“DEVELOPMENT OF DESIGN CRITERIA AND OPTIONS FOR PROMOTING LAKE RESTORATION OF LAKE BOSOMTWE AND IMPROVED LIVELIHOODS FOR SMALLER-HOLDER FARMERS NEAR LAKE BOSOMTWE - GHANA, WEST AFRICA”

by

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Dedicated to my family and friends

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ABSTRACT

Author: Baldwin, Grace, L. MSABE
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Title: Development of design criteria and options for promoting lake restoration of Lake Bosomtwe and improved livelihoods for smaller-holder farmers near Lake Bosomtwe - Ghana, West Africa
Committee Chair: Dr. Robert M. Stwalley III.

The Lake Bosomtwe impact crater is located in the Ashanti region of Ghana, West Africa. The impact crater diameter from rim to rim is approximately 10.5 km wide with a lake located at the center. Three different districts touch the lake containing 155,000 hectacres of land. There are approximately 7,500 people from 24 villages, and 12 of those villages reside within walking distance of the lake shore. Within the last ten years, the lake has been subjected to overfishing and environmental degradation. The health of the lake has declined due to overfishing and algae blooms caused by improper fertilization rates. Because of these factors, residents of the area have been forced to transition to subsidence farming as their main vocation. According to the Ghana Statistical Service group, 97.6% of the population participates in some form of rural crop farming (Ghana Statistical Service, 2010). Experience with common practices such as crop rotation, fertilizer use, and erosion control is extremely limited. The lake has not been recommended for recreational use due to the excess runoff in the form of agrochemicals, liquid, and organic waste. Caged aquaculture and traditional fishing within Lake Bosomtwe is currently illegal.

A comprehensive Institutional Review Board (IRB) survey was developed for the six primary research questions to be examined. From these six research questions, 147 specific questions were developed. Three of the 147 questions were to obtain Global Positioning System (GPS) data for community households, pit latrines, and water wells or boreholes. This study sought to interview 10-15 farmers per village, for each of the 12 villages located along the shore of Lake Bosomtwe of their perspective on land use change/cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. These surveys were collected in the form of oral responses, for which 118 small-holder farmers

were interviewed. Of the participants surveyed, 66% were qualified to answer all questions, and 100% of participants completed the survey.

Some specific statistical tests were conducted based of market assessment survey. It was determined that no association between gender and level of education existed. Meaning, that female participants interviewed have just as many opportunities as male participants to pursue education beyond Junior High School (JHS). Yield averages between the villages on the north side of the lake with road access and villages on the southern portion of the lake with limited to no road access were determined to be significantly different. It was determined that road access does affect village yield. When comparing average usable yields between villages located on the northern side of the lake with road access or between villages on the southern side of the lake with limited to no road access, these results were not statistically significant. No significant difference in the scores for villages with road access on the northern side of the lake and villages with limited to no road access on the southern side of the lake existed. Therefore, road access does not affect village usable yield. Through statistical analysis an association was determined between people who practice bathing and washing in the lake and those who practice fishing as a form of livelihood.

Four decision matrices were created to prioritize the following items: Farm Components, technologies to showcase at an appropriate technology center, improved farming practices to showcase through Demonstration Plots, and extension outreach topics. The top three results for the Farm Components were: Appropriate Technology Center (ATC), Demonstration Plots, and a Micro-Credit Union. The top three technologies to showcase as part of the ATC are: PICS Bags, Moisture Meters, and Above-Ground Aquaculture. The three demonstration plots recommended terracing/erosion control, crop rotation, and cover crops. The highest priority extension outreach topics were: basic home/farm finance, improving health through washing stations, and post-harvest loss prevention. The top three priorities of each decision matrix will be the focus of further study, so that these topics can be developed and programs focusing on these needs can be implemented in collaboration with the community partners.

1. INTRODUCTION

1.1 Project Back Ground

The Lake Bosomtwe impact crater is located in the Ashanti region of Ghana, West Africa. The impact crater diameter from rim to rim is approximately 10.5 km wide with a lake located at the center. Three different districts touch the lake containing 155,000 hectacres of land. There are approximately 7,500 people from 24 villages, 12 of which reside within walking distance of the lake shore. A map of the local region showing the villages is presented in Figure 1. Restoration and promotion of small-holder farmer effectiveness is key to economic development, and this study will help establish an initial census of agricultural practices in the region which are known to have a significant effect on the lake health.

Within the last ten years, the lake has been subjected to overfishing and environmental degradation. The health of the lake has declined due to overfishing and algae blooms caused by improper fertilization rates. Because of these factors over the last seven years, residents of the area have been forced to transition to subsidence farming as their main vocation. Experience in common practices such as crop rotation, fertilizer use, and erosion control is extremely limited.

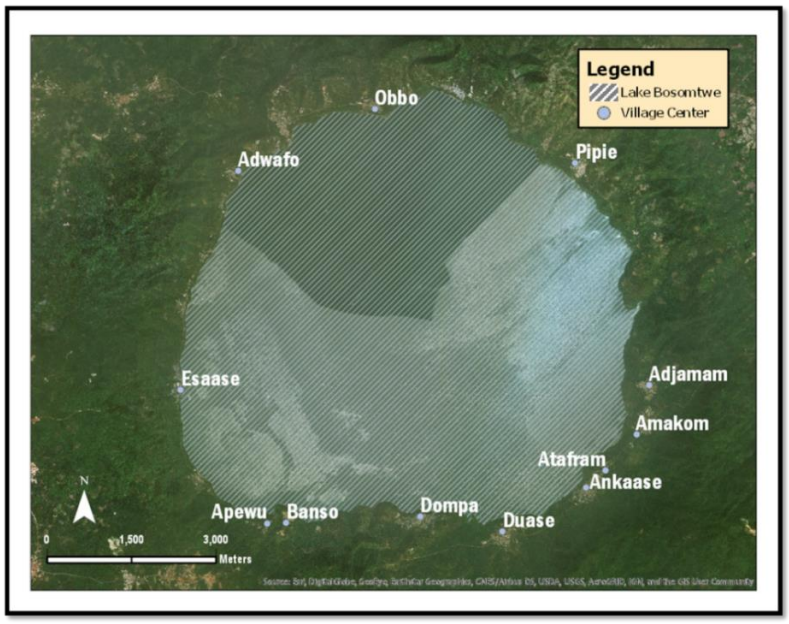


Figure 1 Lake Bosomtwe (Baldwin, 2019)

The area surrounding Lake Bosomtwe is very mountainous, and this location falls within the tropical forest zone of Ghana. People living within the impact crater cultivate crops in primarily clay soils, with shallow soil profiles, often on the sides of hills with 20% slope or greater. A single perennial stream feeds into the lake on the south west side. The lake is primarily dependent on rainfall within the impact crater for replenishing its water level. Shrinkage of the lake has been a concern due to the large amount of silt deposits that are carried by excess runoff.

Certain activities within the Lake Bosomtwe impact crater are done very close to the lake shore (Wireko, 2015). These activities include the use of toilet facilities, swine operations, and crop farming. Within the area, 72.5% of the farms are located within 300 m or less of the lake (Wireko, 2015). It was found that 89.8% of the swine operations were located less than 20 m from the lake (Wireko, 2015). The lake has not been recommended for recreational use since 2016, due to the excess runoff in the form of agrochemicals, liquid, and organic waste (Nketia, et al., 2016) . In addition, the king of the region has outlawed certain forms of fishing activities within the lake. Caged aquaculture and traditional fishing within Lake Bosomtwe is currently illegal. Fishing conducted above ground, or on land properly cited away from the lake, is legal. Lake Bosomtwe is seen as a national asset that could be developed as a way for the country of Ghana to further stimulate their growing tourism industry. However, this natural resource has been severely mis-managed.

According to the Ghana Statistical Service group 97.6% of the population participates in some form of rural crop farming (Ghana Statistical Service, 2010). The average annual household income in this area is $100 USD (Ghana Statistical Service, 2010). The purpose of this project is to collect information needed to design an extension demonstration farm that will promote improved conservation agricultural practices to local farmers, and through the demonstration of these conservation practices, help restore and better manage Lake Bosomtwe. Through the adoption of modern agriculture methods, it is likely that both the health of Lake Bosomtwe can be restored and the livelihoods of smallholder farmers in the area can be increased.

This project was first proposed by the Methodist Church Ghana Kumasi Bishop Christopher Nyarko Andam, while visiting the Lake Bosomtwe area with a team from Global Resources

Connections Inc (GRC), an non-governmental organization (NGO) from Lafayette, Indiana. This trip took place during the summer of 2016. The overall project was started as part of a senior design capstone project in Purdue's Agricultural & Biological Engineering (ABE) Department by the current graduate student, Grace Baldwin (Baldwin & Stwalley, 2017). A follow-up trip took place during the summer of 2017 to conduct a 20-acre baseline soil survey and to install some initial demonstration plots to show vegetative terracing with the help of a farm manager. Unfortunately, within the Lake Bosomtwe impact crater, crop farming, swine operations, and human relief activities are conducted very close to the lake shore. There is a minimum of one pit latrine located in each village. Since farming and pig operations are sited closely near the lake, organic waste, agrochemicals, and other liquid wastes run into the lake. In addition, the lake is also being used for irrigation purposes. This is not a recommended practice because of the high amounts of salt in the lake, but it is common place.

This study developed a comprehensive IRB survey that allowed farmers from the 12 villages to share their needs, insights, and ideas, so that these could be incorporated into the design of a demonstration farm and focus extension outreach activities. Farmers participated in one on one interviews answering over 140-questions, which allowed for the following types of data to be collected: demographic, land use, farming practices, water sanitation, and hygiene, and fishing. Spatial data was also collected for drinking water sources, pit latrines, and village centers. Going forward, this survey will serve as the most current comprehensive needs assessment for this area. Analysis of collected market assessment data is essential to the design of an extension demonstration farm and future outreach extension programing. Summary statistical figures were created to help summarize and visualize the extensive survey results to the project partners. Respondents' statistics were calculated for each question and for the overall survey. Statistical analyses were conducted in IBM SPSS to determine statistically significant findings. Four decision matrices were created to prioritize the following items: Farm Components, technologies to showcase at an Appropriate Technology Center, improved farming practices to showcase through demonstration plots, and extension outreach topics. The top three results of each decision matrix will be the focus of further study. These topics will be developed, and specific programs will be implemented to address the expressed needs of small-holder farmers within the area in collaboration with the project partners.

2. LITERATURE REVIEW

The following information was obtained prior to the implementation of the market assessment survey. Pre-existing community resources and the project partners within the community of interest were reviewed. A current understanding of the local climate and soil fertility for the region are provided. The following agronomic farming practices for the area were investigated: food and cash crops grown, crops sold at market, fertilizer and livestock, and irrigation. The potential for value added products and current transportation options was examined. An overview of the current sanitation options within the country of Ghana was highlighted. Two water quality reports based-on studies conducted through Kwame Nkrumah University of Science and Technology (KNUST) were reviewed. The reports provided significant insight into the current water quality of the lake. These reports helped provide a frame work in understanding the water quality of the lake both for recreational and irrigation purposes. The topic of rainwater harvesting for both drinking and domestic use was also covered as it pertains to the water quality and quantity of Lake Bosomtwe.

2.1 Community Resources

The primary study partner in the community was Bishop Andam of the Methodist Church Ghana Kumasi Diocese. On site at the Amakom Methodist Clinic, the project's main contact was Mr. Hilton Terry Kessie PA, who is the Director of the Amakom Methodist Clinic. Bishop Andam has selected Mr. Ebenezer as the farm's main extension officer. He is a former government officer from the Ghana Ministry of Food and Agriculture (MOFA), and he has served more than 20 years as an agriculture extension officer and staff member at the Amakom Methodist Clinic. The Lake Bosomtwe Community Health Management Team is composed of village representatives from each village, and it works in collaboration with the Amakom Methodist Clinic. This committee includes village chiefs, village assembly men and women, the management team of the Amakom Clinic, and church representatives. GRC is a non-for-profit organization who connects people to resources working in developing countries. They work in Ghana and connected the graduate student to the Methodist Church Ghana Project partner for

work on this project. This survey represents a smaller defining effort within a larger project. The support of these community leaders for this work was strong.

Since the summer of 2009, the graduate student has gone on multiple trips to Ghana. She has spent multiple months in Ghana as part of GRC and has continually been hosted by the Methodist Church Ghana. She lived in country and worked as a Development Engineer with the Ghana Methodist Relief Services Water, Sanitation, & Hygiene (WASH) program during the summer of 2015. Through this experience, she worked on 32 different projects throughout the country of Ghana. The graduate student, in partnership with GRC, has started some demonstrations plots at the current agricultural demonstration site over the last year. The graduate student was specifically asked by Bishop Christopher Andam to develop the demonstration farm at Lake Bosomtwe as part of her Senior Capstone Project under the supervision of Dr. Robert Stwalley. This project has evolved into her master's thesis work and was designed for the Lake Bosomtwe community based upon the ongoing work of GRC and the Methodist Church Ghana.

2.2 Climate

The dominant agro-ecological zone that Lake Bosomtwe resides is the Deciduous Forest Zone (VOTOMOBILE, 2015). Within this zone, the dominant land use systems are forest and agricultural plantations. Lake Bosomtwe falls in the Ashanti region. This region experiences not one, but two growing seasons, therefore allowing the cultivation of multiple crops over the course of a year. The two seasons are often referred to as the major season and minor season (VOTOMOBILE, 2015). During the first season, the major harvest is produced. Planting time for the major season occurs in mid-March to April, with harvest in August/September. Planting occurs after the rains have helped established a good soil moisture. Typically, three rains occurring in a week is considered enough to provide a good starting moisture level (VOTOMOBILE, 2015). During the second season, the minor harvest is produced. The planting time for the minor season occurs during third week of August through mid-October. The length of the minor growing season is approximately 90 days. The harvest then occurs from November to January.

2.2.1 Ghana Climate Data

Historical and projected climate data was obtained through The World Bank Group (2019). Climate data specific to Ghana was obtained from their global records. Figure 2 provides the Average Monthly Temperature and Rainfall of Ghana based-on the years 1901-2016. This data is for the entire country and is not site specific to the Lake Bosomtwe location.

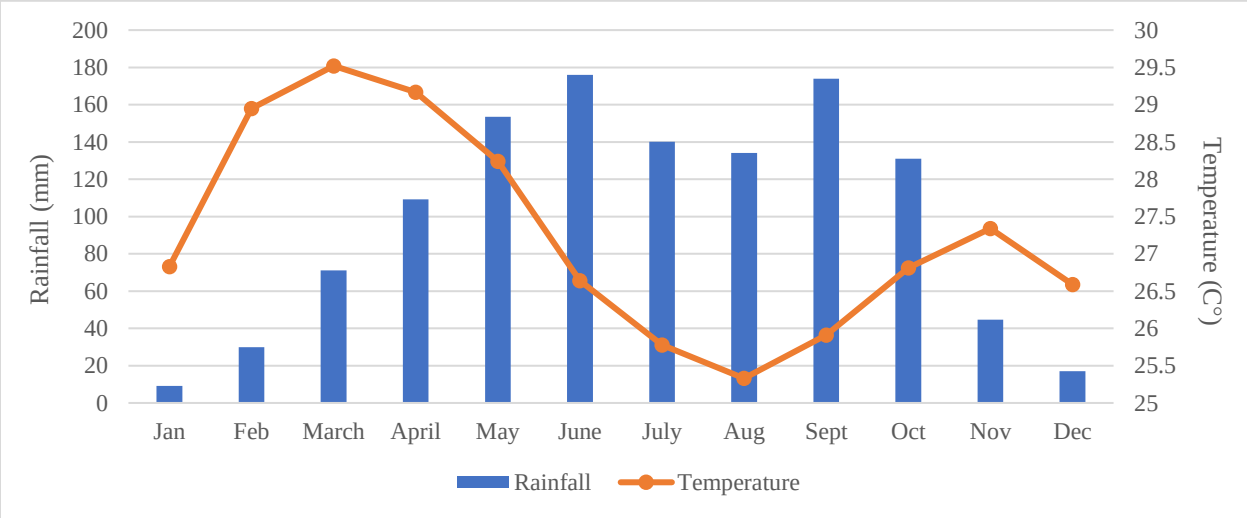


Figure 2 Average Monthly Temperature and Rainfall for Ghana 1901-2016
(The World Bank Group, 2019)

This dataset was produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA). The highest projected rainfall averages were during the months of June and September. The lowest rainfall averages were projected for the November to March time period. This time frame also experienced the highest average temperatures. The lowest average temperatures occurred during the months of June through September. This data provides a broad overview of the current climate conditions of the country.

2.2.2 CLIMWAT

CLIMWAT was used to obtain data from the following weather station located in Kumasi, Ghana. The red dot, displayed in Figure 3, shows the location of the Kumasi Weather station obtained from CLIMWAT. The following data was accessible via this program: minimum temperature, maximum temperature, relative humidity, wind speed, hours of sun, solar radiation

(MJ/m^2/day), monthly rainfall, and evapotranspiration (ETo) (mm/day). The data extracted from CLIMWAT obtained contains data from 1971-2000 (FAO, 2015). Using internal algorithms, CLIMWAT compiles the most recent prediction for the data. The Kumasi weather station was chosen because it is the closest to the farm location. Lake Bosomtwe Methodist Clinic is located 35 km from Kumasi. Since precipitation data tends to vary greatly from location to location, weather data that is both newer and closer to the project location is needed to provide a more accurate understanding of the actual precipitation in Lake Bosomtwe area. A weather station was recently installed at the project site. However, it was destroyed during a power surge.

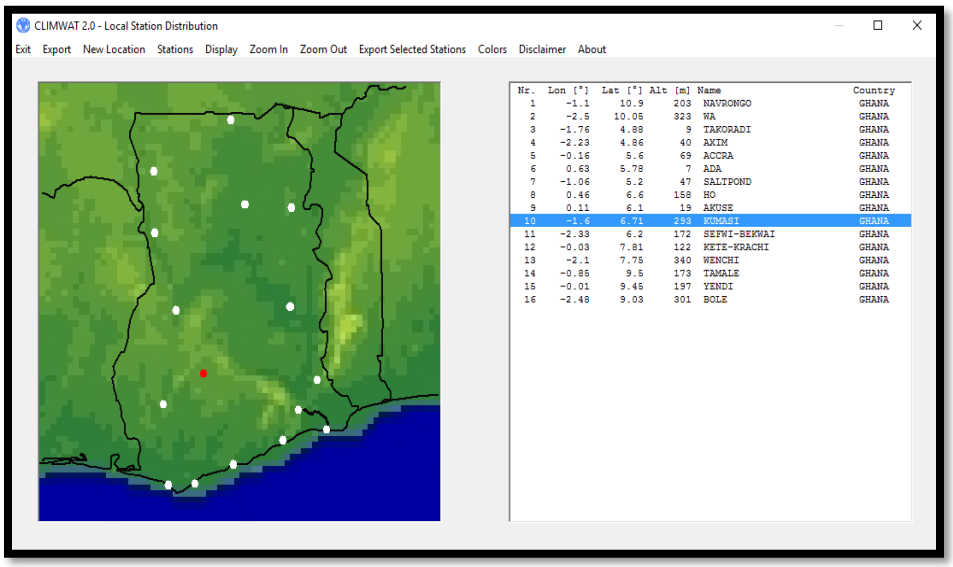


Figure 3 CLIMWAT Kumasi Weather Station

2.3 **Lake Regeneration (Water Quality)**

Lake regeneration is an important topic for research, specifically improving the water quality of the lake. With better water quality, water from the lake could be used for irrigation on farms. Previously, this area has had multiple problems with algae blooms. These have occurred a couple of times, and during each encounter, the algae blooms have drastically reduced the fish population in the lake. Two studies were conducted by the Kwame Nkrumah University of Science and Technology (KNUST) Geomatics Engineering Department, which were helpful in gaining a better understanding of the lake water quality. Both assessments were published in the *International Journal of Agriculture and Crop Sciences*. The first assessment (Nketia, et al.,

2014) was conducted evaluating the lake water for irrigation use and the second (Nketia, et al., 2016) for recreational use.

The first study uses the following water quality parameters: temperature, pH, Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), Soluble Sodium Percent (SSP), Residual Sodium Carbonate (RSC), Kelly's ratio, and other trace elements which were determined by the methods described in Richards (1954), Todd (1980), Eaton (1950), and Kelly (1953), respectively. The study was carried out in February 2014, and ten sampling locations were analyzed. The results were compared with international water quality standards set for irrigation. The average of the ten water samples for each of the previously mentioned parameters was taken and input into Table 1.

The study concluded that due to the pH, SAR, SSP, RSC, KR, Mg, Ca, and Na, the water from the lake was not suitable for irrigation. Through talking to locals, the study also concluded that the lake water contained a high salinity, making it unsuitable for irrigation. Due to these results, further studies regarding the water quality of the lake were undertaken. When comparing the results of this study to the Food and Agriculture Organization (FAO) standards for salinity and electrical conductivity (EC), the water still seems useable, and not perhaps as bad as the Nketia, et al., (2014 & 2016) papers suggested. A comparison of the KNUST assessment to FAO standards will be discussed later. The main parameter concerns for agricultural use are sodium, salinity, and EC or TDS.

Table 1 Water Quality Data for Irrigation

Item	Ave. Value	None	Slight to Moderate	Severe
Temp (C°)	32.5			
pH	8.85	Normal Range: 6.5-8.4		
Electrical Conductivity (EC) (ds/m)	1.28	<0.7	**0.7-3.0**	>3.0
TDS (mg/L)	77.8	**<450**	450-2000	>2000
Na+ (meq/L)	11.04	<3.0	3.0-9.0	**>9.0**
K+ (meq/L)	1.1			
Ca^{2+} (meq/L)	0.15			
Mg^{2+} (meq/L)	0.57			
B (meq/L)	0.09	**<0.7**	0.7-3.0	>3.0
Cu^{2+} (mg/L)	0.04			
Mn^{2+} (mg/L)	0.02			
Pb^{2+} (mg/L)	Trace			
Cl^- (meq/L)	2.64	<4.0	**4.0-10.0**	>10.0
HCO_3^- (meq/L)	10.74	**0-120**	120-180	180-600
CO_3^{2-} (meq/L)	10.34			
SO_4^{2-} (mg/L)	5.57			
NO_3^- (meq/L)	0.73	**<5**	5.0-30.0	>30
PO_4^{3-} (meq/L)	0.79			
SAR (12-20)	18.47	**>2.9**	2.9-1.3	<1.3
SSP %	94			
RSC (meq/L)	20.36			
KR	15.33			

Note: Values underlined and bolded indicate where each averaged water parameter fell in.

In February of 2016, another assessment was conducted by the Geomatics Engineering Department at KNUST, evaluating the water quality of Lake Bosomtwe for recreational purposes. Water samples were collected from ten different locations, and the following

parameters were analyzed: temperature, EC, pH, total coliform, fecal coliform, and E. Coli. The results of the study fell within the World Health Organization's (WHO) guidelines for good recreational water, with the exception of pH and alkalinity. The following parameters from this study were helpful: total hardness, Nitrate, Ammonium, Phosphate, and total coliforms. The total hardness of the water samples varied from 17.99 and 28.00 mg/l, with an average of 20.37 mg/l. This indicated that the water was generally soft, since the average is below 60.0 mg/l (Nketia, et al., 2016). The total coliform ranged between 0.00 and 5.00 colonies/100 ml, with an average value of 3.5 colonies/100 ml. This was inline with the limit set by WHO guidelines for Safe Recreational Water and Environment (2006) requirement, with critical value of 200.00 colonies/100 ml (Nketia, et al., 2016). The level of E. Coli ranged between 2.00 and 8.00 colonies/100 ml, with an average value of 3.8 colonies/100 ml. This is within the WHO limit (2003), which has a critical value of 100 colonies/100 ml. One of the main problems with this second assessment is that TDS was unable to be analyzed, due to a lack of facilities near the site location. The paper summarized by saying that the water could be used for recreational purposes (Nketia, et al., 2016).

2.4 **Irrigation**

The parameters of the most importance with regard to irrigation are Na+ or sodium, EC, TDS, Cl- or chloride, and B or Boron. The main concern is salinity levels, since salts can affect both the soil structure and crop yield. Most salts present in the soil are a direct result of the presence of salts in the irrigation water used. The amounts and combinations of these substances define the suitability of water for irrigation and the potential for plant toxicity (Texas A&M AgriLife Extension Service, 2016). The two main types of salt problems are total salinity and sodium. Water salinity is usually measured in TDS or EC. High salinity is a hazard for plant growth. Sodium hazards are usually expressed in terms of SAR. Sodium is absorbed and becomes attached to soil particles making the soil harder. When the soil becomes hard, more issues with water percolation occur, due to the soil drying and becoming increasingly impervious to water. Boron is also of concern, because it can also accumulate in the soil leading to nutrient imbalances. Permissible limits for classes of irrigation water are shown in Table 2. The average EC value from Table 1 is 1.28 ds/m, indicating a total dissolved solid (TSS) value, of 819.2

µmhos. Based on the TSS value, the water from Lake Bosomtwe falls in Class 3, permissible for irrigation use.

Table 2 Permissible limits for classes of irrigation water

Classes of water	Concentration, total dissolved solids	
	Electrical conductivity µmhos*	Gravimetric ppm
Class 1, Excellent	250	175
Class 2, Good	250-750	175-525
Class 3, Permissible[1]	750-2,000	525-1,400
Class 4, Doubtful[2]	2,000-3,000	1,400-2,100
Class 5, Unsuitable[2]	3,000	2,100

*Micromhos/cm at 25 degrees C.
[1]Leaching needed if used
[2]Good drainage needed and sensitive plants will have difficulty obtaining stands

Based on Table 1 the average SAR value for the Lake Bosomtwe water was found to be 18.47. This value when applied in Table 3, falls in the high range for sodium content within water. The high value indicates that the water is generally unsuitable for continuous use.

Table 3 Sodium hazard of water based on SAR values

SAR values	Sodium hazard of water	Comments
1-10	Low	Use on sodium sensitive crops such as avocados must be cautioned.
10 - 18	Medium	Amendments (such as Gypsum) and leaching needed.
18 - 26	High	Generally unsuitable for continuous use.
> 26	Very High	Generally unsuitable for use.

The average EC value measured from the KNUST water quality assessment for irrigation use was 1.28 ds/m or 1.28 mmhos/cm. The average SAR value from the same assessment was 18.47. These values when referenced with Table 4 indicate sodic conditions, because the EC value is less than 4, and the SAR value is greater than 13.

Table 4 Classification of salt-affected soils based on analysis of saturation extracts.

(Adapted from James et all., 1982)

Criteria	Normal	Saline	Sodic	Saline-Sodic
EC_e (mmhos/cm)	<4	>4	<4	>4
SAR	<13	<13	>13	>13

If the water from Lake Bosomtwe was used over time without the chemical amendments, it is likely that sodium may build-up and destroy the permanent soil structure, making the soil impervious to water (Texas A&M AgriLife Extension Service, 2016). The addition of gypsum, a chemical amendment, should be used in combination with leaching for farmers using the lake water for irrigation. Gypsum contains calcium which helps correct sodium conditions within the soil. The calcium present in gypsum, replaces absorbed sodium within the soil and helps restore the infiltration capacity within the soil profile (Texas A&M AgriLife Extension Service, 2016). The addition of gypsum is especially helpful to break-up compaction within soil profiles containing high amounts of clay (Texas A&M AgriLife Extension Service, 2016). This means that leaching or the use of an amendment alone will not likely be effective within the impact crater (Texas A&M AgriLife Extension Service, 2016). In order to combat these high sodium conditions for farmers irrigating with the lake water, an excess of water may be applied with every irrigation to provide enough water to thoroughly flush the salts beneath the root zone, along with an application of gypsum. This is especially applicable to farmers who farm along the banks of the lake.

2.5 **Rainwater Harvesting**

Since lake water alone will not be an acceptable form of irrigation, it will be necessary to develop a rainwater harvesting plan for the farm. The clinic site contains multiple roofed buildings. These do not contain any gutter systems. Three 1000-liter polytanks are located on the clinic grounds. However, the pump used for this system is electric, so during power outages water from this source cannot be used. It should also be noted that these polytanks supply water to the two main clinic buildings and five staff residency homes. The addition of polyvinyl chloride (pvc) piping or the local square metal gutters could be used to collect rainwater for use in irrigation. Additionally, examples of rainwater harvesting would be a helpful technology to

promote to the local people that might enable them to cultivate higher yielding crops. The rainwater would not contain the high amounts of sodium that the lake water does.

The previously obtained average monthly rainfall data was used to project the average monthly rainwater harvesting potential for two different size buildings. Figure 4 displays the average monthly projected results for two different scenarios. Scenario one is based-on a catchment area of one of the Amakom Clinic buildings. This building has a sloping aluminum metal roof with an area of 78.0 m^2. The measurements used for this building are considered standard for the clinic buildings present. The catchment area used for this building was much bigger than personal homes throughout the area. A second projection was completed that was closer to catchment area of a normal personal home. For this projection, a catchment area of 13.1 m^2 was used. To determine these projections the rainwater harvesting potential was calculated by multiplying the monthly rainfall, times the catchment area, times the runoff coefficient.

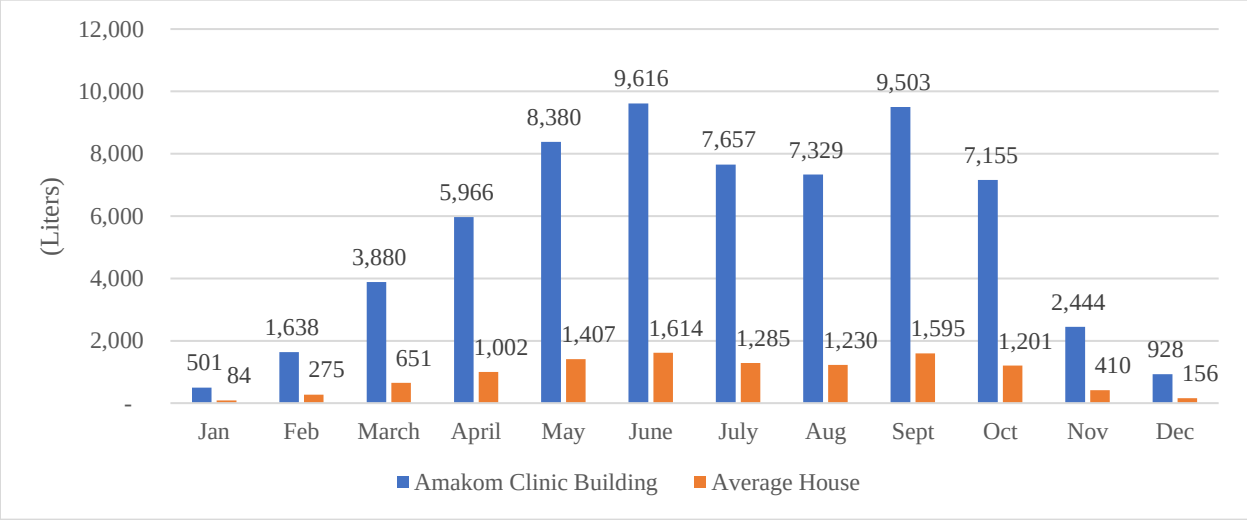


Figure 4 Average Monthly Rainwater Harvesting Net Runoff Potential

Note: Roof Catchment Area Amakom Clinic Building – 78.0 m^2
Average House Roof Catchment Area – 13.1 m^2
Runoff Coefficient for Sloping Aluminum Metal Roofs - 0.7 (Ward et al., 2010)

Based-on the average monthly rainwater potential, the number of times a standard (55 gal) barrel could be filled during each month throughout the year was calculated. Figure 5 displays the results.

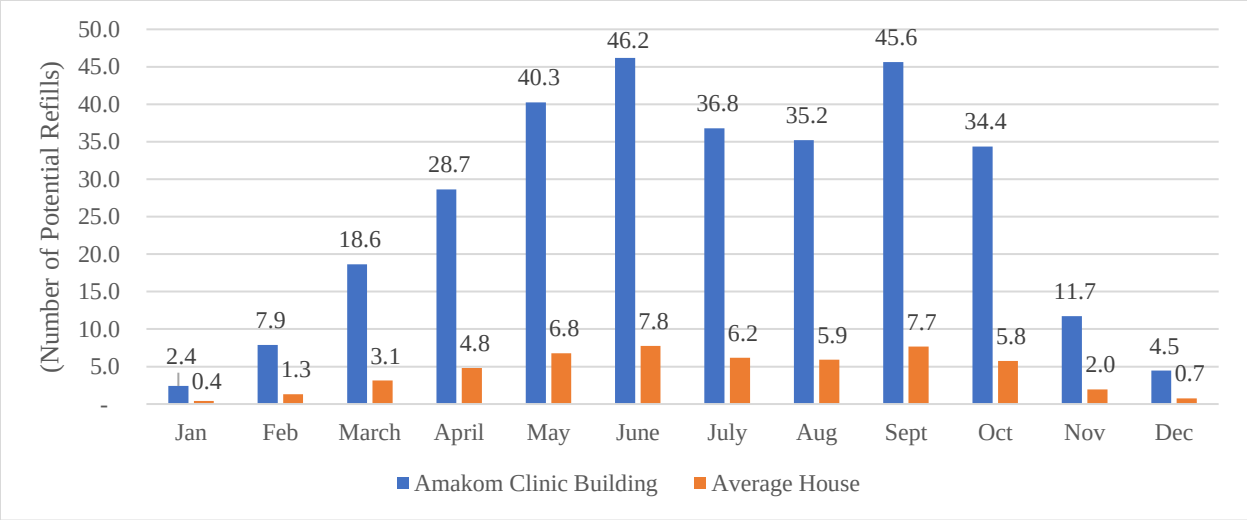


Figure 5 Average Monthly Rainwater Harvesting Potential Number of Fills

Note: Assumes 1 – 55 Gallon rain barrel for use

Table 5 displays the SPHERE minimum total basic survival water needs. The average water used for drinking, cooking, and personal hygiene in any household is 15 liters per person per day, or for an average month of 30 days, 450 liters. For a family of five, 2,252 liters of water would be required to meet the minimum for all domestic uses.

Table 5 Simplified table of basic survival water needs (SPHERE, 2018)

Survival needs: water intake (drinking and food)	2.5-3 litres per day	Depends on: the climate and individual physiology
Basic hygiene practices	2-6 litres per day	Depends on: social and cultural norms
Basic cooking needs	3-6 litres per day	Depends on: food type, social as well as cultural norms
Total basic water needs	7.5-15 litres per day	

Based-on the potential rainwater harvesting values calculated and potential amount collected per month, the Amakom clinic building would provide sufficient rain water for most purposes listed

in Table 5, except during the months of December, January, and February. During these months, the numbers would fall below the desired minimum. When comparing the average household potential for rainwater collection, the amount of water collected for a family of five with one 55 gallon rain barrel would not be sufficient for all basic water needs. This amount of water could be used to accomplish some tasks. A second rain collection item would need to be used to collect additional rainwater, once that barrel fills. This provides initial insight as to the potential impact that rainwater harvesting could provide to the Lake Bosomtwe community.

2.6 Current Sanitation Options in Ghana

2.6.1 Public Toilets

Throughout Ghana there are several different current toilet or sanitation options. Public toilets in Ghana are considered the alternative to bucket latrines. However, public toilets are not free for use; they are pay facilities. When the user enters the stall to use a public restroom, there are normally two bricks, one for each foot, and a hole to swat over. The cost in Kumasi for example is $0.03-$0.20 per use. The problem with public toilets is that they can be a significant financial burden for many. The average Ghanaian household has 5 children, plus the parents. The cost for each person to pay for the use of the toilet over time builds-up and quickly becomes a burden. Public latrines are only open for certain hours, and all people are forced to use other options, at least for part of the day.

2.6.2 Open Defecation

Due to the burdens of public toilets, people are forced to consider open defecation. This is considered common in Ghana, and it is not unusual to walk by someone openly defecating. There are cultural norms associated with open defecation. It is considered appropriate for children to openly defecate, and there is no cultural stigma associated with this practice. For an adult, urinating in a public place is normal. Adult males will urinate into the street gutter from the side of a road, in a bush, or in the street. Adult females stand and squat in a street gutter to urinate or in nearby bushes. Openly defecating is done in a bush or among shrubs. For adults, there is a sense of shame that is associated with openly defecating. The problems with any form of open defecation is that regardless of the cultural acceptance of the practice, it spreads disease

and can cause contamination to the surrounding water sources. Open defecation is a concern around Lake Bosomtwe, because not all villages have developed sanitation options.

2.6.3 Flying Toilets

During the night, to avoid cost and trip time, people in the home use a chamber pot or flying toilet. The chamber pot is a cooking or steel pot with a lid. People use the pot, and after use, a lid is placed of the pot. The contents in the pot are then emptied into a plastic bag and thrown in roadside ditches, garbage piles, or waterways. Because this practice forces the user to handle the waste and then does not include appropriate disposal of the waste, this practice should be discouraged.

2.6.4 Bucket Latrines

A metal or plastic bucket built into a small privy is what's known in Ghana as a "bucket latrine". These are built into a common area of a multi-family compound. The contents within the bucket are emptied at night. In Kumasi, night-soil collectors come after dark to empty the buckets for a fee. This type of toilet was outlawed in Ghana in 1990, because the government had no way of regulating how the night-soil collectors disposed of the waste, once it was collected. Additional problems were associated with the night hours of the collectors, contributing to the current prohibition of the practice. Although now outlawed, bucket latrines are still present in more rural areas of Ghana.

2.6.5 Pit Latrines & Water Closets

A pit latrine or water closet consists of a toilet with an underground collection tank beneath it and a privacy shelter built around the toilet. The cost to install a single pit latrine within a home is approximately $500-$700 USD. The tank is meant to be emptied every few years, once full. The main problem with pit latrines is that once the tank fills, it must be emptied or a new pit latrine must be dug. Pit latrines are designed to be installed where space is not a concern, so that once a tank fills, a new pit latrine can be installed. The new latrine is used while the other pit latrine's waste filters, sits, and decomposes. Since the original pit latrine design, new alternatives have been created, but these have caused the total cost of a system to increase.

2.6.6 Municipal Sewer Systems

The two largest cities in Ghana are the capital, Accra, and followed by Kumasi. Accra is located along the coast, whereas Kumasi is located in the middle of Ghana within the Ashanti region. Both of these cities have municipal sewer systems. However, what currently exists is not sufficient. The Kumasi municipal sewer system has only three waste water treatment plants, and only about 1,000 homes are connected to the system (Wyatt, 2011). This is of great concern, because the population of Kumasi is over 1 million people. However, aside from Kumasi and Accra, most other locations within Ghana are severely underdeveloped with regard to municipal sewer systems.

2.7 Soil Fertility

For the Ashanti region of Ghana, some general soil type information was found Figure 6. Surface horizons, within this region, are predominantly light textured, with sandy loams and loams being common. The lower soil horizons contain slightly heavier textures varying from sandy loams to clays. The bottom layers include mostly heavier textured soils. Many soils contain large amounts of either gravel and stone or concretionary materials. These materials, due to their presence and structure, affect the water holding capacity of the soils in which they are present (GSS, 2010). From looking at ArcGIS maps of Ghana from the Food and Agriculture Organization, the following soil information was found: sand 45-60%, silt 20-30%, clay 20-30%, and gravel 1-10%. This information gives an initial idea of the current soil levels. Using the FAO soil world soil-layer, the soil series was determined for the potential farm location.

ORTHIC ACRISOL

Horizon	Depth cm	pH		Cation exchange me % — $BaCl_2$ - triethanolamine pH 8.2									$CaCO_3$ %
		H_2O	KCl	CEC	TEB	% BS	Ca	Mg	K	Na	Al	H	
Ah	0—33	5.5		14.2	4.8	34	2.8	0.9	1.2	0.0			
E	48—79	5.2		8.6	1.5	18	0.4	0.5	0.7	0.0			
Bt	79—117	4.9		9.3	2.3	25	0.8	0.7	0.8	0.0			
C	130-183+	5.0		8.2	3.5	43	1.6	1.7	0.3	0.0			

Horizon	Sol. salts	Organic matter				Particle size analysis %						Flocc. index	CEC clay
		% C	% N	C/N	% OM	stones	c. sand	f. sand	silt	clay	texture		
Ah		2.1	0.18				4	30	32	35			41
E		0.7	0.19				4	28	29	39			22
Bt		0.2	0.05				2	24	25	49			19
C		0.1	0.04				1	25	31	43			19

ORTHIC ACRISOL **Ao**

Griffin form, Griffin series South Africa

Reference J.J. van der Eyk, C.N. Macvicar, J.M. de Villiers, *Soils of the Tugela basin*, p. 169. Natal, Town and Regional Planning Commission, 1969

Location Mooi river; 29° 08'S, 29° 59' 30"E

Altitude 1 524 m

Physiography Undulating; profile taken from upper part of hill

Drainage Impeded at depth

Parent material Beaufort shale

Vegetation *Themeda* and *Trachypogon* grassland

Climate Rainfall 900 mm

Profile description

Ah **0-33 cm** Moist; very dark greyish brown (10YR 3/2) clay loam; strong fine subangular blocky; porous; friable; gradual smooth boundary.

AB **33-48 cm** Moist; dark yellowish brown (10YR 4/4) clay loam; structureless; porous; friable; gradual smooth boundary.

E **48-79 cm** Moist; yellowish brown (7.5YR 5/6) clay loam; structureless; porous; friable; very small hard iron concretions; clear smooth boundary.

Bt **79-117 cm** Moist; red (2.5YR 4/6-4/8) silty clay; structureless; porous; friable; gradual wavy boundary.

BC **117-130 cm** Identical with above but with many fine red (10R 4/8) and yellowish brown (10YR 5/6) speckles which are traces of weathered shale; diffuse smooth boundary.

C **130-183+ cm** Moist; variegated red, pink, yellowish brown and greyish brown weathered Beaufort shale with stratified structure preserved; silty clay.

Figure 6 Soil Type (FAO/UNESCO Soil Map of the World, 2017)

This analysis was reconfirmed by viewing an additional FAO soil layer and UN soil layer. The following soil information was obtained identifying the soil as a Orthic Acrisol. This specific soil type is present in the forest zone of Ghana around Lake Bosomtwe. Based-on the soil profile, the following crops are recommended: cassava, beans, sorghum, and eleusine (FAO/UNESCO Soil Map of the World, 2017). Crops such as groundnuts, and even cotton or tobacco could be additional options to enhance soil health.

One of the biggest challenges regarding the soil will be leaching. Since sodic soil conditions are present, a leaching plan to manage the salinity levels will be needed. To determine the leaching requirement, the electrical conductivity in the root zone layer of the soil must be measured. ECHO (Harter & Motis, 2016) has published a paper documenting the results of measuring electrical conductivity of the soil by use of a multi-meter. Depending on the soil, an occasional or annual leaching, where water is ponded on the surface, should be an easy and effective method for controlling soil salinity.

2.8 Food Crops & Cash Crops

By flushing the salts below the crop root zone, crops will be able to maintain productivity. There are certain crops that can perform better than others under salinity conditions. From the KNUST water quality assessment for irrigation use, the average EC value is 1.28 ds/m. This value, when applied to Table 6 from the Texas A&M AgriLife Extension Service (2016), can be used to determine the approximate yield potential for different crops. Table 6 displays the percent yield potential based on the electrical conductivity of the irrigation water (EC_{iw}) applied in mmhos/cm.

Table 6 Irrigation water salinity tolerances for different crops.

(Adapted from Ayers and Westcot, 1976)

Crop	Yield potential, EC_{iw}			
	100%	90%	75%	50%
Field crops				
Barley	5.0	6.7	8.7	12.0
Bean (field)	0.7	1.0	1.5	2.4
Broad bean	1.1	1.8	2.0	4.5
Corn	1.1	1.7	2.5	3.9
Cotton	5.1	6.4	8.4	12.0
Cowpea	0.9	1.3	2.1	3.2
Flax	1.1	1.7	2.5	3.9
Groundnut	2.1	2.4	2.7	3.3
Rice (paddy)	2.0	2.6	3.4	4.8
Safflower	3.5	4.1	5.0	6.6
Sesbania	1.5	2.5	3.9	6.3
Sorghum	2.7	3.4	4.8	7.2
Soybean	3.3	3.7	4.2	5.0
Sugar beet	4.7	5.8	7.5	10.0
Wheat	4.0	4.9	6.4	8.7
Vegetable crops				
Bean	0.7	1.0	1.5	2.4
Beet	2.7	3.4	4.5	6.4
Broccoli	1.9	2.6	3.7	5.5

Table 6 (continued)

Crop	Yield potential, EC_{iw}			
	100%	90%	75%	50%
Cabbage	1.2	1.9	2.9	4.6
Cantaloupe	1.5	2.4	3.8	6.1
Carrot	0.7	1.1	1.9	3.1
Cucumber	1.7	2.2	2.9	4.2
Lettuce	0.9	1.4	2.1	3.4
Onion	0.8	1.2	1.8	2.9
Pepper	1.0	1.5	2.2	3.4
Potato	1.1	1.7	2.5	3.9
Radish	0.8	1.3	2.1	3.4
Spinach	1.3	2.2	3.5	5.7
Sweet corn	1.1	1.7	2.5	3.9
Sweet potato	1.0	1.6	2.5	4.0
Tomato	1.7	2.3	3.4	5.0
Forage crops				
Alfalfa	1.3	2.2	3.6	5.9
Barley hay	4.0	4.9	6.3	8.7
Bermudagrass	4.6	5.7	7.2	9.8
Clover, Berseem	1.0	2.1	3.9	6.8
Corn (forage)	1.2	2.1	3.5	5.7
Harding grass	3.1	3.9	5.3	7.4
Orchard grass	1.0	2.1	3.7	6.4
Perennial rye	3.7	4.6	5.9	8.1
Sudan grass	1.9	3.4	5.7	9.6
Tall fescue	2.6	3.9	5.7	8.9
Tall wheat grass	5.0	6.6	9.0	13.0
Trefoil, big	1.5	1.9	2.4	3.3
Trefoil, small	3.3	4.0	5.0	6.7
Wheat grass	5.0	6.0	7.4	9.8
Fruit crops				
Almond	1.0	1.4	1.9	2.7
Apple, Pear	1.0	1.6	2.2	3.2
Apricot	1.1	1.3	1.8	2.5
Avocado	0.9	1.2	1.7	2.4
Date palm	2.7	4.5	7.3	12.0
Fig, Olive, Pomegranate	1.8	2.6	3.7	5.6
Grape	1.0	1.7	2.7	4.5
Grapefruit	1.2	1.6	2.2	3.3
Lemon	1.1	1.6	2.2	3.2
Orange	1.1	1.6	2.2	3.2
Peach	1.1	1.4	1.9	2.7
Plum	1.0	1.4	1.9	2.8
Strawberry	0.7	0.9	1.2	1.7
Walnut	1.1	1.6	2.2	3.2

Note: Based on conductivity of the irrigation water (EC_{iw}) measured in mmhos/cm the electrical

Within the Lake Bosomtwe area, there are a wide variety of crops grown. The following crops are currently grown on local farm land: maize, plantain, cassava, and small amounts of cocoyam (Kessie, personal conversation, 2018). According to Table 6, field crops grown that received an application of lake water could potentially yield the following: corn/maize 90-75%, groundnut 100%, sorghum 100%, and soybeans 100%. Without further conversations with farmers in the area, it was difficult to know how many farmers truly irrigated and what water source they used.

Cash crops currently grown in Lake Bosomtwe area are: maize, palm oil, citrus, along with cocoa, plantain, and cassava, when in season. Both cassava and plantain take a year to grow. Talking with farmers specifically about the main crops they grow and what crops they feel would be excellent cash crops was required for any survey to be relevant. It should be noted that Ghanaians living within the Ashanti region of Ghana do not refer to Lake Bosomtwe with the whole name. Rather, they simply refer to it as Lake.

2.9 Crops to be sold at market

The Kumasi market, one of the largest markets in Ghana, is one of the best locations for items that might be sold. There is not a specific market day in Kumasi, because every day is market day. Certain crops and animals could be sold immediately, and others could be used to create value added products, all of which could be sold at Lake Bosomtwe market. Crops such as maize and cassava sold as cash crops might be specifically good for the area. Maize could be sold to senior high-schools and other tertiary institutions in the area. Surrounding Lake Bosomtwe, there are also smaller markets in Kuntanase, Bekwai, and Beposo. Kuntanase is approximately a 10 to 15-minute drive outside of Lake. Kuntanase is the transportation hub that farmers going to Kumasi would use to take a bus. It is a 3 to 5 hour drive depending on the driver and the roads to reach this market.

Bekwai, is located past the south rim of the impact crater. This market is not accessible to everyone within Lake Bosomtwe, but it is an option for farmers living within villages along the southern portion of Lake Bosomtwe. These markets are all technically outside of the lake region, but within walking distance by Ghanaian standards. Bekwai’s market is of particular interest,

because it is known for selling vegetables and vegetable inputs. Specific organizations come to this market to buy these products. Additionally, the Agric officer is stationed in Kuntanase.

2.10 Fertilizer & Livestock

Both fertilizer and livestock will be needed for the farm. Currently within the Lake Bosomtwe area, the following types of livestock are present: chickens, pigs, goats, and sheep (Kessie, personal conversation, 2018). Until the last ten years or so, fishing was a main source of protein for this area, prior to algae blooms reoccurring since 2009 in the lake. The fish present were mostly mud fish and tilapia. Though not currently raised in this area, cattle are present in other locations in Ghana. However, raising cattle incurs more upfront costs, and beef is generally disliked by Ghanaians.

Potential livestock raised will serve multiple purposes. First, the animals will produce manure, which can contribute to the fertilizer needed. However, it is unlikely that enough manure can be produced from just the raised animals for sustainable fertilizer use. Purchased fertilizer will be needed to supplement this material. Another possible option would be to utilize household waste from the local nearby villages. Secondly, the animals can eventually be sold at market to provide additional income to the clinic.

2.11 Value-Added Products

A couple different types of livestock could be raised that could be used to produce value-added products. Layer hens could be raised for egg production. The eggs can be sold at market. If the eggs can be packaged, they can then be sold to the hotel industry. This sector is continually expanding and has a continued demand for packaged eggs to use in cooking. Broiler chickens could also be raised to produce chicken meat that could be sold. If the meat can be packaged or processed, it will fetch a higher price and is more likely to be sold into the hotel industry.

There is also an opportunity to raise pigs for pork production. Over the past years, the number of Chinese people present in Ghana has greatly increased. Their presence has led to a demand for pork production. The hotel industry would also be interested in purchasing pork, if there was a

way to process or package the meat. From an economic perspective, items that have more processing and packaging done locally, will be able to be sold at a better price. Potential crops that could provide added value would be Chaya and certain grasses. Chaya is a spinach type tree that has been developed as chicken feed in Ghana. The leaves can be harvested as chicken feed or for human consumption, if cooked. They cannot be eaten raw by humans, but once cooked, are an excellent source of protein. The plant is highly nutritious containing: calcium, phosphorus, and iron; and vitamins A and C as well as niacin, riboflavin, and thiamine (ECHO, 2019). The leaves and stem can be chopped up and added to soups and stews or mixed with onions and eggs to make tortillas. This crop is helpful, because it can be cooked similar to cassava, for traditional Ghanaian meals like contumere.

2.12 Transportation

For transportation in and out of the crater, the clinic has an ambulance which is used for official and staff movement. A vehicle or form of transportation would be needed to transport animals, crops, or value-added products, to the Kumasi or smaller surrounding markets. Although public transportation is available, it is such an ordeal to get out of Lake to other markets that it is extremely easy to damage crops. There is also a small clinic boat that acts as an ambulance, on the lake bringing people in need of medical assistance to the clinic. This boat could potentially be used to help local farmers get their crops to market, if there was a way to cover the boat fuel costs. The boat fuel is a diluted mixture of normal gasoline. Some of the villages are only accessible by boat. A lack of transportation options clearly limits farmers from getting their goods to market.

2.13 Appropriate Technology Center, Lab Space, & Machine Shop

Appropriate technology is “technology that is suitable to the social and economic conditions of the geographic area in which it is to be applied, is environmentally sound and promotes self-sufficiency on the part of those using it (Merriam-Webster, 2019).” A platform is needed to facilitate educational infrastructure, in the form of a classroom that will be needed to facilitate extension outreach services. This same structure would also showcase appropriate technologies. The clinic currently has a conference room that could be used until an educational center could

be built, but a classroom specifically designed for the demonstration farm will be needed. A lab space or area for a machine shop will also be needed. This type of platform is used in multiple locations throughout the world to disseminate new technologies, promote conservation agriculture, and conduct outreach extension activities. ECHO is one such example.

ECHO an NGO located in Fort Myers Florida, uses an Appropriate Technology Center (ATC) as a component of their Global Demonstration Farm (ECHO, 2019). The ATC is used to showcase adaptive technologies. ECHO offer's courses, workshops, showcases adaptive technologies, and all of which promote conservation agricultural practices (ECHO, 2019). This entity has operated for over 35 years and has multiple Regional Impact Centers throughout the world (ECHO,2019). Each of their centers utilizes an ATC so as to promote relevant and appropriate technologies, and conservation agricultural practices to small-holder farmers. ECHO has tried and tested this type of platform. The ATC must include a lab space and machine shop. It is critical to the demonstration farm showcase appropriate technologies to help improve local livelihoods.

2.14 **Mechanization**

Mechanization can allow farmers to perform multiple field tasks that previously required extensive labor and man power to conduct by hand. Lake Bosomtwe falls within the tropical forest zone of Ghana and is therefore much less likely to have concentrated efforts towards mechanization, as opposed to the more semi-arid areas within the country. The adoption rate of mechanization within the tropical forest areas of Ghana is between 2-10 percent (Ghana Statistical Service, 2016). Mechanization within the Lake Bosomtwe area is not common. Field tasks within the area are accomplished through the use of pick axes, machetes, and tree branches sharpened to a point. Laborers or community members can be hired to assist other farmers in performing field tasks. Special consideration should be taken when evaluating the use of mechanized equipment for the area, due to the intense hill slopes in which many farmers would want to use it. Some farmers within the area farm on the tops of the mountains and hill slopes 20% or greater (Kessie, personal conversation, 2018). The introduction of mechanization within the Lake Bosomtwe area could provide greater opportunities to help farmers conduct field operations despite variable weather patterns, increased off-farm generation potential, and the reduction of labor requirements (Diao, Silver, & Takeshima, 2017).

3. METHODS

The focus of this study was the development of a comprehensive market assessment survey of farmers living within the Lake Bosomtwe area in order to provide direction in the development of a demonstration farm. The survey was developed in response to six overarching research questions. The participant selection process is presented. Social survey data processing, coding, analysis, and summary figure generation are addressed. Specific statistical tests were applied to determine if certain findings were statistically significant. Cumulative response values were calculated for each question and for the overall survey results. Four decision matrices were developed to prioritize: Farm Components, what technologies should be show cased as part of the Appropriate Technology Center, which plots to demonstrate, and outreach extension program topics. The decision factors, weights and ratings for each decision matrix are summarized.

3.1 Social Survey Methodology

A comprehensive Institutional Review Board (IRB) survey was developed for the following six research questions. Appendix A provides all of the components required for IRB approval.

Goals & Research Questions

Potential was seen to utilize a market assessment survey for the design and prioritization of a demonstration farm. The following goals were set forth.

- To develop and prioritize the components shown on a demonstration farm
- The farm will serve as a demonstration to the Lake Bosomtwe community improved agricultural methods

Research Questions

1) What are the household demographics of the residents within the villages of the Lake Bosomtwe area?
2) What are the views of residents within the villages of the Lake Bosomtwe area regarding the current land use and how that has changed over the last thirty years?

3) What are the agronomic farming practices of the residents within the villages of the Lake Bosomtwe area?
4) What are the livestock farming practices of the residents within the villages of the Lake Bosomtwe area?
5) What are the water use and sanitation practices of the residents within the villages of the Lake Bosomtwe area?
6) What are the fishing practices of the residents within the villages of the Lake Bosomtwe area?

From these six research questions, 147 specific questions were developed. Three of the 147 questions were used to obtain Global Positioning System (GPS) data for community households, pit latrines, and water wells or boreholes. This study sought to interview 10-15 farmers per village, for each of the 12 villages located along the shore of Lake Bosomtwe on their perspectives on land use and ground cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. Demographic data on participants was also collected. Information in the form of an oral response was collected and recorded on a survey form by the interviewer, and a sample response can be seen in Appendix B.

3.1.1 Subjects to be included

The participants included in this study were individuals that practice farming and live within the Lake Bosomtwe impact crater. There was no gender specific requirement for participants, but subjects had to be older than 18 years. Only one farmer per household was interviewed. There are 12 different villages directly located along the Lake Bosomtwe shore line. The maximum number of subjects that could be enrolled in the study was no more than 250 participants, roughly 22 farmers each from the 12 villages within the impact crater. Farmers were interviewed from each of the different villages, so that a thorough understanding of the current farming practices throughout the Lake Bosomtwe area could be determined. These data were needed so that farmers' input from each of these communities could be used in the design of a demonstration farm that specifically addressed local needs. Participants did not qualify for this study if they did not participate in some form of farming or fishing within the Lake Bosomtwe impact crater, or if they were younger than 18 years old.

3.1.2 Recruitment of Subjects and Obtaining Informed Consent

Participants were recruited by going from house-to-house within each of the 12 villages. Potential subjects were asked if they participated in any form of farming. If the potential subject was involved in any form of farming activity, they were asked if he or she would be willing to provide 60 minutes of their time to take part in this study. The potential subject could choose to be interviewed at that moment, a later time, or not at all. The waiver of consent form was read orally to the potential subject, and the individual could decide whether or not to participate at that time. Ghana is a relatively peaceful country, and the graduate student has spent multiple years working within the Lake Bosomtwe area. The graduate student was the only person present during the participant home survey interviews. There were no safety concerns. A copy of the Research Participant Recruitment Script and Research Participant Information Sheet can be viewed in Appendix A.

3.1.3 Procedures for Payment of Subjects

Participation in this study was purely voluntary. The subjects were not compensated in any way.

3.1.4 Confidentiality

Subject's names were not asked for, nor recorded. The survey data set was identified only by a code identifier. For each of the villages, the village name was listed, and the farmer interviewed was given a number 1-22, based upon the sequence order in which the farmers were interviewed. For example, Village 1 - Farmer 1, Village 1 - Farmer 2, all the way through Village1 - Farmer 22. The sequence then moved to Village 2 - Farmer 1, Village 2 - Farmer 2 through Village 2 - Farmer 22. This system was used for each of the 12 villages and all participants. Data set identification was used administratively to insure the overall accuracy and integrity of the aggregate data set. The identification code key was not used for any other purposes, and under no circumstances was any individually identifiable information from the data set disclosed to anyone.

A Waiver of Documented Consent was obtained to minimize the identifiable contact information with the survey data sets. While in Ghana, the collected data sheets were stored in a locked

cabinet that only the graduate student had access to. After returning to Purdue University, the data sheets were collected and were stored in a locked cabinet and also stored on a secured password protected Purdue computer. The original survey data sheets have been retained under locked conditions. They will be destroyed when no longer needed. Only project personnel have had access to the collected data on Purdue's campus. The survey data stored on the Purdue computer will be kept indefinitely, as the work moving forward from this project is seen as extending significantly into the future.

3.1.5 Potential Risks to Subjects

The risk to participants was minimal. It was no greater than everyday activities. Subjects choosing to participate in the study were asked to orally respond to questions, and the subject's responses were recorded. There were no medical risks associated with this study. The only potential risk was the subject's possible exposure of personal information. To minimize this exposure, all responses were kept confidential. A subject's name was not recorded or asked. Breach of confidentiality was a risk related to this research. Although this risk was only a slight possibility, the safeguards described in the confidentiality section were continuously in place. Additional permission to record a subject's household location was requested. This information was not recorded if the subject did not give additional approval. Participants could have been concerned about sharing their annual household income and household location. It was stressed to subjects considering participation in this study that their personal names would be in no way linked to any of the data and that their personal names would be kept confidential. Subjects' personal names, household income, and household location, remained confidential throughout the entire project.

3.1.6 Benefits to be Gained by the Individual and/or Society

There were no direct benefits for the subjects choosing to participate in this study. However, the subject's choice to participate in the study could provide future benefits to all farmers living in the Lake Bosomtwe area. The data collected from the participants interviewed were used to make informed decisions of what improved agricultural practices should be demonstrated on a future agriculture demonstration farm and outreach extension programing.

The collection of GPS data points was intended to allow this study to determine if certain farmers by geographic location experience similar or different losses in yield, differences in practices, or care more about certain crops or animals than others. The collected data will lead to more intentional development programing, so that if certain villages experience differences or similarities in problems, such as losses in crop yields, excess fertilizer use, or other various scenarios, improved agricultural alternatives can be shown and demonstrated on the demonstration farm and specific outreach extension programming recommended.

3.1.7 Investigator's Evaluation of The Risk-Benefit Ratio

Risks for all possible harm to participants were negligible, because participant names were not recorded or collected. Participants were asked orally to respond to questions regarding demographic information, land use information, farming practices information, water, sanitation, hygiene information, and fishing information. Responses were only used for statistical summaries, so no individual risk of exposure was involved. Taking part in this study was voluntary with no direct benefits to the subjects. However, the potential benefits to the entire local community from the results of this survey were significant, as it was intended that these results would guide the design of the demonstration farm plan and outreach extension programming.

3.1.8 Written Informed Consent Form

If a written consent document had been used in this study, it would have been the only link between the subject's identity and the project records. This study requested and received a Waiver of Documented Consent. There was no danger of mis-communication through an interpreter, since the national language of Ghana is English. This study was conducted in English.

3.1.9 Waiver of Informed Consent or Signed Consent

This research activity was considered minimal risk, because the risk was not greater than everyday activities. For each of the villages located along the Lake Bosomtwe shore, farmers were interviewed, one per household. Each participant was asked to answer questions orally. If a consent form linking the subject to the study had been used, it would have been the only link between the subject and the study. Release of that information could cause social or economic

risk to the participant that would be greater than minimal risk. This study requested a waiver of documented (signed) consent. This study did not need and was not interested in recording the specific names of the participants. If the subjects provide signed consent, it would have been the only record linking the subject to the research. This research did not include any activities that would have required signed consent in a non-research context. This study provided any potential research participant with an information sheet that contained all of the elements of a consent form, but without the signature line. This sheet was given to each potential participant to keep and an example of the approved IRB form can be viewed in Appendix A.

3.1.10 International Research

Within the Lake Bosomtwe community, English is used exclusively and is considered the appropriate language in which to ask questions. Bishop Andam and the Methodist Church Ghana hosted the study out of the Amakom Methodist Clinic, where the graduate student lived while conducting the survey. During this experience, feedback from the community members was collected. Summary statistics were created and generated from the survey data. The summary statistics were used to prioritize and refine the demonstration farm design and extension outreach program topics in collaboration with the project partners. The investigators in this study communicated through email primarily, but also through phone conversations. The graduate student investigator used an in-country Ghana phone, so that calls could be made in-country, but also back to the USA to communicate with the Principle Investigator (PI). Weekly communication took place between the PI and the graduate student throughout the time frame of the study.

3.2 Social Survey Data Processing

Data entry for the survey forms utilized an Excel spread sheet via the first in and first out (FIFO) method. A blank data collection survey is provided in Appendix A. For each question, the responses were cleaned and verified for accuracy of entry. The combined data set of the responses was additionally checked to insure each question’s data field was completed and accurate. To preserve original survey responses, the adjustments were documented in a data cleaning diary. Analyses were performed using Microsoft Excel 2016. The qualitative structure of the survey questions required coding survey answers to compare responses across the 118

participants interviewed. Standardization, coding, and analysis of responses were based on the question format shown in Table 7. If participants that didn't qualify to answer certain questions, their responses for each question were recorded as not applicable or N/A. Sometimes certain participants after additional explanation and question framing did not understand certain questions or were unsure of how to answer. In this case, a response of "Not Sure or Didn't Know" know was recorded and standardized for per question. Double data entry was conducted to insure any potential errors were eliminated and to avoid any discrepancies. Batch error checking was conducted for each question. The entire combined data set was reviewed to look for any inconsistencies and resolve any issues related to missing, duplicated, or incomplete data. Samples of the raw data sets and the cleaned sets are included in Appendix C.

For each option of every open response question, a "count if" statement was created in Excel to count the number of times a specific option was given for all 118 respondents. The count total was then divided by the total sample size to calculate the percent of participants that answered for each specific option. This metric was calculated for every question. Figures based-on the summary statistics for each question were generated and are shown in Appendix D.

Figures 7-11 provide examples of figures shown in Appendix D. Pie charts were generated for yes/no response questions and for multiple-choice-questions, where the number of options was four options or less seen in. Pie charts were also generated in place of a vertical bar chart, when one of the responses was predominately N/A. Vertical bar charts were generated for questions having five options or more. Combination horizontal bar charts were created to show responses of multiple questions that were all focused around the same topic. An example of this would be the three questions focused around having a local farmers' cooperative. Another figure example are the histograms that were created for the amount of water collected for domestic use and for the amount of rainwater collected. These questions were recorded in a numeric range format, and they are more appropriately displaying in this manner.

Table 7 Coding and Analysis Procedures for Survey Responses Based on Question Format

Question Format	Coding & Analysis Procedure	Example Questions
Yes/No	Excel Count statement to determine number of response (yes; no) Descriptive Statistics were calculated for all responses.	Is there a Farmers Cooperatives(s) in your local area? Do you practice crop rotation?
Numerical	Converted to numerical value (0, 5, 25, etc.). Excel Count Statement to determine number of each response. Descriptive Statistics were calculated for all responses.	How much water do you collect for domestic use? How much rain water do you collect?
Multiple Choice (General)	Excel Count statement to determine number of response (a, b, c, d, e, f) Descriptive Statistics were calculated for all responses.	How many months out of the year do you irrigate? How often do you purchase eggs during a week?
Multiple Choice to Value	Value recorded and in the absence of the value an average value was assigned. Descriptive Statistics were calculated for all responses.	How much is one of your animals sold for?
Multiple Choice (Range Based)	Converted each multiple-choice option containing a range to the option's average based-on the range. Descriptive Statistics were calculated for all responses.	What is your average crop yield for the major harvest? What is your average crop loss during the major growing season?
Created Categories	Created Categories based on emergent response themes. Excel Count statement to determine number of responses for each category and descriptive statistics were calculated for all responses.	What human activities have you observed around the lake? What do you believe are the main contributing factors to your loss of crop?
Open-Ended (Specify)	Summaries of common themes were created for response, quotations were selected to highlight these points. Excel Count statement for each response was created and descriptive statistics were calculated.	In your option, what do you believe is the cause of the reduction or otherwise of fish stock in the lake? What benefits would you hope this fishing program would provide you?

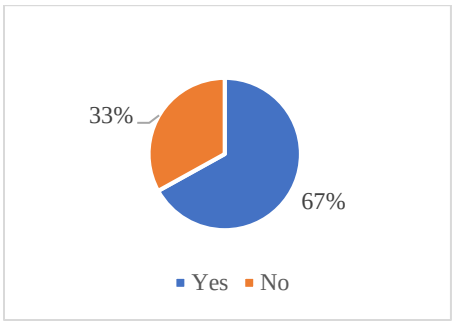


Figure 7 Do you purchase seed?

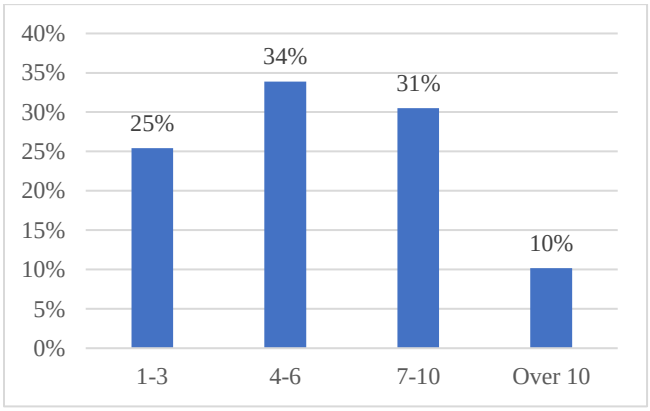


Figure 8 Number of People per Household

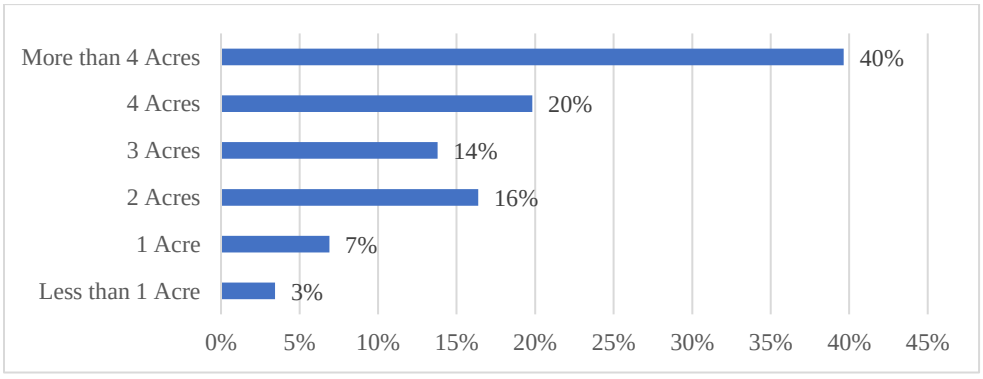


Figure 9 Farm Size

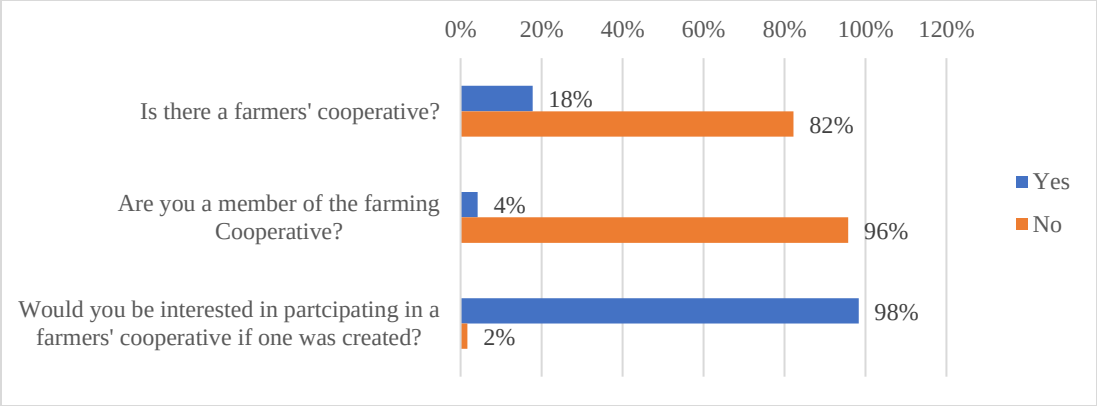


Figure 10 Farmer Cooperative Interest

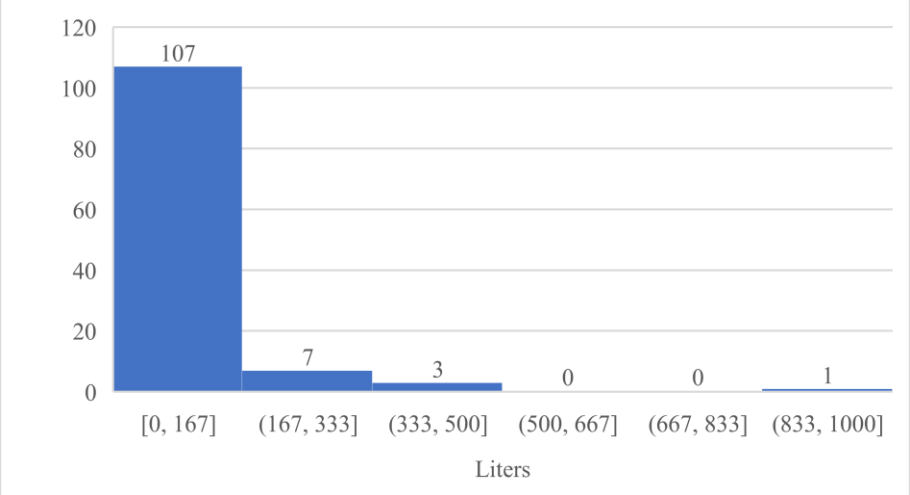


Figure 11 Frequency distribution of the amount of rainwater collected Per Capita

Summary response values were calculated for every survey question. A number of participants did not qualify to answer all questions. An example of this would be a farmer that didn't raise livestock, or a farmer that didn't irrigate his or her crops. In such cases, these participants would not be asked additional follow-up questions regarding rearing livestock or irrigation, because the questions were not applicable, or the participant was not qualified to answer. Therefore, these participants' recorded responses for such follow-up questions were recorded as N/A. For the purposes of this study, a response of N/A is still considered a complete a response, but it is not considered a qualified response. The percent of participants qualified to answer each question was calculated, and the percent of participants that completed each question was also calculated.

