Human Needs and Global Resources Program, Wheaton College

Sean Christopher Lyon
Interdisciplinary Studies: Biology and Business

May 10 – December 8, 2017

ECHO East Africa

Ngaramtoni, Arusha, Tanzania

In Partial Fulfillment of the Requirements for the HNGR Certificate

Tanzanian Agroecology:

Ecosystem-Level Biodiversity on Maize Smallholdings

ABSTRACT

In highly-fertile regions such as East Africa, industrialized agricultural practices to maximize production have slashed biodiversity, which reduces the functioning of ecosystem services valuable to human and landscape health. A review of literature demonstrates a paucity of information regarding agroecological interactions in the Arusha region of Tanzania. Although some studies have investigated the impact of avian biodiversity on crop productivity, these types of studies have not been conducted in maize fields. Therefore, I sought to learn more about the connections between avian biodiversity and crop production of smallholder maize farmers in Arusha, Tanzania. In this study, fields were chosen along a north-south transect in the Afromontane Dry Transitional Forest vegetation zone west of the town of Ngaramtoni. At each farm, I identified the birds using point-count surveys, recorded all trees in and around crop fields, and described common arthropod pests on crops. I interviewed each farmer whose field was surveyed about crop production and attitudes towards biodiversity of trees and birds. The average farmer interviewed was 44.5 years old, and most agreed that insects are the primary threat to their crop. The most prevalent tree species was *Grevellia robusta,* a species introduced from Australia, and the most abundant bird species was the Pied Crow (*Corvus alba)*. Each farmer cultivated an average field size of 1.6 acres. Ten of 12 farmers planted the trees surrounding their field, regardless of ownership status. These results indicate that the local biodiversity is dominated by introduced and generalist species, but that farmers have significant potential as agents of ecological change. These results are of utmost importance to both farmers and ecologists, as they help to elucidate the future of crop productivity in a changing landscape.

BACKGROUND

Tropical agriculture is under increasing threat due to a changing climate (IPCC 2007). Tropical agricultural systems are dependent upon rainfall to maintain soil moisture (Dawoe et al. 2017). As a result, many of these food-producing systems are endangered by changes in the timing and amount of rainfall (Esham et al. 2018). Farmers in tropical regions are often economically disadvantaged and forced to farm on marginal soils. This vulnerability is exacerbated by climate changes. Changes in air composition and temperature affect rainfall patterns, which reduce the stability of rain-fed agricultural systems. Ensuring the health of vulnerable communities must involve food security (Jones and Ejeta 2016).

Studies of ecosystem services are demonstrating significant financial impacts of ecosystem health (Kellermann et al. 2008). Ecosystem services are the aspects of the earth that benefit humans (Şekercioğlu 2010) and can be categorized as one of four distinct types: supporting, provisioning, regulating, and cultural services. Supporting services assist in the development of 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 are nonmaterial benefits such as spiritual and religious value, cultural heritage, and a sense of place (Millennium Ecosystem Assessment 2003).

Birds provide an important regulating ecosystem service to farmers by controlling pests and reducing the need for pesticides. In Jamaican Blue Mountain coffee farms, birds consumed insects at a rate resulting in economic benefits of USD $44 to $105 per hectare (Kellermann et al. 2008). Later that year, another Jamaican study indicated that insect-eating birds in coffee fields provided pest-reduction services of up to $310 per hectare per year (Johnson et al. 2008). Birds provide the same service on apple orchards in the Netherlands, as great tits (*Parus major*) similarly reduced the detrimental effects of insect pests on apple production. This resulted in higher yield of apples of approximately 3.1 kg per tree (Mols and Visser 2002). Integrated pest management (IPM) involves natural processes such as predation playing roles in the pest-reduction that farmers need to have a healthy crop. Birds are an important part of an IPM system, providing a powerful effect on the productivity of fields, as the coffee and orchard studies demonstrate. This economic value of birds in the landscape is a powerful incentive for finding ways of attracting birds to farm plots. We predict that improved bird diversity recorded on the farm will result in improved yields, and that bird and tree diversity can be correlated.

