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Agricultural Development in the Northern Savannah of Ghana

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AGRICULTURAL DEVELOPMENT IN THE NORTHERN SAVANNAH OF GHANA

by

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AGRICULTURAL DEVELOPMENT IN THE NORTHERN SAVANNA OF GHANA

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Abstract:

Since declaring independence in 1957, the Republic of Ghana has become a stable constitutional democracy. Ghana's economy has grown substantially over the past decade, yet remains primarily agrarian, accounting for 50% of the total employment and 25% of the country's Gross Domestic Product. Smallholder rain-fed farming using rudimentary technologies dominates the agricultural sector accounting for 80% of total agricultural production. Approximately 90% of smallholder farms are less than two hectares in size, and produce a diversity of crops. The major crops cultivated in Ghana include numerous cereal, root and tuber, leguminous, fruit, vegetable and industrial crops. Maize is the most widely cultivated crop in Ghana, and accounts for a significant proportion of the daily caloric intake. However, significant yield gaps exist where actual maize yields are 50 to 80% less than achievable yields.

The following document was written after conducting a three month 2012 summer internship in Ghana as an agronomic expert volunteer for the Ghana Agricultural Development and Value Chain Enhancement (ADVANCE) Project. My primary objectives included monitoring ADVANCE crop production demonstration plots and farmers' fields to diagnose and address crop health issues, with the goal of identifying why smallholders in the north continue to get lower than expected yields even when good

agronomic practices (GAPs) are being implemented. Observations indicate GAPs are not being adopted, partly because they are not often being implemented correctly at demonstration plots. The benefits of GAPs can be better realized through improved planning, communication, cooperation and education among all participants.

This document is divided into four chapters. The first chapter is an introduction to the Republic of Ghana. Chapter 2 is a brief introduction to agriculture production in Ghana, emphasizing agriculture in the northern savannah and the major challenges facing development in the north. Chapter 3 is a detailed summary of my experience working on the ADVANCE Project. The final chapter discusses how agricultural development—in particular maize productivity—can be improved in the northern savannah of Ghana.

DEDICATION

I dedicate this work to my mentor and dear friend, Dr. Robert Wiedenmann. Without your endless support and encouragement, honest criticism, thoughtful guidance and genuine care, I would not have achieved all I have achieved, learned all I have learned, grown all I have grown, or experienced all I have experienced.

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CHAPTER 1

INTRODUCTION TO GHANA

Country Overview

After overcoming a history of slave trading, war and political and economic turmoil, the Republic of Ghana has become a stable constitutional democracy. In March of 1957, Ghana declared independence from British colonial rule, becoming the first sub-Saharan African country to gain independence (CIA 2013).

Ghana has a population of roughly 25 million people (World DataBank 2013) spread across ten administrative regions (Figure 1) and 170 districts (CIA 2013). The people of Ghana are composed of numerous ethno-linguistic groups and religions creating a culturally diverse nation (CIA 2013).

Ghana's commitment to democracy, peace and human rights has resulted in strong relationships with powerful democratic countries such as the United States. Over 50 years ago, Ghana became one of the first developing countries to receive development assistance from the United States, and assistance continues. Today, the United States remains a major trading partner with Ghana, and the two countries often collaborate on various international issues (USAID 2012).

Geography

Ghana lies within latitude 4^{o} 44'N and 11^{o} 11'N and 3^{o} 11'W and 1^{o} 11'E longitude. Covering approximately 238,500 km^2, Ghana is bordered by Cote-d'Ivoire to the west, Togo to the east, and extends inland from the southern coast along the Gulf of

Guinea to the border of Burkino Faso (Oppong-Anane 2006). The overall topography is low and gently undulating with slopes of less than one percent. Despite the gentle slopes, approximately 70% of the land is susceptible to significant erosion. Ghana's geography is marked by five distinct geographic regions: Low Plains, Akwapim-Togo Ranges, Ashanti Uplands, Volta Basin and High Plains (aquastat – Ghana 2005).

The Low Plains consist largely of flat grassy scrub lands, undulating hills and valleys and the coastal river network. The Akwapim-Togo Mountain Range begins near the mouth of the Densu River, near Ghana's capital, Accra, and stretches approximately 320km northeast along the boundary of Togo. The average peak heights are around 460m, with the tallest peak being 880m. The Ashanti Uplands geographic region is comprised of the strongly rolling forested Southern Ashanti Uplands, and the Kwahu Plateau. This plateau separates the southwestern river network and the Volta river network. The southwestern river network originates from the plateau and drains south into the Gulf of Guinea. The Volta river network lies northeast of the plateau within the Volta Basin and High Plains geographic regions (aquastat – Ghana 2005). The Volta Basin is Ghana's primary drainage system and includes the world's largest reservoir, Lake Volta (CIA 2013). The general terrain of the High Plains in northern Ghana is defined by a dissected plateau with rivers draining into Lake Volta (aquastat – Ghana 2005).

Agro-ecological Zones and Climate

Ghana is composed of six agro-ecological zones (Figure 2) distinguished by natural vegetation and influenced by climate and soil characteristics. Variation in precipitation and temperature are controlled by the movement and interaction of continental and maritime winds. The evergreen rain forest, deciduous rain forest, transition and coastal savannah zones make up the southern half of the country. These agro-ecological zones have a bimodal equatorial rainfall pattern, allowing for two annual growing seasons (major and minor growing seasons) (Table 1). The Guinea and Sudan Savannah make up the northern half of Ghana. These agro-ecological zones have a unimodel tropical monsoon, allowing for only one growing season (major season) (Table 1). The single growing season in the north is bound by the harmattan period, which begins in December and ends in March. Harmattan refers to the hot, dry continental winds that blow from the northeast across the Sahara desert and into Ghana causing extremely hot, dry days, and cool nights (Oppong-Anane 2006).

Annual precipitation in Ghana ranges from 600 to 2800 mm (Figure 3 and Table 1). Annual precipitation generally decreases from the hot and humid southwest coast, north, to the relatively hot and dry savannah (average of 1000 mm). However, the lowest annual precipitation typically occurs within the warm southeast coastal savannah zone (600 to 1200 mm) (Oppong-Anane 2006). Relative humidity also tends to decrease from south to north, creating a general increase in evapotranspiration potential in the north relative to the south (Figure 4) (Barry *et al.* 2005).

Temperatures do not have the same degree of variation across the country as precipitation (Figure 5). The mean monthly temperature across Ghana rarely falls below 25^{o}C, a consequence of Ghana's proximity to the equator and absence of wide-spread high altitude regions. Mean annual temperature is 27^{o}C. Mean maximum annual temperature approaches 40^{o}C, while mean minimum annual temperature is nearly 15 ^{o}C (Oppong-Anane 2006).

Soils

The soils of Ghana are developed from highly weathered parent material (FAO 2005). Alluvial and eroded shallow soils are common to all agro-ecological zones. Most soils are inherently infertile, or infertile as a result of human activities (Oppong-Anane 2006). Figure 6 illustrates the dominant soils of Ghana. The southern half of the country is dominated by Acrisols, which are rich in clay, but have low fertility and toxic amounts of aluminum (Bridges 1997). Along with Acrisols, Ferralsols dominate the rainforest zone, and are characterized by high contents of kaolinitic clay, metal oxides, and low cation exchange capacity (Bridges 1997). The far southeast of the country contains a variety of soil types that are known to be largely unsuitable for cultivation and crop production (Bridges 1997). The northern half of Ghana is dominated by Luvisols. Luvisols are defined as having a mixed mineralogy, high nutrient content and good drainage (Bridges 1997). Table 2 provides information on soil characteristics by administrative region. Percent organic matter and nitrogen are particularly low in the savannah and transition zones (FAO 2005). Data in this table support the general concept that most of Ghana's soils have low fertility.

