Bird diversity and land use on the slopes of Mt Kilimanjaro and the adjacent plains, Tanzania

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This study of bird distribution in the main land-use categories of the slopes of Mt Kilimanjaro, Tanzania, aims at understanding potential impacts of the land-use changes on birds. A land-use map of the study area was derived from a Landsat image, and land-use change information came from an earlier study by the author. Bird data were collected by observations along timed, standardized walks. Shannon (1948) indices of bird diversity for highlands, bushland and lowlands were 3.29, 2.99, and 2.62. The highland category was divided into two subcategories, homegarden and highland garden, as bird populations of the two were distinct. Highland garden had a higher diversity (3.15) than homegarden (3.07). The lower species diversity and number of individuals in homegardens was probably due to lower niche diversity and more human disturbance. Lowland fields had low diversity indices as they are dominated by large flocks of birds. The equitability indices for highlands, bushlands and lowlands were 0.82, 0.80 and 0.65, respectively. Each land-use type had many species that were not seen in the others. As bushland is disappearing, the species currently threatened are the 15 bushland species that are not found in other land-use types. Growing population pressure leading to deagrarianization of the homegarden area is likely to affect homegarden bird populations, though it is not clear whether the very high human population density will prevent it from supporting a highland garden type of a bird population.

Key words: similarity, biodiversity, land-use change.

INTRODUCTION

Land-use change is known to be a key driver of biodiversity change (Sala et al. 2000). Over the decades land-use changes on Mt Kilimanjaro have had significant impacts on both floral and faunal diversity. Changes from natural vegetation to cultivated land have led to a decrease in indigenous plant species diversity, and an increase in exotic plant species (Misana et al. 2003). Intense habitat alteration has also contributed to the disappearance of many species of birds (Moreau 1944) and mammals (Newmark et al. 1991; O’Kting’atti & Kessy, 1991; Noe 2002). Land-use changes have also led to land degradation, which in turn negatively affects species richness (Misana et al. 2003).

Demand for land to satisfy the food production needs of the growing human population has been the most important driver of land-use change. The southern slopes of Mt Kilimanjaro below the forest reserve boundary (at about 1800 m) are now dominated by agriculture varying from the intensive tree-dominated homegarden systems adja-

cent to the forest to the extensive fields on the lowland plains at about 700 m. Interspersed with this are remnant bushland areas. Soini (2005a) used aerial photographs from 1961, 1982 and 2000 to show that the main changes were the gradual disappearance of natural bushland vegetation and the expansion of cultivated land. In the early 1960s, bushland (mainly Anderson’s (1982) categories of wooded grasslands, bushed grasslands and bushlands) covered 40% of the study area. By 2000, remaining bushland covered just 7% of the area. Increasing exploitation of the remaining bushland for grazing, firewood collection and volcanic brick cutting, associated with the increased human population of the lowlands is also changing the nature of the habitat. Most of the bushland appears overgrazed and large trees have been cut down. Bushlands have become very fragmented and are now found mainly on the tops of isolated steep volcanic hills. The mean patch size of bushlands in the study area has decreased from 119.4 ha in 1961 to 35 ha in 2000. The core bushland area, calculated with a 50 m buffer zone, has decreased from 4238.6 ha in 1961 to a mere 680.1 ha in 2000.

Homegardens, the tree-dominated highland
farming system, has not extended to lower altitudes since 1961, but this land-use type has undergone significant internal changes, largely due to increasing fragmentation as farms are subdivided among sons. The number of trees has decreased as more land is needed for houses, yards and vegetable gardens. The area is now more densely populated than many areas categorized as urban. Population density in the highlands (1200–1800 m) is about 650 persons per km² (Moshi Rural District Council, pers. comm.).

The lowlands have only recently been used for cropping and permanent habitation, previously being considered either too dry or with a high incidence of malaria. Lowlands now have approximately 250 persons per km², but the population tends to be clustered in settlements, leaving bush and agricultural areas with much lower human densities.

Much research on bird diversity emphasizes the general negative effects of conversion of natural habitats to human-dominated habitats (e.g. Blankespoor 1991; Myers 1992; Ranjit Daniels et al. 1992; Andrade & Rubio-Torgler 1994; Brooks et al. 1997; Estrada et al. 1997; Castelletta et al. 2000; Sinclair et al. 2002; Daily et al. 2001). But human-dominated and agricultural habitats vary considerably and therefore responses of birds to habitat changes differ depending on their lifestyle strategies (Robinson et al. 2001; Wolf et al. 2001; Tworek 2002). However, fragmentation of habitats usually leads to a decrease in numbers of a species or eventually its absence (e.g. Winter & Faaborg 1999; Cornelius et al. 2000; Zanette 2000; Zanette et al. 2000; Johnson & Igl 2001; Beier et al. 2002; Herkert et al. 2003; Kurosawa & Askins 2003). This study comparing bird distribution in the main land-use categories of the study area aims at understanding potential future impacts of the land-use changes on birds. As avian communities have been found to function as indicators of overall biodiversity and environmental decline or recovery (e.g. Nohr & Jorgensen 1997; Canterbury et al. 2000; Chase et al. 2000), bird distribution should give an indication of the general biodiversity levels of the main land-use categories of the study area.