MATERIALS AND METHODS

Description of Study Site

This study was conducted in Arusha Region of north-central Tanzania, and area which borders Kenya to the north. Mount Meru rises from the plains of northern Tanzania, and its unique topography makes the region a center for small-scale agriculture. Fertile volcanic soils and elevation-determined rainfall predispose the land toward productive farming. To the west of the city of Arusha itself is the trading town of Ngaramtoni, which has begun to merge with the city of Arusha due to urban sprawl. The coordinates of the study site were centered around latitude 3°17'21.9"S and longitude 36°37'55.7" E. The farms were surveyed during August 2017, during the dry season. Average temperatures in August range from 12 degrees to 22 degrees Celsius, and the air is very dry, with the last rains having fallen two months prior. August is the very end of the growing season and the beginning of the harvest season, which concludes in the first weeks of September.

Surveys occurred within the Afromontane Dry Transitional Forest. This zone is found on dry lower slopes of East African mountains. It is also found in uplands associated with Somalia-Masai bushlands (Kindt et al. 2015). Characteristic species found here include the Nile Tulip or siala tree (*Markhamia lutea*) and the 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 cash-crop agriculture is dominant due to the rich soils. The study site lies close to the border transition for this vegetation zone, and neighboring farms outside of the border were excluded from the study.

Before implementation in the community of Ngaramtoni (subvillage of Seuri), permission to survey was first sought from the village elder, or *mwenyekiti*. Twelve hand-cultivated farms in the Seuri subvillage were surveyed spanning an end-to-end distance of 4 km total. Each of the farms were dominated by maize (*Zea mays*), but every field was also intercropped with other species, primarily legumes. All surveyed farms had a standing crop of maize.

Methods

Avian surveys were conducted at 9:20 am ± 20 minutes via point-counts in which all of the birds visible within 360° of the point were recorded. *Birds of East Africa* by Terry Stevenson and John Fanshawe (2004) was used for the positive identification of these species. The start of the first point count began at 9:20 am ± 20 minutes. This was in an effort to balance the earliest human capacity to travel to the farm with the highest behavioral activity of the local bird species, which are consistently more active during morning hours than during midday or afternoon.

Trees immediately at the edge of the field, or found within the field, were indexed, taking into account both the abundance and range of species present. To the identity the species, Najma

Dharani's *Field Guide to the Common Trees and Shrubs of East Africa* (2011) was consulted, and if a positive identification was not forthcoming, expert staff members at ECHO East Africa, a locally-based conservation agriculture NGO, provided identifications. All notations for birdlife and trees were taken on paper data sheets and transcribed upon return to the office.

Pest prevalence was assessed qualitatively. Through the use of a sheet of random numbers from 1- 20 and a compass, the number steps to be taken in each cardinal direction within the field were determined. After walking in the fourth direction, the plant found in front of the surveyor was assessed. With the assistance of another investigator, the plant was visually assessed from tassel to roots, and the observations were recorded in a sound file. Any insect pests or evidence of arthropods (webbing, feces, damage to the plant) was described, and non-invasive checking under husk leaves revealed any insects that were not immediately apparent. These data were then transcribed.

Each farmer whose farm experienced a biodiversity assessment of birds and trees was also interviewed orally regarding cropping practices and general demographic information. A data sheet directed and standardized which information was collected from the respondent. Tanzanian university students assisted in the oral administration of the survey, in an effort to ensure accuracy of comprehending respondents' answers. Additionally, these assistants acted as cultural brokers, allowing for the farmers to feel more comfortable during the survey process. Generally, the survey took between 30 and 45 minutes to complete, depending on the extent of the farmer's response. The content of each interview was focused on the farmer's experience of farming as well as their cropping approach. Demographic data such as age were collected alongside historical data on when they personally began farming and when their farms were converted from forest to farmland for the first time. Cropping approaches included the primary crops grown, what they perceive the top pests to be, whether or not chemical inputs are used, and yield from the farm.