Economy

Ghana's economy has remained primarily agrarian; however, there is a shift towards the service sector (USAID 2012). The agriculture sector makes up over 50% of

Ghana's total employment and approximately 25% of the nation's Gross Domestic Product (GDP). The cocoa industry, in particular, is extremely important for Ghana, contributing around 30% of export revenue (Ashitey 2012). The service sector is the fastest growing sector of the economy. As of 2011, this sector accounted for nearly 50% of Ghana's GDP, and employed approximately 30% of the Ghanaian work force. Although employment in the industrial sector is less than 20% of Ghana's total employment, this sector makes up approximately 25% of Ghana's GDP (World DataBank 2013). Furthermore, the industrial sector provides the greatest contributions to the country's foreign exchange earnings through exports of oil, gold, bauxite, aluminum, manganese ore, diamonds, natural gas and electricity (CIA 2013).

Development

Over the past three decades, Ghana has experienced significant development and growth, becoming one of Africa's great success stories (IFAD 2012). In 2011, Ghana's economy experienced the world's greatest economic growth at 13.4% (USAID 2012). According to a 2012 report from the Center for Global Development, Ghana moved from a low-income country to a middle-income country in late 2010—a decade earlier than planned. This dramatic economic growth was fostered by a stable government and relatively conducive investment climate (Moss and Majerowicz 2012). Along with impressive economic growth, Ghana has experienced a steady decline in poverty and hunger over the past decade (IFAD 2012), and is on a fast track to achieving the first Millennium Development Goal of halving 1990 levels of poverty and hunger by 2015 (Wiggins and Leturque 2011). Unfortunately, this development is not equally distributed throughout the country. In the northern regions, poverty, hunger, poor nutrition and health, and high mortality rates among women and children are persistent, and must be addressed (FAO 2010).

CHAPTER 2

AGRICULTURE AND DEVELOPMENT CHALLENGES FOR SMALLHOLDERS IN THE NORTHERN SAVANNAH OF GHANA

Agriculture

Approximately 155,000 km^2 (68%) of Ghana's total land area is classified as agricultural land (World DataBank, 2013). Approximately 78,500 km^2 of this land is under cultivation, and 300 km^2 is irrigated. Smallholder rain-fed farming using rudimentary technologies dominates the agricultural sector accounting for 80% of total agricultural production. Approximately 90% of smallholder farms are less than two hectares in size, and produce a diversity of crops. Larger farms and plantations primarily cultivate cocoa, oil-palm, rubber and coconut, and to a lesser extent, cereals and pineapples (MOFA 2011).

The major crops cultivated in Ghana are shown in Table 3, and include numerous cereal, root and tuber, leguminous, fruit, vegetable and industrial crops (FAO 2005). Staple crops include cereals (e.g., maize and rice), roots and tubers (e.g., yam and cassava) and legumes (e.g., cowpea and groundnuts). Fruits (e.g., avocado and mango) and vegetables (e.g., tomatoes and peppers) provide essential micronutrients, and industrial crops (e.g., cocoa and oil-palm) are important cash crops for export revenue.

Physical and biological characteristics of the agro-ecosystem, as well as socioeconomic factors, dictate what crops and farming systems will produce the greatest benefits or lowest risk for the farmer and household (Barry *et al.* 2005, FAO 2005). Table 4 shows where the major crops are grown within the six agro-ecological zones.

Tropical tree crops are generally restricted to the southern agro-ecological zones, with the exception of sheanut and cashew, which occur in the northern savannah. Maize and rice are grown in all regions, while sorghum and millet are grown primarily in the transition and northern savannah zones. Starchy crops and vegetables are grown in all regions. Legumes production occurs in all regions except for the high rainforest, and tree crop production is common in all regions except for the Sudan Savannah (FAO 2005, Appiah 2008).

Two major farming systems are utilized by smallholder farmers in Ghana: bush fallow and continuous cropping (Gyasi 1995, Barry *et al.* 2005). Within these farming systems are two types of cropping systems: polyculture and monoculture. Polyculture is a cropping system where two or more crops are cultivated on the same land. Mixed cropping and intercropping are variations of the polyculture system. Mixed cropping is when two or more crops are grown simultaneously without a particular row arrangement (intermingled). Intercropping is simultaneously cultivating crops in alternate rows. Monoculture is a cropping system where a single crop is cultivated on a particular area of land.

Bush fallow is a system of land rotation between natural vegetation (bush) and crops. Farmers practicing bush fallow farming, farm an area of land for several years, temporarily abandon the cultivated land, and shift to another plot of land that will be cleared and cultivated. This system occurs in all agro-ecological zones where soil nutrients are not being replenished by alluvial deposits, commercial fertilizers or manure (Oppong-Anane 2006, Barry *et al.* 2005), and where households can afford to let land remain uncultivated long enough to replenish soil fertility after several years of cropping (Oppong-Anane 2006).

In the northern savannah, the bush fallow system begins in the dry season when the bush is cleared except for socioeconomically valuable trees such as the sheanut tree (*Vitellaria paradoxa*), dawadawa (*Parkia biglobosa*) and nitrogen fixing trees (Barry *et al.* 2005). Staple crops are mixed or intercropped among economic trees for two to three years, after which time the land is temporarily abandoned allowing for the reestablishment of natural vegetation and soil nutrients. Monocropping is also practiced where farmers cultivate cash crops such as cotton, tobacco, cashews or staple foods for sale in the market (Barry *et al.* 2005, Oppong-Anane 2006). In any one year, the average farmer has nearly one hectare of land dedicated to food production, while the remainder is left fallow. The fallow period has been dramatically decreasing from 15 to less than five years as population density and land pressure increases (Gyasi 1995, Barry *et al.* 2005). The result is decreasing soil quality and greater potential for significant yield reductions.

The continuous cropping system is an intensely cultivated system with no fallow period, and may include poly- or monoculture systems. In the northern savannah, the continuous cropping system is known as the “compound system” referring to the location of the system, which is often adjacent to the compound (group of homes) (Barry *et al.* 2005, Gyasi 1995). The compound system is spatially divided into the inner and outer zones. The inner zone—referred to as the “kitchen garden”—is where vegetables are intercropped (Gyasi 1995). The outer zone is intercropped or monocropped with various staple crops among economically important trees. In these zones, traditional fertilizers, such as household refuse and livestock manure, help maintain soil fertility. Beyond the compound farming system, farmers may have a bush-fallow system with short fallow periods (Barry *et al.* 2005, Gyasi 1995). These areas are often monocultures of cash crops such as cotton, tobacco or staple crops for sale in the market (Oppong-Anane 2006).

Livestock, such as cattle, goats and chickens are commonly integrated into Ghana's farming systems—a practice known as mixed crop-livestock production. Ghana's livestock production is predominantly found in the northern regions. Livestock help meet food needs, provide draft power for field preparation, and manure for soil nutrients. Livestock may also be used as an important source of income, and serve as the household's savings bank or insurance in difficult times (Oppong-Anane 2006).

Development Challenges

Ghana has experienced substantial economic growth and a steady decline in poverty and hunger since the 1990s. However, this development has not been experienced equally across the country. Today, there is a dramatic north-south divide where poverty, as well as food and nutrition insecurity remains widespread in the northern savannah (IFAD 2012). In the three northern regions (Northern, Upper East and Upper West) making up the northern savannah, the prevalence of poverty is at 52 to 88%, compared to around 30% in the Brong-Ahafo and Volta regions, and 12 to 20% in the five southern regions (Greater Accra, Ashanti, Central, Eastern and Western) (Al-Hassan and Poulton 2009).