STUDY SITE

The study area is situated on the southeastern slopes and adjacent plains of Mt Kilimanjaro, the highest (5895 m) mountain in Africa, in northern Tanzania (03°04’S, 37°22’E). Three distinct altitudinal agro-ecological zones can be identified (Fig. 1a): 1) a lowlands zone of extensive livestock farming and open crop fields, with remnant bushland patches; 2) a midlands maize/bean belt which is a mosaic of homegardens and open fields, with few bushland patches interspersed between; and 3) a highland homegarden area dominated by coffee and banana, with many large trees. Lowlands extend up to about 900 m, midlands up to 1200 m and the homegarden area to about 1800 m above sea level, up to the lower forest boundary. Annual rainfall varies according to the altitude, being 400–900 mm in the lowlands, 1000–1200 mm in the midlands and 1200–2000 mm in the homegarden area (Moshi Rural District Council, pers. comm.; Zongolo et al. 2000). This study focused on lowlands and homegarden areas as this is where most change has been detected.

There are considerable differences in human disturbance levels between homegardens, bushlands and lowlands. The homegarden area is a very disturbed habitat throughout the year, bushlands are to some extent disturbed by firewood collection and grazing all around the year. The level of disturbance in lowlands depends on the cultivation activities taking place in the fields. This study took place at times when there was little human activity in the lowland fields.

LANDSAT IMAGE INTERPRETATION

Land-use information used in this survey is based on Landsat +ETM satellite image interpretation (Fig. 1c) and Anderson’s (1982) vegetation survey. Land-use change information is based on study of aerial photographs from 1961, 1982 and 2000 (Soini, 2005a). The Landsat image was taken on 17 February 2000, only one day after the aerial photographs of the year 2000. Land-use information from the Landsat image was used here as it is more detailed and objective than visual interpretation of the aerial photographs.

The image was auto-classified by the Fuzzy C Mean algorithm (TNTmips 6.4 manual 2000). This was the only method out of a number tested (including Simple One-Pass Clustering, K Means, Minimum Distribution Angle, ISODATA, Self Organization and Adaptive resonance) that could satisfactorily distinguish between bushland and lowland agricultural land.

Landsat (ETM) bands 2, 3, 4, 5, 6h and 7 were used in the classification. The original number of classes was fifteen and the maximum iteration time ten. Seven land-use categories were left in the final interpretation. The initial merging was done
Fig. 1. The study area on the southern slopes of Mt Kilimanjaro in Tanzania. Land-use map derived from Landsat + ETM image of February 2000.
based on accumulated knowledge of the area due to extensive fieldwork, landscape photographs and aerial photographs. Three by three (3 × 3) pixel majority filter was later applied to the classification. Ground-truthing was conducted in mid-February 2002. This was done by selecting 56 control points, eight points from each of the categories except the tiny forest patches in the upper part of the study area and the lowland fields. The Tracking analyst facility of a real-time Global Positioning System (GPS) was used to navigate to the control points. The NDVI image was the best reference for defining the forest boundary even though using NDVI in the auto-classification did not distinguish forest from adjacent homegardens. Percentages of ground-truthing points (total of 56 points) at which each land cover component was found were used in defining the class descriptions (Table 1). In addition, photographs taken from known points (other than the ground-truthing points), and the aerial photographs were used as additional information in finding the right class descriptions.

Anderson’s (1982) vegetation classification of the region still remains the most comprehensive, but few patches of original vegetation types remain. All the land-use classes in the study area are, in one way or another, modified by human activities. Class 3 (Table 1) is close to Anderson’s Wooded grassland with *Acacia* and *Combretum*, though in places trees are wide apart due to the continuous utilization of the area by humans and livestock. Settlements (or scattered homesteads) consisting of small houses that are easily seen in the aerial photographs cannot be distinguished as a class of their own in a Landsat image as grass roofs and mud or stone walls have the same reflectance as surrounding areas and widely scattered small iron/zinc roofs do not make enough change to the reflectance of the Landsat image bands to be able to distinguish settlements from the other classes. Aerial photographs were used to define settlement areas for Fig. 1. Class 4 is mostly a remnant of Anderson’s Bushed grassland or Bushland. In places *Commiphora* can be found with *Acacia*. Class 5 represents areas with much bare soil, exposed, and includes the brick cutting sites on some of the volcanic conical hills. Class 6 can be a fallow/uncultivated field which some bushy vegetation has taken over. In the text all four classes of non-cultivated land in the lowlands are simply referred to as bushland.

| Land-use class |
|----------------|
| 1. Homegardens, riverines, forest* |
| 2. Lower homegardens, Riverines |
| 3. Wooded grassland or settlements with shrubs/trees (hedges in settlements) |
| 4. Bushland, grassland or fallow |
| 5. Much bare soil, scattered bush/shrubs/trees |
| 6. Open grassy area or terraced field |
| 7. Lowland agricultural fields (cultivated) |

*Note: The two small patches of forest in the study area were not ground-truthed.*

| Class | Coffee/banana farm | Big trees close together | Dense bush | Scattered bush/shrubs | Bare soil | Stony soil | Grass cover | Homesteads | Homesteads |
|-------|--------------------|--------------------------|-----------|-----------------------|----------|-----------|------------|-----------|-----------|
| 1. Homegardens, riverines, forest* | 100 | 75 | 25 | 75 | 25 | 75 | 25 | 12.5 | 87.5 |
| 2. Lower homegardens, Riverines | 75 | 100 | 37.5 | 12.5 | 37.5 | 12.5 | 37.5 | 12.5 | 87.5 |
| 3. Wooded grassland or settlements with shrubs/trees (hedges in settlements) | 100 | 75 | 25 | 75 | 25 | 75 | 25 | 12.5 | 87.5 |
| 4. Bushland, grassland or fallow | 50 | 100 | 25 | 75 | 25 | 75 | 25 | 12.5 | 87.5 |
| 5. Much bare soil, scattered bush/shrubs/trees | 37.5 | 37.5 | 87.5 | 12.5 | 12.5 | 87.5 | 12.5 | 12.5 | 87.5 |
| 6. Open grassy area or terraced field | 12.5 | 12.5 | 87.5 | 12.5 | 12.5 | 87.5 | 12.5 | 12.5 | 87.5 |
| 7. Lowland agricultural fields (cultivated) | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed | Class not ground-truthed |
BIRD DIVERSITY

