

## Economic valuation of rice crop damage by Red-billed Quelea and other pest birds on a rural irrigation scheme in western Kenya

## ABSTRACT

**Aims:** The study aimed to estimate economic losses incurred by farmers from damage of rice crop by granivorous pest birds and evaluate the implication of this for sustainable food security.

**Study design:** Line transect bird sampling with spatial and temporal replications; bird feeding rate determination; per-season and per annum estimation of rice damage

**Place and duration of study:** Ahero Rice Irrigation scheme in western Kenya from November 2011 and February 2013.

**Methodology:** To estimate economic losses of rice we first estimated granivorous bird density from two census periods from whence we then estimated seasonal and annual quantities of rice damage by calculating the birds' feeding rates. We then valued economic damage as a factor of the crop loss and prevailing producer market price of rice and finally estimated net economic loss by subtracting the cost of hiring labour to scare birds from damaging mature crop. Period of bird damage was restricted to the period between crop-maturity to harvest.

**Results:** Estimated annual loss was 407 tonnes or 7.7% of potential yield for the whole irrigation scheme excluding bird scaring costs. This was equivalent to translated to Ksh. 40.7 million annually at 1 USD = 87 Ksh. And represented a 31.1% of net income. Inclusive of bird scaring costs, annual losses were Ksh. 20,763/ha equivalent to 39.5% of net income. Annual rice damage due to *Q. quelea* were almost equal to those from other pest birds (15 compared to 192 tonnes).

**Conclusion:** This loss magnitude considerably undermines efforts to reduce rural poverty and attain sustainable food security. In addition to the crop-guarding method, reducing losses from damage by the pest birds requires integration of several measures that have proved successful elsewhere, adoption of improved farming technologies and planting recently developed high-yield rice varieties.

**Keywords:** Economic valuation; rice damage; pest birds; *Quelea quelea*; Ahero; Kenya irrigation; Kenya

## 1. INTRODUCTION

Irrigation fields where rice (*Oryza sativa*, L.) is grown are becoming increasingly significant as habitat for birds worldwide [1,2,3,4]. This is largely associable to loss in the last century of an estimated 50 % of global natural wetland cover that constitutes significant habitat for many birds, [5]. This is in comparison to a corresponding increase in global rice field cover estimated to be covering 164 million hectares as of 2012 [6,5,7]. In Brazil alone, the 9<sup>th</sup> biggest producer of paddy-rice corresponded to a 90 % loss in wetland cover since 1970 [8]. The importance of rice fields as foraging habitat is underscored by the fact that they have continued to attract birds because the negative effects resulting from control and management of soil, pests and diseases or weeds [9,10] are counterbalanced by the reliable periodicity of habitat conditions from agronomic practices many of which boost abundance of the birds' food prey [5,11].

While a few bird species use the rice fields for breeding purposes [6], the vast majority use them primarily as foraging or wintering grounds during wider dispersal [2,3]. Thus, the various foraging guilds select foraging sites based on their suitability in terms of spatio-temporal availability, quality and quantity abundance of food resources, or level of predation risk [12,13,5]

For foraging purposes, many granivorous birds consume seeds of grains and grasses; frugivores consume fruits of many flowering plants that bloom during the rainy [14]; insectivores prey on the highly diverse communities of arthropods, some of which are aerial pests of rice while raptors prey on aquatic and terrestrial vertebrate prey including other small birds and their eggs [12,15]. As a benefit to rice farming, while the birds forage for prey across the paddies, some of

them make important contribution to control of rice pests or disease transmitting vectors of some human diseases [16,17].

One of the greatest challenges to food security among many countries in sub-Saharan Africa is the perennial loss of crops to vertebrate pests, which undermines production targets, lead to national food deficits, contributes to undernourishment and accelerates poverty levels especially among rural populations [18,19]. In particular, large flocks of granivorous birds such as Red-billed Quelea *Quelea quelea* and other weavers, are among the most commonly cited rice pest vertebrate across sub-Saharan Africa where the crop is a key staple [20,21,22,7]. The burden of damage by these birds is aggravated by the perennial and seasonal arrivals by these pest birds as well as the fact that most rice farmers operate at small-scale subsistence scales and have limited capacity to invest in sustainable measures to control the birds [19,23].

Although rice is not the leading staple grain crop in Kenya, it is consumed by all communities and is the most immediate alternative to maize or wheat products [19]. Most households consume rice at least twice each week as an accompaniment for a variety of other dishes, and is on the menu of nearly all restaurants and hotels in the country. It is even more important among urban households where its price is comparatively lower than that of maize meal [19,20]. In many marginal rural households, rice meal is at times the sole source of protein nutrition [20,24]. Rice production in the Kenya is however insufficient to meet local demand, making it necessary to import the commodity to bridge the deficit [24,25]. The crop is typically grown under irrigation in 5 main agricultural development schemes in the country [24,26].

Loss of grain crop to granivorous bird pests is usually heaviest during the period from crop maturity to harvesting or in case of poor storage in the field after harvesting during which rice may be the sole source of nutrition for the pests [23,27]; Red-billed Quelea alone is considered



responsible for the loss of an estimated total annual loss of USD 54 million in value of rice and other small grains across its sub-Saharan Africa range [28] or USD 70 million worldwide.

Many studies have been conducted on the importance of rice fields as suitable habitats for birds but they have focused on waterbirds [1,14], predominantly conducted in the temperate, Mediterranean or Asiatic regions [1,30,31]. In comparison, a number of studies have been conducted in Africa on importance of grain fields for granivorous birds [21,23,29,32,33]. The most recent of these studies have given considerable attention to damage to rice by the highly invasive, widely distributed, sporadically itinerant and gregarious Red-billed Quelea [21,23,32; 33]. However, no studies have been conducted to economically quantify the losses of rice crop in various irrigation schemes in Kenya despite several anecdotal complaints by farmers and reports in the mainstream national media [34,35,36].