Numerous development studies conducted in Ghana conclude that improved agricultural production—the livelihood for over 70% of inhabitants in northern Ghana—is necessary to bring northern Ghana out of poverty (Al-Hassan and Poulton 2009, Al-Hassan and Diao 2007, Shepherd 2005). The causes of poverty and hunger are numerous and complex. In the north, socioeconomic issues, such as inadequate education and health care, fewer economic opportunities, poor infrastructure and government corruption impede agricultural development. Environmental issues, such as soil infertility and degradation, harsh and erratic climatic conditions and pest pressures create additional challenges to increasing agricultural production. Further adding to these challenges is the unreliable availability of advanced agricultural technologies, and the limited knowledge on improved agronomic production and management practices among farmers. Finally, inadequate communication and collaboration among the Ministry of Food and Agriculture (MOFA) and the Ministry of Education (MOE), has resulted in a significant gap between research, education and extension. As evident from the discussion below, this gap has created significant obstacles for agricultural development, and improved livelihoods for smallholder farmers. In an effort to support equal development, several European countries, Canada and the United States continue to support pro-poor development projects in Ghana's northern regions (CIA 2013, USAID 2013).

CHAPTER 3

ADVANCE PROJECT

About ADVANCE

The Ghana Agricultural Development and Value Chain Enhancement Program (ADVANCE) is a five-year Farmer-to-Farmer project (2009 to 2013) designed by ACDI/VOCA, and funded by the United States Agency for International Development (USAID) (ACDI/VOCA 2012). Based in Washington, D.C., "ACDI/VOCA is an economic development organization that fosters broad-based economic growth" and raises living standards through its work in agribusiness, food security, enterprise development, financial services and community development (ACDI/VOCA 2013a). The name ACDI/VOCA comes from the "1997 merger of Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance" (ACDI/VOCA 2013b). The joining of these two nonprofit international economic development organizations "achieved new economies of scale and blended the complementary strengths of ACDI's long-term development approaches and VOCA's people-to-people volunteer activities" (ACDI/VOCA 2013b).

Headquartered in Ghana's capital, Accra, ADVANCE has regional offices located in Techiman (Brong-Ahafo Region), Tamale (Northern Region), Bolga (Upper East Region) and Wa (Upper West Region). The objective of the ADVANCE project is to facilitate the sustainable transformation of Ghana's maize, rice and soya agricultural sub-sectors into productive, efficient and competitive systems at the local, regional and international scales.

Using a market-driven value-chain approach, ADVANCE links northern smallholder farmers to other players within the agricultural value-chain (MOFA, banks, input dealers, private sector, commodity aggregators, end markets and media) to establish long-term relationships and transform small-scale agriculture into sustainable businesses. This relationship building is driven primarily by ADVANCE Business Facilitators (BFs)—including Commodity BFs, Financial Services BFs, Inputs and Equipment BFs, and Outreach BFs. As a part of USAID's Farmer-to-Farmer program, ADVANCE relies partially on expert volunteers from the United States to work alongside ADVANCE BFs to support and strengthen the capacity of various players along the value-chains through the transfer of technical knowledge (ACDI/VOCA 2012).

The ADVANCE project aligns with the United States Government's global hunger and food security initiative, referred to as Feed the Future (ACDI/VOCA 2012). Feed the Future, "supports country-driven approaches to address the root causes of hunger and poverty. Through this Presidential initiative, the United States is helping countries transform their own agricultural sectors to grow enough food to sustainably feed their people" (Feed the Future 2012).

As mentioned previously, the northern regions of Ghana have high levels of poverty and food and nutrition insecurity relative to the rest of Ghana (World DataBank 2013, IFAD 2012). Sizeable yield gaps between attainable and farm-level yields play a significant role in preventing northern Ghana from escaping poverty and becoming food secure. According to ACDI/VOCA (2012), low productivity in the north is a consequence of smallholder farmers' unfamiliarity with modern agricultural technologies such as the use of certified seed, agrochemicals, inoculants and improved production and management practices, as well as affordable access to such technologies.

As part of the transformation strategy, ADVANCE works to educate smallholder farmers on modern agricultural technologies—referred to as good agronomic practices (GAPs)—to increase productivity and, in turn, farmers' profits and quality of life (ACDI/VOCA 2012). Such education comes in the form of "actor-led" in-field (hands-on) demonstration activities. "Actors" include experts on GAPs, such as MOFA extension agents and agrochemical representatives. The idea behind "actor-led" demonstrations is that actors are not only experts in GAPs, including proper handling and use of agrochemicals, but are respectable people who will remain in their positions after the ADVANCE project is over. In other words, the "actor-led" approach to education increases the likelihood of sustainable development. In situations where experts are not available, ADVANCE Commodity BFs conduct demonstrations.

Demonstrations of GAPs were performed at demonstration plots set up across the three northern regions and parts of the Brong-Ahafo Region north of the 8^{th} parallel north. Demonstration plot design and activities were planned by Commodity Team Leaders (TLs) and the Environmental Specialist stationed at the headquarters office in Accra, as well as the Regional Coordinators (RCs), BFs and Project Director located at regional offices. Demonstrations were conducted on land managed by cooperating farmers who were chosen based on their progressive crop production abilities and community leadership. These farmers were referred to as nucleus farmers. Demonstration plots varied in size from approximately 0.2 to 0.8 hectares (0.5 to 2.0 acres) depending on the number of GAPs being demonstrated. Demonstration plots were divided up and either planted to different crop varieties, the same variety with different fertilizer or herbicide treatments, or simply divided in two with one half managed under traditional practices and the other half managed using a particular GAP (e.g., proper row spacing). Farmers were provided with seed or inputs being demonstrated, as well as free actor-led demonstration. Demonstration plots provided farmers with the opportunity to observe and perform GAPs after such practices were explained and demonstrated on-site. Throughout the season, farmers and anyone passing by the demonstration plots would be able to observe demonstrations. Furthermore, farmers were able to keep the grain or beans harvested from demonstration plots.

Assignment Description

From 19 May, 2012 to 11, August 2012, I served as a crop health expert volunteer for ADVANCE. I was based at the Techiman Regional Office for the first three weeks, and a few days during the last week in Ghana. My time spent in the northern regions included 10 days in Wa, 20 days in Tamale and two weeks in Bolga. The assignment included supervising and reporting on in-field maize demonstration activities at demonstration plots, and monitoring maize health within the various regions. In particular, I was asked by ADVANCE’s Chief of Party to identify why crop yields continue to be lower than expected even when GAPs are being implemented. Part of the assignment was also to serve as the on-site Environmental Specialist, which included making sure that all demonstration plot activities were in compliance with the environmental guidelines required by USAID and Ghana. Finally, where appropriate, I provided recommendations to improve crop health and demonstration activities at demonstration plots. Assignment outputs included biweekly reports, relevant fact sheets and a final report. Reports were composed to journal my activities, as well as identify problems, provide recommendations, and outline the actions and anticipated impact of recommendations.

Summary of Assignment Issues and Recommendations

Issue/problem: GAPs are not often being correctly, clearly or consistently explained or demonstrated by experts at ADVANCE demonstration plots.

Possible Causes: In general, the actors leading the demonstrations are not adequately prepared for their task of explaining and demonstrating GAPs, and/or do not have a good working knowledge of GAPs. ADVANCE works to facilitate and supervise the education of farmers on GAPs with, in general, unprepared and/or under qualified actors (MOFA extension agents, agrochemical representatives, ADVANCE personnel). It is difficult for ADVANCE to facilitate or supervise activities (GAPs) that they themselves may not always understand. Ministry of Food and Agriculture extension agents have inadequate education and training, and lack consistent opportunities for organized continued education.