Three main walk routes were selected in each of the three main land-use categories. Highlands were sampled by two routes in the homegarden area and one route in the highland garden area. Each main category had one additional walk done in another location. Within each land-use category, timed walks were undertaken each morning (three hours) and evening (two hours) starting from a central point. All birds within about 30 m from a predefined route were recorded. The aim was to walk along straight transects, but due to the terrain and obstructions this was not always possible. In the homegarden area footpaths were used.

Three main bushland routes were on Mabungo hill (840–1000 m) and the adjacent area (820–840 m) to the west (Fig. 1b). Mabungo area was selected because it is the largest single area of bushland in the study area and has enough uninterrupted bushland to accommodate a bird transect. Two routes were on Mabungo hill, the other main walk below the hill reached all the way to a small stream to the west of the hill. One additional walk was done in the evening on Nanga hill (830–900 m). This area comprises a very small patch of bushland in the middle of agricultural fields. Bushland walks were done in the middle of uninhabited patches, but there were schools and homesteads immediately adjacent to the walk areas.

Lowland walks (700–750 m) crossed open agricultural land where maize (Zea mays), millet (Eleusine coracana), beans (Phaseolus vulgaris) and sunflower (Helianthus annuus) were grown. There are some scattered trees on these open fields. The most common tree species in the lowlands is Faidherbia albida. Other typical farm trees include Azadirachta indica, Cassia siamea, Euphorbia tirucalli, Senna siamea, Leucaena leucocephala, Mangifera indica (Soini 2005b). One lowland walk was done east of Mue river (760–770 m) (Fig. 1b).

The sample area in the highlands consisted of both traditional Chagga homegardens and a European type garden (highland garden) (1300–1340 m). Homegardens immediately surrounded the highland garden. Both of the highland areas were close to a river. Homegardens are a traditional agroforestry farming systems in which coffee (Coffea arabica) and banana (Musa spp.) are the main crops. Many other food crops are grown and many trees are integrated into the system. The most conspicuous trees and/or useful species for the farmers include Albizia spp., Cordia holstii, Croton macrostachyus, Grevillea robusta and Rauwolfia caffra (Soini 2005b; A. Kessy, pers. comm.). Sometimes flowers are grown for decoration close to the house. The highland garden has much open space covered by grass, scattered trees of many species, both indigenous and exotic, flowerbeds, and a hedge partly around. An old vegetable garden was part of the highland garden survey area.

Walking pace was adjusted to make the length of all the walks approximately the same. Identification was visual except in some rare cases when voice was used if the bird could not be seen. Bird field guides by Van Perlo (1995), Zimmerman et al. (1999) and Stevenson & Fanshawe (2002) were used in identification. Nomenclature follows Stevenson & Fanshawe (2002) which is based on the official East African list edited by Britton (1980) and updated in 1996.

The first part of the bird survey was conducted in the cool–dry season, between late May and July in 2001. The second part was done during the shorter rainy season, in November 2002. This was done to capture variation due to the presence and absence of migratory species and dry–rainy season variation. Six morning records and six evening records were collected from each land-use category, eight records from May–July, four from November.

Diversity was measured by species number and Shannon index ($H$) (Shannon 1948). This takes into account evenness as well as number of species. It is estimated as

$$H = -\sum P_i \ln(P_i)$$

where $P_i$ is a proportion of the total number of birds belonging to species $i$ and $\ln(P_i)$ is the natural logarithm of that proportion, and summation is over all species. Since $H$ depends on the number of species and that is a random variable, it is not possible to estimate the variance of $H$ (Legendre & Legendre 1998). However, a value of $H$ can be calculated for each walk, and the mean diversity per walk calculated along with a standard deviation. The mean diversity per walk measures a different aspect of bird diversity than the overall diversity for a land use, but can be used to compare land-use types. Evenness or equitability is measured as the ratio of $H$ to its maximum value, calculated as $J = H/\log(S)$, where $S$ is the number of species (Legendre & Legendre 1998).

Similarity between land-use categories was measured with the Similarity Index (SI) (Odum 1971),
SI = \(2^*C/(A+B)\)
in which \(C\) is the number of species common to both land-use categories, \(A\) is number of species in one land-use category, \(B\) is number of species in another land-use category.

Further analyses used each walk as a sample. Sample- and individual-based species accumulation curves were calculated for each land-use type (Kindt & Coe 2005).

Ordination was used to show bird species associations and their relationship with land use and season. Canonical analysis of principal coordinates (CAP) (Anderson & Willis 2003) with the Odum similarity measure was used with the walks divided into six classes by land use and season. Species abundances were transformed using log(abundance + 1) for the ordination to prevent the results being dominated by the few flocking species with very large numbers of individuals seen on few walks.