The average percent of participants qualified to answer all questions, and the average percent of participants that completed all questions, were calculated.

3.3 Statistical Analysis

Specific statistical tests were applied to determine if certain findings were statistically significant. Two Pearson Chi-square tests and two independent samples t-tests were conducted in IBM SPSS. To determine if an association between gender and level of education existed a Pearson Chi-square test was conducted in IBM SPSS. All participants attending schooling levels lower than JHS level were assigned a value of zero. Participants having attended JHS level or higher were assigned a value of one. The following values were assigned for participants: one for male and zero for female. A Pearson Chi-square test was conducted to determine if an association existed between people who bathe and wash in the lake and those who participate in fishing as a livelihood. Those that participated in bathing and washing received a value of one. Participants that did not wash and bathe received a value of zero. Participants that did not fish were assigned a value of zero. To determine if road accessibility impacted yields and usable yields separate independent samples t-tests were conducted. Usable yield is the yield from the harvest less the harvest losses. Three villages with limited to no road access, were selected and are located on the south half of the lake. These three villages experience greater slopes. These villages have a very difficult time getting their produce to market as opposed to the other villages. Three villages were selected that have road access, are located on the northern half of the lake, and these villages experience less slope. Three villages were each selected so as to keep each sample size close to the same.

3.4 ArcGIS Pro Analysis

GPS coordinates of community pit latrines, boreholes, and community village centers were taken for all 12 villages using a Garmin Inreach Explorer +. All participants declined to have GPS locations recorded for their homes, even though all their survey responses would be kept anonymous. As an alternative, a central location to each village was taken so that averaged survey responses by village could be evaluated spatially. This allowed for some survey questions to be tied to the data spatially, though not nearly as many as had been previously hoped.

Community members walked the graduate student to pit latrine and borehole locations. The number of stalls at each pit latrine was recorded in addition to the GPS coordinates. The GPS coordinates were brought into ArcGIS Pro using the KML to layer tool. Attribute fields labeled "X_Coordinate and Y_Coordinate" were added to the layer attribute table. The "Add XY Coordinates" tool was then used to add the X and Y coordinates to the newly added fields in the attribute table. This main layer contained all the community village center, pit latrine, and borehole data. The select layer by attribute tool was used to export and create four separate layers: Village Centers, Boreholes, Pit Latrines, and Shack.

The layer called shack, was given its own separate layer in order to differentiate the symbology in ArcGIS Pro. There was only one shack recorded, and it was named this because it was not a proper pit latrine. This was the only sanitary option for one of the villages. The Multiple Ring Buffer tool was used to create two buffer rings at 15-meter and 30-meter centered around each pit latrine location. According to the SPHERE minimum standards in water supply, sanitation, and hygiene promotion, the minimum distance between a ground water source and a pit latrine is 30 meters (SPHERE, 2018). By creating buffers around each pit latrine spatially, it could be determined if any of the pit latrines were located too close to community water wells or the lake shore. Citing of community pit latrines too close to either source could lead to leakages or sewage seepage that could escalate the lake water quality problems. Additionally, communal pit latrines are only recommended to provide facilities for a maximum of 20 people per day per stall, but this is not always possible in displaced populations (SPHERE, 2018). In such situations, as many as 50 people per toilet could be used temporarily, but this must be decreased to 20 as rapidly as possible (SPHERE, 2018). Conducting an initial broad spatial analysis in ArcGIS Pro allowed this study to determine if pre-existing drinking water and sanitation options met the minimum SPHERE standards.

3.5 Design Matrices

Four design matrices were created for the following topics: Farm Components, what technologies should be showcased as part of the Appropriate Technology Center, what plots to demonstrate, and initial outreach extension program topics. The components for each of the matrices were based-on the most significant summarized statistical results as obtained from the survey. Table 8 illustrates the following weighting and ranking scheme was used for each response. Appendix C provides the decision factors and weights for each matrix cell.

Table 8 Decision Matrix Weight & Rating

Weight	Description	Rating	Description
0	Don't Know	0	Don't Know
1	Not at all important	1	Not a good fit
2	Not very important	2	Low fit
3	Somewhat important	3	Fit
4	Important	4	Good fit
5	Very important	5	Excellent fit

4. RESULTS

The following selected results and figures provide an example of the summary statistical information generated to support the research question investigation. The summary statistical figures in their entirety can be viewed in Appendix D. One-hundred and eighteen small-holder farmers took part in this study. Of the participants surveyed, 66% were qualified to answer all questions, and 100% of participants completed the survey. Individual and cumulative respondence value results can be seen in Appendix C. The ArcGIS Pro results by village showcase the GPS data obtained and the analysis conducted. The results of specific statistical tests performed can be viewed in Appendix C. Results of the four different design matrices, Farm Components, the Appropriate Technology Center (ATC), Demonstration Plots, and extension outreach and program topics, are presented as well. The top three priorities from each decision matrix will be the focus of a future study. This future study will include the design, development, and follow-up design refinement with the in-country project partners. The data collected in the current project will guide the design study component of the long range project.

4.1 Social Survey Results

4.1.1 Demographic

Multiple questions were asked of residents in order to obtain an understanding of existing household demographics within the Lake Bosomtwe area. As seen in Figure 12, the villages of Banso and Duase each account for 7% of the sampled participants, while the rest of the villages except Amakom, account for 8 or 9% each of the sample set. Both Banso and Duase were significantly harder villages to access then the other villages, because there was no road. The clinic boat was used to reach these locations. However, as shown in Figure 12, there was minimal variation in the results between the different villages in the number of participants interviewed.

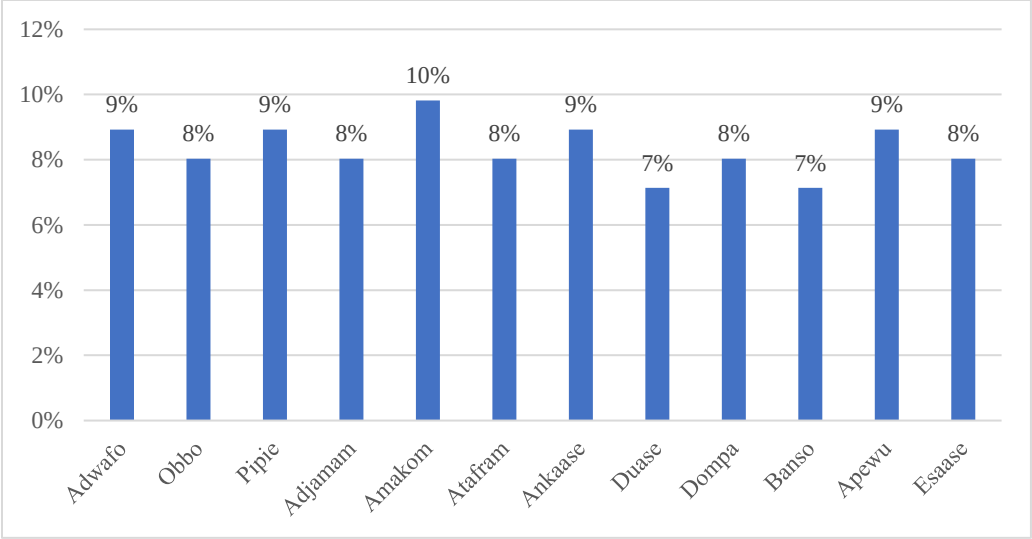


Figure 12 Sample Size by Village

Figure 13 displays the percent of participants interviewed by village and gender. The villages of Dompa and Esaase did not have any female farmers interviewed. The villages of Adjamam, Ankaase, Apewu, Banso, Duase, had a higher percentage of male farmers interviewed, while the villages of Atafram, Obbo, and Pipie had a higher percentage of female farmers interviewed.

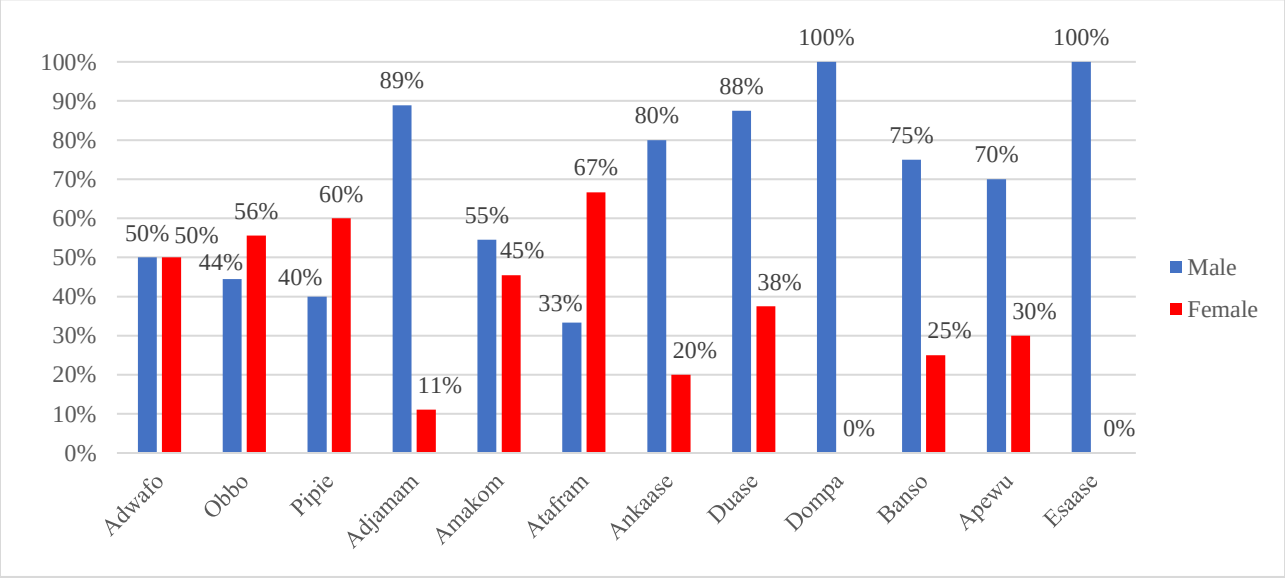


Figure 13 Sample Size by Village & Gender

Adwafo and Amakom were villages where the participants interviewed were nearly equally split between the sexes. Participants were asked in multiple choice range format about their age. This question was designed to produce a range and not a specific age value, so as to maximize the number of responses received and to account for cultural nuances. For the Lake Bosomtwe area, it is very common that participants would not necessarily have a birth certificate and would not necessarily know their exact birthday or age. It is entirely possible that they were orphaned at some point or were raised by someone other than their biological parents. Asking someone their age is considered, within this cultural context, to be a sensitive piece of information and could result in the person being interviewed feeling a sense of shame for not knowing. Therefore, asking participants to choose which age range they fall into, allowed participants to maintain a sense of dignity.

Figure 14 displays the participants evaluated by age and gender. The highest percentage of participants interviewed was between the age of 41 to 60 at 55%. The gender of participants within this age range was split at roughly 2:1 for male to female. The lowest percentage of participants interviewed were those between the ages of 18-20. The age and gender results were nearly the same for participants either over 60 or between the ages of 21-40.

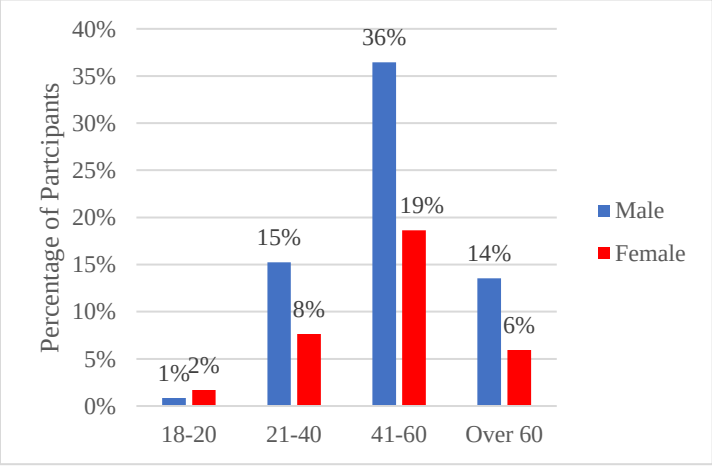


Figure 14 Survey Participants by Age and Gender

Figure 15 provides the portion of participants interviewed by their level of education obtained and gender. The majority of the participants interviewed, 70% of the total, had attended school

up through a Middle School Leaving Class (MSLC) or Junior High School (JHS) level. These two schooling levels are equivalent in Ghana, but they are called two different things, based-on the years that a participant attended school. The JHS is the more up-to-date and current educational name, while the MSLC designation is considered part of the older educational system. A modernization effort from 1989-1990 transitioned MSLC to Junior Secondary School (JSS) (Kan-uge, personal conversation, 2019). From 2000-2008 the JSS was transitioned again to the current system known as Junior High School (JHS) (Kan-uge, personal conversation, 2019). This level would be similar to the attending middle school in the United States. Participants only reported either attending MSLC or JHS. No participants reported attending JSS. Fourteen percent of participants had only attended up to a Primary Level of schooling.

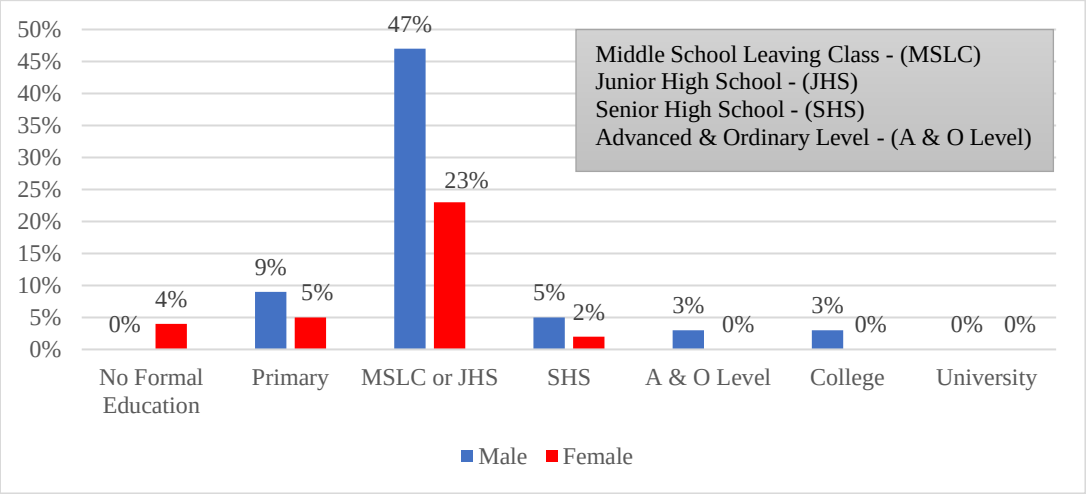


Figure 15 Participants by Education & Gender

Seven percent of participants had attended through Senior High School, and 3% received Advanced & Ordinary Level (A & O Level) work. Senior High School in Ghana would be similar to a High School Equivalency in the USA. A & O level is the education obtainment received by attending a Trade School, post-Senior High School. In Ghana there are two ways to obtain what would be considered a U.S. Bachelor's degree equivalency. The first option is to attend College, which is a 3-year program that is primarily sponsored by the government. After so many years of working within the education system as a teacher, you can qualify to go back to school and finish 2 years of schooling at a University. This equates to a Bachelor's degree. College is closer to obtaining an Associate's degree in the United States. It does not equate to a

Bachelor's degree. The alternative option is to be directly admitted to a University, which is a 4-year program but is more expensive and not sponsored by the government. Pursuing education through the 3+2 program allows more people within Ghana to obtain higher education. None of the participants interviewed attended University, 3% attended College, and 3% attended A & O level. It should be noted that the 4% of women that had no formal education and were all over the age of 60. It is likely that when they were of the age to attend school, fewer opportunities existed. At that time, the government did not provide subsides to attend school. Overall, a higher percentage of men attended school than women. This suggested the statistical question of: Is there an association between gender and level of education?

Figure 16 displays the average number of people per household. Of the participants interviewed, 34% reported that 4 to 6 people were residing per household. The percent number of people per household across the ranges was nearly the same, with 34 % having 4 to 6 people per household, 31% having 7 to 10 people per household, and 25% having 1 to 3 people per household. Ten percent of the participants interviewed said that over 10 people lived in their household.

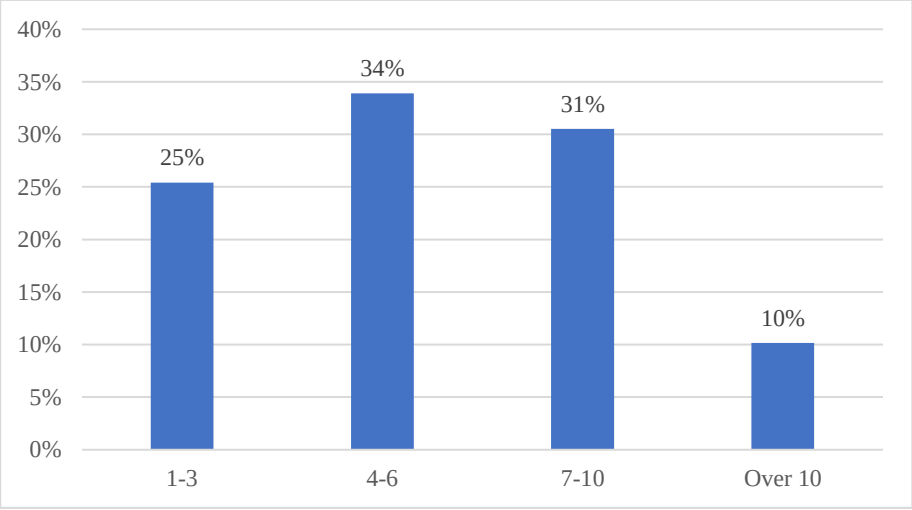


Figure 16 Number of People per Household

It is important to note that families around Lake Bosomtwe tend to count multiple generations of their relatives in their household number. For example, a father interviewed may be accounting for two sets of parents, his biological parents and his in-laws, then his spouse, and their children.

Figure 17 shows the average number of children per household. Twenty-three percent of participants said that over 10 children lived within their household. It is important to highlight cultural context when interpreting this figure. Children were noted as those under age 18. In Ghana, especially in more rural settings, it not uncommon that a father has multiple wives or relations with multiple women. In addition, birth contraceptives are not normally used in rural settings. Married couples in monogamous relationships, generally do not use birth contraceptives until after an initial child bearing. Ghanaian women from rural areas on average desire 4.7 children versus a desired 3.9 in urban areas (GDHS, 2008). The data collected showed, thirty-one percent of the participants had 4 to 6 children living within their household which was inline with the 2008 reported survey conducted by Ghana Demographic and Health Survey (GDHS, 2008).

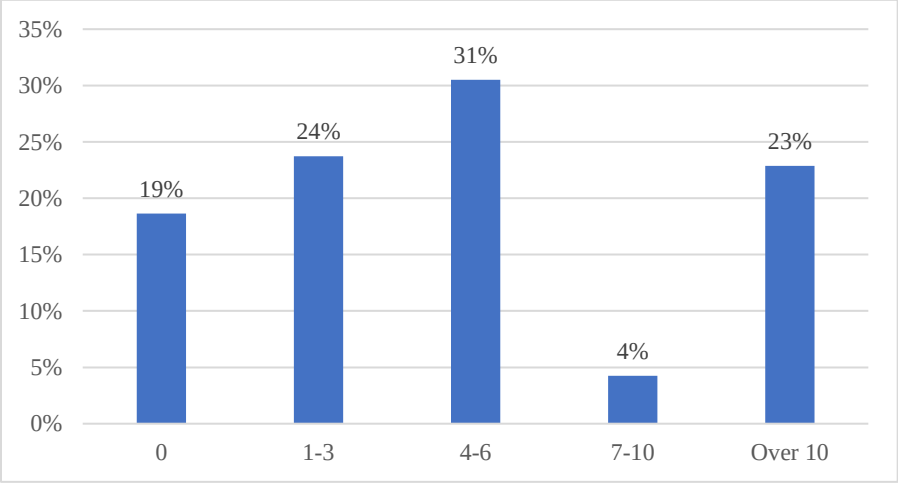


Figure 17 Children per Household

Participants were asked to report the age ranges of all the children living within their household through four follow-up multiple choice range-based question. The number of children living within a household age 5 or younger is of significant interest. Children age 5 and younger are more susceptible to a variety of health-related issues, as this is a key period in their critical health development. As seen in Figure 18, 45% of households had no children under the age of five living with them.

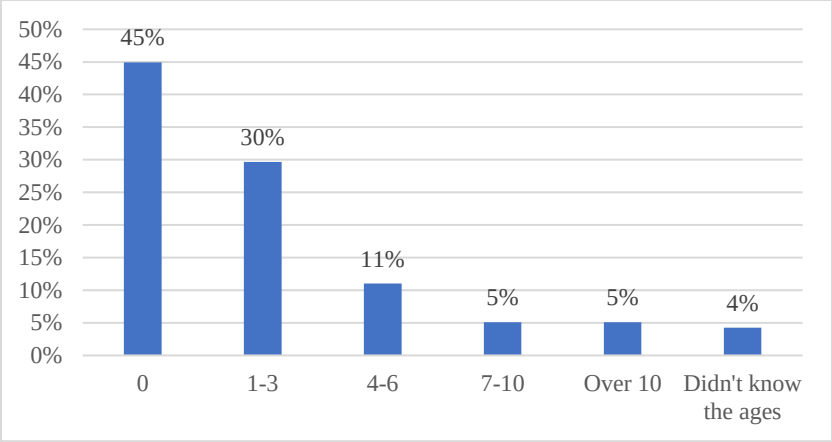


Figure 18 Children per Household Age 5 or Younger

Thirty percent of households had 1 to 3 children under the age of five living within their household. Eleven percent of households had four to six children ages five or younger, while 5% of participants reported having 7 to 10 children or over 10 children under the age of five within their households. In these cases where families reported more than three children under the age of five living within their household, the participant interviewed was likely counting multiple families residing within a household compound. However in some cases, a single set of parents may have had four children all under the age of five and had the children one right after another.

Participants were asked what they did for a living, and the aggregate results are seen in Figure 19. The highest response for participants as their main source of livelihood was farming, at 68%. Twenty-eight percent of participants acknowledged both farming and fishing as their main source of livelihood. No participants interviewed reported that they only fished. Smaller percentages of participants recorded that they participated in one of the following combinations as their livelihood: education, farming and education, or trading. It is a highly significant finding from this study with regard to the larger range plan of developing an outreach/extension demonstration farm that 98% of the participants were engaged in some form of farming.

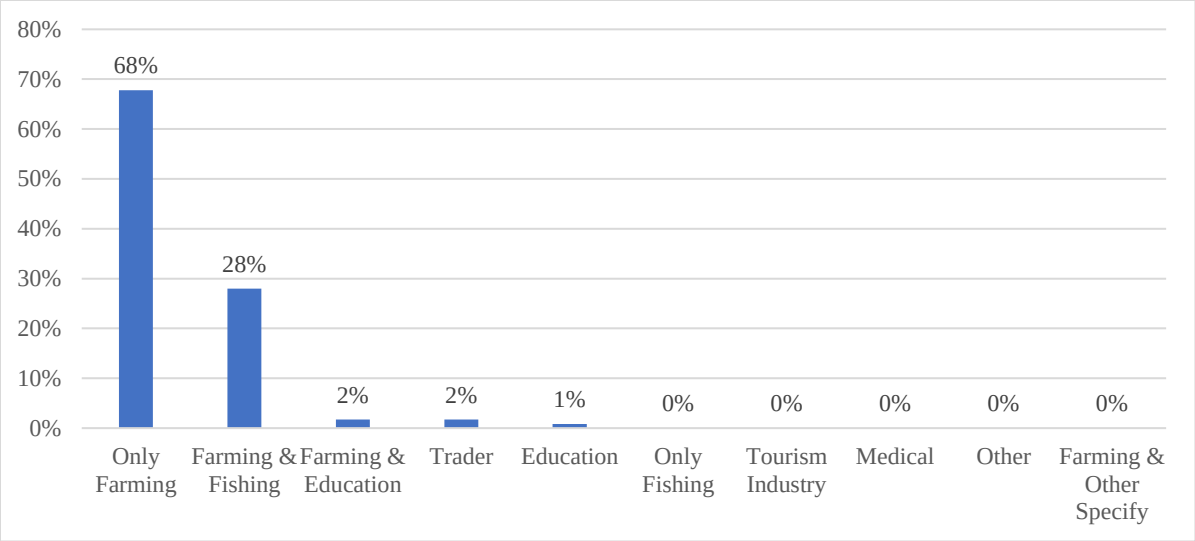


Figure 19 Livelihood of Participants

The results of participants' annual household income are seen in Figure 20. This question was designed as a range and not a specific number, so as to maximize the number of responses received and to account for cultural nuances. Household income is a very sensitive piece of information. Asking for a specific value could result in the person being interviewed feeling a sense of shame for being asked, causing a reluctance to answer with a specific number. Therefore, asking participants to choose which income range they fell into allowed participants to maintain a sense of dignity, while obtaining the information for the study.

The Ghana Statistical Service reported that the annual household income for the towns within Lake Bosomtwe is on average annually $100 USD (Ghana Statistical Service, 2015). Some participants interviewed for this study were chiefs of villages or village elders that do make a higher amount than the household average reported by the Ghana Statistical Service, and these are included within the 42% of households making 400 Ghd annually or above.

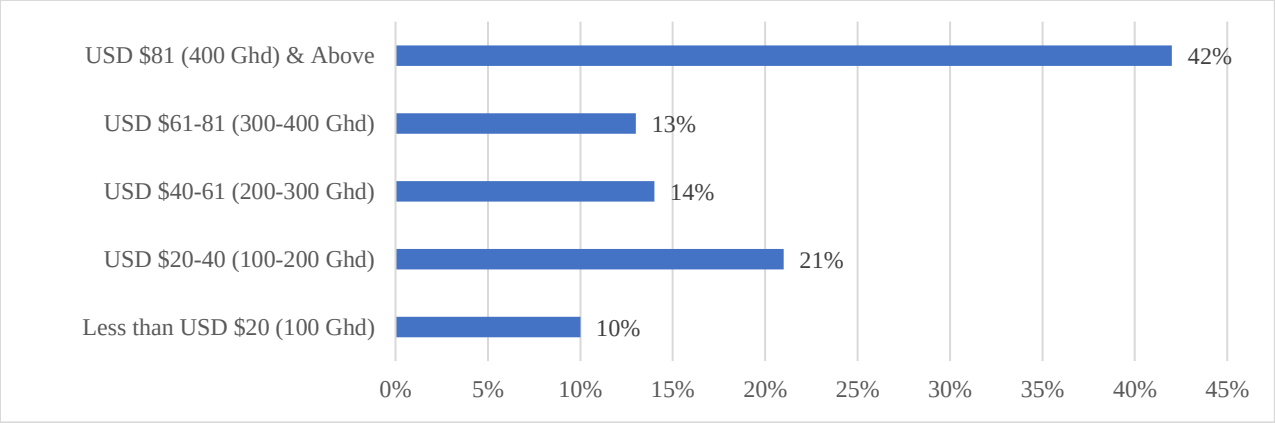


Figure 20 Annual Household Income of Participants
Note: Ghana Cedi – (Ghd)
USD 1$ = ₵4.94 Ghd

Annual Income per capita was calculated based-on the participant reported annual household income and number of people per household. Both values were recorded in range based format. The average was taken for each range based response. The calculated average annual income value was divided by the average number of people per household value to obtain a per capita value. A histogram of the data was created to determine the number of data points within each bin. The percentage of data points within each bin was calculated. The results are displayed in Figure 21. The highest two reported per capita categories were $1-9 (at 40%) followed by $9-17 (at 34%).

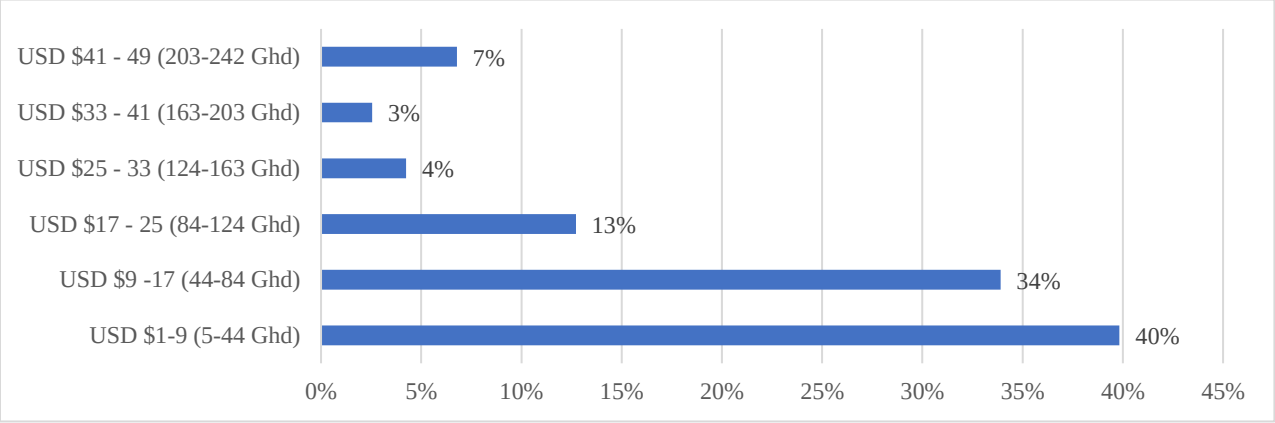


Figure 21 Annual Income Per Capita

Note: Ghana Cedi – (Ghd)
USD 1$ = ₵4.94 Ghd

4.1.2 Land Use

Participants' belief regarding their perspective on land cover is displayed in Figure 22. Participants were asked if they felt land cover was changing. Of the participants interviewed, 86% of them believed that the natural land cover change within their village or the area surrounding Lake Bosomtwe was decreasing. Only 4% of participants believed it was stable, while 10% of participants believed that the land cover was increasing.

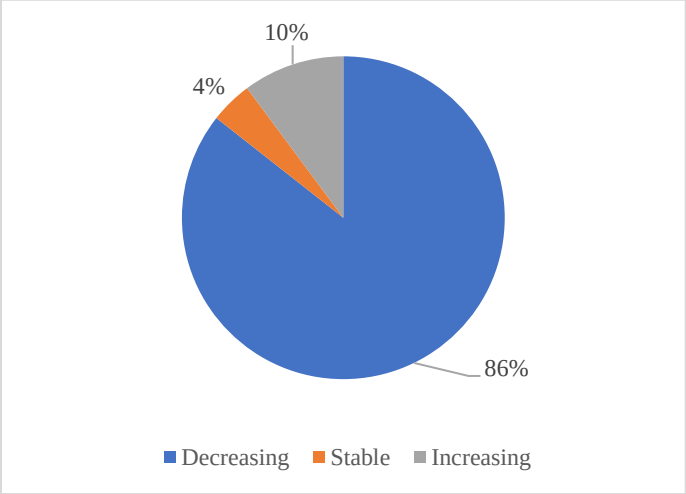


Figure 22 Participant's Belief Regarding Land Cover

There were five major emerging causes that participants believed were the reason for diminishing groundcover. As seen in Figure 23, the two highest reported causes were traditional farming practices and financial constraints. What participants meant by financial constraints, was that they were unable to make enough money to allow them to adapt their current everyday practices towards new practices that would help stop land use change. Low soil productivity was reported at 11%.

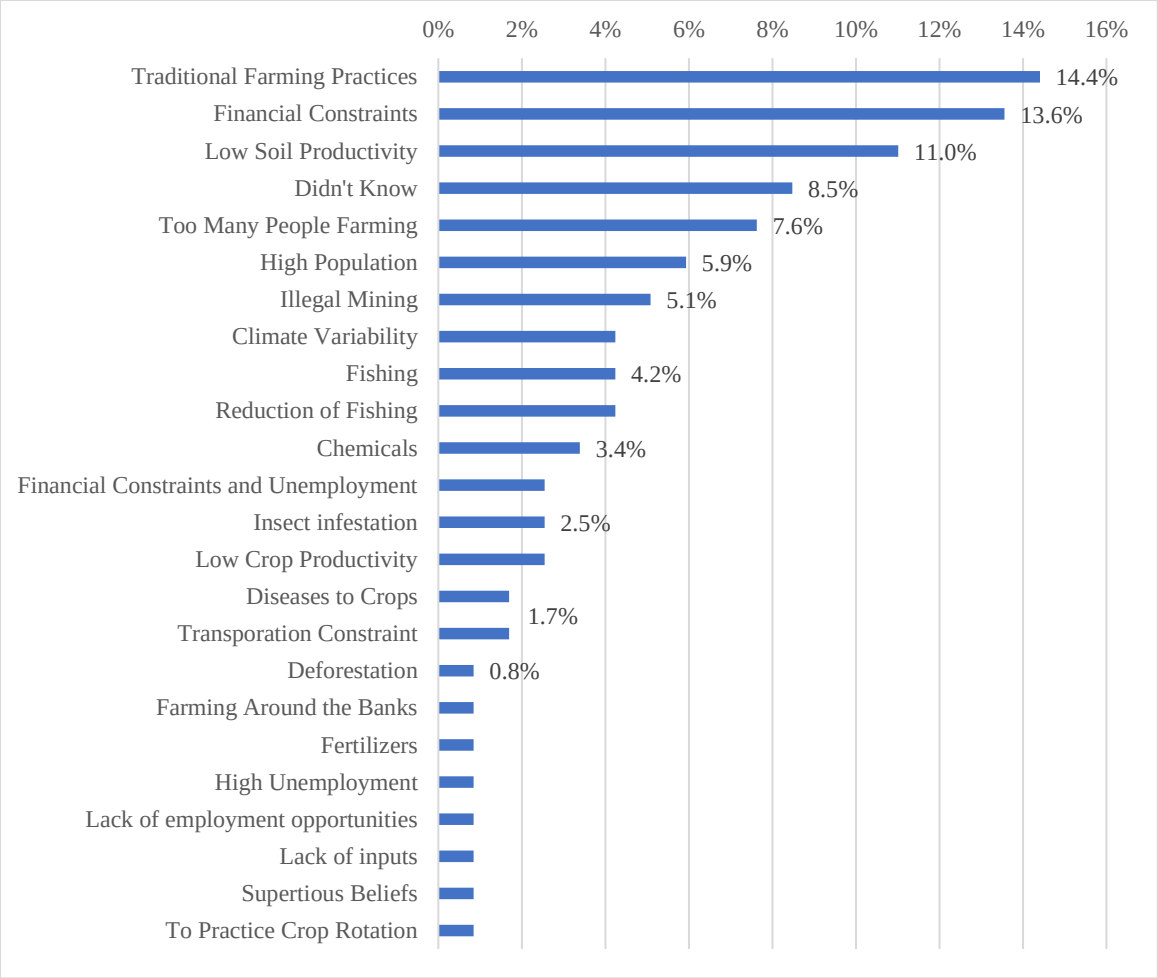


Figure 23 Key Causes of Land Cover Change According to Participants

Approximately nine percent of participants believed that the natural land cover was changing, but they did not know what the main cause was. Additionally, another eight percent of the participants felt that too many people were farming, which had led to the land use change. The other reasons were recorded, but they were more variant and diverse than the other reported reasons.

Figure 24 displays participants' various opinions as to what should be done to prevent detrimental land use change at Lake Bosomtwe. The highest response was to replant trees at 17%, and outcome was reflective of prior extension programing within the area.

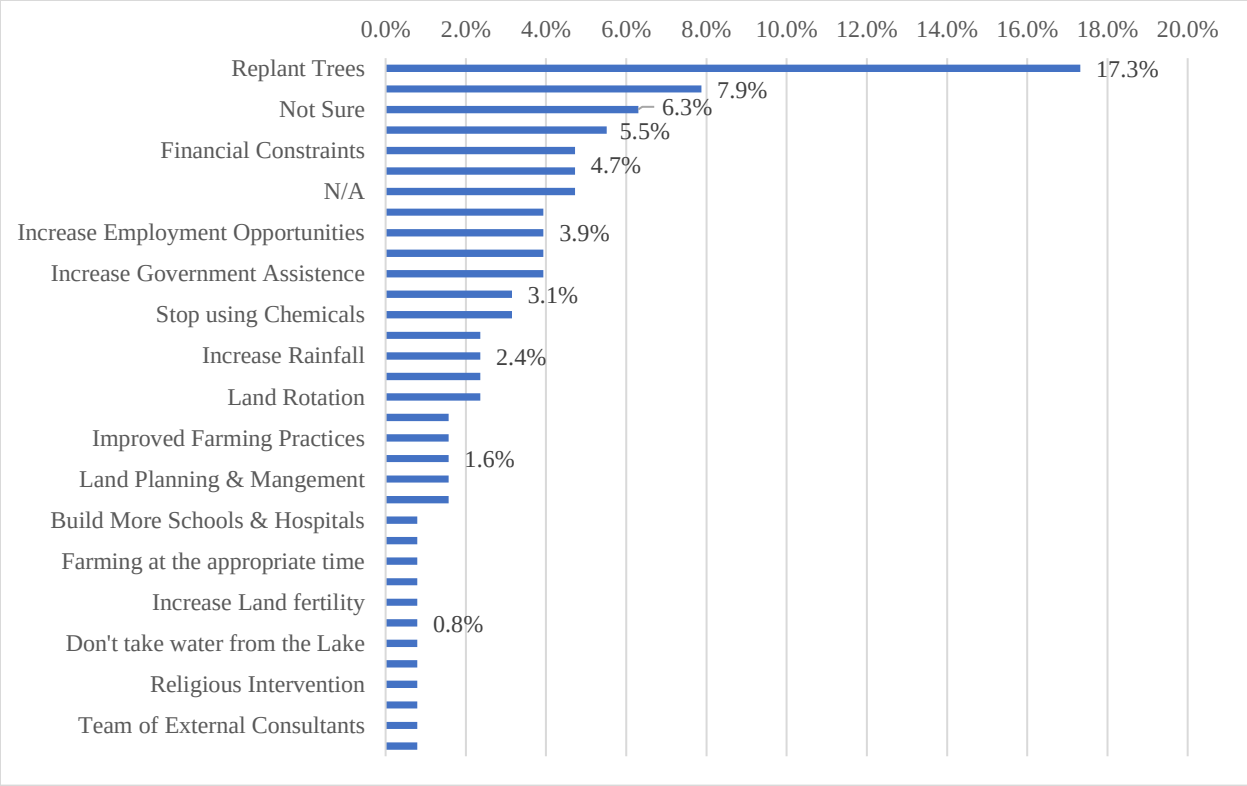


Figure 24 What participants feel should be done to prevent/stop Land Cover Change

There had been some effort in the past to plant coconut trees in the villages of Banso, Duase, Ankaase, and Adjamam to help restore the natural forest canopy, but that project has seen diminished activity. The second highest response, at 8%, was appropriate chemical application. Better community management, financial constraints, and promoting land preservation, were mentioned by 5-6% percent of participants. Five percent of the total participants were not qualified to answer this question, because they felt that land use change was stable or increasing. Six percent of the participants were unsure how to improve the situation.

As shown in Figure 25, farming was the main activity noted around Lake Bosomtwe, at 27%. Bathing & washing were noted by 14%, and farming around the banks of the lake was observed by 11% of the participants. All participants reported bathing and washing for both personal hygiene and domestic use.

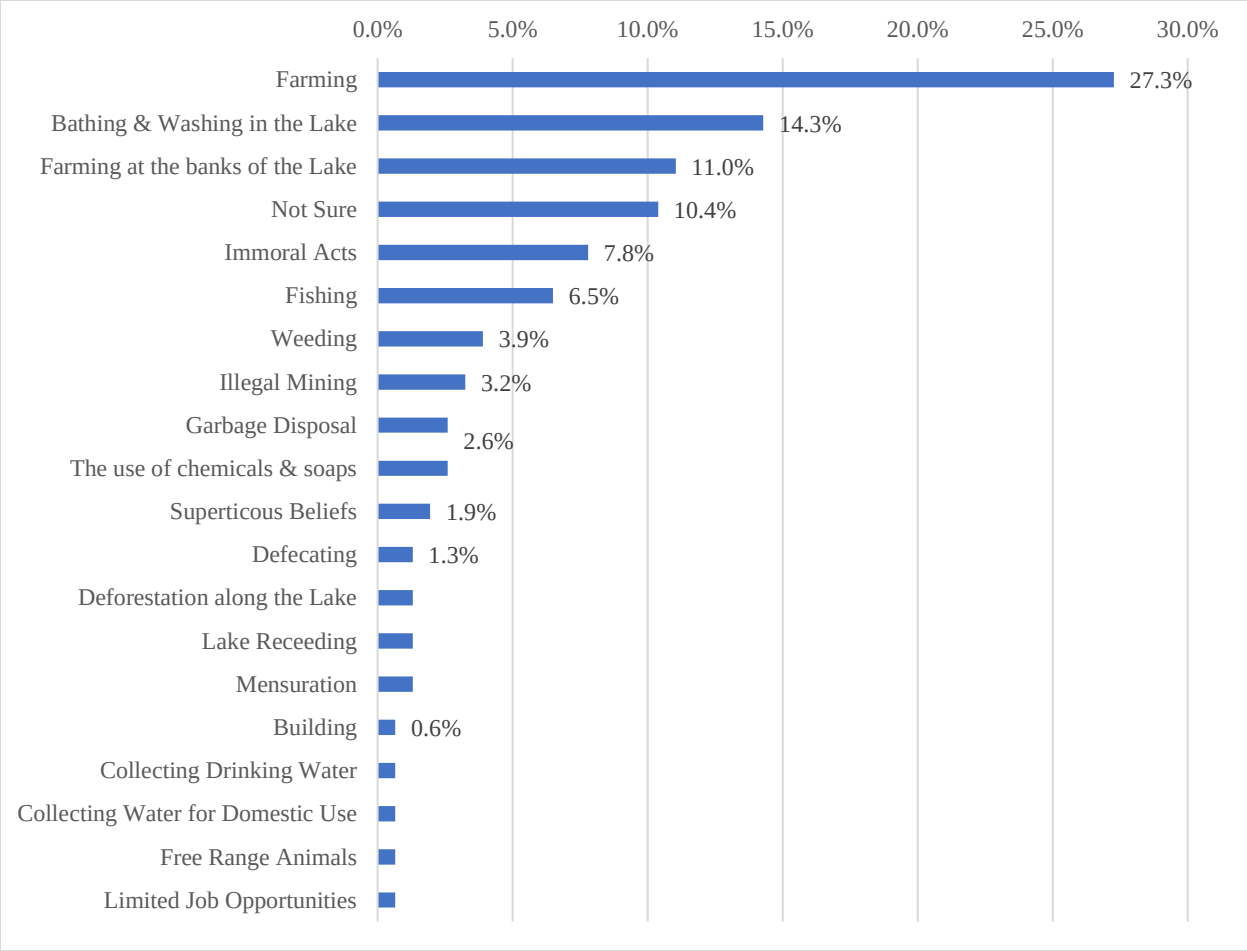


Figure 25 Human Activities observed around Lake Bosomtwe

Some participants were not sure what human activities they had observed around the lake, and in many of those cases, did not live within walking distance of the lake shore or lived in more mountainous or higher inclined areas. Those participants accounted for 10% of those interviewed. Eight percent of participants mentioned that within their villages, community members participated in immoral acts or sexual intercourse around or within the lake. This response was specifically given in the context of young adults living within the Lake Bosomtwe area and was mentioned by participants who were primarily over the age of 60. Only 6% of participants mentioned they observed any fishing activities around the lake. The use of chemicals and soaps, garbage disposal, defecation, and mensuration near the lake were also recorded as activities of concern to the health and hygiene of both the people and lake. Though these activities were reported by participants at significantly lower percentages than others, they still

provided helpful insight into the cultural habits of the community members living within the area.

Figure 26 portrays the main land use activity reported by participants. Agriculture was reported at 96%, with 3% of participants not understanding the classification options after further explanation. Only 1% of the participants reported the main land use as urban/settlement. There were no recorded responses for forest as the main land use option.

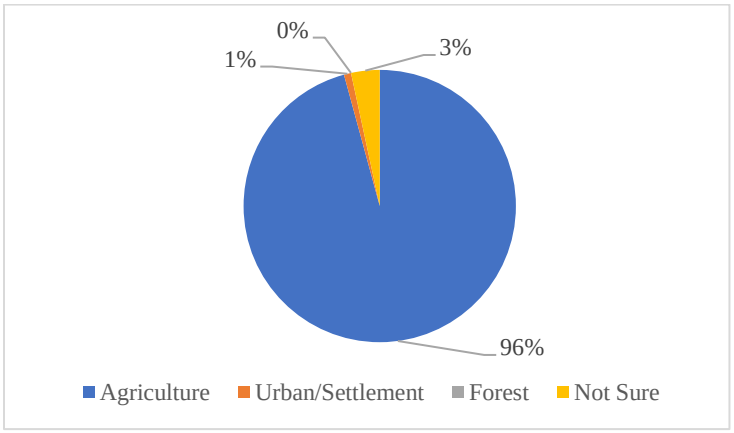


Figure 26 Main Land Use Activity According to Participants

Numerous activities were reported by survey participants occurring in Lake Bosomtwe area, and 86% of participants believed that the current land use activities within the Lake Bosomtwe watershed affected the long term productivity of the lake shown in Figure 27. This was important to note, because many participants want to change the current activities occurring near the lake. Older participants went into great detail about how the land use around Lake Bosomtwe had changed greatly. Primarily, they have witnessed the change from fishing to farming and an increase in superstitious beliefs. The superstitious beliefs related to respecting the lake as a deity and performing customary rights to the lake through animal sacrifices. These participants believed that the immoral acts and WASH activities conducted by community members in the lake were the reason the lake was not healthy and productive anymore and was decreasing in water quality. These participants believed the lake was angry for these activities occurring nearby and was no longer blessing them by producing fish.

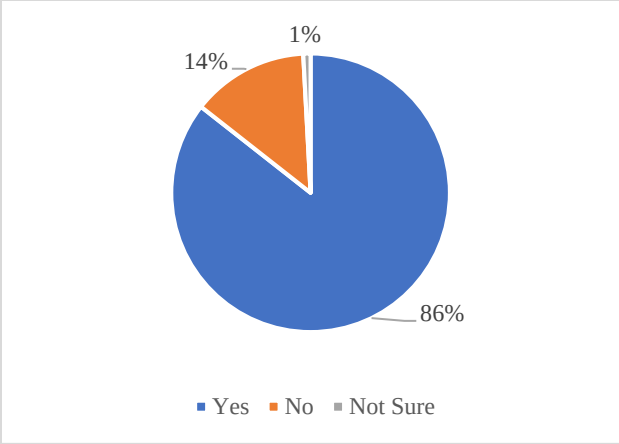


Figure 27 Can the land use activities within the watershed affect the productivity of the lake, long term?

4.1.3 Farming Practices & Fishing

To understand the current agronomic farming practices, livestock farming practices, and fishing practices of the residents within the villages of the Lake Bosomtwe area, a series of questions on agricultural practices were asked, and the results were analyzed to guide the planning of the proposed demonstration farm.

4.1.3.1 Farmer Demographics

A plot of ground within the impact crater is typically one quarter acre. Participants with an average farm size of more than four plots were reported at 40%. Twenty percent of participants reported an average farm size of four plots or one acre. Only 3% of participants said their average farm size was less than one plot. Thirty-nine percent of farmers stated that their farms were located at a distance of 500 meters or greater from the lake shore. These farms were located near the tops of the impact crater. These farmers reported farming on mountain tops or having multiple plots, existing outside the impact crater, and therefore were quite distant to reach. These same people also had plots within the impact crater that they included in their plot number, in addition to those outside the crater. Nineteen percent of participants reported a farm distance of 100 to 400 meters from the lake. Fifteen percent of participants farms were located less than 20 meters from the lake shore. The main crops reported grown on location regardless of season, in order of preference were maize, plantain, cassava, and cocoyam. Minor crops reported grown

were okra, cocoa, and peppers, with various other small vegetable crops named. Appendix D contains the Farmer Demographics results referenced here.

4.1.3.2 Farmer Cooperative Interest

Figure 28 demonstrates participants' interest in the establishment or current membership in a farmers' cooperative. Eighty-two percent of participants said that no farmers' cooperative currently existed, while 18 % said that a farmers' cooperative did exist. The farming cooperative that the 18% referred to was not a general farmers' cooperative, but rather the Ghana Cocoa Cooperative. The Ghana Cocoa Board has different cocoa-focused farmers' cooperatives throughout the entire country, but the organization's focus is on cocoa production only and is not a general cooperative focused on multiple types of crops. When asked if those surveyed currently are a member of a farming cooperative 4% said they work with the Ghana Cocoa Cooperatives, the remaining 96% are not members of any farming cooperative. When asked if participants would be interested in joining a cooperative that addressed multiple different crops, 98% said they would choose to participate, if one was created. It was confirmed through additional conversations with the demonstration farm manager and district agriculture extension officer, that currently no general farmers' cooperative existed within the Lake Bosomtwe impact crater, except extensions of the Ghana Cocoa Board Cooperative. These findings are extremely important, because a cooperative could provide additional training and tangible benefits to community members and showed strong community interest.

If through the proposed extension demonstration farm, or through a few villages coming together, a farmers' cooperative or multiple cooperatives within the area were created, they could register to become formally recognized by the Ghana Government. These organizations could receive monthly, and in some cases even bi-weekly, benefits from the Ghana government. These benefits include reduced taxes on certain produce, better access to inputs, and pesticides to address the growing army worm problem throughout the area. Administration of their programs would be through the district agric extension office in Bekwai, but this structure could be adapted to be facilitated through the proposed extension demonstration farm.

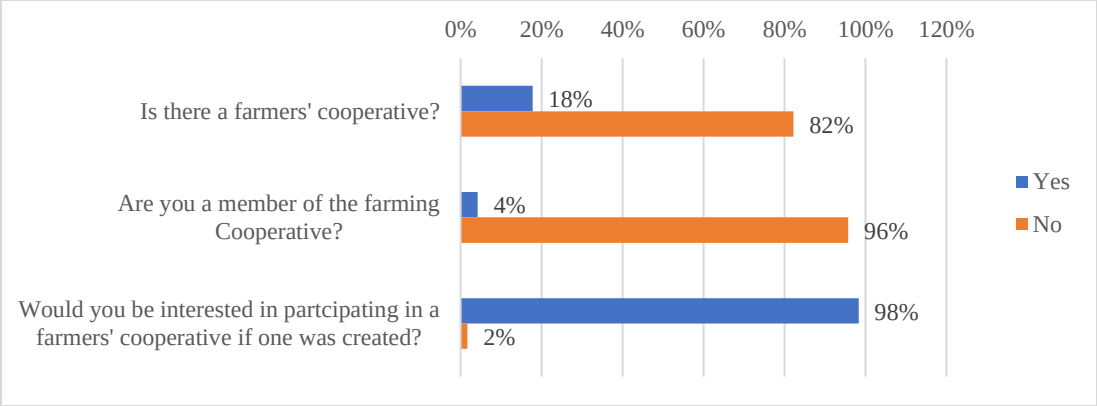


Figure 28 Farmer Cooperative Interest

4.1.3.3 Yields & Post-Harvest Losses

Participants were asked in multiple-choice range-based question format their average yield and losses for both the major and minor growing seasons. Farmers were asked these questions in range format to minimize the likelihood that a participant might feel shame in reporting their yield and losses. Not all farmers interviewed grow the same crops. In Ghana, cassava, plantain, maize, and yams or cocoyams are the highest reported crops produced (CountrySTAT Ghana, 2019). For the Ashanti Region of Ghana, Ministry of Food and Agriculture (MOFA) reported an annual production of 1,842,66 Metric Tons (MT) of cassava, 253,374 MT of maize, and 925,015 MT of plantain (MOFA), & Statistics, Research and Information Directorate (SRID), 2011). For this region, cassava 49%, maize 6% and plantain 14% contributed to the total production of major crops (MOFA & SRID, 2011). The market assessment survey showed that annually the three most commonly crops grown by farmers in the Lake Bosomtwe area are maize (1), plantain (2), and cassava (3). These results are shown in Appendix C. Many farmers put a higher priority on these three specific crops as opposed to others, because these crops are used in staple Ghanaian dishes.

In order to collect comparative yield and loss data, farmers were asked what their total loss and yield were for each season in range format. Each range option, the mean was taken based-on the range and the average for the community calculated. Crop combination weights were generated for each different crop pattern reported and can be seen in Appendix C. This weighting was based-on the MOFA reported contribution of each crop to the total production of major crops (MOFA & SRID, 2011). These weights were applied to both the yields and losses reported. This

weighting determined what percentage of the yield or loss accounted for each crop mentioned which was based-on the reported yield and loss values. The sum of both the major and minor reported yields were added together to obtain an annual yield for each farmer. This same process was used to obtain an annual post-harvest loss annual value for each crop reported. Based-on the survey results obtained, the highest crops reported grown were cassava, plantain, and maize. Average annual yield per capita values were calculated for each village and were compared to the Ashanti region average yield per capita value to determine if the villages around Lake Bosomtwe produce more or less than the regional average. This analysis was conducted only for cassava, plantain, and maize. These results are displayed in Figures 29-31. Only two villages, Dompa and Esaase, reported yields higher than that of the regional average, as seen in Figure 29. The villages of Adwafo, Obbo, and Duase reported yields below the regional average, but were quite close. The villages of Adjamam, Amakom, Atafram, Ankaase all reported cassava yields ranging from 70-80 kg, only half of the regional average per capita.

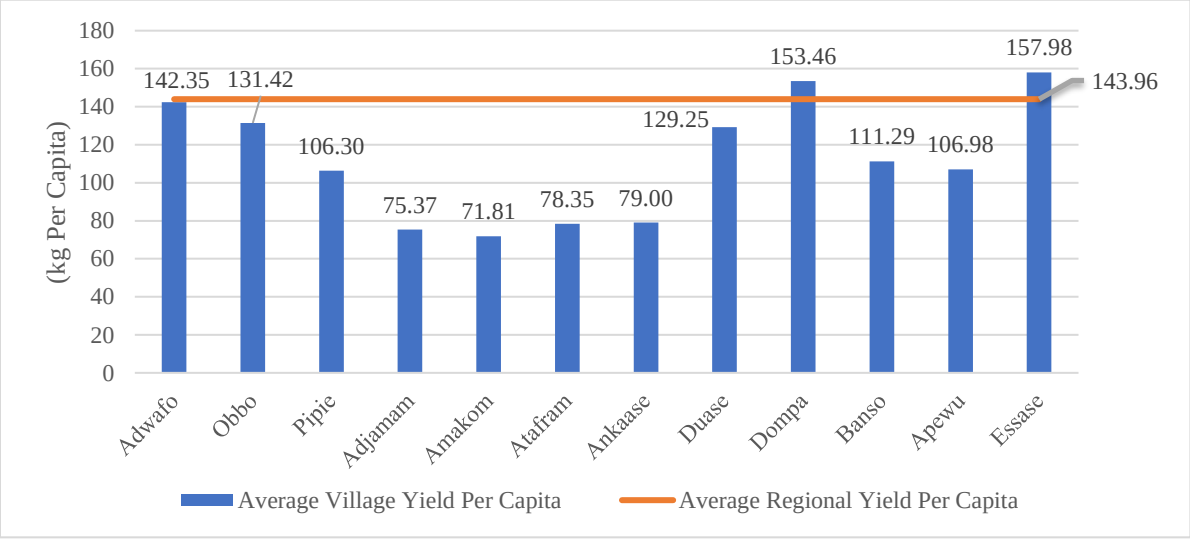


Figure 29 Village Average Yield compared to Regional Average Yield (Per Capita - Cassava)

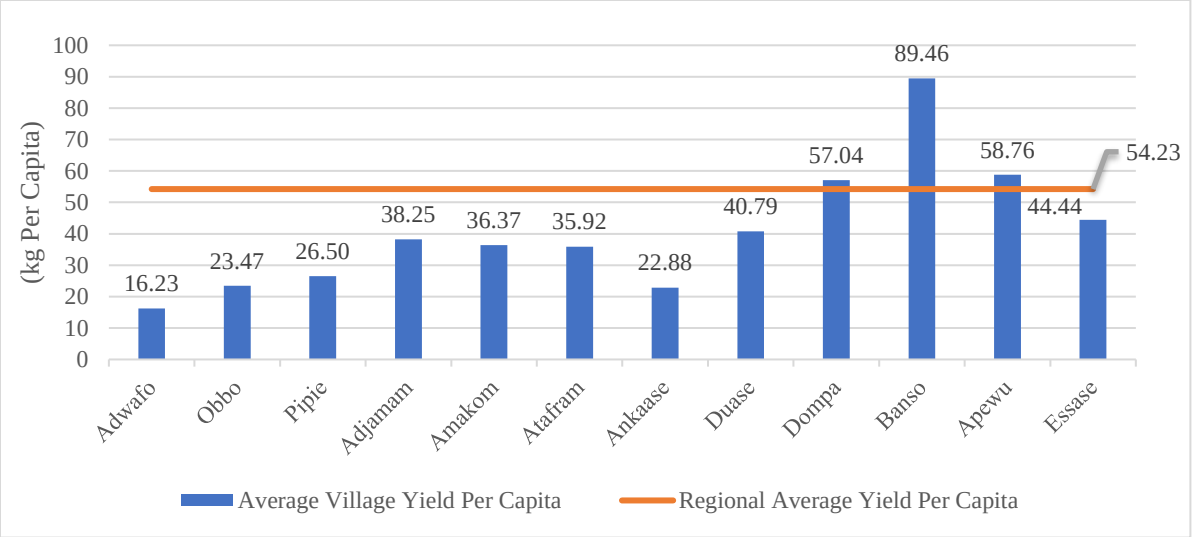


Figure 30 Village Average Yield compared to Regional Average Yield (Per Capita - Maize)

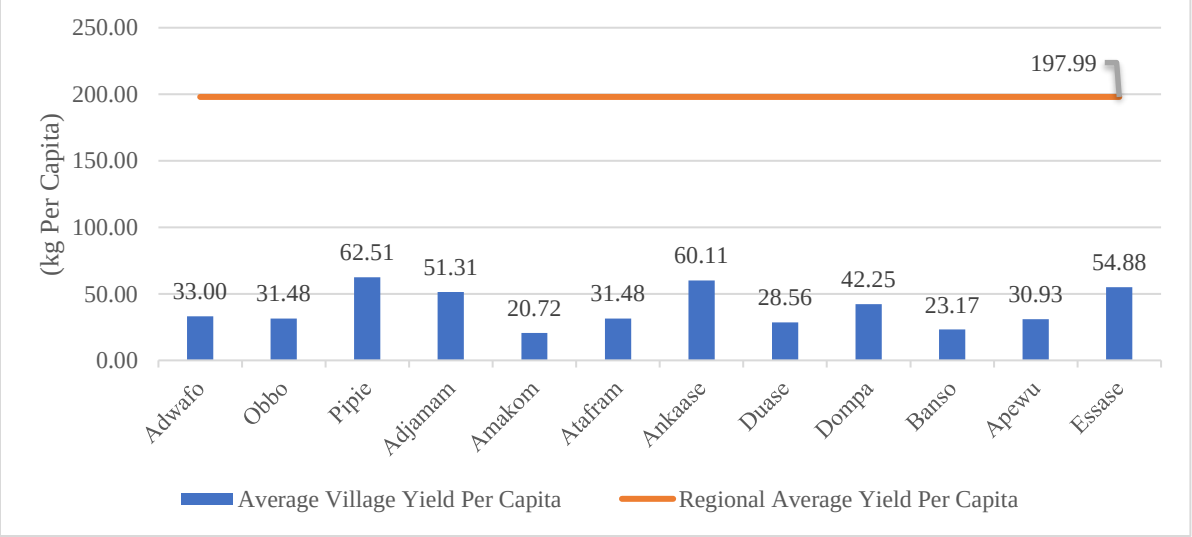


Figure 31 Village Average Yield compared to Regional Average Yield (Per Capita - Plantain)

All villages, except Dompa, Banso, and Apewu, reported lower average per capita yield values than that of the regional average for maize. Banso reported producing a much higher per capita yield of maize than the other villages. The villages of Dompa and Apewu, though above the national regional per capita yield, are only above this by a small margin. For all villages, the average per capita yield values reported for plantain were significantly lower than the regional average. A collaborative Continental Programme on Post-Harvest Losses (PHL) Reduction

report was composed by FAO and the African Development Bank (ADB). Reported mean PHL annual percentages by crop for Ghana were determined: cassava 26.5%, maize 28%, and plantain 11% (FAO-ADB, 2011). These percentages were used to calculate the regional and by village PHL values. Average annual PHL per capita values were calculated for each village and were compared to the Ashanti region average PHL per capita value to determine if the villages around Lake Bosomtwe reported higher or lower post-harvest losses than that of the regional average. This analysis was conducted only for cassava, maize, and plantain. The results are displayed in Figures 32-34.

Seven of the 12 villages reported higher PHL for cassava then the regional average. Specifically, the villages of Pipie and Ankaase reported very high PHL at 71% and 90%. Only three villages reported PHL less than the cassava PHL value. The villages of Awafo and Duase hovered slightly below the regional average. For maize, three of the 12 villages reported higher PHL than the regional average. The Bosomtwe area has a history of underperforming for maize production compared to the national level (MOFA & SRID, 2015).

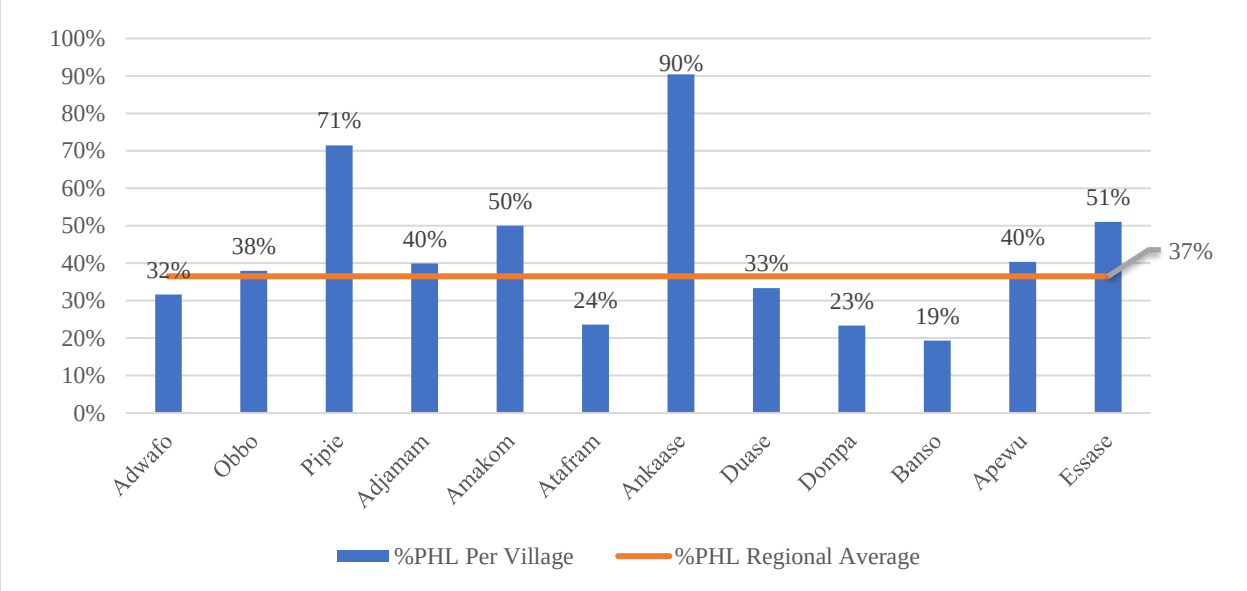


Figure 32 Village Average % PHL compared to Regional Average % PHL
(Per Capita - Cassava)

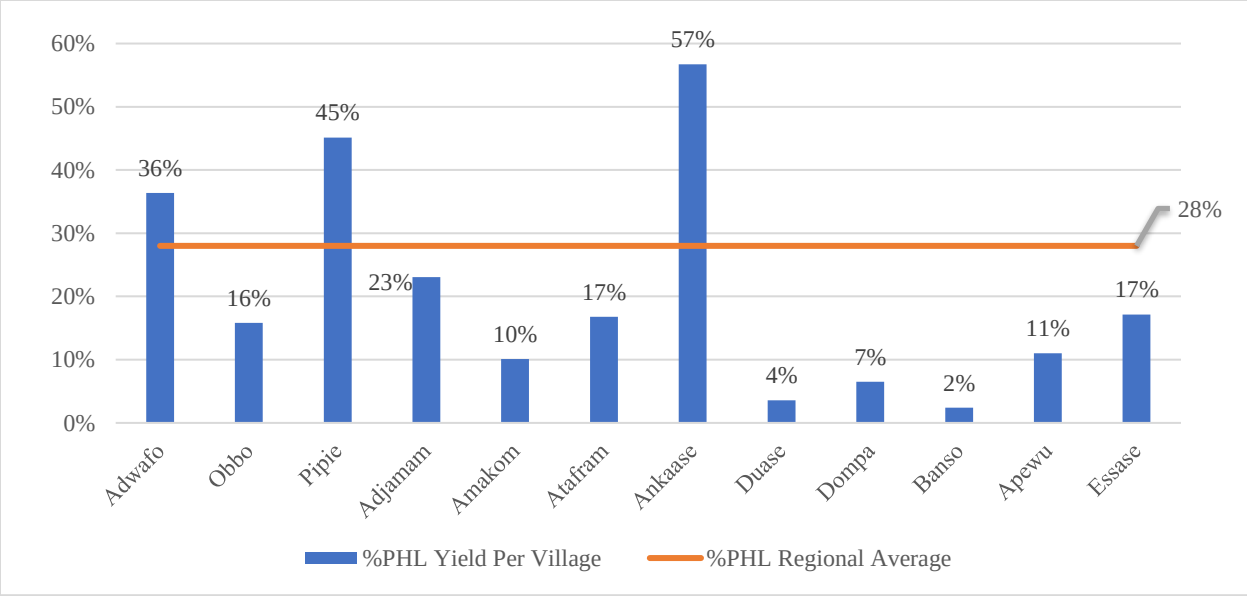


Figure 33 Village Average % PHL compared to Regional Average % PHL (Per Capita – Maize)

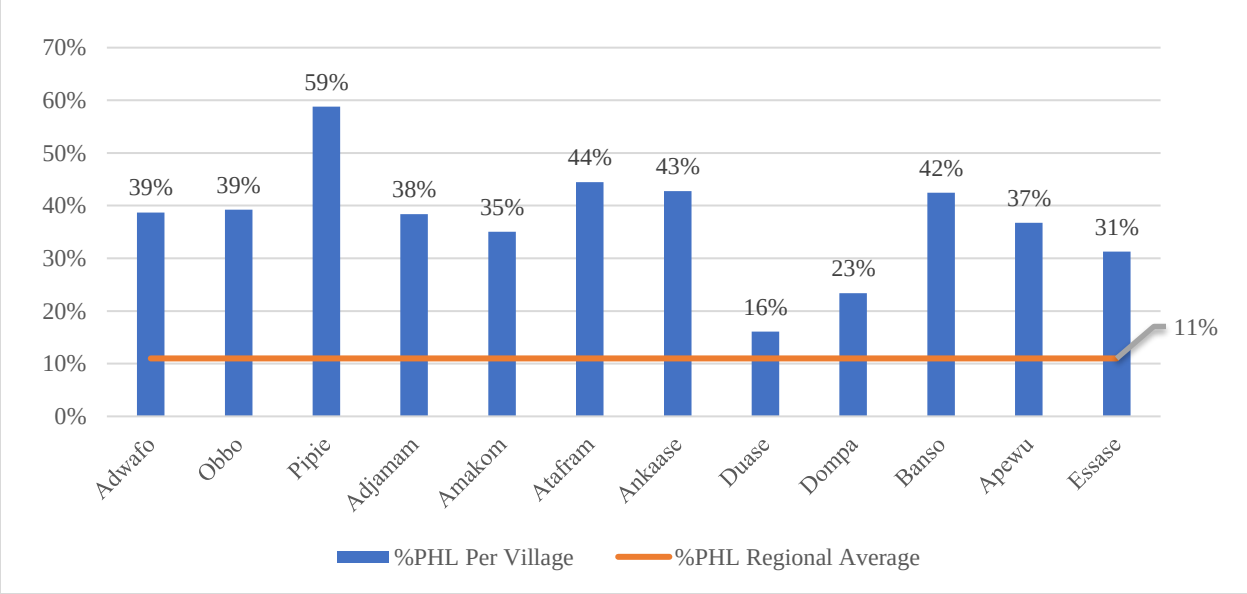


Figure 34 Village Average % PHL compared to Regional Average % PHL (Per Capita - Plantain)

Ankaase experienced nearly two times the PHL as the regional average for maize. Nine of the villages reported PHL less than the regional PHL maize value. Specifically, Banso, Duase, and Dompa reported PHL less than 10%. For plantain, all villages reported PHL exceeding the

regional PHL. With the exception of Duase and Dompa, the villages all reported PHL nearly three to four times that of the regional PHL value. Plantain had the highest number of farmers growing this crop, and all villages reported higher losses than the regional PHL value. Adwafo, Pipie, and Ankaase had significantly higher PHL reported values compared to the other villages. Pipie, Amakom, Ankaase, and Esaase all had significantly higher PHL values than that of the regional PHL values. The villages of Pipie and Ankaase reported experiencing the most significant PHL amongst all three crops.