RESULTS

General Farm Results:

Every farm in the study area was organic, with no farmers reporting any use of fertilizers or pesticides. All cultivation was performed by hand. The farmers interviewed cultivated a total of 19.1 acres of land, ranging from 0.3 acres to 4 acres, and averaging 1.6 acres per farmer.

Avian Survey Results:

718 individual birds were recorded in the avian point-count surveys, with 38 species total seen during the survey period. Most (n=218, 30.4%) of the individual birds seen were the Pied Crow (*Corvus alba*), followed by Baglafecht Weavers (*Ploceus baglafecht*) (17.6% , n=126). Bird species richness ranged from 4 to 13 species, averaging 10.8 species per farm.

Figure 1: Summary Results of Avian Survey

Site #:	Site Area (acres)	Bird species total:	Bird records total on site:	Bird Population Density (birds/acre)	Shannon:
2A	0.33	**10**	**54**	163.6	1.634
3A	0.34	**10**	**45**	132.4	1.679
4A	0.24	**12**	**59**	245.8	1.967
5A	0.19	**10**	**28**	147.4	2.175
6A	0.28	**14**	**92**	328.6	1.781
7A	0.26	**12**	**50**	192.3	2.105
8A	0.83	**4**	**50**	60.2	0.662
9A	0.25	**9**	**23**	92.0	1.978
10A	0.89	**12**	**42**	47.2	2.017
11A	0.55	**11**	**49**	89.1	1.845
12A	0.66	**13**	**144**	218.2	1.832
13A	0.30	**12**	**82**	273.3	2.23

Figure 2: Most-abundant Bird Species in Avian Survey

#	Species Seen	Total Sightings	Average Per Farm	Average per Watch-Hour
1	*Corvus alba*	236	18.2	29.5
2	*Ploceus baglafecht*	126	10.5	15.75
3	*Colinus striatus*	39	3.25	4.88
4	*Streptopelia semitorquata*	35	2.92	4.38
5	*Merops bullockoides*	29	2.41	3.625

Tree Index Results:

Tree species richness ranged from 1 to 20 species, averaging 9.83 species per farm. I saw a total of 48 tree species across all survey sites. The most common species observed was the Australian silky oak (*Grevellia robusta*) with 543 unique counts, followed by native croton (*Croton megalocarpus*), recorded 49 times. 888 total trees were seen across the farms, and thus 61.1% of all trees species were *Grevellia robusta.*

Figure 3: Summary Results of Tree Index

Site #:	Site Area (acres):	Tree species total:	Tree records total:	Tree population density (trees/acre):	Shannon:
2A	0.33	**8**	**92**	278.8	1.302
3A	0.34	**11**	**60**	176.5	1.752
4A	0.24	**13**	**70**	291.7	2.183
5A	0.19	**13**	**87**	457.9	1.677
6A	0.28	**8**	**81**	289.3	1.284
7A	0.26	**5**	**61**	234.6	0.529
8A	0.83	**1**	**108**	130.1	N/A
9A	0.25	**6**	**31**	124.0	1.399
10A	0.89	**14**	**52**	58.4	1.806
11A	0.55	**8**	**139**	252.7	0.679
12A	0.66	**7**	**39**	59.1	1.705
13A	0.30	**20**	**68**	226.7	2.588

Figure 4: Most-abundant Tree Species in Tree Survey

#	Species Seen	Total Sightings	Average Per Farm	Average per Acre
1	*Grevellia robusta*	543	45.3	105.8
2	*Croton megalocarpus*	49	4.08	9.55
3	*Musa acuminata x balbisiana*	39	3.25	7.60
4	*Senna spectibilis*	34	2.83	6.63
5	*Jacaranda mimosifolia*	28	2.33	5.46
6	*Croton macrostachyus*	28	2.33	5.46

Pest Prevalence Results:

Primary arthropod pests were aphids (Genus *Aphidoidea*), European earwigs (*Forficula auricularia*), and corn borer (*Ostrinia nubilalis*). Aphids and earwigs were both found in 9 of 12 fields (75%), and species of caterpillars (some of which were *O. nubilalis*) were seen in 6 of 12 fields (50%). Other problems including fungus, phosphorus deficiency (evidenced by russet leaf coloration), and moles (family Spalacidae) were found to be affecting the fields. In two instances, Baglafecht Weavers (*Ploceus baglafecht)* were seen to be predating the corn crop itself within the field of vision of the point-count surveyor.

