)* Forssk.ex Endl.	Chat	Shrub	✔	✔	✔
4		*Juniperus procera* Endl	Tid	Tree		✔	
5	Euphorbaceae	*Croton macrostachyus* Del.Hochest.ex Del	Bisana	Tree			✔
6	Fabaceae	*Millettia ferruginea* (Hochest.) Back.	Birbira	Tree		✔	
7	Icacinaceae	*Apodytus dimidiata* var. acutifolia (A.Rich.)Boutique	Donga	Tree		✔	
8	Melianthaceae	*Bersama abyssinica* Fresen.	Azamir	Tree			
9	Moraceae	*Ficus sur* Forssk L.	Sholla	Tree		✔	✔
10		*Ficus sycomorus* L.	Bamba	Tree	✔	✔	✔
11		*Ficus vasta* Forssk L.	Warka	Tree	✔	✔	✔
12	Myrtaceae	*Sizygium guineense* (Wild.) DC.	Doquma	Tree		✔	✔
13	Podocarpaceae	*Podocarpus falcatus* (Thunb.) Mirb.	Zigba	Tree		✔	
14	Rubiaceae	*Rothmannia urcelliformis* (Hiern) Robyns	Barya koba	Tree		✔	

No	Family Name	Botanical Name	Growth habit	Status	Dirma	Yiganda	Chimba
15	Sapotaceae	*Mimusops kummel* A.DC.	Eshe	Not evaluates		✔	✔
16	Ulmaceae	*Celtis afaricana* Burm.f.	Kawa	Tree		✔	
17	Mimosoideae	*Albezia schimperiana*	Sesa	Tree		✔	✔

Appendix 4. Change detection between 1986 and 2013.

LULC 1986	LULC 2013	Area, m^2	%
Cultivated land	Farm village with trees and cultivation	958431.2	9.7
Cultivated land	Grass land	1449053.7	14.6
Cultivated land	Intensively cultivated land	7335464	73.9
Cultivated land	Marsh land	93155.2	0.9
Cultivated land	Natural forest	51737.9	0.5
Cultivated land	Shrub land	32681.1	0.3
Farm village with tree and cultivation	Farm village with trees and cultivation	2730373.4	27.1
Farm village with tree and cultivation	Grass land	882515.7	8.8
Farm village with tree and cultivation	Intensively cultivated land	5383736	53.4
Farm village with tree and cultivation	Marsh land	571638.5	5.7
Farm village with tree and cultivation	Natural forest	422203.4	4.2
Farm village with tree and cultivation	Shrub land	87947.1	0.9
Grass land	Farm village with trees and cultivation	15.1	0.2
Grass land	Intensively cultivated land	6087.7	99.8
Natural forest	Farm village with trees and cultivation	20957.6	0.8
Natural forest	Grass land	1124.3	0
Natural forest	Intensively cultivated land	32	0
Natural forest	Marsh land	24762.2	1
Natural forest	Natural forest	2533929.8	98.2
water body	Farm village with trees and cultivation	1146.5	0.8
water body	Marsh land	72.4	0.1
water body	Water body	136799.7	99.1
Wetland	Farm village with trees and cultivation	506824.4	9.5
Wetland	Grass land	29254.5	0.5
Wetland	Intensively cultivated land	75098.7	1.4

LULC 1986	LULC 2013	Area, m^2	%
Wetland	Marsh land	3978530	74.3
Wetland	Natural forest	597242.4	11.2
Wetland	Shrub land	42063.1	0.8
Wetland	Water body	122628.6	2.3

9. PLATE

Plate 15. Crane nest searching, nest location, eggs and measurements.

Plate description: A and B. Nest searching, C. Crane with nest, D, F-H. Nest with eggs, E. Nest without egg, I. Egg marking at crane nest, J. Egg measurement at nesting site, K. Dirt eggs, L. Egg weight measurement, M. Juvenile crane at Chimba, and N. A parent with pre-fledged cranes.

Plate 16. Black Crowned Crane feed collection, type and diet analysis.

A B C

D E F

G H I

I J K

Plate description: A. Mounting of macrophytes, B. *Oryza longistaminata* seed, C. *Leersia hexandra* seed, D. Crane feces, E. Crane feces collected, F. Feces prepared for lab analysis, G and H. Macroinvertebrate collection in the field, I. Macroinvertebrate biomass samples, I and J. Fecal analysis in the lab, K. Grass panicles ready for oven dry and weight measurement.