4.1.3.4 Major Causes of Post-Harvest Loss

Farmers' were asked about factors they attributed as the cause of their post-harvest losses. Responses were recorded for both growing seasons. Many participants provided more than one cause. If an individual provided more than one factor, these factors were separated, so that the total number of times each factor was mentioned could be accounted for. Each factor was standardized and calculated individually. The results can be viewed in Appendix D. The highest recorded factor or cause for the major season was financial constraints at 19.5% and 12.5% for the minor season.

Insect damage to crops was the second highest reported cause, with 15.4% reported during the major season and 9.6% during the minor season. Over the last five years, Lake Bosomtwe has been subjected to army worm infestation. It is a major concern of both the government of Ghana and of the local farmers within the Lake Bosomtwe area. This issue extends beyond Ghana and has affected much of West Africa in terms of hindering maize production. The government of Ghana has made pesticides available through the local Bekwai extension agent to help farmers address army worm problems on their farms. However, not enough farmers have access to the pesticides, and they still encounter major crop loss even with appropriate application.

A lack of private transportation options, or options to transport produce, a lack of storage facilities for crops post-harvest, and climate variability were all potential causes of losses reported with percentages between 5.7-7.4%. These reasons seem to be very interrelated. Participants that said financial constraints were the main cause of their loss meant that they didn't have enough funds to be able to do a variety of things that they know they could help them

minimize their losses. Examples of these activities were the use of additional funds to hire more laborers to harvest their crop quicker, hire laborers to help transport their product to market, provide alternative transportation options to help move their crops to market, and install improved on-farm storage options. Without hiring laborers, farmers typically cannot work fast enough to get the crops out of the fields before decay starts.

Participants typically indicated that they had a difficult time transporting their crops to market, once they were ready. They have to travel on public transport in many cases, which means the crops during transportation are very likely to be damaged. In addition, there are a limited number of alternate transportation options. There is only a single 16 passenger van that operates in the area, but this option only runs one time during the day and doesn't have a defined stop schedule. The farmer typically has to pay an additional fee for the products that he or she is transporting, and often, these are stored on the top of the vehicle. The opportunity for lost product is significant as the main road going in and out of Lake Bosomtwe is quite bad. Some of the villages such as Duase and Dompa are not road accessible, which means farmers are limited to transporting their goods only as far as they can carry it. An alternative option is to try and transport goods on the back of a small motorcycle, but this is also an opportunity for a lot of dropped goods.

Climate variability was also mentioned. The majority of the participants surveyed do not irrigate their crops unless their farms are located within 20 m of the lake shore. Some farmers do irrigate during the dry season. Eleven percent of the participants said they irrigated during only the dry season months. The majority of farmers, 89%, do not irrigate their crops and rely solely on rainfall to meet their crops moisture needs. Many farmers do have the perspective that farming on the mountain tops will increase their yield, because there is less land cover near the tops. However, these farmers practically rock climb straight-up in many cases, to reach their farms. The villages around Lake Bosomtwe also experience a greater amount of humidity in the air, due to the proximity of the lake. This is one of the reasons drying and storage of crops post-harvest is much harder in this area. In addition, farmers are using ineffective traditional practices to store their crops. A combination of these circumstances contribute to the high post-harvest loss results.

4.1.3.5 Local Seed Practices

Farmers were specifically asked about whether they saved seed from a previous harvest for the following growing season or if they purchased seed. Those that purchased seed were asked where they purchased it and how far they traveled to acquired it. As seen in Figure 35, 33% of the participants saved seed from a previous harvest. Of those that purchased seed, 67% said they would choose to purchase seed locally, if it was available. Forty-one percent of the people that purchased seed said that they traveled over 60 miles to purchase seed, and 24% of those people purchased seed in Kumasi. A farmer must take at least three different buses to get to the Kumasi.

Once they arrive in Kumasi, it is normally the end of the day. As a general practice, most farmers cannot afford a hotel room to stay the night. Farmers are left with two less expensive options. They could stay with family or friends for the night and wake-up early the next day to attend the market. It is much more common for farmers to sleep on the side of the road in Kumasi until the next day. This of course is dangerous and ill-advised due to the safety risks, but it is considered normal by Ghanaian standards.

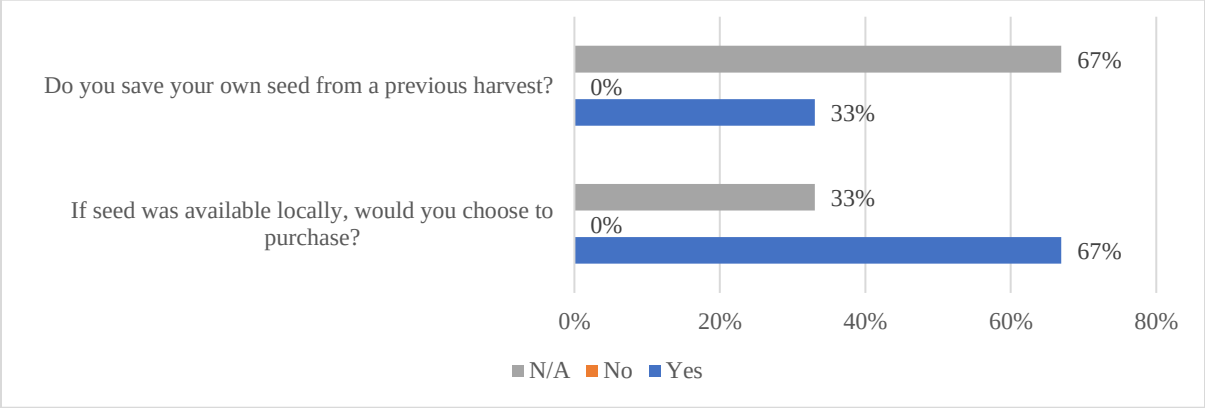


Figure 35 Participants that Save Seed and Purchase Seed

4.1.3.6 Seed Bank & Nursery Interest

Farmers were specifically asked, if there were any crops that they currently are not growing, but that they wished they could grow. Ninety percent of participants said yes to this question. Oranges were the highest reported crop of interest at 14%. Cocoa and cashews were reported at

9% and 8%, followed by peppers, and coconuts at 7% and 6%. Seven percent of participants were not interest in growing any new crops. Various other crops that participants expressed an interest in growing were reported at lower percentages. Primarily, various vegetables and fruits were followed by trees for furniture or boat making. Farmers were also asked if a seed bank was locally available, would they choose to purchase from this source. An overwhelming majority of respondents, 97%, said yes. The crops participants would want to purchase were cocoa at 17%, oranges at 12%, beans at 6%, and tomatoes at 5%. Sixty-seven percent of participants said they would choose to purchase from a local nursery, if one was available. Various other crops were mentioned. Farmers immediately connected with the idea of a local seed bank, as it was something they could relate to and understand. The idea of a nursery was more difficult for participants to understand. Participants were confused about the difference between a seed bank and a nursery. When provided more information, participants still showed more interest in the seed bank than the nursery.

Participants reported at a 63% rate that financial difficulties have hindered them from growing other types of crops. This is not surprising, but it's important to note that many of the people surveyed have not attended school long enough to reach certain Senior High School classes that focus on small farm management and family finances. In general, most older participants did not attend school when such classes were offered. Additionally, obtaining a small loan within Ghana is quite hard especially for those within the Lake Bosomtwe area. These loans are not geared for farmers, nor does crop insurance exist. Many farmers would consider obtaining a small loan from an institution, but it will likely charge a very high interest rate and expect the money back within 1 or 2 weeks. This is clearly unsuitable for agricultural enterprises. Additionally, in Ghana, many people default on loans. There is no farmer money management training, and there is no effective mechanism in country to provide capital to these farmers.

4.1.3.7 Field Clearing

4.1.3.7.1 Slash & Burn Agriculture

Participants were asked specific questions regarding their field management techniques. These topics included: slash and burn frequency, crop rotation, erosion control/slope protection, and the application of agrochemicals. Participants overwhelmingly reported, at 92%, slashing their field

and then burning the brush and field waste in preparation for planting. Only 8% reported not following this traditional in-county farming practice. When asked about the frequency of practicing slash and burn, 45% of participants said they do this regularly. Participants reported that 42% slash and burn at minimum once per year, and 34% utilize the practice twice a year, for each growing season. Some farmers, 14%, reported burning 3 times a year, but there did not seem to be a significant number of farmers conducting the practice at this frequency.

Thirty-six percent of participants conducted slashing and burning once in a while, and 11% reported doing this only occasionally. Participants that practiced slashing and burn clearing were asked if they would consider letting the brush decompose on its own. Seventy-two percent said yes, and 80% of participants believed that allowing the brush, old crops, and weeds to decompose naturally would yield benefits. Some farmers handling excess brush and weeds were clearing it, while others were allowing it to decompose after cutting without clearing.

4.1.3.7.2 Crop Rotation

It should be noted that the U. S. concept of crop rotation, such as a rotation of maize to a legume and back to maize, is not considered a traditional farming practice within the Lake Bosomtwe area. Many people say they practice crop rotation. However, all they are inferring is that they allow the land to be fallow for a growing season after a previously collected harvest. A season later, they will go back to planting the same crop again. Participants responding to questions regarding crop rotation for this study were specifically asked if they use the same piece of land each season, and if they grew the same crop or different crops from season to season. Seventy-four percent of the participants reported that they did not practice crop rotation, as defined by alternating crops grown on a single plot of land. Twenty-six percent of participants reported that they did practice crop rotation. However, of the people who said they did practice crop rotation, only 2% alternated using a legume crop such as cowpea or beans, with other crops. Sixty-two percent did not qualify to answer this question, because they did not practice any type of crop rotation. The three highest reported crops in rotation with a legume were: maize (11%), plantain (10%), and tomatoes (4%).

4.1.3.7.3 Erosion Control & Slope Protection

Eighty-eight percent of participants reported that they do not practice any form of erosion control or slope protection, with only 12% of participants claiming that they do practice some form of erosion control. Local reported methods were the use of self-dug trenches (7%), soil bags (3%), and the use of weeds to block excess water from leaving the field (3%). The use of vetiver and the practice of using planks to block slope erosion were mentioned by 1% each.

4.1.3.7.4 Agrochemicals Use & Application

Participants were asked specifically about their rate and use of agricultural chemicals on their farms. The majority of participants only reported use of one of the following agrochemicals: herbicide, pesticide or fertilizer. Seventeen percent of participants reported not using any form or combination of agrochemicals on their farm, including animal droppings. Herbicides-only was the highest reported use at 33%, with pesticide-only use at 18%, and the use of fertilizer-only at 14%. The pesticide only response makes sense, due to the growing number of issues with army worms. Participants were asked how often they applied agrochemicals, but 99% of participants asked did not want to say how often they applied. Only 1% stated they applied fertilizer three times during the major growing season. Seventy-one percent of participants chose not to say where they obtained their agrochemicals. Of these participants, 29% were not qualified to answer this question.

4.1.3.8 Livestock Production

Seventy-five percent of participants reported that they raised livestock. Twenty-five percent reported they did not raise any form of livestock. The two primary animals were goats (39%) and meat poultry (19%). Fifty-seven percent of participants reported they raised caged livestock. Only 19% reported they allow their animals to roam as free-range animals. It was unexpected that so many of the surveyed farmers raised their livestock in a confined fashion. Only 1% of participants said they allow their animals to alternate between a caged and free-range. As seen in Figure 36, participants that raised livestock were asked a series of questions regarding what they use as animal feed. Fifty-eight percent of participants reported that they grew their own feed, while 23% said they did not. Only 16% of participants said they purchased animal feed, while 83% did not purchase animal feed.

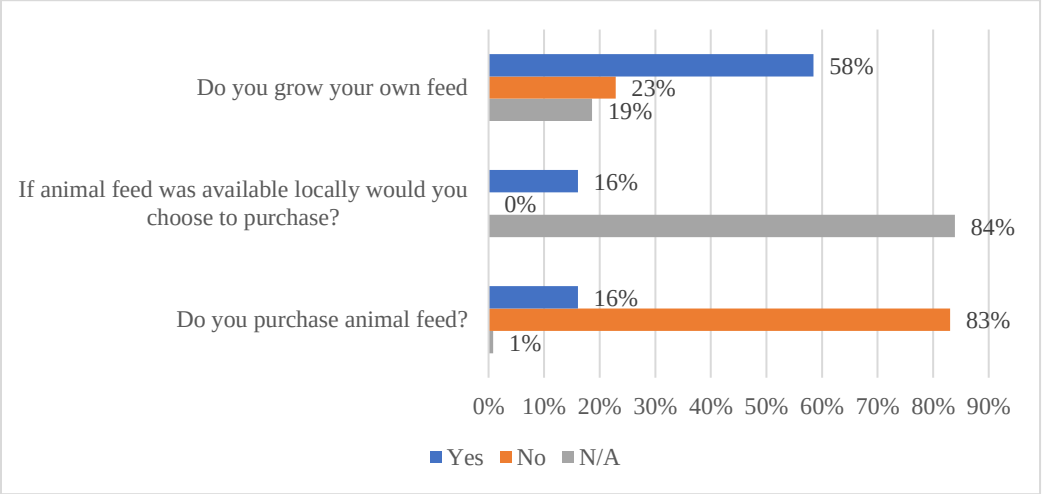


Figure 36 Participants that grow feed or are interested in purchasing feed

4.1.3.9 Fishing

Within the Lake Bosomtwe area, there are people who participate in fishing and fish mongering. The practice of selling fish is known as fish mongering. All participants were asked if they engaged in any form of these activities. Only 28% of the 118 survey participants said they participated in some form of fishing activity, while 72% reported no fishing. Ninety-four percent of the qualified participants responded that they had, in recent years, observed changes in the lake as a fishery. When asked if the change in fish catch had affected their income, 20% said yes, 2% said no, and 78% of participants did not qualify to answer this question. When asked why the fish catch had changed, 8% cited a superstitious belief or religious reason for the change. Appendix D presents more details for the fishing results referenced.

Participants were asked a series of questions related to the potential creation of fishing focused outreach extension program, or cooperative, to gauge initial interest. As seen in Figure 37, twenty-six percent of participants said there were no current fishing programs in which they participated. Participants were asked if a small-scale program was created whether they would choose to participate or not.

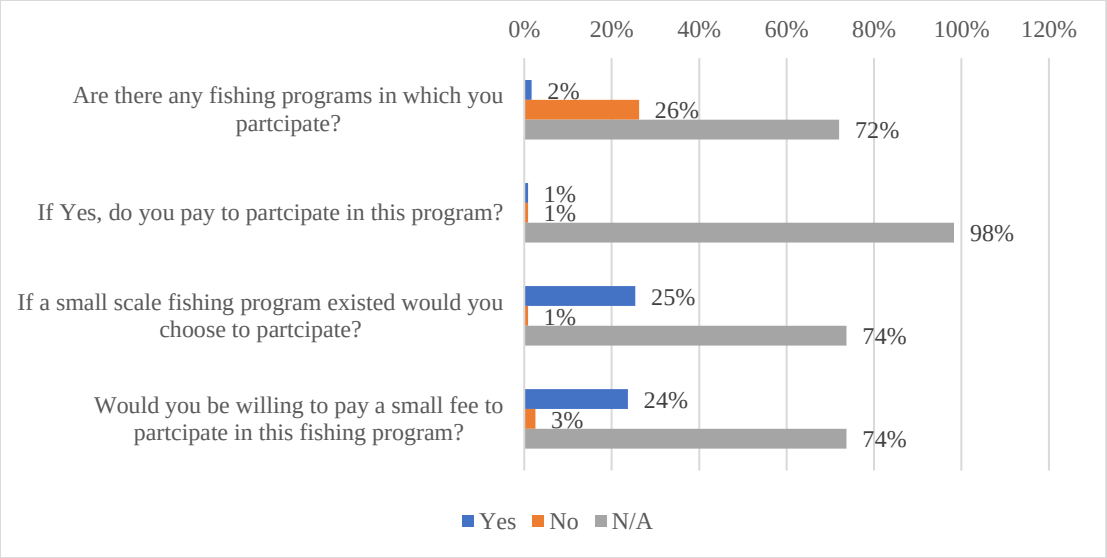


Figure 37 Fishing Extension Program Outreach Interest

Twenty-five percent said they would choose to participate, and 24% were willing to pay a small fee to participate in such a program. When asked what benefits participants hoped to gain from the program, 14% hoped it would increase their income, 8% hoped it would increase their fishing skillset, and 5% hoped it would help provide them and their families with more food to eat. Participants that had experience fishing or fish mongering were specifically asked if any alternative livelihood program had been created to help them transition from fishing to farming, since fishing in the lake is considered illegal. Participants reported that 25% felt no such program existed and would choose to participate in a program if one was created. Seventy-four percent of participants were not qualified to answer this question because they did not participate in fishing. Only one percent reported that they would not choose to participate in a fishing related program if one existed.

4.1.4 Water, Sanitation, & Hygiene

Participants were asked a variety of questions related to their personal water habits both for drinking and domestic use, along with sanitation and hygiene practices. This was critical a topic for the market survey due to the importance of this topic in overall community health, well-being, and economic activity.

4.1.4.1 Water use

The most common reported response for a drinking water source was a community borehole at 85%, followed by a nearby stream at 10%. The villages of Apewu, Banso, Dompa, and Duase, are all located along the south portion of the impact crater. A perineal stream near these villages drains into Lake Bosomtwe during periods of excessive rain. The village of Dompa had no borehole from which to access well water. The villages of Dompa, Duase, and Banso are only accessible by boat and not by road. Installing a borehole at Dompa has been an on-going problem. Transporting a well drilling rig into these locations would be extremely challenging and costly. This issue also explained the use of the specific drinking water sources mentioned. Regardless of source, 99% of participants do not treat their water before drinking it. This is extremely concerning, because boiling water insures potential viruses within the water are de-activated and unable to reproduce following treatment. The most commonly reported distance of participants' drinking water source from the lake was less than 20 meters. This is concerning, and spatial modeling based-on the GPS coordinates should be completed at the next stage of the project to see if this is actually a valid conclusion. Fifty-one participants reported that they collect between 0 to 73 liters of water per day for domestic use in their household, and 39 participants reporting obtaining 73 to 146 liters per day. Sixteen participants reported collecting between 219 to 246 liters per day.

4.1.4.2 Rainwater Harvesting Interest

Since few of the farmers reported that no form of irrigation was in use, questions were asked to try and understand if rainwater harvesting was currently taking place within communities for drinking, domestic, or on farm use. Farmers were asked if they currently had roof gutters. Seventy-five percent reported that they had roof gutters. The remaining 23.7% reported that they did not have any roof gutter as shown in Figure 38.

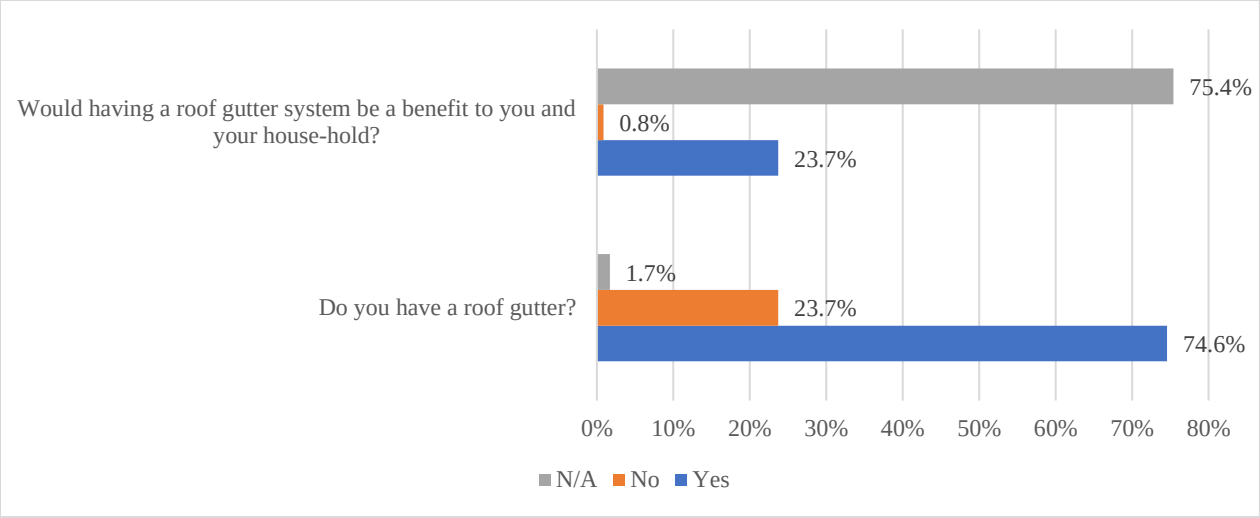


Figure 38 Participants interest in having a roof gutter

Of the participants who did not have a roof gutter system, 23.7% believed it would be beneficial for their household to have one. Reducing the number of times someone within their household would have to walk to collect water was a common rationale for this answer. All participants were asked if they collected rainwater in some form, and 94% of participants did. When asked if they collected it to a central location, 74% did. The three primary ways of collecting the water was by a large bucket (at 16%), a roof gutter, or gallon-sized container (at 14% each). Various other things were used to collect rain water from small bowls, buckets, paint buckets, metal pans, to gallon drums, and containers. People simply use what they have available. When asked what purpose the rain water was used, 36% responded for domestic purposes only, 32% for drinking water only, and 29% for both drinking and domestic use. No one reported using rainwater for irrigation or crops in any form. Eighty-six percent of participants who collected rainwater said they collected between 0 and 370 liters of water. Forty-seven percent reported collecting between 740 and 1110 liters of water.

4.1.4.3 Pit Latrine & Toilet Community Options

Participants were asked specific questions regarding restroom facilities both in the home and at the community level. Eighty percent of participants reported that they did not have a toilet in their home. Of the 20% of participants that reported having a toilet in their home, 14% reported that it was within 20 meters walking distance of the lake shore. This is a serious concern,

because these sanitation options are likely to have potential leaching or seepage issues. If no toilet was present in the home, participants were asked where they used the restroom. A community pit latrine was the highest reported response at 78%, with in the bush, and around people's homes, receiving 1% each.

4.2 Statistical Analysis Results

4.2.1 Participants by Gender & Level of Education

Based-on the results of Figure 15 participants by gender and level of education, a more specific statistical analysis was required to determine if an association between gender and level of education existed. A Pearson Chi-square test was conducted in IBM SPSS to determine if an association existed. All participants that attended schooling levels lower than JHS level were assigned a value of zero. Participants having attended JHS level or higher were assigned a value of one. The following values were assigned for participants: one for male and zero for female. No association was found between gender and level of education X^2 (1, N = 118) = 0.14, $p >$ 0.05. This indicated that despite Figure 15 potentially suggesting that females received less opportunities to pursue education than males, this was not statistically true. The results indicated that regardless of gender there were just as many opportunities for females to pursue education as males. The complete results of this analysis may be seen in Appendix C.

4.2.2 Participants that Bathe & Wash in the lake and Participate in Fishing

It was reported that 76% of participants have bathed or washed in the lake. A specific statistical analysis was conducted to determine if an association existed between people who bathe and wash in the lake and those who participate in fishing as a livelihood. A Pearson Chi-square test was conducted in IBM SPSS to determine if an association existed. Those that participated in bathing and washing received a value of one. Participants that did not wash and bathe received a value of zero. Participants that did not fish were assigned a value of zero. Participants that fished were assigned a value of one. An association was found between people who practiced bathing and washing in the lake and those who practiced fishing as a form of livelihood X^2 (1, N = 118) = 10.85, p = 0.01. This indicated that there is a significant association between people who wash or bathe in the lake and those that participate in fishing. The results indicated that people who bathe and wash in the lake are likely to be fisherman and that there is a

statistical association between the two. People that bathe and wash in deeper sections of the lake than the shoreline are in fact fishermen. When they are fishing, they will actually be near the center of the lake on a small wood plank floating. Fishermen tend to sit in the water all day and wash/bathe after leaving the lake at the end of each day. These people are also likely to swim or wade. Most Ghanaian do not know how to swim and are in fact scared of water or are concerned of drowning. People that are participating in fishing also tend to live closer to the lake shore. People that do not fish, generally don't know how to swim and are less likely to be in the lake. These people are less likely to bathe and wash in deeper sections of the lake. If they reported bathing or washing, they are more likely to only do so at the minimal shoreline. These people tend to live farther from the lake shore and walk inland. When all participants were asked if they believed their activities have affected the lake water quality, 86% said they believed it did. The complete results of this analysis may be seen in Appendix C.

4.2.3 Road Accessibility Impact on Yields & Usable Yields

The villages of Esaase, Banso, and Duase have limited to no road access, are located on the south half of the lake. Farms in these areas are on greater slopes. Farmers from these villages either carry produce to market on foot or take a motorcycle. These villages have a very difficult time getting their produce to market as opposed to the other nine villages surveyed. The villages of Adwafo, Obbo, and Pipie have road access, are located on the northern half of the lake, and these villages experience less slope. The three villages located on the southern half of the lake have limited to no road access and experience higher inclines. Three villages were each selected so as to keep each sample size close to the same. Usable yield is the yield from the harvest less the harvest losses. To determine if a statistically significant difference existed between village yields or village usable yields and villages with or without road access, independent samples t-tests were conducted. The six villages are portrayed in Figure 39. An independent samples t-test was conducted to compare yields of villages on the north side of the lake with road access (N = 29) and villages on the southern portion of the lake with limited to no road access (N = 30). There was a significant difference in the scores for villages with road access (M = 265.52, SD = 121.452) and villages with limited to no road access (M = 190.00, SD = 121.698), $t(57) = -2.39$, $p < 0.05$.

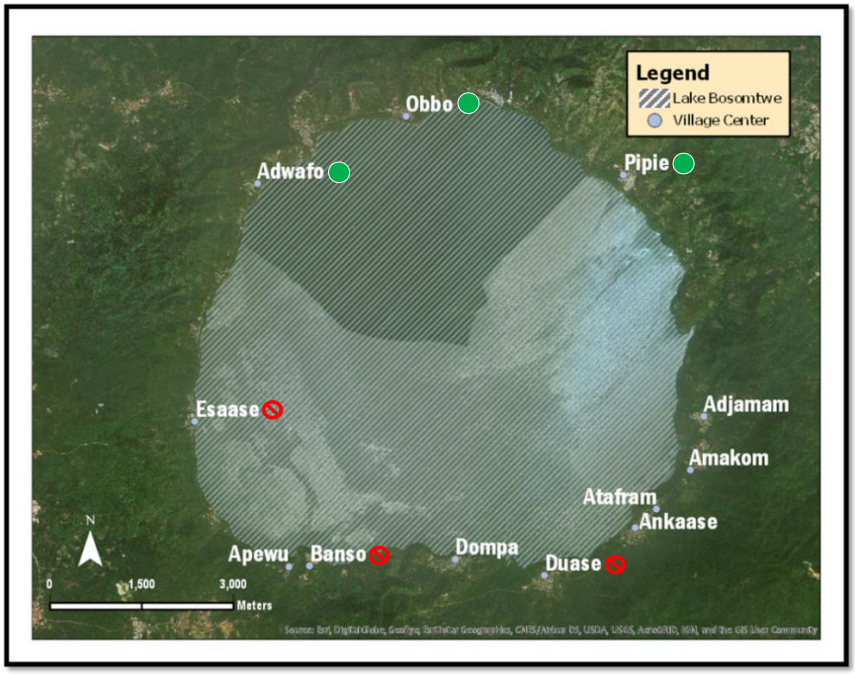


Figure 39 Lake Bosomtwe Road Accessibility (Baldwin, 2019)

Note: Villages with Road Access Adwafo, Obbo, Pipie (Green)
Villages without Road Access Esaase, Banso, Duase (Red)

These results indicated that road access does affect village yield. Specifically, the results suggest that when roads are accessible, yields are higher. The results also suggest that southern villages with higher sloped areas produce less yield than villages located in the northern portion of the lake farming on less sloped areas.

A second independent samples t-test to compare usable yields of villages on the north side of the lake with road access (N = 29) and villages on the southern portion of the lake with limited to no road access (N = 30). There was no significant difference in the scores for villages with road access (M = 141.38, SD = 131.318) and villages with limited to no road access (M = 92.50, SD = 92.650), $t(57) = -1.66$, $p > 0.05$. These results indicate that road access does not affect village usable yield. Specifically, the results suggest that when roads are accessible, or the surrounding areas have more or less sloped areas, useable yields are not statistically affected . The results also suggest that southern villages with higher sloped areas do not have less usable yield than villages located in the northern portion of the lake farming on less sloped areas. The results for each statistical test conducted is summarized in Table 9.

Table 9 Summery Statistical Analysis Results

Pearson Chi-square Tests			
Participants by Gender & Level of Education			
X^2 (1, N = 118) = 0.14, p > 0.05			
Participants that Bathe & Wash in the lake and Participate in Fishing			
X^2 (1, N = 118) = 10.85, p = 0.01			
Independent Samples t-tests			
Road Accessibility Impact on Yields			
Villages on the north side of the lake with road access	(N = 29)	(M = 265.52, SD = 121.452)	t (57) = -2.39, p < 0.05
Villages on the southern portion of the lake with limited to no road access	(N = 30)	(M = 190.00, SD = 121.698)	
Road Accessibility Impact on Usable Yields			
Villages on the north side of the lake with road access	(N = 29)	(M = 141.38, SD = 131.318)	t (57) = -1.66, p > 0.05
Villages on the southern portion of the lake with limited to no road access	(N = 30)	(M = 92.50, SD = 92.650)	

4.3 ArcGIS Pro Results

Using the village center, pit latrine, and borehole GPS locations collected, 11 different maps were created. Figures 40-50 summarize the latrine and borehole location results per village. Due to the high accuracy of the GPS location points compared with the large area surrounding Lake Bosomtwe, individual maps were created and magnified so that the locations of interest could be viewed. Figure 40 illustrates the village of Adwafo. This village did not have a community pit latrine, rather they had the equivalent of a shack that the community uses as a restroom. A separate layer called shack was created to distinguish this, as opposed to more developed communities with pit latrines throughout the Lake Bosomtwe area. A multiple ring buffer was created around each location to highlight the minimum distance from the lake shore.

A layer called Lake Bosomtwe was color coded in a hatched white color and was created to help distinguish the lake shoreline comparatively with the other locational data. The red pin symbology was used to highlight the village center in each figure.

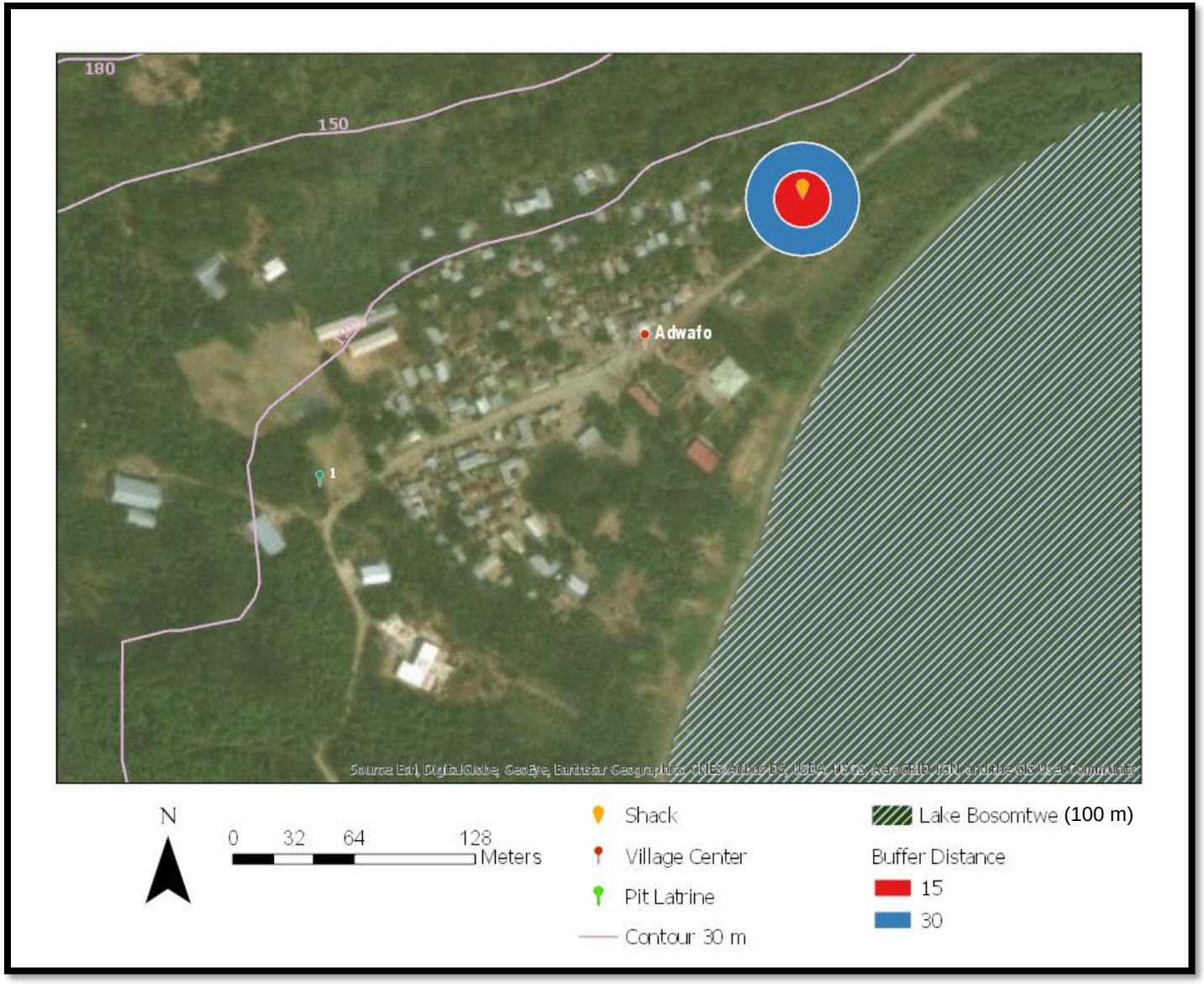


Figure 40 ArcGIS Pro Results Adwafo

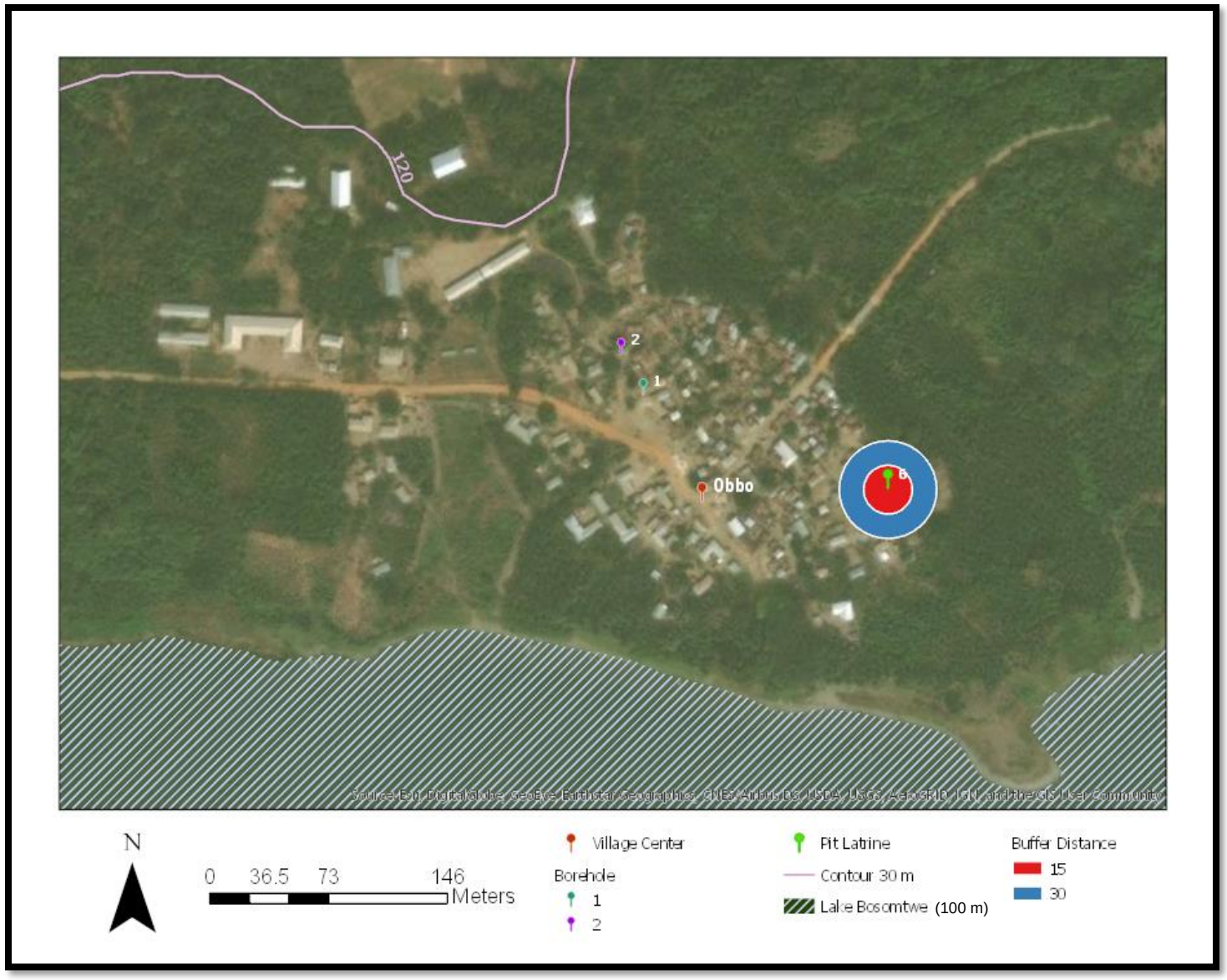


Figure 41 ArcGIS Pro Results Obbo

Figure 42 ArcGIS Pro Results Pipie

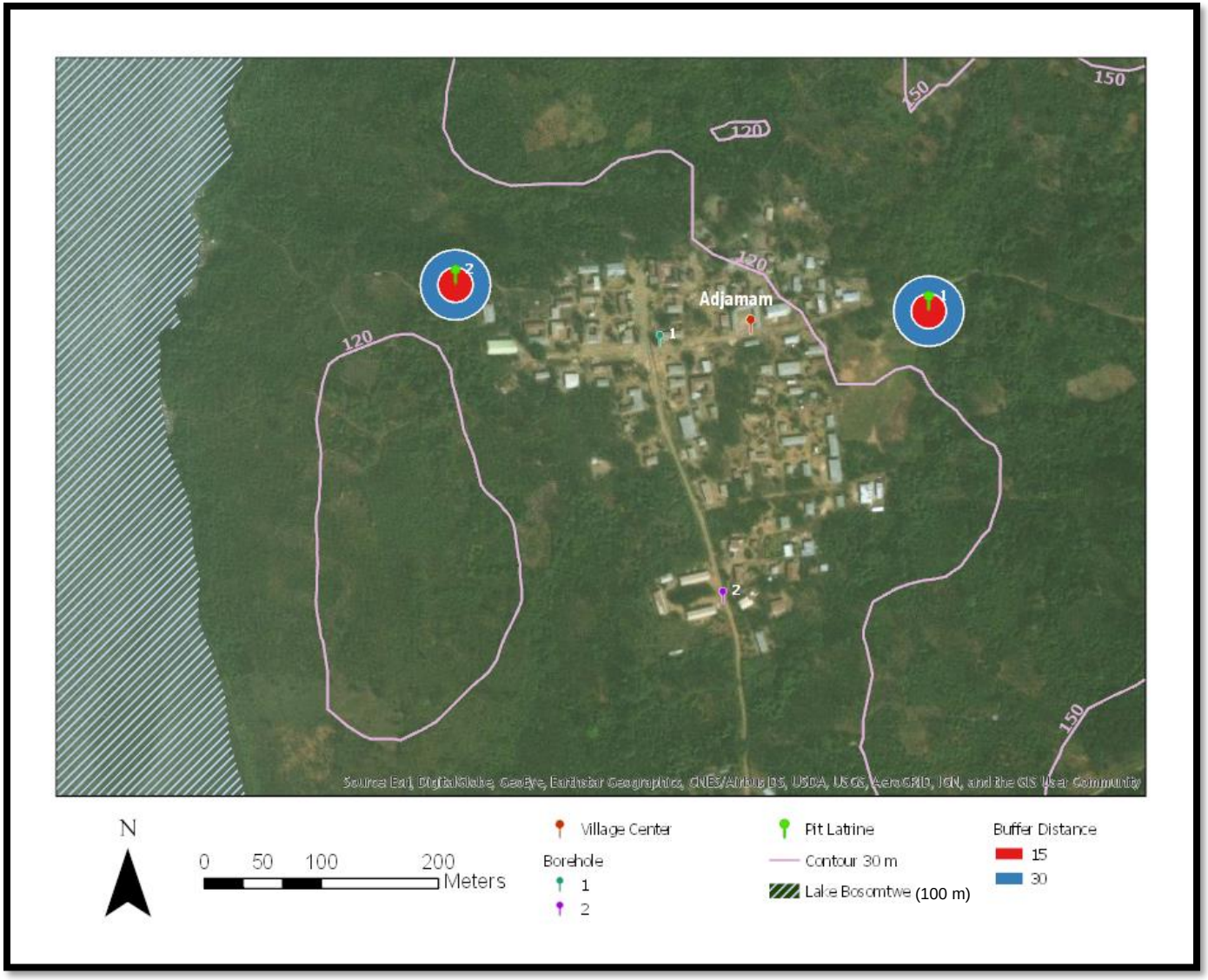


Figure 43 ArcGIS Pro Results Adjamam

Figure 44 ArcGIS Pro Results Amakom

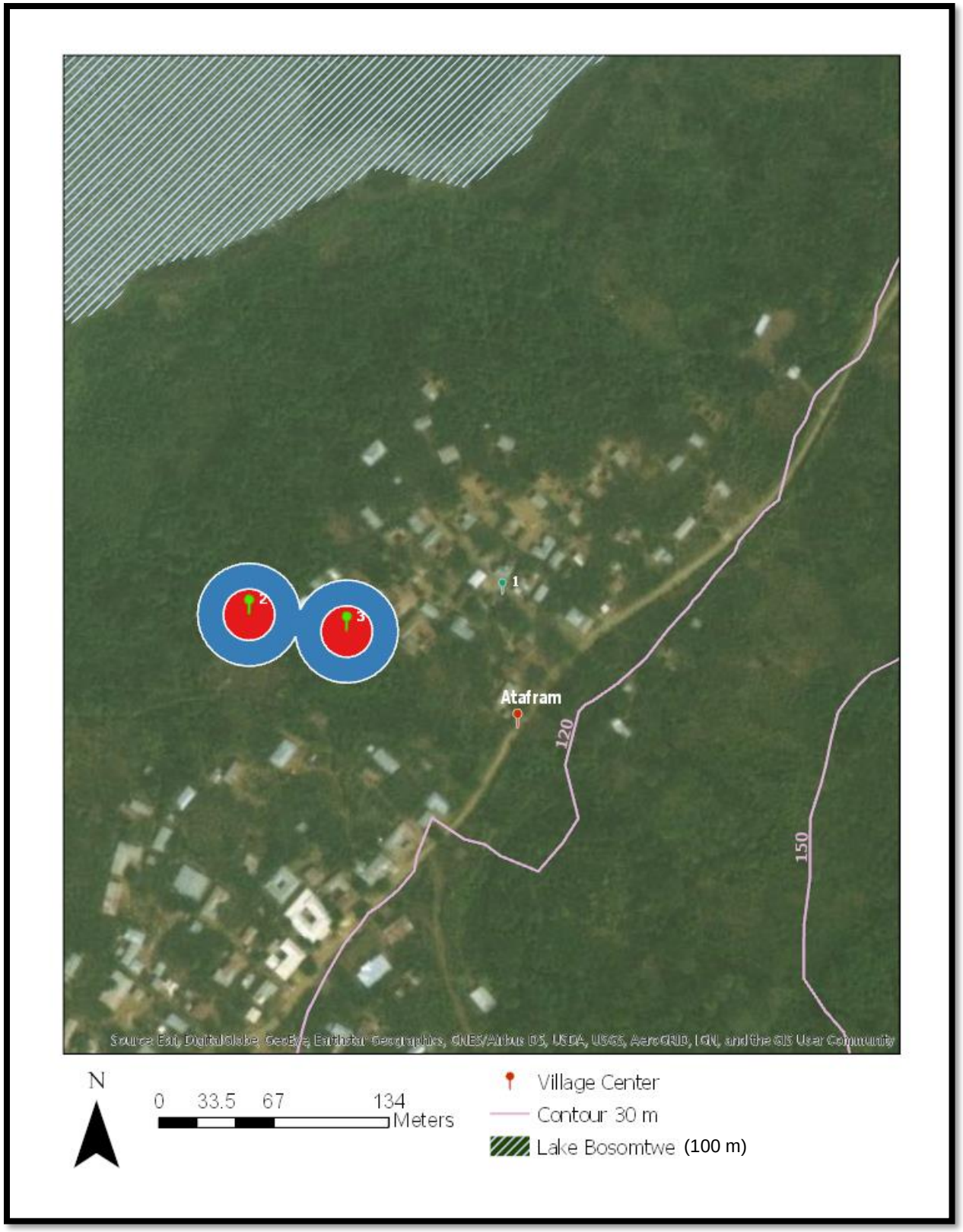


Figure 45 ArcGIS Pro Results Atafram

Figure 46 ArcGIS Pro Results Ankaase

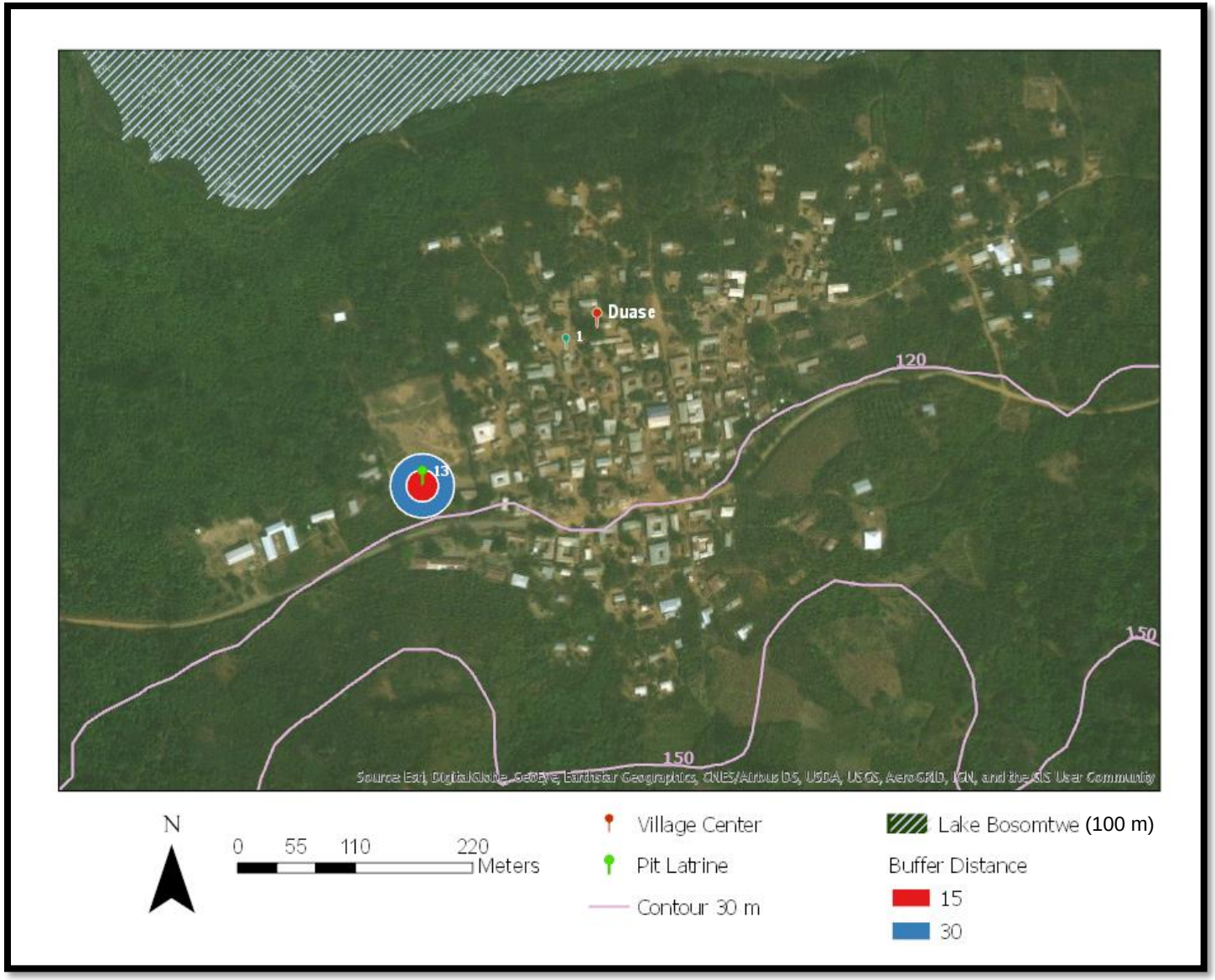


Figure 47 ArcGIS Pro Results Duase

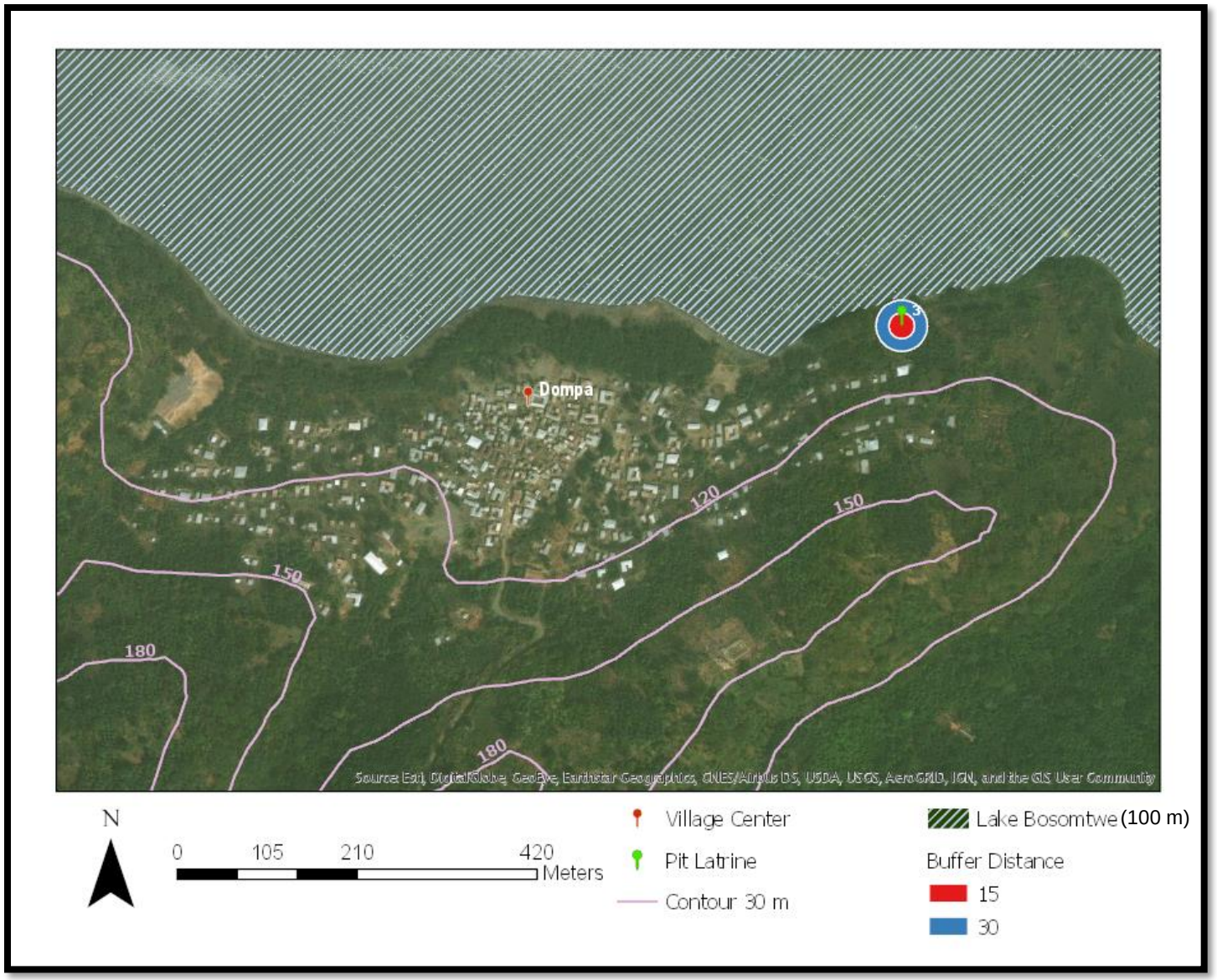


Figure 48 ArcGIS Pro Results Dompa

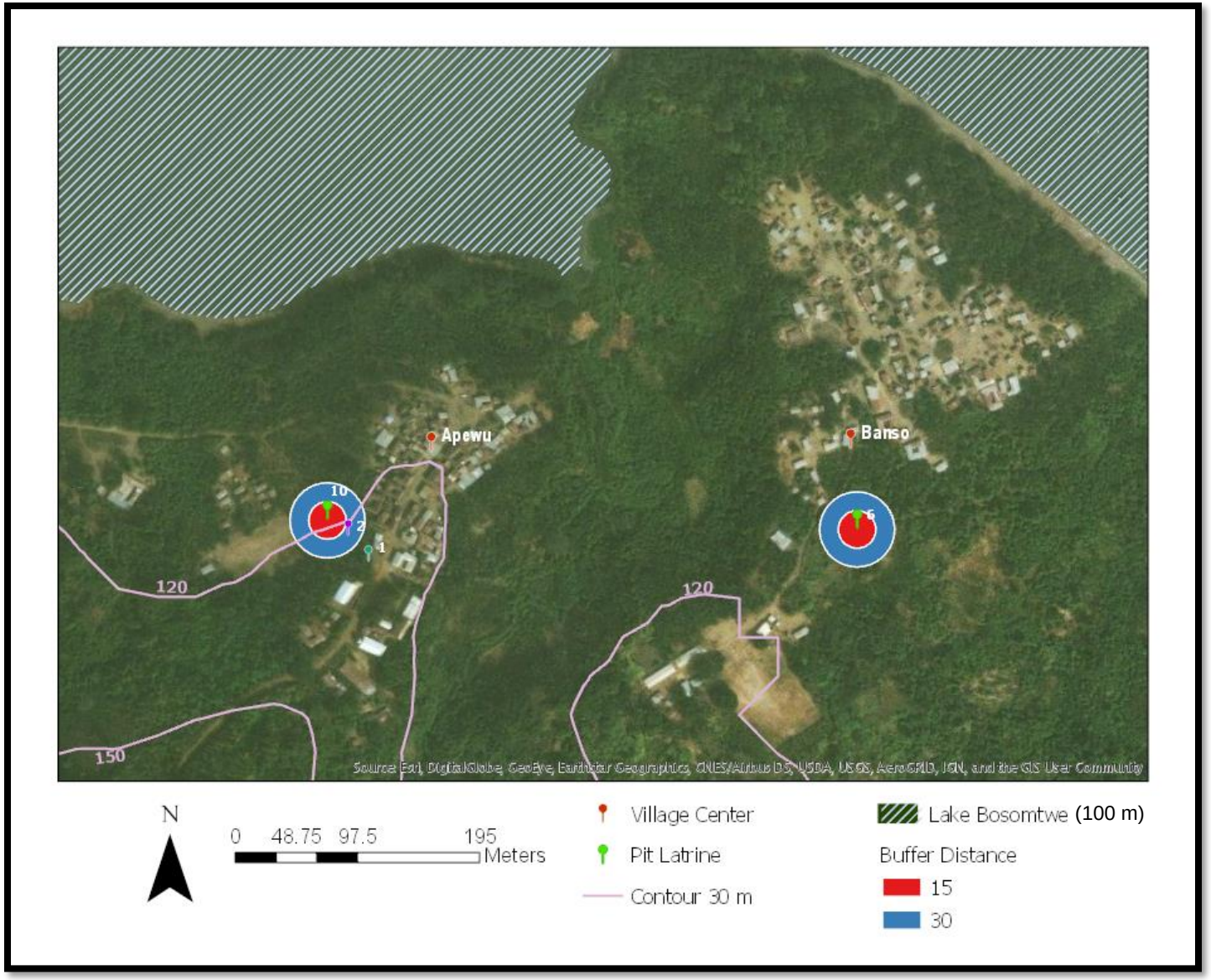


Figure 49 ArcGIS Pro Results Banso & Apewu

Figure 50 ArcGIS Pro Results Esaase

Turquoise and purple pin symbology was used to distinguish community boreholes. The neon green pin symbology was chosen to identify the pit latrines.

Figure 42 displays that the village of Pipie had two community boreholes and a pit latrine containing 8 stalls. The pit latrine met the minimum distance requirement between the wells and the lake, although the second well was sited closer to the pit latrines than preferred. As seen in Figure 43, Adjamam cited two pit latrine locations, both within the minimum requirements from water well sources. The first pit latrine had only one stall. The second pit latrine had two stalls. Two wells are located within Adjamam. One well is located on the south side of Adjamam. This same well is also used by community members from Amakom. Figure 44 displays the results for Amakom. This village had no cited pit latrine or water well sources. However, they were within a short walking distance to Adjamam. Amakom community members walk to Adjamam to obtain well water and use the pit latrine. Specifically, they obtain water from the Adjamam well, located on the south side of the village.

As seen in Figure 45, Atafram cited one well source and two pit latrines. The two pit latrines were quite close together, but both met the minimum distance requirement from the drinking water source. One pit latrine had two stalls, and the other had three stalls. The village of Atafram is quite small compared to the other villages surrounding Lake Bosomtwe. The one well as a source of drinking water is capable of meeting the demand of this community and the neighboring village of Ankaase. However, the number of pit latrines is insufficient for both villages, based-on the number of people reported per household. The current pit latrine options, if properly maintained, would be enough for Atafram, but not for both villages. Figure 46 shows that Ankaase only had only one single stall pit latrine. Often, Ankaase community members walked to the two stall Atafram pit latrine as an alternative. However, the path between the two villages goes through the basin, and because a latrine option is not central to Ankaase, many people just use the surrounding area, rather than using any kind of sanitary facility. It cannot be emphasized enough the vital need for expanding the number of stalls available within Ankaase and installing them within a location central to the community. Ankaase does not have their own developed well, rather they share a well with Atafram.

Figure 47 illustrates that Duase has one pit latrine containing 13 stalls. This was recently installed by an NGO with six stalls in front and another seven behind those. This facility is brand new, and this village has the best quality pit latrine of all the villages located within the impact crater. These pit latrines more than meet the minimum distance requirement from the drinking water source. This community has one common fountain, but it is currently broken. The community members reported that their current drinking water source was actually a perineal stream that runs near-by. This village is not accessible by road, so it would be nearly impossible to get a well-rig in. The same German NGO that helped install the pit latrines, helped install the fountain. The source for the fountain was pumped water from a piping network from the one of the neighboring villages. A larger pipe within that network recently broke, and the cost to replace the pipe is beyond the means of the community. Currently, they are simply living with the situation. The NGO that installed the system told the village that they are working on replacing the pipe, but the estimated cost for the section was $3,000 USD. This village needs a safe, developed water source. A well, rainwater harvesting efforts, or the use of low-cost water filtration technologies to help clean the existing water prior to use would be acceptable.

As seen in Figure 48, Dompa had a single three stall pit latrine and no source of drinking water. This pit latrine barely meets the minimum distance requirement to the lake shore and is located on a slope of 12%. Due to this proximity, it is recommended that a new community pit latrine be developed that is more central to the community and is not as close to the lake nor located on an incline. It is likely there are seepages from the facility, due to the current location. During the data gathering, the lake shore covered the normal walking path to the latrine. Contamination was clearly occurring along the path, because people use the restroom before actually getting to the latrine. Sometimes the lake is high enough that the latrine is surrounded by two feet of water. Very few community members actually use the latrine during high water events. At night time, community members do not walk to this location to relieve themselves anyway, they just evacuate around their houses. This community's latrine pit was obviously below the water table, and it is a near certainty that this facility is contributing to the contamination of the lake. The implementation of a central community pit latrine would greatly decrease the fecal matter being transported into the lake from this village and improve overall community sanitation.

The results for Banso and Apewu are portrayed in Figure 49. Banso did not have a developed well source, but it had a pit latrine containing six stalls. The pit latrine was well located beyond the lake shore. Apewu has two community boreholes and one pit latrine containing 10 stalls. The pit latrine is located downhill of the second community borehole. The second community borehole is within 15-30 meters of the community pit latrines. Because of the number of stalls in this pit latrine, it does not meet the minimum distance requirements set by SPHERE and is a high level of concern. The first community borehole was also cited as too close the second community borehole. The first borehole meets the minimum distance requirements from pit latrine. Both boreholes and the pit latrine are beyond the distance requirement from the lake shore. However, the village of Apewu is almost entirely sited on steep slope. Excess runoff from both boreholes occurs along the same path as the pit latrine, and this is a cause for concern.

The results for Esaase are displayed in Figure 50. Esaase had two community boreholes and one 10 stall pit latrine. The two boreholes were located centrally to the village. These boreholes meet the minimum distance requirement from the pit latrines and the lake shore. Relocation of the current latrines and community boreholes further from the lake shore would be preferable. A single stall pit latrine is only recommended per 20 people, so in most cases, the number of pit latrine stalls per village is insufficient to insure all community members have access to appropriate sanitation. An overarching concern within each village is the lack proper facilities for bathing, washing clothes, and hand washing facilities, following the use of a pit latrine. All these functions are currently reported by community members as being conducted within the lake due to the lack of adequate facilities.

4.4 **Design Matrices Results**

Four different design matrices were developed to prioritize the demonstration farm elements of interest as indicated by the market survey. The Farm Components block focuses on what pieces or facilities that should be a part of the proposed demonstration farm. The ATC and Demonstration Plots scored the highest in this evaluation. Individual design matrices were created for both of these pieces. The ATC matrix helped address which specific technologies should be a higher priority to showcase on the farm. The Demonstration Plots matrix helped prioritize what specific farming practices should be shown through small plots on the farm. An

additional matrix was created to prioritize the extension outreach and program topics. Twenty-three decision factors were developed with weights to prioritize the components of each design matrix.

4.4.1 Farm Components

The five components were chosen in collaboration with the in-country partners based-on the summary statistics results were: Seed Bank, Nursery, Micro-Finance Union, ATC, and Demonstration Plots. A seed bank would allow for seed to be purchased locally by farmers. It also would allow the farm to create a process that it would eventually reduce external seed purchases. A nursery would allow for small plants to be purchased locally. Starter plants produced in a nursery would provide a more diverse selection of cultivation choices for local farmers. Both services would generate income for the farm, helping it become more self-sufficient. The Micro-Finance Union was a selected component for the farm, because of the number of survey participants repeatedly stated that finances or a lack of finances was their main concern. Ghana lending conditions make it nearly impossible for small-holder farmers to access credit for use on their farm. If provided with the correct instruction, these farmers could work towards saving for certain farm associated needs, but they need to be provided with tangible examples and appropriate extension outreach. The ATC'S primary focus would be to showcase appropriate technologies. This essential component to the farm can help address the problems that local farmers are facing in very tangible and innovative ways. Technologies shown on the farm could be rented-out as a service or eventually purchased on an individual basis or through farming cooperatives. Specific farming practices, such as erosion/slope control, crop rotation, irrigation, and agrochemical application should be showcased through demonstration plots. Table 10 displays the outcome weighted scores and ranks for each of the different Farm Component options. The ATC received the highest total score of 368, placing it as the top priority component of the farm. This was in part due to some of the following factors: high post-harvest loss, poor or in-appropriate up-keep of sanitation facilities and drinking water sources, and a severe lack of irrigation. In order to determine the specific technologies to be taught as part of the ATC programs, a separate decision matrix was created.

Table 10 Decision Matrix Results: Farm Components

Farm Components		
	Rank	***Score***
Appropriate Technology Center	**1**	368
Demonstration Plots	**2**	358
Micro-Finance Union	**3**	355
Seed Bank	**4**	285
Nursery	**5**	275

The Demonstration Plots received a total score of 358. This topic received a second order of priority, due to the large number of participants not performing the following conservative agricultural practices: crop rotation, compost, slope or erosion control protection, irrigation, a lack of biomass or mulch, and a severe lack of knowledge with regards to agrochemical applications. Additionally, the Demonstration Plots can be used to demonstrate insect damage at various stages of crop growth. In order to prioritize the highest priority farming practices that should be shown on Demonstration Plots an additional decision matrix was created.

A Micro-Finance Union or a service that could provide qualified farmers with the opportunity to obtain a loan came in a close third in priority to the Demonstration Plots. The difference in priority between the two, is the higher up-front cost anticipated to support a micro-credit loan program. Social norms and general economic knowledge in the communities have not yet attained levels of development to support traditional lending. Current money lenders in Ghanaian society are unlikely to appreciate this local lending option and will object. The establishment of such a Micro-Credit Union carries a significantly higher risk due to start-up costs and additional cultural consideration as compared to other Farm Components. Significant additional thought and planning would be required to pursue this option.

The seed bank received the fourth priority recommendation at 285, but the nursery at 275 was close. In general, there was high interest from local participants in purchasing their seed locally, for those who do not save or grow their own seed. Participants felt that purchasing seed locally would allow them to save costs in traveling to purchase seed from vendors outside and also allow them to diversify their kinds of crops grown. The seed bank received a better score than the

nursery for a few reasons. The majority of participants had a hard time understanding what a nursery was and how it was different then the seed bank. Participants had a hard time determining what small plants they would even want to purchase. These reasons led to less community interest in a nursery and a stronger preference towards a seed bank. Therefore, the nursery received a lower score then the seed bank. These two components are critical to the farm, because they allow for the farm to become self-sufficient by relying on its own internally developed resources. These components can be money makers for the farm, benefit the local people, and strengthen the local economy. The seed bank will also help facilitate the new introduction of crops that are of interest to community members, but that are not currently sourced locally. This will also help promote crop diversity within the area.

4.4.2 Appropriate Technology Center

There were nine different technologies considered inclusion in the ATC. Table 11 displays the outcome weighted scores and ranks for each of the different technologies for the ATC.

Table 11 Decision Matrix Results: Appropriate Technology Center

Appropriate Technology Center					
	Rank	***Score***		***Rank***	***Score***
PICS Bags	**1**	339	**Pit Latrine Maintenance/Care**	**5**	286
			Low-Cost Dryers	**6**	282
Moisture Meters	**2**	316	**Low-Cost Irrigation Systems**	**7**	276
Above ground aquaculture	**3**	300	**Roof Rain Water Harvesting**	**8**	264
Hand Washing Station(s)	**4**	291	**Low-Cost in-home toilet options**	**9**	259

The most commonly reported crop grown annually for the area was maize, followed by plantain and cassava. The higher than regional average post-harvest loss results reported in the area

placed two post-harvest loss technologies as the top technologies. PICS bags are a post-harvest crop storage technique that received the highest score in the ATC decision matrix. These bags are shown in Figures 51 and 52. These hermetic triple-layer bags protect grain from insect damage without using chemicals (Purdue University, 2015). This technology received a score of 339, because it has already been well established in other areas of Ghana. Contacts have been made with the in-country distributor, and it could be a regular technology showcased on the farm and purchased by local people. Additionally, the farm will use PICS bags for all post-harvest crop storage. This technology is one of the lowest cost implementation options. The average price of a PICS bag in Ghana is $4-5 USD per bag. The bags could be purchased in bulk by the farm to help lower the cost of bags.

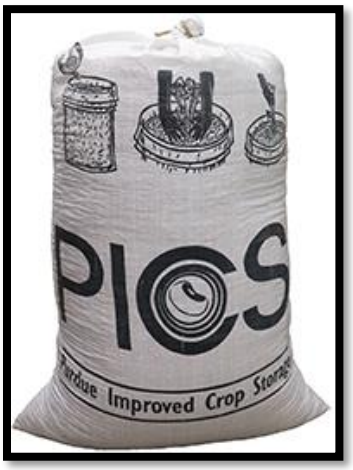


Figure 51 Purdue Improved Crop Storage (PICS) (Braund, C. 2017)

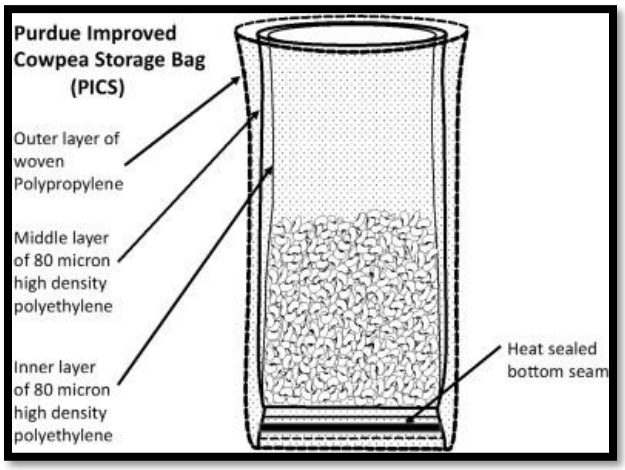


Figure 52 Purdue Improved Crop Storage Layers (Murdock, L., & Baoua, I., 2014)

Low-cost moisture meters to determine if crops have reached the appropriate moisture content are essential to post-harvest crop loss prevention. They allow a farmer to determine if crops are dry enough for storage. Although local farmers currently store whole maize cobs, the practice of removing the kernels from the cob greatly decreases the moisture level of the corn and can help prevent additional spoilage. Farmers currently place a corn kernel between their teeth and crunch-down on it to determine the moisture content. Of course, this is not accurate. There are multiple low-cost alternative technologies that could be introduced to farmers to determine the moisture content of their grain. Examples include, but are not limited to, a simple soda bottle and

salt test as cited by Reader & Motis (2017) and The Organic Farmer (2015) as seen in Figure 53 and 54.