In this study, we aimed to estimate economic losses incurred by farmers from damage of rice crop by bird pests at Ahero Rice Irrigation Scheme in western Kenya and the implication of this for attainment of national sustainable food security. We also aimed to compare contribution of *Q. quelea* to rice crop damage relative to other granivorous crop pests in the irrigation scheme, and explore available options for reducing such losses. The study is significant and unique as it is the first attempt to quantify losses of rice from damage to bird pests in Kenya in monetary terms. Therefore the results are an important contribution in filling this information gap and constitute a significant basis for multi-stakeholder policy formulation to tackle the bird pest problem that can be applicable at the local level but can also be up-scaled to the national and regional levels.

## 2. METHODS

### 2.1 Study Area

Ahero Rice Irrigation Scheme is part of the Kenya National Irrigation Board's Western Regional project which also includes West Kano and Bunyala schemes. It lies in the Kano Plains on the eastern margin of the Winam Gulf of Lake Victoria, 20 km east of Kisumu City [26,37]. The area is predominantly grassland country, most of which is intensively cultivated with mean annual rainfall of 1082 mm, maximum precipitation occurring from between March and May and a less intense period between October and December. Annual temperature ranges between 17-32 °C with average humidity of 65% (37). The irrigated area is located between 0°07'S-09'S and between 34°54' 34°58'E a total of 880 hectares (Figure 1) and covers 878 hectares supplied with water from River Nyando which runs along its margin [37, Njoka pers. com] see Figure 1. The rice irrigation scheme is divided into 12 irrigation blocks ranging from 31-115 ha and which had a total of 533 farming household units during the study and each farmer/unit is allocated a 4-acre (1.6 ha) paddy-field [37, Otieno pers. obs]. Water is harnessed from the river but pumped into the scheme from the northeast margin to flow southwestwards under gravity through the inter-block channels and into smaller inlets controlled by levees before finally entering the paddy-fields. Rice is planted in two seasons each year which often coincides with local rainfall patterns and harvesting takes place in July and January.

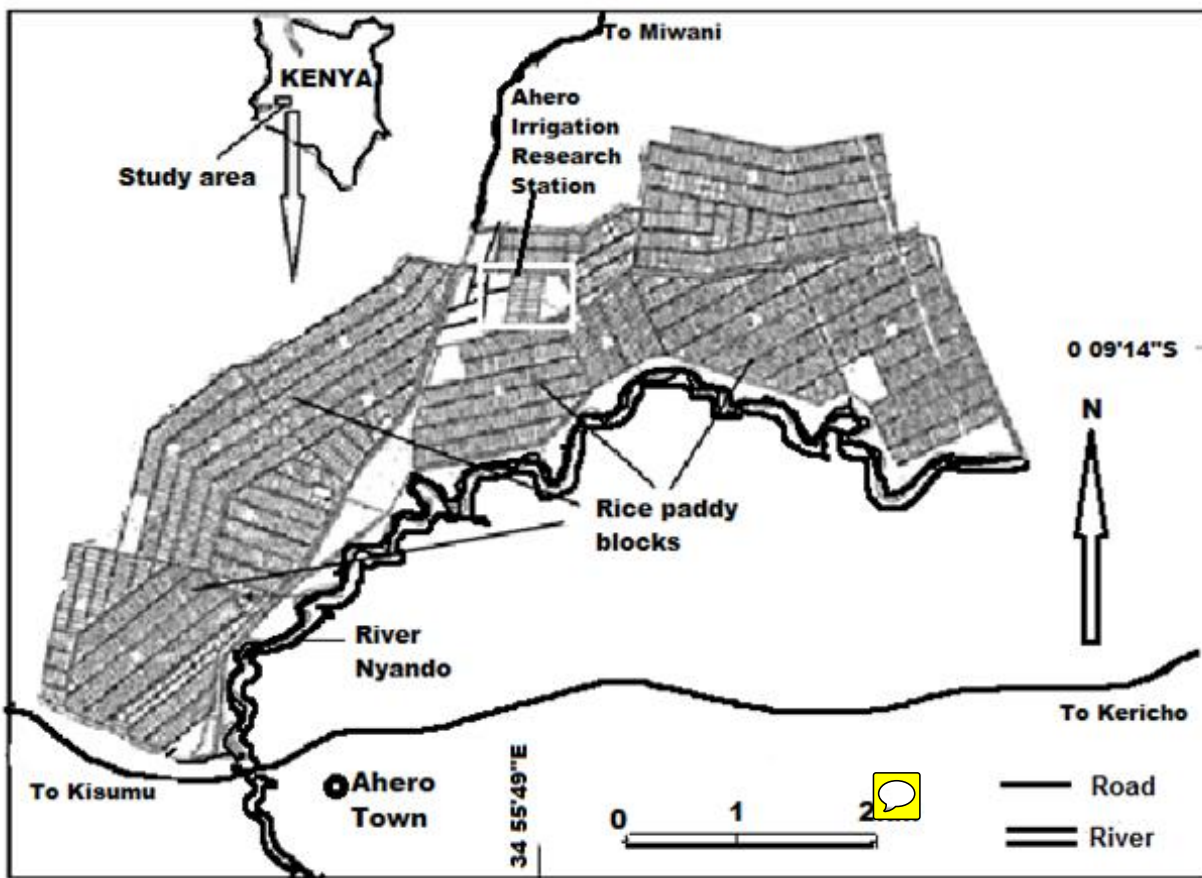


**Figure 1.** Map of study area showing various paddy-fields where sampling was conducted. (Adopted from 37).

The site hosts large regular populations of resident and annually wintering Palearctic birds [38,39], the latter starting to arrive in western Kenya as early as October and stay on proceed towards southern Africa, arriving again on their way back to their Mediterranean and temperate breeding habitats between February and March [38].