Farmer Interview Results:

Farmers interviewed (n=12) ranged in age from 29 to 65 years old, with an average age of 44.25 years. Every farmer grew maize (*Zea mays*), and each intercropped with beans (*Phaseolus vulgaris*) as well. 41.6% (n=5) also reported that they intercropped with pigeon pea (*Cajanus cajan*) in the field. On the smallholder farms, 25% also reported growing sunflowers, and 8.5% (n=1) reported growing each of pumpkin greens, bananas, and lablab (respectively, *Cucurbita maxima, Musa acuminata x balbisiana,* and *Lablab purpureus*). 91.6% (n=11) did not practice crop rotation of any type—they intercropped beans and maize in the same plot season after season. Ten out of 12 farmers (88.5%) reported that they viewed insects as a primary agricultural pest. 88.5% (n=10) of farmers responded that they had planted the trees surrounding their field. The 9 farmers who knew when their crop fields were converted to farmland reported a range of 12 to 100 years since cultivation first began on their land, with an average among the 9 farms of 46.4 years of cultivation. Eleven farmers responded about how long they have been on their current piece of land, with a range from 1 to 40 years of cultivation, averaging 17.8 years.

DISCUSSION

The hypothesis originally intended in this research was not able to be effectively ascertained because of generalized, imprecise reporting of crop yields by the farmers, some of whom thought back to their best yields while others just described the previous growing season. Linguistic limitations prevented clarification with the respondents during the survey, and once the data were analyzed, no clear relationship between biodiversity of the field and the crop yield was found. Farmer average age reported above was 44.25 years, which is quite high given the demographic trends in Tanzania. If this is representative of the nation as a whole, it is likely that drastic measures will need to occur to involve young people in the process of farming, or the country may face difficulties with food production. That the majority did not use any pesticides or fertilizers indicates that soil health may be improved in their field, providing a richer feeding ground for insectivorous birds. Migratory species rely on the presence of insects after completing their migration, so these fields could assist in their feeding ecology upon arrival. A remarkably high number of farmers reported that they were responsible for planting the trees around their field, which is especially surprising given that several farmers volunteered the information that they do not own the plot of land that they farm. This demonstration of personal agency and investment in the landscape offers hope for the regeneration of biodiversity, and may be a way to introduce species of trees that were historically prevalent in the area but have diminished due to agriculture.

In both the birds and tree species seen, there is a very large gap between the most-abundant species and those that were next-highest in prevalence. This is a clear loss of biodiversity as the landscape is dominated by fewer generalist species rather than a more even distribution of specialist species.

The summary tables above (Figure 1, Figure 3) demonstrate the results of all observations. Of note is that site 13A has the highest Shannon Index ratings among all study sites for both birds and trees (Shannon: 2.230, 2.588 respectively). Site 5A contained the second-highest avian diversity (Shannon: 2.175) while Site 4A had the second-highest tree diversity (Shannon: 2.183). Tree surveys revealed that the Australian silky oak, *Grevellia robusta*, was by far the most prevalent species found in the region, accounting for 61% of all trees observed.

Some of the limitations of the researcher resulted in species not being positively identified, and the table below with the most prevalent bird species only counts those which were positively identified. Another observer with deeper experience in the birdlife or northern Tanzania may come to different conclusions with a richer base of positive identifications.

REFERENCES

Dawoe, E.K., V.R. Barnes, and S.K. Oppong. 2017. Spatio-temporal dynamics of gross rainfall partitioning and nutrient fluxes in shaded-cocoa (*Theobroma cocoa*) systems in a tropical semi-deciduous forest. *Agroforestry systems.* **92**:2, 397-413.

Esham, M., B. Jacobs, H.S.R. Rosairo, and B. B. Siddighi. 2018. Climate change and food security: a Sri Lankan perspective. *Environment, Development and Sustainability* **20**:3, 1017-1036.