Figure 53 Salt Jar/Bottle Test (The Organic Farmer, 2015)

Figure 54 Salt jars with subsamples of maize seed (Reader & Motis, 2017)

Note: Salt at bottom of jar indicates dry seed (left)

Salt sticking to glass jar indicates wet seed (right).

Additionally, the moisture content greatly affects the price that farmers receive at market. Dried maize below 13% will receive a much better price at market than above 15%. The use of moisture meter technology on the farm received a score of 316, because it requires very little knowledge and can greatly reduce the rate of post-harvest loss.

Above-ground aquaculture systems came-in third as a priority of interest to show on the demonstration farm. This technology would allow for fish to be grown in an above ground, legal facility, and it could be structured to provide a supplemental protein source for the community. The major general concern with the promotion of such a technology is that the up-front cost is too high for a single household. The addition of aquaculture related technologies could help decrease the number community members fishing in the lake, improve the water quality, and help the fish present in the lake to repopulate.

Showcasing the use of hand washing and washing stations for clothes and dishes cannot be stressed enough. With the exception of Adwafo, all villages have some form of a pit latrine. None of these villages have anything outside the pit latrine for the washing of hands afterward. Many people utilize the lake for washing their clothes and dishes. None of the villages have dedicated bathing or washing stations where people might bathe, shower, or wash clothes or dishes. The addition of a simple washing station would make a monumental difference within these communities. There are low cost hand washing technologies that are connected to a continuous flowing water source and those that are not. As seen in Figure 55, a community hand washing station could simply be a small tank that has a spout fixed at the end and a bar of soap attached to it as an alternative.

Additionally, the amount of bathing and washing that occurs in the lake must decrease, if there is to be any hope of improving the lake water quality. In order to do this, there must be alternative options for community members. Implementing a low cost washing station used both for hand washing and domestic washing would be a great option. These are normally made out of a concrete base, have a few spouts, and a small amount of pipe that runs from the small water tank to the spouts or is attached to a flowing water pipe. In the tank situation, it would need to be refilled after use, but specific households turns could be designated by community leaders within

each village specific households to refill it. Regardless, it would be a good technology to showcase on the farm.

Figure 55 Polytank & Washing Station (India Spiti Health Project. (n.d.))

A low-cost community shower set-up should also be considered, similar to that of a campsite shower. This could utilize flowing water or be set-up as more of an enclosed and designated area for showering that is similar to that of pit latrines with doors and a way to collect the waste water through drains. A tank that is refilled whenever needed could be an alternative way to have water flow to the showers, if piped water is not a feasible option due to village location. Overall, the idea of washing stations came in fourth in terms of priority at 291, followed by pit latrine maintenance/care at 286 in fifth. The technology of a proper pit latrine should be shown on the farm, and specifically proper maintenance and care of the latrine. These demonstrations are needed to show how one can properly be constructed and managed. Regular cleaning and maintenance of the latrine would be a high priority for the demonstration unit. In order to promote improved sanitation, it is critical that the upkeep of latrines be shown. They must either be pumped-out or properly abandoned once they reach capacity. A major issue with all the pit

latrines is a failure to pump them out once full. The latrines that were part of this study have only a minimum of one pit latrine per village, with the exception of Adwafo.

Low-cost dryers came in 6th, with a score of 282. This technology received a lower score than other technologies because of the up-front cost of a dryer for a farmer. These would be essential for use on the demonstration farm. The use of low-cost dryers could help address post-harvest losses related to specific crops such as cassava and plantain. However, the majority of farmers will each want their own, and in most cases, the local farmers will not be able to afford such an option. If a dryer could be rented, this could be an option, or if farmer cooperatives chose to purchase one collaboratively. Low-cost irrigation technologies would also be important to showcase on the farm, specifically low-cost ram pumps would be a great benefit locally, due to the large slope that most farmers have on their plots. The biggest issue with promoting irrigation technologies would be that the majority of farmers do not irrigate and are scared about the cost of such technologies. They currently practice entirely rainfed agriculture, so there will be a significant challenge in getting farmers to adopt such technologies, until they visually can see them. This technology received a score of 276.

Hand-in-hand with the irrigation technology is the use of rain water harvesting. Showcasing this process received a score of 264. This would be a natural technology to choose to implement on the farm, since the clinic already has so many buildings that could be adapted to collect rain water. The reason this technology received a lower score than others is mostly due to the fact that many of the community members lacked an awareness of the benefits from this practice. It would be helpful to see how it integrates into the overall operations of the demonstration farm.

Participants were all asked if they had a toilet within their home. Almost no one did. An admirable goal would be if families were able to have personal in-home toilet. For most, this is not an option, due to the cost. Low-cost community in-home toilet options could be a showcased technology, but a system for collecting the waste per toilet needs to be in place first, as well as more in-country contacts with plumbing suppliers. These things would be needed to make the likelihood of adoption of in-home toilets have a greater chance of success. This option received a score of 259. This technology received a lower score than others, because there was simply less

community interest. It would be a more difficult technology to implement without a significant amount of community buy-in.

4.4.3 Demonstration Plots

Residents of this area have little experience in improved agriculture technologies and know almost nothing about topics such as crop rotation, fertilizer use, and erosion control. The top three methods to showcase on Demonstration Plots were erosion control/slope protection, crop rotation, and cover crops as seen in Table 12.

Table 12 Decision Matrix Results: Demonstration Plots

Demonstration Plots		
	Rank	***Score***
Terracing & Erosion Control	**1**	244
Crop Rotation	**2**	237
Cover Crops	**3**	231
Raised Beds (Vegetables)	**4**	207
Slope Crops (Crops that grow well with high inclines)	**5**	186
Crops for Animal Feed/Caged Livestock	**6**	179

Terracing/erosion control was the number one recommended plot at 244. Terracing is currently not practiced by local farmers. There are some vetiver plants in Ankaase that were installed by the extension officer for waste water management, but not for farm purposes. An erosion control method is needed to reduce runoff into the lake and increase the infiltration of water into the soil. The area has very shallow soil profiles, and there are multiple potential types of terracing that could be utilized. Traditional step terracing is one of the most common examples, but this type of terracing requires heavy equipment and a lot of labor. It is not very cost effective for this situation. A second option to consider is creating a series of vegetative barriers that will create step terraces overtime. By planting vetiver along the contour of the field, a vegetative barrier will begin to develop. Plant-retained sediment will build-up over time, as seen in Figure 56.

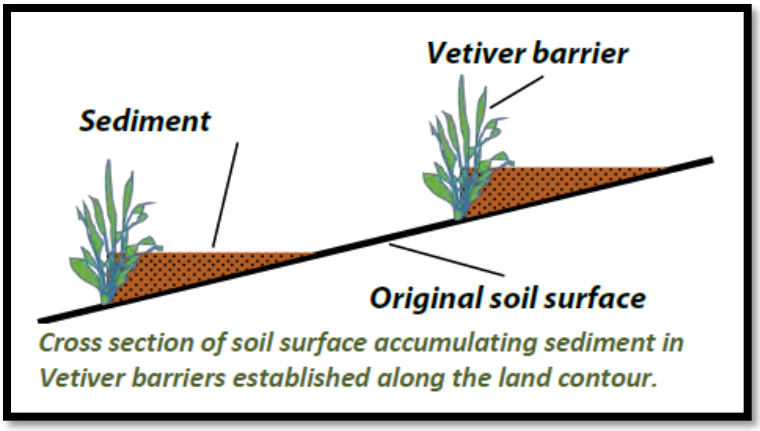


Figure 56 Sediment Accumulation (USDA, 2015)

As sediment increases, step terraces form. Although it requires some time to become effective, this method mitigates the need for large amounts of labor and heavy equipment required to install traditional terraces. The most common crop used for vegetative barriers is vetiver. There are over 130 different types of vetiver or elephant grasses present around the world. They are not an invasive crop and can be killed when they are no longer needed. These terracing crops should help reduce runoff into the lake. They contain a tight root structure allowing more moisture to be kept on the field. These types of plants are used in many phytoremediation projects and are originally from parts of South-East Asia and India. It is strongly recommended that vegetative terracing be promoted to help prevent erosion, increase infiltration capacity to the soil, and improve water quality going to the lake.

Crop rotation was ranked second, receiving a score of 237. The process is important in this area as monocropping is very common. Few people practice a legume-based crop rotation, and due to this circumstance, the majority of the soil in the area is nitrogen deficient. An intensive legume alternative is needed to demonstrate proper rotation and improve soil health. The use of cover crops in the area is non-existent. To prevent bare soil and improve soil health, cover crops will be essential. Nitrogen fixing cover crops should be promoted to help prevent erosion control and improve soil health. This method received a score of 231 and ranks in the top three plots to demonstrate.

The use of raised beds specifically for growing vegetables can be used both to help manage salinity for farmers, whose farms are located on the banks of the lake. There was some expressed interest from farmers to begin growing various vegetables. The use of raised beds applied less to all farmers, and therefore it received a score of 207 or fourth place in priority. Raised beds in combination with leaching or additional irrigation can help manage the poor soil conditions present at Lake Bosomtwe that some farmers experience. Crops that grow well on an incline, in the presence of excess water, with varying pH, received a score of 186. This would be geared towards showing crops that are capable of handling a wide range of soil pH and grow well in the presence of excess water. A potential example could be bananas. This was not as high on the priority list compared to showing other practices, because it would affect fewer people.

A plot showcasing caged livestock and how certain crops can be used as healthy animal feed options received the lowest priority and a score of 179. More participants than previously believed are already raising their animals in a caged set-up, and they put little priority on the specific diet of their animals. Animals that are caged within these communities are primarily fed rice. This demonstration plot would be helpful to community members that are interested in raising livestock but do not already do so. The feed portion of the plot would be helpful when accompanied by an animal weighing day or extension program. A program focused on farmers seeing the weight gain difference for animals fed on the demonstration farm diet compared to those that just let their animals roam or are caged would be a helpful practical demonstration.

4.4.4 Extension Outreach Program Topics

As seen in Table 13, the number one extension outreach program topic was basic home and farm finance, at 342. This was the major reported success constraint, regardless of the specific question or topic reported by participants. The target outreach of this program would be to small-holder farmers, but depending on resources and the program evaluation, it could be expanded to other members of the Lake Bosomtwe community. The second priority program was “Improving Health through Washing Stations,” at 339. This was ranked quite high, because the programing could greatly decrease both point and non-point source pollution going into the lake. The main contributing factors of pollution occurring in the lake are community members washing, bathing,

and using the lake as a restroom. This program topic was also ranked quite high, because it would greatly improve the overall health of the community members.

Table 13 Decision Matrix Results: Extension Program Topics

Extension Program Topics						
	Rank	***Score***			***Rank***	***Score***
Basic Home/Farm Finance	**1**	342		**Land Preservation**	**6**	311
				Waste Management	**7**	302
Improving Health through Washing Stations	**2**	339		**In-field Pest Management**	**8**	281
Post-Harvest Loss Prevention	**3**	322		**Appropriate Seed Storage/Germination Tests**	**9**	275
Appropriate Chemical Application	**4**	320		**Irrigation**	**10**	265
Pit Latrine Maintenance/Care	**5**	319		**Effect of diet on Livestock**	**11**	229

The Post-Harvest Loss Prevention received a score of 322, placing it as the third priority program. This program would not directly improve the lake water quality, but it would be extremely impactful to farmers' economic potential. All the villages surveyed, with a single exception, reported 50% or more of their crops lost post-harvest, regardless of growing season. It is essential to address the importance of moisture content, post-harvest storage, and the use of drying technologies with farmers. To help minimize post-harvest losses, farmers need exposure to modern practices.

The topic of appropriate chemical application received a fourth-place priority, with a score of 320. The use of appropriate application of fertilizers, pesticides, and herbicides needs to be addressed. Based-on the participants surveyed, very few people use any of these, but the participants that do use these agrochemicals, do not dispose of them properly, nor do they understand the appropriate rate at which to apply them. It is very common for a bottle of army

worm pesticide to be obtained from the local extension office. The powder pesticide and water are mixed and then sprayed or poured directly on the plants. After the bottle is emptied, it is often thrown near the water source where the pesticide was prepared. Additionally, some of the remaining pesticide typically spills near the concrete base surrounding the water source. This same process happens for the other agrochemicals as well.

Pit Latrine Maintenance/Care received a score of 319 and a fifth priority on the list.
The main problem with pit latrines is that once the tank fills, it must be emptied, or a new pit must be dug. Pit latrines are not designed to be installed where space is limited, only where space is not a concern. A new latrine is typically used while another pit latrine's waste filters, sits, and decomposes. An alternative is for villages with multiple stalls or more than one pit latrine, to alternate between which is used. It is critical that specific extension programing is offered regarding on going care and maintenance of existing pit latrines. This topic should also include emptying, construction of pit latrines, and new design improvements such as venting.

The sixth priority topic was land preservation with a total of 311. Multiple people in the survey expressed that the reason they felt land cover was changing was due to the non-conservation of the land and the failure to replant trees. This topic would cover the importance of caring for the existing natural resources and targeting current practices that could be modified to improve the overall living situation within the area. This topic received a lower priority than the others in the survey results, because obtaining a higher economic potential was more important to community members. Waste management was ranked seventh in order of priority with a score of 302. This topic would specifically address the benefits of separating waste within a community or household level into separate buckets. This practice is promoted through ECHO, and it allows for recycled materials, non-recycled materials, waste water, and table scraps to be used more efficiently on the farm or within the community. The use of such a system would allow for those that do have livestock to feed them better diets. It would improve the proper disposal of waste, and it would promote the reduction of trash and waste in the communities and the lake.

In-field pest management received a score of 281 and was ranked 8th. This topic would address pest management throughout a crop's different stages of growth and address how to look for signs of insect damage. Specifically, this would target the army worm issues that farmers currently are facing. This training would also provide additional insight regarding other pests. Appropriate Seed Storage/Germination Tests received a score of 275 for 9th place priority. This specific program was performed on extension farms throughout the 1920s in the United States by Extension Services. A workshop would be held within individual villages or within a few villages close together. Farmers within a community or multiple communities would be invited to bring samples of their seed that could be tested, along with samples from the demonstration farm to teach farmers how to identify good seed prior to planting and how to perform a paper towel seed germination test. Farmers would be shown what signs to look for in seed selection and procedures to test their seed before planting. Storage options could also be discussed. Extension program topics will be selected to help farmers address major problems they are facing in storing their seed after harvest, but prior to planting.

The topic of Irrigation received a priority of tenth and a score of 265. Very few farmers expressed any interest in irrigating as their major concern/constraint, compared with other topics previously mentioned. This topic very easily could be addressed in combination with the rainwater harvesting and low-cost irrigation technologies shown on the farm. However, this topic was not as critical in the eyes of farmers. A program focused on the effect of diet on livestock, received the lowest priority at 229, because of a low likelihood of impact. The idea of having a weighing day could provide a unique learning platform to farmers. The program could focus on allowing local farmers to bring their animal to the farm for weighing day and comparing that to the demonstration farms' animals being raised. The topic of feed diet in comparison for the different animals could be talked about and strongly emphasized. This could also provide a platform for community members to see the weight difference and consider growing some of the plants that are incorporated to the demonstration farms animals' diets.

4.4.5 Final Results

Based-on the results for all four weighted matrices, a priority table was created to summarize final results and is shown in Table 14. The top three ranking Farm Components were the ATC, Demonstration Plots, and the Micro-Credit Union. For the ATC, PICS Bags, Moisture Meters and Above-ground Aquaculture were the highest ranking technologies to showcase. The Demonstration Plots matrix determined priorities should focus on Terracing and Erosion Control, Crop Rotation, and Cover Crops. The recommended program topics for Extension Program Outreach were: Basic Home and Farm Finance, Improving Health through Washing Stations, and Post-Harvest Loss Prevention. The summary results of the four different design matrices have been used to prioritize the demonstration farm elements of interest, as indicated by the market survey.

Table 14 Summary Priority Table

Farm Components		Appropriate Technology Center		Demonstration Plots		Extension Program Topics	
	Rank		***Rank***		***Rank***		***Rank***
Appropriate Technology Center	1	**PICS Bags**	1	**Terracing & Erosion Control**	1	**Basic Home/Farm Finance**	1
Demonstration Plots	2	**Moisture Meters**	2	**Crop Rotation**	2	**Improving Health through Washing Stations**	2
Micro-Finance Union	3	**Above ground aquaculture**	3	**Cover Crops**	3	**Post-Harvest Loss Prevention**	3
Seed Bank	4	**Hand Washing Station(s)**	4	**Raised Beds (Vegetables)**	4	**Appropriate Chemical Application**	4
Nursery	5	**Pit Latrine Maintenance/ Care**	5	**Slope Crops (Crops that grow well with high inclines)**	5	**Pit Latrine Maintenance/Care**	5
		Low-Cost Dryers	6	**Crops for Animal Feed/Caged Livestock**	6	**Land Preservation**	6
		Low-Cost Irrigation Systems	7			**Waste Management**	7
		Roof Rain Water Harvesting	8			**In-field Pest Management**	8
		Low-Cost in-home toilet options	9			**Appropriate Seed Storage/Germination Tests**	9
						Irrigation	10
						Affect of diet on Livestock	11

5. CONCLUSIONS AND RECOMMENDATIONS

A series of conclusions and recommendations are proposed based-on the comprehensive market assessment survey, ArcGIS Pro utilization, statistical analyses, and engineering decision matrices. A summary of the overall sanitation, pit latrine, and drinking water source infrastructure was included. The decision matrices results helping plan design priorities for the demonstration farm and outreach extension programing are integrated and summarized. Recommendations outside the scope of this study are suggested ideas based-on the obtained and analyzed data. These recommendation topics include: the formalization of a Farmers Cooperatives, WASH recommendations, and micro-business potential ideas.

5.1 Conclusions

A comprehensive Institutional Review Board (IRB) survey was developed to investigate six research questions and conducted within the 12 villages located within the Lake Bosomtwe impact crater. From these six research questions, 147 specific questions were developed. Three of the 147 questions were to obtain Global Positioning System (GPS) data for community households, pit latrines, and water wells or boreholes. This study interviewed roughly 10 farmers per village. Farmers shared their perspectives regarding land use change/cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. Demographic data of the participants was obtained. Surveys were conducted in the form of oral responses. One-hundred and eighteen small-holder farmers took part in this study. Of the participants surveyed, 66% were qualified to answer all questions, and 100% of participants completed the survey. The market survey provided sufficient information required to support the detailed design of an extension demonstration farm.

Specific statistical tests were conducted based of market assessment survey. The Chi-square test showed that there was no association between gender and level of education. The results indicated that regardless of gender there were just as many opportunities for females to pursue education as males.

An independent samples t-test was conducted to compare yields of villages on the north side of the lake with road access and villages on the southern portion of the lake with limited to no road access. It showed statistically significantly results. The scores for villages with road access and villages with limited to no road access showed that road access does affect village yield. Villages that have accessible roads have higher yields. Southern villages with higher sloped areas produced less yield than villages located in the northern portion of the lake farming on fewer sloped areas.

An independent samples t-test to compare usable yields of villages on the north side of the lake with road access obtained was determined not to be statistically significant. No significant difference in the scores for villages with road access and villages with limited to no road access existed. Therefore, road access does not affect village usable yield. Villages with roads that are more accessible, or the surrounding areas that have more or less sloped areas, do not have statistically higher useable yields. Southern villages with higher sloped areas do not have less usable yield than villages located in the northern portion of the lake farming on less sloped areas.

Through the use of a Pearson Chi-square test, it was determined that an association existed between people who practice bathing and washing in the lake and those who practice fishing as a form of livelihood. Individuals who bathe and wash in the lake are more likely to be fishermen, and there is a statistical association between the two. Fishermen bathing and washing in the lake do so in deeper sections of the lake. This occurs, because fishermen are more likely to know how to swim. Individuals that bathe and wash, but do not participate in fishing, do so near the shoreline or in shallow sections of the lake.

The GPS data obtained was analyzed in ArcGIS Pro. Pit latrine, borehole, village centers, and non-hygienic restroom options were all visualized in map form. The spatial analysis led to the determination of current point pollution sources contributing to the lake or drinking water contamination. Every community except Adwafo had a pit latrine or used the nearest villages' pit latrine. Each village lacked proper facilities for bathing, washing clothes, and hand washing facilities after use of a pit latrine. All these functions were currently reported by community members as being conducted within the lake, due to the lack of facilities. It is a conclusion of this

study that low-cost hand-washing stations, pit latrine emptying, and washing stations should be low-cost technologies showcased as part of the ATC on the Demonstration Farm. The implementation of such technologies within the communities would yield drastic improvements both for communities and the environmental quality of the lake.

The market survey provided sufficient information required to support the design an extension demonstration farm. Four decision matrices were created to prioritize the following items: Farm Components, technologies to showcase at the Appropriate Technology Center, improved farming practices to showcase through Demonstration Plots, and extension outreach topics. The prioritization of components to include on the demonstration farm were first an ATC and Demonstration Plots. The outcome of the ATC decision matrix determined that the first priority should be the promotion of PICS bags, followed by low cost moisture meters and showcasing above ground aquaculture systems. It was determined that the three most important farming practices to showcase in order of priority were Terracing/Erosion Control, Crop Rotation, and Cover Crops. The top three results in order of prioritization for the extension outreach topics were Basic Home and Farm Finance, Improving Health through washing stations, and post-harvest loss prevention. The top three priorities of each decision matrix will now be further developed based-on these results, followed by design refinement with the in-country project partners.

5.2 Recommendations

The following recommendations are outside the scope of this study but are suggested ideas based-on the obtained and analyzed data.

5.2.1 Formalization of a Farmers Cooperative

The formalization of a farmers' cooperative structured and organized by community leaders is strongly recommended, in order to further support small-holder farmers with the Lake Bosomtwe area. The only cooperative currently in existence is the Ghana Cocoa Board, that only works with cocoa farmers. A general cooperative that provides benefits for farmers of multiple crops does not exist. Such entities do exist in Ghana elsewhere, but they are not formally recognized within the Lake Bosomtwe area. A single cooperative that is collaborative amongst all the

villages located along the lake shore would be an ideal option. Alternatively, multiple cooperatives at a village level could be created and might potentially be more practical in terms of management, but they would lack the size to tackle larger projects. Smaller cooperatives would most likely include farmers from 3 to 4 villages in near proximity. Farmer cooperatives help facilitate training, pooling of resources, exchange of knowledge, and skill refinement. The farmer cooperatives can be formally recognized and registered by the Government of Ghana. Such registration allows for farmers within the cooperative to receive specific benefits, subsides, and training. Whether through a farmers' cooperative or multiple organizations within the area, a general cooperative that is not limited to one crop is highly needed. The formalization and organization of a farmers' cooperative is strongly recommended.

5.2.2 Water, Sanitation, & Hygiene, (WASH) Recommendations

The village of Adwafo needs a proper pit latrine with multiple stalls. The non-hygienic structure that currently exists is not sufficient for the community. It is recommended that the villages of Amakom and Ankaase develop their own pit latrines central to each village. The village of Ankaase is the fastest growing of the villages located along the lake shore. Due this rapid growth, it is strongly recommended that central pit latrine services to the community be developed. The current low level pit latrine utilized by the village of Dompa should be abandoned, due to its close proximity to the lake. A central pit latrine facility for Dompa should be implemented. Duase lacks a proper drinking water source, and one should be developed. However, due to the lack of road accessibility of Dompa, a non-traditional construction method will need to be considered. It is the recommendation of this study, that hand-washing stations, pit latrine emptying, and/or washing stations be low-cost technologies showcased as part of the ATC on the demonstration farm. The implementation of such technologies within the communities would yield drastic improvements, both for communities and the environmental quality of the lake. This study provided an initial broad analysis of pre-existing drinking water and sanitation options located along the shore of Lake Bosomtwe. It is recommended that further analysis be conducted to determine the additional number of stalls and water bore holes needed to meet the SPHERE standard for each village.

5.2.3 Basic Home & Farm Finance Extension Program

Personal and small business finance could be a program offered through the micro-credit union located on the demonstration farm. It is recommended that following the completion of the basic home and family finance course, participants would receive a certificate. Only after the completion of the finance course would participants qualify to receive a micro-credit loan. This loan would eventually need to be paid back, but this payment would not necessarily need to be in the form of funds, it could be in the form of products or goods produced through their farm. Such a payment could then continue to allow the demonstration farm to be sufficient. It is suggested that the farm offer its own service rather than partner with a pre-existing micro-credit union. The main issue of partnering with a pre-existing institution is that they will set interest rates that are too high for residents of the Lake Bosomtwe area. Therefore, to make this option work, the farm would have to use profits to subsidize the interest rate, such that the farmer might then be able to afford the option. Other church organizations throughout Ghana offer similar ministry outlets to church members. Having such an option through the demonstration farm would allow for lower interest rates to be set, that are more feasible than other lending competitors. Even if the farm could not offer the micro-credit loan up-front, the need for farmers within the area to have a basic understanding of personal and small business finance is crucial.

5.2.4 Micro-Business Ideas

As an outcome of this study, there are a few micro-business ideas that could create additional income for people living within the Lake Bosomtwe area that require further research. In Ghana, there is an animal known as a grass cutter. It is a ground hog-like rat that looks similar to a Guinee Pig. Their meat is considered a delicacy, and they are all around the lake. When cooked, the meat is similar to roast beef in taste and texture. Specifically, grass cutters eat cowpea or legume-based plants. Inevitably, by showcasing legumes or cowpea on the Demonstration Plots, they will come to eat. The first micro-business idea would be to develop a grass-cutter farm or harvesting existing grass cutters. Traps could be set to collect the grass-cutter and then sell out to members of the community. The idea of farming grass cutters as a micro-business at the lake could be very successful, if there was expressed interest. Further research would need to be conducted.

There are three business concepts related to providing better services with regards to sanitation. The first is a pit latrine emptying service. Within a developing country, full pit latrines are most often just abandoned. The communities in which they reside are unable to empty them, once full. Such communities simply do not have the funds, the training, or knowledge to properly handle this waste. There are enough communities around Lake Bosomtwe that having a pit latrine collection service that operated when needed could be an interesting idea. If a fee could be paid per community to pump-out latrines, that would be best. Transporting the waste would have to be an issue addressed. There are various options that have been developed within Ghana and other locations that could be used. Once the waste was collected, it would need to be transported to a processing facility. The closest is in Kumasi. An alternative use might include developing and utilizing the collected sludge in a biodigester.

An in-home, toilet collection service would be an additional idea. Specifically, toilets would have a collection sack placed inside. After so many uses, the sack would be disposed of in a normal trash can located outside the home. The bin would then be picked-up once a week, transporting all the trash to the nearest waste treatment site. An additional service or component could be renting a toilet and eventually paying-off its use. This type of in-home toilet option would only work if enough people chose to pursue it.

An alternative idea to an in-home toilet collection service, could be the installation and adoption of composting toilets. In Eastern Africa, composting toilets have shown great promise as they continue to be adopted at the household level. Composting toilets are unique in that they do not require any water for flushing and are not connected to any municipal water and or sewer system. “In a composting toilet system, human urine, feces, and toilet paper are collected by gravity in a composting tank (Anand & Apul, 2011).” The compost from the dry toilet and urine are excellent nutrient-rich resources that could be used as fertilizer or soil conditioner, but these must be managed safely due to the presence of pathogens (Anand & Apul, 2011).

A commonly expressed concern related to the loss of crop post-harvest was a limited number of public transportation options and a lack of private transportation options. A transportation service would not be needed year-round, but a vehicle or multiple vehicles focused on helping

farmers get their crops to market during key times of year could greatly reduce their post-harvest losses. Specifically, the appeal of such a service would be as an alternative option to an over-crowded bus. The price point would require further research to determine what would be competitive. This concept would have high start-up costs. However, if farmers could afford to get a taxi to transport their goods to market during key times of year at an affordable price point, it would make such an option extremely appealing. This service would connect farmers to markets and help farmers reduce post-harvest loss due to transport.

APPENDIX A. IRB SURVEY COMPONENTS

The following appendix contains all forms created that were required to obtain approval from the Purdue Institutional Review Board (IRB) to conduct the Market Assessment Survey. Components included are: the IRB Cover Page, Application Narrative, Research Participant Recruitment Script, Research Participant Information Sheet, and the Survey Questionnaire.

Cover Page for IRB Submissions

x

Revised 4 Dec 2017

COVER PAGE FOR IRB SUBMISSION
Purdue University, Institutional Review Board

Type of Submission: [x] Human subjects determination worksheet [*complete both sides of this form*]
[x] New exemption determination [*complete both sides of this form*]
[x] New application narrative [*complete both sides of this form*]
Check here if you believe your protocol will require full board review: [x]

*Complete only #1 & 2 below **AND** PI signature at bottom of page 2*

- [ ] Amendments to approved protocol / **IRB Protocol #:**
- [ ] Renewal of approved protocol / **IRB Protocol #:**
- [ ] Revisions requested by IRB / **IRB Protocol #:**
- [ ] Study Closure / **IRB Protocol #:**

1. Project Title: Development of design criteria and options for promoting lake restoration of Lake Bosomtwe and increased livelihoods for smaller-holder farmers near Lake Bosomtwe in Ghana, West Africa

2. Principal Investigator: Dr. Robert M. Stwalley, Assistant Professor, Agricultural & Biological Engineering, rms3@purdue.edu, +1 765 49-41791

   (Name, Title, Department, E-mail, Phone; ***Must sign at the bottom of page 2***)

3. Co-Investigators, Key Personnel and/or Consultants (Name, Title, Department, E-mail, Phone, for each):

   Grace Baldwin, Graduate Student, Agricultural & Biological Engineering, baldwing@purdue.edu, +1-765-479-0731

4. Has the PI and all Co-Investigators, Key Personnel and Consultants completed CITI training?
   - [x] Yes (Proceed to 5)
   - [ ] No (STOP here: CITI training must be completed by all prior to submission of this application)

5. This project will be conducted at the following location(s):
   - [x] Purdue, West Lafayette Campus [ ] Purdue, Regional Campus (Specify): _____
   - [x] Other (Specify, including city and state): Lake Bosomtwe Ghana West Africa

6. Check the box(es) below if your project involves any of the following (check all that apply):
   - [ ] Vulnerable populations (Children, pregnant women, or prisoners/incarcerated individuals)
   - [ ] Elderly persons
   - [x] Economically/educationally disadvantaged persons
   - [ ] Mentally/emotionally/developmentally disabled persons
   - [ ] Minority groups and/or non-English speakers
   - [ ] University students (Purdue PSY Department subject pool? Yes [ ] No [ ])

1

7. Indicate the anticipated maximum number of subjects to be enrolled or number of records or specimens to be included under this protocol as justified by the hypothesis and study procedures: 250
(Suggestion: if unsure, err on the side of a higher sample size)

8. Will this project involve the use of an investigational new drug (IND), investigational medical device or an FDA-approved drug/device for an unapproved use: ☐ YES ☒ NO

9. Check the box(es) below if your project involves any of the following (check all that apply):

- ☐ Intervention(s) that include medical or psychological treatment
- ☐ Use of voice, video, digital, or image recordings
- ☐ Subject compensation: Please indicate the maximum payment amount to a subject: US $_____
- ☐ VO2 max exercise test
- ☐ Magnetic Resonance Imaging (MRI) (Location: Purdue Campus ☐ Other ☐)
- ☐ Radioactivity/ Radioisotopes (Radiation Safety Committee approved? Yes ☐ No ☐)
- ☒ Request for Waiver of informed consent
- ☐ Request for Waiver of documentation (signed) of informed consent
- ☐ Use of blood: Total amount of blood: _____(volume) over _____ days.
- ☐ Use of human tissue, cell lines, or other human bodily fluids
- ☐ Use of Protected Health Information (PHI) obtained from healthcare practitioners or institutions
- ☐ Use of academic records obtained from an educational institution

10. Suggest the appropriate IRB to review your research given your study (final decision determined by IRB):

- ☐ Biomedical (*research involving human diseases, epidemiology, drugs, devices)*
- ☒ Social/Behavioral (*research involving education, social and behavioral science)*

11. How will this study be funded?

☒ Unfunded ☐ Purdue University ☐ External sponsor (provide name): _____

12. The Principal Investigator on this application is responsible for ensuring that all persons responsible for the design, conduct, or reporting on this research protocol have disclosed any research-related Significant Financial Interests (SFIs), see here. All Investigators with SFIs, are required to fill out a Research Related Significant Financial Interest Disclosure at: https://webapps.ecn.purdue.edu/VPR/PDD
Do you or any investigator on this study have a Significant Financial Interest related to this study?

☐ YES ☐ UNSURE (Contact fcoi@purdue.edu) ☒ NO

By signing below, I give my assurance that information supplied to IRB relevant to this project is complete and accurate. All materials submitted for review within this submission, unless otherwise indicated, are the original work of myself or those working in collaboration with me. I agree to accept responsibility for the scientific conduct of this project and agree to uphold the policies and procedures of the Purdue IRB and approved protocol(s). I understand my obligations as Principal Investigator. I agree to oversee the project to comply with all federal, state, and local laws regarding the protection of human participants in research.

Robert M. Stwalley III — Signature of Principal Investigator

5 Sep 2018 — Date Signed

Application Narrative

Revised 12 Aug 2018

APPLICATION NARRATIVE FORM
Purdue University, Institutional Review Board

1. Project Title: Development of design criteria and options for promoting lake restoration of Lake Bosomtwe and increased livelihoods for smaller-holder farmers near Lake Bosomtwe in Ghana, West Africa

2. Principal Investigator: Dr. Robert M. Stwalley III, Assistant Clinical Professor of Agricultural & Biological Engineering, rms3@purdue.edu, +1-765-494-1791___
(Name, Title, Department, E-mail, Phone)

A. PROPOSED RESEARCH RATIONALE

- The Lake Bosomtwe impact crater is located in the Ashanti region of Ghana, West Africa. The impact crater diameter from rim to rim is approximately 6.5 miles wide with a lake located at the center. Three different districts touch the lake containing 380,000 acres of land. There are approximately 7,500 people from 24 villages, and of the 24 villages, 12 reside within walking distance of the lake shore. Restoration and promotion of small-holder farmer effectiveness is key to economic development, and this survey will help establish an initial census of agricultural practices in the region which are known to have a significant effect on the lake health.

- Within the last seven years, the lake has been subjected to overfishing and environmental degradation. Health of the lake has declined due to overfishing and algae blooms caused by improper fertilization rates. Because of these factors over the last seven years, residents of the area have been forced to transition to subsidence farming as their main vocation. Experience in common practices such as crop rotation, fertilizer use, and erosion control is extremely limited.

- The area surrounding Lake Bosomtwe is very mountainous, and this location falls within the tropical forest zone of Ghana. People living within the impact crater cultivate crops in clay soils, with shallow soil profiles, often on the sides of hills with 20% slope or greater. The lake contains no outlet and is entirely dependent on rainfall within the impact crater for replenishing its water level. Shrinkage of the lake has been a concern due to the large amount of silt deposits that are carried by excess runoff. The Lake has not been recommended for recreational use due to the excess runoff in the form of agro-chemicals, liquid, and organic waste. Lake Bosomtwe is seen as a national asset that could be developed as a way for the country of Ghana to further stimulate their growing tourism industry. However, this natural resource has been severely under-managed.

- According to the Ghana Statistical Service group 97.6% of the population participants in some form of rural crop farming. The annual household income in this area according to the Ghana Statistical Service group is $100 USD. The purpose of this project is to eventually create an extension demonstration farm that will promote improved conservation agricultural practices to local farmers, and through the demonstration of conservation practices, help restore and better manage Lake

Bosomtwe. Through the adoption of modern agriculture methods, it is likely that both the health of Lake Bosomtwe can be restored and the livelihoods of smallholder farmers in the area can be increased.

- This project was first proposed by the Methodist Church Ghana Kumasi Bishop Christopher Nyarko Andam while visiting the Lake Bosomtwe area with a team from Global Resources Connections Inc (GRC), an NGO from Lafayette, Indiana. This trip took place during the summer of 2016. The project was started as part of a senior design capstone project in Purdue's Agricultural & Biological Engineering (ABE) Department by the current graduate student, Grace Baldwin. A follow up trip took place during the summer of 2017 to conduct a 20-acre baseline soil survey, and to install some initial demonstration plots to show vegetative terracing with the help of a farm manager. The roles of the Methodist Church Ghana, Bishop Andam, and Global Resource Connections Inc. (GRC) are to serve as social community consultants for this study only. The Methodist Church Ghana, Bishop Andam, and Global Resource Connections Inc (GRC) will not handle the data collected in any form, nor have any interaction with participants, and therefore they will not require CITI training.

- Unfortunately, within the Lake Bosomtwe impact crater, crop farming, swine operations, and human relief activities are conducted very close to the lake shore. There is one pit latrine located in each village. In addition, since farming and pig operations are sited closely to the lake, organic waste, agro-chemicals, and other liquid wastes likely run into the lake. In addition, the lake is also being used for irrigation purposes. This is not a recommended practice because of the high amounts of salt in the lake.

- To address the restoration of Lake Bosomtwe, to increase the knowledge basin for small-holder farmers, and to increase the livelihoods of small-holder farmers, it is critical that the community members be involved in the design of this extension farm. This study seeks to interview one farmer per house hold, and 22 farmers for each of the 11 villages located along the Lake Bosomtwe shore. To help address these issues in a culturally appropriate manner, this project collaborates with the community, the Amakom Methodist Clinic, the Methodist Church Ghana, and Global Resources Connections Inc (GRC). A trip is proposed so that the feedback received from the community members surveyed can be used to further refine the demonstration farm design. The purpose of this study is the restoration of Lake Bosomtwe by the promotion of conservation agriculture to small-holder farmers that will increase their livelihoods through the use of a demonstration farm. This study seeks a direct understanding from the farmers residing in the 11 villages located along the shore of Lake Bosomtwe of their perspective on land use change/cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. This survey activity will collect input from farmers so that it can be incorporated into design decisions demonstrated on the agricultural demonstration farm. The information collected from this study is critical to the planning, design, and implementation of the larger demonstration farm project.

Research Question (s)

1) What are the household demographics of the residents within the villages of the Lake Bosomtwe area?
2) What are the views of residents within the villages of the Lake Bosomtwe area on the current land use and how that has changed over the last thirty years?
3) What are the agronomic farming practices of the residents within the villages of the Lake Bosomtwe area?

4) What are the livestock farming practices of the residents within the villages of the Lake Bosomtwe area?
5) What are the water use and sanitation practices of the residents within the villages of the Lake Bosomtwe area?
6) What are the fishing practices of the residents within the villages of the Lake Bosomtwe area?

B. SPECIFIC PROCEDURES TO BE FOLLOWED

- Subjects will be asked in English to answer questions orally regarding demographic data, land use/cover, farming practices, water, sanitation, hygiene, and fishing. Subjects will be asked for consent that their household GPS location be recorded. Subject names will not be taken or recorded. Subjects will remain confidential.

- The following information in the form of an oral response will be collected and recorded on a survey form by the interviewer:

Demographic Data

1. Village name
2. Village household sequence number
3. Subject Gender
4. Subject's Age group
5. Marital status
6. Primarily level of education
7. Number of people within the subject's household
8. Number of children within the subject's household
9. Number of children per subject's household under the age of 5 years old
10. Number of children per subject's household under the ages 6-10 years old
11. Number of children per subject's household under the ages 11-15 years old
12. Number of children per subject's household under the ages 15-18 years old
13. Subject's source (s) of living
14. Subject's Annual household income
15. If the Subject is a native to the village he or she currently lives in
16. Subject's length of time living in village

Land Use Change Data

17. If the subject feels land use is changing within the Lake Bosomtwe Area
18. What the subject feels are the key causes of land use/land cover change
19. What the subject feels are the main factors affecting his or her personal decisions related to land use or management, in order of importance
20. If the subject feels land cover is changing what should be done to prevent the situation
21. What human activities the subject has observed around Lake Bosomtwe
22. What the subject believes is the main land use activity within the subject's village

23. If the subject believes land use activities within the watershed affect the productivity of the lake, long term.

Farmer Practices Data

24. The size of the subject's farm
25. The distance of the subject's farm from the lake
26. The approximate slope of the subject's field
27. If there is a Farmer Cooperative (s) in the subject's local area
28. If the subject does or does not participants in the local Farmers' Cooperative (s)
29. If no Farmer's Cooperative (s) exist would the subject be interested in participating in one if it was created
30. The subject's average crop yield for both the major & minor harvests
31. If the subject experiences any loss of crop due to post harvest loss during the major or minor growing seasons
32. If there is a loss of crop what the subject feels are the main contributing factors to the loss of crop during the major or minor growing seasons
33. If the subject has crop loss due to post harvest lost during the major or minor growing seasons, how much is lost?
34. The time of year the subject prepares his or her field for the major or minor growing seasons
35. What crops the subject grows during the major growing season and the minor growing season
36. If the subject grows vegetables if they grow them in raised beds
37. If the subject purchases seed
38. Where the subject purchases seed from
39. What vendor the subject purchases the seed from
40. How far the subject travels to purchase seed if it is outside the Lake Bosomtwe impact crater
41. If the seed was available locally if the subject would choose to purchase seed locally
42. If the subject saves seed from a previous harvest rather than purchasing seed
43. Any crops the subject wishes he or she could grow but currently don't grow
44. Any obstacles that cause the subject to be unable to grow the crop (s) desired
45. If a local seed bank was available, to purchase seed from, if the subject would choose to purchase seed from this bank
46. If a local seed bank was available, what type of seed (s) the subject would like to be able to purchase
47. If a nursery was available, to purchase small plant (s) or tree (s) from, if the subject would choose to purchase seed from this nursery
48. If a nursery was available, what type of small plant (s) or tree (s) the subject would like to be able to purchase
49. If there are any specific crops the subject believes would be good cash crops
50. Where would the subject choose to sell these cash crops
51. If the subject practices slash & burn agriculture
52. How often the subject practices slash & burn agriculture
53. How many times the subject practices slash and burn method during a year

54. If the subject would consider allowing the excess brush, weeds, and excess to decompose on the field without slash burning
55. If the subject believes there is any benefit to allowing the brush to decompose on the field
56. How the subject clears the field before planting if they don't practice slash & burn agriculture
57. What the subject does with the brush once it has been cleared from the field
58. If the subject allows the brush to decompose on the field
59. If the subject practices crop rotation
60. What crops the subject uses in crop rotation
61. If the subject practices any form of erosion control or slope protection
62. If the subject uses any agrochemicals for farming
63. If used, the frequency that a subject uses agrochemicals for farming
64. If used, when agrochemicals are applied during the major and minor growing seasons
65. Where the subject purchases agrochemicals
66. If the subject knows any possible effects of the use of these farm inputs on the lake
67. If the subject irrigates
68. If the subject irrigates, what time of the year
69. If the subject irrigates, how many months out of the year, the subject irrigates
70. If the subject irrigates, during a week that the subject irrigates how much water is applied to the field daily
71. If the subject irrigates, what is the water source used for irrigation
72. If the irrigation source is lake water, if the subject leaches his or her field
73. If the lake water is used for irrigation, if mixes the lake water with another source of water
74. What the subjects mixing source of water is
75. If the lake water is used for irrigation, if the subject allows the collected lake water to sit over night before use
76. If the subject believes there are any negatives effects from using water from the lake long term for irrigation
77. If the subject participants in livestock rearing
78. If the subject raises livestock
79. What types of livestock does the subject raise
80. The number of livestock raised for each type of livestock
81. If the subject purchases animal feed
82. If the subject purchases animal feed, where the feed is purchased
83. If the subject would be willing to purchase from a local vendor rather than an outside source
84. If the subject grows their own feed
85. If the subject raises poultry for egg production, does the subject sell those eggs
86. If the subject raises poultry for egg production, does the subject package those eggs
87. For a subject selling eggs, describe the packaging
88. For a subject selling eggs, the number of eggs sold in a week
89. The price that the number of eggs are sold at by the subject
90. The frequency that the subject sells the specified number of eggs during a week
91. If the subject believes selling packaged eggs to nearby hotels in the area could be profitable
92. If the subject purchases eggs
93. Where the subject purchases eggs
94. How often during a week the subject purchases eggs

95. How much money the subject's household spends on eggs for one week
96. If the subject raises animals, are they caged or free range
97. How much the subject sells an animal (s) for at market, if raised
98. If there is any potential tourism facility in the subject's community
99. What the distance of the tourism facility is to the lake shore, within the subject's community

Water, Sanitation, & Hygiene Data

100. If the subject has bathed in the lake
101. If the subject believes his or her activities an affect the quality of the water in the lake
102. If the subject has a toilet in the home
103. What the distance of the subject's toilet facility is from the lake
104. If the subject doesn't own a toilet where the subject uses the toilet
105. What the subject's household's main source of drinking water is
106. If the subject uses the lake water for drinking if the subject treats the water before drinking
107. If the subject believes there are any negative health effects from using water from the lake water long term
108. If the subject believes there are negative effects, what the subject believes the effects might be
109. Where the subject collects drinking water from
110. How many times in a week the subject walks to collect water
111. The distance of the subject's drinking source from the lake
112. The distance the subject travels to collect drinking water
113. How much time it takes for the subject to walk to the drinking water source
114. How many minutes on average the subject stands in a que for water
115. How much water the subject uses for domestic use
116. If the subject has a roof gutter
117. If the subject collects the water from the gutter system into a central location/container
118. If the subject doesn't own a roof gutter system, if the subject believes a roof gutter system would or would not be beneficial to his or her household
119. If the subject collects rain water
120. If the subject collects rain water
121. How much water the subject collects
122. What type of use the subject uses the water collected for
123. If the subject collects rain water, how does the subject collect the water

Fishing

124. If the subject has observed any changes in the lake in recent years
125. If the subject engages in any fishing activity
126. If the subject engages in fishing/fish mongering, how often
127. If the subject engages in fishing/fish mongering, how long the subject has been engaged in fishing/fish mongering
128. How much the subject makes in a day if the subject goes fishing
129. How many people within the subject's household engage in fishing activities

130. If there are any fishing programs in which the subject participants
131. If the subject participants in a fishing program, if the subject pays a fee to participate
132. If the subject participants in a fishing program, what benefits the program provides to the subject
133. If the subject doesn't participate in a fishing program and still participants in fishing, if they would choose to participate in a small-scale fishing program if one existed
134. If no fishing program currently exist, what benefits the subject would like to gain if the subject chose to participate
135. If the subject would be willing to pay a small fee to participate in the fishing program if a fishing program was created
136. If the subject believes the fish stock in the lake over the years has changed
137. If the subject believes the fish stock has changed, how has the fish stock changed
138. If the change in fish catch from the lake has affected the subject's income
139. If the subject's income has been affected due to the change in fish catch, how
140. If there is any alternative source of livelihood program in the subject's community
141. If there is an alternative livelihoods program in the subject's community, does it utilize the subjects fishing/fish mongering skills
142. If the subject believes the trend in size and fish catch show that the fish stock has changed
143. What the subject believes is the cause of the fish reduction or otherwise fish stock in the lake
144. If there is any alternative source of livelihood program in the subject's community

GPS Data

145. GPS location for subject's home
146. GPS location for village hand pumps
147. GPS location for village pit latrines

C. SUBJECTS TO BE INCLUDED

The participants included in this study will be individuals that practice farming and live within the Lake Bosomtwe impact crater. There is no gender specific requirement for participants. To participate, subjects must be older 18 years. Only one farmer per household will be interviewed. There are 11 different villages directly located along the Lake Bosomtwe shore line. The maximum number of subjects to enroll in this study will be no more than 250 participants, roughly 22 farmers each from 11 different villages within the Lake Bosomtwe impact crater. Farmers should be interviewed from each of the different villages, so that a thorough understanding of what the current farming practices throughout the Lake Bosomtwe impact crater can be determined. These data are needed so that farmers input from each of these communities can be used in the design of a demonstration farm. Participants will not qualify for this study if they do not participate in some form of farming or fishing within the Lake Bosomtwe impact crater. Participants will not qualify for this study, if they are younger than 18 years old.

D. RECRUITMENT OF SUBJECTS AND OBTAINING INFORMED CONSENT

Participants will be recruited by going from house-to-house within each of the 11 villages. Potential subjects will be asked if they practice in any form of farming. If the potential subject is involved in any form of farming activity, they will be asked if he or she would be willing to provide 60 minutes of their time to participate in this study. The potential participant could choose to be interviewed at that moment, a later time, or not at all. The waiver of consent form will be read orally to the potential subject, and the potential subject can decide whether or not to participate at that time. Ghana is a relatively peaceful country, and Grace Baldwin has spent multiple years working within the Lake Bosomtwe area. She will be the only person present during the participant home survey interviews.

E. PROCEDURES FOR PAYMENT OF SUBJECTS

Participation in this study is purely voluntary. The subjects will not be compensated in any way.

F. CONFIDENTIALITY

- Subject's names will not be asked for or recorded. The survey data set will only be identified by a code identifier. For each of the 11 villages, the village name will be listed, and the farmer interviewed will be given a number 1-22, based upon the sequence order in which the farmers are interviewed. For example, Village 1 - Farmer 1, Village 1 - Farmer 2, all the way through Village1 - Farmer 22. The sequence will then move to Village 2 - Farmer 1, Village 2 - Farmer 2 through Village 2 - Farmer 22. This system will be used for each of the 11 villages and all participants. Data set identification will be used administratively to insure the overall accuracy and integrity of the aggregate data set. The identification code key will not be used for any other purposes, and under no circumstances will any individually identifiable information from the data set ever be disclosed.

- We are requesting a Waiver of Documented Consent to minimize identifiable contact with the survey data sets. While in Ghana the collected data sheets will be stored in a locked cabinet that only Grace Baldwin will have access to. After returning to Purdue University the data sheets collected will be stored in a locked cabinet and also stored on a secured password protected Purdue computer. The original survey data sheets will be retained under locked conditions for three years following an initial publication of the research. Those sheets will be destroyed after that date. Only Dr. Stwalley and Grace Baldwin will have access to the collected data while on Purdue's campus. The survey data stored on the Purdue computer will be kept indefinitely, as the work moving forward from this project is seen as extending significantly into the future.

G. POTENTIAL RISKS TO SUBJECTS

- The risk to participants is minimal. It is no greater than every day activities. Subject's choosing to participate in the study will be asked to orally respond to questions, and the subject's responses recorded.

- There are no medical risks associated with this study.

- The only potential risk to the subject is possible exposure of personal information. To minimize this exposure, all responses will be kept confidential. A subject's name will not be recorded or asked.

- Breach of confidentiality is a risk related to this research. Although this risk is a possibility, safeguards are in placed as listed in the confidentiality section.

- Additional permission to record a subject's household location will be requested. This information will not be recorded, if the subject does not additionally approve.

- Participants could be concerned about sharing their annual household income and household location. It will be stressed to subjects considering participation in this study that their personal names will be in no way linked to any of the data and that their personal names will be kept confidential. Subjects' personal names will never be requested, so that a subject's household income and household location will remain confidential.

H. BENEFITS TO BE GAINED BY THE INDIVIDUAL AND/OR SOCIETY

- There are no direct benefits for subjects choosing to participate in this study. However, the subject's choice to participate in this study could provide future benefits to all farmers living in the Lake Bosomtwe area. The data collected from the participants interviewed will be used to make informed decisions of what improved agricultural practices should be demonstrated on a future agriculture demonstration farm.

- The collection of GPS data points will allow this study to determine if certain farmers by geographic location experience similar or different losses in yield, differences in practices, or care more about certain crops or animals than others. These collected data will lead to more intentional development programing, so that if certain villages experience differences or similarities in problems, such as losses in crop yields, excess fertilizer use, or other various scenarios, improved agricultural alternatives can be shown and demonstrated on the demonstration farm. In the future, the implementation of such practices should provide opportunity for increases in farmer household productivity, increased economic development, and better management of Lake Bosomtwe as a natural resource.

I. INVESTIGATOR'S EVALUATION OF THE RISK-BENEFIT RATIO

- Risks for all possible harm to participants are negligible, because participant names will not be recorded. Participation and subject names will be never be collected and always remain confidential. Participants will be asked orally to respond to questions regarding demographic information, land use information, farming practices information, water, sanitation, hygiene information, and fishing information. Responses will only be used is statistical summary, so no individual risk of exposure is involved.

- Subjects will be asked if a GPS point can be recorded, so that their survey responses are linked to that household location. However, the householder's name will remain confidential.

- Participation in this study is voluntary with no direct benefits to the subjects. However, the potential for benefit to the entire local community from the results of this survey is significant, as it is intended that these results will guide the design of the demonstration farm plan.

J. WRITTEN INFORMED CONSENT FORM

- If a written consent document was used within the study, it would be the only link between the subject's identity and the project records.

- The national language in the country of Ghana is English. The Lake Bosomtwe impact crater is located within Ghana, West Africa, and this study will be conducted in English. This study is requesting a Waiver of Documented Consent.

K. WAIVER OF INFORMED CONSENT OR SIGNED CONSENT

- This research activity should be considered minimal risk, because the risk will not be greater than everyday activities. For each of the 11 villages located along the Lake Bosomtwe shore, 22 farmers will be interviewed, 1 per household. Each participant will be asked to answer questions orally.

- If a consent form linking the subject to the study was used, it would be the only link between the subject and the study. Release of that information could cause social or economic risk to the participant that would be greater than minimal risk.

- This study requests a waiver of documented (signed) consent. This study is not interested in recording the specific names of the participants. If the subjects provide signed consent, it would be the only record linking the subject to the research.

- This research does not include any activities that would require signed consent in a non-research context.

- This study will provide any potential research participant with an information sheet that contains all of the elements of a consent form, but without the signature lines. This sheet will be given to the each potential participant to keep.

L. INTERNATIONAL RESEARCH

- Our main partner is Bishop Andam of the Methodist Church Ghana Kumasi Diocese. On site at the Amakom Methodist Clinic, our project's main contact is Mr. Hilton Terrie Kessie PA, who is the Director of the Amakom Methodist Clinic. Bishop Andam has selected as the farm's main extension officer, a former government officer from the Ghana Ministry of Forestry and Agriculture (MOFA), who has served more than 20 years as an agriculture extension officer and staff at the Amakom Methodist Clinic. The Lake Bosomtwe Community Health Management Team is composed of village representatives from each village, and it works in collaboration with the Amakom Methodist Clinic. This committee includes village chiefs, village assembly men and women, the management team of the Amakom Clinic, and church representatives. GRC, is a non-for-profit organization who connects people to resources working in developing countries. They work in Ghana and have connected the graduate student to the Methodist Church Ghana Project partner to work on this project, as a continuation of the now graduate student's undergraduate capstone project into her master's thesis. This survey represents a small defining project within a larger effort. The support of these community leaders for this work is strong.

- The graduate student has been going to Ghana since the summer of 2009 and has gone on multiple trips to Ghana. She has spent multiple weeks in country as part of GRC and has continually been hosted by the Methodist Church Ghana. She lived in country and worked as a Development Engineer with the Ghana Methodist Relief Services WASH program. During this experience, she worked on 32 different projects throughout the country of Ghana over one summer. The graduate student in partnership with GRC was has started some demonstrations plots at the current agricultural demonstration site over the last year. The graduate student was specifically asked by Bishop Christopher Andam to develop the demonstration farm at Lake Bosomtwe as part of her Senior Capstone Project under the Supervision of Dr. Robert Stwalley. This project has since continued into her Master's Thesis work. The proposed study was invited into this community based upon the ongoing work of GRC and the Methodist Church Ghana.

- Ghana's National language is English, and therefore, this study will be conducted in English. Within the Lake Bosomtwe Community English is used and is considered appropriate to ask questions in. Bishop Andam and the Methodist Church Ghana will host the study out of the Amakom Methodist Clinic, where the graduate student will be living to conduct the survey. The study will be conducted in a house to house manner in each of the 11 villages.

- Investigators in this study will communicate through email primarily, but they will also have contact through phone conversations. The graduate student investigator will have use of an in-country Ghana phone, so that calls can be made in country but also back to the USA to communicate with IRB and the Principle Investigator. Weekly emails and meetings will take place between the PI and the graduate student throughout the time frame of the study.

M. SUPPORTING DOCUMENTS *(check all document that you will be submitting to IRB)*

x Recruitment advertisements, flyers, emails and letters.
x Survey instruments, questionnaires, tests, debriefing information, etc.
___Consent Form, Parental Permission, Assent Form
x Translated consent and recruitment documents
___If the research is a collaboration with another institution, that institution's IRB or ethical board approval for the research or request for IRB deferral.
___If the research accesses the PSYC 120 Subject pool include the description to be posted on the web-based
recruitment program and the debriefing form to be used.
___Local review approval or affirmation of appropriateness for international research.
___If the research will be conducted in schools, businesses or organizations, include a letter from an appropriate administrator or official permitting the conduct of the research.
___If the study involves an investigational drug/device, include product information or investigator brochure
x Other (RESEARCH PARTICIPANT INFORMATION SHEET)

Research Participant Recruitment Script

RESEARCH PARTICIPANT RECRUITMENT SCRIPT

Development of design criteria and options for promoting lake restoration of Lake Bosomtwe and increased livelihoods for smaller-holder farmers near Lake Bosomtwe in Ghana, West Africa

Dr. Robert M. Stwalley III
Agricultural & Biological Engineering
Purdue University

A. Introduction

Good Morning/Good Afternoon, sir/madam:

My name is Grace Baldwin, and I am a graduate student at Purdue University in United States. Do you have a minute?

I am an agricultural engineer, and I am conducting a research study with my major professor, Dr. Bob Stwalley. We were asked to conduct this study by our partners, the Amakom Methodist Clinic, the Methodist Church Ghana, Kumasi Bishop Christopher Nyarko Andam, and Global Resource Connections Inc. (GRC), to include farmers' ideas, concepts, and needs into the development of an agricultural demonstration farm at Lake Bosomtwe.

B. Immediate opportunity to opt-out

To participate in this study, you must be age 18 or older and be engaged in some form of farming or fishing operation(s) within the Lake Bosomtwe area. Your answers to this survey will remain confidential.

I am here to ask if you are interested in hearing more about our study. Is it ok for me to continue?

- If individual says "no, not interested"
  - Response: Stop, say thank you but do not continue

- If individual says yes, then continue or make plans to revisit at a more continent time.

C. Make a brief statement about why he/she was selected.

I approached you to see if you would like to participate in this study. Specifically, I am seeking participants that are age 18 or older and are engaged in some form of farming or fishing operation within the Lake Bosomtwe area.

This study seeks to learn directly from farmers residing in the 11 villages located along the shore of Lake Bosomtwe of their perspectives on land use change and ground cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. This survey will access the input collected from farmers and fishers, so

that their feedback can be incorporated into the design decisions for the agricultural demonstration farm. There will be no immediate or direct benefits to you if you choose to participate in this study. However, your choice to participate could provide future benefits to all citizens living in the Lake Bosomtwe area.

D. <u>Are you interested in hearing more information?</u>

So, are you interested in hearing some details about the research study?

- If not interested, thank the individual for his/her time.
- If interested, then move to the consent form.

Research Participant Information Sheet

RESEARCH PARTICIPANT INFORMATION SHEET

Development of design criteria and options for promoting lake restoration of Lake Bosomtwe and increased livelihoods for smaller-holder farmers near Lake Bosomtwe in Ghana, West Africa

Dr. Robert M. Stwalley III
Agricultural & Biological Engineering
Purdue University

Key Information

Please take time to review this information carefully. This is a research study. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign or agree to this form. You should be sure that you understand what you will do in taking this survey and any possible risks or benefits from doing so.

The purpose of this study is to access local knowledge regarding the restoration of Lake Bosomtwe by the promotion of conservation agriculture to small-holder farmers that will increase their farm yields and household incomes through the use of a demonstration farm. This study works with the Amakom Methodist Clinic, the Methodist Church Ghana, and Global Resources Connections Inc. (GRC). This study seeks to learn directly from farmers residing in the 11 villages located along the shore of Lake Bosomtwe of their perspective on land use change/cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. This survey activity will collect input from farmers so that it can be incorporated into design decisions demonstrated on the agricultural demonstration farm.

The information collected from this study is critical to the planning, design, and implementation of the larger demonstration farm project. Individual survey responses will take no more than an hour. Survey responses will be collected over a five-week period and recorded. The use of this data will be used to support the work of Grace Baldwin's graduate thesis work. The original survey data sheets will be stored under locked conditions for three years following an initial publication of the research. The survey data will be stored on a Purdue University computer and will be kept indefinitely and may be used for future projects.

What is the purpose of this study?

This study seeks to enroll no more than 250 farmers, roughly 22 farmers per village, living in the 11 villages located along the Lake Bosomtwe shore. This study seeks to learn directly from farmers living in these villages their perspective on land use change and ground cover in the Lake Bosomtwe area, current farming practices, current water sanitation and hygiene practices, and current fishing practices. The information collected from this study is critical to the development of a larger demonstration farm for the Lake Bosomtwe area.

What will I do if I choose to be in this study?

If you choose to participate in this study, you will be asked in English to answer oral questions regarding the following topics: demographic information, land use/cover change, farming practices, water, sanitation hygiene, and fishing. You will be asked for consent that a GPS location of your household be recorded. Your name will not be recorded and all your answers to this survey will remain confidential. The data collect as part of this study will include your personal responses to the oral questions answered, and your household's GPS location. As part of this study this data will be kept confidential and your name not recorded. There are no experimental procedures as part of this survey, all you need to do is answer each question asked to the best of your ability.

How long will I be in the study?

If you choose to participate in this survey, this will take a one-time commitment of 60 minutes.

What are the possible risks or discomforts?

If you choose to participate in this study please be aware that you will be asked to provide your average annual household income, the location of your household, your crop yield during the major and minor harvests, and any crop losses experienced during the major and minor growing seasons. Your answers to these questions, will not be shared. They will be kept confidential. Your answers to these questions will only reference which of one of the 11 villages within the Lake Bosomtwe impact crater that you are from and that you are 1 of 22 farmers interviewed from your village. Breach of confidentiality is a risk related to this research. Although this risk is a possibility, safeguards are in placed as listed in the confidentiality section. There are no greater risks associated with this study than that which you would encounter during your normal day activities.

Are there any potential benefits?

There are no direct benefits to you if you choose to participate in this study. However, your choice to participate could provide future benefits to farmers living in the Lake Bosomtwe area. The data collected from you will be used to make informed decisions of what improved agricultural practices should be demonstrated on an agriculture demonstration farm. The collection of your household GPS data point along with other farmer's GPS household data points will allow this study to determine if around the entire lake certain farmers due to location experience similar or different losses in yield, differences in practices, and care about certain crops or animals more than others. This data collected will lead to more intentional development programing. If certain villages experience differences or similarities in problems such as losses in crop yields, excess fertilizer use, or other various scenarios, improved agricultural alternatives can be shown and demonstrated on the demonstration farm because of this study. In the future, the implementation of such practices may provide opportunities for increases in farmer household productivity, increased economic development, and better management of Lake Bosomtwe as a natural resource.

Will information about me and my participation be kept confidential?

If you choose to participate in this study your name will not be recorded. You will be referred to in this study as the village that you are from, and which farmer 1 through 22 you are. An example of how you will appear is as follows, this example uses the village of Amakom as the example village: Amakom Farmer 1 or Amakom Farmer 2. Only the Principle investigator, Dr. Robert Stwalley, and the graduate student, Grace Baldwin, will have access to raw data recorded. The use of this data will be used to support the work of Grace Baldwin's graduate thesis work. While in Ghana the collected data sheets will be stored in a locked cabinet that only Grace Baldwin will have access to. After returning to Purdue University the data sheets collected will be stored in a locked cabinet and also stored on a secured password protected Purdue University computer. The original survey data sheets will be retained under locked conditions for three years following an initial publication of the research. Those sheets will be destroyed after that date. Dr. Stwalley and Grace Baldwin will have access to the collected data while on Purdue's campus. The project's research records may be reviewed by Purdue University's Agricultural and Biological Engineering Department and by other departments at Purdue University responsible for regulatory and research oversight. The survey data stored on the Purdue computer will be kept indefinitely and may be used for future projects.

What are my rights if I take part in this study?

Your participation in this study is voluntary. You may choose not to participate, or if you agree to participate, you may change your mind later and withdraw from the study at any time. If you choose to withdraw from the study at any time, any data already collected from you will be deleted. Participation or withdrawal from this study at any time will in no way harm your relations with anyone associated with this study.

Who can I contact if I have questions about the study?

1st Point of Contact
PI: Dr. Robert M. Stwalley III
Phone:+1-765-494-1791
Email: rms3@purdue.edu

Graduate Student: Grace Baldwin
Phone: 1-765-479-0731
Email: baldwing@purdue.edu

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu)or write to:
Human Research Protection Program - Purdue University
Ernest C. Young Hall, Room 1032
155 S. Grant St.,
West Lafayette, IN 47907-2114

Survey Questionnaire Lake Bosomtwe, Ghana

Survey for Social Data

Section A. Demographic Information

1. Village Name: _____
2. Farmer Number: _____
3. Gender a) Male b) Female
4. Age Group a) 18-20 b) 21-40 c) 41-60 d) Over 60
5. Marital Status a) Unmarried b) Married
6. What is your level of education?
   a) Primary b) MSLC/JHS c) SHS d) A & O Level e) University
   f) College

   Primary School
   Middle School Level Class – (MSLC)
   Junior Highschool – (JHS)
   Senior Highschool – (SHS)
   (A & O Level)
7. Number of people per household
   a) 1-3 b) 4-6 c) 7-10 d) Over 10
8. Number of children per household
   a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10
9. Number of children per household under the age of 5 years old
   a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10
10. Number of children per household ages 6-10 years old
    a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10
11. Number of children per household ages 11-15 years old
    a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10
12. Number of children per household ages 15-18 years old
    a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10

13. What do you do for a living?
    a) Fishing b) Farming c) Fishing & Farming d) Tourism Industry e) Medical

    f) Education g) Other (Specify): _____

14. What is your annual household income? a) Less than 100 GHD b) 100-200 GHD
    c) 200-300 GHD d) 300-400 GHD e) 400 & Above

15. Are you a native of this village? a) Yes b) No
    If No,
    15.1 How long have you lived in this village?
    a) Less than 10 Years b) 10- 20 Years c) 20 - 30 Years
    d) More than 30 Years

Section B. Land Use Changes

16. In your view, the natural land use/cover around Lake Bosomtwe shows that it is (mark the appropriate box)

State of Land Use/Cover	Mark with X
Stable	
Decreasing	
Increasing	

17. What are the main factors that affect your decisions related to land use or management?
    Note: List in Order of importance _____

18. In your view, if you think land cover change is changing, what should be done to prevent the situation?
    _____

19. What human activities have you observed around the lake?
    _____

20. What do you believe the main land use activity is within your village?
    _____

21. Can the land use activities within the watershed affect the productivity of the lake, long term?
    Yes b) No

Section C. Farmer Practices

22. What is the size of your farm? a) 1 acre b) 2 acres c) 3 acres d) 4 acres
    e) Less than 1 acre f) More than 4 acres g) Specify: _____

23. What is the distance of your farm from the lake?
    a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m
    e) 400-500 m f) 500 m or greater

24. Is there a Farmers Cooperative(s) in your local area? a) Yes b) No
    If Yes,
    24.1 Are you a member of the local Farmer (s) Cooperative in your area?
    Explain: _____

    If No,
    24.1 Would you be interested in participating in a Farmers Cooperative if one was created?
    Explain: _____

25. What is your average crop yield for the major harvest?
    a) Less than 50 kg b) 50-100 kg c) 100-200 kg d) More than 200 kg

26. What is your average crop yield for the minor harvest?
    a) Less than 50 kg b) 50-100 kg c) 100-200 kg d) More than 200 kg

27. Do you experience any loss of crop due to post harvest loss during the major growing season?
    a) Yes b) No
    If Yes,
    27.1 What do you believe are the main contributing factors to your loss of crop?
    Specify: _____

    27.2 What is your average crop loss during the major growing season?
    a) Less than 50 kg b) 50-100 kg c) 100-200 kg d) More than 200 kg

28. Do you experience any loss of crop due to post harvest loss during the minor growing season?
    a) Yes b) No
    If Yes,
    28.1 What do you believe are the main contributing factors to your loss of crop?
    Specify: _____

    28.2 What is your average crop loss during the minor growing season?
    a) Less than 50 kg b) 50-100 kg c) 100-200 kg d) More than 200 kg

29. What time of the year do you prepare your lands for farming during the major season?
    _____

30. What time of the year do you prepare your lands for farming during the minor season?
_____

31. Which of the following crops do you grow during the major growing season?
Note: Mark the crop grown with an X.

Crops	**Grown During Major Season**
Cash Crop	
Cocoa	
Oil Palm	
Food Crops	
Cassava	
Maize	
Plantain	
Vegetables	
Cabbage	
Carrots	
Eggplant	
Okra	
Onions	
Other	
Specify 1:	
Specify 2:	
Specify 3:	

32. Which of the following crops do you grow during the minor growing season?
Note: Mark the crop grown with an X.

Crops	**Grown During Minor Season**
Cash Crop	
Cocoa	
Oil Palm	
Food Crops	
Cassava	
Maize	
Plantain	
Vegetables	
Cabbage	
Carrots	
Eggplant	
Okra	
Onions	
Other	
Specify 1:	
Specify 2:	
Specify 3:	

33. Do you purchase seed? a) Yes b) No

If Yes,

33.1 Where do you purchase your seed?

a) From a local vendor b) Outside the Impact Crater, Specify: _____

If Outside the Impact Crater, Specify,

33.1.1 How far do you travel to purchase seed?

a) Less than 2-miles b) 2-5 miles c) 6-10 miles d) 11-30 miles e) 31-45 miles

f) 46-60 miles g) Over 60 miles, Specify: _____

33.1.2 If seed was available locally, from a seed bank or seed vendor would you choose to purchase from one of these sources? a) Yes b) No

If No,

33.1 Do you save your own seed from a previous harvest? a) Yes b) No

34. Are there any crops that you are currently not growing, but you wish you were able to grow?
a) Yes b) No If Yes, Specify: _____

34.1 What are the major obstacles that have hindered you from being able to grow the crops specified? Specify: _____

34.2 If a seed bank was available locally to purchase seed from, would you choose to purchase from this source?
a) Yes b) No

35. If a nursery was available locally to purchase small plants or trees from, would you choose to purchase from this source?
a) Yes Explain: _____
b) No Explain: _____

36. If a nursery was locally available what type of small plants or trees would you want to be able to purchase?
Specify: _____

37. Are there specific crops you believe would be good cash crops? a) Yes b) No
If Yes,
37.1 Specify: _____

37.2 Where would you sell these crops? Specify: _____

38. Do you practice slash & burn agriculture? a) Yes b) No

If Yes,

38.1 How often? a) Regularly b) Occasionally c) Once in a while

38.2 How many times do you practice slash and burn method per year? _____

38.3 Would you be willing to clear the brush, weeds, excess, without burning, and allow the brush, weeds, and excess to decompose on the field without slash burning?

a) Yes b) No Explain: _____

38.4 Do you believe there is any benefit to allowing the brush to decompose on the field?

a) Yes b) No Explain: _____

If No,

38.1 How do you clear your field before planting? Specify: _____

38.2 What do you do with the brush cleared from the field? Specify: _____

38.3 Do you allow the remaining brush that has been cleared to decompose on the field?

a) Yes b) No

39. Do you practice crop rotation? a) Yes b) No

If Yes,

39.1 What crops do you use for crop rotation? Specify: _____

40. Do you practice any form of erosion control or slope protection? a) Yes b) No

If Yes,

40.1 Explain: _____

41. Do you use any of the following agrochemicals for farming?

Inputs	Yes	No
Fertilizers		
Weedicides		
Pesticides		
Animal Droppings		

41.1 If Yes, how often?

Inputs	Frequency Applied During Major Season	Frequency Applied During Minor Season
Fertilizers		
Weedicides		
Pesticides		
Animal Droppings		

41.2 If Yes, how many times do you apply during the major growing season?

Inputs	Frequency
Fertilizers	
Weedicides	
Pesticides	
Animal Droppings	

41.3 If Yes, how many times do you apply during the minor growing season?

Inputs	Frequency
Fertilizers	
Weedicides	
Pesticides	
Animal Droppings	

41.4 Where do you purchase your agrochemicals for farming? Specify: _____

42. Do you water your crops? a) Yes b) No
If Yes,

42.1 What time of year do you irrigate? Specify: _____

42.2 How many months out of the year do you irrigate?
a) Less than 1 b) 1-2 c) 3-4 d) 4-5 e) 6-7
f) More than 8

42.3 During a week that you irrigate, how much water do you apply to your field daily?
a) 0.5 in b) 0.75 in c) 1 in d) 1.5 in
e) Specify: _____

42.4 What water source do you use for irrigation?
a) Lake water b) Borehole c) Pipe borne water d) Bottled or Sashe water
e) Specify: _____
If Lake water,

Notes: Leaching is the practice of adding additional water to the field to push salts present in the soil past the plant's root zone, so as to not hinder crop growth.