## 2.2 Sampling

The study was carried out between November 2011 and February 2013 to span two full rice cropping seasons (November 2011-February 2012 and April-July 2012). Sampling was conducted all 12 field blocks. Birds were surveyed in 52 total counts, twice in each of the two field seasons. A period of 6-8 days was allowed between the first and second bird survey for each field block during each field season to reduce any temporal biases of over-estimation due to multiple counts of same individuals. The two field seasons were also chosen to also capture presence of wintering Palearctic species [38,39]. Birds were surveyed from 0630-0930 hrs, capturing the peak feeding activity [40] with surveyors worked in pairs such that an experienced Ornithologist made the observations while a partner recorded the data. Information on the seasonal rice production cycle, yield rates, costs of farm inputs and other expenses involved in rice production was obtained from direct interviews with personnel at the Ahero Rice Research Centre and individual farmers.

## 2.3 Data analyses and calculations

Analyses were performed in SPSS version 16 and R program [41,42]. The paddy-field sizes were all of the same size namely 4 acres but the field block sizes were different. Bird abundance was determined as the average from all counts across both field seasons; species richness was the cumulative total from all observation from all counts for each site while species diversity was determined using the Shannon Diversity index  $H' = - \sum p_i \ln p_i$  where  $p_i$  is the proportion of the total number of individuals of the  $i$ th species of all individuals of all species;  $\ln$  is the natural logarithm [43]. Diversity indices were compared between the two periods: before crop maturity and from maturity to harvest so as to evaluate how pest to compare their abundances between the two periods. This was because many of the granivorous pest birds also occur on rice fields in

earlier stage of rice growth during which they feed on seed of other plants before the rice matures [22]. Some of them also consume arthropods in the rice fields during these early flooding stages especially weavers (Ploceidae) and widowbirds *Euplectes* sp [38,44]. Abundances were derived from the means of the hierarchically partitioned values of individual observation clusters, multiplied by number of encounters and divided by total sampling area [40,45]. The significance of all statistical tests were set within the 95% confidence interval ( $P = 0.05$ ).

The granivorous pest birds were subdivided into three main groups: Red-billed Quelea (Ploceidae) that was the predominant group; other weavers and allies (Ploceidae); doves and pigeons (Columbidae) and other granivores (Estrildidae, Fringillidae and Viduidae).

We estimated the rice crop damaged by the granivorous birds as a function of their mean daily feeding rates and their mean abundance [46,47]. To minimize over-estimation, the period for which crop damage was estimated included only that of the final 42-45 days from crop maturity to end of harvesting. We estimated the quantity of rice damage per paddy-field averaging 4 acres (1.6 ha) in kg and for the entire scheme of 1,556 paddies (878 ha) both seasonally and annually (two seasons of 3-4 months each). Estimation of economic loss was conducted by presuming a rice producer market price of Ksh.100 (USD 1.15) per kg.

Rice crop loss was calculated at two levels: loss from direct bird consumption or loss from a combination of bird damage and the cost of guarding crops from pest birds. Percent economic loss from bird damage was calculated from the relationship:

$$EL_{BDP} = [((S_T - PC_T) - BL_T) / S_N] * 100$$

where  $EL_{BDP}$  = percent economic loss due to bird damage;  $S_T$  = total sales;  $PC_T$  = total cost of production;  $BL_T$  = total loss due to bird damage and  $S_N$  = net sales.

Total sales itself was the difference between production volume in kg multiplied by the unit cost per kg and the cost of farm production. We used the flat unit cost of hiring personnel for crop-guarding during the critical period as Ksh. 9,000 for each of the two crop seasons, from information obtained directly from many rice farmers. However, crop-guarding does not result into total elimination of bird damage [29]. Field investigations in many part of west and North Africa reported an average success rate of only 60 % for the crop-guarding as a bird control measure meaning there is a 40% chance of rice loss despite crop-guarding. This is because firstly, while Quelea forage on the fields from as early as 0500 hrs to as late as 1830 hrs each day [38,44,48], crop guards are rarely able to commence guarding duty before 0700 hrs and rarely continue beyond 1730 hrs. Secondly, it is practically non-feasible for one guard that is usually engaged, to diligently protect a 4-acre mature crop from all flocks of granivorous birds for 13 continuous hours of light. Finally, efficiency of crop guarding duty is often contingent upon favourable weather and logistical conditions including daily commuting distance from the guard's homestead to the field site [29]. Thus the total economic crop loss due to birds was determined as

$$EL_{TB} = \{[(100-60)/100 * EL_{BD}] + L_{CG}\}$$

where  $EL_{TB}$  = total loss due to birds (including cost of crop guarding);  $EL_{BD}$  = economic loss due to bird damage;  $L_{CG}$  = loss due to cost of crop guarding.

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

A total of 17 species of granivores from 4 families were encountered (Table 1) with Red-billed Quelea as the most abundant and most frequently encountered. In overall, there was higher abundance of all granivorous birds during the maturity and harvest of the rice crop than before

maturity ( $t_{(74)} = 2.275$ ,  $p = 0.026$ ).   Overall diversity of the granivorous birds was higher in the period before rice maturity than during maturity and harvesting ( $H' = 0.4886$ ) but lowest during the late stages of crop maturity and harvesting ( $H' = 0.2530$ ) when other granivorous species were overwhelmingly dominated by large flocks of red-billed Quelea

