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Promoting Biodiversity on Maize Smallholdings

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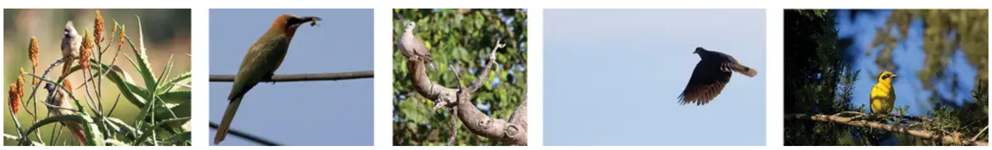
The following article contains results and insights from Sean Lyon's Human Needs and Global Resources (HNGR) internship at the ECHO East Africa Regional Impact Center in Ngaramtoni, Tanzania. The HNGR Program is run by Wheaton College in Wheaton, Illinois, USA. Sean was an intern from May 10th to December 8th, 2017, during which time he conducted on-farm surveys for bird diversity.



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Biodiversity benefits smallholders

Farmers in tropical regions are often economically disadvantaged and farm on marginal soils. Their vulnerability is exacerbated by realities such as climate change, regional conflicts, and disease outbreaks (Stocking, 2001). In our efforts to address the agricultural needs of vulnerable communities, we often focus on the crops being grown. In this article, I want to draw attention to the ecological context in which that food production occurs.

A healthy ecosystem provides key services that benefit humans (Şekercioğlu, 2010). Many of these services include a positive financial impact (Kellermann *et al.*, 2008). Ecosystem services can be categorized as one of four distinct types: supporting, provisioning, regulating, and cultural services. Supporting services contribute to the other three services, and include soil formation, nutrient cycling, and primary production. Provisioning services provide products such as food, fresh water, and fuelwood directly from the ecosystem. Regulating services include disease regulation, water purification, and pest moderation. Cultural services offer nonmaterial benefits such as spiritual and religious value, cultural heritage, and a sense of place (Millennium Ecosystem Assessment, 2003).

Birds contribute to farm production

Birds provide an important regulating ecosystem service to farmers by controlling pests and thus reducing the need for pesticides. Studies of insectivorous birds on coffee farms have shown economic benefits of USD $44 to $310 per hectare per year (Kellermann *et al.*, 2008; Johnson et al., 2009). Recent research of birds' diets in maize fields that border prairie ecosystems revealed that an economically-important crop pest, the northern corn rootworm, was consumed by 34.5% of the birds studied; the benefit was calculated to be worth USD $275 per hectare (Garfinkel *et al.*, 2020). Another study found that birds of prey can decrease the population of rodents in farm fields by nearly 50% (Kay *et al.*, 1994). Furthermore, studies of Kenyan sun coffee farms showed that both birds and ants provided pest control services, and that fragments of forest nearby the field promoted pest removal (Milligan *et al.*, 2016).

The high economic value and the increased production potential for farmers are powerful incentives for attracting birds to farm plots. However, there are some instances where birds are implicated in the destruction of crops. For example, birds sometimes dig up seeds that have been planted, eat young seedlings, damage mature fruits, or consume the seeds of cereal crops. These are considered to be ecosystem disservices provided by birds. Despite this reality, Şekercioğlu *et al.* (2016) thoroughly analyzed worldwide research and found that though localized losses of crops may be high, overall, birds consume only about 1% of crops. These crop losses due to birds' activities are much lower than losses due to insect and rodent pests. Additionally, a bird often thought to be a major crop pest in Venezuela (dickcissel, *Spiza americana*), was found to be more beneficial than detrimental once all costs were considered, including the costs of lethal control measures--both in terms of finances and of impact on human health (Basili and Temple, 1999). The services provided by birds (among others, eating insects and rodents, fertilizing fields, consuming the seeds of pest plants, and dispersing indigenous plants) far outweigh their cost.

Purpose of our study

Through this observational study, Erwin Kinsey, Dr. Kristen Page, and Sean Lyon (hereafter "we") sought to clarify the interrelationships of birds, trees and pests on maize/bean intercropping smallholdings in northern Tanzania, and to hear directly from farmers about their own participation in agroecosytem functioning. In this article, I (SL) focus specifically on lessons learned from observing birds in these farmers' fields.