42.3.1 Do you practice leaching? a) Yes b) No

If Yes,

42.3.2 Do you mix the lake water with another source of water before using the water for irrigation? a) Yes b) No

If Yes,

42.3.2.1 What is your other source that you mix the lake water with?

a) Lake water b) Borehole c) Pipe borne water
d) Bottled or Sashe water e) Specify: _____

42.3.2.2 Do you allow the water collected to sit over night before applying it to your field? a) Yes b) No

42.3.2.3 Do you believe there are any negative effects from using water from the lake long- term? a) Yes b) No

43. Do you participate in livestock rearing? a) Yes b) No

If Yes,

43.1 What animal (s)?

Mark the animal raised with X for Yes raised

Animal	Yes	No
Goat		
Guinee Fowl		
Poultry for Eggs		
Poultry for Meat		
Piggery		
Cows for Beef		
Cows for Dairy		
Grass Cutter		
(Other): Specify		

43.1.1 The farmer raises chickens for eggs? a) Yes b) No

43.2 Do you purchase animal feed? a) Yes b) No

If Yes,

43.2.1 Where do you purchase your feed? Specify: _____

43.2.2 If animal feed was available locally would you choose to purchase from a local vendor? a) Yes b) No

If No,

43.2.1 Do you grow your own feed? a) Yes b) No

43.1.2 Do you or a member of your household purchase eggs? a) Yes b) No

If Yes,

43.1.2.1. Where do you purchase eggs? Specify: _____

43.1.2.2. How often do you purchase eggs during a week?

a) 1 b) 2 c) 3 d) 4 e) 5 f) daily

g) Specify: _____

43.1.2.3. For one week how much money does your household spend on eggs?

Specify: _____

If Yes for rearing poultry for eggs,

43.1.2 Do you or a member of your household sell the eggs produced? a) Yes b) No

If Yes,

43.1.3 Where do you sell your eggs?

a) Specify: _____

43.1.4 Do you package your eggs? a) Yes b) No

If Yes,

43.1.1.4.1. Describe packaging? a) plastic sack b) cardboard carton

c) Specify: _____

43.1.5 How many eggs do you sell in a week?

Place an X in the Egg Sold column. List Price of eggs.

List number for the Frequency.

Number of Eggs	Eggs Sold	Price for Eggs Only	Frequency of Sold per week
1-3			
4-6			
7-9			
10-12			
Other (Specify):			

43.1.6 Do you believe selling packaged eggs to the nearby hotels could be profitable? a) Yes b) No

44.3 Are your animals caged or free range? a) Caged b) Free Range

c) Specify_____

44.4 How much is one of your animals sold for at market? Specify: _____

44.5 Where do you sell your animal(s)? Specify: _____

45. Is there any tourism facility in your community? a) Yes b) No
Specify: _____

If Yes,

45.1 What is the distance of the facility from the lake shores?
a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m
e) 400-500 m f) 500 m or greater

Section D. Water, Sanitation, & Hygiene

46. Have you bathed/washed in the lake before? a) Yes b) No

47. Do you believe your activities can affect the quality of the water in the lake? a) Yes b) No

48. Do you have a toilet facility in your house? a) Yes b) No

If Yes,
48.1 What is the distance of your toilet facility from the lake?
a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m
e) 400-500 m f) 500 m or greater

If No,
48.1 Where do you go to toilet? _____

49. What is your main source of drinking water for your household?
a) Lake water b) Borehole c) Pipe borne water d) Bottled or Sashe water

e) Specify: _____

If from Lake,

49.1 Do you treat the water before drinking? a) Yes b) No

50. How many times in a week do you walk to collect water?

a) 1-2 times b) 2-3 times c) 3-4 times d) Over 4 times e) Specify: _____

51. What distance must you travel to collect drinking water?
a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m

e) 400-500 m f) 500 m or greater

52. What is the distance of your drinking water source from the lake?

a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m

e) 400-500 m f) 500 m or greater

53. How much time does it take you to walk to your drinking water source?

a) Less than 5 minutes b) 5-15 minutes c) 15-30 minutes

d) 30-45 minutes e) 45-60 minutes f) Over 60 minutes

g) Specify: _____

54. How many minutes on average do you stand in a que for water?

a) Less than 5 minutes b) 5-15 minutes c) 15-30 minutes

d) 30-45 minutes e) 45-60 minutes f) Over 60 minutes

g) Specify: _____

55. How much water do you collect for domestic (liters)? Specify: _____

56. Do you have a roof gutter? a) Yes b) No

If yes,

56.1 Do you collect the water that collects in the gutter into a central location/container?

a) Yes b) No

If No,

56.1 Would having a roof gutter system be a benefit to you and your household?

a) Yes b) No

If Yes,

56.1.1 How would it benefit you and your household? Specify: _____

If No,

56.1.1 Explain why you feel a roof gutter system would not be a benefit to you and your house-hold.

_____

57. Do you collect rainwater? a) Yes b) No

If Yes,

57.1 How much rain water do you collect? Specify: _____

57.2. What do you use the rain water for? a) Domestic use b) Drinking c) Irrigation
d) Specify: _____

57.3 How do you collect the rainwater? Specify: _____

Section E. Fishing

58. Have you observed any changes in the lake in recent years? a) Yes b) No
Give reasons for your answer:
_____

59. Do you engage in any fishing activity? a) Yes b) No
If yes,

59.1 How often do you go fishing/ fish mongering? _____

59.2. How long have you been engaged in fishing/ fish mongering? _____

59.3 How much do you make in a day if you go fishing? _____
59.4 How many people within your household are engaged in fishing activities? Specify:
_____
59.5 Are there any fishing programs in which you participate?

a) Yes b) No

If Yes,
59.5.1. Do you pay a fee to participate in this fishing program? a) Yes b) No

59.5.2. What benefits does this fishing program provide to you?
Specify: _____

If No,
59.5.1. If a small-scale fishing program existed, would you choose to participate?
a) Yes b) No Explain: _____

59.5.2. What benefits would you hope this fishing program would provide to you?
Specify: _____

59.5.3. Would you be willing to pay a small fee to participate in this fishing program?
a) Yes b) No Explain: _____

60. Has the change in fish catch from the lake affected your income? a) Yes b) No
If Yes,

60.1 How? _____

60.2 Is there any alternative source of livelihood program in your community? a) Yes b) No

If Yes,

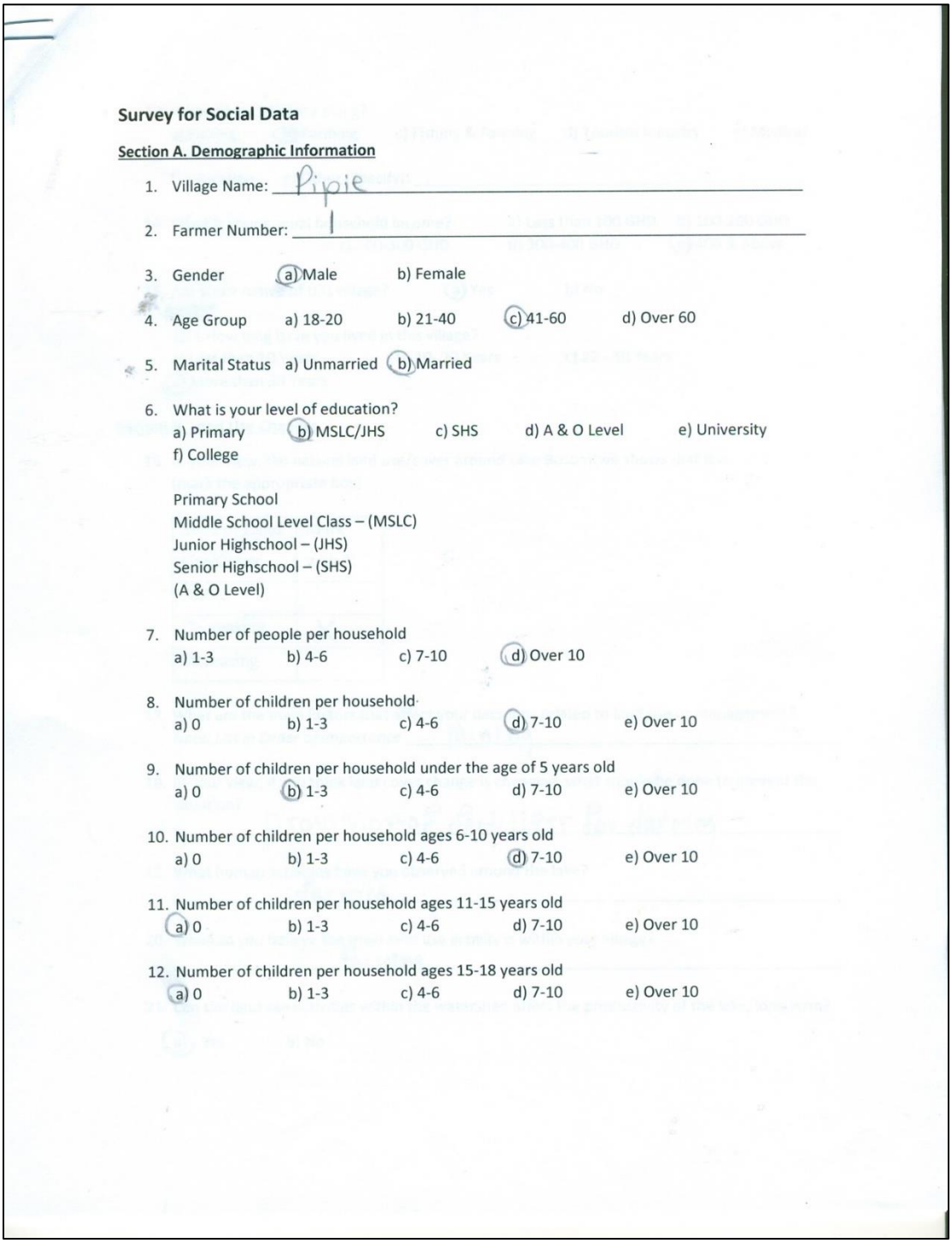
60.2.1 Does this program allow you to utilize your knowledge and skills from fishing/fish mongering?
a) Yes b) No

61. The trend in size and fish catch shows that, fish stock is
a) Stable b) Decreasing c) Increasing
d) I don't know/ I feel unqualified to answer

62. In your opinion, what do you believe is the cause of the reduction or otherwise of fish stock in the lake? _____

APPENDIX B. COMPLETED FORM

The following form provides an example of the filled-out survey conducted in written form.



Survey for Social Data

Section A. Demographic Information

1. Village Name: Pipie
2. Farmer Number: 1
3. Gender (a) Male b) Female
4. Age Group a) 18-20 b) 21-40 (c) 41-60 d) Over 60
5. Marital Status a) Unmarried (b) Married
6. What is your level of education?
   a) Primary (b) MSLC/JHS c) SHS d) A & O Level e) University
   f) College

   Primary School
   Middle School Level Class – (MSLC)
   Junior Highschool – (JHS)
   Senior Highschool – (SHS)
   (A & O Level)

7. Number of people per household
   a) 1-3 b) 4-6 c) 7-10 (d) Over 10
8. Number of children per household
   a) 0 b) 1-3 c) 4-6 (d) 7-10 e) Over 10
9. Number of children per household under the age of 5 years old
   a) 0 (b) 1-3 c) 4-6 d) 7-10 e) Over 10
10. Number of children per household ages 6-10 years old
    a) 0 b) 1-3 c) 4-6 (d) 7-10 e) Over 10
11. Number of children per household ages 11-15 years old
    (a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10
12. Number of children per household ages 15-18 years old
    (a) 0 b) 1-3 c) 4-6 d) 7-10 e) Over 10

13. What do you do for a living?
a) Fishing (b) Farming c) Fishing & Farming d) Tourism Industry e) Medical
f) Education g) Other (Specify): _____

14. What is your annual household income? a) Less than 100 GHD b) 100-200 GHD
c) 200-300 GHD d) 300-400 GHD (e) 400 & Above

15. Are you a native of this village? (a) Yes b) No
~~If No~~
15.1 How long have you lived in this village?
a) Less than 10 Years b) 10- 20 Years c) 20 - 30 Years
(d) More than 30 Years

Section B. Land Use Changes

16. In your view, the natural land use/cover around Lake Bosomtwe shows that it is (mark the appropriate box)

State of Land Use/Cover	Mark with X
Stable	
Decreasing	X
Increasing	

17. What are the main factors that affect your decisions related to land use or management?
Note: List in Order of importance Mining

18. In your view, if you think land cover change is changing, what should be done to prevent the situation?
Provision of fertilizer for farming

19. What human activities have you observed around the lake?
farming

20. What do you believe the main land use activity is within your village?
farming

21. Can the land use activities within the watershed affect the productivity of the lake, long term?
(a) Yes b) No

Section C. Farmer Practices

22. What is the size of your farm? a) 1 acre b) 2 acres c) 3 acres d) 4 acres

e) Less than 1 acre (f) More than 4 acres g) Specify: _____

23. What is the distance of your farm from the lake?

a) Less than 20 m (b) 20-50 m c) 50-100 m d) 100-400 m

e) 400-500 m f) 500 m or greater

24. Is there a Farmers Cooperative(s) in your local area? a) Yes (b) No

If Yes,

24.1 Are you a member of the local Farmer (s) Cooperative in your area?

Explain: _____

If No,

24.1 Would you be interested in participating in a Farmers Cooperative if one was created?

Explain: yes

25. What is your average crop yield for the major harvest?

a) Less than 50 kg b) 50-100 kg (c) 100-200 kg d) More than 200 kg

26. What is your average crop yield for the minor harvest?

a) Less than 50 kg (b) 50-100 kg c) 100-200 kg d) More than 200 kg

27. Do you experience any loss of crop due to post harvest loss during the major growing season?

(a) Yes b) No

If Yes,

27.1 What do you believe are the main contributing factors to your loss of crop?

Specify: poor road network to selling place

27.2 What is your average crop loss during the major growing season?

(a) Less than 50 kg b) 50-100 kg c) 100-200 kg d) More than 200 kg

28. Do you experience any loss of crop due to post harvest loss during the minor growing season?

(a) Yes b) No

If Yes,

28.1 What do you believe are the main contributing factors to your loss of crop?

Specify: poor road network to selling place

28.2 What is your average crop loss during the minor growing season?

(a) Less than 50 kg b) 50-100 kg c) 100-200 kg d) More than 200 kg

29. What time of the year do you prepare your lands for farming during the major season?

February

30. What time of the year do you prepare your lands for farming during the minor season?

July

31. Which of the following crops do you grow during the major growing season?
Note: Mark the crop grown with an X.

Crops	Grown During Major Season
Cash Crop	
Cocoa	
Oil Palm	
Food Crops	
Cassava	X
Maize	X
Plantain	X
Vegetables	
Cabbage	
Carrots	
Eggplant	
Okra	
Onions	
Other	
Specify 1:	
Specify 2:	
Specify 3:	

32. Which of the following crops do you grow during the minor growing season?
Note: Mark the crop grown with an X.

Crops	Grown During Minor Season
Cash Crop	
Cocoa	
Oil Palm	
Food Crops	
Cassava	X
Maize	X
Plantain	X
Vegetables	
Cabbage	
Carrots	
Eggplant	
Okra	X
Onions	
Other	
Specify 1:	
Specify 2:	
Specify 3:	

33. Do you purchase seed? (a) Yes b) No

If Yes,

33.1 Where do you purchase your seed?

a) From a local vendor (b) Outside the Impact Crater, Specify: Kumasi

If Outside the Impact Crater, Specify,

33.1.1 How far do you travel to purchase seed?

a) Less than 2-miles b) 2-5 miles c) 6-10 miles d) 11-30 miles e) 31-45 miles

f) 46-60 miles (g) Over 60 miles, Specify: _____

33.1.2 If seed was available locally, from a seed bank or seed vendor would you choose to purchase from one of these sources? (a) Yes b) No

If No,

33.1 Do you save your own seed from a previous harvest? a) Yes b) No

34. Are there any crops that you are currently not growing, but you wish you were able to grow?

(a) Yes b) No If Yes, Specify: Orange

34.1 What are the major obstacles that have hindered you from being able to grow the crops specified? Specify: Financial Problem

34.2 If a seed bank was available locally to purchase seed from, would you choose to purchase from this source?

(a) Yes b) No

35. If a nursery was available locally to purchase small plants or trees from, would you choose to purchase from this source?

(a) Yes Explain: _____

b) No Explain: _____

36. If a nursery was locally available what type of small plants or trees would you want to be able to purchase?

Specify: Beans

37. Are there specific crops you believe would be good cash crops? (a) Yes b) No

If Yes,

37.1 Specify: Orange

37.2 Where would you sell these crops? Specify: Kumasi

38. Do you practice slash & burn agriculture? (a) Yes b) No

If Yes,

38.1 How often? (a) Regularly b) Occasionally c) Once in a while

38.2 How many times do you practice slash and burn method per year? 2

38.3 Would you be willing to clear the brush, weeds, excess, without burning, and allow the brush, weeds, and excess to decompose on the field without slash burning?

(a) Yes b) No Explain: _____

38.4 Do you believe there is any benefit to allowing the brush to decompose on the field?

(a) Yes b) No Explain: _____

If No,

38.1 How do you clear your field before planting? Specify: _____

38.2 What do you do with the brush cleared from the field? Specify: _____

38.3 Do you allow the remaining brush that has been cleared to decompose on the field?

a) Yes b) No

39. Do you practice crop rotation? (a) Yes b) No

If Yes,

39.1 What crops do you use for crop rotation? Specify: Tomato + Okra

40. Do you practice any form of erosion control or slope protection? a) Yes (b) No

If Yes,

40.1 Explain: _____

41. Do you use any of the following agrochemicals for farming?

Inputs	Yes	No
Fertilizers	X	
Weedicides	X	
Pesticides	X	
Animal Droppings		

41.1 If Yes, how often? Didn't say

Inputs	Frequency Applied During Major Season	Frequency Applied During Minor Season
Fertilizers		
Weedicides		
Pesticides		
Animal Droppings		

41.2 If Yes, how many times do you apply during the major growing season?

Inputs	Frequency
Fertilizers	
Weedicides	
Pesticides	
Animal Droppings	

Didn't Say

41.3 If Yes, how many times do you apply during the minor growing season?

Inputs	Frequency
Fertilizers	
Weedicides	
Pesticides	
Animal Droppings	

Didn't say

41.4 Where do you purchase your agrochemicals for farming? Specify: Didn't Say

42. Do you water your crops? a) Yes (b) No
If Yes,

42.1 What time of year do you irrigate? Specify: _____

42.2 How many months out of the year do you irrigate?
a) Less than 1 b) 1-2 c) 3-4 d) 4-5 e) 6-7
f) More than 8

42.3 During a week that you irrigate, how much water do you apply to your field daily?
a) 0.5 in b) 0.75 in c) 1 in d) 1.5 in
e) Specify: _____

42.4 What water source do you use for irrigation?
a) Lake water b) Borehole c) Pipe borne water d) Bottled or Sashe water
e) Specify: _____
If Lake water,

Notes: Leaching is the practice of adding additional water to the field to push salts present in the soil past the plant's root zone, so as to not hinder crop growth.

42.3.1 Do you practice leaching? a) Yes b) No

If Yes,

42.3.2 Do you mix the lake water with another source of water before using the water for irrigation? a) Yes b) No

If Yes,

42.3.2.1 What is your other source that you mix the lake water with?

a) Lake water b) Borehole c) Pipe borne water
d) Bottled or Sashe water e) Specify: _____

42.3.2.2 Do you allow the water collected to sit over night before applying it to your field? a) Yes b) No

42.3.2.3 Do you believe there are any negative effects from using water from the lake long- term? a) Yes b) No

43. Do you participate in livestock rearing? (a) Yes b) No

If Yes,
43.1 What animal (s)?
Mark the animal raised with X for Yes raised

Animal	Yes	No
Goat		
Guinee Fowl		
Poultry for Eggs		
Poultry for Meat		
Piggery		
Cows for Beef		
Cows for Dairy		
Grass Cutter		
(Other): Specify	X Sheep	

43.1.1 The farmer raises chickens for eggs? a) Yes (b) No

43.2 Do you purchase animal feed? a) Yes (b) No

If Yes,

43.2.1 Where do you purchase your feed? Specify: _____

43.2.2 If animal feed was available locally would you choose to purchase from a local vendor? a) Yes b) No

If No,

43.2.1 Do you grow your own feed? (a) Yes b) No

43.1.2 Do you or a member of your household purchase eggs? a) Yes (b) No

If Yes,

43.1.2.1. Where do you purchase eggs? Specify: _____

43.1.2.2. How often do you purchase eggs during a week?

a) 1 b) 2 c) 3 d) 4 e) 5 f) daily

g) Specify: _____

43.1.2.3. For one week how much money does your household spend on eggs?

Specify: _____

If Yes for rearing poultry for eggs,

43.1.2 Do you or a member of your household sell the eggs produced? a) Yes b) No

If Yes,

43.1.3 Where do you sell your eggs?

a) Specify: _____

43.1.4 Do you package your eggs? a) Yes b) No

If Yes,

43.1.1.4.1. Describe packaging? a) plastic sack b) cardboard carton

c) Specify: _____

43.1.5 How many eggs do you sell in a week?

Place an X in the Egg Sold column. List Price of eggs.

List number for the Frequency.

Number of Eggs	Eggs Sold	Price for Eggs Only	Frequency of Sold per week
1-3			
4-6			
7-9			
10-12			
Other (Specify):			

43.1.6 Do you believe selling packaged eggs to the nearby hotels could be profitable? a) Yes b) No

44.3 Are your animals caged or free range? (a) Caged b) Free Range

c) Specify_____

44.4 How much is one of your animals sold for at market? Specify: 300 Gh¢

44.5 Where do you sell your animal(s)? Specify: Pipie

45. Is there any tourism facility in your community? a) Yes b) No
Specify: _____

If Yes,

45.1 What is the distance of the facility from the lake shores?
a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m
e) 400-500 m f) 500 m or greater

Section D. Water, Sanitation, & Hygiene

46. Have you bathed/washed in the lake before? a) Yes b) No

47. Do you believe your activities can affect the quality of the water in the lake? a) Yes b) No

48. Do you have a toilet facility in your house? a) Yes b) No

If Yes,
48.1 What is the distance of your toilet facility from the lake?
a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m
e) 400-500 m f) 500 m or greater

If No,
48.1 Where do you go to toilet? Public one

49. What is your main source of drinking water for your household?
a) Lake water b) Borehole c) Pipe borne water d) Bottled or Sashe water
e) Specify: _____

If from Lake,

49.1 Do you treat the water before drinking? a) Yes b) No

50. How many times in a week do you walk to collect water?
a) 1-2 times b) 2-3 times c) 3-4 times d) Over 4 times e) Specify: _____

51. What distance must you travel to collect drinking water?
a) Less than 20 m b) 20-50 m c) 50-100 m d) 100-400 m
e) 400-500 m f) 500 m or greater

52. What is the distance of your drinking water source from the lake?
a) Less than 20 m (b) 20-50 m c) 50-100 m d) 100-400 m
e) 400-500 m f) 500 m or greater

53. How much time does it take you to walk to your drinking water source?
a) Less than 5 minutes (b) 5-15 minutes c) 15-30 minutes
d) 30-45 minutes e) 45-60 minutes f) Over 60 minutes
g) Specify: _____

54. How many minutes on average do you stand in a que for water?
(a) Less than 5 minutes b) 5-15 minutes c) 15-30 minutes
d) 30-45 minutes e) 45-60 minutes f) Over 60 minutes
g) Specify: _____

55. How much water do you collect for domestic (liters)? Specify: 5 gallons

56. Do you have a roof gutter? (a) Yes b) No

If yes,

56.1 Do you collect the water that collects in the gutter into a central location/container?
(a) Yes b) No

If No,

56.1 Would having a roof gutter system be a benefit to you and your house-hold?
a) Yes b) No

If Yes,

56.1.1 How would it benefit you and your household? Specify: _____

If No,

56.1.1 Explain why you feel a roof gutter system would not be a benefit to you and your house-hold.
_____

57. Do you collect rainwater? (a) Yes b) No

If Yes,

57.1 How much rain water do you collect? Specify: 5 gallons

57.2. What do you use the rain water for? (a) Domestic use (b) Drinking c) Irrigation
d) Specify: _____

57.3 How do you collect the rainwater? Specify: With rober

Section E. Fishing

58. Have you observed any changes in the lake in recent years? a) Yes b) No
Give reasons for your answer:
_____

59. Do you engage in any fishing activity? a) Yes b) No
If yes,

59.1 How often do you go fishing/ fish mongering? _____

59.2. How long have you been engaged in fishing/ fish mongering? _____

59.3 How much do you make in a day if you go fishing? _____
59.4 How many people within your household are engaged in fishing activities?
Specify: _____

59.5 Are there any fishing programs in which you participate?

a) Yes b) No

If Yes,
59.5.1. Do you pay a fee to participate in this fishing program? a) Yes b) No

59.5.2. What benefits does this fishing program provide to you?
Specify: _____

If No,
59.5.1. If a small-scale fishing program existed, would you choose to participate?
a) Yes b) No Explain: _____

59.5.2. What benefits would you hope this fishing program would provide to you?
Specify: _____

59.5.3. Would you be willing to pay a small fee to participate in this fishing program?
a) Yes b) No Explain: _____

60. Has the change in fish catch from the lake affected your income? a) Yes b) No
If Yes,

60.1 How? _____

60.2 Is there any alternative source of livelihood program in your community? a) Yes b) No

If Yes,

60.2.1 Does this program allow you to utilize your knowledge and skills from fishing/fish mongering?
a) Yes b) No

61. The trend in size and fish catch shows that, fish stock is
a) Stable b) Decreasing c) Increasing
d) I don't know/ I feel unqualified to answer

62. In your opinion, what do you believe is the cause of the reduction or otherwise of fish stock in the lake? _____

APPENDIX C. REFERENCED TABLES

Supporting response reference tables are found in Appendix C. Examples of both the raw and cleaned survey data are portrayed in tabular form. The calculated aggregate response values for the entire survey and the per question response values are presented. The complete statistical analyses conducted in IBM SPSS are provided in tabular form. The decision matrix weighting and final ratings used to rank the potential programs are shown. Each of the four decision matrices created are exhibited in their entirety. A summary table of the results for all four decision matrices is provided.

Example Raw Survey Data

(1)_Village_Name	Pipie	Duase	Banso	Adwafo	Adjamam
(2)_Farmer_Number	1	10	5	3	2
(3)_Gender	male	male	female	male	male
(4)_Age_Group	41_60	41_60	41_60	over_60	21_40
(5)_Marital_Status	married	married	married	married	married
(6)_What_is_your_level_of_education	mslc_jhs	mslc_jhs	mslc_jhs	mslc_jhs	mslc_jhs
(7)_Number_of_people_per_household	over_10	4_6	1_3	4_6	1_3
(8)_Number_of_children_per_household	7_10	0	4_6	4_6	1_3
(9)_Number_of_children_per_household_under_the_age_of_5_years_old	1_3	0	0	4_6	0
(10)_Number_of_children_per_household_ages_6_10_years_old	7_10	0	1_3	1_3	0
(11)_Number_of_children_per_household_ages_11_15_years_old	0	0	1_3	1_3	1_3
(12)_Number_of_children_per_household_ages_15_18_years_old	0	0	1_3	0	0
(13)_What_do_you_do_for_a_living	farming	farming	farming other_specify	farming	farming__fish
(13)_Other_Specify			Trader		

(14)_What_is_your_annual_household_income	more_than_400_	more_than_400_	200-300_ghd	less_than_100_	300-400_ghd
(15)_Are_you_a_native_of_this_village	yes	yes	yes	yes	yes
(15.1)_How_long_have_you_lived_in_this_village	more_than_30_y	more_than_30_y	more_than_30_y	more_than_30_y	20-30_years
(16)_In_your_view_the_natural_land_use_cover_around_Lake_Bosomtwe_shows_that_it_is	decreasing	decreasing	decreasing	decreasing	decreasing
(17)_What_are_the_main_factors_that_affect_your_decisions_related_to_land_use_or_management_(over_the_last_30_years)	Mining	High population	Diseases to crop	Too many farming	Farming
(18)_In_your_view_if_you_think_land_cover_change_is_changing_what_should_be_done_to_prevent_the_situation	Provision of Fertilizer for farming	Nothing in mind	Chemicals to help prevent the diseases	Planting of trees	planting of trees
(19)_What_human_activities_have_you_observed_around_the_lake	Farming	Throwing refuse in the lake	Farming	Farming	Farming
(20)_What_do_you_believe_the_main_land_use_activity_is_within_your_village	Farming	Farming	Farming of oil palm and farming crops	Farming	Farming
(21)_Can_the_land_use_activities_within_the_watershed_affect_the_productivity_of_the_lake_long_term	yes	yes	yes	yes	yes

(22)_What_is_the_size_of_your_farm	more_than_4_ac	more_than_4_ac	more_than_4_ac	4_acres	1_acre
(23)_What_is_the_distance_of_your_farm_from_the_lake	20_50_m	500_m_or_great	500_m_or_great	100_400_m	less_than_20_m
(24)_Is_there_a_Farmer(s)_cooperative_in_your_area	no	no	no	yes	no
(24.1)_If_Yes_Are_you_a_member_of_the_local_Farmer(s)_Cooperative_in_your_area	N/A	N/A	N/A	no	N/A
(24.1)_If_No_Would_you_be_interes_e_if_one_was_created	yes	yes	yes	yes	yes
(25)_What_is_your_average_crop_yield_for_the_major_harvest	100_200_kg	50_100_kg	less_than_50_k	100_200_kg	50_100_kg
(26)_What_is_your_average_crop_yield_for_the_minor_harvest	50_100_kg	less_than_50_k	less_than_50_k	50_100_kg	less_than_50_k
(27)_Do_you_experience_any_loss_of_crop_due_to_post_harvest_loss_during_the_major_growing_season	yes	No	yes	No	yes
(27.1)_If_Yes_What_do_you_believe_are_the_main_contributing_factors_to_your_loss_of_crop	Poor road network to selling place		Diseases		Over production
(27.2)_What_is_your_average_crop_loss_during_the_major_growing_season	less_than_50_k		less_than_50_k		50_100_kg

(28)_Do_you_experience_any_loss_of_crop_due_to_post_harvest_loss_during_the_minor_growing_season	yes	No	yes	No	yes
(28.1)_What_do_you_believe_are_the_main_contributing_factors_to_your_loss_of_crop	Poor road network to selling place		Disease		Over production
(28.2)_What_is_your_average_crop_loss_during_the_minor_growing_season	less_than_50_k		less_than_50_k		less_than_50_k
(29)_What_time_of_the_year_do_you_prepare_your_lands_for_farming_during_the_major_growing_season	February	June	May	March	April
(30)_What_time_of_the_year_do_you_prepare_your_lands_for_farming_during_the_minor_growing_season	July	August	July	August	August
(31)_Which_of_the_following_crops_do_you_grow_during_the_major_growing_season	cassava maize plantain	cocoa maize plantain other_please_s	cocoa oil_palm cassava maize plantain	cassava maize plantain	cassava maize plantain
(32)_Which_of_the_following_crops_do_you_grow_during_the_minor_growing_season	cassava maize plantain okra		maize	onions	maize okra
(31.1)_Other_Pl ease_Specify_crops_grown_001 Major		Cocoyam			

(32.1)_Other_Please_Specify_crops_grown_Minor					
(33)_Do_you_purchase_seed	yes	no	yes	no	yes
(33.1)_If_Yes_Where_do_you_purchase_your_see	outside_of_lak		outside_of_lak		outside_of_lak
(33.1)_Specify_Where_do_you_purchase_your_seed	Kumasi		Ahafo Bogoso		Konongo
(33.1.1)_How_far_do_you_travel_to_purchase_seed	over_60_miles_		over_60_miles_		over_60_miles_
(33.1.2)_If_seed_was_available_locally_from_a_seed_bank_or_seed_vendor_would_you_choose_to_purchase_from_one_of_these_sources	yes		yes		yes
(33.1)_If_No_Do_you_save_your_own_seed_from_a_previous_harvest		yes		yes	N/A
(34)_Are_there_any_crops_that_you_are_not_currently_growing_but_wish_you_were_able_to_grow	yes	yes	yes	yes	yes
(34)_If_Yes_Specify	Orange	Pepper	Plantain oil palm	Orange and Coconut	Orange
(34.1)_What_are_the_major_obstacles_that_have_hindered_you_from_being_able_to_grow_the_crops_specified	Financial problem	Finances	Finances	Financial problem	Scarcity of land

(34.2)_If_a_seed_bank_was_available_locally_to_purchase_seed_from_would_you_choose_to_purchase_from_this_source	yes	yes	yes	yes	yes
(35)_If_a_nursery_was_available_locally_to_purchase_small_plants_or_trees_from_would_you_choose_to_purchase_from_this_source	yes	yes	yes	yes	yes
(36)_If_a_nursery_was_locally_available_what_type_of_small_plants_or_trees_would_you_want_to_be_able_to_purchase	Beans	Tomatoes peppers	Oil palm plantain	Orange	Cocoa
(37)_Are_there_specific_crops_you_believe_would_be_good_cash_crops	yes	yes	yes	yes	yes
(37.1)_If_Yes_Specify	Orange	Pepper	Cocoa	Orange	Orange and Cocoa
(37.2)_Where_would_you_sell_these_crops_Specify	Kumasi	Locally	Bekwi	Adwafo	Adjamam
(38)_Do_you_practice_slash_and_burn_agriculture	yes	no	yes	yes	yes
(38.1)_If_Yes_How_often	regularly		once_in_a_whil	regularly	regularly
(38.2)_How_many_times_do_you_practice_slash_and_burn_method_per_year	2		Once	2	1

(38.3)_Would_you_be_willing_to_clear_the_brush_weeds_and_excess_without_burning_and_allow_the_brush_weeds_and_excess_to_decompose_on_the_field_without_slash_burning	yes		yes	yes	no
(38.4)_Do_you_believe_there_is_any_benefit_to_allowing_the_brush_to_decompose_on_the_field	yes	yes	yes	yes	yes
(38.1)_If_No_How_do_you_clear_your_field_before_planting_Specify		Weeding			
(38.2)_What_do_you_do_with_the_brush_cleared_from_the_field_Specify		Let it decompose			
(38.3)_Do_you_allow_the_remaining_brush_that_has_been_cleared_to_decompose_on_the_field		yes			
(39)_Do_you_practice_crop_rotation	yes	no	yes	no	yes
(39.1)_If_Yes_What_crops_do_you_use_for_crop_rotation_Specify	Tomato and okra		Maize cassava		plantain
(40)_Do_you_practice_any_form_of_erosion_control_or_slope_protection	no	yes	no	no	no

(40.1)_If_Yes_Explain		allows weeds to block excess water			
(41)_Do_you_use_any_of_the_following_agrochemicals_for_farming	fertilzers weedicides pesticides	weedicides	fertilzers weedicides pesticides		weedicides
(41.1)_If_Yes_How_often					
(41.2)_If_Yes_How_many_times_do_you_apply_during_the_major_growing_season					
(41.3)_If_Yes_How_many_times_do_you_apply_during_the_minor_growing_season					
(41.4)_Where_do_you_purchase_your_agrochemicals_for_farming_Specify					
(42)_Do_you_water_your_crops	no	no	yes	no	no
(42.1)_If_Yes_What_time_of_year_do_you_irrigate_Specify			March		
(42.2)_How_many_months_out_of_the_year_do_you_irrigate			more_than_8		
(42.3)_During_a_week_that_you_irrigate_how_much_water_do_you_apply_to_your_field_daily			1_in		
(42.3)_Specify					

(42.4)_What_water_source_do_you_use_for_irrigation			lake_water		
(42.4)_Specify					
(42.3.1)_Do_you_practice_leaching			no		
(42.3.2)_If_Yes_Do_you_mix_the_lake_water_with_another_source_of_water_before_using_the_water_for_irrigation			no		
(42.3.2.1)_If_Yes_What_is_your_other_source_that_you_mix_the_lake_water_with					
(42.3.2.1)_Specify					
(42.3.2.2)_Do_you_allow_the_water_collected_to_sit_over_night_before_applying_it_to_your_field			yes		
(42.3.2.3)_Do_you_believe_there_are_any_negative_effects_from_using_water_from_the_lake_long_term			no		
(43)_Do_you_participate_in_livestock_rearing	yes	yes	yes	yes	yes
(43.1)_If_Yes_which_animals_do_you_r	other_specify	goat_poultry_for_me	goat	poultry_for_me	poultry_for_me
(43.1)_Specify	Sheep				
(43.1.1)_The_farmer_raises_chickens_for_eggs	no	no	no	no	no

(43.2)_Do_you_purchase_animal_feed	no	no	no	no	no
(43.2.1)_If_Yes_Where_do_you_purchase_your_feed					N/A
(43.2.2)_If_animal_feed_was_available_locally_would_you_choose_to_purchase_from_a_local_vendor					N/A
(43.2.1)_If_No_Do_you_grow_your_own_feed	yes	yes	yes	yes	yes
(43.1.2)_Do_you_or_a_member_of_your_household_purchase_eggs	no	no	yes	no	yes
(43.1.2.1)_Where_do_you_purchase_eggs		Bekwi	Bekwi		Konongo
(43.1.2.2)_How_often_do_you_purchase_eggs_during_a_week		2	1		1
(43.1.2.3)_For_one_week_how_much_money_does_your_household_spend_on_eggs		120	45		30 cedis
(43.1.2)_If_Yes_for_rearing_poultry_Do_you_or_a_member_of_your_household_sell_the_eggs_produced					
(43.1.3)_If_Yes_Where_do_you_sell_your_eggs_Specify					
(43.1.4)_Do_you_package_your_eggs					

(43.1.1.4.1)_If_Yes_Describe_the_packaging					
43.1.5)_How_many_eggs_do_you_sell_in_a_week					
(43.1.6)_Do_you_believe_selling_packaged_eggs_to_the_nearby_hotels_could_be_profitable					
(44.3)_Are_your_animals_caged_or_free_range	caged	caged	caged	caged	free_range
(44.4)_How_much_is_one_of_your_animals_sold_for_at_market_Specify	300 Ghd	300	200		
(44.5)_Where_do_you_sell_your_animal(s)_Specify	Pipie	Locally	Locally		
(45)_Is_there_any_tourism_facility_in_your_community	no	no	no	no	no
(45.1)_If_Yes_What_is_the_distance_from_the_lake_shores					
(46)_Have_you_bathed/washed_in_the_lake_before	yes	yes	yes	yes	yes
(47)_Do_you_believe_your_activities_can_affect_the_quality_of_the_water_in_the_lake	yes	yes	yes	yes	yes
(48)_Do_you_have_a_toilet_facility_in_your_house	no	no	no	no	no

(48.1)_If_Yes_What_is_the_distance_of_your_toilet_facility_from_the_lake					
(48.1)_If_No_where_do_you_go_to_toilet	Public one	Public toilet	Public toilet	public One	Public
(49)_What_is_your_main_source_of_drinking_water_for_your_household	borehole	borehole	other_specify	borehole	borehole
(49)_Specify			Stream		
(49.1)_Do_you_treat_the_water_before_drinking					
(50)_How_many_times_in_a_week_do_you_walk_to_collect_water	over_4_times	1_2_times	over_4_times	over_4_times	over_4_times
(50)_Specify					
(51)_What_distance_must_you_travel_to_collect_drinking_water	less_than_20_m	less_than_20_m	less_than_20_m	less_than_20_m	less_than_20_m
(52)_What_is_the_distance_of_your_drinking_water_source_from_the_lake	20_50_m	less_than_20_m	less_than_20_m	less_than_20_m	less_than_20_m
(53)_How_much_time_does_it_take_you_to_walk_to_your_drinking_water_source	5_15_minutes	less_than_5_mi	less_than_5_mi	less_than_5_mi	less_than_5_mi
(54)_How_many_minutes_on_average_do_you_stand_in_que_for_water	less_than_5_mi	less_than_5_mi	less_than_5_mi	5_15_minutes	less_than_5_mi
(55)_How_much_water_do_you_collect_for_domestic_use(liters)_Specify	5 Gallons		5 Gallons	6 Gallons	4 Gallons

(56)_Do_you_have_a_roof_gutter	yes	yes	no	yes	yes
(56.1)_If_No_Would_having_a_roof_gutter_sys			yes		N/A
(56.1.1)_Explain_why_you_feel_a_roof_gutter_system_would_not_be_a_benefit_to_you_and_your_household_Specify					
(56.1)_If_Yes_How_would_it_benefit_your_household_Specify			Collection of water		N/A
(56.1)_If_Yes_Do_you_collect_the_water_that_collects_in_the_gutter_into_a_central_location/container	yes	yes		yes	yes
(57)_Do_you_collect_rainwater	yes	yes	yes	yes	yes
(57.1)_If_Yes_How_much_rain_water_you_collect_Specify	5 Gallons	15 Gallons	10 Gallons	7 Buckets	3 Gallons
(57.2)_What_do_you_use_the_rain_water	domestic_use drinking	domestic_use	domestic_use drinking	domestic_use drinking	domestic_use
(57.2)_Specify					
(57.3)_How_do_you_collect_the_rainwater_Specify	with rober	with rober	gal containers	with bucket	with rober

(58)_Have_you_observed_any_changes_in_the_lake_in_recent_years	yes	yes	yes	yes	Yes
(59)_Do_you_engage_in_any_fishing_activity	no	no	no	no	yes
(59.1)_How_often_do_you_go_fishing/fish_mongering					2
(59.2)_How_long_have_you_been_engaged_in_fishing/fish_mongering					long time
(59.3)_How_much_do_you_make_in_a_day_if_you_go_fishing					80 Ghd
(59.4)_How_many_people_within_your_household_are_engaged_in_fishing_activites_Specify					1
(59.5)_Are_there_any_fishing_programs_in_which_you_participate					no
(59.5.1)_If_Yes_Do_you_pay_to_participate_in_this_fishing_program					
(59.5.1)_If_No_If_a_small_scale_fishing_program_existed_would_you_choose_to_participate					yes
(59.5.2)_If_Yes_What_benefits_does_this_fishing_program_provide_to_you_Specify					

(59.5.2)_What_benefits_would_you_hope_this_fishing_program_would_provide_to_you					it will provide income
(59.5.3)_Would_you_be_willing_to_pay_a_small_fee_to_participate_in_this_fishing_program					yes
(60)_Has_the_change_in_fish_catch_from_the_lake_affected_your_income					yes
(60.1)_If_yes_how					resulted in low income
(60.2)_Is_there_any_there_any_alterna					no
(60.2.1)_Does_this_program_allow_you_to_utilize_your_knowledge_and_skills_from_fishing/fish_mongering					
(61)_The_trend_in_size_and_fish_catch_shows_that_fish_stock_is					decreasing
(62)_In_you_opinion_what_do_you_believe_is_the_cause_of_the_reduction_or_otherwise_of_fish_stock_in_the_lake					weather conditions
POINT_X	-1.38324	-1.39486	-1.42939	-1.43702	-1.37142
POINT_Y	6.52911	6.47043	6.471726	6.527822	6.4937

Example Clean Survey Data

(1)_Village_Name	Pipie	Duase	Banso	Adwafo	Adjamam
(2)_Farmer_Number	1	10	5	3	2
(3)_Gender	male	male	female	male	male
(4)_Age_Group	41_60	41_60	41_60	over_60	21_40
(5)_Marital_Status	married	married	married	married	married
(6)_What_is_your_level_of_education	mslc_jhs	mslc_jhs	mslc_jhs	mslc_jhs	mslc_jhs
(7)_Number_of_people_per_household	over_10	4_6	1_3	4_6	1_3
(8)_Number_of_children_per_household	7_10	0	4_6	4_6	1_3
(9)_Number_of_children_per_household_under_the_age_of_5_years_old	1_3	0	0	4_6	0
(10)_Number_of_children_per_household_ages_6_10_years_old	7_10	0	1_3	1_3	0
(11)_Number_of_children_per_household_ages_11_15_years_old	0	0	1_3	1_3	1_3
(12)_Number_of_children_per_household_ages_15_18_years_old	0	0	1_3	0	0
(13)_What_do_you_do_for_a_living	farming	farming	farming_other_specify	farming	farming___fish
(13)_Other_Specify	N/A	N/A	Trader	N/A	N/A
(14)_What_is_your_annual_household_income	more_than_400_	more_than_400_	200_300_ghd	less_than_100_	300_400_ghd

(15)_Are_you_a_native_of_this_village	yes	yes	yes	yes	yes
(15.1)_How_long_have_you_lived_in_this_village	more_than_30_y	more_than_30_y	more_than_30_y	more_than_30_y	20_30_years
(16)_In_your_view_the_natural_land_use_cover_around_Lake_Bosomtwe_shows_that_it_is	decreasing	decreasing	decreasing	decreasing	decreasing
(17)_What_are_the_main_factors_that_affect_your_decisions_related_to_land_use_or_management_(over_the_last_30_years)	illegal mining	High population	Diseases to crops	too many people farming	traditional farming practices
(18)_In_your_view_if_you_think_land_cover_change_is_changing_what_should_be_done_to_prevent_the_situation	increase access to inputs	Nothing in mind	Crop disease prevention	Replant trees	Replant trees
Continued	N/A	N/A	Appropriate chemical application	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(19)_What_human_activities_have_you_observed_around_the_lake	Farming	Garbage Disposal	Farming	Farming	Farming
(20)_What_do_you_believe_the_main_land_use_activity_is_within_your_village	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture

(21)_Can_the_land_use_activities_within_the_watershed_affect_the_productivity_of_the_lake_long_term	yes	yes	yes	yes	yes
(22)_What_is_the_size_of_your_farm	more_than_4_ac	more_than_4_ac	more_than_4_ac	4_acres	1_acre
(23)_What_is_the_distance_of_your_farm_from_the_lake	20_50_m	500_m_or_great	500_m_or_great	100_400_m	less_than_20_m
(24)_Is_there_a_Farmer(s)_cooperative_in_your_area	no	no	no	yes	no
(24.1)_If_Yes_Are_you_a_member_of_the_local_Farmer(s)_Cooperative_in_your_area	N/A	N/A	N/A	no	N/A
(24.1)_If_No_Would_you_be_interes_e_if_one_was_created	yes	yes	yes	yes	yes
(25)_What_is_your_average_crop_yield_for_the_major_harvest	100_200_kg	50_100_kg	less_than_50_k	100_200_kg	50_100_kg
(26)_What_is_your_average_crop_yield_for_the_minor_harvest	50_100_kg	less_than_50_k	less_than_50_k	50_100_kg	less_than_50_k

(27)_Do_you_experience_any_loss_of_crop_due_to_post_harvest_loss_during_the_major_growing_season	yes	No	yes	No	yes
(27.1)_If_Yes_What_do_you_believe_are_the_main_contributing_factors_to_your_loss_of_crop	lack of options to transport produce	N/A	crop diseases	N/A	lack of storage facility for crops post-harvest
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(27.2)_What_is_your_average_crop_loss_during_the_major_growing_season	less_than_50_k	N/A	less_than_50_k	N/A	50_100_kg
(28)_Do_you_experience_any_loss_of_crop_due_to_post_harvest_loss_during_the_minor_growing_season	yes	No	yes	No	yes
(28.1)_What_do_you_believe_are_the_main_contributing_factors_to_your_loss_of_crop	lack of options to transport produce	N/A	crop diseases	N/A	lack of storage facility for crops post-harvest
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(28.2)_What_is_your_average_crop_loss_during_the_minor_growing_season	less_than_50_k	N/A	less_than_50_k	N/A	less_than_50_k

(29)_What_time_of_the_year_do_you_prepare_your_lands_for_farming_during_the_major_growing_season	February	June	May	March	April
(30)_What_time_of_the_year_do_you_prepare_your_lands_for_farming_during_the_minor_growing_season	July	August	July	August	August
(31)_Which_of_the_following_crops_do_you_grow_during_the_major_growing_season	cassava	cocoa	cocoa	cassava	cassava
Continued	maize	cassava	oil_palm	maize	maize
Continued	plantain	plantain	cassava	plantain	plantain
Continued	N/A	other_please_s	maize	N/A	N/A
Continued	N/A	N/A	plantain	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(31.1)_Other_Please_Specify_crops_grown_001 Major	N/A	Cocoyam	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(32)_Which_of_the_following_crops_do_you_grow_during_the_minor_growing_season	cassava	maize	maize	onions	maize
Continued	maize	N/A	N/A	N/A	okra
Continued	plantain	N/A	N/A	N/A	N/A
Continued	okra	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A

(32.1)_Other_Please_Specify_crops_grown_Minor	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(33)_Do_you_purchase_seed	yes	no	yes	no	yes
(33.1)_If_Yes_Where_do_you_purchase_your_see	outside_of_lak	N/A	outside_of_lak	N/A	outside_of_lak
(33.1)_Specify_Where_do_you_purchase_your_seed	Kumasi	N/A	Ahafo Bogoso	N/A	Konongo
(33.1.1)_How_far_do_you_travel_to_purchase_seed	over_60_miles_	N/A	over_60_miles_	N/A	over_60_miles_
(33.1.2)_If_seed_was_available_locally_from_a_seed_bank_or_seed_vendor_would_you_choose_to_purchase_from_one_of_these_sources	yes	N/A	yes	N/A	yes
(33.1)_If_No_Do_you_save_your_own_seed_from_a_previous_harvest	N/A	yes	N/A	yes	N/A

(34)_Are_there_any_crops_that_you_are_not_currently_growing_but_wish_you_were_able_to_grow	yes	yes	yes	yes	yes
(34)_If_Yes_Specify	orange	peppers	Plantain	orange	orange
Continued	N/A	tomatoes	oil palm	coconut	N/A
(34.1)_What_are_the_major_obstacles_that_have_hindered_you_from_being_able_to_grow_the_crops_specified	finances	finances	finances	finances	Scarcity of land
(34.2)_If_a_seed_bank_was_available_locally_to_purchase_seed_from_would_you_choose_to_purchase_from_this_source	yes	yes	yes	yes	yes
(35)_If_a_nursery_was_available_locally_to_purchase_small_plants_or_trees_from_would_you_choose_to_purchase_from_this_source	yes	Yes	Yes	Yes	yes
(36)_If_a_nursery_was_locally_available_what_type_of_small_plants_or_trees_would_you_want_to_be_able_to_purchase	Beans	Tomatoes	oil palm	Orange	Cocoa
Continued	N/A	peppers	plantain	N/A	N/A

(37)_Are_there_specific_crops_you_believe_would_be_good_cash_crops	yes	yes	yes	yes	yes
(37.1)_If_Yes_Specify	Orange	Tomatoes	Cocoa	Orange	Orange
Continued	N/A	peppers	N/A	N/A	Cocoa
(37.2)_Where_would_you_sell_these_crops_Specify	Kumasi	locally	Bekwai	locally	locally
(38)_Do_you_practice_slash_and_burn_agriculture	yes	no	yes	yes	yes
(38.1)_If_Yes_How_often	regularly	N/A	once_in_a_whil	regularly	regularly
(38.2)_How_many_times_do_you_practice_slash_and_burn_method_per_year	2	N/A	1	2	1
(38.3)_Would_you_be_willing_to_clear_the_brush_weeds_and_excess_without_burning_and_allow_the_brush_weeds_and_excess_to_decompose_on_the_field_without_slash_burning	yes	N/A	yes	yes	no
(38.4)_Do_you_believe_there_is_any_benefit_to_allowing_the_brush_to_decompose_on_the_field	yes	yes	yes	yes	yes
(38.1)_If_No_How_do_you_clear_your_field_before_planting_Specify	N/A	Weeding	N/A	N/A	N/A

(38.2)_What_do_you_do_with_the_brush_cleared_from_the_field_Specify	N/A	Let it decompose	N/A	N/A	N/A
(38.3)_Do_you_allow_the_remaining_brush_that_has_been_cleared_to_decompose_on_the_field	N/A	yes	N/A	N/A	N/A
(39)_Do_you_practice_crop_rotation	yes	no	yes	no	yes
(39.1)_If_Yes_What_crops_do_you_use_for_crop_rotation_Specify	tomatoes	N/A	maize	N/A	plantain
Continued	okra	N/A	cassava	N/A	N/A
(40)_Do_you_practice_any_form_of_erosion_control_or_slope_protection	no	yes	no	no	no
(40.1)_If_Yes_Explain	N/A	allows weeds to block excess water	N/A	N/A	N/A
(41)_Do_you_use_any_of_the_following_agrochemicals_for_farming	fertilzers	weedicides	fertilzers	i_do_not_use_any_of_the_above_	weedicides
Continued	weedicides	N/A	weedicides	N/A	N/A
Continued	pesticides	N/A	pesticides	N/A	N/A
(41.1)_If_Yes_How_often	Didn't say	Didn't say	Didn't say	Didn't say	Didn't say
(41.2)_If_Yes_How_many_times_do_you_apply_during_the_major_growing_season	Didn't say	Didn't say	Didn't say	N/A	Didn't say

(41.3)_If_Yes_How_many_times_do_you_apply_during_the_minor_growing_season	Didn't say	Didn't say	Didn't say	N/A	Didn't say
(41.4)_Where_do_you_purchase_your_agrochemicals_for_farming_Specify	Didn't say	Didn't say	Didn't say	N/A	Didn't say
(42)_Do_you_water_your_crops	no	no	yes	no	no
(42.1)_If_Yes_What_time_of_year_do_you_irrigate_Specify	N/A	N/A	March	N/A	N/A
(42.2)_How_many_months_out_of_the_year_do_you_irrigate	N/A	N/A	more_than_8	N/A	N/A
(42.3)_During_a_week_that_you_irrigate_how_much_water_do_you_apply_to_your_field_daily	N/A	N/A	1_in	N/A	N/A
(42.3)_Specify	N/A	N/A	N/A	N/A	N/A
(42.4)_What_water_source_do_you_use_for_irrigation	N/A	N/A	lake_water	N/A	N/A
(42.4)_Specify	N/A	N/A	N/A	N/A	N/A
(42.3.1)_Do_you_practice_leaching	N/A	N/A	no	N/A	N/A
(42.3.2)_If_Yes_Do_you_mix_the_lake_water_with_another_source_of_water_before_using_the_water_for_irrigation	N/A	N/A	no	N/A	N/A

(42.3.2.1)_If_Yes_What_is_your_other_source_that_you_mix_the_lake_water_with	N/A	N/A	N/A	N/A	N/A
(42.3.2.1)_Specify	N/A	N/A	N/A	N/A	N/A
(42.3.2.2)_Do_you_allow_the_water_collected_to_sit_over_night_before_applying_it_to_your_field	N/A	N/A	yes	N/A	N/A
(42.3.2.3)_Do_you_believe_there_are_any_negative_effects_from_using_water_from_the_lake_long_term	N/A	N/A	no	N/A	N/A
(43)_Do_you_participate_in_livestock_rearing	yes	yes	yes	yes	yes
(43.1)_If_Yes_which_animals_do_you_r	other_specify	goat	goat	poultry for meat	poultry for meat
(43.1)_Specify	sheep	N/A	N/A	N/A	N/A
Continued	N/A	poultry for meat	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(43.1.1)_The_farmer_raises_chickens_for_eggs	no	no	no	no	No
(43.2)_Do_you_purchase_animal_feed	no	no	no	no	no
(43.2.1)_If_Yes_Where_do_you_purchase_your_feed	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A

(43.2.2)_If_animal_feed_was_available_locally_would_you_choose_to_purchase_from_a_local_vendor	N/A	N/A	N/A	N/A	N/A
(43.2.1)_If_No_Do_you_grow_your_own_feed	yes	yes	yes	yes	yes
(43.1.2)_Do_you_or_a_member_of_your_household_purchase_eggs	no	yes	yes	no	yes
(43.1.2.1)_Where_do_you_purchase_eggs	N/A	Bekwai	Bekwai	N/A	Konongo
Continued	N/A	N/A	N/A	N/A	N/A
(43.1.2.2)_How_often_do_you_purchase_eggs_during_a_week	N/A	2	1	N/A	1
(43.1.2.3)_For_one_week_how_much_money_does_your_household_spend_on_eggs	N/A	120	45	N/A	30
(43.1.2)_If_Yes_for_rearing_poultry_Do_you_or_a_member_of_your_household_sell_the_eggs_produced	N/A	N/A	N/A	N/A	N/A
(43.1.3)_If_Yes_Where_do_you_sell_your_eggs_Specify	N/A	N/A	N/A	N/A	N/A
(43.1.4)_Do_you_package_your_eggs	N/A	N/A	N/A	N/A	N/A
(43.1.1.4.1)_If_Yes_Describe_the_packaging	N/A	N/A	N/A	N/A	N/A

(43.1.5)_How_many_eggs_do_you_sell_in_a_week	N/A	N/A	N/A	N/A	N/A
(43.1.6)_Do_you_believe_selling_packaged_eggs_to_the_nearby_hotels_could_be_profitable	N/A	N/A	N/A	N/A	N/A
(44.3)_Are_your_animals_caged_or_free_range	caged	caged	caged	caged	free_range
(44.4)_How_much_is_one_of_your_animals_sold_for_at_market_Specify	300	600, 400 per goat, 200 per meat chicken	200	Didn't say	Didn't say
Goat Price	N/A	400	200	N/A	N/A
Poultry for Eggs Price	N/A	N/A	N/A	N/A	N/A
Poultry for Eggs Meat Price	N/A	200	N/A	30	20
Pig Price	N/A	N/A	N/A	N/A	N/A
Cow for Beef Price	N/A	N/A	N/A	N/A	N/A
Sheep Price	300	N/A	N/A	N/A	N/A
(44.5)_Where_do_you_sell_your_animal(s)_Specify	Locally	Locally	Locally	Didn't say	Didn't say
Continued	N/A	N/A	N/A	N/A	N/A
(45)_Is_there_any_tourism_facility_in_your_community	no	no	no	no	no
(45.1)_If_Yes_What_is_the_distance_from_the_lake_shores	N/A	N/A	N/A	N/A	N/A
(46)_Have_you_bathed/washed_in_the_lake_before	yes	yes	yes	yes	yes

(47)_Do_you_believe_your_activities_can_affect_the_quality_of_the_water_in_the_lake	yes	yes	yes	yes	yes
(48)_Do_you_have_a_toilet_facility_in_your_house	no	no	no	no	no
(48.1)_If_Yes_What_is_the_distance_of_your_toilet_facility_from_the_lake	N/A	N/A	N/A	N/A	N/A
(48.1)_If_No_where_do_you_go_to_toilet	Community pit latrine	Community pit latrine	Community pit latrine	Community pit latrine	Community pit latrine
(49)_What_is_your_main_source_of_drinking_water_for_your_household	borehole	borehole	other_specify	borehole	borehole
(49)_Specify	N/A	N/A	Nearby stream	N/A	N/A
(49.1)_Do_you_treat_the_water_before_drinking	N/A	N/A	N/A	N/A	N/A
(50)_How_many_times_in_a_week_do_you_walk_to_collect_water	over_4_times	2-3_times	over_4_times	over_4_times	over_4_times
(50)_Specify	N/A	N/A	N/A	N/A	N/A
(51)_What_distance_must_you_travel_to_collect_drinking_water	less_than_20_m	less_than_20_m	less_than_20_m	less_than_20_m	less_than_20_m
(52)_What_is_the_distance_of_your_drinking_water_source_from_the_lake	20_50_m	less_than_20_m	less_than_20_m	less_than_20_m	less_than_20_m

(53)_How_much_time_does_it_take_you_to_walk_to_your_drinking_water_source	5_15_minutes	less_than_5_mi	less_than_5_mi	less_than_5_mi	less_than_5_mi
(54)_How_many_minutes_on_average_do_you_stand_in_que_for_water	less_than_5_mi	5_15_minutes	less_than_5_mi	5_15_minutes	less_than_5_mi
(55)_How_much_water_do_you_collect_for_domestic_use(liters)_Specify	5 Gallons	1 Gallon	5 Gallons	6 Gallons	4 Gallons
(55)_Conversion_Amount_of_water_collected_ for_ domestic_ use_ (L)	100	20	100	120	80
(56)_Do_you_have_a_roof_gutter	yes	yes	no	yes	yes
(56.1)_If_No_ Would_having_a_roof_gutter_sys	N/A	N/A	yes	N/A	N/A
(56.1.1)_Explain_why_you_feel_a_roof_gutter_system_would_not_be_a_benefit_to_you_and_your_household_Specify	N/A	N/A	N/A	N/A	N/A
(56.1)_If_Yes_ How_would_it_benefit_your_household_Specify	N/A	N/A	Collection of water	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(56.1)_If_Yes_ Do_you_collect_the_water_that_collects_in_the_gutter_into_a_central_location/container	yes	yes	N/A	yes	yes

(57)_Do_you_collect_rainwater	yes	yes	yes	yes	yes
(57.1)_If_Yes_How_much_rain_water_you_collect_Specify	5 Gallons	2 Gallons	10 Gallons	7 Buckets	3 Gallons
(57.1)_Amount of rain water collected (L)	100	40	200	70	60
(57.2)_What_do_you_use_the_rain_water	domestic_use	domestic_use	domestic_use	domestic_use	domestic_use
Continued	drinking	N/A	drinking	drinking	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(57.2)_Specify	N/A	N/A	N/A	N/A	N/A
(57.3)_How_do_you_collect_the_rainwater_Specify	large rober	large rober	gallon containers	bucket	large rober
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(58)_Have_you_observed_any_changes_in_the_lake_in_recent_years	yes	yes	yes	yes	yes
(59)_Do_you_engage_in_any_fishing_activity	no	no	no	no	yes
(59.1)_How_often_do_you_go_fishing/fish_mongering	N/A	N/A	N/A	N/A	10
(59.2)_How_long_have_you_been_engaged_in_fishing/fish_mongering	N/A	N/A	N/A	N/A	15
(59.3)_How_much_do_you_make_in_a_day_if_you_go_fishing	N/A	N/A	N/A	N/A	80

(59.4)_How_many_people_within_your_household_are_engaged_in_fishing_activites_Specify	N/A	N/A	N/A	N/A	1
(59.5)_Are_there_any_fishing_programs_in_which_you_participate	N/A	N/A	N/A	N/A	no
(59.5.1)_If_Yes_Do_you_pay_to_participate_in_this_fishing_program	N/A	N/A	N/A	N/A	N/A
(59.5.1)_If_No_If_a_small_scale_fishing_program_existed_would_you_choose_to_participate	N/A	N/A	N/A	N/A	yes
(59.5.2)_If_Yes_What_benefits_does_this_fishing_program_provide_to_you_Specify	N/A	N/A	N/A	N/A	N/A
(59.5.2)_What_benefits_would_you_hope_this_fishing_program_would_provide_to_you	N/A	N/A	N/A	N/A	increase income
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(59.5.3)_Would_you_be_willing_to_pay_a_small_fee_to_participate_in_this_fishing_program	N/A	N/A	N/A	N/A	yes
(60)_Has_the_change_in_fish_catch_from_the_lake_affected_your_income	N/A	N/A	N/A	N/A	yes

(60.1)_If_yes_how	N/A	N/A	N/A	N/A	loss of income
Continued	N/A	N/A	N/A	N/A	N/A
Continued	N/A	N/A	N/A	N/A	N/A
(60.2)_Is_there_any_there_any_alterna	N/A	N/A	N/A	N/A	no
(60.2.1)_Does_this_program_allow_you_to_utilize_your_knowledge_and_skills_from_fishing/fish_mongering	N/A	N/A	N/A	N/A	N/A
(61)_The_trend_in_size_and_fish_catch_shows_that_fish_stock_is	N/A	N/A	N/A	N/A	decreasing
(62)_In_you_opinion_what_do_you_believe_is_the_cause_of_the_reduction_or_otherwise_of_fish_stock_in_the_lake	N/A	N/A	N/A	N/A	climate variability
POINT_X	-1.38324	-1.39486	-1.42939	-1.43701736	-1.37142
POINT_Y	6.52911	6.47043	6.471726	6.527821974	6.4937

SPSS Results

An alpha level of 0.05 was used for all SPSS tests.