**Table 1.** Checklist of granivorous birds encountered in the study area.

| Family       | Common name                    | Scientific name                  |
|--------------|--------------------------------|----------------------------------|
| Columbidae   | Emerald-spotted Wood Dove      | <i>Turtur chalcospilos</i>       |
|              | Red-eyed Dove                  | <i>Streptopelia semitorquata</i> |
|              | Ring-necked Dove               | <i>Streptopelia capicola</i>     |
|              | Speckled Pigeon                | <i>Columba guinea</i>            |
| Estrildidae  | African Fire-finch             | <i>Lagonosticta rubricata</i>    |
|              | Red-billed Firefinch           | <i>Lagonosticta senegala</i>     |
|              | Red-billed Quelea              | <i>Quelea quelea</i>             |
|              | Red-cheeked Cordon-bleu        | <i>Uraeginthus bengalus</i>      |
| Fringillidae | Streaky Seedeater              | <i>Serinus striolatus</i>        |
|              | Yellow-rumped Seedeater        | <i>Serinus xanthopygius</i>      |
| Viduidae     | Pin-tailed Whydah              | <i>Vidua macroura</i>            |
| Ploceidae    | Grosbeak Weaver                | <i>Amblyospiza albifrons</i>     |
|              | Jackson's Golden-backed Weaver | <i>Ploceus jacksoni</i>          |
|              | Red-billed Buffalo Weaver      | <i>Bubalornis niger</i>          |
|              | Speke's Weaver                 | <i>Ploceus spekei</i>            |
|              | Village Weaver                 | <i>Ploceus cucullatus</i>        |
|              | Black Bishop*                  | <i>Euplectes gierowii</i>        |
|              | Southern Red Bishop*           | <i>Euplectes orix</i>            |

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\*Consumers both plant material and arthropods

It was estimated that in the absence of crop-guarding, overall loss of rice crop would be 215.1 tonnes per year due to Red-billed Quelea alone, equivalent to economic loss of Ksh. 21.2 million per year of two crop seasons. For each paddy field, this loss totaled 138 kg annually equivalent to Ksh. 13,624 per paddy field, Ksh 8,515 per ha or 16.2% of realized net income. The overall damage caused by all granivorous birds put together, in absence of crop-guarding, would amount to 407 tonnes annually, equivalent to 7.7% of expected yield. This translates to Ksh. 40.7 million (USD 467,816) annually or 164 kg per ha valued at Ksh 16,375/ha or 31.1% of net income. When cost of crop-guarding are included, the 60 % reduction in bird damage (representing guarding effectiveness rate) is undermined by the unit cost of hiring personnel for crop-guarding work. Each paddy-field then losses Ksh. 20,763/ha and the whole scheme Ksh. 59.5 million per year which erodes 3.7 % of total sales or 39.5% of realized net income. This is because the cost of crop-guarding alone is at least Ksh. 28 million per year.

The most destructive birds to the rice crop were Red-billed Quelea (53 %) and other weavers (Ploceidae = 36 %) while the least destructive were doves/pigeons (Columbidae = 9 %) and smaller granivores (Fringillidae and other Estrildidae = 2 %) see Figure 2. Thus the combined losses due to the other granivores bird pest birds are almost as much as those of due to *Q. quelea*.

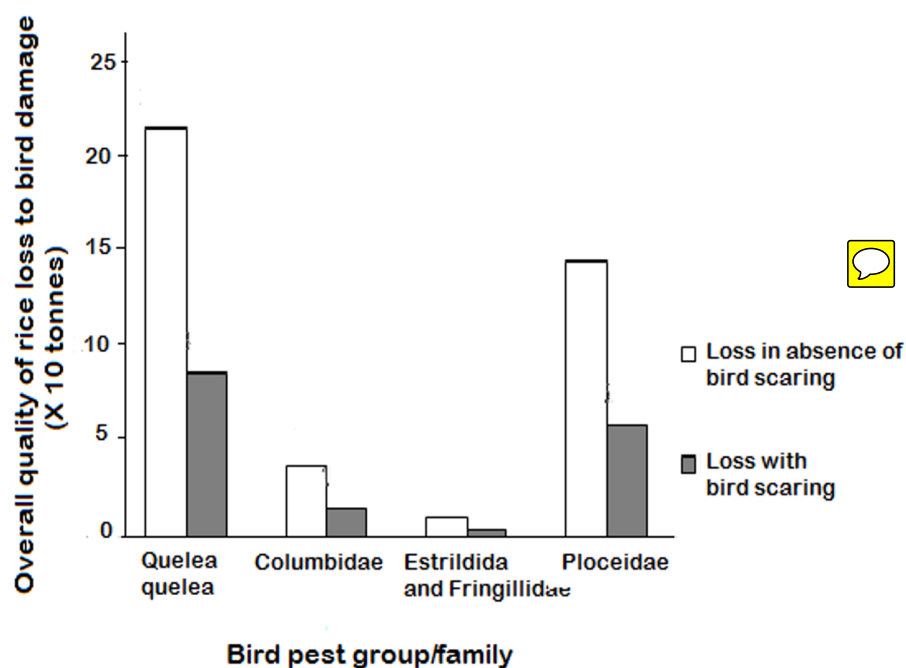


**Figure 2.** Estimated total annual quantity of rice crop loss to various pest bird groups.

Even when the other granivores were combined, the Red-billed Quelea caused the highest economic loss to rice production in the irrigation scheme (Figure 3).