IPCC, 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Report of the Working Group II. Cambridge University Press, U.K., p. 973.

Johnson, M.D., J.L. Kellermann, and A.M. Stercho. 2009. Pest reduction services by birds in shade and sun coffee in Jamaica. *Animal Conservation.* **13**:140-147.

Jones, A.D., and G. Ejeta. 2016. A new global agenda for nutrition and health: the importance of agriculture and food systems. *Bulletin of the World Health Organization* **94**:3, 228-229.

Kellermann, J.H., M.D. Johnson, A.M. Stercho, and S.C. Hackett. 2008. Ecological and Economic Services Provided by Birds on Jamaican Blue Mountain Coffee Farms. *Conservation Biology* **22**:1177-1185.

Kindt R., P. van Breugel, C. Orwa, J.P.B. Lillesø, R. Jamnadass, and L. Graudal. 2015. *Useful tree species for Eastern Africa: a species selection tool based on the VECEA map.* Version 2.0. World Agroforestry Centre (ICRAF) and Forest & Landscape Denmark.

Lambin E.F., H.J. Geist, and E. Lepers. 2003. Dynamics of land-use and land-cover change in tropical regions. Annu Rev Environ Resour 28:205–241.

Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Wellbeing. A Framework for Assessment.* Island Press, Washington, DC, U.S.A.

Mols, C.M.M., M.E. Visser. 2002. Great tits can reduce caterpillar damage in apple orchards. *Journal of Applied Ecology* **39**:888–899.

Şekercioğlu, Ç.H. 2010. Ecosystem functions and services. In: Sodhi NS, Ehrlich PR (eds) *Conservation Biology for All.* Oxford University Press, Oxford, pp 45–72

Şekercioğlu, Ç.H. 2016. *Why Birds Matter: Avian Ecological Function and Ecosystem Services.* University of Chicago Press, Chicago, Illinois, U.S.A.

Stevenson, T., and J. Fanshawe. 2004. *Birds of East Africa: Kenya, Tanzania, Uganda, Rwanda, Burundi.* Helm Field Guides, Bloomsbury Publishing, London, U.K.

Stocking, M.A. 2001. *Land Degradation,* International Encyclopedia of the Social & Behavioral Sciences, pp. 8242–8247

SUPPLEMENTARY MATERIALS/APPENDICES

APPENDIX I: Permission to Research from Village Official

K.K Mwenyekiti wa Kitongoji cha Seuri

MWENYEKITI WA KITONGOJI CHA SEURI
TAREHE 26/7/2017
SAHIHI
KATA YA OLTRUMET

ECHO
EAST AFRICA IMPACT CENTER
P.O. Box 15205, Arusha – Tanzania
Simu: +255754480184
24 Julai, 2017

KWA: Ofisi ya Mwenyekiti
Kitongoji cha ~~Ekenywa~~ Seuri
Ngaramtoni – ARUSHA

Ndugu Mwenyekiti,

Kuh: Mtajwa Sean Lyon Kufanya Uchunguzi wa Kilimo katika Kijiji Chetu

Rejea hapo juu, tunapenda kumkaribisha Sean Lyon, ambaye anafanya kazi ya kujitolea kwa ECHO kuchunguza viumbe hai katika mashamba ya wanakijiji wanaomruhusu. Ataangalia aina na idadi za ndege, na wadudu waharibifu, na wadudu rafiki na aina za miti katika mashamba.

Atafanya chini yangu, Mkurugenzi wa ECHO Afrika Mashariki. Uchunguzi wake utatusaidia kufikiria mambo yanayosababisha matatizo au mafanikio katika mazingira tofauti za mashamba. Atatumia wakati kwa makini kutumia muda katika mashamba, kukusanya idadi na inatarajiwa kuchukua masaa kadhaa kwa kila shamba. Lengo la kazi hii ni kugundua mahusiano kati ya aina mbalimbali za mti karibu na shamba, aina gani za ndege zilizopo, na uharibifu wa wadudu ni kiasi gani kwa mazao. Itasaidia ECHO kufanya mapendekezo jinsi ya kuboresha matunzo ya ardhi na mashamba. Mkulima akiwa na wasiwasi kuhusu uwepo kwa Sean, anaweza kuwasiliana name, kwenye simu +255 0754 480 184 kwa majibu ya maswali yoyote.