Effects: When GAPs are not explained or implemented correctly at demonstration plots, farmers do not see or receive the greatest benefits from GAPs. When the extra costs (risks) of GAPs do not pay off, known (less risky) traditional practices will continue being performed.

When there is inconsistency in the way GAPs are explained or demonstrated, farmers become confused. When this occurs, farmers question who or what to believe, and will likely go back to their known traditional practices, and fail to adopt GAPs.

When the proper use of agrochemicals is not explained or demonstrated correctly, clearly or consistently, the health of the crops and environment, and the health of the farmers and community are put at risk.

Recommendation: Ensure farmers receive correct, clear and consistent information on GAPs.

Actions (implement as soon as planning begins for the next season and continue throughout the season):

1. The ADVANCE team must improve communication and organization among each other (TLs, RCs, BFs and Environmental Specialist) and collaborators (farmers, MOFA, agrochemical representatives) during the demonstration plot planning and preparation stages. Communication should continue throughout the season as demonstration plot activities may need to be changed in response to crop health and environmental conditions.
2. It is crucial that the proposed plans (and modified plans) be recorded in a format that is clear, consistent and readily available to all relevant parties. Each demonstration plot should have a document with a clear picture (figure) of the plot set up/design, objective statement(s), a list of the materials needed for the demonstration and a description of how each activity is properly performed (methods).
3. ADVANCE personnel should consult with experts at research institutions or other NGOs to verify that the practices being recommended, explained and demonstrated are appropriate for each crop production site.
4. ACDI/VOCA, ADVANCE should strongly consider collaborating with other NGOs, MOFA and research institutions to develop training and educational material and

ensure any overlap in information given to farmers on GAPs is correct, clear and consistent.

5. ACDI/VOCA may want to shift their focus to facilitating the continued education of MOFA extension agents by linking extension agents with Ghanaian research institutions. As much as possible, MOFA extension agents should understand the current research on crop varieties and best production and management practices for various commodities and locations.
6. Volunteers with expertise in production and management practices, and demonstration plot design, may also prove helpful in the planning stages and the development and review of educational materials for MOFA extension agents and farmers.
7. Commodity BFs should be required to have a Programmatic Pesticide Evaluation Report-Safe Use Action Plan (PERSUAP) manual with them in the field (PERSUAP manual in every office and every vehicle), as well as a checklist of all the relevant information pertaining to the proper handling, mixing, use, disposal and dangers of agrochemicals at every agrochemical demonstration to ensure such information is correctly, clearly and consistently explained.

Anticipated Impact: The implementation of these recommendations will help ensure all demonstration plots are designed with a clear working objective appropriate for each farmer's circumstances, and that the materials and methods necessary to explain and demonstrate all activities (e.g., planting, fertilizer, herbicide, etc.) are drawn out as clearly as possible. There would be fewer mistakes and confusion at demonstrations that could result in demonstration plots with large yield gaps between attainable and actual yields, and a farming community that does not observe or receive the benefits of GAPs. In turn, we will likely see an increase in the number of farmers who properly implement GAPs on their own farms. More importantly, we will minimize harm to the crops, environment and people from improper handling, mixing and application of agrochemicals. Furthermore, the likelihood of disseminating incorrect educational material associated with ADVANCE, ACDI/VOCA and USAID will be greatly reduced if ADVANCE includes experts from MOFA, research institutions and other NGOs on the development and/or review of such materials.

Another anticipated impact from these recommendations is greater potential for sustainability. If relationships are made between MOFA and experts at Ghanaian research institutes, there will be more opportunities for MOFA to gain continued education even when the ADVANCE project is over. Furthermore, farmers will benefit from extension agents with correct and current knowledge on crop varieties and GAPs.

Issue/problem: Demonstration plots are not often well monitored.

Possible Causes: There may be too many demonstration plots to properly monitor, thus resulting in labor and time limitations. In addition, ADVANCE is relying on people (ADVANCE Commodity BFs, MOFA extension agents and farmers) who are not often capable of correctly identifying, diagnosing and monitoring crop health issues at demonstration plots.

Effects: When ADVANCE does not properly monitor the demonstration plots biotic and abiotic stresses go unchecked resulting in crop damage and a decrease in yield. When this occurs, farmers will not see or receive the greatest benefits of

GAPs, and traditional practices will continue to dominate.

Recommendation: Demonstration plots should be monitored at least once a week. Those individuals monitoring the plots need to be trained to recognize and describe an unhealthy crop to experts. The experts can, in turn, begin the process of diagnosing and identifying management recommendations—including the possibility of altering the original planned demonstration activities.

Actions (implemented as soon as planning begins for the next season):

1. If necessary, reduce the number of demonstration plots or hire more people to ensure there are enough human resources to properly monitor each plot every week.
2. ADVANCE personnel should record activities and observations throughout the season in a format used by all offices and personnel.
3. ACDI/VOCA and ADVANCE should develop relationships with experts and/or students at research institutions who can work directly with ADVANCE, MOFA and farmers on demonstration plots to provide more human resources and agronomic expertise in exchange for research treatment replicates.
4. ADVANCE personnel, MOFA extension agents and farmers should understand the importance of monitoring—not just for demonstration plots, but for any farmer's field. Proper monitoring is, in itself, an example of a GAP that should be explained, demonstrated and practiced at demonstration plots. There may be an opportunity for training on monitoring and diagnosis for the most common crop health issues. Training would be provided by an appropriate expert.
5. ACDI/VOCA may want to shift their focus to facilitating the continued education (monitoring for and diagnosing crop health issues) of MOFA extension agents by

linking extension agents with research institutions or other NGO projects doing such training. MOFA extension agents should know how to monitor fields, and identify and manage crop health issues (weeds, insects, diseases, nutrient deficiencies/toxicities).

6. ACDI/VOCA should request volunteers with expertise in fields related to plant health who may also prove helpful in crop monitoring, diagnosis and management of plant health problems. Such volunteers could also provide training and literature on such topics.

Anticipated Impact: Fewer demonstration plots and/or an increase in people available to monitor plots will allow for better monitoring as a result of increased man-hours. Fewer well-monitored and maintained plots are better than many unhealthy, under-yielding plots. Record keeping is a necessary practice in crop health monitoring and project evaluation. Records taken in the same format improves the clarity and consistency of the information, and makes any potential crop health problem much easier to diagnose. It also becomes easier to develop effective management plans or effectively alter original demonstration plot activities.

Working with researchers with a vested interest in the demonstration plots (because the plots serve as a treatment replicate in an experiment), will improve monitoring and the proper diagnosis and management of crop health issues that may occur. Not only will demonstration plots be healthier, but MOFA extension agents and farmers involved in the demonstration plot will have opportunities to learn about agronomic topics from experts. An added bonus could be statistically analyzed data for Monitoring and Evaluation records.

Educating MOFA extension agents and agrochemical representatives on crop monitoring, diagnosis and management through collaboration with research institutions, other NGOs and volunteer experts will increase the potential for sustainability.

Issue/problem: Farmer/community attendance at demonstration plots is low.

Possible Causes: When weather conditions are ideal for farmers to work in their own fields, attendance is usually down. Problems with the cell phone network interfere with the communication needed to plan and inform participants of demonstration activities resulting in low attendance. When nucleus farmers display poor leadership and fail to motivate their outgrowers to attend demonstrations, low attendance is observed. Another cause of low attendance is that many of the demonstration activities require more labor and time relative to traditional practices. The problems discussed above with the way GAPs are explained and demonstrated, may keep farmers from seeing the value of participating. This is especially true when farmers do not observe the benefits of GAPs or get confused when GAPs are explained.