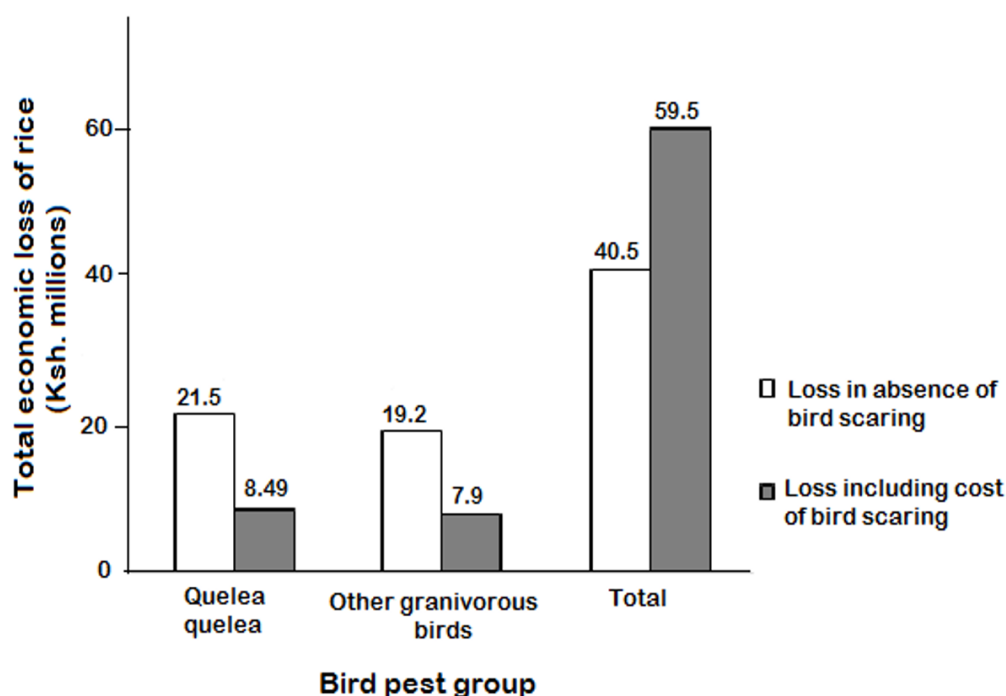


**Figure 3.** Estimated economic loss of rice crop to various granivorous birds at Ahero Rice Scheme.

## 3.2 Discussion

### 3.2.1 Economic valuation of rice damage

The steady decline in diversity of granivorous bird species from the early field flooding stages towards rice-paddy maturity and harvesting depicts a correspondingly steady increase in their dependence on rice as a source of energy. This is because discontinuation of flooding as rice crop matures, leads to loss of weeds and other plants that provide alternative sources of seed food for the birds [15,49]. Researchers in Senegal [22] found observed that many weeds and grasses on rice fields mature earlier than rice and complete their life cycle long before rice is harvested, leaving rice as the only source of food for seed eating birds later in its growth stage. Many bird species for

which mature crop rice is not the main source of food may thus seek foraging opportunities elsewhere, leaving only those that specialize in consuming rice at that stage such as the numerically dominant Red-billed Quelea [38,44].

The gregarious characteristic of Quelea, its adaptability to changing food supplies, constant mobility and habituation against human disturbance [33,44], all provide it with significant foraging advantage over other granivorous birds across the rice fields. These attributes make Quelea responsible for at least half the total loss of rice in Ahero Rice Scheme as well as many other small grained crops throughout its range across the sub-Saharan and southern Africa [38,44]. This range covers some 20 % of Africa's continental land and extends across 25 countries [7].

The estimated total annual loss of rice to pest birds in Ahero Irrigation Scheme is slightly more than estimated by [21] in the Senegal River Valley (SRV) which is a major rice belt in West Africa. This is presumably because of the higher density of rice farmers in Ahero which, combined with the smaller total acreage under irrigation (878 ha compared to ~ 50,000 ha in SRV) serve to minimize bird access to the crop through disturbance, as compared to the case in the larger SRV [50]. Nevertheless the loss in Ahero represents a substantial burden to the local farming community, especially considering that western Kenya is listed among the most economically challenged regions of the country with poverty rates estimated at 48% [51]. Even before including the costs incurred in crop-guarding, the rice lost, at 407 tonnes per year, is enough rice to feed 783 households of 5 members in Kisumu County for one year consuming 2 kg of rice per week interspersed with other food items [19,20]. It is also sufficient to supply 12 boarding high schools with rice meal for one year, each with 550 pupils of 35-50 class sizes [52]. This is an opportunity lost for improving rural nutrition while the revenue lost could go towards significantly combating local poverty rates.



The conditions under which rice is grown in Ahero is nearly similar to those in other rice schemes in Kenya because they are all managed by National Irrigation using integrated irrigation systems [26]. The cropping cycles, field operational techniques, farmer production cost dynamics and pest bird loss patterns (including crop-guarding costs) are also closely comparable to those at Ahero (Otieno pers. obs). It is therefore possible to project the bird pest losses observed at Ahero to the national level. In this regard, the damage to rice caused by red-billed Quelea alone would amount to about Ksh 410.5 million (USD 4.7 million) based on the total acreage of 17,000 ha under [19,24]. This represents 8.7 % of the total annual loss to Quelea damage across the whole of Africa [7] and is higher than the value estimated 10 years ago for Somalia (USD 1 million) [32]. For Kenya, it also depicts an increase in damage by more than 300 % since 1952 according to estimates by [23]. Considering losses to all granivorous pest birds combined, projected national loss would be valued at 11,000 tonnes equivalent to Ksh. 1.1 billion (USD 13.2 million). This is enough to reduce the country's rice imports by about 7% based on 2001 figures [28] thus narrowing the national deficit to some degree and contributing towards overall national rice sufficiency [25].

Despite the considerable acreage under rice production in Kenya the annual demand for rice in the country still stands at 280,000 tonnes which still far exceeds the local production supply of 122,465 tonnes causing a rice deficit of 157,535 tonnes [25]] For instance in 2012, the country exported only USD 2.5 million worth of rice, which was 1.3 % of the USD 191 million imported [28], making Kenya virtually a 100 % net importer of the crop. Therefore, for self-sufficiency to be attained, the country needs to increase production through greater intensification [20], increased irrigation acreage [19], local marketing efficiency or reduction of post-harvest losses [20,22,53]. Rice importation creates a dis-incentive for farmers because it creates unfair international competition, depresses local producer market prices, raises retail prices due to import levies,

erodes foreign exchange reserves and provides disincentives against increased production efforts [19].