T-Test Road Access & Yield for 6 Villages

Note: Villages with Road Access Adwafo, Obbo, Pipie Value (1)
Villages without Road Access Esaase, Banso, Duase Value (0)

Village Name	Road Access	Yield (kg)	Usable Yield (kg)		Village Name	Road Access	Yield (kg)	Usable Yield (kg)
Adwafo	1	400	0		Esaase	0	225	0
Adwafo	1	325	100		Esaase	0	225	75
Adwafo	1	150	0		Esaase	0	225	75
Adwafo	1	500	350		Esaase	0	225	75
Adwafo	1	400	300		Esaase	0	150	0
Adwafo	1	300	300		Esaase	0	325	175
Adwafo	1	225	225		Esaase	0	100	0
Adwafo	1	225	225		Esaase	0	100	50
Adwafo	1	50	50		Esaase	0	50	0
Adwafo	1	400	400		Esaase	0	325	0
Obbo	1	150	0		Banso	0	150	75
Obbo	1	150	0		Banso	0	225	125
Obbo	1	225	225		Banso	0	175	75
Obbo	1	150	150		Banso	0	50	0
Obbo	1	175	75		Banso	0	50	0
Obbo	1	400	300		Banso	0	275	200
Obbo	1	250	0		Banso	0	150	150
Obbo	1	225	225		Banso	0	225	225
Obbo	1	325	325		Banso	0	325	325
Pipie	1	300	0		Banso	0	50	50
Pipie	1	300	0		Duase	0	500	275
Pipie	1	400	100		Duase	0	225	75
Pipie	1	150	0		Duase	0	100	50
Pipie	1	150	150		Duase	0	500	0
Pipie	1	400	300		Duase	0	75	50
Pipie	1	225	175		Duase	0	25	0
Pipie	1	100	50		Duase	0	225	225
Pipie	1	500	0		Duase	0	225	225
Pipie	1	150	75		Duase	0	100	100
					Duase	0	100	100

Group Statistics					
Road		N	Mean	Std. Deviation	Std. Error Mean
Yield	No Road	30	190.00	121.698	22.219
	Road	29	265.52	121.452	22.553

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Yield	Equal variances assumed	0.222	0.639	-2.385	57	0.020	-75.517	31.661	-138.916	-12.118
	Equal variances not assumed			-2.385	56.940	0.020	-75.517	31.659	-138.916	-12.119

T-Test Road Access & Usable Yield for 6 Villages

Note: Villages with Road Access Adwafo, Obbo, Pipie Value (1)
Villages without Road Access Esaase, Banso, Duase Value (0)

Group Statistics					
Road		N	Mean	Std. Deviation	Std. Error Mean
PHL	No Road	30	92.50	92.650	16.916
	Road	29	141.38	131.318	24.385

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PHL	Equal variances assumed	7.856	0.007	-1.657	57	0.103	-48.879	29.507	-107.965	10.207
	Equal variances not assumed			-1.647	50.206	0.106	-48.879	29.678	-108.483	10.724

Pearson Chi-square test Gender & Schooling

Gender	Schooling	Frequency
0	0	11
0	1	29
1	0	24
1	1	54

Note: Gender Female Value Assigned (0)
Gender Male Value Assigned (1)
Lower than JHS Value (0)
JHS Level or Higher Value (1)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Gender * Schooling	118	100.0%	0	0.0%	118	100.0%

Gender * Schooling Crosstabulation

			Schooling		
			Lower than JHS	JHS or Higher	Total
Gender	Female	Count	11	29	40
		Expected Count	11.9	28.1	40.0
		% within Gender	27.5%	72.5%	100.0%
		% within Schooling	31.4%	34.9%	33.9%
		% of Total	9.3%	24.6%	33.9%
		Standardized Residual	-0.3	0.2	
	Male	Count	24	54	78
		Expected Count	23.1	54.9	78.0
		% within Gender	30.8%	69.2%	100.0%
		% within Schooling	68.6%	65.1%	66.1%
		% of Total	20.3%	45.8%	66.1%
		Standardized Residual	0.2	-0.1	
Total		Count	35	83	118
		Expected Count	35.0	83.0	118.0
		% within Gender	29.7%	70.3%	100.0%
		% within Schooling	100.0%	100.0%	100.0%
		% of Total	29.7%	70.3%	100.0%

Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.135[a]	1	0.713		
Continuity Correction[b]	0.024	1	0.877		
Likelihood Ratio	0.136	1	0.712		
Fisher's Exact Test				0.832	0.442
Linear-by-Linear Association	0.134	1	0.714		
N of Valid Cases	118				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.86.

b. Computed only for a 2x2 table

Directional Measures						
			Value	Asymptotic Standard Error[a]	Approximate T	Approximate Significance
Nominal by Nominal	Lambda	Symmetric	0.000	0.000	.[b]	.[b]
		Gender Dependent	0.000	0.000	.[b]	.[b]
		Schooling Dependent	0.000	0.000	.[b]	.[b]
	Goodman and Kruskal tau	Gender Dependent	0.001	0.006		.714[c]
		Schooling Dependent	0.001	0.006		.714[c]

a. Not assuming the null hypothesis.

b. Cannot be computed because the asymptotic standard error equals zero.

c. Based on chi-square approximation

Symmetric Measures			
		Value	Approximate Significance
Nominal by Nominal	Phi	-0.034	0.713
	Cramer's V	0.034	0.713
	Contingency Coefficient	0.034	0.713
N of Valid Cases		118	

Pearson Chi-square test Participants that Bathe & Wash in the lake and Fish

Bathing & Washing	Fishing	Frequency
1	1	32
1	0	58
0	1	1
0	0	27

Note: Participation in Bathing & Washing in the Lake Value (1)
No Participation in Bathing & Washing in the Lake Value (0)
Participation in Fishing Value Assigned (1)
No Participation in Fishing Value Assigned (0)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Bathe * Fishing	118	100.0%	0	0.0%	118	100.0%

Bathe * Fishing Crosstabulation

			Fishing		
			No Fish	Yes Fish	Total
Bathe	No	Count	27	1	28
		Expected Count	20.2	7.8	28.0
		% within Bathe	96.4%	3.6%	100.0%
		% within Fishing	31.8%	3.0%	23.7%
		% of Total	22.9%	0.8%	23.7%
		Standardized Residual	1.5	-2.4	
	Yes	Count	58	32	90
		Expected Count	64.8	25.2	90.0
		% within Bathe	64.4%	35.6%	100.0%
		% within Fishing	68.2%	97.0%	76.3%
		% of Total	49.2%	27.1%	76.3%
		Standardized Residual	-.8	1.4	
Total		Count	85	33	118
		Expected Count	85.0	33.0	118.0
		% within Bathe	72.0%	28.0%	100.0%
		% within Fishing	100.0%	100.0%	100.0%
		% of Total	72.0%	28.0%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.845[a]	1	.001		
Continuity Correction[b]	9.315	1	.002		
Likelihood Ratio	14.086	1	.000		
Fisher's Exact Test				.001	.000
N of Valid Cases	118				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.83.

b. Computed only for a 2x2 table

Directional Measures

			Value	Asymptotic Standard Error[a]	Approximate T	Approximate Significance
Nominal by Nominal	Lambda	Symmetric	.000	.000	.[b]	.[b]
		Bathe Dependent	.000	.000	.[b]	.[b]
		Fishing Dependent	.000	.000	.[b]	.[b]
	Goodman and Kruskal tau	Bathe Dependent	.092	.030		.001[c]
		Fishing Dependent	.092	.031		.001[c]

a. Not assuming the null hypothesis.

b. Cannot be computed because the asymptotic standard error equals zero.

c. Based on chi-square approximation

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.303	.001
	Cramer's V	.303	.001
	Contingency Coefficient	.290	.001
N of Valid Cases		118	

Respondent Table

Survey Summary Respondent Results

% of Applicants that Qualified to Answer all questions	% of Applicants that Completed the survey
66%	100%

Survey Respondence Results Per Question

Question Number	Count N/A	% Qualified	% Completed
1	0	100%	100%
2	0	100%	100%
3	0	100%	100%
4	0	100%	100%
5	0	100%	100%
6	0	100%	100%
7	0	100%	100%
8	0	100%	100%
9	0	100%	100%
10	0	100%	100%
11	0	100%	100%
12	0	100%	100%
13	0	100%	100%
14	0	100%	100%
15	0	100%	100%
15.1	5	96%	100%
16	0	100%	100%
17	0	100%	100%
18	17	86%	100%
19	0	100%	100%
20	0	100%	100%
21	0	100%	100%
22	0	100%	100%
23	0	100%	100%
24	0	100%	100%
24.1	0	100%	100%
24.1	0	100%	100%
25	0	100%	100%
26	11	91%	100%
27	0	100%	100%
27.1	34	71%	100%
27.2	34	71%	100%
28	10	92%	100%
28.1	47	60%	100%
28.2	48	59%	100%
29	0	100%	100%
30	11	91%	100%
31	0	100%	100%

Question Number	Count N/A	% Qualified	% Completed
32	16	86%	100%
33	0	100%	100%
33.1	39	67%	100%
33.1.1	39	67%	100%
33.1.2	39	67%	100%
33.1	79	33%	100%
34	0	100%	100%
34.1	13	89%	100%
34.2	0	100%	100%
35	0	100%	100%
36	39	67%	100%
37	0	100%	100%
37.1	41	65%	100%
37.2	41	65%	100%
38	0	100%	100%
38.1	9	92%	100%
38.2	9	92%	100%
38.3	9	92%	100%
38.4	0	100%	100%
38.1	111	6%	100%
38.2	112	5%	100%
38.3	112	5%	100%
39	0	100%	100%
39.1	0	100%	100%
40	0	100%	100%
40.1	101	14%	100%
41	0	100%	100%
41.1	0	100%	100%
41.2	34	71%	100%
41.3	34	71%	100%
41.4	34	71%	100%
42	0	100%	100%
42.1	105	11%	100%
42.2	105	11%	100%
42.3	108	8%	100%
42.4	105	11%	100%
42.3.1	112	5%	100%
42.3.2	112	5%	100%

Question Number	Count N/A	% Qualified	% Completed
42.3.2.1	117	1%	100%
42.2.2	112	5%	100%
42.2.3	112	5%	100%
43	0	100%	100%
43.1	29	75%	100%
43.1.1	0	100%	100%
43.2	1	99%	100%
43.2.1	98	17%	100%
43.2.2	99	16%	100%
43.2.1	22	81%	100%
43.1.2	14	88%	100%
43.1.2.1	89	25%	100%
43.1.2.2	89	25%	100%
43.1.2.3	89	25%	100%
43.1.2	110	7%	100%
43.1.3	117	1%	100%
43.1.4	117	1%	100%
43.1.4.1	117	1%	100%
43.1.5	117	1%	100%
43.1.6	110	7%	100%
44.3	28	76%	100%
44.4	28	76%	100%
44.5	28	76%	100%
45	0	100%	100%
45.1	112	5%	100%
46	0	100%	100%
47	0	100%	100%
48	0	100%	100%
48.1	94	20%	100%
48.1	24	80%	100%
49	2	98%	100%
49.1	117	1%	100%
50	1	99%	100%
51	2	98%	100%
52	2	98%	100%
53	2	98%	100%
54	2	98%	100%
55	5	96%	100%

Question Number	Count N/A	% Qualified	% Completed
56	2	98%	100%
56.1	89	25%	100%
56.1	30	75%	100%
56.1.1	93	21%	100%
56.1.1	117	1%	100%
57	2	98%	100%
57.1	12	90%	100%
57.2	7	94%	100%
57.3	7	94%	100%
58	0	100%	100%
59	0	100%	100%
59.1	85	28%	100%
59.2	85	28%	100%
59.3	85	28%	100%
59.4	85	28%	100%
59.5	85	28%	100%
59.5.1	116	2%	100%
59.5.2	116	2%	100%
59.5.1	87	26%	100%
59.5.2	87	26%	100%
59.5.3	87	26%	100%
60	85	28%	100%
60.1	87	26%	100%
60.2	86	27%	100%
60.2.1	114	3%	100%
61	85	28%	100%
62	85	28%	100%

Yield and Loss Data Weights Per Crop Combination

For the Ashanti Region of Ghana, MOFA reported cassava 49%, maize 6% and plantain 14% contributed to the total production of major crops (MOFA & SRID, 2011).

Note: Cassava – C, Maize – M, Plantain – P, Other - O

C+O		
Scale Value		1.8
	Based Off Data	Values Scaled
Cassava	49%	89%
Other	6%	11%

P+O		
Scale Value		5
	Based Off Data	Values Scaled
Plantain	14%	70%
Other	6%	30%

M+O		
Scale Value		8.3
	Based Off Data	Values Scaled
Maize	6%	50%
Other	6%	50%

C+M		
Scale Value		1.87
	Based Off Data	Values Scaled
Cassava	49%	92%
Maize	6%	8%

M+P		
Scale Value		5
	Based Off Data	Values Scaled
Maize	6%	30%
Plantain	14%	70%

P+M+O		
Scale Value		3.84
	Based Off Data	Values Scaled
Plantain	14%	54%
Maize	6%	23%
Other	6%	23%

P+M+O		
	Based Off Data	Values Scaled
Plantain	14%	54%
Maize	6%	23%
Other	6%	23%

M+O+O		
Scale Value		5.53
	Based Off Data	Values Scaled
Maize	6.0%	33.2%
Other	6.0%	33.2%
Other	6.0%	33.2%

P+M+O+O		
Scale Value		3.13
	Based Off Data	Values Scaled
Plantain	14%	44%
Maize	6%	19%
Other	6%	19%
Other	6%	19%

C+M+P		
Scale Value		1.45
	Based Off Data	Values Scaled
Cassava	49%	71%
Maize	6%	9%
Plantain	14%	20%

C+M+O		
Scale Value		1.65
	Based Off Data	Values Scaled
Cassava	49%	81%
Maize	6%	10%
Other	6%	9%

C+P+O		
Scale Value		1.45
	Based Off Data	Values Scaled
Cassava	49%	71%
Plantain	14%	20%
Other	6%	9%

C+P+O		
Scale Value		1.45
	Based Off Data	Values Scaled
Cassava	49%	72%
Plantain	14%	20%
Other	6%	8%

C+P+O+O		
Scale Value		1.33
	Based Off Data	Values Scaled
Cassava	49%	65%
Plantain	14%	19%
Other	6%	8%
Other	6%	8%

C+M+P+O		
Scale Value		1.3
	Based Off Data	Values Scaled
Cassava	49%	65%
Maize	6%	8%
Plantain	14%	19%
Other	6%	8%

C+M+P+O+O		
Scale Value		1.24
	Based Off Data	Values Scaled
Cassava	49%	61%
Maize	6%	7%
Plantain	14%	17%
Other	6%	7%
Other	6%	7%

C+M+P+O+O+O		
Scale Value		1.5
	Based Off Data	Values Scaled
Cassava	49%	51%
Maize	6%	7%
Plantain	14%	15%
Other	6%	9%
Other	6%	9%
Other	6%	9%

Decision Matrix Weight, Rating, & Results

Decision Matrix Weight & Rating Description

Weight	Description	Rating	Description
0	Don't Know	0	Don't Know
1	Not at all important	1	Not a good fit
2	Not very important	2	Low fit
3	Somewhat important	3	Fit
4	Important	4	Good fit
5	Very important	5	Excellent fit

Decision Matrix: Farm Components

Decision Factors		Seed Bank	Nursery	Micro-Finance Union	Appropriate Technology Center	Demonstration Plots
Criteria	Wt.					
Increased GDP potential (Local people)	5.0	15	15	25	25	20
Increases Employment opportunities	5.0	15	15	15	15	15
Increases equal opportunities for Women	3.0	6	6	12	9	6
Increases access to health care (Local people)	3.0	3	3	9	12	6
Increases Community Collaboration	4.0	8	8	12	16	8
Increases Farmers Knowledge Base	4.0	16	16	20	20	20
Increases Technology Transfer	4.0	16	16	20	20	16
Number of People Positively Impacted	5.0	15	15	25	20	20
Increases Clinic/Farm Revenue	5.0	25	25	10	15	15
Decreases Non-Point Pollution (Lake)	5.0	5	5	20	20	25
Decreases Point Source Pollution (Lake)	5.0	5	5	20	20	10
Promotes protection of the environment	5.0	10	10	15	20	25
Promotes Land Restoration	5.0	15	15	15	20	25

Decision Factors		Seed Bank	Nursery	Micro-Finance Union	Appropriate Technology Center	Demonstration Plots
Criteria	**Wt.**					
Increases Crop Diversification	4.0	20	20	12	8	20
Promotes adoption of diversifying diets	4.0	12	12	8	8	16
Promotes access to better sanitation	4.0	4	4	12	16	8
Decreases child mortality rate under the age of 5	3.0	3	3	9	12	6
Culturally Acceptable	5.0	15	15	15	25	20
Feasibility	4.0	12	12	16	16	16
Longevity	4.0	16	16	16	16	12
Up front low Cost	4.0	12	12	8	8	12
Materials available in Country	4.0	12	12	16	12	12
High Community Interest	5.0	25	15	25	15	25
Weighted Scores		285.0	275.0	355.0	**368.0**	358.0
Priority		**5**	**4**	**3**	**1**	**2**

Decision Matrix: Appropriate Technology Center

Decision Factors		PICS Bags	Low-Cost Dryers	Moisture Meters	Above ground aquaculture	Roof Rain Water Harvesting	Low-Cost Irrigation Systems	Low-Cost in-home toilet options	Pit Latrine Maintenance Care	Hand Washing Station(s)
Criteria	Wt.									
Increased GDP potential (Local people)	5.0	20	20	20	20	15	20	10	10	10
Increases Employment opportunities	5.0	20	20	20	20	15	15	15	15	10
Increases equal opportunities for Women	3.0	9	9	9	9	6	6	6	6	6
Increases access to health care (Local people)	3.0	6	6	6	6	6	6	6	12	12
Increases Community Collaboration	4.0	8	12	8	12	8	8	8	12	12
Increases Farmers Knowledge Base	4.0	16	16	20	16	12	12	4	4	4

Decision Factors		PICS Bags	Low-Cost Dryers	Moisture Meters	Above ground aquaculture	Roof Rain Water Harvesting	Low-Cost Irrigation Systems	Low-Cost in-home toilet options	Pit Latrine Maintenance Care	Hand Washing Station(s)
Criteria	Wt.									
Increases Technology Transfer	4.0	16	12	16	12	8	8	12	12	12
Number of People Positively Impacted	5.0	20	10	20	10	10	10	10	15	15
Increases Clinic/Farm Revenue	5.0	25	15	20	15	15	15	5	5	5
Decreases Non-Point Pollution (Lake)	5.0	5	5	5	5	5	15	15	15	15
Decreases Point Source Pollution (Lake)	5.0	5	5	5	20	15	15	20	20	25
Promotes protection of the environment	5.0	10	10	10	20	15	10	20	20	20
Promotes Land Restoration	5.0	10	10	10	20	10	10	15	15	20

Decision Factors		PICS Bags	Low-Cost Dryers	Moisture Meters	Above ground aquaculture	Roof Rain Water Harvesting	Low-Cost Irrigation Systems	Low-Cost in-home toilet options	Pit Latrine Maintenance Care	Hand Washing Station(s)
Criteria	Wt.									
Increases Crop Diversification	4.0	12	12	8	4	4	12	4	4	4
Promotes adoption of diversifying diets	4.0	12	12	8	16	8	8	4	4	4
Promotes access to better sanitation	4.0	8	8	8	8	12	8	20	20	20
Decreases child mortality rate under the age of 5	3.0	12	9	12	9	6	3	12	12	12
Culturally Acceptable	5.0	25	15	20	15	20	15	15	15	15
Feasibility	4.0	16	8	16	4	12	12	8	12	12
Longevity	4.0	16	16	16	12	16	12	12	12	8

Decision Factors		PICS Bags	Low-Cost Dryers	Moisture Meters	Above ground aquaculture	Roof Rain Water Harvesting	Low-Cost Irrigation Systems	Low-Cost in-home toilet options	Pit Latrine Maintenance Care	Hand Washing Station(s)
Criteria	**Wt.**									
Up front low Cost	4.0	12	12	16	12	8	8	8	8	12
Materials available in Country	4.0	20	8	12	8	16	16	12	16	16
High Rate of Adoption	4.0	16.0	12.0	16.0	12.0	12.0	12.0	8.0	12.0	12.0
High Community Interest	5.0	20	20	15	15	10	20	10	10	10
Weighted Scores		**339.0**	282.0	316.0	300.0	264.0	276.0	259.0	286.0	291.0
Priority		**1**	**6**	**2**	**3**	**8**	**7**	**9**	**5**	**4**

Decision Matrix: Demonstration Plots

Decision Factors		Terracing/Erosion Control	Crop Rotation	Cover Crops	Raised Beds (Vegetables)	Crops for Animal Feed/Caged Livestock	Slope Crops (Crops that grow well with high inclines)
Criteria	Wt.						
Increased GDP potential (Local people)	5.0	15	15	15	15	15	15
Increases Employment opportunities	5.0	10	10	10	15	15	15
Increases equal opportunities for Women	3.0	6	6	6	6	6	6
Increases access to health care (Local people)	3.0	6	6	6	6	6	6
Increases Community Collaboration	4.0	8	8	8	8	8	8
Increases Farmers Knowledge Base	4.0	20	20	20	16	16	16
Increases Technology Transfer	4.0	8	8	8	8	8	8
Number of People Positively Impacted	5.0	20	20	20	20	10	20

Decision Factors		Terracing/Erosion Control	Crop Rotation	Cover Crops	Raised Beds (Vegetables)	Crops for Animal Feed/Caged Livestock	Slope Crops (Crops that grow well with high inclines)
Criteria	Wt.						
Decreases Non-Point Pollution (Lake)	5.0	25	20	20	10	5	10
Decreases Point Source Pollution (Lake)	5.0	10	10	10	10	10	10
Promotes protection of the environment	5.0	25	25	20	10	10	10
Promotes Land Restoration	5.0	25	25	20	10	10	10
Increases Crop Diversification	4.0	12	16	16	16	12	12
Promotes adoption of diversifying diets	4.0	8	12	16	16	12	8
Promotes access to better sanitation	4.0	8	8	8	8	8	4
Decreases child mortality rate under the age of 5	3.0	3	3	3	3	3	3
Culturally Acceptable	5.0	20	15	15	20	15.0	15
Feasibility	4.0	12	12	12	12	12.0	12.0
Longevity	4.0	16	16	16	12	12.0	12

Decision Factors		Terracing/Erosion Control	Crop Rotation	Cover Crops	Raised Beds (Vegetables)	Crops for Animal Feed/Caged Livestock	Slope Crops (Crops that grow well with high inclines)
Criteria	**Wt.**						
Up front low Cost	4.0	12	12	12	12	12	12
Materials available in Country	4.0	12	12	12	12	12	12
High Rate of Adoption	4.0	8	8	8	12	8.0	12
High Community Interest	5.0	10	15	10	15	10.0	15
Weighted Scores		**244.0**	237.0	231.0	207.0	179.0	186.0
Priority		**1**	**2**	**3**	**4**	**6**	**5**

Decision Matrix: Extension Program Topics

Decision Factors		Basic Home/ Farm Finance	Land Preservation	Appropriate Chemical Application	In field Pest MGMT	Seed Storage/Germination Tests	Post-Harvest Loss Prevention	Irrigation	Affect of diet on Livestock	Waste MGMT	Pit Latrine Maintenance/Care	Improving Health through Washing Stations
Criteria	Wt.											
Increased GDP potential (Local people)	5.0	25	15	20	15	20	25	15	10	15	15	15
Increases Employment opportunities	5.0	15	10	10	10	10	20	15	15	15	15	15
Increases equal opportunities for Women	3.0	15	6	6	9	9	9	6	6	6	6	6
Increases access to health care (Local people)	3.0	6	6	6	6	6	6	6	6	9	12	12
Increases Community Collaboration	4.0	12	12	12	12	12	16	12	12	16	16	16
Increases Farmers Knowledge Base	4.0	20	12	16	16	16	20	12	12	12	12	12

Decision Factors		Basic Home/ Farm Finance	Land Preservation	Appropriate Chemical Application	In field Pest MGMT	Seed Storage/Germination Tests	Post-Harvest Loss Prevention	Irrigation	Affect of diet on Livestock	Waste MGMT	Pit Latrine Maintenance/Care	Improving Health through Washing Stations
Criteria	**Wt.**											
Increases Technology Transfer	4.0	12	8	8	8	12	12	12	8	12	16	16
Number of People Positively Impacted	5.0	25	20	20	20	25	25	15	10	15	25	25
Increases Clinic/Farm Revenue	5.0	15	10	15	15	10	20	15	10	15	15	10
Decreases Non-Point Pollution (Lake)	5.0	10	25	25	15	10	10	10	10	20	15	20
Decreases Point Source Pollution (Lake)	5.0	10	25	20	15	10	10	15	10	20	20	25
Promotes protection of the environment	5.0	10	25	20	10	10	10	10	5	20	20	25
Promotes Land Restoration	5.0	10	25	20	10	10	10	10	5	20	20	25
Increases Crop Diversification	4.0	8	8	8	12	8	12	16	16	4	4	4

Decision Factors		Basic Home/ Farm Finance	Land Preservation	Appropriate Chemical Application	In field Pest MGMT	Seed Storage/Germination Tests	Post-Harvest Loss Prevention	Irrigation	Affect of diet on Livestock	Waste MGMT	Pit Latrine Maintenance/Care	Improving Health through Washing Stations
Criteria	**Wt.**											
Promotes adoption of diversifying diets	4.0	8	8	8	12	8	12	16	16	4	4	4
Promotes access to better sanitation	4.0	12	8	4	4	4	4	4	4	16	20	20
Decreases child mortality rate under the age of 5	3.0	9	6	9	6	9	9	6	6	12	12	15
Culturally Acceptable	5.0	15	15	10	15	15	15	15	15	10	10	15
Feasibility	4.0	20	12	20	16	16	16	8	12	12	12	12
Longevity	4.0	20	16	16	12	12	16	16	12	16	16	12
Up front low Cost	4.0	20	12	20	16	16	12	8	12	16	12	8
Materials available in Country	4.0	20	12	12	12	12	8	8	12	12	12	12
High Community Interest	5.0	25	15	15	15	15	25	15	5	5	10	15
Weighted Scores		342	311	320	281	275	322	265	229	302	319	339
Priority		**1**	**6**	**4**	**8**	**9**	**3**	**10**	**11**	**7**	**5**	**2**

Summary Priority Table

Farm Components		Appropriate Technology Center		Demonstration Plots		Extension Program Topics	
	Rank		*Rank*		*Rank*		*Rank*
Appropriate Technology Center	1	**PICS Bags**	1	**Terracing & Erosion Control**	1	**Basic Home/Farm Finance**	1
Demonstration Plots	2	**Moisture Meters**	2	**Crop Rotation**	2	**Improving Health through Washing Stations**	2
Micro-Finance Union	3	**Above ground aquaculture**	3	**Cover Crops**	3	**Post-Harvest Loss Prevention**	3
Seed Bank	4	**Hand Washing Station(s)**	4	**Raised Beds (Vegetables)**	4	**Appropriate Chemical Application**	4
Nursery	5	**Pit Latrine Maintenance/ Care**	5	**Slope Crops (Crops that grow well with high inclines)**	5	**Pit Latrine Maintenance/Care**	5
		Low-Cost Dryers	6	**Crops for Animal Feed/Caged Livestock**	6	**Land Preservation**	6
		Low-Cost Irrigation Systems	7			**Waste Management**	7
		Roof Rain Water Harvesting	8			**In-field Pest Management**	8
		Low-Cost in-home toilet options	9			**Appropriate Seed Storage/Germination Tests**	9
						Irrigation	10
						Affect of diet on Livestock	11

APPENDIX D. SURVEY RESULT FIGURES

The results for all specific questions of the entire market survey are provided in Appendix D. Only a few of the many summary statistical figures created were presented in the main body of this study, but all are presented here.

Survey Summary Statistics

Demographic

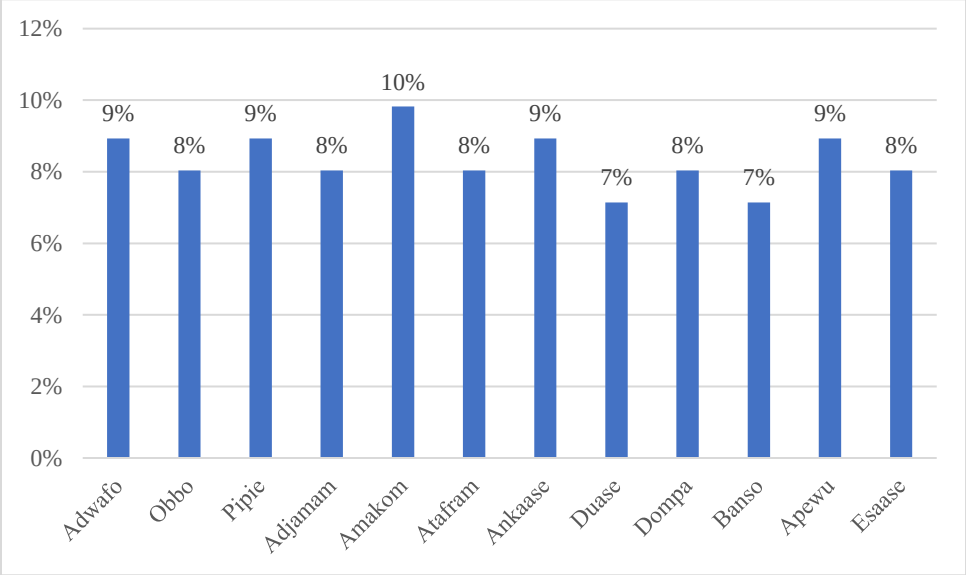


Figure D-1. Sample Size by Village

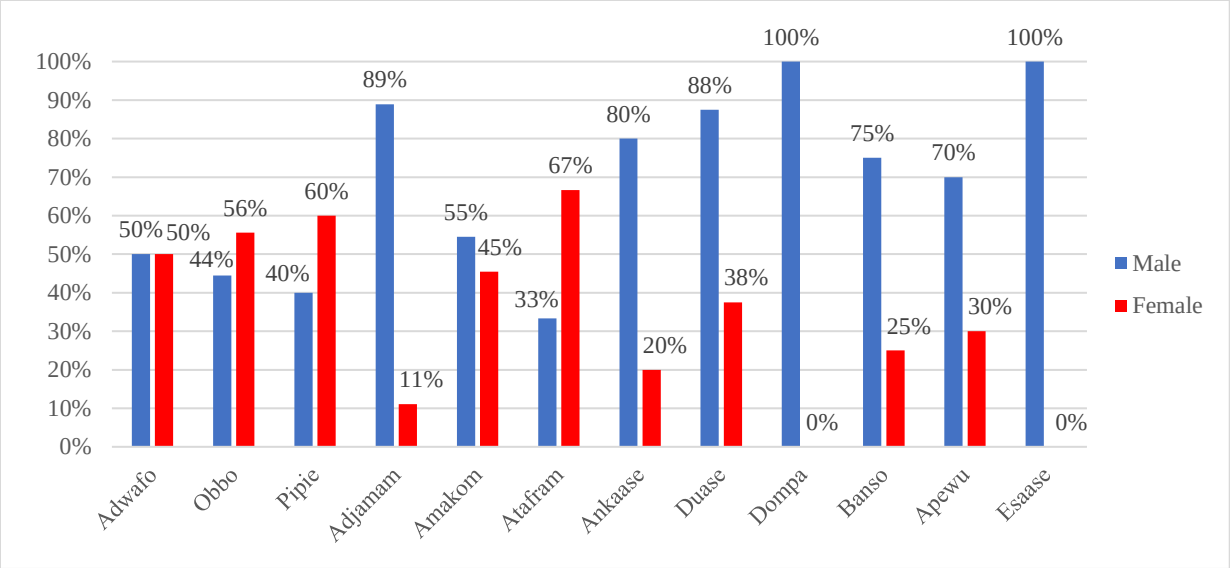


Figure D-2. Sample Size by Village & Gender

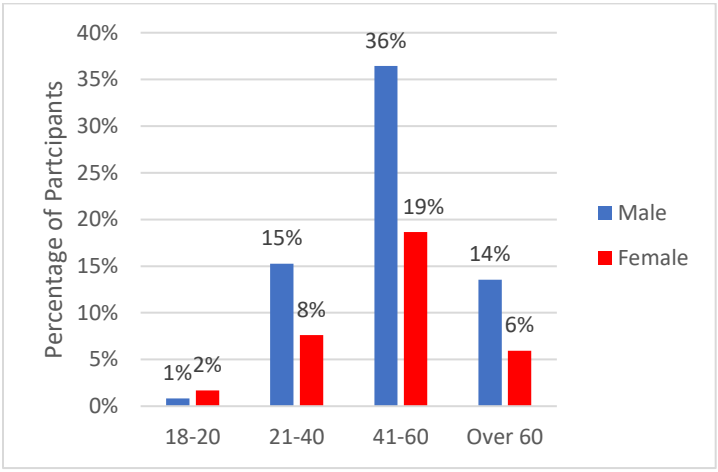


Figure D-3. Survey Participants by Age and Gender

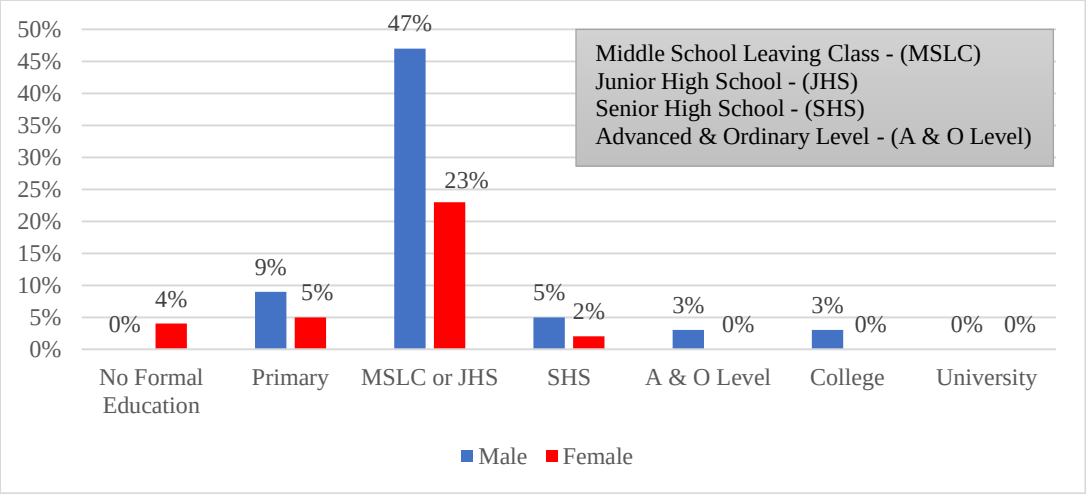


Figure D-4. Participants by Education & Gender

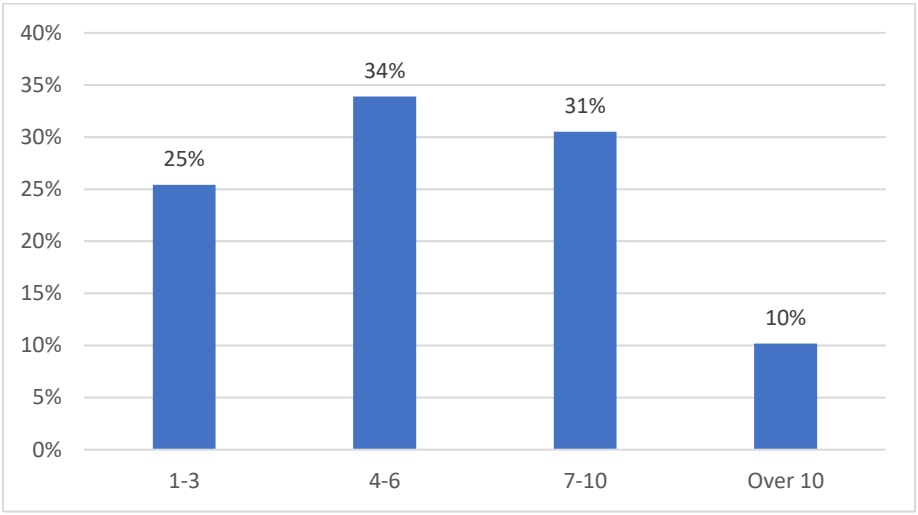


Figure D-5. Number of People per Household

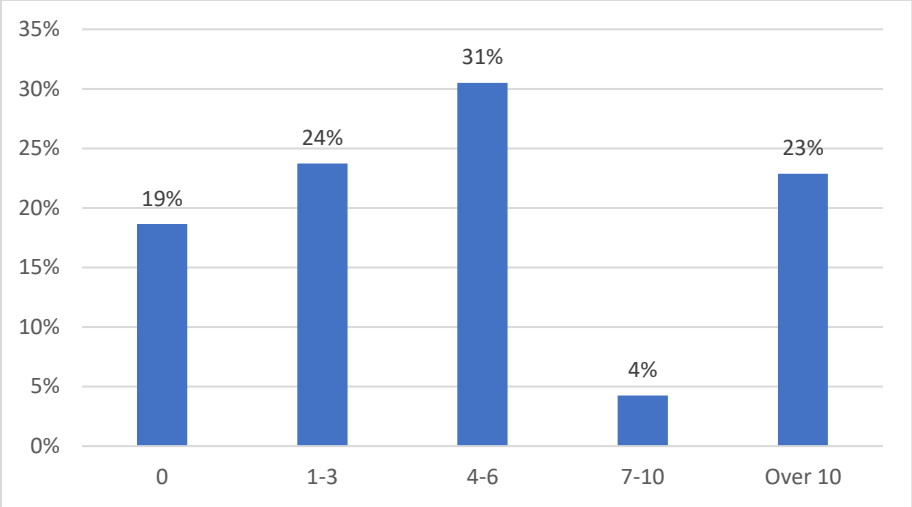


Figure D-6. Children per Household

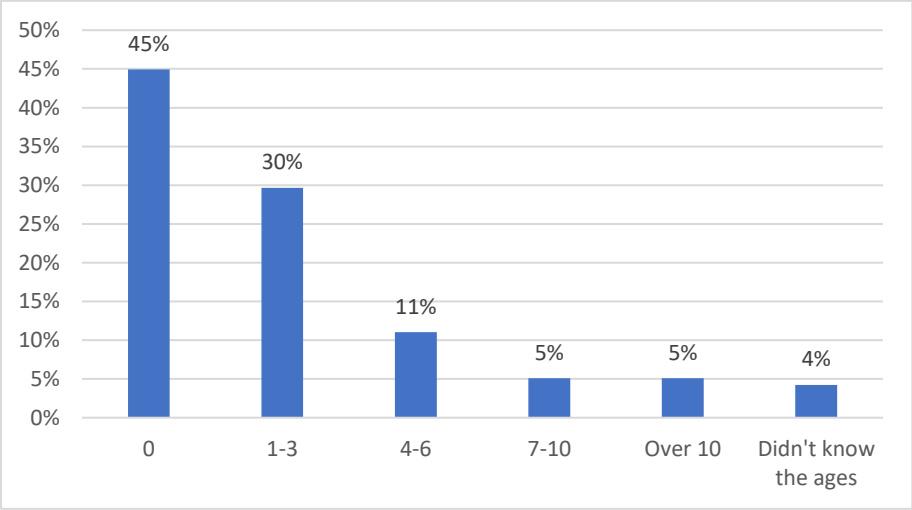


Figure D-7. Children per Household Age 5 or Younger

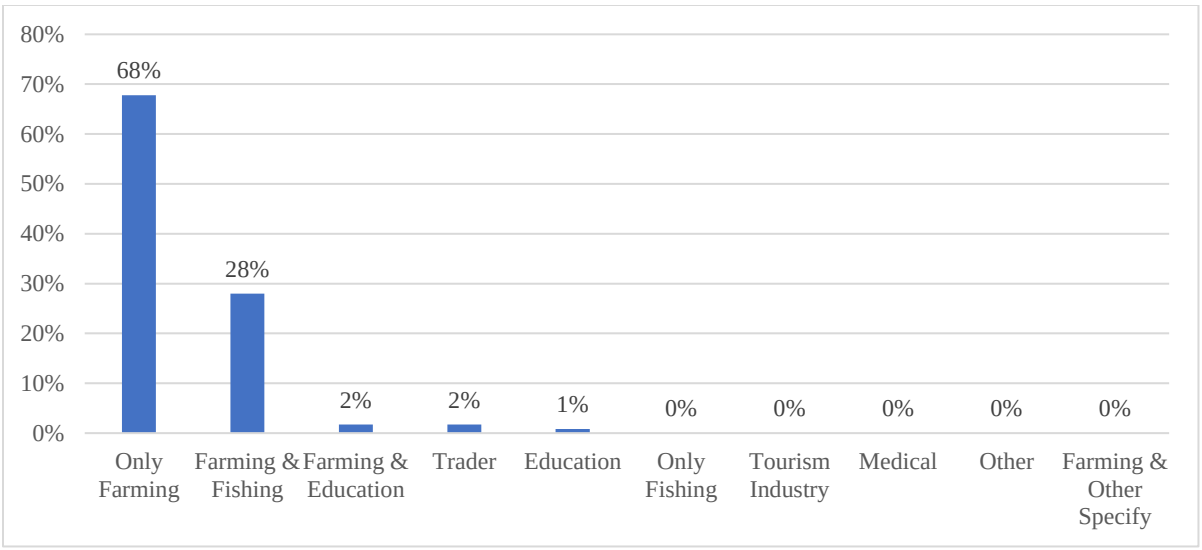


Figure D-8. Livelihood of Participants

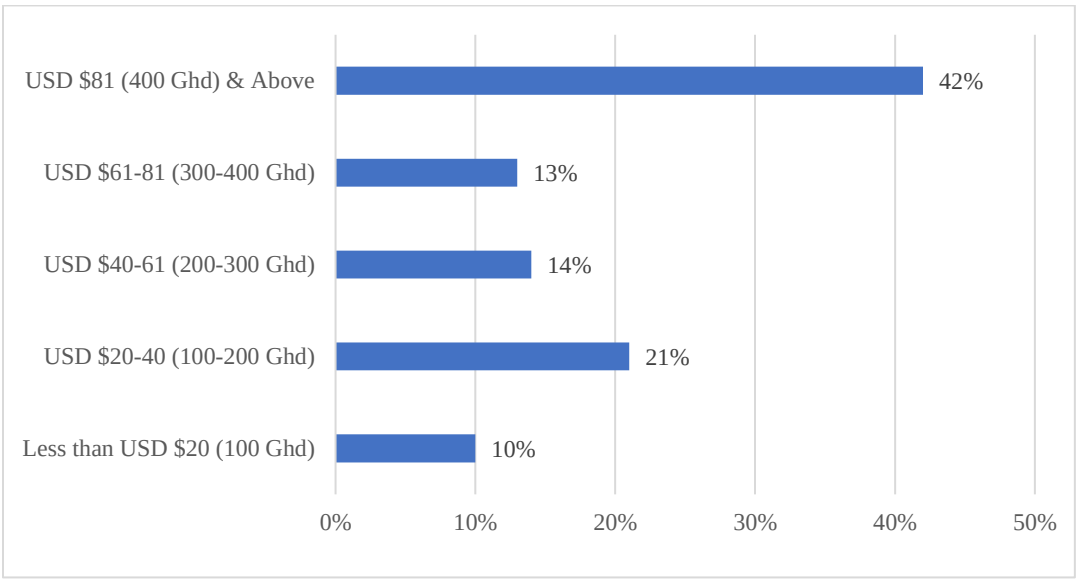


Figure D-9 Annual Household Income of Participants

Note: Ghana Cedi – (Ghd)

USD 1$ = ₵4.94 Ghd

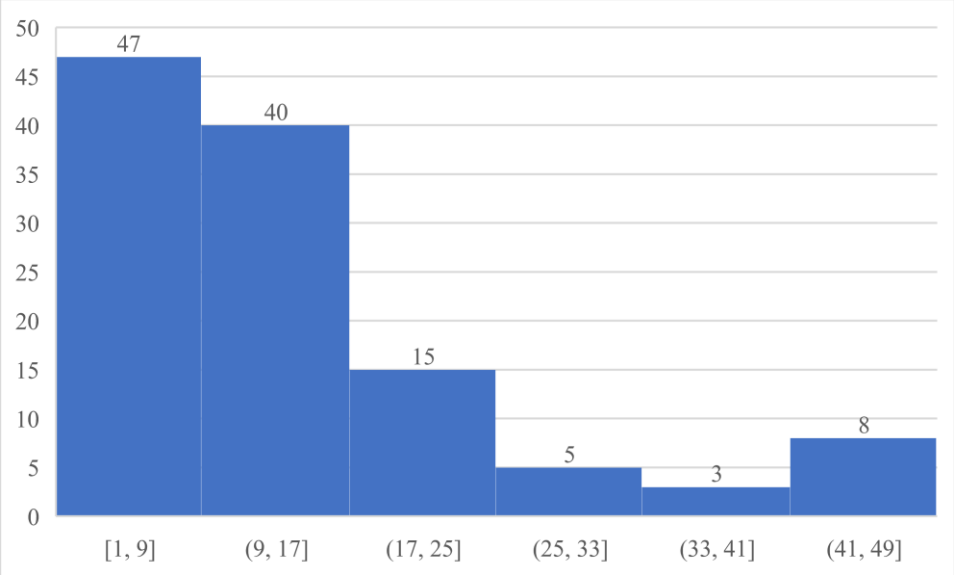


Figure D-10 Frequency Distribution Annual Income of Per Capita – (USD)

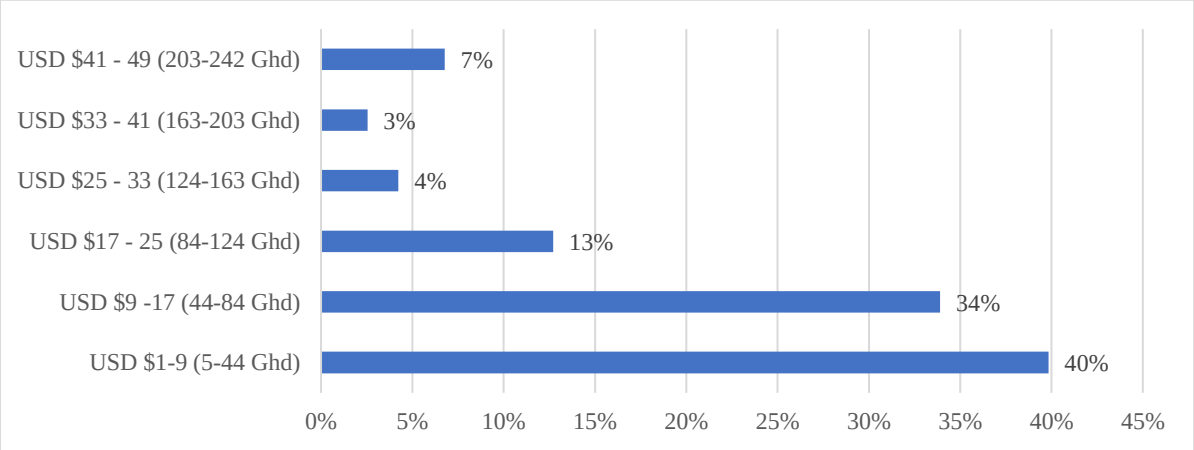


Figure D-11 Annual Income Per Capita

Note: Ghana Cedi – (Ghd)

USD 1$ = ₵4.94 Ghd

Land Use

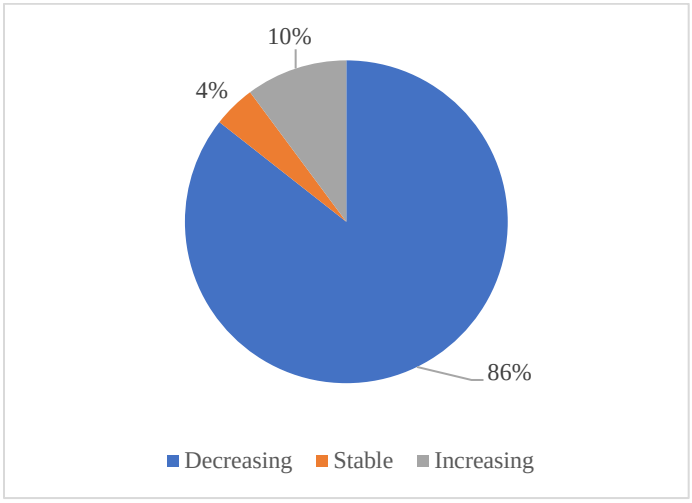


Figure D-12. Participant's Belief Regarding Land Cover

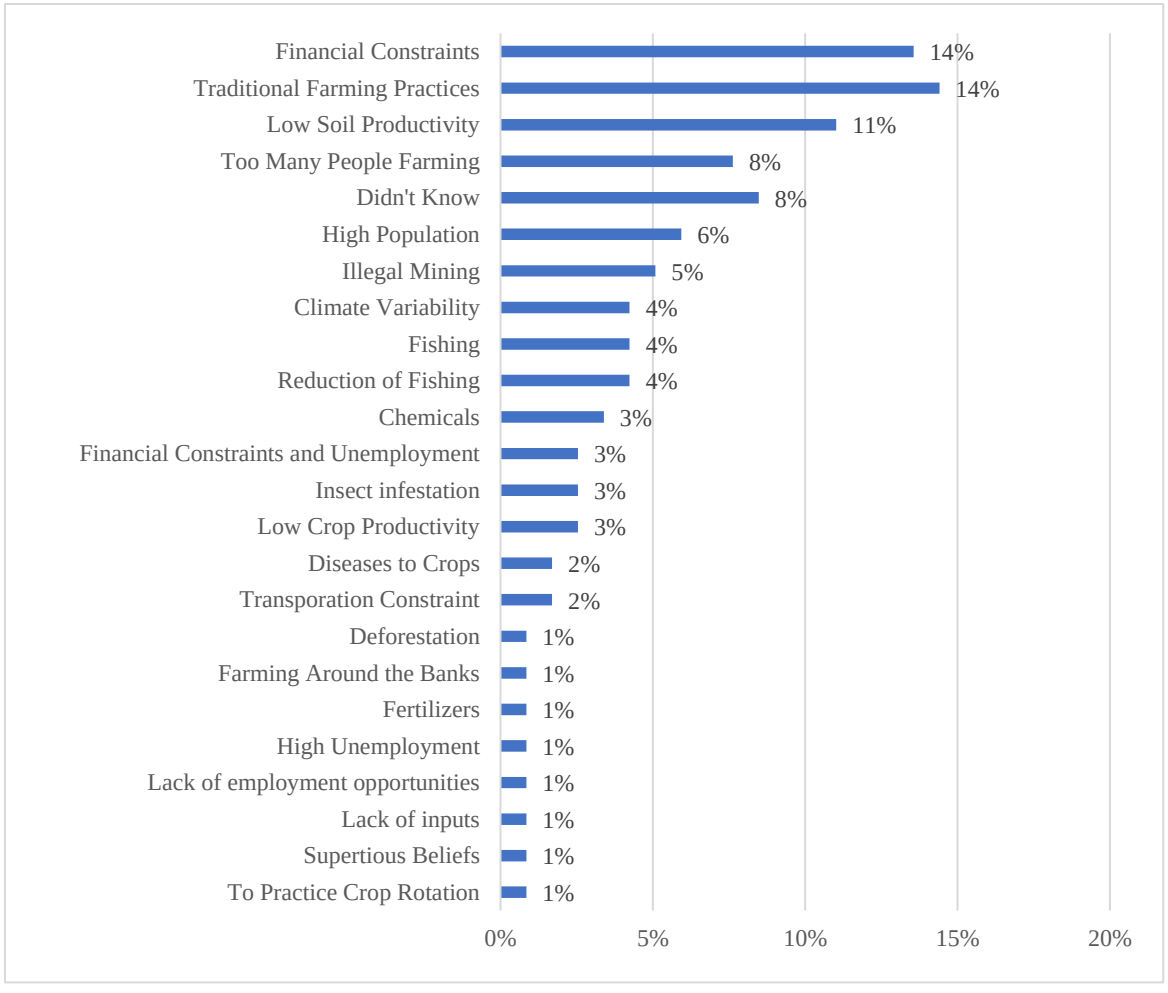


Figure D-13. Key Causes of Land Use Change According to Participants

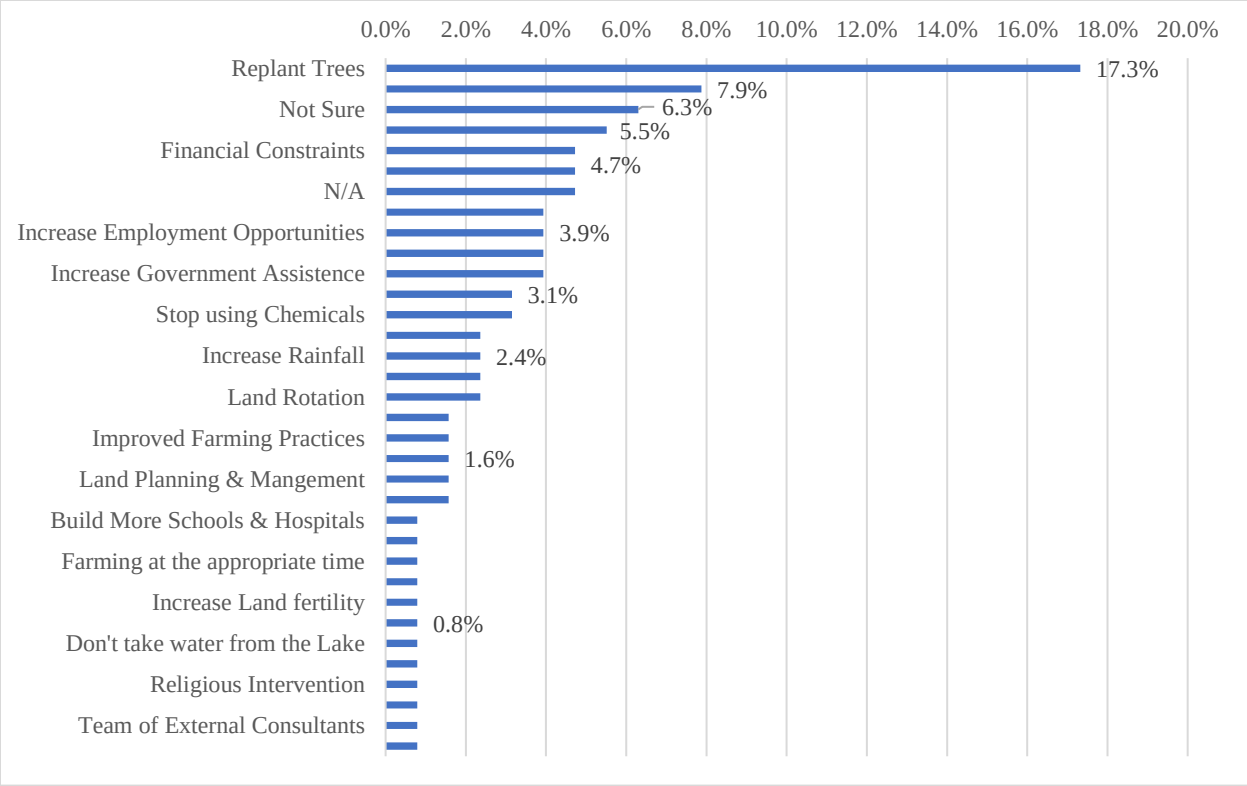


Figure D-14. What participants feel should be done to prevent/stop Land Use/Change

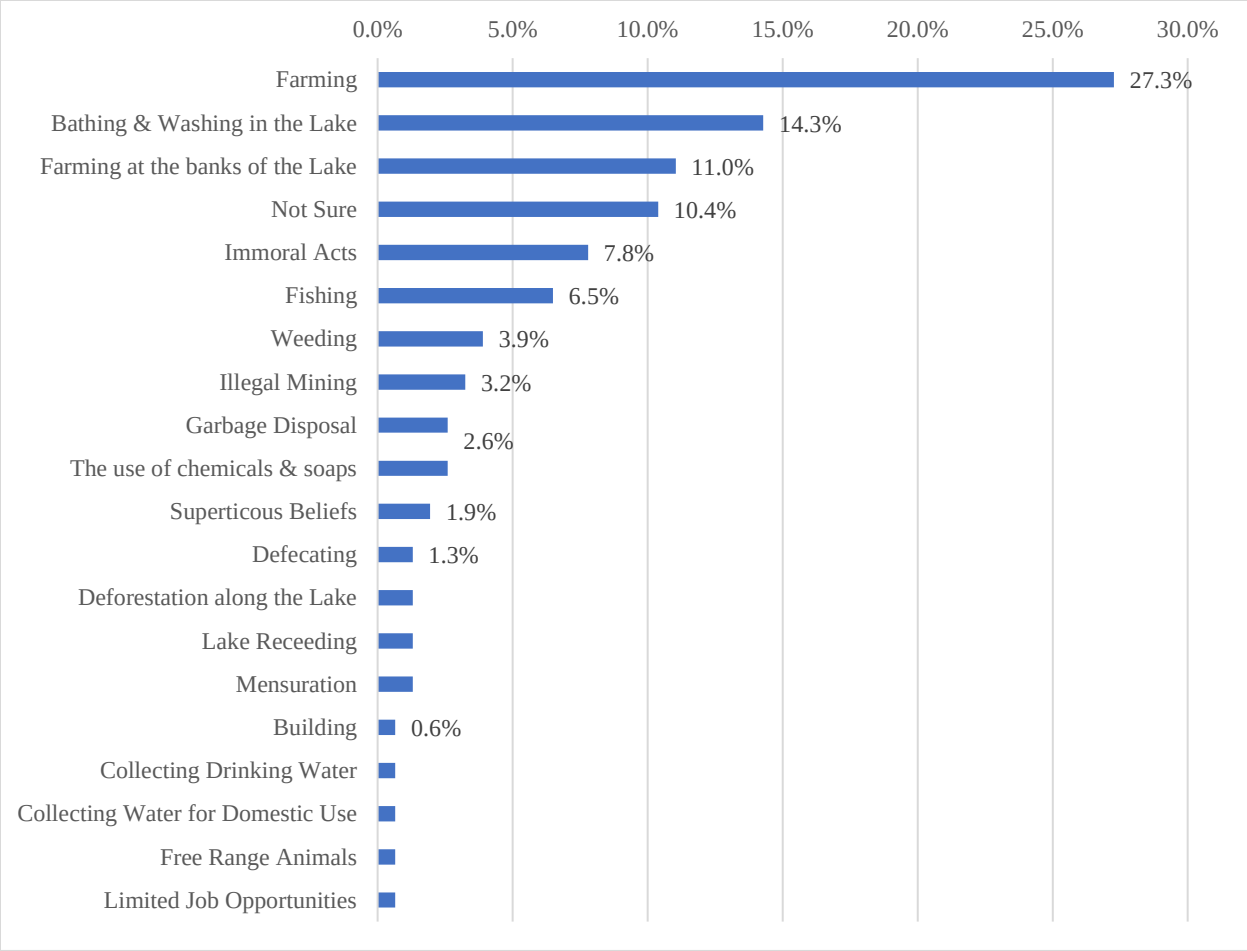


Figure D-15. Human Activities observed around Lake Bosomtwe

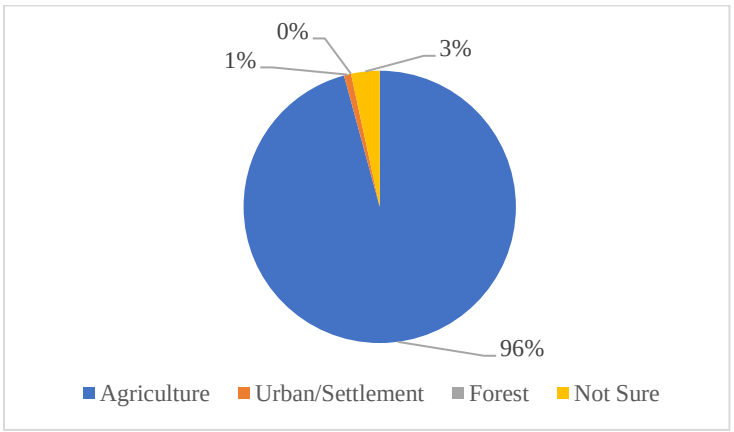


Figure D-16. Main Land Use Activity According to Participants

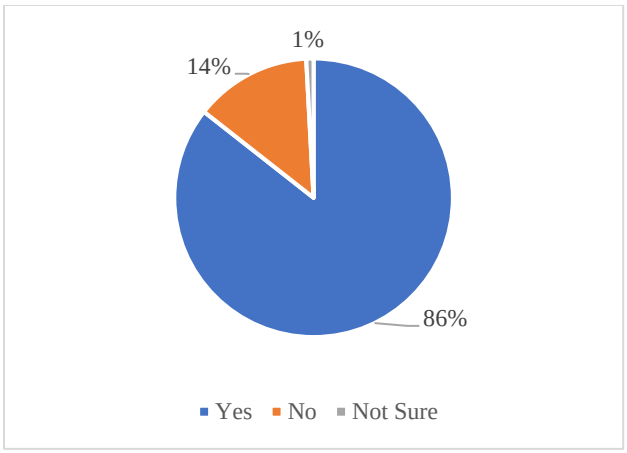


Figure D-17. Can the land use activities within the watershed affect the productivity of the lake, long term?

Farming Practices

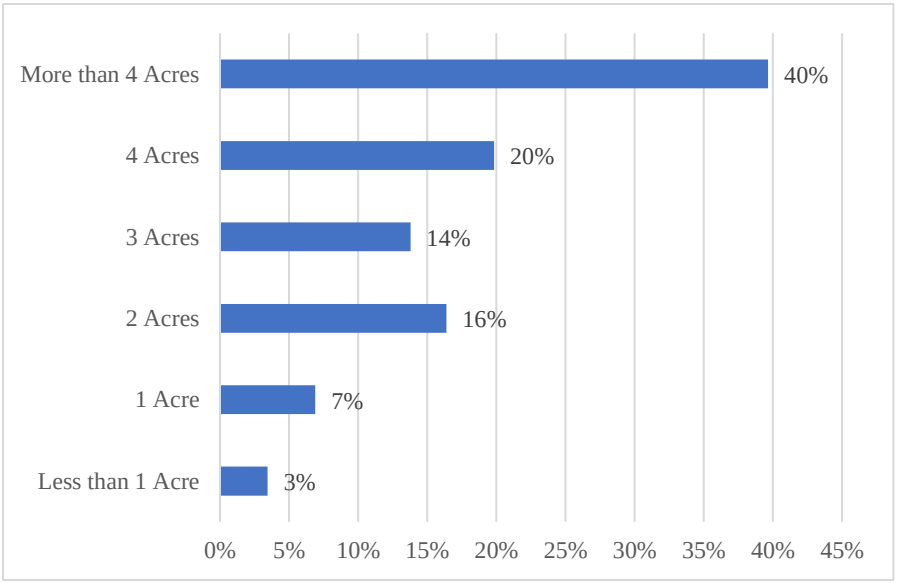


Figure D-18. Farm Size

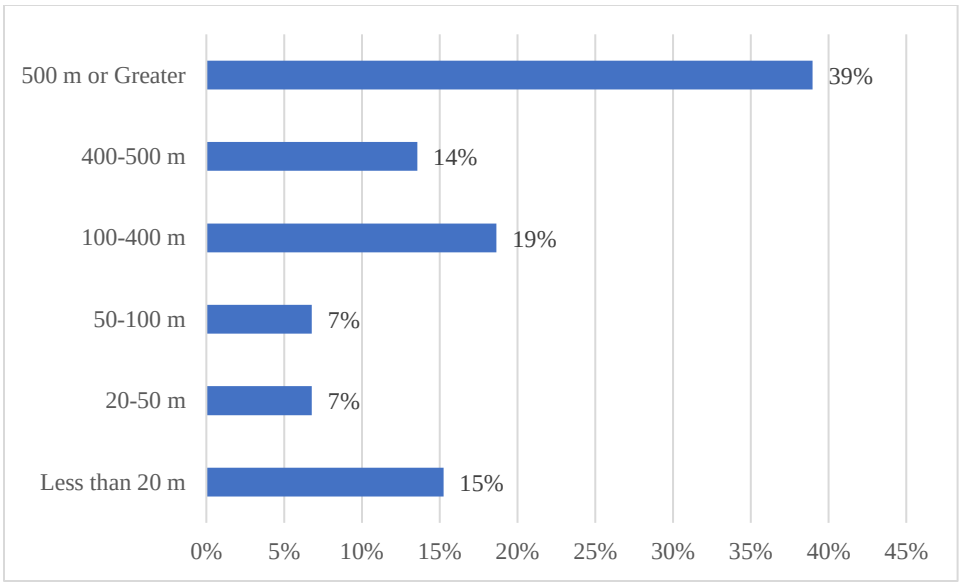


Figure D-19. Farm Distance from Lake

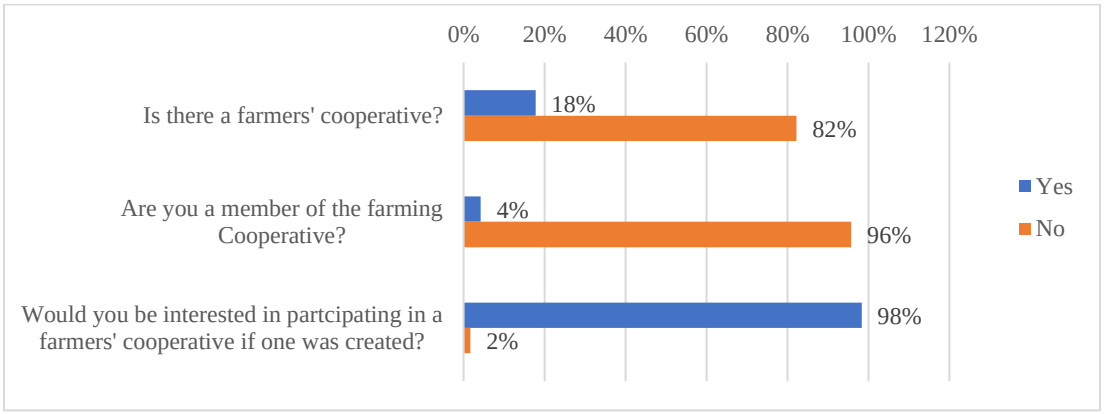


Figure D-20. Farmer Cooperative Interest

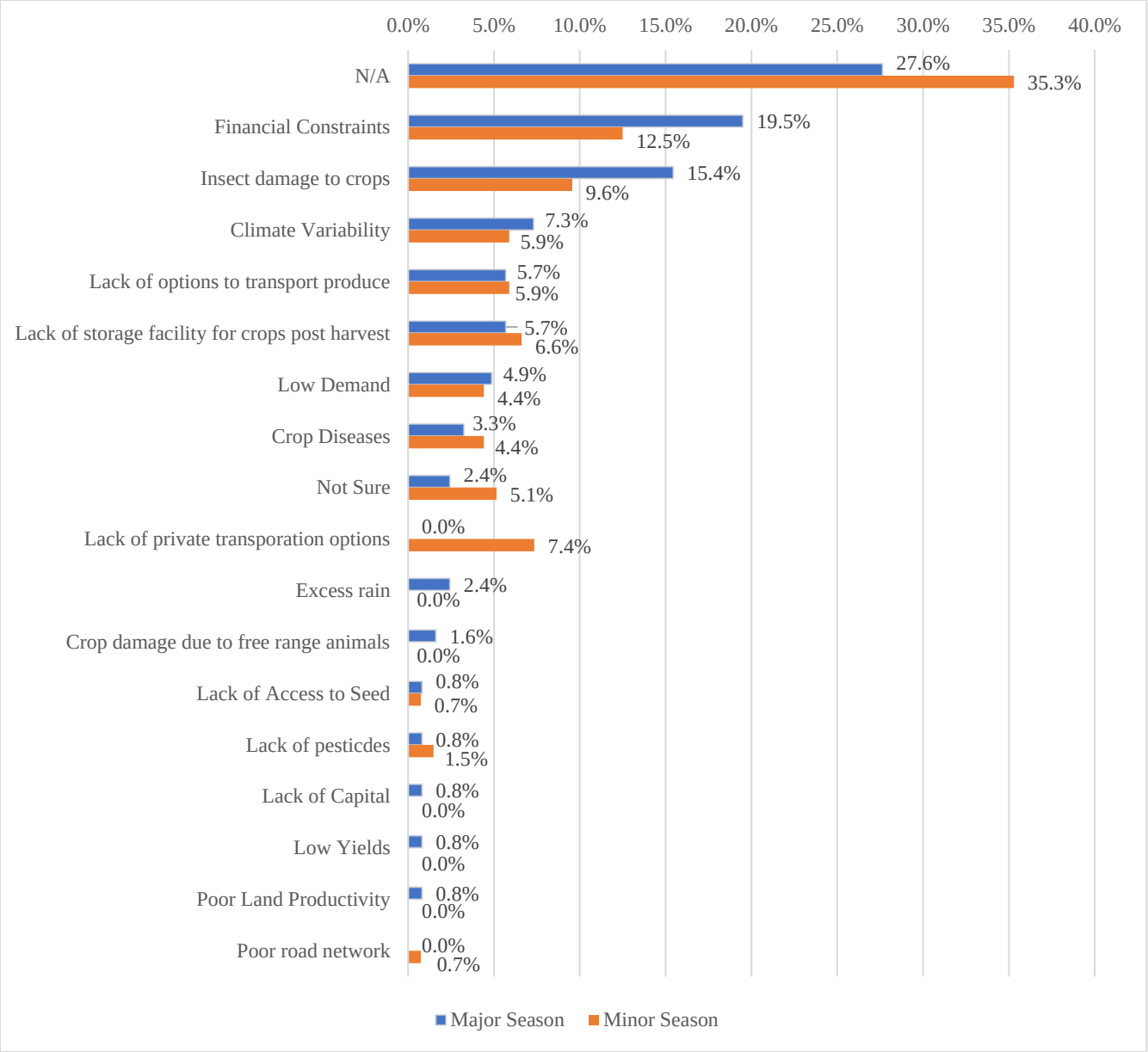


Figure D-21. What do you believe are the major causes of your post-harvest loss during major season and minor season?