Effects: When GAPs are explained and demonstrated correctly, clearly and consistently, low attendance translates to fewer people receiving valuable agricultural education and training. When fewer people are reached, fewer people will begin implementing GAPs—greatly limiting the success of the ADVANCE project.

Recommendation: Increase farmer/community attendance at demonstration plots.

Actions (implemented as soon as planning begins for the next season):

1. ADVANCE should identify committed innovative farmers who are willing to work as

good leaders in their community. Good leaders and motivators are needed to bring about change!

2. See the actions that address the first two recommendations above. In theory, these actions will result in demonstration plots with real observable benefits from GAPs, and participants that have received correct, clear and consistent explanations and demonstrations of GAPs.
3. ADVANCE should increase the use of audiovisual training. Such trainings attract large audiences, and have great potential for positive impacts.
4. ADVANCE personnel can film parts of explanations and demonstrations at various demonstration plots to create audiovisual training videos specific for certain crops and regions. The "stars" of these videos will be the actor experts and farmers ADVANCE is trying to reach. This may be an area ACDI/VOCA will want to bring in expert volunteers to assist with such a big (but likely hugely beneficial) project. In the event resources to create such videos are limited, PowerPoint presentations could be created using pictures of actors and farmers working at demonstration plots and used at audiovisual training sessions.
5. ADVANCE could give out awards (agrochemicals, personal protective gear, measuring tape, string, cell phone airtime, tools, etc.) to participants for answering questions on the GAPs that were explained and demonstrated at the last demonstration. This will encourage farmers and community members to attend and pay attention at demonstrations, as well as go to the next demonstration activity.
6. ADVANCE could provide a snack during long demonstrations (e.g., planting, harvesting). From what I understand, ADVANCE is moving away from this because

they want people to come because they see the tremendous value in ADVANCE's service and want to learn; not because they get a free snack. Snacks may also serve as a distraction, not to mention they are costly for the project. However, food and drink is strongly connected to social interactions and cross all language and cultural barriers. Therefore, food and drink is one of the easiest ways to form or strengthen a relationship, which is, in part, what ADVANCE is trying to do.

7. ADANCE could give out awards to farmers who attend demonstrations and implemented GAPs on their farms (1^{st}, 2^{nd}, 3^{rd} place).

Anticipated Impact: The anticipated impacts of these actions include increased attendance, as well as increased audience attentiveness and participation, and in turn, education.

Issue/problem: Maize seeding rates and row spacing were confusing to ADVANCE personnel and farmers

Possible Causes: Seeding rates and row spacing differ among maize varieties, and it is difficult to find information about seeding rates and row spacing.

Effects: Resources are not optimally utilized when incorrect seeding rates and/or row spacing are used because crop density will be either too high or too low. In turn, farmers do not see or receive the greatest yield benefits from their maize variety.

Recommendation/Action: Encourage/support the addition of seeding rate and row spacing information (pictures and/or writing) to certified maize seed bags.

Anticipated Impact: The anticipated impact of this action is that there will be an increase in correctly planted maize fields. In turn, farmers will see and receive greater benefits from their maize varieties, and there will likely be an increase in the implementation of GAPs.

Issue/problem: Field soil characteristics, in particular nutrient content, are generally unknown.

Possible Causes: Soil tests are not often available. Where soil tests are available, they are viewed as an extra cost with no perceived benefits.

Effects: Soil fertility management is not being conducted in the most economically efficient fashion.

Recommendations/Actions:

1. ADVANCE could include soil testing as a GAP demonstration. The soil testing service could be provided by an academic or government research institution, MOFA or private company, and include fertilizer recommendations, based on soil test results.
2. ADVANCE could incorporate soil test kits into the value chain. Soil testing kits could be sold at agrochemical shops.

Anticipated Impact: Farmers, ADVANCE personnel, MOFA and researchers will gain a better understanding of the soil quality, which will allow for more precise soil nutrient management and increases in yield.

Assignment Conclusions

A number of significant problems need addressed. Many of these problems help answer the overarching question proposed by the Chief of Party at the beginning of this assignment: why do crop yields continue to be lower than expected, even when GAPs are being implemented? What was not known is that GAPs are often not being implemented correctly; hence the significant yield gap continually observed.

It cannot be ignored, that when the ADVANCE project ends, farmers will rely on MOFA extension agents with limited education and resources for advice on the implementation of good production and management practices. If the educational needs of extension agents are not addressed, any improvements in agricultural productivity, and the reductions in environmental degradation, will not be sustainable.

Although the problems observed are significant, I also observed an ADVANCE team with a strong work ethic and moral values. Their passion for improving the livelihoods of Ghanaians was inspiring, and the farmers and communities impacted were appreciative of the ADVANCE efforts. I strongly believe that the benefits of the ADVANCE project can be better realized and more sustainable when these dedicated workers incorporate the recommended actions listed above.

CHAPTER 4

IMPROVING AGRICULTURAL PRODUCTIVITY IN THE NORTHERN SAVANNAH OF GHANA: EMPHASIS ON MAIZE

Poverty and hunger in Ghana's northern savannah are significantly greater than in the southern half of the country (IFAD 2012). To address this inequality, pro-poor development has become a focus in Ghana's northern regions to reduce poverty and increase food and nutrition security (USAID 2013). The FAO (1996) defines food security on both the national and household level as existing "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." Food and nutrition security requires healthy food to be available, accessible and properly utilized (Negin *et al.* 2009). One strategy that aids in poverty reduction and increased food and nutrition security is improved agricultural productivity through innovative technologies that support sustainable development (Al-Hassan and Diao 2007, Shepherd *et al.* 2005).

Although maize is not native to Ghana, it has become the most widely cultivated staple crop in the country and accounts for a significant proportion of daily caloric intake (Akinola *et al.* 2007, Morris *et al.* 1999). A 1998 survey by CRI/CIMMYT found that maize is the primary source of income for 45% of households in the northern savannah, and the second source of income for 21% (Morris *et al.* 1999). Improved maize varieties planted in Ghana include both open-pollinated varieties (OPV) and hybrids. Varieties range from extra-early maturing (80-85 days) to intermediate maturing (105-110 days). Resistance to maize streak virus and the parasitic weed, witchweed (*Striga* spp.) are common to most improved varieties. Nearly all improved varieties are protein enhanced (quality protein variety), and have drought tolerance (Tengan *et al.* 2011).

In 2010, average maize yield for Ghana was 1.7 metric tons per hectare (27 bushels per acre) (MOFA 2011). A yield of 1.7 metric tons per hectare is over 50% less than the achievable yield of popular improved maize varieties planted in Ghana, including 69% less than Obatanpa (5.5 metric tons per hectare), and 78% less than the Mamaba (7.5 metric tons per hectare) (Tengan *et al.* 2011). These numbers indicate there is room for significant improvements in maize production, and great potential to increase smallholder income, and food and nutrition security.

The principal environmental limitations to maize production in the northern savannah include poor soil quality, weeds and weather extremes (e.g., drought and torrential rainfall). See Table 5 for average monthly climatic data from Tamale, Northern Region. Significant losses from insects and diseases are less problematic (Kassam *et al.* 1975), but nonetheless important to monitor and manage. These problems are compounded by socioeconomic problems related to infrastructure, health care, education, gender equality, land policy, market stability, credit access, technology access, environmental quality and research and extension support and collaboration.

For over 30 years, scientists have been promoting three principal good agronomic practices (GAPs) for improved production of maize and other row crops in Ghana: (1) use of certified seed from improved maize varieties, (2) planting in rows, and (3) use of agrochemicals (Morris *et al.* 1999). The following discusses these three practices, how they can be improved and what additional practices show potential to improve maize and overall agricultural production in the northern savannah.