RESULTS

A total of 119 species was recorded. Table 2 compares the number of species and diversity of the three land-use categories. As it became apparent that the species diversity and composition was very different in the two types of highland environments, highland data were analysed separately in the diversity analysis. The highland garden has the highest diversity index, followed by homegardens and bushland. Lowlands, with the highest number of individuals and as high number of species as in highlands, ranks as the least diverse when measured by Shannon index as the distribution is very uneven, with large numbers of just a few flocking species. This is reflected in the Equitability index which is lowest for the lowlands (Table 2).

The sample-based species accumulation curves (Fig. 2a) show that the sample sizes of 12 walks per land-use type were large enough to detect major differences in species numbers. The curves were not asymptotic so further walks would be expected to detect more species. The right hand end of the curve for lowland is steeper than that for highland, so the total number of species is probably higher in the lowlands. That the sampling did not detect all species is to be expected, as the study was not designed with that objective in mind.

Lowlands have highest abundances of birds (Table 2). The extent to which differences in species numbers are explained by differences in

| Habitat       | Number of species (S) | Mean number of birds per walk (range) | Diversity index (H) (mean ± S.D.) | Evenness (J) |
|---------------|-----------------------|--------------------------------------|-----------------------------------|--------------|
| Lowlands (12) | 57                    | 135 (23–498)                         | 2.624 ± 0.58                      | 0.65         |
| Bushland (12) | 43                    | 45 (24–71)*                          | 2.988 ± 0.28                      | 0.80         |
| Highlands (12) | 57                   | 64 (11–125)                          | 3.293 ± 0.33                      | 0.82         |
| Homegardens (5) | 32                   | 38 (11–62)                           | 3.067 ± 0.39                      | 0.82         |
| Highland garden (7) | 49 | 83 (50–125)                      | 3.147 ± 0.58                      | 0.82         |

*Five individuals on Nanga hill.
abundance is revealed by the individual-based species accumulation curves (Fig. 2b). On a ‘per bird’ scale, highlands have most species, with lowlands the fewest. The few flocking species are responsible for this result, with the curves for each land-use type being almost identical if the three flocking species are excluded from the analysis (data not shown).

Figure 3 shows the rank abundance curves for all three land-use categories. Lowlands have very high number of individuals of only three species. Bushland has one species well above the others. Highlands represent a land-use category with lowest number of individuals, but a more even distribution.

Much of the bird activity in the lowland field area is concentrated in and around the scattered trees in the fields and rows of trees along the roads. Crops were just ripening during the May–July survey and attracted big flocks of chestnut weavers (Ploceus rubiginosus) and wattled starlings (Creatophora cinerea). The number of individuals of these species in May–July is well above any other species, being 318 for chestnut weavers and 216 for wattled starlings. Grosbeak weavers (Amblyospiza albifrons) were also numerous. All these most numerous species were absent in November. In November, two months after the crops had been harvested, large flocks of red-billed queleas (Quelea quelea) were the most numerous species. Over 400 individuals were counted. The next most numerous species were the long-tailed fiscal (Lanius cabanisi) and speckled mousebird (Colius striatus), but these two were present in both seasons. Thirty-three of the lowland species were present in May–July only, eleven (out of which two are migrants) were spotted in November only.

The common bulbul (Pycnonotus barbatus) was the most numerous species (136 sightings) in the bushlands, with nearly four times as many as the next most numerous species. Trilling cisticola (Cisticola woosnami), pied crow (Corvus albus), speckled mousebird (Colius striatus) and yellow-rumped seedeater (Serinus reichenowi) all had more than 30 sightings. One evening walk was done on the small Nanga hill, but only four species were spotted during a two-hour walk. Seventeen bushland species were spotted in May–July only, nine (two of which were migrants) in November only.

Highlands had several numerous species. The most common ones were the common bulbul (Pycnonotus barbatus) with 94 sightings, variable sunbird (Cinnyris venusta) with 93 sightings, speckled mousebird (Colius striatus) with 84 sightings, black-and-white mannikin (Lonchura bicolor) with 53 sightings, and Baglafecht weaver (Ploceus baglafecht) with 39 sightings. Seventeen highland species were spotted in May–July only, sixteen in November only (two of which were migrants).

Cultivated lowland and bushland show highest similarity (SI = 0.42). This is partly because these two land-use categories are at the same altitude. Another explanation may be the proximity of the highland sample area to the natural forests of the Kilimanjaro Forest Reserve, making the bird
communities of the highlands more similar to the forest bird communities. (How well tree-based agricultural systems support forest bird communities elsewhere is discussed later in this paper; see Discussion). Similarity indices for bushland and highlands, and lowlands and highlands were 0.28 and 0.18, respectively. All land-use categories had a considerable number of species that were not seen in another land-use category, 33 species in lowlands, 15 species in bushland, and 39 species in the highlands (Table 3), which suggests that differences in bird communities are a result of land use and not only altitude. Only six species were seen in all land-use categories.

The ordination (Fig. 4) confirms two important results. First, there are distinct associations of bird species in each land use. There is no overlap in the samples from each land-use type. In other words, given a sample record of species and abundance there would be no confusion as to which land-use type it came from. Second, differences in bird associations between land uses are larger than between seasons, with the only noticeable seasonal difference in the lowlands.