Technical support for wider adoption of new farming technologies and higher yielding varieties has also been proposed as an option for increasing rice production, which may offset losses to pest birds. For instance, planting seeds of the New Rice For Africa (NERICA) varieties [54,55] has been observed to considerably increase production in west Africa where it was first adopted 8 years ago [54,56,57]. According to the Africa Rice Centre, NERICA is a fast-growing variety that can increase per hectare yields by up to 25-30 % more than Basmati variety, which is currently the most widely grown by Kenyan farmers [26,55,57]

It is important to note that by virtue of their massive invasiveness and colonial tendencies, *Q. quelea* also play significant roles in suppressing agricultural weeds by consuming their seed especially outside the rice maturity and harvesting period. Furthermore, in the Ahero Scheme, the actual economic loss of rice crop to bird damage *per se* is only a fraction (68 %) of the total estimated economic losses reported. The cost of crop-guarding adds to the remaining 32 %. Unfortunately, failing to scare away the birds through crop-guarding might result in total crop loss and as such crop-guarding is currently unavoidable.

### 3.2.2 Control of pest birds

The challenge in controlling *Quelea* populations lies in the fact that the birds move in sporadic flocks of unpredictable sizes and reproduce at high rates over short periods thereby overwhelming most control logistics employed [32]. Due to their large numbers, they are capable of causing massive grain loss within very short periods despite the small sizes and food intake rates of individual birds [7,21,38,44]. Furthermore, like other agricultural pests, *Quelea* are expected to

increase in numbers and cause more serious crop damage across its range in coming years as rainfall patterns become more unpredictable or deficient due to climate change.

No single control measure has been proved completely successful in eliminating damage of rice and other grain crops by *Quelea* or other colonial granivorous birds in any part of Africa although many different methods have been tried including crop-guarding, using poisonous chemicals to kill off the birds, use of explosive sounds, destroying the birds' roosting and breeding sites, mass capturing, planting buffer grain crops to distract the birds or using decoys [21,23,29]. Reidinger and Libay [58] reported success in controlling weaver pests on corn by covering parts of the crops with very sticky glue to trap some of the birds whose distress calls effectively discouraged other birds from feeding on the crop fields in Nebraska. However, many of these strategies have various environmental, policy and economic drawbacks. For instance, birds quickly habituate against decoys, use of pesticides to kill the birds can result into pollution of water bodies or poisoning of non-target species including humans [10] while capturing the birds, using chemicals or materials such as sticky glue that distresses the birds conflicts with wildlife protection laws of many countries including Kenya. According to the Kenya Wildlife Conservation Act of 2009, for instance, it is a criminal offence for anyone to capture, handle, restrict, harm translocate the birds or destroy roosting and breeding areas without express permission from wildlife authorities or their qualified agents [59]. Additionally, part of the costs of any such special control measures undertaken by wildlife authorities on behalf of the farmers might have to be shared with the farmers, depending on specific logistical circumstances involved. This presents a considerable deterrence to the farmers to collaborate with wildlife authorities to find a solution to the pest bird problem. Similarly, hiring labour to scare guard the crop against bird damage steeply increases

production costs planting buffer crops to cushion the main crop not only requires extra acreage but is also ineffective against large flocks of invading pest birds.

Improving effectiveness in managing the pest birds should therefore would entail employing an integration of several control measures. Scientists in working in the Senegal River Valley observed that granivorous bird pests are initially attracted to paddy-fields by many weeds that provide their seed food while rice is still immature but because weeds mature and die off earlier than rice, the birds then later turn on to rice as the sole source of food [22]. They thus argued that controlling weeds on rice fields and planting early-maturing varieties may help to minimize rice loss by ensuring that the mature crop is exposed to pest birds for a shorter period. The authors further suggested in combination with this measure, farmers should also try to experiment with planting at different times around the year and growing quick maturing varieties, in addition to crop-guarding around the harvesting season.

Another potentially effective and sustainable solution that has been proposed is that of using specially designed barrier netting to block pest bird access to the crop during the final period of maturity and harvesting [29]. As an example, netting barriers was successfully used in an exclusion experiment to test the role of insectivorous birds in controlling arthropod pests on cornfields in Canada [17]. They were also observed to be effective in a number of rice fields in Senegal, Mali and Nigeria [29] and in controlling House Sparrow *Passer domesticus* access to vineyards in Israel [60]. Despite initial cost outlays, maintenance costs and the fact that it would also bar other bird species that are beneficial in controlling arthropod pests on rice this could provide a longer term solution as it would singularly and effectively protect the crop from virtually all granivorous pest birds [29,32,58,61] and at concurrently eliminate the need for crop-guarding labour, thus reducing overall production costs. Attracting birds of prey such as hawks, eagles,

falcons, buzzards, kites, harriers or even crows to the rice fields also been proposed as a solution. Such birds are effective predators on small passerine birds including *Quelea* [44,62] but they rarely occur on the rice fields due to either lack of perching surfaces like tree, or due to human disturbance. Perching surfaces may be constructed and erected across the paddy-fields from where the birds of prey would predate upon the flocks of pest birds or discourage them from landing upon the crop [44,62]. The method was used to attract the Australian Harrier *Circus approximans* to control frugivorous birds in a New Zealand vineyard with great success [63]. Two groups of researchers [64,65] also attributed declines in many European farmland birds to predation pressure by carnivorous birds. Attracting predatory birds on the rice fields would have the additional benefit of controlling populations of other such rice pests as rodents and squirrels [64,66]. Patching surfaces could consist of a series of tall poles, trusses or beams made out of wood or plastic piping and erected at specific intervals across the rice field in the period during rice maturity and harvest. After harvesting, the structures would need to be dismantled until the following season because large populations of birds of prey on agricultural landscapes may considerably and indiscriminately reduce populations of smaller birds by destroying their nests, chicks and eggs thereby destabilizing the ecosystem [62]. Effectiveness of this measure would also require controlled human traffic across the fields to minimize disturbance to the birds of prey.