Improved Maize Varieties and Certified Seed

The use of improved maize varieties is the most common GAP adopted by farmers in Ghana, and as of 1997, is practiced by over two-thirds of farmers in the northern savannah (Morris *et al.* 1999)—this percentage is certainly higher today. The proposed reason for wide-adoption is that farmers can improve yields without changing production practices and without purchasing additional inputs (Morris *et al.* 1999). Thus, the use of improved maize varieties provides greater economic returns relative to other GAPs. A 1999 report on the adoption of the three GAPs mentioned above, found that farmer-estimated yields increased 88% when they switched from a local to a improved maize variety, and a 60% yield-increase over a 10 year period after the technology was adopted (Morris *et al.* 1999). Therefore, it is clear that the promotion of, and increased access to, improved maize varieties should continue.

Certified maize seed from improved varieties should be produced under strict standards to ensure high quality seed. Farmer-saved seed is typically produced, handled and processed under poor conditions, resulting in lower yields. A study conducted by Asiedu *et al.* (2007) found that farmers in the forest and transition zones of Ghana who used certified maize seed produced a grain yield nearly 50% greater than that of farmers who sowed saved seed from the previous maize crop. However, approximately 90% of maize seed planted annually in Ghana is uncertified, farmer-saved seed (Asiedu *et al.* 2007).

One reason for the low rate of certified seed use is that farmers cannot afford certified seed every year, and they likely do not experience the same yield benefits as those found in carefully conducted research studies. Another reason is the low production capacity of certified seed in Ghana. In 2003, only enough certified seed was produced to plant 10% of the total maize production area (Asiedu *et al.* 2007). Furthermore, farmers in remote areas have less access to certified seed, which is primarily acquired from extension agents or input dealers (Morris *et al.* 1999). Although the use of certified seed must continue being promoted as a GAP, focus must shift to address the constraints to certified seed production and dissemination to smallholder farmers. The Ghanaian government must also work to increase opportunities for farmers to receive small loans or subsidies to purchase certified seed.

Row Planting

Row planting with a particular intra- and inter-row spacing between plants is promoted for three reasons. First, and most importantly, row planting allows for proper row spacing, which optimizes crop resource use efficiency. Crops planted too closely will compete for resources, whereas crops planted too far apart will not effectively utilize resources. Either scenario can result in yield reductions. Second, insect and disease pressures are reduced because proper spacing allows for adequate air movement. Air movement reduces the occurrence of humid microclimates ideal for many insects and pathogens. Finally, crops planted in rows allows for easier farming practices such as pest and nutrient management. It is easier to monitor and apply fertilizers or pesticides to crops planted in rows. Enhanced crop resource use efficiency, reduced pest pressures and easier farm management practices all contribute to increases in yield.

Planting density is determined by intra- and inter-row plant spacing and seeding rate per hole. Recommendations for optimum planting density come from research institutions or agricultural companies, and differ slightly among maize varieties. Varieties planted at two seeds per hole, such as Obatanpa and Mamaba, should have an intra-row spacing between 40 and 45 cm, and inter-row spacing between 75 and 80 cm (Tengan *et al.* 2011). Varieties planted at one seed per hole, such as PAN 53, are recommended to have an intra-row spacing of 25 cm and an inter-row spacing of 75 cm (Wienco Agriculture 2010). Using these numbers, maize planting density is approximately 53,200 to 66,500 plants per hectare (21,600 to 33,250 plants per acre). The upper portion of this range is similar to those in the fertile United States Midwest (Farnham 2001).

Although significant on-farm research has been conducted in Ghana, planting recommendations from the Crops Research Institute of Ghana are not site-specific. Instead, recommendations are for production on land that has deep, moderately heavy, sandy-loam soils with minimum shading (Tengan *et al.* 2011). Many low-income farmers in the northern savannah have less than ideal soils, and their fields are often interspersed with economically and culturally valuable trees that increase shading. One important question is, whether the planting densities recommended above are appropriate for the harsh, drought-prone environment in northern Ghana.

Drought-prone environments in the United States Great Plains produce rainfed (dryland) maize at planting densities between 25,000 and 50,000 plants per hectare (10,000 and 20,000 plants per acre) (Allen 2012, Lyon *et al.* 2008). These densities are substantially lower than those recommended for the northern savannah of Ghana.

Although the northern savannah receives nearly twice as much rain as areas of drought prone maize production in the United States (Oppong-Anane 2006, Taylor 2011), the precipitation typically comes as torrential rainfall events (Oppong-Anane 2006) leading to significant runoff. Furthermore, the water-holding capacity of the soil in the northern savannah is low (FAO 2005). Therefore, it seems appropriate to suggest that site-specific research be conducted to determine if lower maize planting densities in the northern savannah could be a successful strategy for Ghana's risk adverse farmers.

Studies conducted on rain-fed maize production in the United States Great Plains found that reducing plant density through a practice known as skip-row planting not only minimizes the risk of yield loss or crop failure in years of drought, but may increase yields in drought prone environments (Allen 2012, Lyon *et al.* 2009). As the name suggests, skip-row planting is the alternation of planting one or more rows and skipping one or more rows. The idea behind this practice is that fewer plants per hectare will increase soil water reserves within skipped rows for use later in the season when roots are longer and drought conditions are more likely. Typical skip-row arrangements include plant two rows, skip two rows (P2S2); plant two rows, skip one row (P2S1); and plant one row, skip one row (P1S1). Planting densities in skip-row fields range from 25,000 to 50,000 plants per hectare (10,000 to 20,000 plants per acre) (Lyon *et al.* 2009).

The practice of skip-row planting has become a popular planting alternative for maize farmers in the United States Great Plains where average precipitation is less than 700 mm (Lyon *et al.* 2009). An exhaustive study conducted by Lyon *et al.* (2009) on skip-row planting in Nebraska, Kansas and Colorado, found that skip-row planting improved yield over the standard planting practice in lower-yielding environments, and that P2S2 had greater yield gains compared to P2S1 and P1S1. Additional benefits noted in the study include yield stabilization—an important factor for unpredictable environments and risk adverse farmers (Lyon *et al.* 2009).

Skip-row expert, Robert Klein of the University of Nebraska, asserts that the success of skip-row planting relies on soil water management, especially in skipped rows where weeds and evaporation can be a problem. In the United States, weeds and evaporation are managed by leaving heavy residues from the previous crop on the soil and planting glyphosate-resistant maize to allow applications of the glyphosate herbicide during the growing season (Sorensen 2009). In the northern savannah of Ghana, residues are often burned or worked into the soil using a hoe, bullock plow or tractor. Furthermore, glyphosate-resistant maize is unavailable, and weeds are often poorly managed due to labor constraints (Ekboir *et al.* 2002) or improper use of herbicides. Therefore, for skip-row planting to be successful in Ghana, residues would need to remain on the soil surface, and weeds would need to be more closely monitored and managed.

Another method to reduce risk and possibly increase maize yields in the northern savannah, is to continue using standard row planting, but decrease planting density by increasing intra- and/or inter-row spacing. A change in row spacing may be an easier practice for extension agents to teach and farmers to understand than skip-row planting patterns. An additional benefit would be savings in seed costs, possibly leading to greater adoption.

Environmental conditions in the northern savannah of Ghana are dramatically different than those in the United States Great Plains. However, without research indicating otherwise, it seems logical to speculate that maize farmers in the northern savannah of Ghana would obtain more stable and possibly higher yields under lower planting populations. Extensive site-specific research would need to be conducted to support this hypothesis. It must be noted, that lower planting densities would require better weed, residue and soil water management to ensure potential benefits are realized. Therefore, efforts should be made to develop and evaluate the benefits of small-scale manual equipment that can be used to prepare seed beds with minimum soil disturbance, and manual planters capable of planting into residues. Furthermore, similar efforts should be aimed at developing small-scale water collection methods that would allow within season water distribution during periods of intermittent drought.