**DISCUSSION**

Several studies have shown that while agroforestry systems or plantations may provide habitat for a large number of bird species that depend to some extent on forests, they cannot substitute for forest (Thiollay 1995; Perfecto et al. 1996; Reitsma et al. 2001; Perfecto & Vandermeer 2002). Kara (1995) studied bird species composition and activity in two highland habitats on the slopes of Mt Kilimanjaro, moderately modified riverine forest and a severely disturbed riverine forest (the latter a coffee/banana-dominated homegarden) and found reduced bird species diversity, especially in the shrubby layer in the severely disturbed habitat, but species composition was very similar in the tree canopy in the two habitats. Naidoo (2004) found that tree density was associated with increased numbers of bird species regardless of land-use type across different stages of forests and agricultural land in Mabira forest in Uganda. However, he stated that raising the tree density in the agricultural areas around Mabira forest to 126 trees/ha would have little general impact on making the songbird community structure similar to forest communities, except in a 400 m zone next to an intact forest, where the community similarity between an agroforest and the intact forest would increase by one third. From the number of trees per farm (O’kting’ati & Hussein 1986) one can estimate that the Chagga homegardens had a tree density of 57 trees/ha in the 1980s. This figure, far from the tree density of proposed by Naidoo (2004), suggests that the Chagga homegardens would not be able to act as a substitute for forest birds. As there is no original forest left in the same altitudes as the homegardens in the study area (or the all southern slopes of Kilimanjaro), comparison of tree density and bird diversity of intact forests and homegardens is impossible. On the

![Fig. 3. Bird species rank abundance in the lowlands, bushland and highlands on the southeastern slopes of Mt Kilimanjaro.](http://africanzoology.journals.ac.za)
other hand, as an increasing number of home-
gardens are turning into highland gardens (Soini 2005a), it is more informative to compare the 
homegardens with the highland garden rather 
than with an intact forest. In this context it is inter-
esting that Jones & Eason (1995) found that just the 
presence of trees increases bird activity.

Homegardens are an agricultural system with 
an unusual diversity of plant species (O’ktingati 
et al. 1984), but the system is dominated by coffee 
and banana. Owing to the agricultural system and 
constant mulching of the soil the variety of food 
available in the coffee/banana system for birds is 
limited. Such niches as open spaces and thickets, 
which are abundant in the highland garden, are 
not common in the homegardens. Also, human 
disturbance of birds is frequent in the home-
gardens. The average plot size is 0.6 hectares (Soini 
2005a,b), with approximately 77 m separating the 
main houses of neighbouring farms.

The remaining bushlands are small fragments in 
the middle of the lowland agricultural fields (Soini 
2005a,b).
2005a). Also, riverine woodland has become very fragmented with only a row or two of trees remaining along a watercourse and these are increasingly threatened by firewood and timber collection. In addition to the bushland species, another likely group of threatened species in the study area are the riverine bird species which were found, but not treated as a separate group, in this study due to the very small areas.

Lowlands are seemingly very rich in birds. However, the diversity is not high as the land-use type is dominated by flocking birds. The low diversity index seems to reflect the overall diversity of the agricultural system in the lowlands (Misana et al. 2003). The land is dominated by open fields of maize and beans, with some millet, sunflower and groundnuts in between. These agricultural lands support a much higher number of birds than the remaining bushland. However, only half of the bushland species were found in these lowland agricultural fields.

Both the northern summer survey (May–July) and northern winter survey (November) were done at times when there was very little agricultural activity in the lowlands. During land preparation (usually January–March), planting (March), weeding (till May) and harvesting times (July/August) human disturbance is at its peak in the lowlands (Fernandes et al. 1984; Zongolo et al. 2000). More studies are needed on the effects of different agricultural activities during different times of the year.

The two seasons were selected in order to capture variation in the presence of migratory species and to capture variation in bird communities between the rainy and dry seasons. This study revealed only a few known northern migrants, but there were large differences in the most numerous

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**Fig. 4.** Ordination of bird species using a canonical principal coordinates analysis. Species (O) and walks (+) are plotted on the first two principal axes. Points for walks are connected to the centroid of the observations for that land use (L: lowland, B: bushland, H: highland) and season (S: May–July, W: November). Species most characteristic of each land use are labelled 1: chestnut weaver, 2: wattled starling, 3: grosbeak weaver, 4: red-billed quelea, 5: long-tailed fiscal, 6: speckled mousebird, 7: common bulbul, 8: trilling cisticola, 9: pied crow, 10: yellow-rumped seedeater, 11: variable sunbird, 12: black-and-white mannkinik, 13: Baglafecht weaver, 14: white-eyed slaty flycatcher, 15: African mourning dove, 16: white-browed sparrow-weaver, 17: cinnamon-breasted rock bunting, 18: grey wren-warbler, 19: blue-naped mousebird, 20: red-eyed dove.
species between the two seasons in the lowlands. It seems that two observation times during the year are not adequate to understand the seasonal variation in bird communities and the impact of intra-African migration. From these data it is not possible to predict what might have been observed at other seasons.

It is apparent that the number of walks done for this study did not reveal all the species present in the land-use categories. However, the records give a useful indication of the relative levels of diversity in the three land-use types. More species were spotted on each subsequent walk. The difference in species number between homegardens (32) and highland garden (49) would not be as large if the same number of walks had been done in both areas. However, it is obvious that two additional walks in homegardens cannot add 17 more species and in doing so change the main conclusion of this study concerning these two highland sub-categories.

Detectability of birds varies in the three land-use categories. Birds are more easily spotted in the lowland fields, highland garden and bushlands (in that order) than in the homegardens. It is possible that some birds were missed in treetops of the tall trees in the homegarden area. However, this is not considered to be a significant bias as several species were spotted in the tree canopy. A clear bias was introduced by identifying birds 30 m on either side of the transects as high-flying birds such as swallows and swifts were not recorded.