More recent developments in bird pest management research have also focused increasing attention on using modeling of existing climate data, rainfall patterns and crop seasonality which together with satellite tracking, can be used to generate early warning systems for expected invasions by *Quelea* and other pest species across their ranges [33,44].

## 4. CONCLUSIONS

Rice damage by pest birds leads to high direct and indirect losses of income to farmers in Ahero Rice Scheme and undermines efforts to reduce poverty, improve rural population welfare and achieve national food security. Minimizing loss to the bird pests requires combining different measures to control their access to the crop that are part of a wider integrated pest management strategy. Using crop-guarding measures is currently the most widely applied and effective measure by farmers to minimize bird pest damage but its high unit cost still adds substantially to overall production costs thus diminishing returns for farmers. Investing in physical barrier netting equipment to protect the crop promises to be a viable solution that would both eliminate bird damage and reduce overall production costs. However in addition, there is need for institutional intervention mechanism to support rice farmers in form of a national bird pest control policy, technical incentives for increasing production as well as more streamlined marketing systems for better prices. Finally, control and management measures against pest birds should also recognize the significant positive role that some of the bird species (*Euplectes sp* and Ploceidae) also play in controlling densities of arthropod crop pests.

## **ETHICAL APPROVAL**

Not applicable

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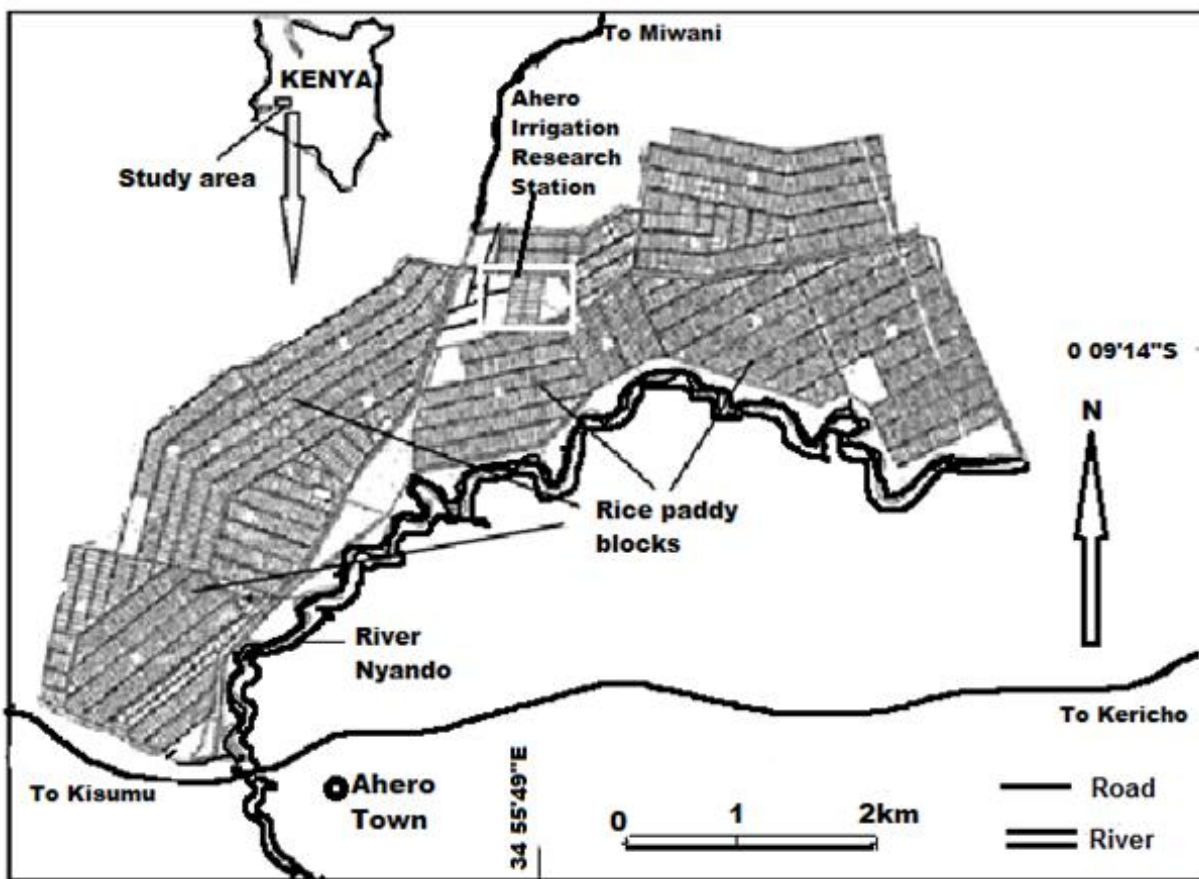