Natanguliza shukrani kwa kumkubali Sean Lyon na kumtia moyo awe na amani katika jamii yenu.

Wako katika kujenga taifa.

Erwin Kinsey

Erwin Kinsey, Mkurugenzi
ECHO
Arusha, Tanzania

APPENDIX II: Survey Form in Swahili

Namba ya dodoso:____ Dodoso la Agroekologia kwa Mkulima

Tarehe: Eneo:

Jina na Umri wa Mkulima Anayohojiwa:

1. Ni lini ardhi hii ilibadilishwa kutoka msitu na kuwa shamba la kuzalisha mazao? ___________
2. Ni mwaka gani ulianza kulima shamba hili? ___________
3. Shamba hili lina ekari ngapi ?___________
4. Ni mazao gani ya msingi ambayo unapanda shambani kwako?

   ☐ Mahindi ☐ Maharagwe ☐ Mbaazi ☐ Ngwara ☐ Migomba ☐ Viazi vitamu ☐ Alizeti

   ☐ Mazao mengine__________☐ Mazao mengine__________

5. Je! Unazungusha mazao? ☐ Ndio ☐ Hapana Mzunguko inakuaje?

   ____

6. Je! Viumbe hai gani vinashambulia mazao yako?

   ____

7. Je, unanyunyiza dawa katika mazao yako?

   ☐ Ndiyo ☐ Hapana Aina gani ya dawa ?_________

8. Katika kaya yako umetumia magunia mangapi ya mazao katika mwaka jana? Na uliuza magunia mangapi?

   ___kg ☐ Mahindi ___kg ☐ Maharagwe ___kg ☐ Mbaazi ___kg ☐ Ngwara

   ___kg ☐ Viazi vitamu ___kg ☐ Mazao mengine_________ ___kg ☐ Mazao mengine_______

9. Je! Tangu uanze kulima, umeona aina au idadi ya ndege zimeongezeka au kupungua katika shamba lako hapa? ☐ Namba wengi zaidi ☐ Namba wachache zaidi ☐ Aina wengi zaidi ☐Aina wachache zaidi

   ____

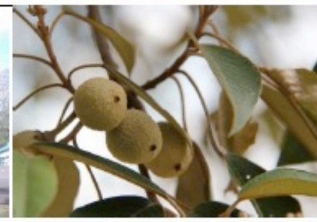
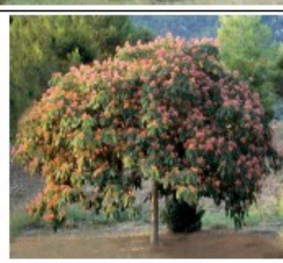
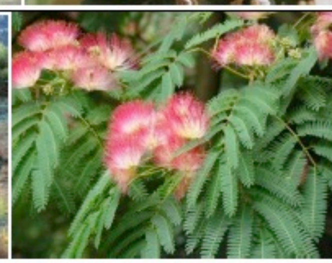
10. Je! Ulipanda miti yoyote karibu au ndani ya shamba lako?

    ☐ Ndiyo ☐ Hapana Ikiwa ndiyo, kwa ulichagua aina hizo za miti?

11. Ni moja kati ya miti ifuatayo ambayo ungechagua na kupanda kwenye shamba lako?

12. Ikiwa siyo miti hii, ungetaka mti gani?

☐ Grevilea ☐ Mkaratusi ☐ Mhoba ☐ Jakaranda ☐ Wattle ☐ Michongoma ☐ Mparachichi ☐ Mwembe ☐ Mtipisi ☐ Mti mwingine ya matunda_______

□ (A) Olyabiyabi/ Mfurufuru		
□ (B) Mringaringa		
□ (C)Olmargoit/Mlalai		
□ (D) Olsanuwesi/Mfuruanga		
□ (E)Loliondo		

APPENDIX III: Survey Form in English

Survey # ____ Tanzanian Agroecology Farmer Survey 2017

Date:

Location:

Name and Age of Farmer Interviewed:

1. When was this field farmed for the first time? ______________
2. What year did you start farming this field? ____________
3. How large is this field, in acres? ________________
4. What are the primary crops that you are growing here?