One main route in each land-use category was located near a stream. In addition, one main lowland route ended half a kilometre from Miwaleni springs, a large spring on the southern boundary of the study area. The highland garden was next to a stream and one homegarden route crossed a stream (in addition of both crossing irrigation furrows). Species preferring areas close to water are therefore expected to occur in all land-use categories.

**CONCLUSION**

The majority (87/119) of species seen were restricted to a single land-use category. This is significant especially in the context of overexploitation of the small fragments of bushland areas. Fifteen bushland species that are apparently not capable of adapting to the neighbouring land-use categories, will disappear from the area if the destruction of bushland fragments continues.

The highland garden had the highest Shannon index of bird diversity. As a quiet area with trees and a variety of niches, the highland garden supports a very rich bird life. Homegardens were the second most diverse followed by bushlands and lowlands.

High population growth and pressure on land in the homegarden area will force farmers to continue subdividing their farms. Some farms have already become so small that they cannot function as farms. How exactly this sub-urbanization will affect bird life is difficult to predict. The new highland gardens that the process creates will be much smaller than the highland garden in this study, and due to the high population density, human disturbance will be high, though probably not as high as in the current homegardens. It is not clear whether the impact of human disturbance allows the area to support a highland garden type of a bird population. Habitat preference and response to habitat change by birds is a complex issue. It is important to formulate future research questions on bird diversity in the area in a way that can clearly distinguish between the different biophysical factors and human disturbance that is likely to be one of the most crucial factors in determining the bird diversity level of a land-use type.

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Appendix 1. Bird species spotted in the three habitats, namely highlands, bushlands and lowland fields, on the southern slopes of Mt Kilimanjaro. Taxonomy according to Stevenson & Fanshawe, 2002. (L = lowlands, B = bushland, H = highlands.)

| Common name                      | Scientific name                  | Land use | Total abundance | When spotted       |
|----------------------------------|----------------------------------|----------|-----------------|--------------------|
| **Ardeidae** (herons, egrets and bitterns) |                                  |          |                 |                    |
| Black-headed heron               | Ardea melanocephala              | L        | 10              | May–July & Nov     |
| Cattle egret                     | Bubulcus ibis                    | L        | 27              | Nov                |
| **Threskiornithidae** (ibises and spoonbills) |                                  |          |                 |                    |
| Hadada ibis                      | Bostrychia hagedash              | H        | 5               | Nov                |
| **Accipitridae** (vultures, eagles, hawks, kites, and allies) |                                  |          |                 |                    |
| Black-shouldered kite            | Elanus caerules                  | L        | 1               | Nov                |
| Palid/Montagu’s harrier          | Circus macrourus/C. pygargus     | B, L     | 2               | Nov                |
| Little Sparrowhawk               | Accipiter minullus               | L        | 2               | Nov                |
| Augur buzzard                    | Buteo augur                      | B, L     | 6               | May–July & Nov     |
| Long-crested eagle               | Lophaetus occipitalis            | L        | 2               | May–July           |
| **Otididae** (bustards)          |                                  |          |                 |                    |
| Kori bustard                     | Ardeotis kori                    | L        | 2               | May–July           |
| **Charadriidae** (plovers)       |                                  |          |                 |                    |
| Crowned lapwing                  | Vanellus coronatus               | L        | 12              | Nov                |
| **Columbidae** (pigeons and doves) |                                  |          |                 |                    |
| African green-pigeon             | Treron calva                     | B        | 13              | May–July           |
| Tambourine dove                  | Turtur tyrmanistria              | H        | 1               | May–July           |
| emerald-spotted wood-dove        | Turtur chalcospilos              | B        | 1               | May–July           |
| Red-eyed dove                    | Streptopelia semitorquata        | B, H     | 23              | May–July & Nov     |
| African mourning dove            | Streptopelia decipiens           | L        | 26              | May–July & Nov     |
| Ring-necked dove                 | Streptopelia capicola            | B, L     | 14              | May–July & Nov     |
| Laughing dove                    | Streptopelia senegalensis        | B, L     | 22              | May–July           |
| **Cuculidae** (cuckoos and coucals) |                                  |          |                 |                    |
| Red-chested cuckoo               | Cuculus solitarius               | H        | 6               | Nov                |
| Klaas’s cuckoo                   | Chrysococcyx klaas               | B        | 1               | May–July           |
| White-browed coucal              | Centropus superciliosus          | B, H, L  | 40              | May–July & Nov     |
| **Caprimulgidae** (nightjars)    |                                  |          |                 |                    |
| Slender-tailed nightjar          | Caprimulgus clarus               | B        | 4               | May–July & Nov     |
| **Colidae** (mousebirds)         |                                  |          |                 |                    |
| Speckled mousebird               | Colius striatus                  | B, H, L  | 174             | May–July & Nov     |
| Blue-naped mousebird             | Urocolumus macrourus             | B        | 21              | May–July           |
| **Alcedinidae** (kingfishers)    |                                  |          |                 |                    |
| Grey-headed kingfisher           | Halcyon leucocephala             | H, L     | 3               | May–July           |
| **Meropidae** (bee-eaters)       |                                  |          |                 |                    |
| Little bee-eater                 | Merops pusillus                  | B, L     | 10              | May–July           |
| **Coraciidae** (rollers)         |                                  |          |                 |                    |
| Lilac-breasted roller            | Coracias caudata                 | L        | 1               | May–July           |
| **Bucerotidae** (hornbills)      |                                  |          |                 |                    |
| African grey hornbill            | Tockus nasutus                   | B, L     | 28              | May–July & Nov     |
| Crowned hornbill                 | Tockus alboterminatus            | H        | 8               | May–July & Nov     |
| Silvery-cheeked hornbill         | Bycanistes brevis                | H        | 10              | May–July           |
Appendix 1 (continued)

| Common name | Scientific name | Land use | Total abundance | When spotted |
|-------------|-----------------|----------|-----------------|--------------|