**Figure 1.** Map of study area showing various paddy-fields where sampling was conducted. (Adopted from 37).

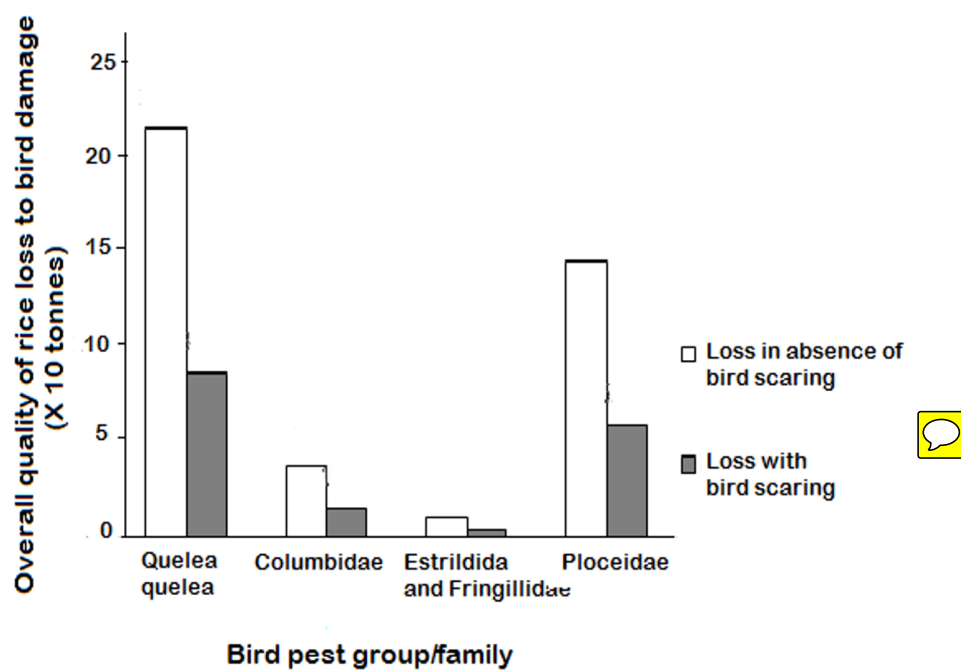


**Figure 2.** Estimated total annual quantity of rice crop loss to various pest bird groups.

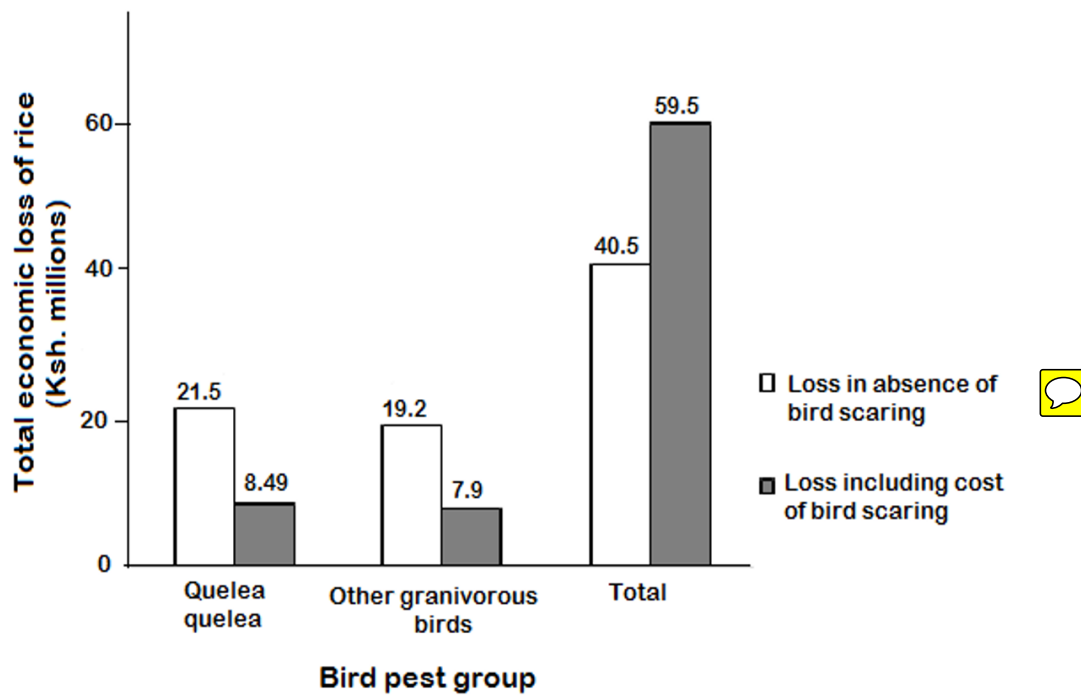


**Figure 3.** Estimated economic loss of rice crop to various granivorous birds at Ahero Rice Scheme.

**Table 1.** Checklist of granivorous birds encountered in the study area.



| Family       | Common name                    | Scientific name                  |
|--------------|--------------------------------|----------------------------------|
| Columbidae   | Emerald-spotted Wood Dove      | <i>Turtur chalcospilos</i>       |
|              | Red-eyed Dove                  | <i>Streptopelia semitorquata</i> |
|              | Ring-necked Dove               | <i>Streptopelia capicola</i>     |
|              | Speckled Pigeon                | <i>Columba guinea</i>            |
| Estrildidae  | African Fire-finch             | <i>Lagonosticta rubricata</i>    |
|              | Red-billed Firefinch           | <i>Lagonosticta senegala</i>     |
|              | Red-billed Quelea              | <i>Quelea quelea</i>             |
|              | Red-cheeked Cordon-bleu        | <i>Uraeginthus bengalus</i>      |
| Fringillidae | Streaky Seedeater              | <i>Serinus striolatus</i>        |
|              | Yellow-rumped Seedeater        | <i>Serinus xanthopygius</i>      |
| Viduidae     | Pin-tailed Whydah              | <i>Vidua macroura</i>            |
| Ploceidae    | Grosbeak Weaver                | <i>Amblyospiza albifrons</i>     |
|              | Jackson's Golden-backed Weaver | <i>Ploceus jacksoni</i>          |
|              | Red-billed Buffalo Weaver      | <i>Bubalornis niger</i>          |
|              | Speke's Weaver                 | <i>Ploceus spekei</i>            |
|              | Village Weaver                 | <i>Ploceus cucullatus</i>        |
|              | Black Bishop*                  | <i>Euplectes gierowii</i>        |
|              | Southern Red Bishop*           | <i>Euplectes orix</i>            |

\*Consumers both plant material and arthropods