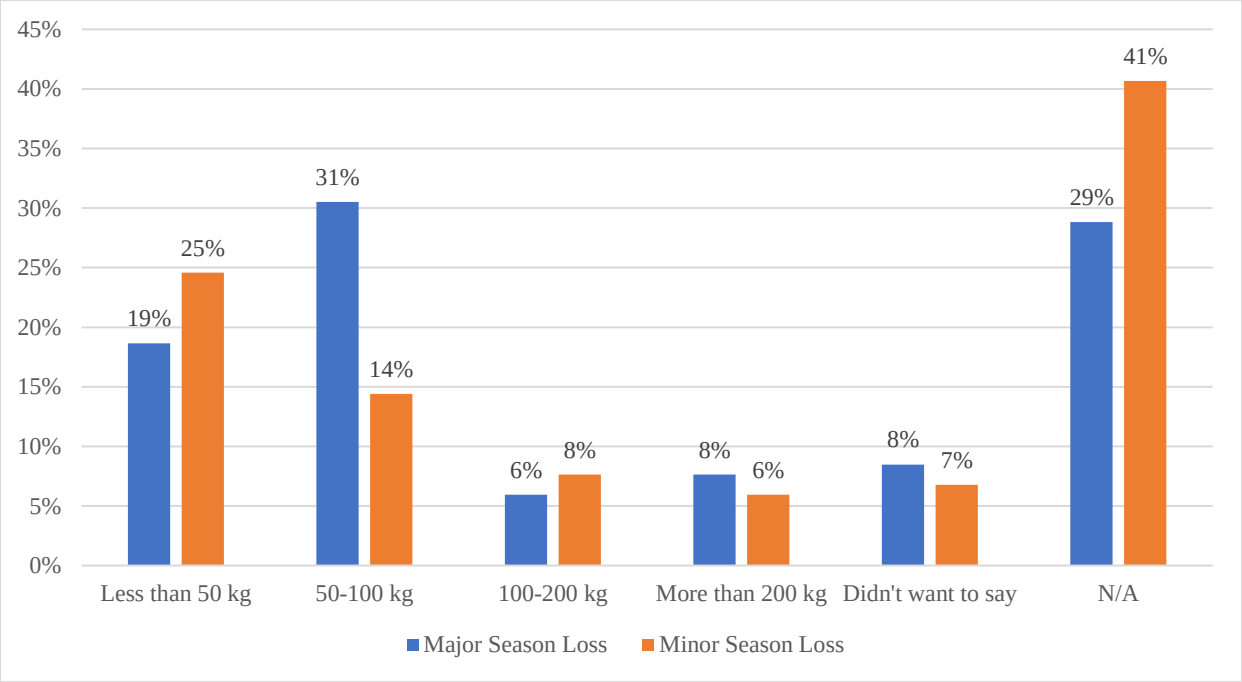


Figure D-22. Average Yield & Loss Per Season

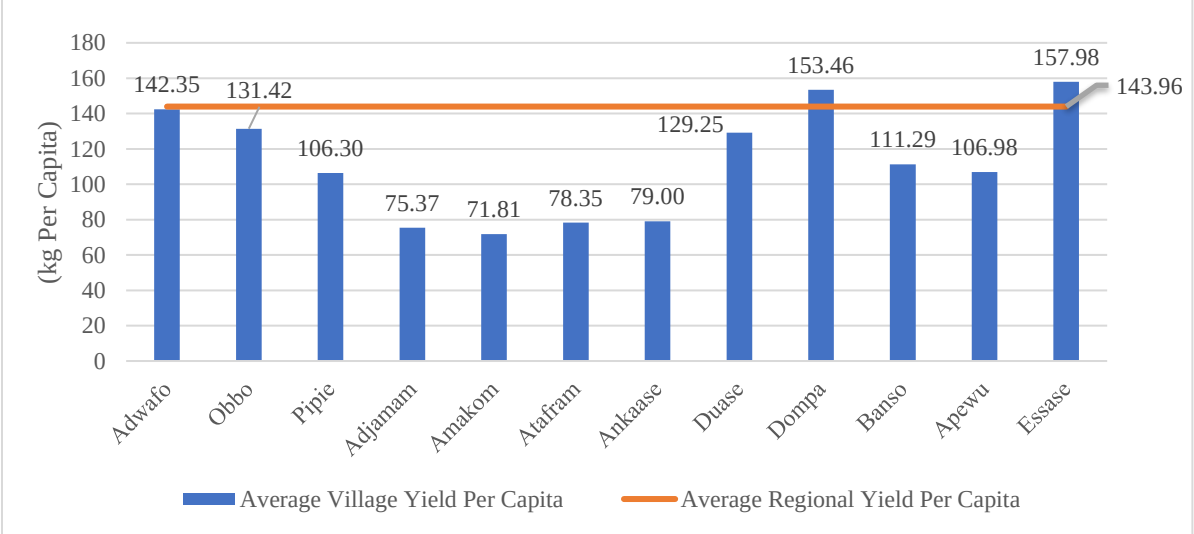


Figure D-23 Village Average Yield compared to Regional Average Yield (Per Capita - Cassava)

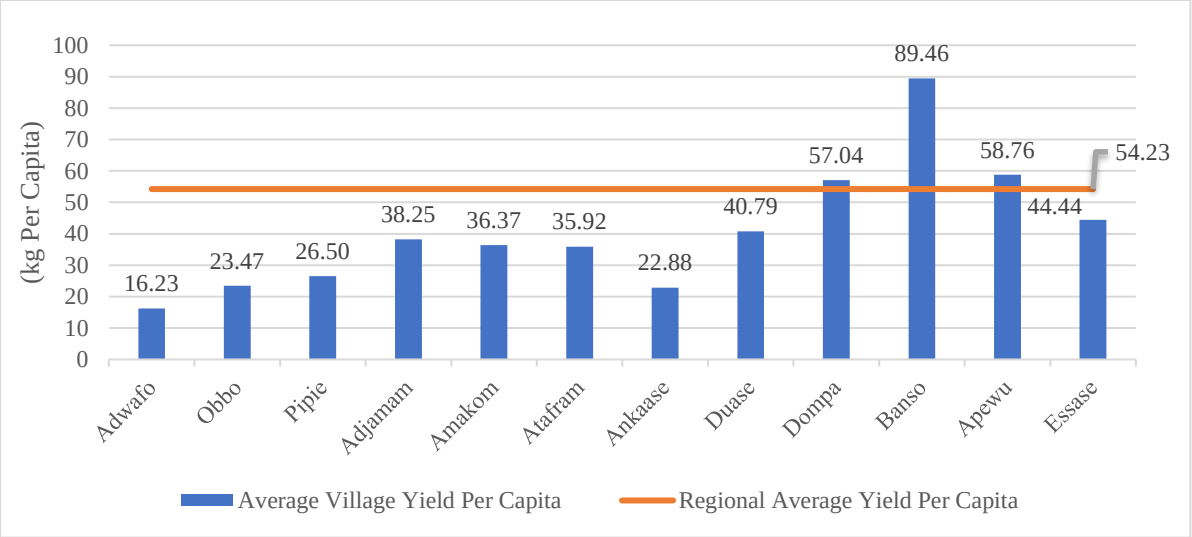


Figure D-24 Village Average Yield compared to Regional Average Yield (Per Capita - Maize)

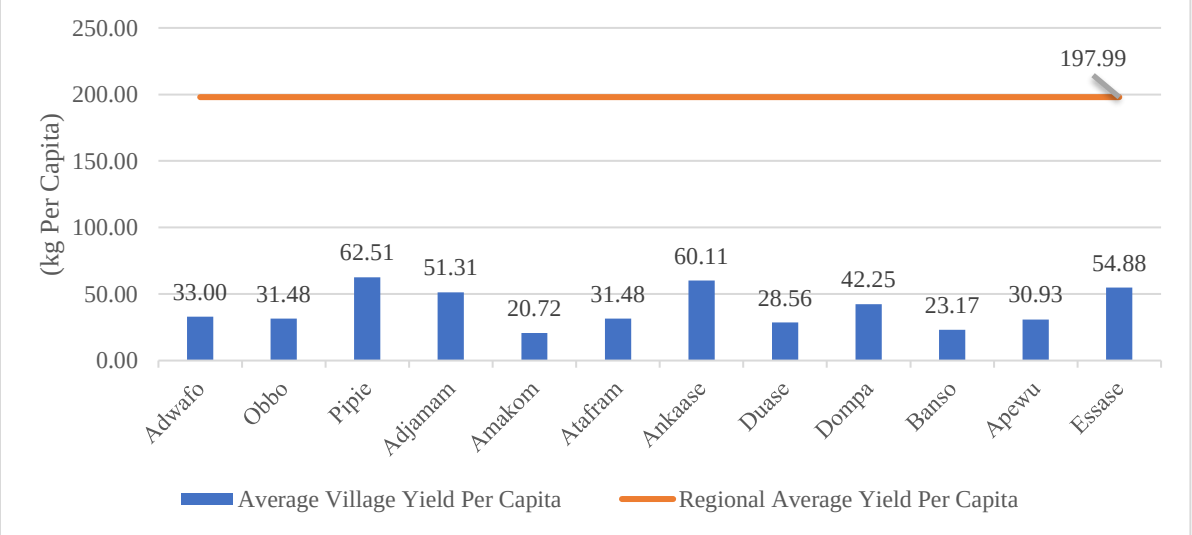


Figure D-25 Village Average Yield compared to Regional Average Yield (Per Capita - Plantain)

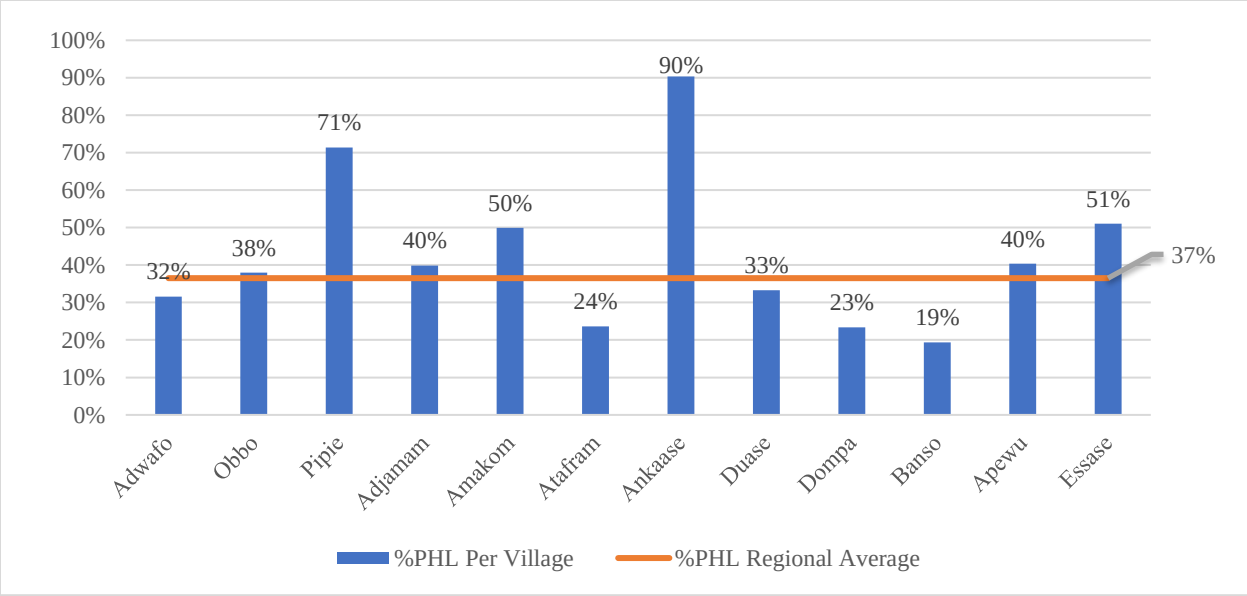


Figure D-26 Village Average % PHL compared to Regional Average % PHL (Per Capita - Cassava)

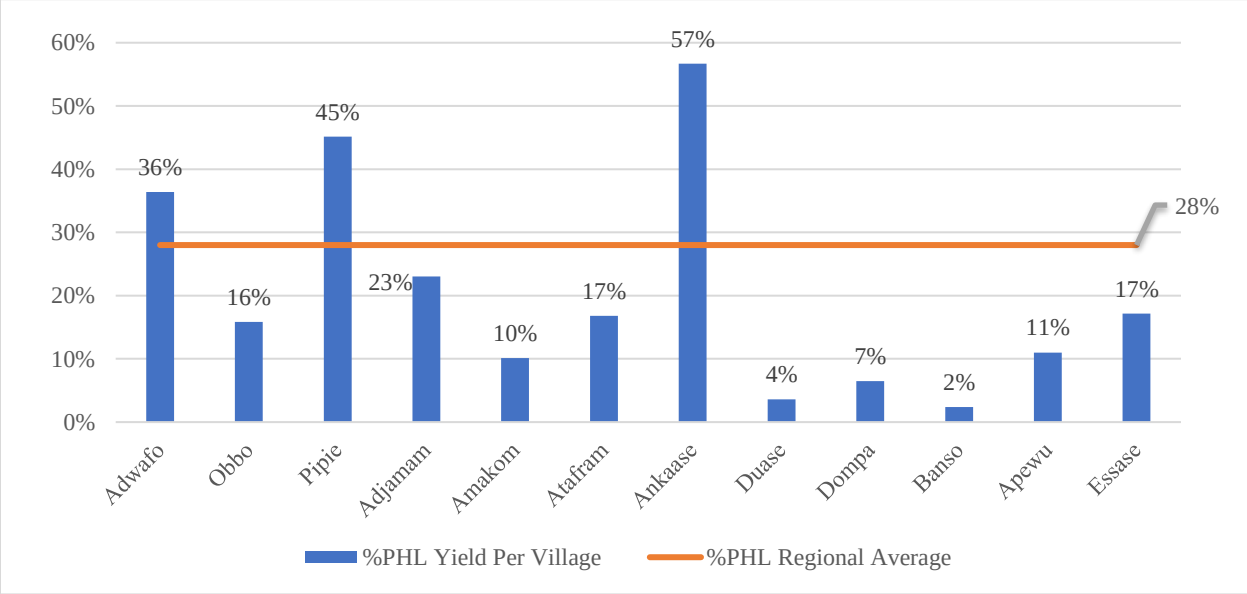


Figure D-27 Village Average % PHL compared to Regional Average % PHL (Per Capita – Maize)

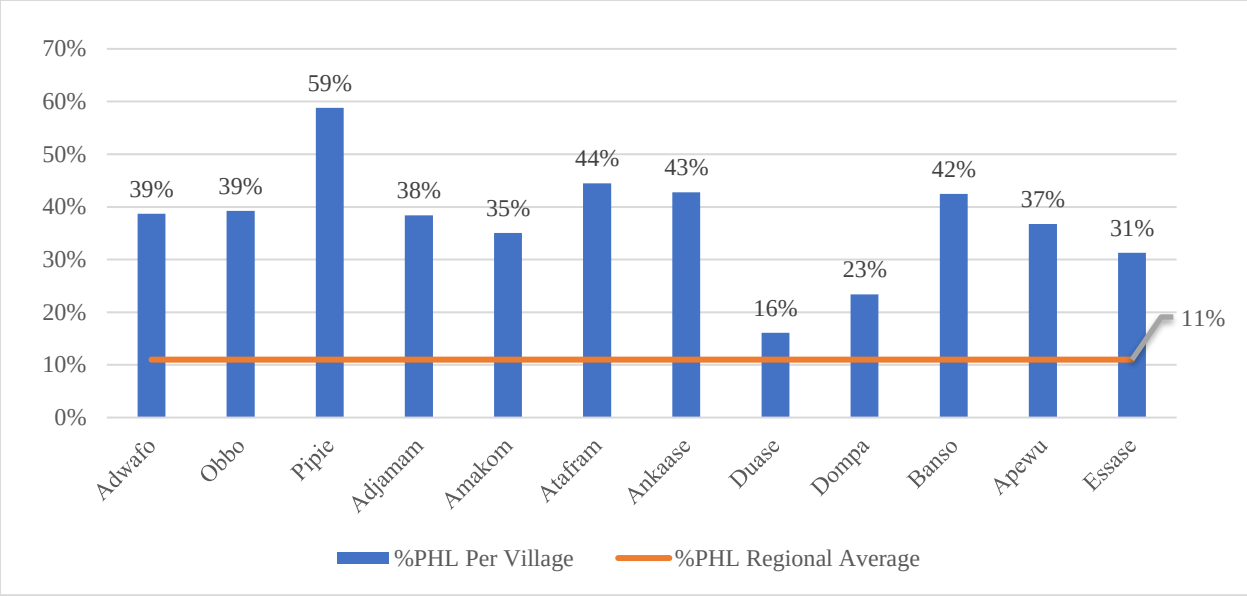


Figure D-28 Village Average % PHL compared to Regional Average % PHL (Per Capita - Plantain)

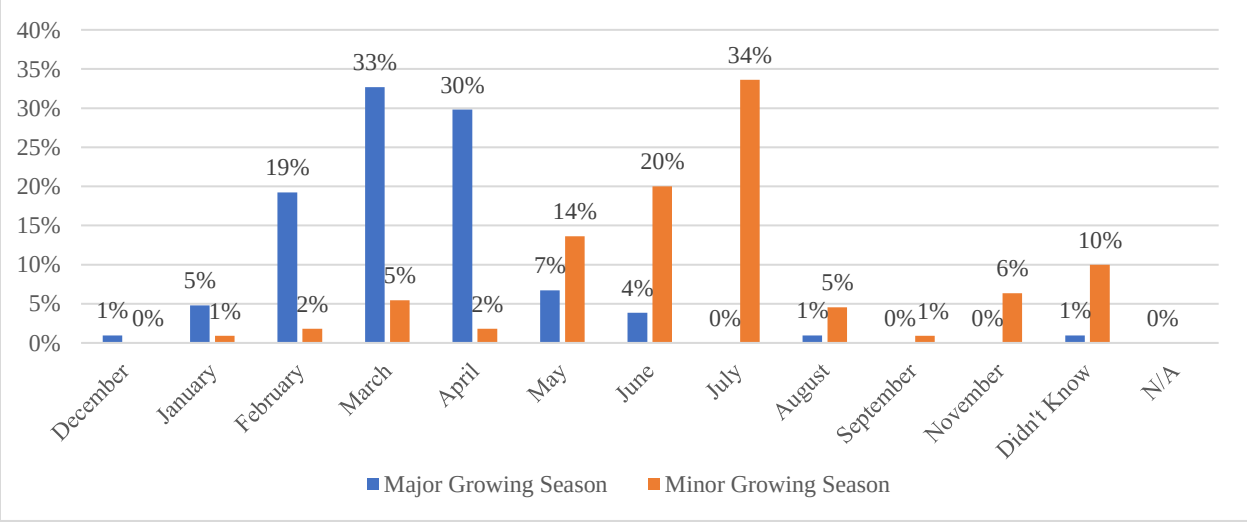


Figure D-29 What time of the year do you plant for the Major or Minor growing season?

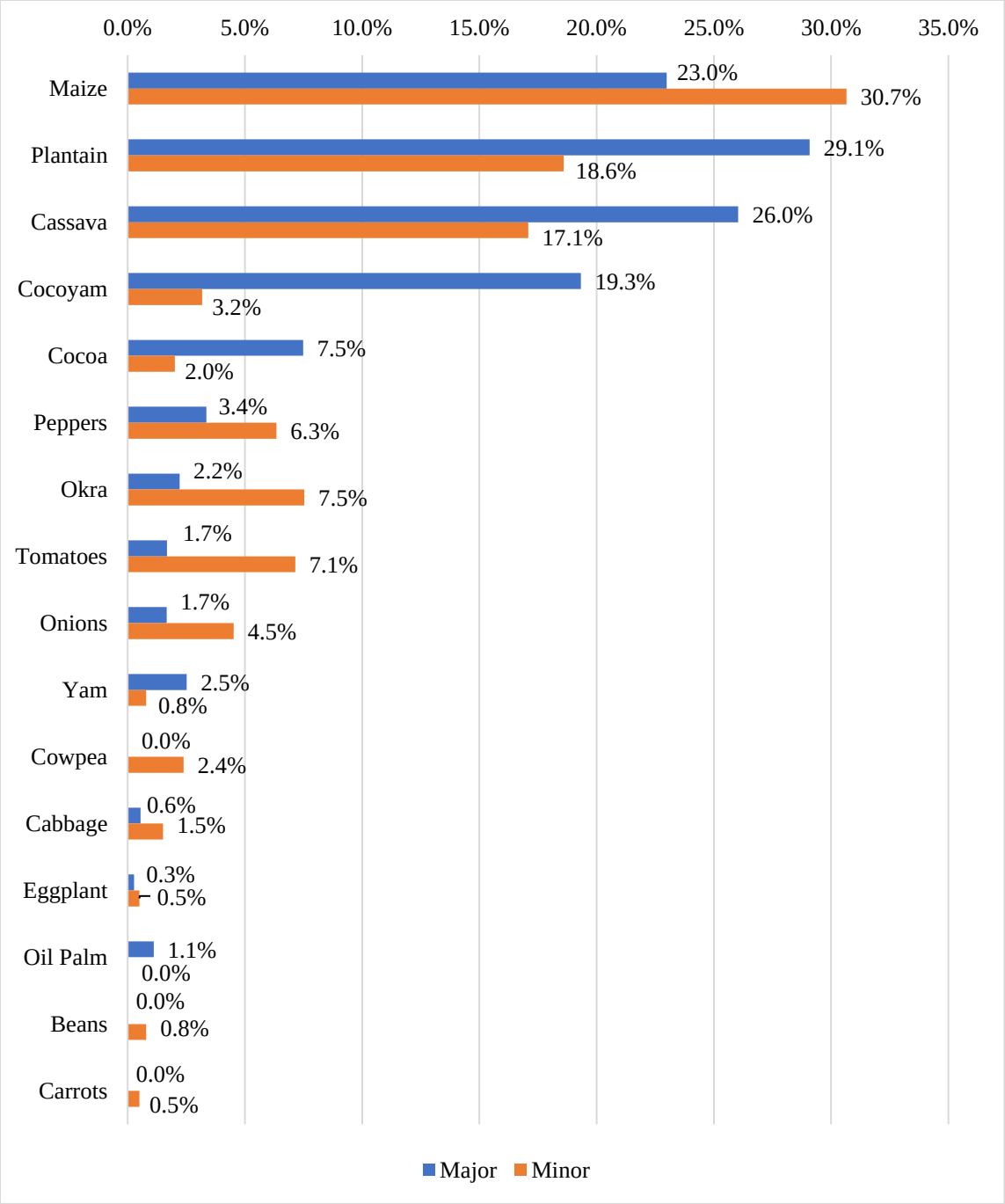


Figure D-30. Crops grown during Major and Minor Growing Season

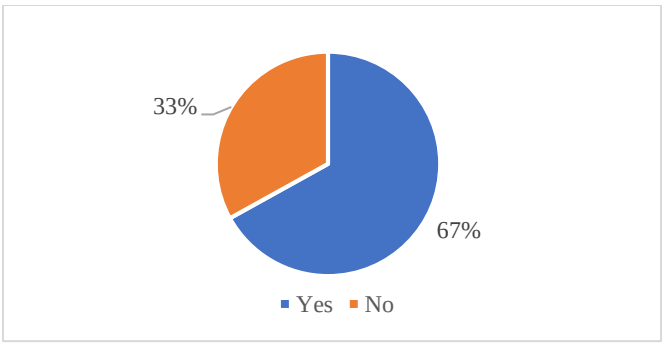


Figure D-31. Do you purchase seed?

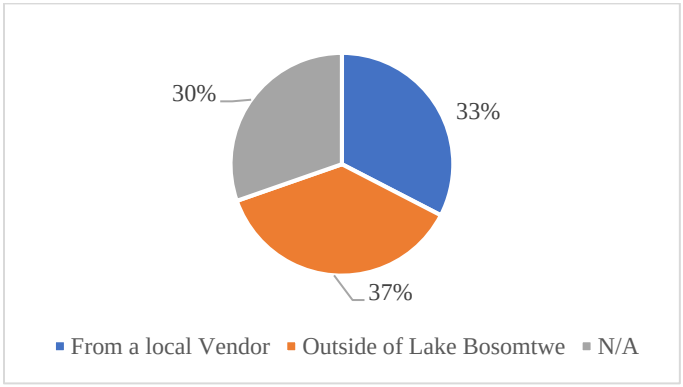


Figure D-32. Where do you purchase seed?

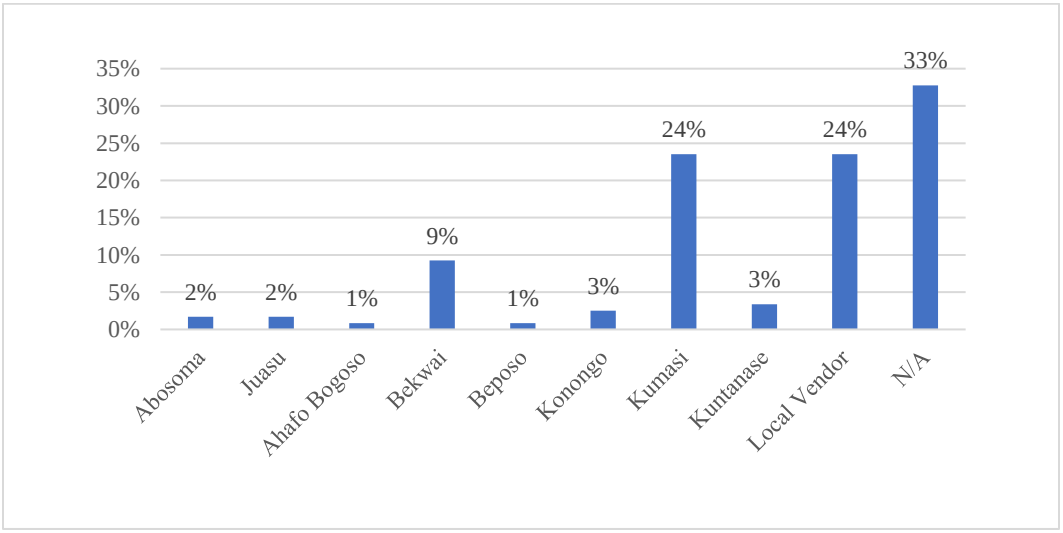


Figure D-33. Where do you purchase seed, specify?

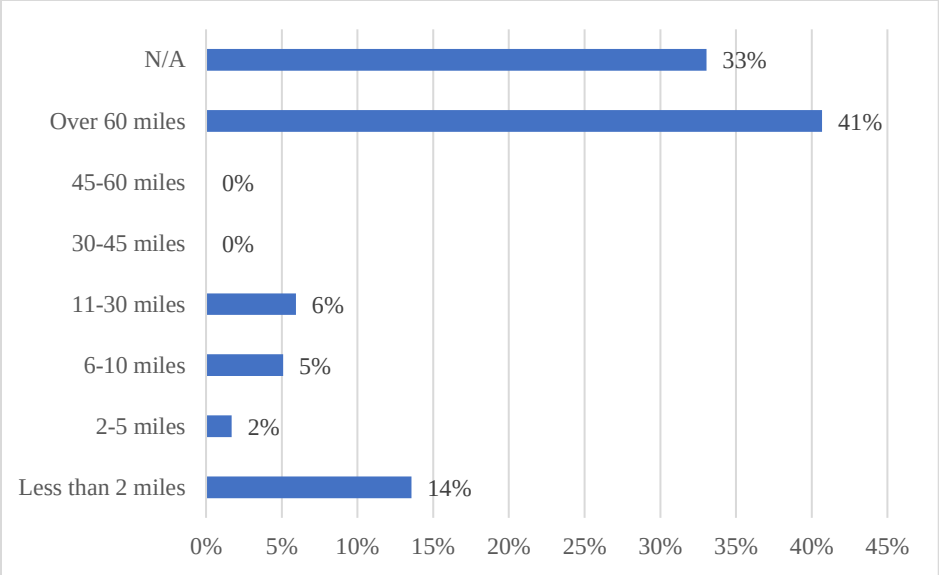


Figure D-34. How far do you travel to purchase seed?

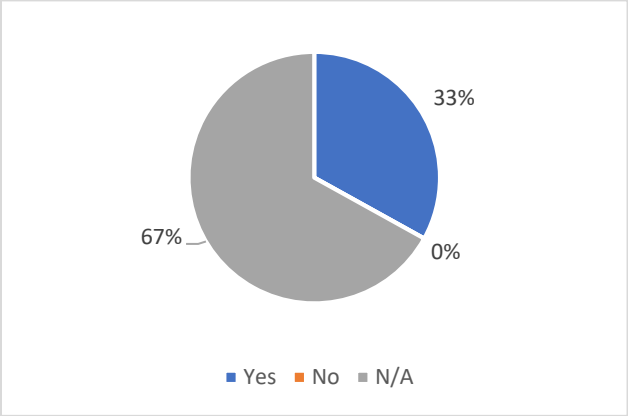


Figure D-35. Do you save your own seed from a previous harvest?

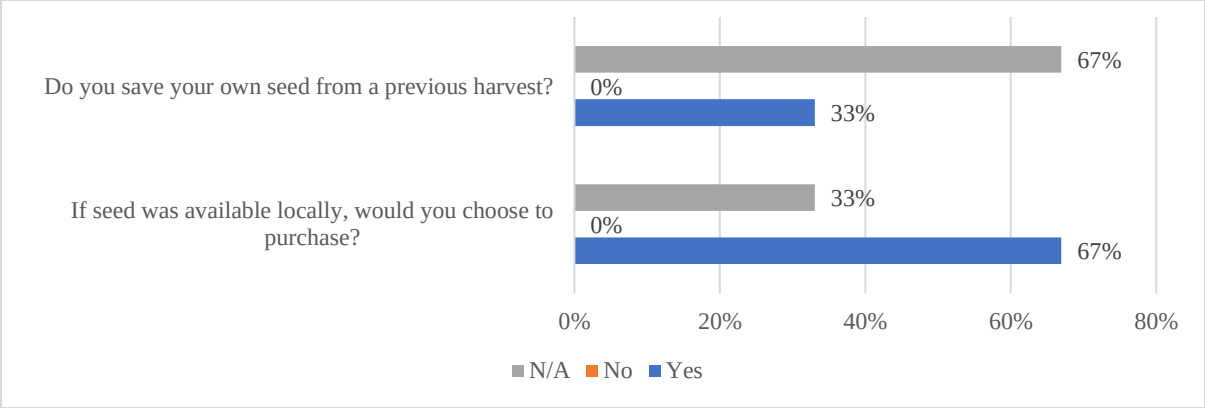


Figure D-36. Partcipants that Save Seed and Purchase Seed

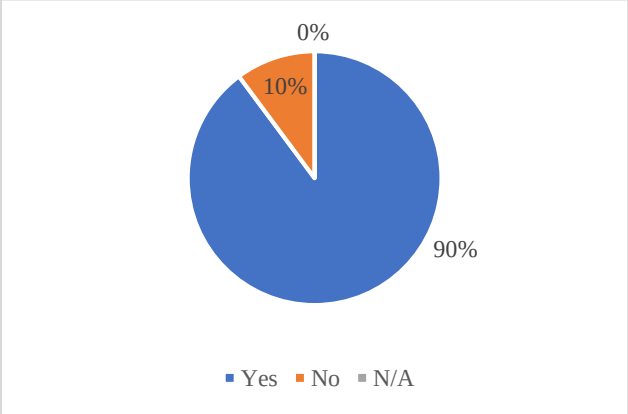


Figure D-37. Are there any crops that you wish you could grow but don’t?

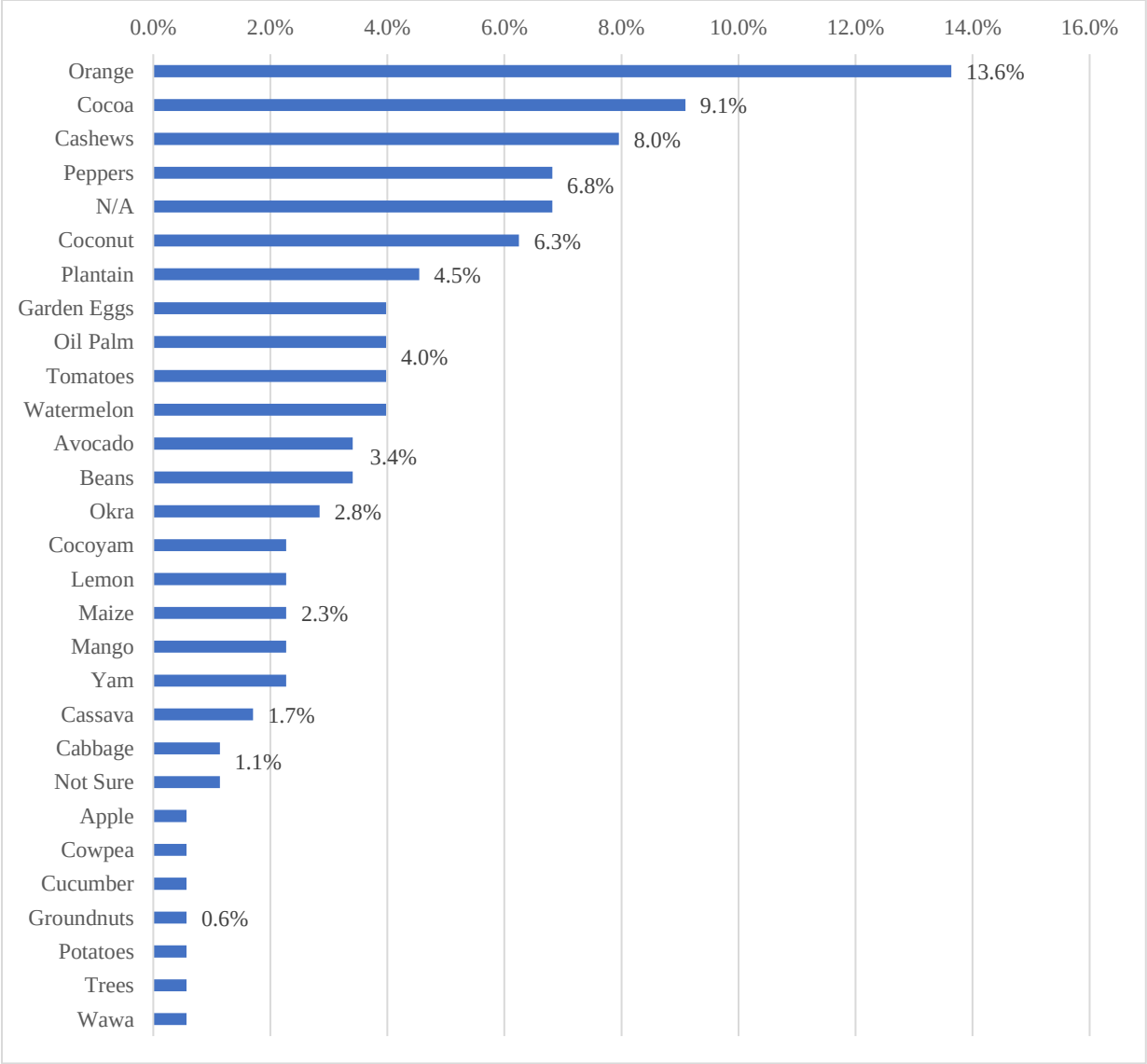


Figure D-38. What crops do you wish you could grow?

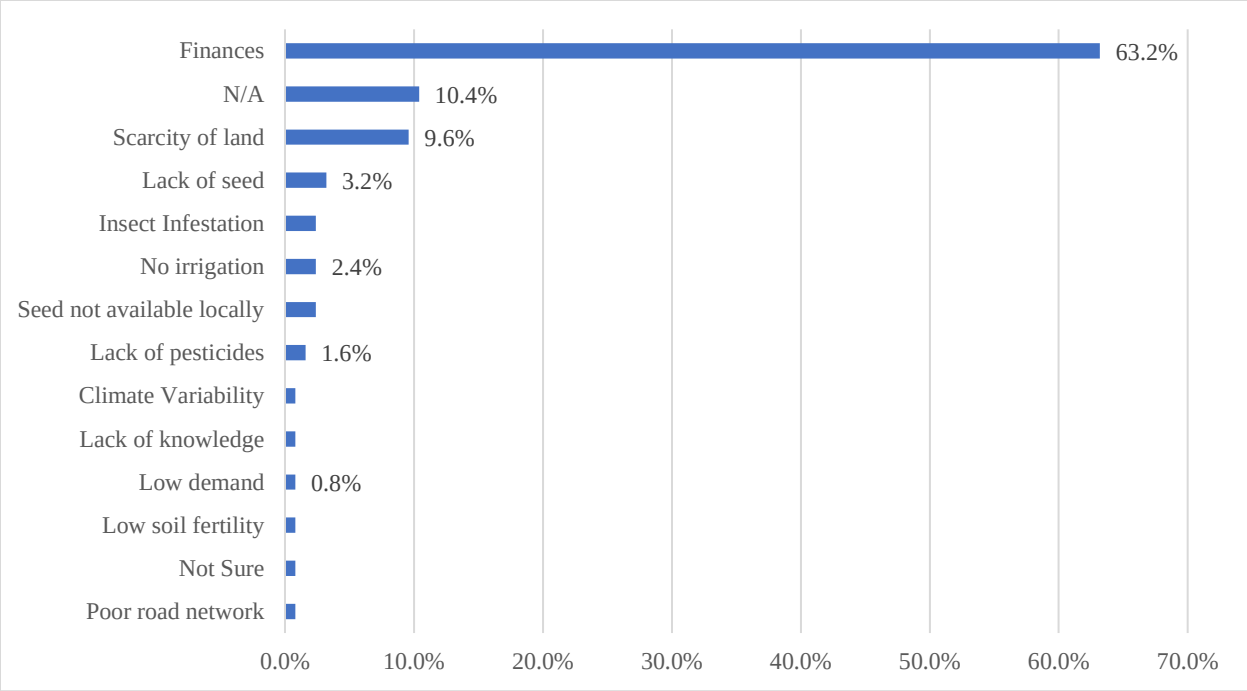


Figure D-39. What are the major obstacles that have kept you from growing the crops specified?

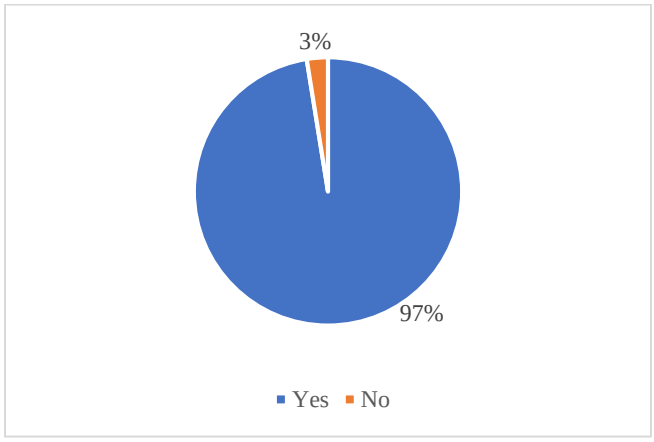


Figure D-40. If a seed bank was available locally to purchase seed from, would you choose to purchase from this source?

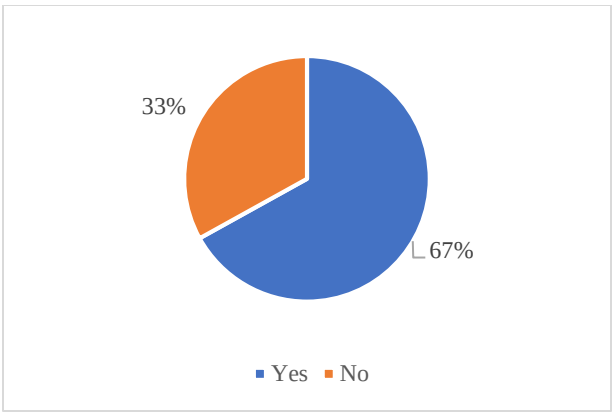


Figure D-41. If a nursery was available locally to purchase small trees or plants from, would you choose to purchase from this source?

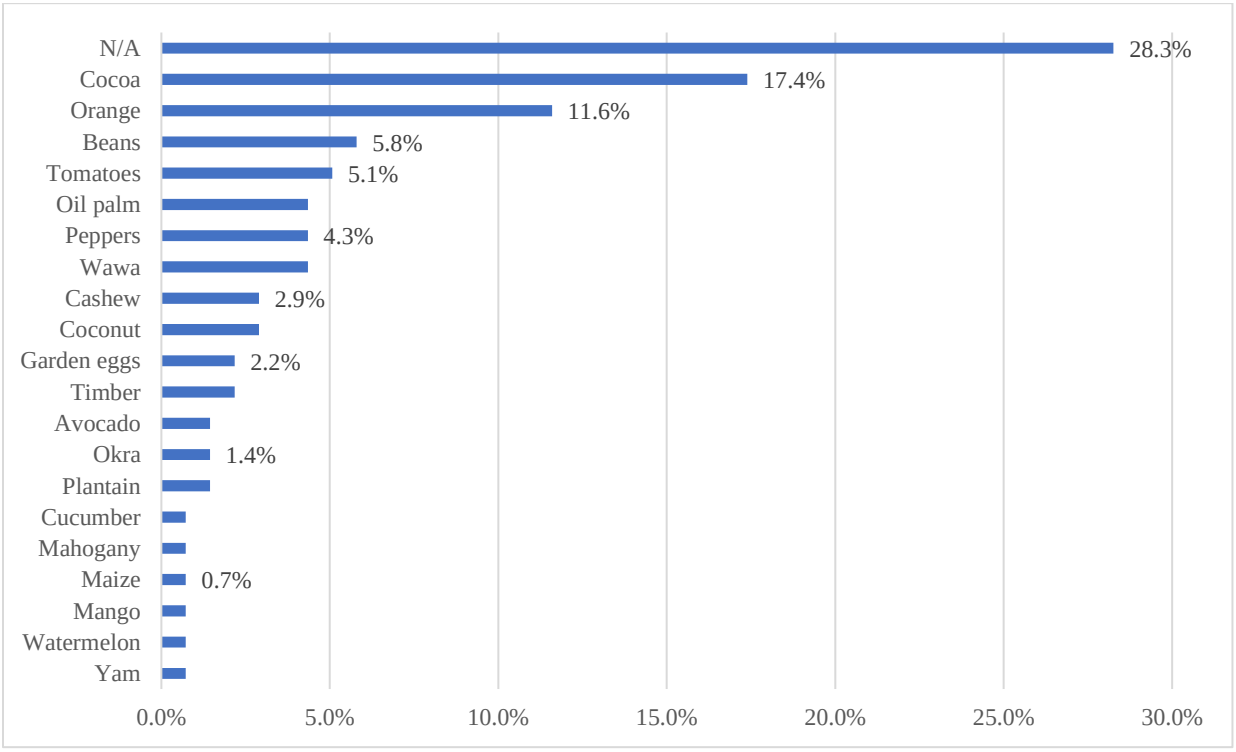


Figure D-42. If a nursery was available locally, what would you choose to purchase?

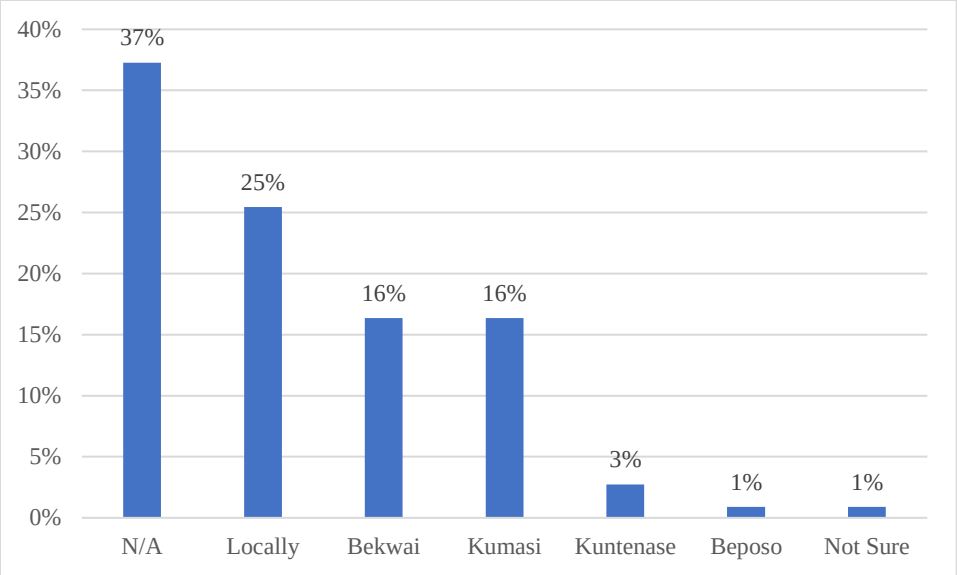


Figure D-43. Where would you sell these crops?

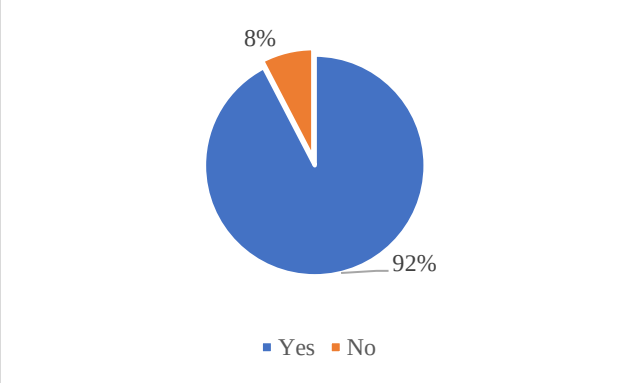


Figure D-44. Do you practice slash and burn?

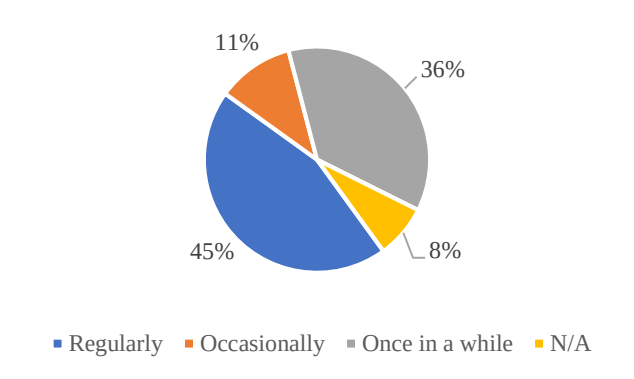


Figure D-45. How often do you practice slash and burn?

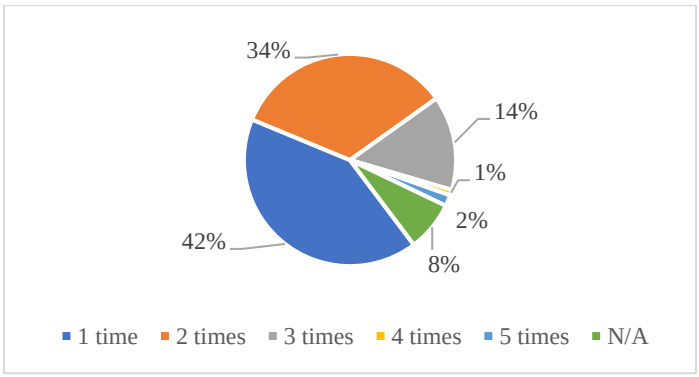


Figure D-46. How many times during the year do you slash and burn?

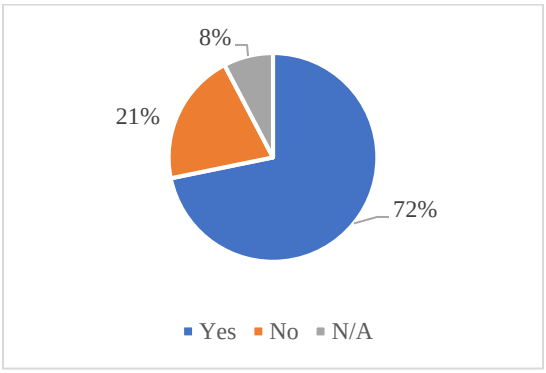


Figure D-47. Would you be willing to not slash and burn but rather let the brush and weeds decompose naturally?

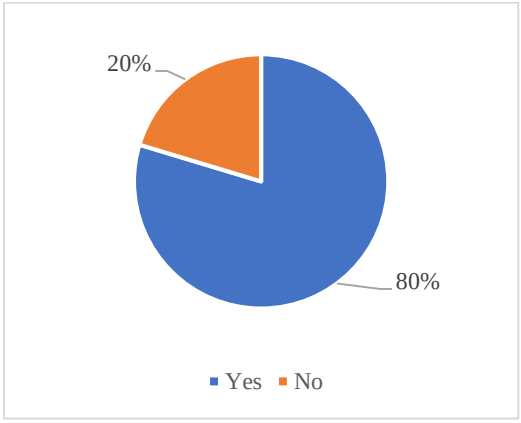


Figure D-48. Do you believe there is any benefit to letting the brush and weeds decompose naturally?

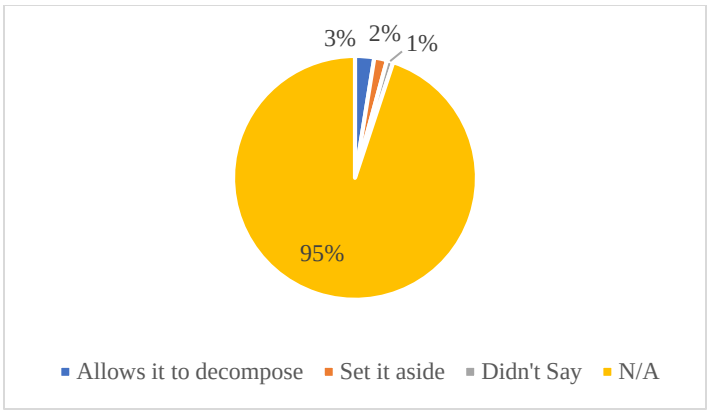


Figure D-49. What do you do with the excess brush and weeds?

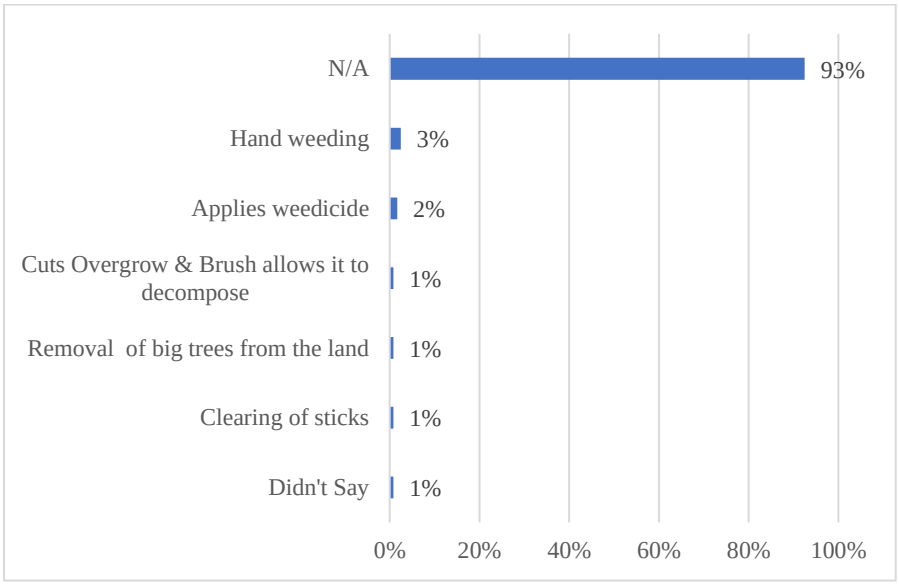


Figure D-50. How do you clear your field?

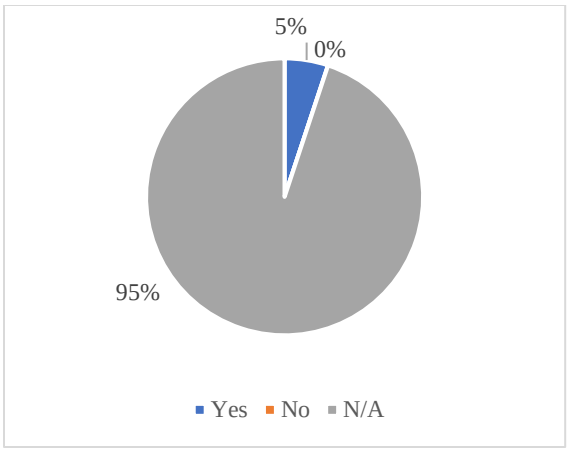


Figure D-51. Do you allow the remaining brush and weeds to decompose naturally?

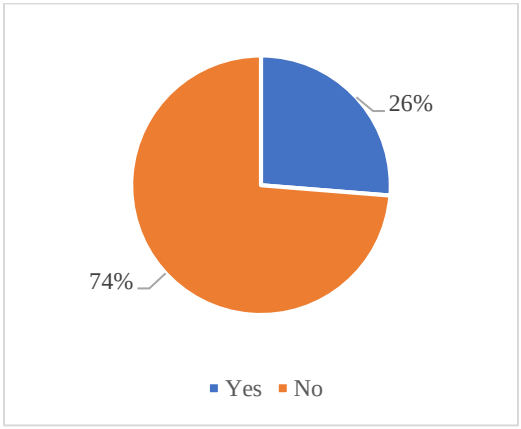


Figure D-52. Do you practice Crop Rotation?

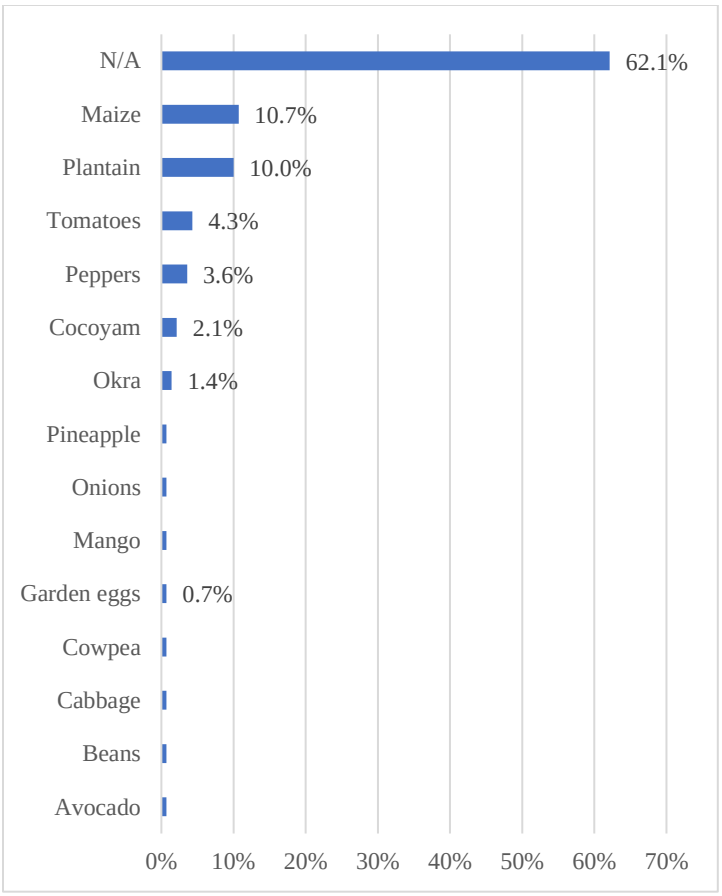


Figure D-53. What crops do you use to for Crop Rotation?

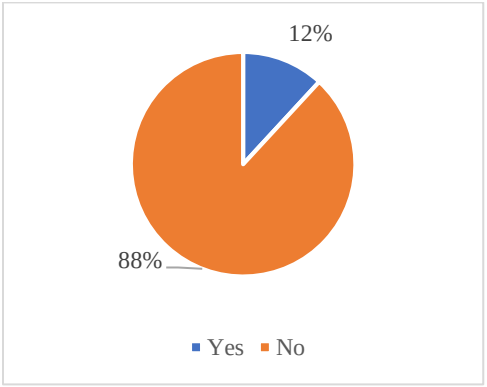


Figure D-54. Do you practice any form of erosion control/slope protection?

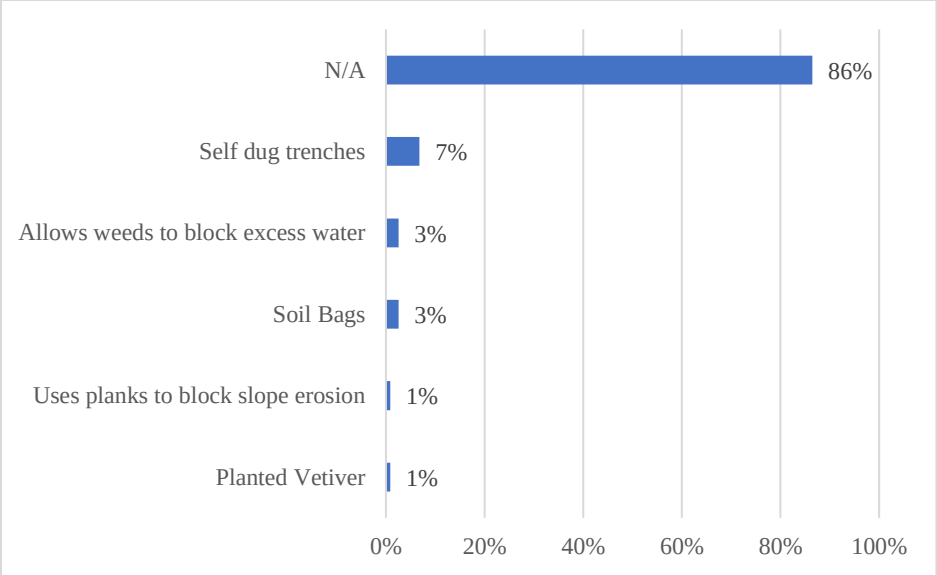


Figure D-55. Local Slope Protection Methods

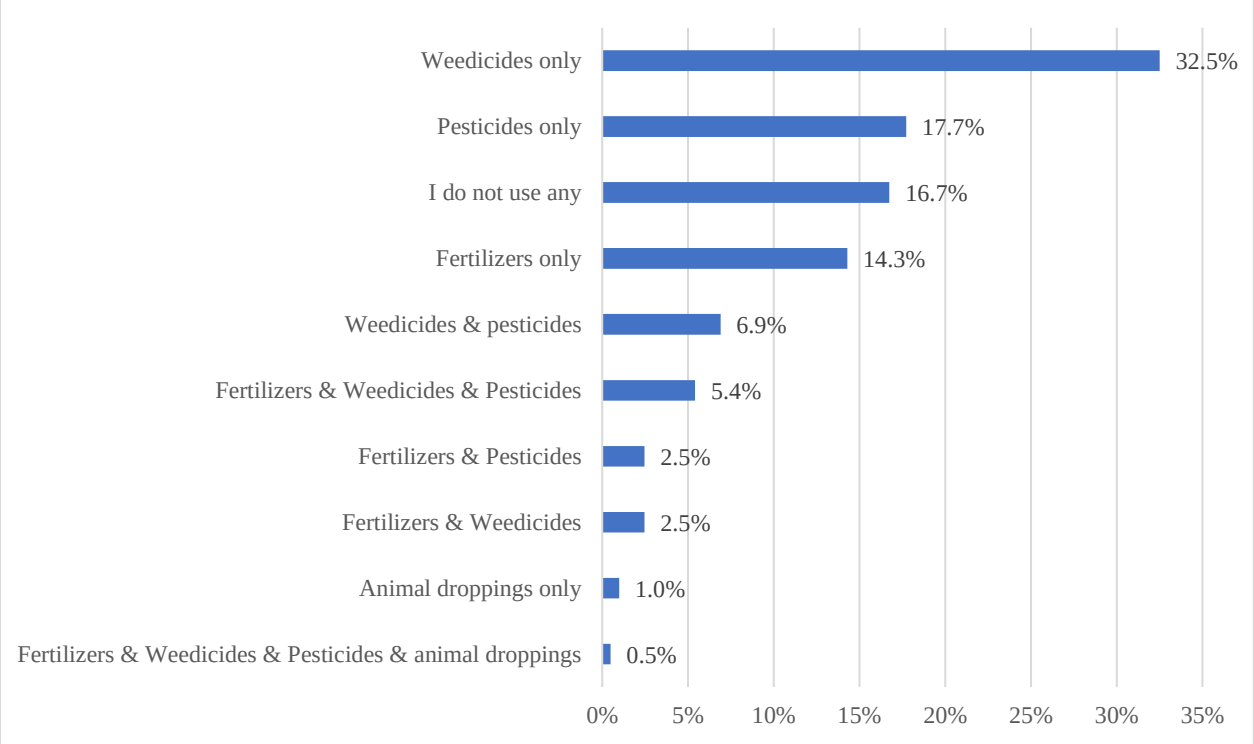


Figure D-56. Do you use animal droppings, fertilizers, pesticides, or weedicides?

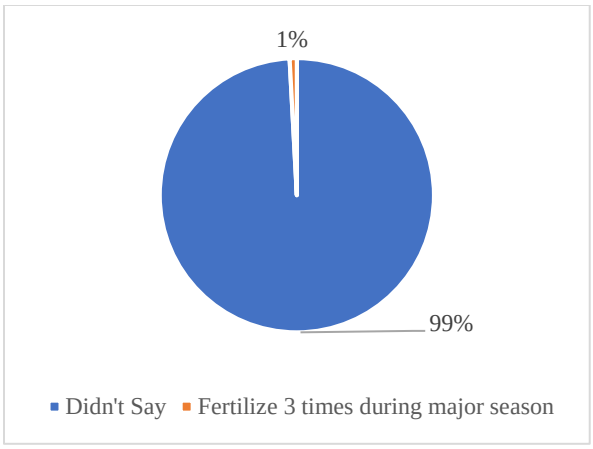


Figure D-57. How often do you apply fertilizer?

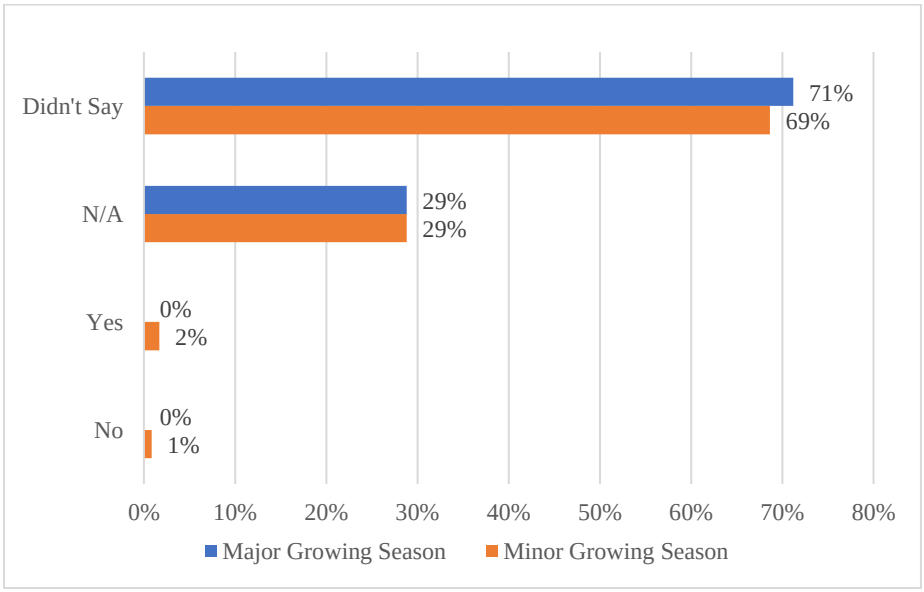


Figure D-58. Do you apply fertilizer during the major or minor growing season?

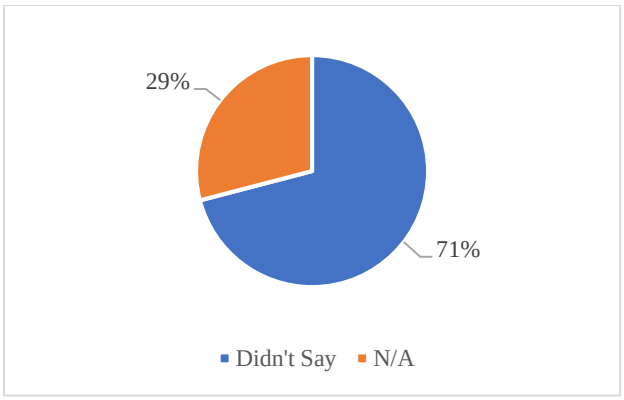


Figure D-59. Where do you purchase your farming agrochemicals from?

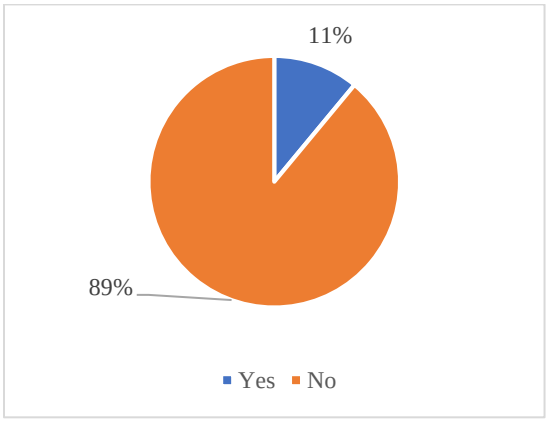


Figure D-60. Do you water your crops?

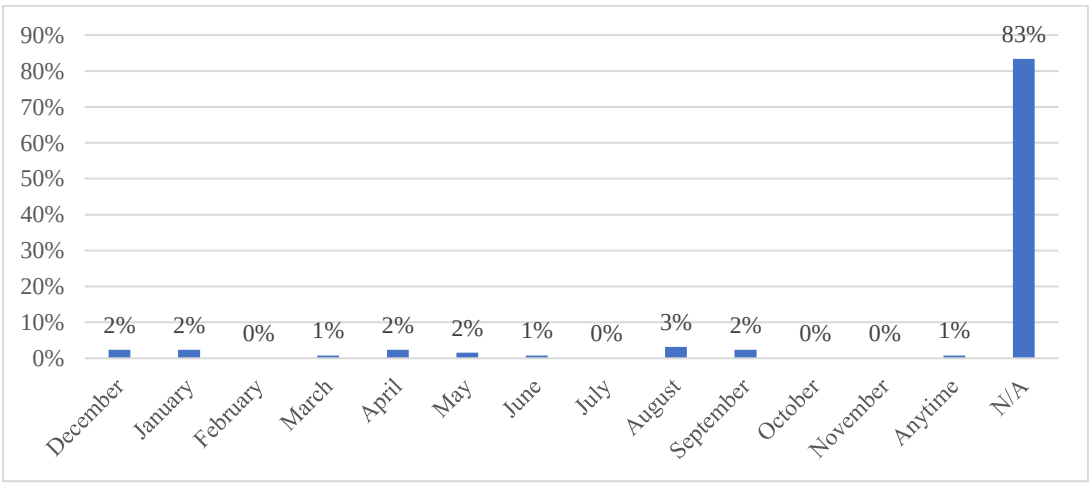


Figure D-61. What time of year do you water your crops?

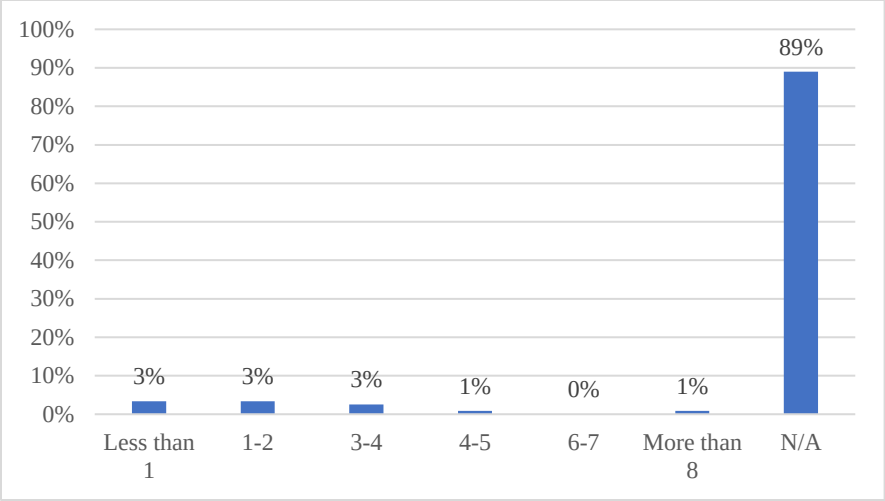


Figure D-62. How many months out of the year do you water your crops?

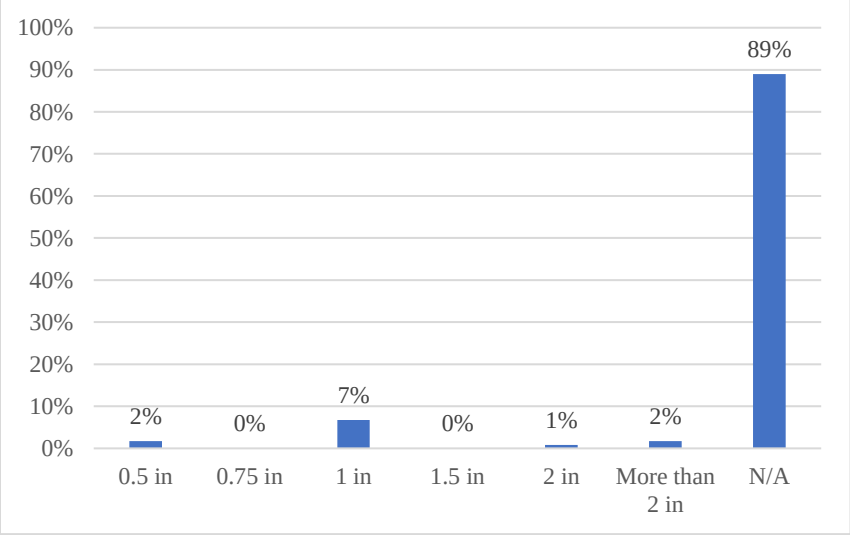


Figure D-63. During a week that you irrigate how much water do you apply daily to your field?

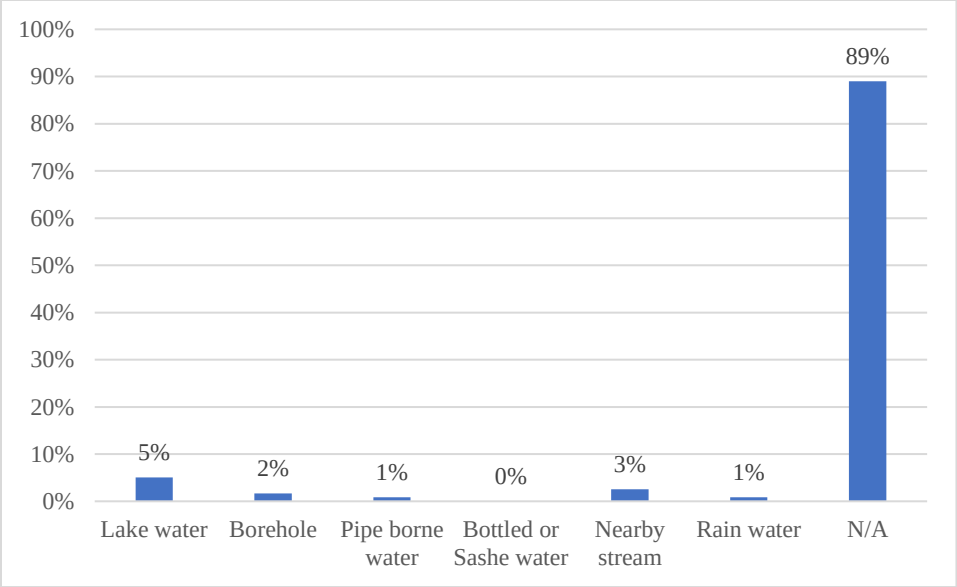


Figure D-64. What water source do you use for irrigation?

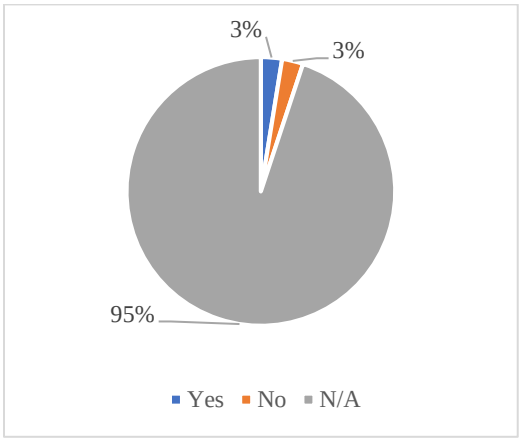


Figure D-65. Do you practice leaching?

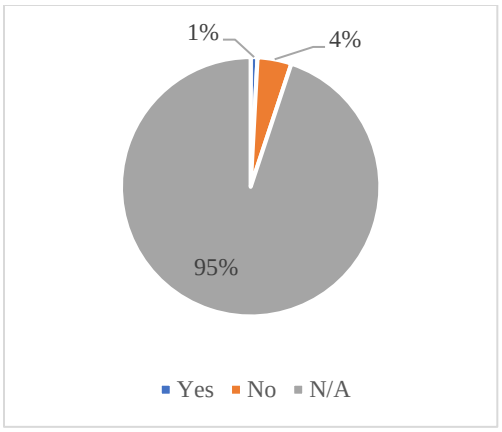


Figure D-66. Do you mix the lake water with another source of water before using the water for irrigation?

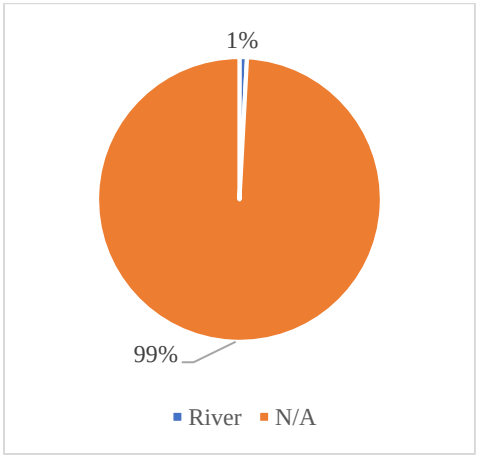


Figure D-67. What is your other source that you mix the lake water with?