**Capitonidae (barbets and tinkerbirds)**
- Moustached green tinkerbird: *Pogoniulus leucomystax*  H  7  Nov
- Spot-flanked barbet: *Tricholaema lachrymosa*  H  19  May–July & Nov
- White-headed barbet: *Lybius leucocephalus*  B  6  May–July & Nov
- Brown-breasted barbet: *Lybius melanopterus*  H  4  May–July

**Indicatoridae (honeyguides and honeybirds)**
- Greater honeyguide: *Indicator indicator*  L  2  May–July

**Picidae (wrynecks and woodpeckers)**
- Grey woodpecker: *Dendropicos goertae*  L  1  May–July

**Motacillidae (wagtails, pipits and longclaws)**
- African pied wagtail: *Motacilla aguimp*  H  3  Nov
- Mountain wagtail: *Motacilla clara*  H  5  May–July
- Long-billed pipit: *Anthus similis*  B  7  May–July
- Pangani longclaw: *Macronyx aurantiigula*  L  9  May–July

**Pycnonotidae (bulbuls, greenbuls and brownbuls)**
- Zanzibar sombre greenbul: *Andropadus importunus*  L  2  May–July
- Common bulbul: *Pycnonotus barbatus*  B, H, L  235  May–July & Nov

**Turdidae (thrushes, robins, chats and relatives)**
- Ruppell’s robin-chat: *Cossypha semirufa*  H  4  Nov
- Cape robin-chat: *Cossypha caffra*  H  5  May–July & Nov
- Spotted morning-thrush: *Cichladusa guttata*  B, L  5  Nov
- White-browed scrub-robin: *Cercotrichas leucophrys*  B, L  4  May–July
- Common stonechat: *Saxicola torquata*  H  1  May–July
- Olive thrush: *Turdus olivaceus*  H  4  May–July

**Sylviidae (warblers)**
- Garden warbler: *Sylvia borin*  L  1  Nov
- Singing cisticola: *Cisticola cantans*  H  2  May–July
- Trilling cisticola: *Cisticola wosnami*  B, L  54  May–July & Nov
- Hunter’s cisticola: *Cisticola hunteri*  H  13  May–July & Nov
- Winding cisticola: *Cisticola galactotes*  L  20  May–July
- Rattling cisticola: *Cisticola chiniara*  L  16  May–July
- Ashy cisticola: *Cisticola cinereolus*  L  1  May–July
- Siffling cisticola: *Cisticola brachypterus*  B  22  May–July
- Tawny-flanked Prinia: *Prinia subflava*  B, L  20  Nov
- Grey wren-warbler: *Calamotrophus simplex*  B  12  May–July & Nov
- Grey-backed camaroptera: *Camaroptera brachyura*  H  8  May–July & Nov
- Red-faced crombec: *Sylvietta whytli*  L  1  Nov
- Somali long-billed crombec: *Sylvietta isabellina*  B  1  May–July
- Buff-bellied warbler: *Phyllolais pulchella*  L  5  May–July

**Muscicapidae (flycatchers)**
- White-eyed slaty flycatcher: *Melaenornis fischeri*  H  24  May–July & Nov
- Pale flycatcher: *Bradornis pallidus*  L  2  Nov