☐ Maize ☐ Beans ☐ Pigeon Pea ☐ Lablab ☐ Bananas ☐ Sweet potatoes
☐Sunflowers ☐ Other crop(s) ____________________________

5. Do you practice crop rotation? ☐ Yes☐ No What are the crops you rotate?

____

6. What are the main pests/problems in your fields?

____

7. Do you spray your crops with pesticides?
☐ Yes ☐ No If yes, what types of pesticides or herbicides?

____

8. How many kilos of crop did this field produce last growing season? ____________
9. Since you started farming, have you seen species or numbers of birds increasing or decreasing around your farm? ☐ More species ☐ Fewer species ☐ Higher numbers ☐ Lower numbers

____

Sources for tree ID photos:

Croton macrostachyus: http://www.westafricanplants.senckenberg.de/images/pictures/euph_croton_macrostachyus_rvbli_2_3460_50d9fa.jpg, http://www.westafricanplants.senckenberg.de/images/pictures/euph_croton_macrostachyus_rvbli_3_3460_38ab62.jpg

Cordia africana: http://www.zimbabweflora.co.zw/speciesdata/images/14/148190-6.jpg, http://www.zimbabweflora.co.zw/speciesdata/images/14/148190-8.jpg

Croton megalocarpus: http://larmat.uonbi.ac.ke/sites/default/files/cavs/agriculture/larmat/images/croton megalocarpus._0.JPG, http://www.zimbabweflora.co.zw/speciesdata/images/16/165160-4.jpg

Albizia spp: https://www.plant-world-seeds.com/images/seed_images/ALBIZIA_JULLIBRISSIN/size3_500x500/ALBIZIA%20JULIBRISSIN1.JPG, https://maxpull-gdvuch3veo.netdna-ssl.com/wp-content/uploads/2013/05/albizia-silk-tree.jpg

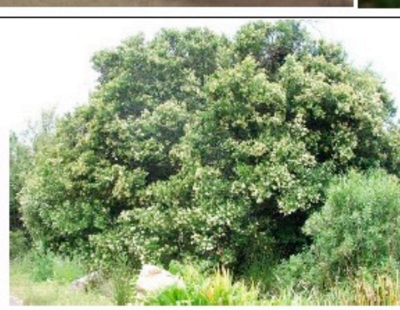
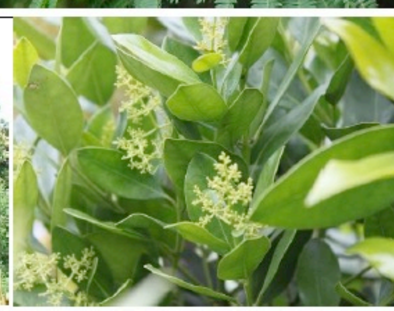
Olea capensis: https://upload.wikimedia.org/wikipedia/commons/2/21/Olea_capensis_capensis_tree_in_flower_cape_town.JPG, https://upload.wikimedia.org/wikipedia/commons/thumb/2/28/X_Ironwood_Tree_Olea_capensis_FoliageDetail_1.jpg/1280px-X_Ironwood_Tree_Olea_capensis_FoliageDetail_1.jpg

10. Did you plant any of the trees around your field? ☐ Yes ☐ No
If yes, which species and why did you choose them?

____

Survey # ____ Tanzanian Agroecology Farmer Survey 2017

Which one of these trees would you pick to plant on your farm? If none, which tree would you want?

□ (A) Croton macrostachycus		
□ (B) Cordia africana		
□ (C)Croton megalocarpus		
□ (D) Albizia spp.		
□ (E)Olea capensis		

APPENDIX IV: Map of Survey Sites (Subvillage Seuri, Ngaramtoni, Arusha, Tanzania)