Agrochemicals

Morris *et al.* (1999) states, "the use of agrochemicals requires a sophisticated understanding of the complex relationship between soil nutrient status, plant growth habits and economics." This statement supports the fact that the use of agrochemicals, such as fertilizers and pesticides, is the least-adopted technology (Morris *et al.* 1999). Another reason for low adoption rates is the high costs of agrochemicals. Although adoption rates are relatively low, agrochemicals continue to gain popularity in Ghana as a result of increased promotion and support from national and international government agencies, NGOs, agrochemical companies and extension agents. The most important recommendation to anyone handling agrochemicals is that they carefully read, understand and follow agrochemical labels.

Fertilizers provide additional nutrients for crops in the northern savannah where available nitrogen and phosphorus are low (FAO 2005). Fertilizers can increase nutrient use efficiency and yield with proper application timing and placement (Jones and Jacobsen 2009). Fertilizer recommendations for maize in the northern savannah are general and do not take into account the enormous spatial variability of soil physiochemical properties. Therefore, efforts in Ghana should be made to support timely and accurate soil testing and specific fertilizer recommendations for smallholder farmers. Such efforts could be incorporated into agricultural development projects. Economic benefits of fertilizers will not be realized until the characteristics of the soil in which fertilizers are being applied are better understood.

Currently, MOFA fertilizer recommendations for maize in the northern savannah include a split application. The split application is appropriate for the northern savannah where soils have low water holding capacity and high nutrient leaching potential. At one to two weeks after planting (3 leaves) two bottle caps full of granular 15:15:15 NPK or 23:10:5 NPK is buried next to each seedling. Four to six weeks after planting (8 – 10 leaves), depending on variety, granular urea or ammonium sulfate is banded along rows below the soil surface.

Fertilizers are susceptible to volatilization (YanHui 2006, Overdahl *et al.* 1991) and rain runoff. Therefore, the placement of the fertilizer under the soil surface near the plant prevents this loss, and increases nutrient uptake. However, crop productivity may be improved by changing the timing of the first fertilizer application to before or at planting. Jones and Jacobson (2009) found that phosphorus application near spring and winter wheat seed at planting increased the amount of phosphorus available to active roots. Because phosphorus is often the most limiting nutrient in the northern savannah as a result of limited soil mobility, studies on fertilizer application timing and placement for maize in the northern savannah may find greater crop productivity when fertilizers are applied early.

Various pesticides are available in Ghana to manage maize pests at various times throughout the growing season. Like fertilizers, timing and placement influences pesticide efficacy. Herbicides are the most commonly used pesticide in northern Ghana, reflecting the importance of weeds as the most significant biotic stress (Kureh and Kamara 2007, Kassam *et al.* 1975). Pre-treated certified seed is available for a few improved maize varieties, protecting the seed from soil insects and diseases during germination and early seedling development. Packets of seed treatments can be purchased separately and mixed with non-treated seed to provide similar protection. The use of pesticides to manage insects and diseases during the season is less common compared to the use of other agrochemicals.

Indeed, agrochemicals have been shown to successfully manage pests and improve crop productivity. However, many agrochemicals have been shown to cause harm to crops, humans and the environment. The potential for such negative impacts is greatly increased when agrochemicals are being promoted for use among communities where literacy is uncommon, access to proper training is low, and acute and chronic exposure is high. This is the situation for the majority of resource-poor rural farmers in the northern savannah. For this reason, it seems irresponsible to recommend the use of pesticides in areas where the safe use of such chemicals is not well understood. Long-term solutions to these problems include improved access to quality education throughout

Ghana, continuing education for extension agents, and a greater number of qualified extension agents accessible to farmers. A short-term solution could be the promotion of small-scale application equipment that requires minimal agrochemical handling, such as the rope wick herbicide applicator. Another solution includes the promotion of ecological principles to manage pests and resources, and increase sustainable agricultural development.

Agroecology

Ecology is a complex field addressing the interactions and relationships occurring among a community of organisms within the environment (i.e., the ecosystem). Once the ecological interactions that benefit ecosystems are understood, this knowledge can be applied to manipulate agroecosystems in a way that is both productive and sustainable. In the northern savannah, where soil fertility is low, drought potential is high, weeds are a significant pest and labor is limited, well-designed patterns of intercropping, crop rotation and livestock integration can sustainably improve production.

A study conducted by Horst and Hardter (1994) found that the physiochemical properties of soil (water infiltration, water-holding capacity, bulk density and aggregate stability) under continuous maize or maize/cowpea rotation, experienced significantly greater soil deterioration compared to a bush-fallow system. This study indicates bush-fallow systems are more sustainable, and should be utilized where it is possible to leave a field fallow for many years. In continuous cropping systems, residues should remain on the soil to enhance soil quality.

The practice of cultivating a kitchen garden is common among smallholder farmers throughout Ghana (Barry *et al.* 2005, Gyasi 1995). Kitchen gardens produce a variety of staple crops prepared for daily consumption. These gardens incorporate diversity—one of the most important ecological principals for maintaining or improving soil quality, managing insects and disease and mitigating risk (Altieri *et al.* 2005, Karpenstein-Machan and Finckh 2002). The benefits from diversity can carry over to the bush-fallow or continuous cropping systems, where monocultures are currently being promoted by a number of government and non-governmental organizations.

In the northern savannah where nitrogen levels are low, yields can be improved when maize is produced on land previously planted to a legume. Legumes develop a mutualistic relationship with nitrogen fixing bacteria, *Rhizobium* spp., increasing soil nitrogen levels. A study conducted in the moist Nigerian Savannah found that nitrogen increased by 100 and 150% in soils incorporated with soybean and the herbaceous legume (*Centrosema pascuorum*), respectively (Adeboye *et al.* 2007). The following maize crop had significantly higher yields than maize planted after fallow.

A study conducted in the Guinea Savannah of Nigeria found that maize grain yields in a maize-soybean rotation were 46% greater than a continuous maize system, and 34% greater than a maize fallow system (Yusuf *et al.* 2007). A similar study found an 85% increase in maize grain yield after two years of soybean, and a 66% increase after two years of cowpea compared to continuous maize production (Kureh and Kamara 2005).

A study conducted by Horst and Hardter (1994) found that maize root densities in continuous maize systems were significantly lower than maize grown in rotation with soybeans. These results suggest that maize water and nutrient acquisition efficiency may be enhanced in a maize-soybean crop rotation system. Crop rotations can also break insect pest and disease cycles (Altieri *et al.* 2005). Kureh and Kumara (2007) found that rotation of maize with soybean or cowpea decreased the incidence of *Striga* infestation relative to a continuous maize system in the northern Guinea Savannah of Nigeria.

The general conclusion from hundreds of intercropping experiments indicates resource use efficiency and combined yields are greater in an intercropped system compared to a monoculture (Innis 1997). Intercropping often results in greater resource use efficiency, weed suppression and reduced insect and disease epidemics. Yield advantages from intercropping range between 20 and 60% in intercropped systems (Altieri 2008).

An economic analysis conducted in central Cameroon on the effects of maize-cowpea intercropped systems on maize stem borers and natural enemies found that the intercropping resulted in greater profits compared to pesticide-treated maize monoculture and a control consisting of an untreated maize monoculture (Aroga and Ambassa-Kiki 2005). The push-pull system developed in Kenya at the International Centre of Insect Physiology and Ecology uses a strategic intercropping pattern to manage stem borers and *Striga*. A legume forage called desmodium is intercropped with maize and deters stem borers from the maize crop (push), while Napier grass planted around the border attracts the pest (pull). The legume also serves to attract beneficial insects and induce abortive germination of *Striga* (Khan *et al.* 2008).