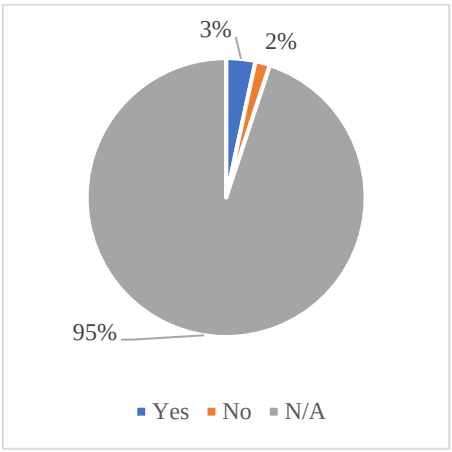


Figure D-68. Do you allow the water collected to sit over night before applying it to your field?

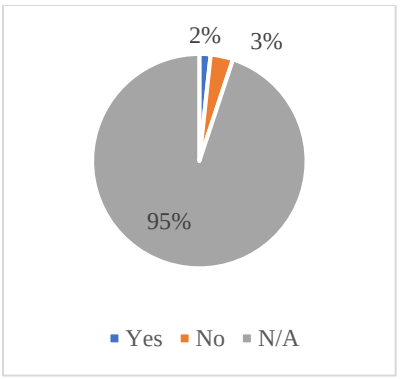


Figure D-69. Do you believe there are any negative effects from using water from the lake long-term?

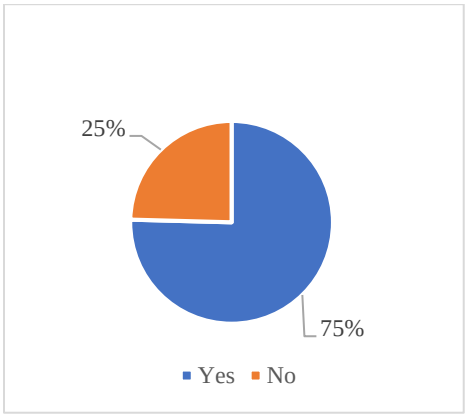


Figure D-70. Do you participate in livestock rearing?

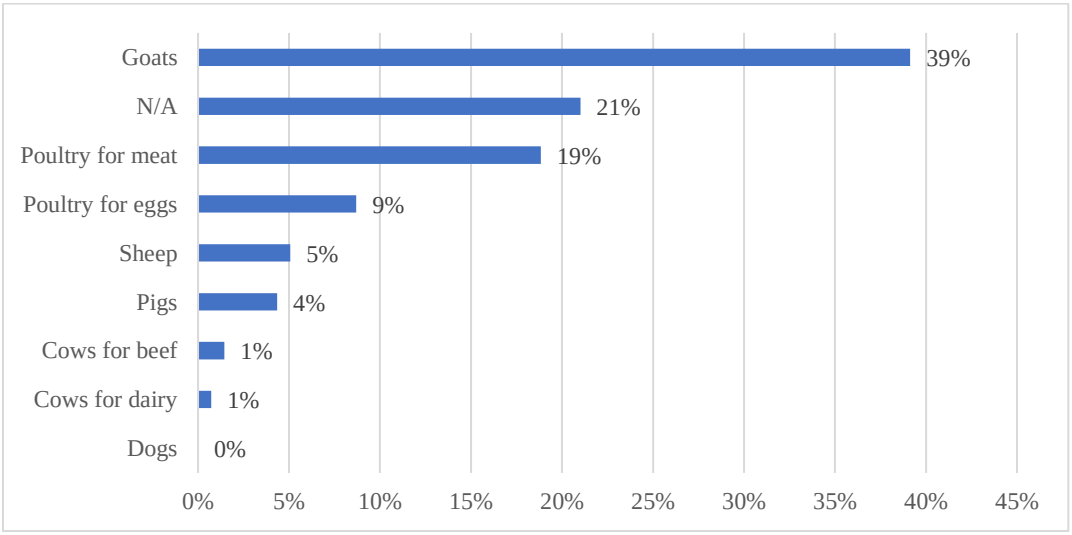


Figure D-71. What animals do you rear?

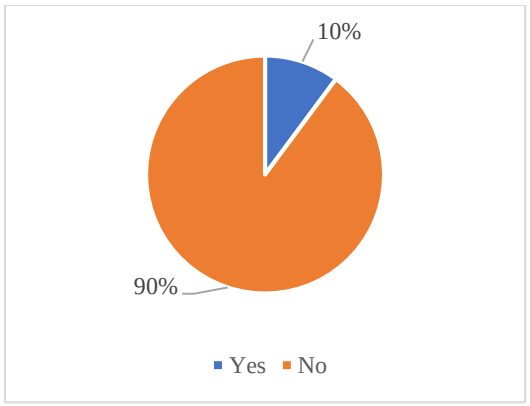


Figure D-72. Do you sell the eggs produced?

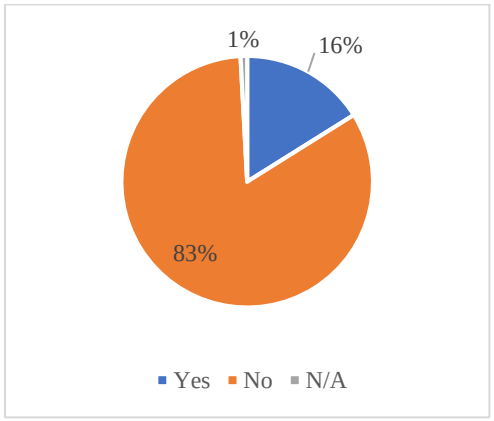


Figure D-73. Do you purchase animal feed?

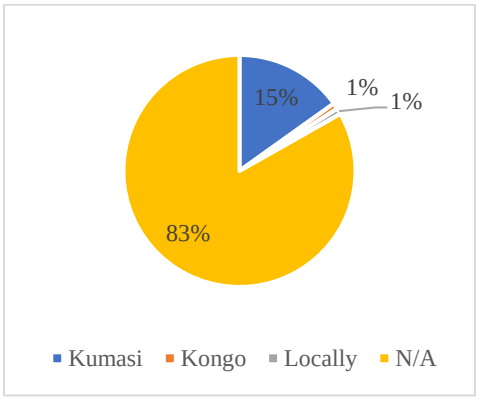


Figure D-73. Where do you purchase animal feed?

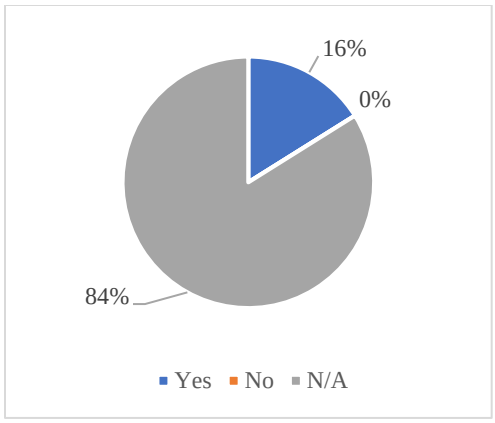


Figure D-74. If animal feed was available locally, would you choose to purchase from a local vendor?

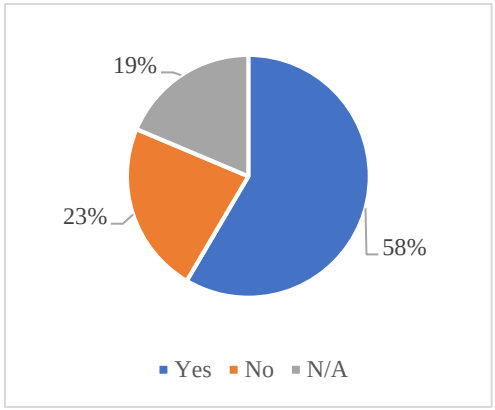


Figure D-75. Do you grow your own feed?

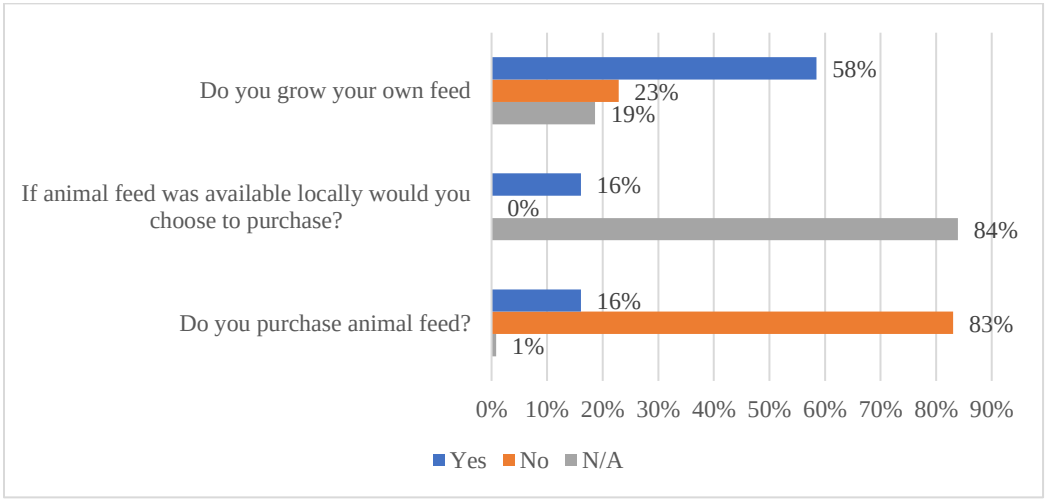


Figure D-76. Participants that grow or purchase feed and those interested in purchasing feed locally.

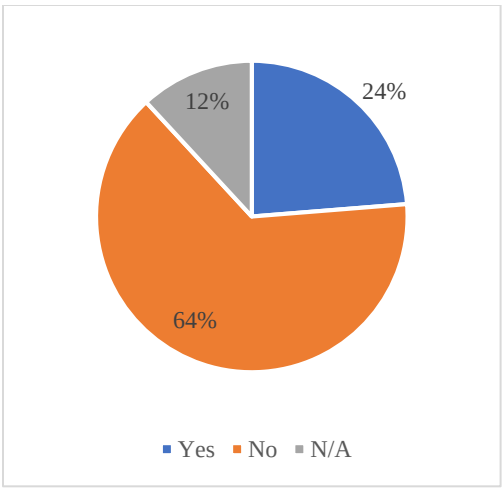


Figure D-77. Do you or a member of your household purchase eggs?

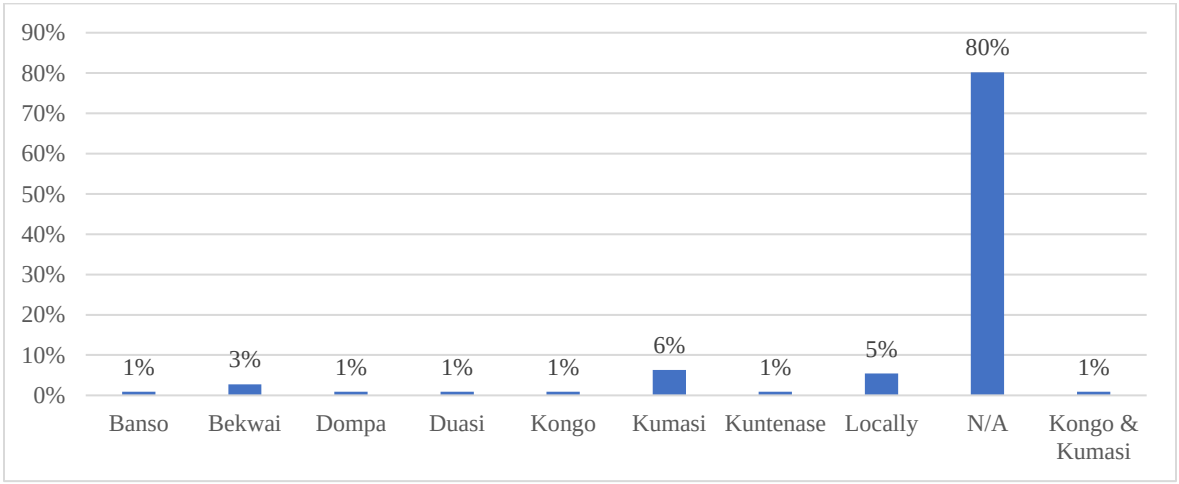


Figure D-78. Where do you purchase eggs?

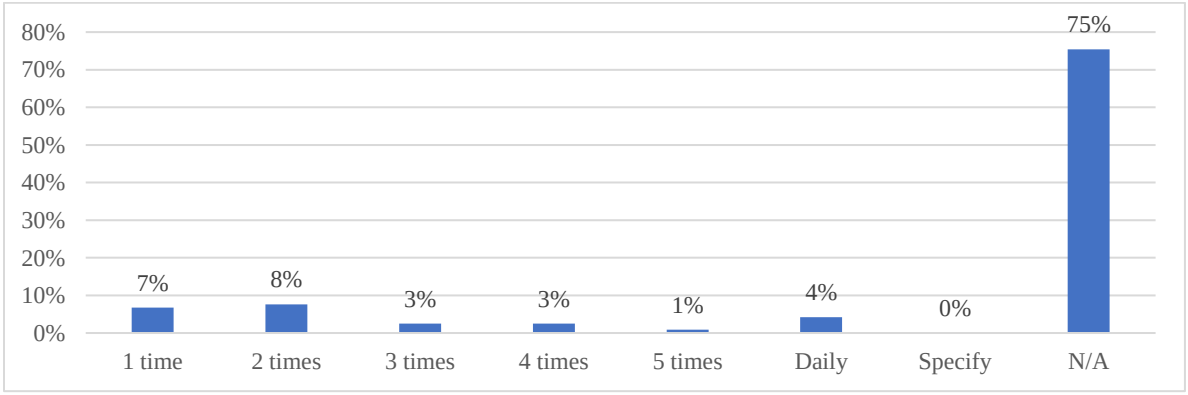


Figure D-79. How often do you purchase eggs during in one week?

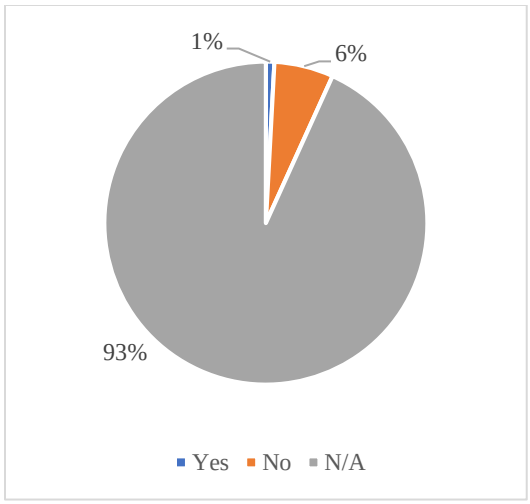


Figure D-80. Do you sell the eggs produced?

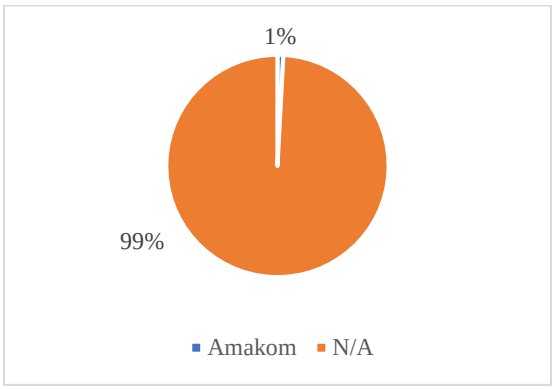


Figure D-81. Where do you sell your eggs?

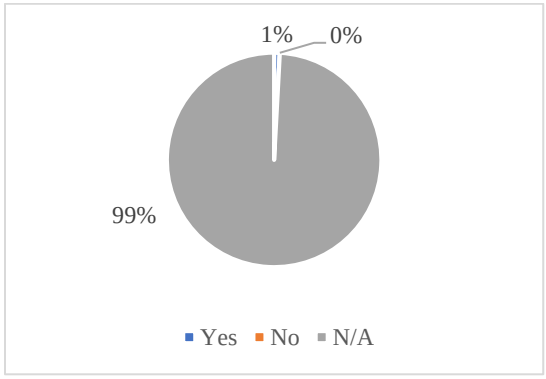


Figure D-82. Do you package your eggs?

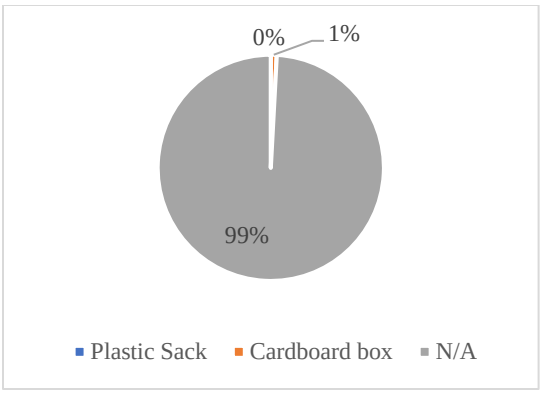


Figure D-83. Describe the packaging.

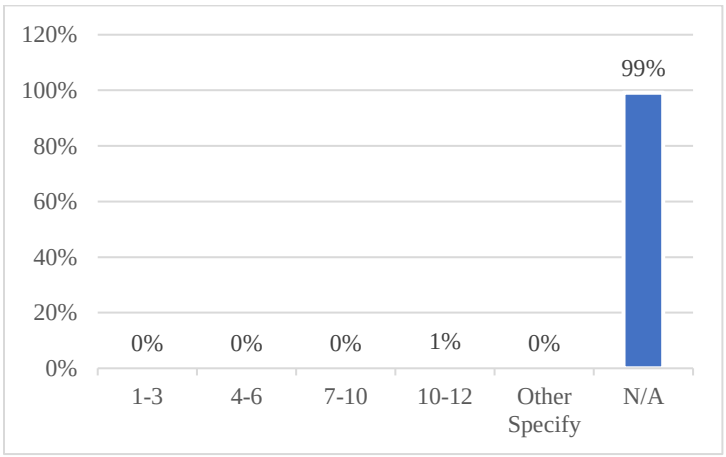


Figure D-84. How many eggs do you sell per week?

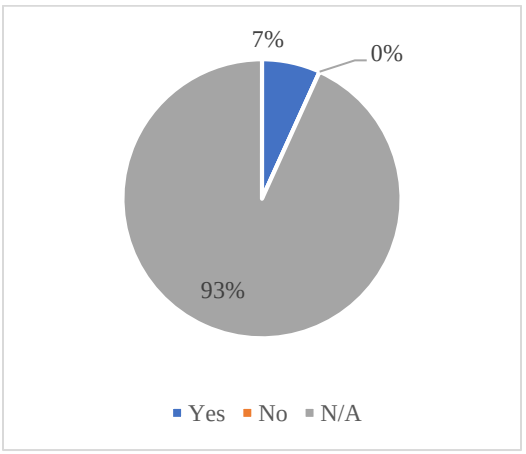


Figure D-85. Do you believe selling packaged eggs to the nearby hotels could be profitable?

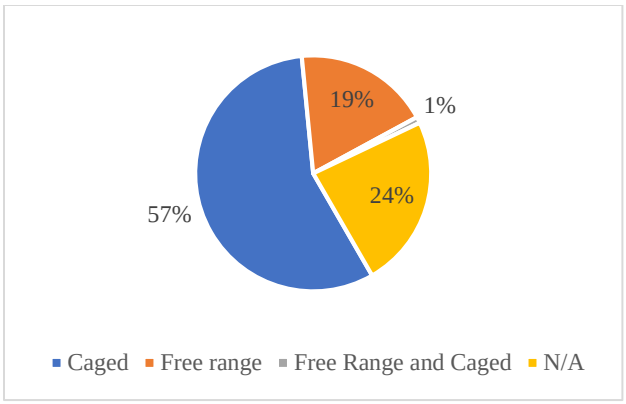


Figure D-86. Are your animals caged or free range?

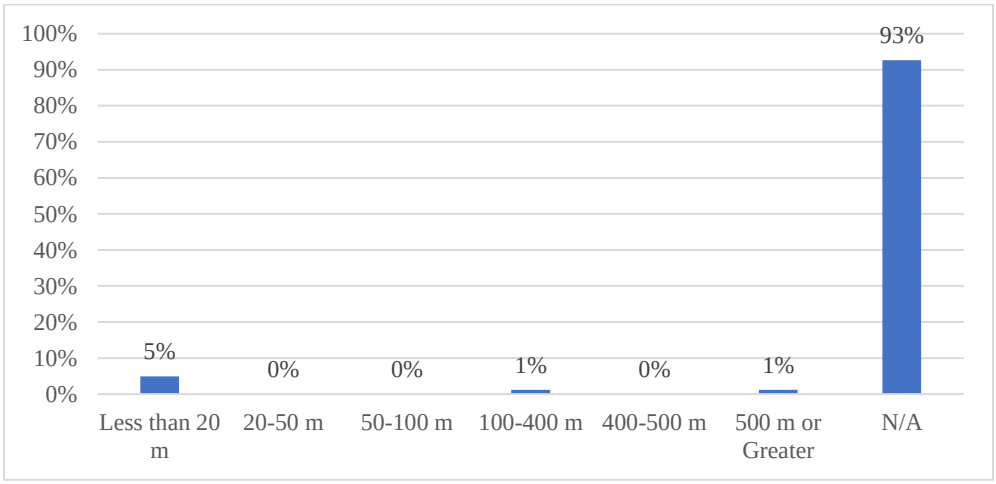


Figure D-87. What is the distance of the facility from the lake shores?

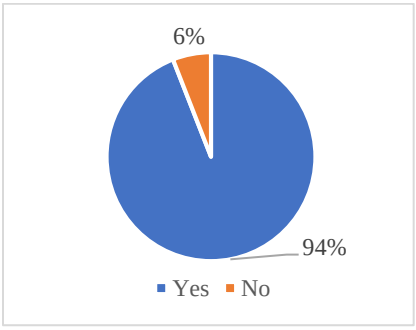


Figure D-88. Have you observed any changes in the lake in recent years?

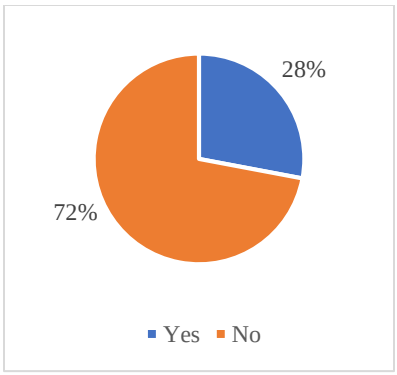


Figure D-89. Do you engage in any fishing activity?

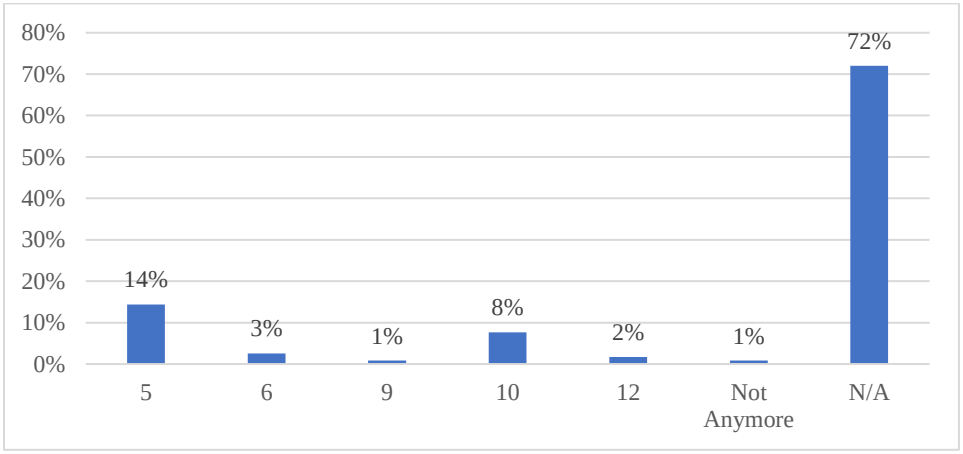


Figure D-90. How often do you go fishing/fishing mongering in one week?

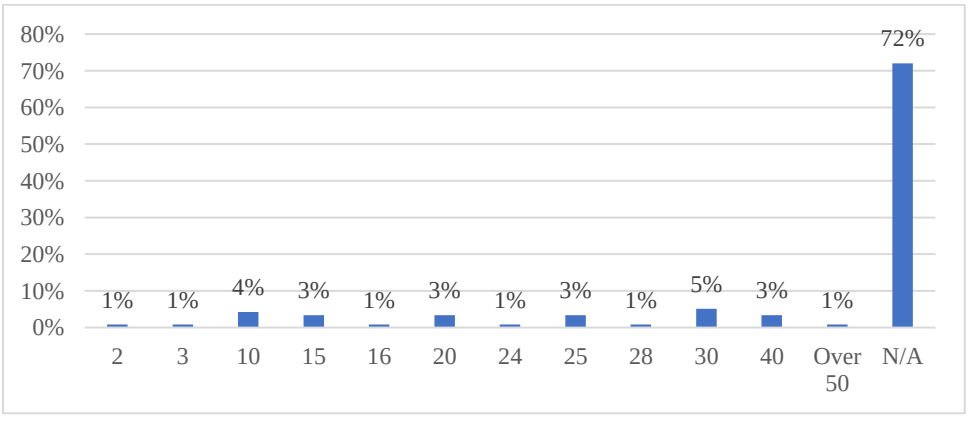


Figure D-91. How long have you been engaged in fishing/fish mongering?

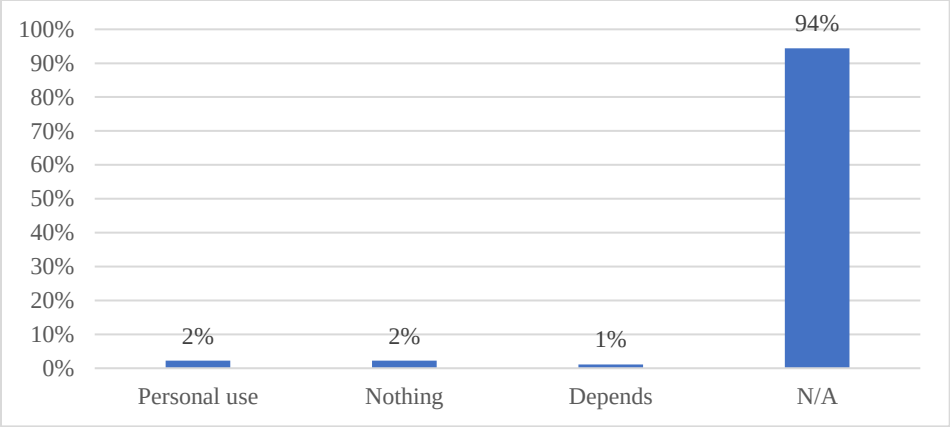


Figure D-92. How much do you make in a day if you go fishing?

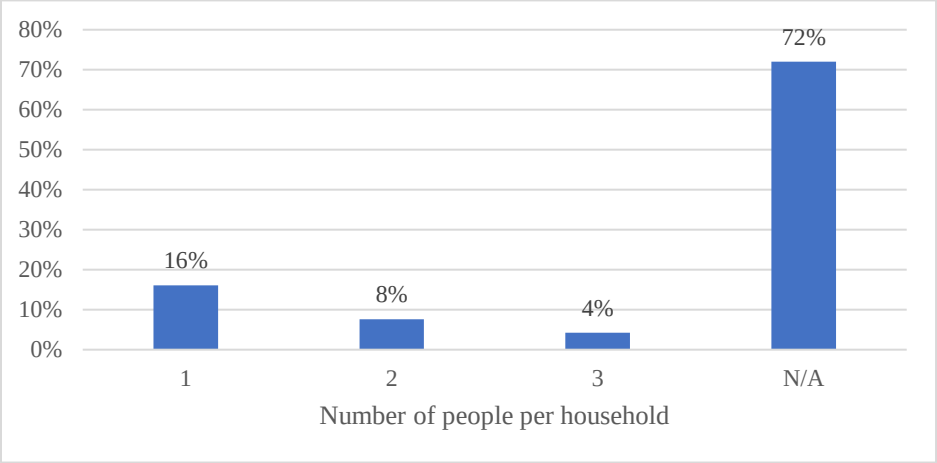


Figure D-93. How many people within your household are engaged in fishing activities?

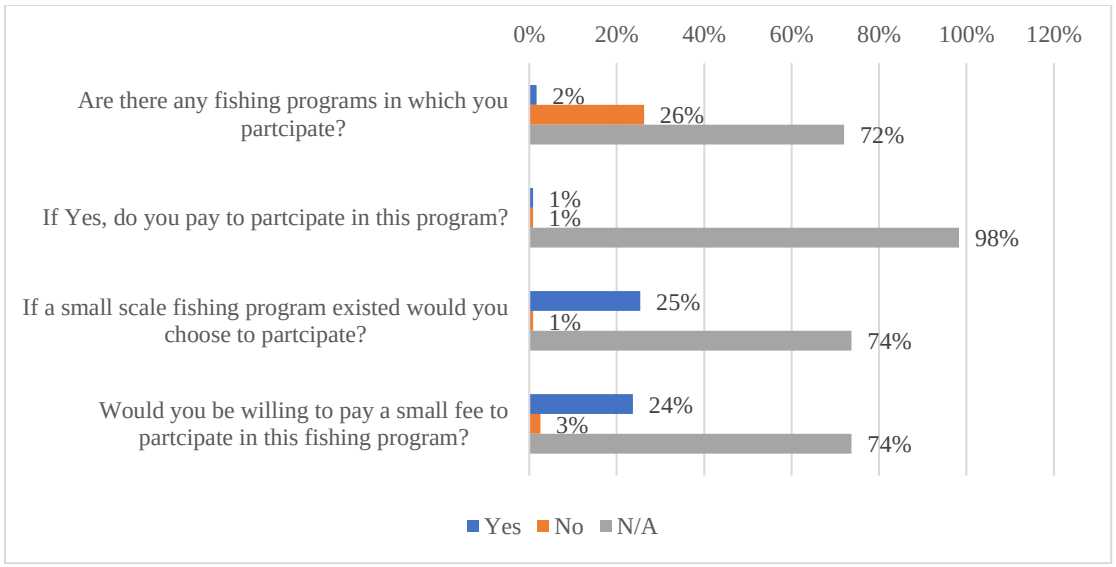


Figure D-94. Fishing Extension Program Outreach Interest

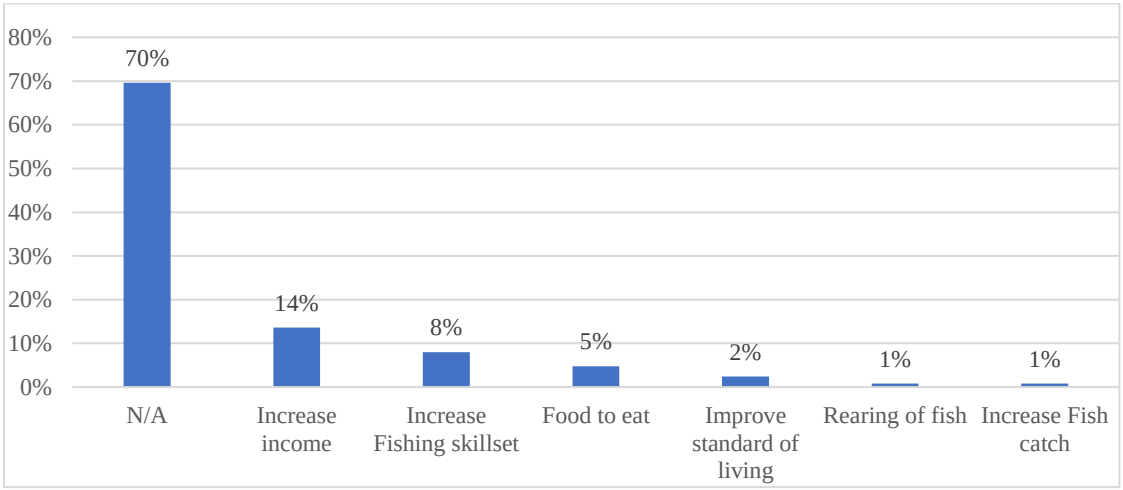


Figure D-95. What benefits would you hope this fishing program would provide to you?

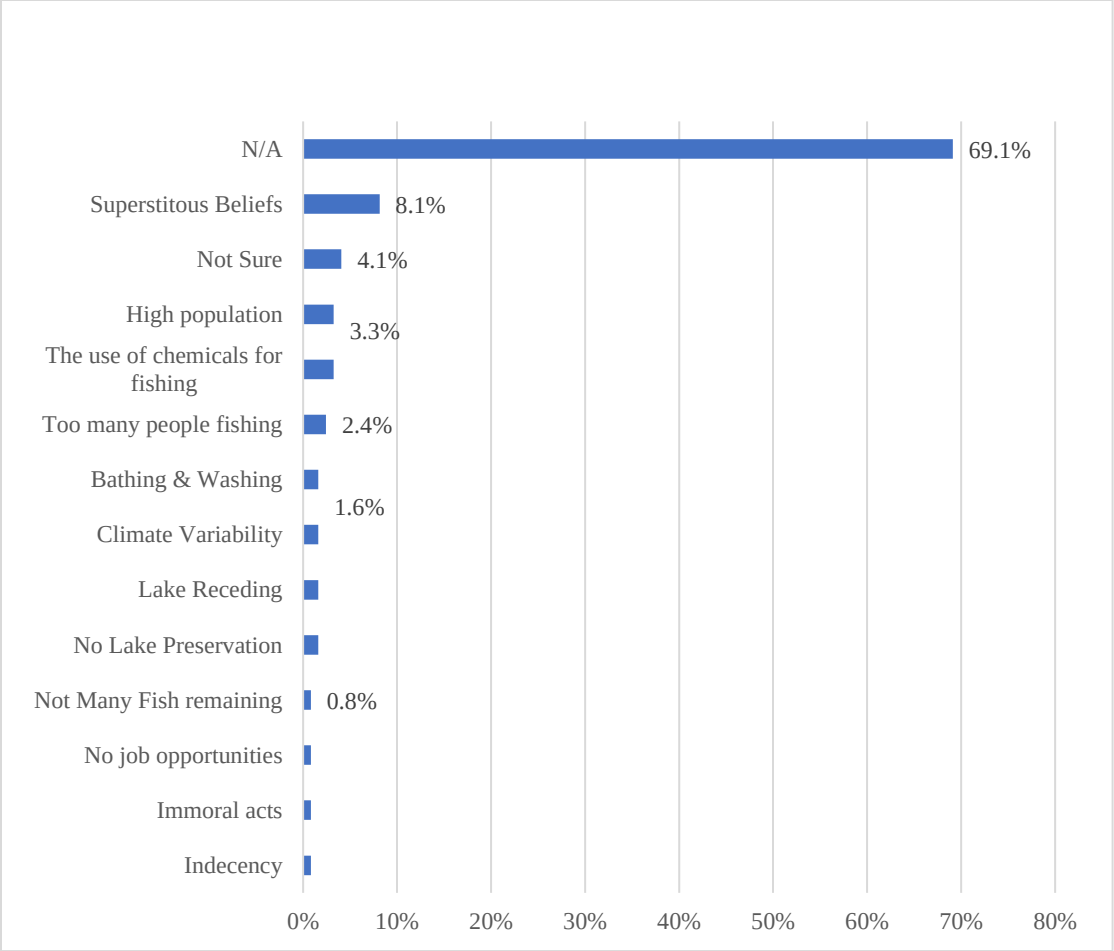


Figure D-96. In your opinion, what do you believe is the cause of the reduction or otherwise of fish stock in the lake?

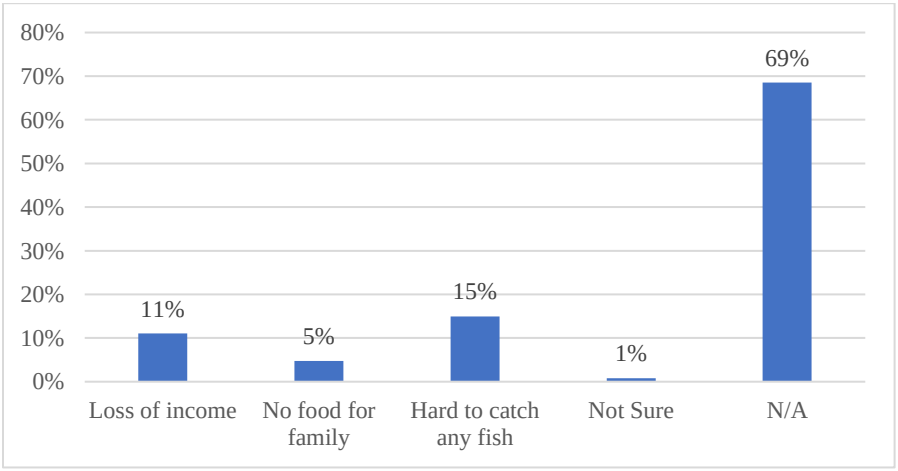


Figure D-97. How has the change in fish catch affected you?

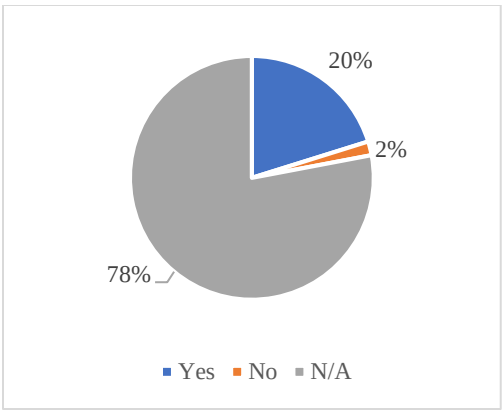


Figure D-98. Has the change in fish catch affected your income?

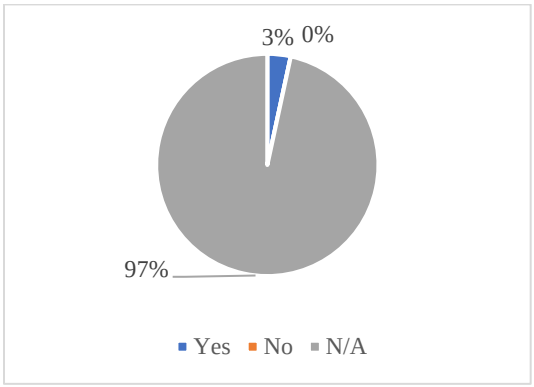


Figure D-99. Does the program allow you to utilize your knowledge and skills from fishing/fish mongering?

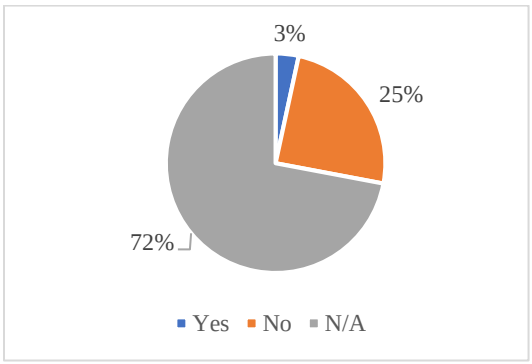


Figure D-100. Is there any alternative livelihood program in your community?

Water, Sanitation, & Hygiene

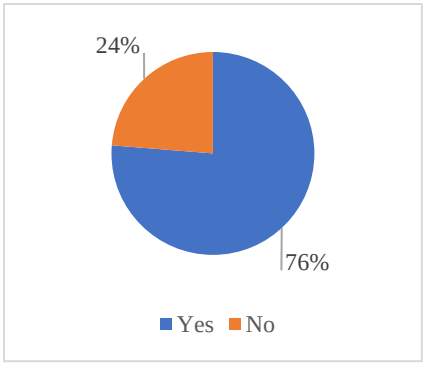


Figure D-101. Have you bathed or washed in the lake before?

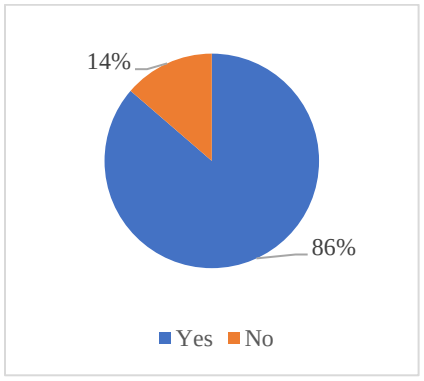


Figure D-102. Do you believe your activities effect the lake water quality?

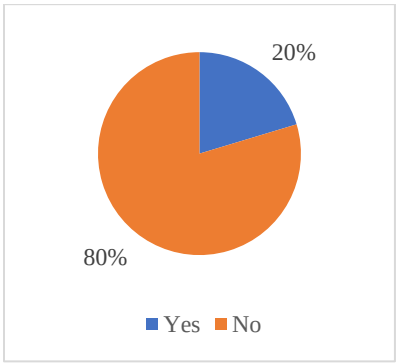


Figure D-103. Do you have a toilet facility within your home?

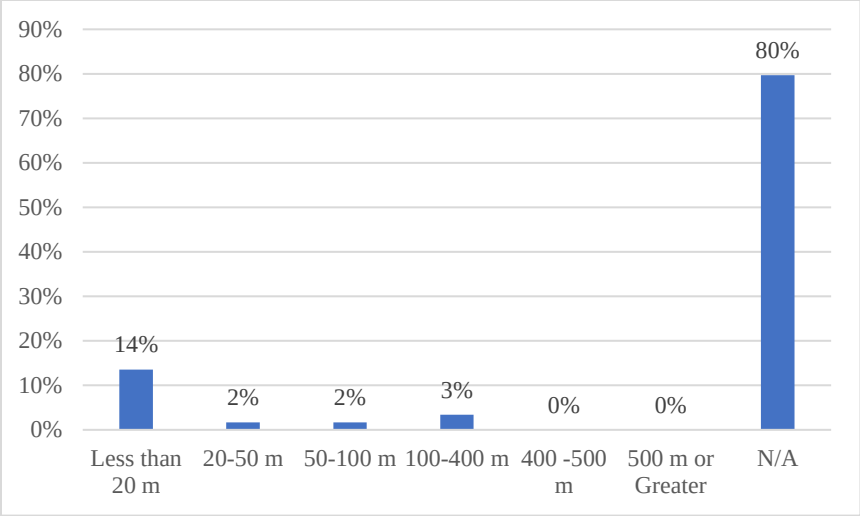


Figure D-104. If Yes, what is the distance of your toilet facility from the lake?

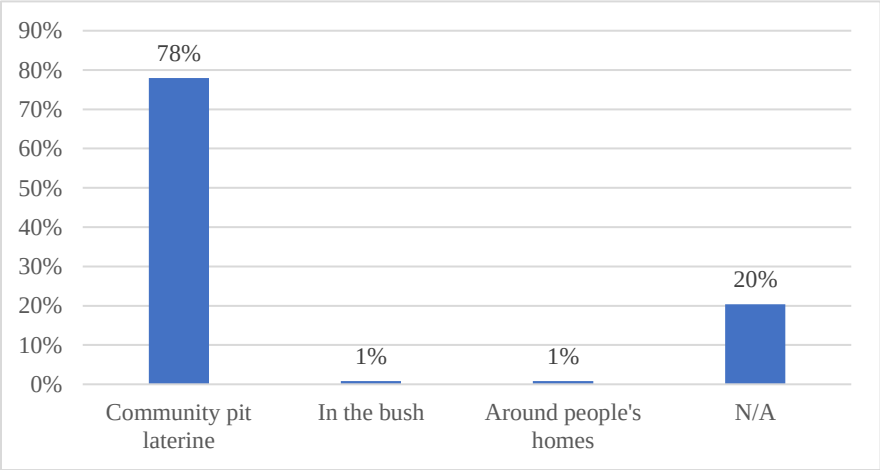


Figure D-105. If No, where do you go to use the toilet?

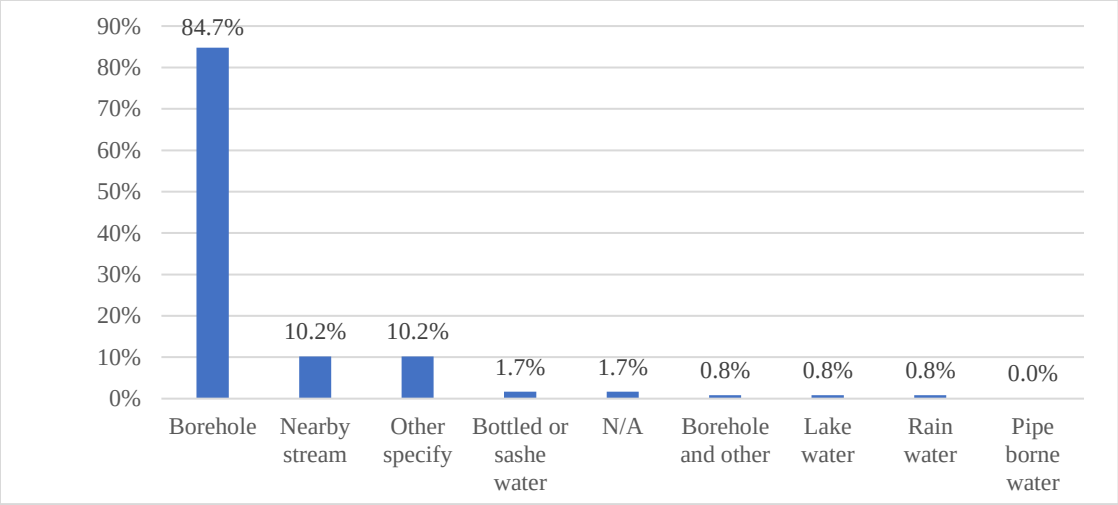


Figure D-106. What is your main source of drinking water for your household?

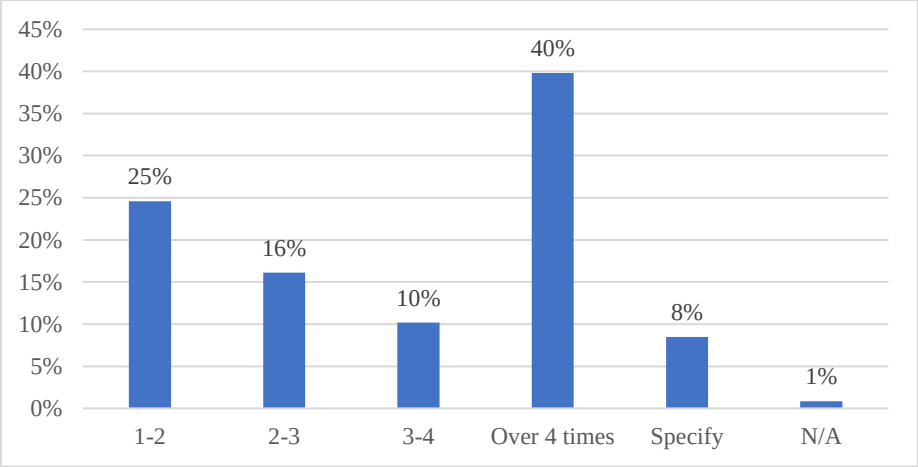


Figure D-107. How many times in a week do you walk to collect water?

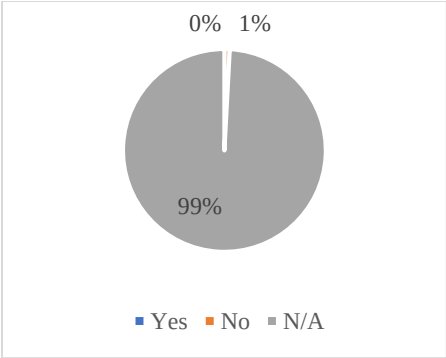


Figure D-108. Do you treat the water before drinking?

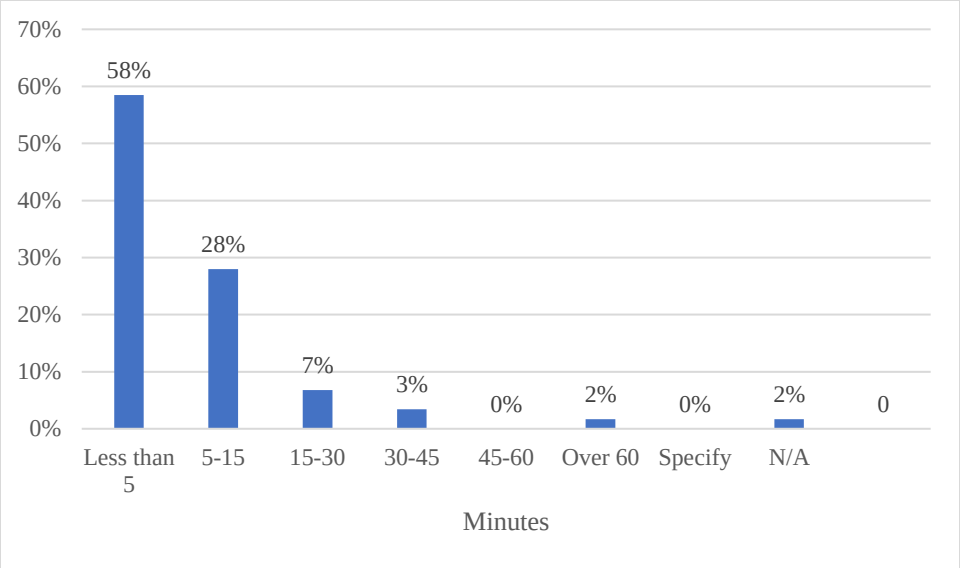


Figure D-109. How many minutes on average do you spend in line waiting for drinking water?

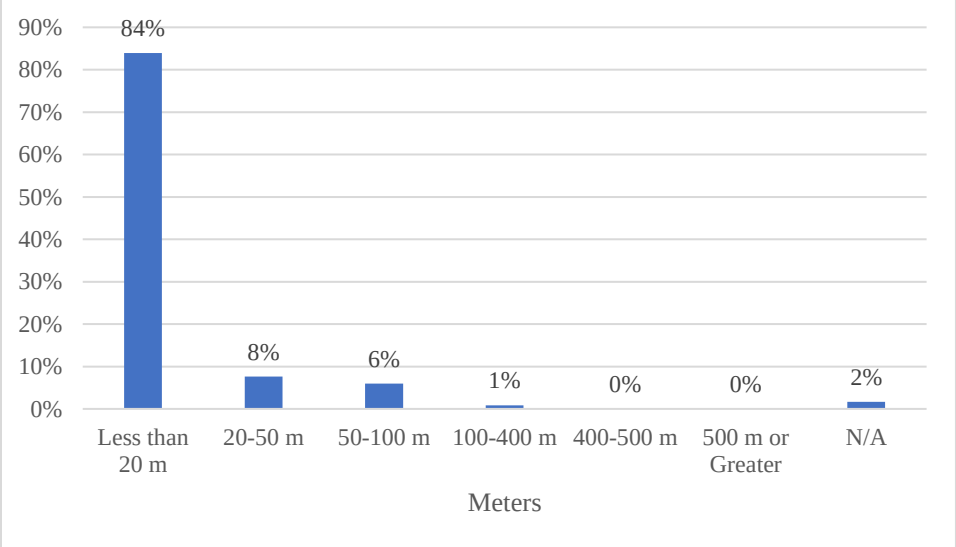


Figure D-110. What distance must you travel to collect drinking water?

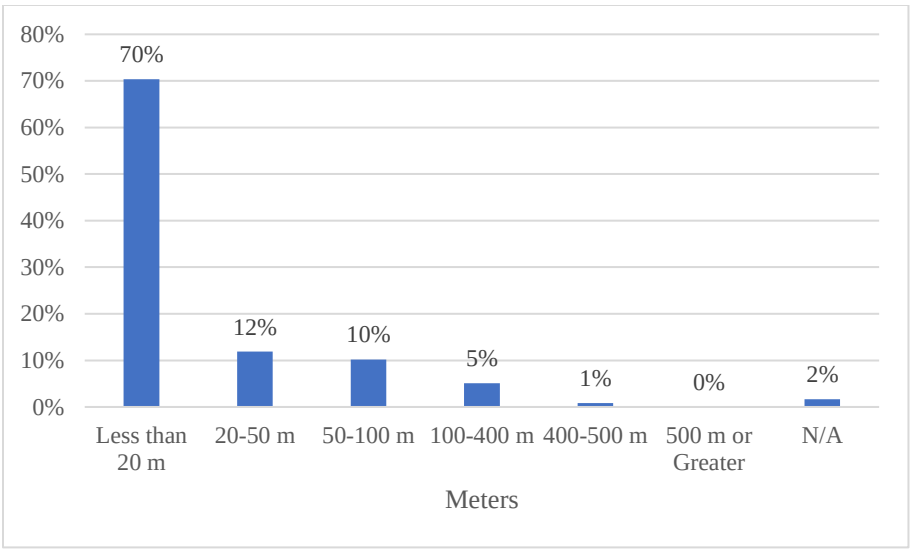


Figure D-111. What is the distance of your drinking water source from the lake?

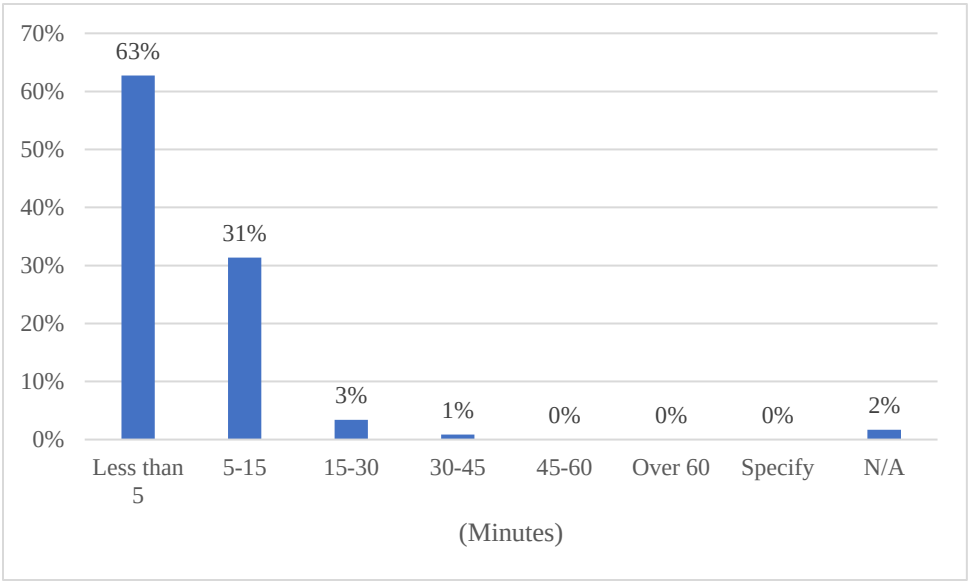


Figure D-112. How much time it take you to walk to your drinking water source?

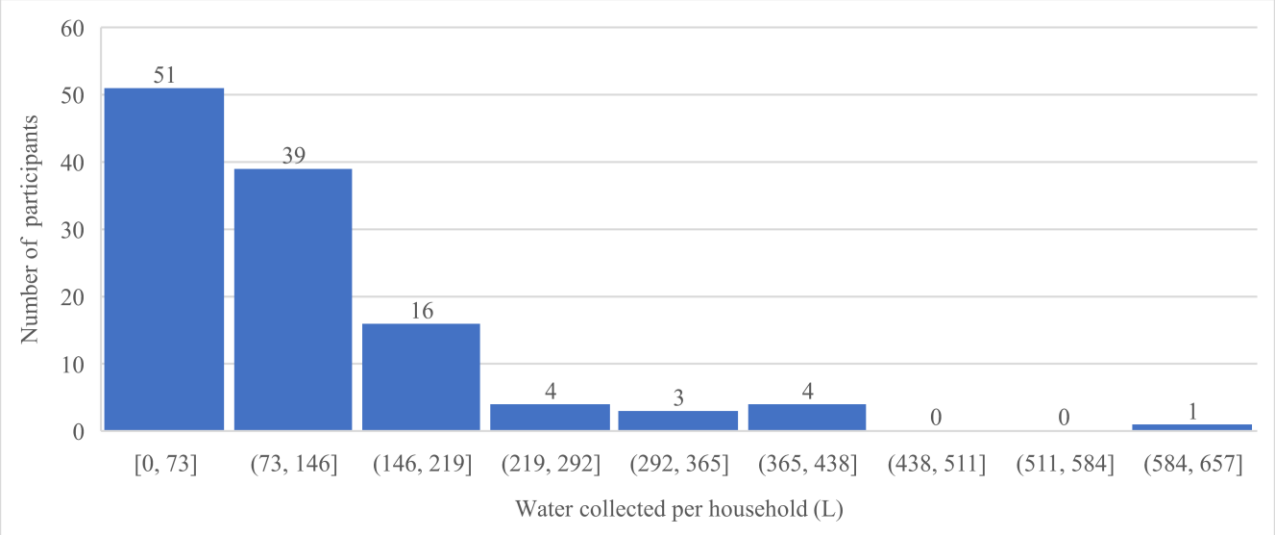


Figure D-113. Frequency Distribution of the Amount Of Water Collected for Domestic use per Household

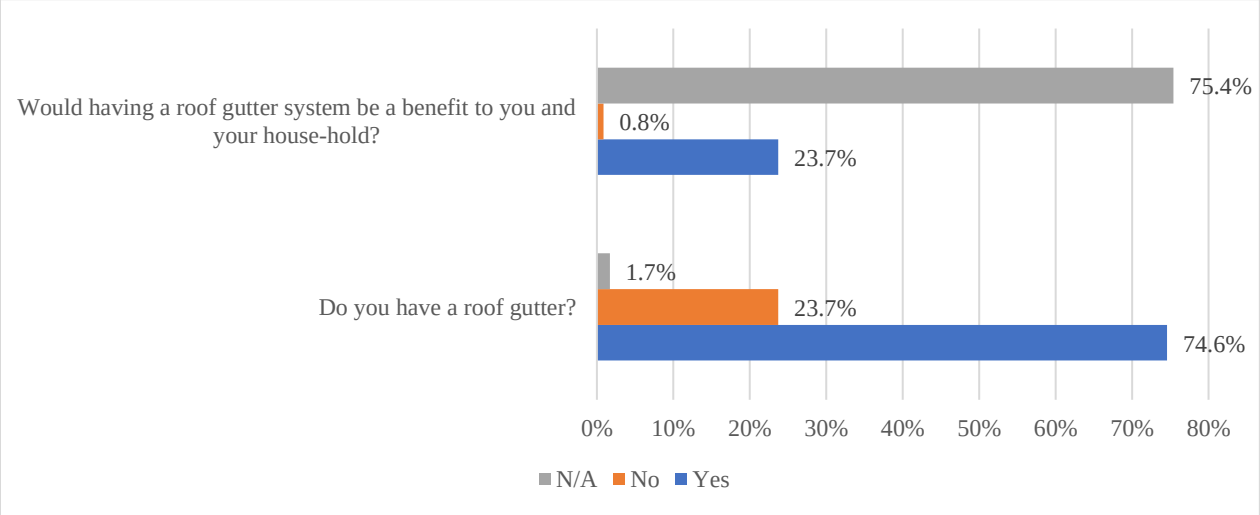


Figure D-114. Participants interest in having a roof gutter.

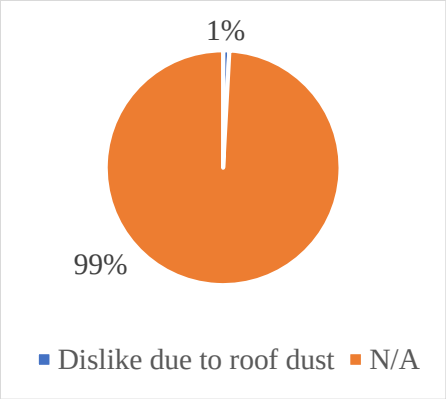


Figure D-115. Explain why you feel a roof gutter would not be a benefit to you and your household

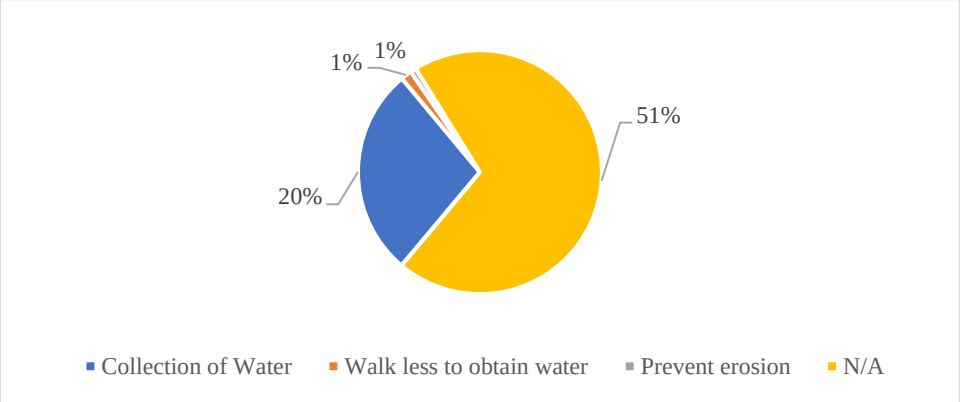


Figure D-116. How would a roof gutter benefit you and your household?

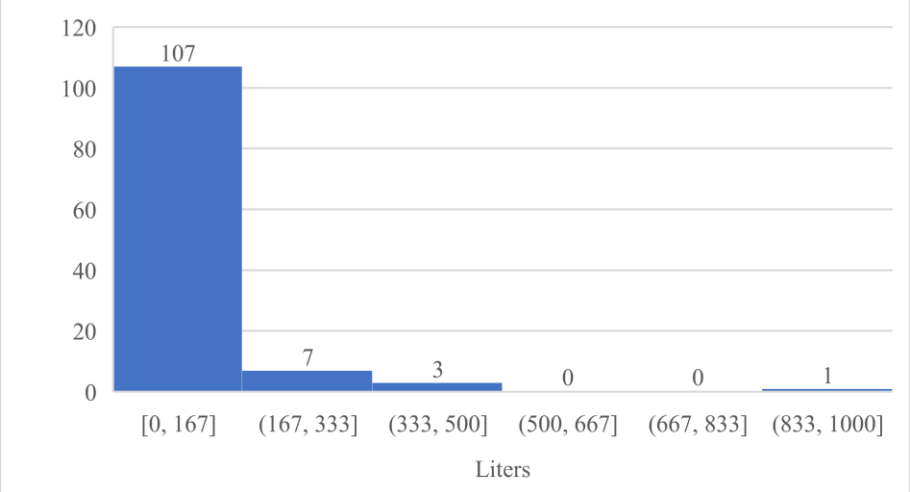


Figure D-117. Frequency distribution of the amount of rainwater collected Per Capita

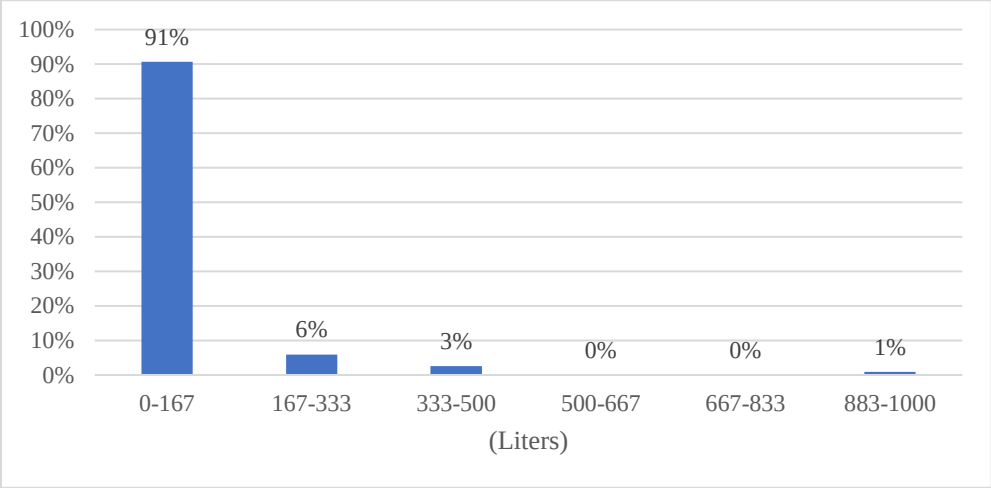


Figure D-118. Amount of rain water collected for domestic use Per Capita

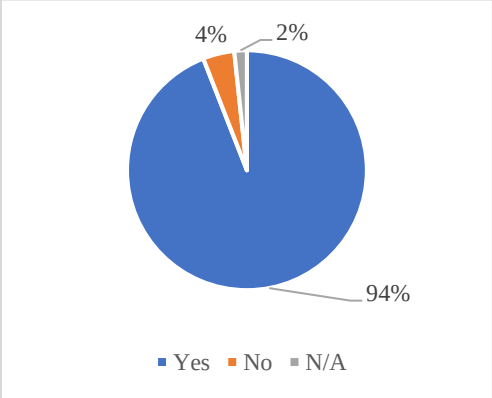


Figure D-119. Do you collect rainwater?

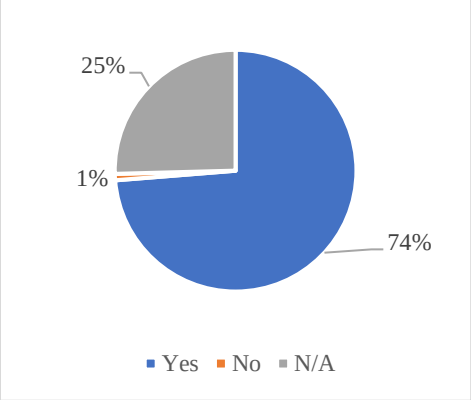


Figure D-120. Do you collect the rainwater to a central location?

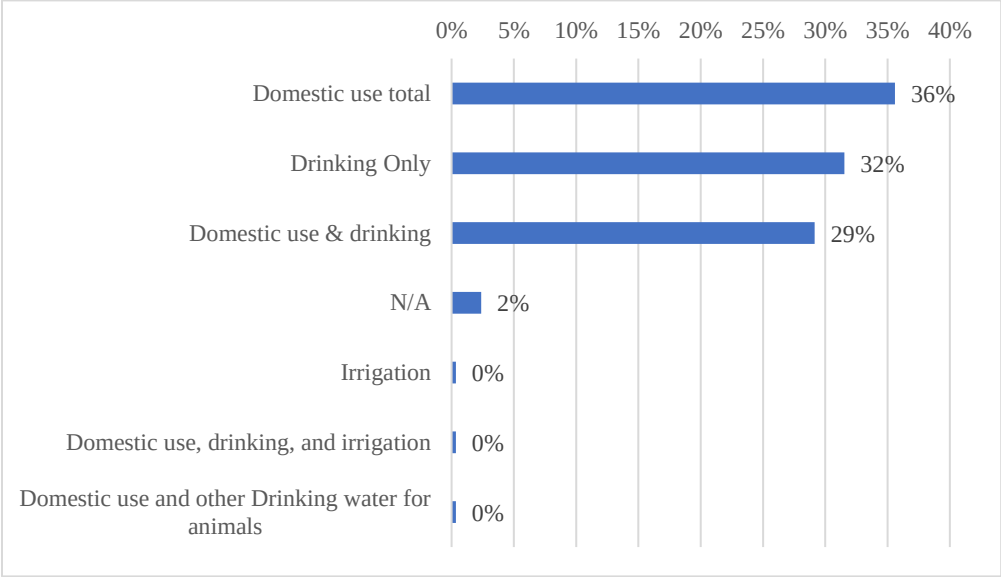


Figure D-121. What do you use the rain water for?

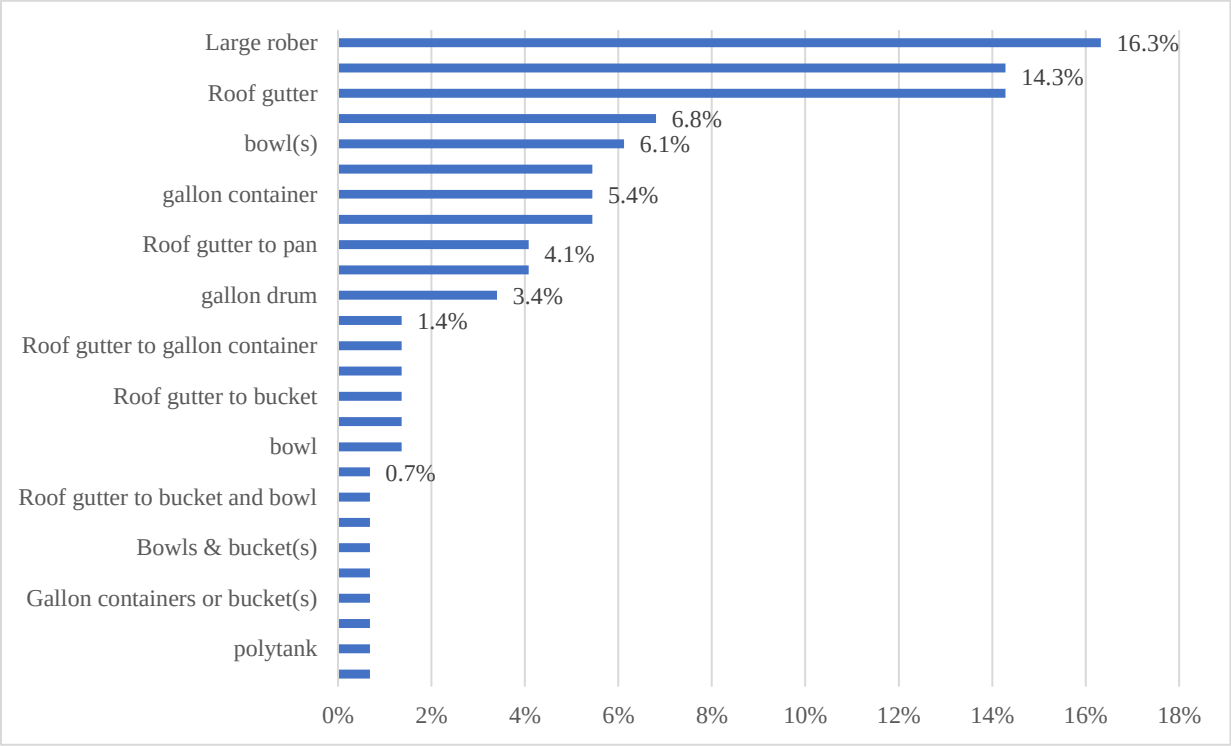


Figure D-122. How do you collect the rainwater?

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