**Platysteiridae (batises and wattle-eyes)**
- Chin-spot batis: *Batis molitor*  B, H  4  Nov
- Black-throated wattle-eye: *Platysteira peltata*  H  2  Nov
| Common name                      | Scientific name                     | Land use | Total abundance | When spotted       |
|----------------------------------|-------------------------------------|----------|-----------------|--------------------|
| **Monarchidae**                  |                                     |          |                 |                    |
| (monarch flycatchers)            |                                     |          |                 |                    |
| African paradise-flycatcher      | Terpsiphone viridis                 | B, H, L  | 13              | May–July & Nov     |
| **Zosteropidae**                 |                                     |          |                 |                    |
| (white-eyes)                     |                                     |          |                 |                    |
| Abyssinian white-eye             | Zosterops abyssinicus               | B, H     | 19              | May–July           |
| **Nectariniidae**                |                                     |          |                 |                    |
| (sunbirds)                       |                                     |          |                 |                    |
| Collared sunbird                 | Hedydipna collaris                  | H        | 3               | May–July           |
| Olive sunbird                    | Cyanomitra olivacea                 | H        | 2               | May–July           |
| Amethyst sunbird                 | Chalcomitra amethystina             | H        | 9               | May–July & Nov     |
| Hunter’s sunbird                 | Chalcomitra hunteri                 | B, L     | 9               | May–July & Nov     |
| Variable sunbird                 | Cinnryanus venusta                  | B, H, L  | 128             | May–July & Nov     |
| Bronze sunbird                   | Nectarinia kilimensis               | H        | 12              | May–July & Nov     |
| **Laniidae**                     |                                     |          |                 |                    |
| (shrikes)                        |                                     |          |                 |                    |
| Long-tailed fiscal               | Lanius cabanisi                     | L        | 68              | May–July & Nov     |
| Common fiscal                    | Lanius collaris                     | B, H     | 7               | May–July & Nov     |
| **Malaconotidae**                |                                     |          |                 |                    |
| (bush-shrikes)                   |                                     |          |                 |                    |
| Brown-crowned tchagra            | Tchagra australis                    | B, H     | 7               | May–July & Nov     |
| Black-backed puffback            | Dryosocus cubla                     | H        | 9               | May–July           |
| **Campephagidae**                |                                     |          |                 |                    |
| (cuckoo-shrikes)                 |                                     |          |                 |                    |
| Black cuckoo-shrike              | Campephaga flavus                   | L        | 1               | May–July           |
| **Oriolidae**                    |                                     |          |                 |                    |
| (Orioles)                        |                                     |          |                 |                    |
| African black-headed oriole      | Oriolus larvatus                    | L        | 1               | May–July           |
| **Corvidae**                     |                                     |          |                 |                    |
| (crows and allies)               |                                     |          |                 |                    |
| Pied crow                        | Corvus albus                        | B, H, L  | 78              | May–July & Nov     |
| **Sturnidae**                    |                                     |          |                 |                    |
| (starlings and oxpeckers)        |                                     |          |                 |                    |
| Red-winged starling              | Onychognathus morio                  | H        | 5               | May–July           |
| Greater blue-eared starling      | Lamprotornis chalybeus               | H        | 3               | Nov                |
| Hildebrandt’s starling           | Lamprotornis hildebrantii           | L        | 2               | May–July           |
| Superb starling                  | Lamprotornis superbus               | L        | 30              | May–July & Nov     |
| Violet-backed starling           | Cinnyricinculus leucogaster         | B, H     | 15              | May–July & Nov     |
| Wattled starling                 | Creatophora cinerea                 | L        | 216             | May–July           |
| **Passeridae**                   |                                     |          |                 |                    |
| (sparrows and petronias)         |                                     |          |                 |                    |
| Grey-headed sparrow              | Passer griseus                      | H        | 12              | May–July & Nov     |
| Yellow-spotted petronia          | Petronia pyrgita                    | L        | 1               | May–July           |
| **Ploceidae**                    |                                     |          |                 |                    |
| (weavers)                        |                                     |          |                 |                    |
| White-browed sparrow-weaver      | Plocepasser mahali                  | B, L     | 39              | May–July & Nov     |
| Grosbeak weaver                  | Amblyospiza ??albifrons              | L        | 54              | May–July           |
| Baglafetch weaver                | Ploceus baglafetch                  | H, L     | 44              | May–July & Nov     |
| Spectacled weaver                | Ploceus ocularis                    | H        | 15              | May–July & Nov     |
| Black-headed weaver              | Ploceus cucullatus                  | H, L     | 10              | May–July & Nov     |
| Chestnut weaver                  | Ploceus rubiginosus                 | L        | 318             | May–July           |
| Red-headed weaver                | Anaplectes rubriceps                | B, H     | 3               | May–July           |
| Red-billed quelea                | Quelea quelea                       | L        | 453             | Nov                |
| **Emberizidae**                  |                                     |          |                 |                    |
| (waxbills)                       |                                     |          |                 |                    |
| Red-billed firefinch¹             | Lagonosticta senegala               | H, L?    | 64              | May–July & Nov     |
### Appendix 1 (continued)

| Common name                             | Scientific name                  | Land use | Total abundance | When spotted       |
|-----------------------------------------|----------------------------------|----------|-----------------|--------------------|
| African firefinch¹                      | Lagonosticta rubricata           | B, H?    |                 | May–July & Nov     |
| Blue-capped cordon-bleu                | Uraeginthus cyanoccephalus       | B        | 6               | May–July & Nov     |
| Southern cordon-bleu                    | Uraeginthus angolensis           | L        | 8               | May–July & Nov     |
| Black-and-white mannikin²               | Lonchura bicolor                 | H        | 78              | May–July & Nov?    |
| Bronze mannikin²                        | Lonchura cucullata               | H        |                 | May–July & Nov?    |
| Maggie mannikin                         | Lonchura fringillioides          | H        | 8               | May–July           |
| Black-winged red bishop                 | Euplectes hordeaceus             | L        | 10              | May–July           |
| White-winged widowbird                  | Euplectes albomotus              | B        | 25              | Nov                |
| Pin-tailed whydah                       | Vidua macroura                   | L        | 2               | May–July           |
| African golden-breasted bunting         | Emberiza flaviventris            | H        | 1               | Nov                |
| Cinnamon-breasted rock bunting          | Emberiza tahapisi                | B        | 23              | May–July & Nov     |

**Fringillidae**

*Seedeaters and canaries*

| Common name                             | Scientific name                  | Land use | Total abundance | When spotted       |
|-----------------------------------------|----------------------------------|----------|-----------------|--------------------|
| Streaky seedeater                       | Serinus striolatus               | H        | 2               | Nov                |
| Yellow-rumped Seedeater                 | Serinus reichenowi               | B, L     | 62              | May–July & Nov     |
| Yellow-crowned canary                   | Serinus canicollis               | H        | 6               | May–July & Nov     |
| African citril                          | Serinus citrinelloides           | H        | 10              | May–July & Nov     |
| Yellow-fronted canary                   | Serinus mozambicus               | H        | 2               | Nov                |
| White-bellied canary                    | Serinus dorsostriatus            | B, L     | 28              | May–July           |
| Brimstone canary                        | Serinus sulphuratus              | B        | 1               | Nov                |

*L = lowlands, B = bushland, H = highlands.

¹Northern migrant.

¹Some misidentification between these two species: information on occurrence in one habitat only not reliable.

²Some misidentification between these two species: combined number given only, occurrence in one or both seasons not reliable.