Stakeholders

Stakeholder inclusion

Prior to implementing this study in the community of Ngaramtoni (subvillage of Seuri), we first sought permission to survey from the village chairman, or *mwenyekiti*. Receiving the consent and welcome of everyone involved in biological or agricultural studies is extremely important. In addition to obtaining written permission from the *mwenyekiti*, we asked every farmer whose property was surveyed for permission to study their farm and crops. Some farmers questioned the impact and purpose of the research, giving us an opportunity to clarify the project and to put the main actors––the farmers themselves––at ease. Some farmers, though initially skeptical, soon opened their fields to our survey. Agroecology is a foreign concept to some people, so the approaches and techniques used when surveying fields can appear strange. Standing in the corner of a field and watching birds for minutes on end is hardly typical behavior in many farming communities!

Study site

This study was conducted in the Arusha Region of north-central Tanzania, a plains-dominated landscape which borders Kenya to the north. Mount Meru rises from these dry plains, and its unique topography makes the region a center for small-scale agriculture; fertile volcanic soils and elevation-determined rainfall predispose the land to productive farming. West of the city of Arusha is Ngaramtoni, a trade town with subvillages where subsistence agriculture is practiced, resulting in a range of landscape modification across the region.

Figure 3. Survey sites in Seuri subvillage, Ngaramtoni, Tanzania. Each surveyed farm is highlighted in yellow. *Source:* Google maps, modifications by Sean Lyon.

Surveys occurred within the Afromontane Dry Transitional Forest zone (Kindt *et al.*, 2015). This vegetation zone is found on dry lower slopes of East African mountains. Characteristic tree species found here include the Nile tulip tree (*Markhamia lutea*) and the silvery-leaved croton (*Croton megalocarpus*). Agricultural activity and deforestation have changed the vegetation composition of the region; therefore, only small fragments of Afromontane Dry Transitional Forest remain (Kindt *et al.*, 2015). Maize and bean intercropping is dominant due to the rich soils. The farms (Figure 3) were surveyed in August 2017, during the dry season. Average temperatures in August range from 12 to 22°C , and the air is very dry, with the last rains having fallen two months prior. August marks the very end of the growing season and the beginning of the harvest season.

We offer these recommendations when gathering agroecology data:

- **Use local languages** for all data sheets, questionnaires, and other survey tools. This makes it easier to show farmers and other respondents what you are doing.
- **Include photos of plants and trees on the survey**, to provide clarity to participants who may not be able to read, or in contexts where multiple languages are spoken.
- **Survey in pairs** (ideally with one person being a native speaker of a local language), for increased safety, improved communication, and the opportunity to share time-consuming responsibilities, such as quantifying trees.

Bird survey methods

We conducted avian (bird) surveys at 9:20 am ± 20 minutes via unlimited point-counts, during which I (SL) recorded all birds visible within 360°. Point-count surveys (described by Verner, 1985) are common in avian research. They involve identifying birds at a single location for a defined period of time, noting both the species and number of individuals of each species. Some point-counts are limited, with birds counted up to a certain distance away from the observer. Others, known as unlimited point-counts, or “point counts without distance estimation” (Verner, 1985), take into account all birds present in the surveyor’s view. I used Birds of East Africa by Terry Stevenson and John Fanshawe (2004) to identify bird species. I stood for ten minutes per corner at each farm field (see Figure 3), recording on a data sheet each species that I saw, and the number of individual birds of that species. That gave me four observation points, totaling forty minutes of bird count-time, for each farm surveyed.

Bird survey results (***Tables 1 & 2***)

718 individual birds were recorded in the avian point-count surveys, with 38 total species seen during the survey period. Most of the individual birds were the pied crow (*Corvus albus*, 30.4%; see Figure 4), followed by baglafecht weavers *(Ploceus baglafecht reichenowi*, 17.6%; see Figure 5). The number of species per farm (bird species richness) ranged from 4 to 14 species, averaging 10.8 species per farm. A point-count survey is not the best survey method for representing avian population density (number of individual birds per unit of land area). However, population density can give a basic understanding of how landscape affects birds, so I have included that calculation here. The Shannon Index (Table 1) is one way of representing species diversity, and is calculated by dividing the number of individuals of a given species by the total number of individuals of all species in an area. In this calculation, the higher the number, the more diverse the study site.

Figure 4. Pied crow (*Corvus albus*). *Source:* Dr. Kristen Page.

Figure 5. Baglafecht weaver (*Ploceus baglafecht reichenowi*). *Source:* Dr. Kristen Page.

Table 2. Most-abundant bird species in avian survey.						
#	**Species seen**	**Common name**	**Total sightings**	**Average per farm**	**Average per watch-hour**	**Feeding groups**
1	*Corvus alba*	pied crow	236	18.2	29.5	Wide diet
2	*Ploceus baglafecht*	baglafecht weaver	126	10.5	15.75	Seed eater
3	*Colius striatus*	speckled mousebird	39	3.25	4.88	Leaf eater
4	*Streptopelia semitorquata*	red-eyed dove	35	2.92	4.38	Seed eater
5	*Merops bullockoides*	white-fronted bee-eater	29	2.41	3.625	Insect eater

Insights gained from bird surveys

There is a large gap between the most-abundant and second-most-abundant species (Table 2). This indicates the presence of a few dominant generalist species in this modified agricultural landscape rather than a greater diversity of specialist species that would be found in the native landscape. Even so, the top five bird species represent four different feeding groups (i.e. species groupings based on dietary preference), with only baglafecht weavers and red-eyed doves sharing a diet. This may indicate that one species exploits each of the main food sources in the ecosystem.

A relevant example of the importance of farmer involvement in bird diversity is found in Site 8A, a large maize/bean intercropped smallholding that was planted entirely with a single, non-native tree species (Australian silky oak, *Grevillea robusta*). This farm showed conspicuously low avian diversity, with just four bird species seen in 40 minutes of watching. With the loss of habitat for insect-eating species, this farm lost any benefit that those birds would provide. Meanwhile, Site 13A, which had a maize/bean intercrop planted amidst an indigenous permaculture, had the highest tree diversity, and bird diversity was above average (12 species, with a study-wide average of 10.8 species) at that site as well. This site could take full advantage of the ecosystem services provided by a variety of birds.

Strategies for Farmers

As smallholders seek to maximize the production of crops, they would do well to consider bird biodiversity. Several modifications can be made to cropping systems to incentivize bird activity.

1. **Plant native species of trees, and avoid the use of nonnative trees.** Fruitbearing or seedbearing trees attract birds throughout the year and provide habitat for them, including during the non-breeding season.
2. **Incorporate buffer zones between fields.** Bushes and trees in hedgerows or windbreaks promote soil fertility and help retain moisture; they also provide nesting sites and perches (http://tommy51.tripod.com/perch.html)for insectivorous birds. Garfinkel and Johnson (2015) demonstrated that the probability of pest removal is higher near hedgerows.
3. **Construct perches near the fields for birds of prey.** Raptors (birds that eat small animals) can reduce the mouse population by half if they are provided with perches spaced 100 m apart (Kay *et al.*, 1994). Raptors are more likely to spend time in a field with stable perches (natural or artificial). This incentivizing can also be accomplished by leaving dead trees standing adjacent to fields.

Smallholder farmers should also consider the importance of birds breeding adjacent to their fields. Many species that eat seeds during most of the year will seek protein-rich insects to feed to their young during the breeding season. Sunbirds, which as adults consume only nectar, feed their young exclusively insects (Markman *et al.*, 1999). Some species of lark (in the widespread family Alaudidae) feed their young at least once every five minutes on average, mostly providing insects and other arthropods. They make dozens or hundreds of forays per day, including in agricultural landscapes where they consume crop pests (Engelbrecht and Mathonsi, 2012). By providing sites for birds to nest (mature trees with cavities, thick brush, or tall grasses are all suitable nest spots), farmers gain resident insect-seeking pairs that feed their young very frequently while their young are in the nest. These parents work constantly to a farmer's advantage if he or she provides habitat for birds during the breeding season.

Conclusion

In our study, the large gap between the most-abundant species and those that were next-highest in prevalence indicated a loss of biodiversity, with the landscape dominated by fewer generalist species rather than a wider distribution of specialist species. However, farmers also can be agents of beneficial ecological change. The results of this study are important to both farmers and development workers, as the insights help clarify that biodiversity is a foundation for the future of crop productivity. This is especially true in a changing global landscape where smallholder farmers are making decisions of ecological importance.

When the livelihoods of smallholder farmers are often fraught with challenges--both economic and environmental--taking an agroecological approach to the farm can help ease the burdens. Birds can benefit farmers in crucially important ways, providing ecosystem services worth several hundred dollars per hectare in pest reduction alone (Garfinkel *et al.*, 2020). Many farmers can easily incorporate tools to incentivize birds to spend time near their fields, by using hedgerows and planting native trees. They can also implement appropriate technologies like constructing simple perches for birds of prey to use while hunting for rodents in their fields. These interventions allow smallholder farmers to participate more fully in supporting local ecological health, and to reap the benefits (high-value native trees also provide longer-term financial security). By applying these principles and techniques, smallholder farmers can provide supporting, provisioning, regulating, and cultural ecosystem services that will benefit themselves, the rest of the community, and the planet as a whole.

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