Northern savannah farmers may also want to consider planting two or more different maize varieties that have different maturity periods. The majority of the land can be planted first to higher yielding intermediate varieties (105-110 days). A week later, an extra-early maturing variety (80-85 days) can be planted. In doing this, the farmer addresses the time and labor constraints, and is able to spread the risk of crop failure.

Vegetation in the northern savannah of Ghana is primarily grassland with patches of socioeconomically valuable, drought-resistant trees (Ansah and Nagbila 2011, Barry *et al.* 2005). Leguminous trees, such as *Leucaena leucocephala, Gliricidia sepium, Vetex doninana and Acacia spp.* increase soil nitrogen, bring water and nutrients up to the crop root zone through long tap roots, reduce erosion and provide minimal shading to reduce evaporation from plants and the soil. These trees also serve as fodder for livestock and a source of green manure. Therefore, efforts should be made to preserve or cultivate these trees within the agroecosystem.

Other valuable trees include the sheanut tree (*Vitellaria paradoxa*), moringa tree *(Moringa oleifera), hanza tree (Boscia sengalensis*) and *Jatropha*. The sheanut tree produces an edible fruit, and the seed is processed into shea butter—an additional source of income, especially for women (Carette *et al.* 2009). The moringa and hanza trees have great potential to contribute to food and nutrition security in the northern savannah. The leaves, shoots, pods, seeds, flowers and roots of the moringa tree are edible and provide many essential vitamins and minerals, as well as medicinal properties (Price 2007). The moringa tree can be intercropped in alleys among field crops, where leaves can serve as a valuable green manure and quality livestock feed (Price 2007, Fahey 2005). Projects are currently underway in Ghana to distribute moringa trees and educate communities on the benefits, uses, cultivation and marketing of moringa (Water Charity 2013, DAG 2011).

According to the NGO Crops for the Future, the hanza tree is also a promising crop to help meet food security needs (Garvi-Bode and Garvi 2013). The fruit and seeds of the hanza tree are edible. The seeds in particular are packed with essential vitamins and minerals and prepared for use in soups, or made into flour for bakery production (Garvi-Bode and Garvi 2013).

Significant controversy has evolved over large transnational land acquisitions in Ghana's northern savannah to cultivate Jatropha as a biofuel crop. One argument is that biofuel companies displace Ghanaian farmers after taking advantage of Ghana's lack of land ownership documents and acquisition regulations (Nyari ND). A humanitarian news site told the story of a farmer who lost his land when the local chief sold it to biofuel investors (Mustapha 2011). Furthermore, land that was previously cultivated to food crops is now producing biofuel feedstock. Still other sources argue that investments in socially and environmentally responsible Jatropha production have the potential to create employment opportunities, generate additional income for rural farmers and increase food security (Boamah 2011). In the news article mentioned above, one farmer was happy to sell his land to biofuel investors, and is now cultivating Jatropha instead of low-profiting food crops (Mustapha 2011).

It is clear that the socioeconomic and environmental risks of large-scale Jatropha production must be carefully studied and determined. Furthermore, the Ghanaian government needs to create land and biofuel policy and regulation to guide decisions on biofuel issues. In the meantime, smallholders in the northern savannah may be able to take advantage of the existing Jatropha biofuel industry and benefit from small-scale Jatropha production. In addition to the benefits of using or selling the feedstock, this drought-resistant tree stabilizes the soil, acts as a green manure and has a deep tap root system that can improve soil quality (Osogo 2010). Jatropha is also known to deter livestock feeding (Osogo 2010). Therefore, farmers can plant Jatropha on marginal lands, along field edges, and possibly intercrop with annual plants to reduce crop loss from grazing animals, and improve soil quality. Additional benefits can be realized if biofuel companies agree to provide smallholders with affordable access to seed cake—a byproduct of biofuel production that can improve fertility (Osogo 2010).

An innovative maize production system uses certified seed, fertilizers, proper planting density and configuration, and well-designed intercropping patterns and crop rotations. Pesticides should be used as a last resort, and only after proper handling and application methods are understood and followed. The success of the agroecosystem will depend on how well practices were matched with environmental conditions, soil and crop characteristics and the farmer and household goals. Therefore, what maximizes sustainable productivity and profits for one farmer may not be appropriate for another. This highlights the importance of understanding field history, ecology, soil quality and conducting site-specific research. Smallholders implementing smart economic and ecological concepts into their production systems can improve soil quality, enhance resource use efficiency, reduce losses from pests and mitigate risk. Such an agroecosystem can yield higher and very likely produce more on less land—thereby addressing the labor constraints felt in northern Ghana.

It is critical that Ghana strengthen the capacity of its research institutions by funding both basic (e.g., soil mapping) and applied (e.g., optimum planting density), site-specific research. The government must also support the continued education and training of extension agents on GAPs. Equally important, efforts should be placed on improving collaboration among researchers (MOE), extension agents (MOFA), development projects, stakeholders and farm communities to ensure the most appropriate GAPs are being correctly implemented.

Policy

Reducing poverty and increasing food and nutrition security constitute a complex task that cannot be accomplished through increased crop yields alone. In fact, after over 30 years of agricultural-led development projects, the northern regions of Ghana remain impoverished (IFAD 2012, Morris *et al.* 1999). Therefore, sustainable improvements in agricultural productivity must be complemented with improvements in infrastructure, health, education, gender equality, land policy, market stability, financial services, technology access, environmental quality and research and extension support, to ensure equal socioeconomic health and stability. These issues interact considerably, and their impacts are largely driven by policy decisions.

The Ghanaian government must step up their support in developing critically needed infrastructure to facilitate easier market access, reduced transaction costs associated with market failures, and increased access to inputs at lower costs. Development must also include increasing the number of well-designed storage facilities to reduce post-harvest losses. Governments should expand the electrical grid to reach all rural communities, and erect weather stations to provide daily weather reports for farming districts. The potential for an irrigation infrastructure is substantial, as evident by the relatively high rainfall, extensive river networks and Lake Volta. Investments in irrigation would increase food and nutrition security by improving and stabilizing yields, extending the growing season and expanding farming options. The government must also facilitate improvements in financial services available to smallholders in rural areas.

Policy must be created to strengthen land-right laws, which will provide land owners incentives to improve the quality of their land without the fear of having it taken away without compensation. Environmental policy and regulation is also crucial for human and ecological health. Sustainable improvement in agricultural productivity cannot be met without conserving natural resources. If land in the northern savannah continues to be degraded through improper land management practices, yields will continue to remain low, as will food and nutrition security. Efforts to map the most vulnerable regions could help direct development resources and prepare for or avoid natural disasters and famines.

Arguably the most important goal for any nation is to ensure a nation of healthy, happy and productive people. A 2009 article by Negin *et al.* on the need for what past United Nations Secretary-General, Kofi Annan calls, a “uniquely African Green Revolution”, highlights the importance of incorporating gender and nutrition components into the system. Empowering women has been shown to improve child health and education. Ensuring women are healthy, especially during pregnancy and while breastfeeding, can help break the hunger and poverty cycle (Negin *et al.* 2009). The African Green Revolution called for by Secretary Annan included equal and sustainable benefits that were not fully realized by the Asian Green Revolution. Collaboration among agricultural, health, nutrition, gender, economic, social science and policy experts must exist for Africa (including Ghana) to escape the pains of poverty, hunger and malnutrition, and realize their potential.

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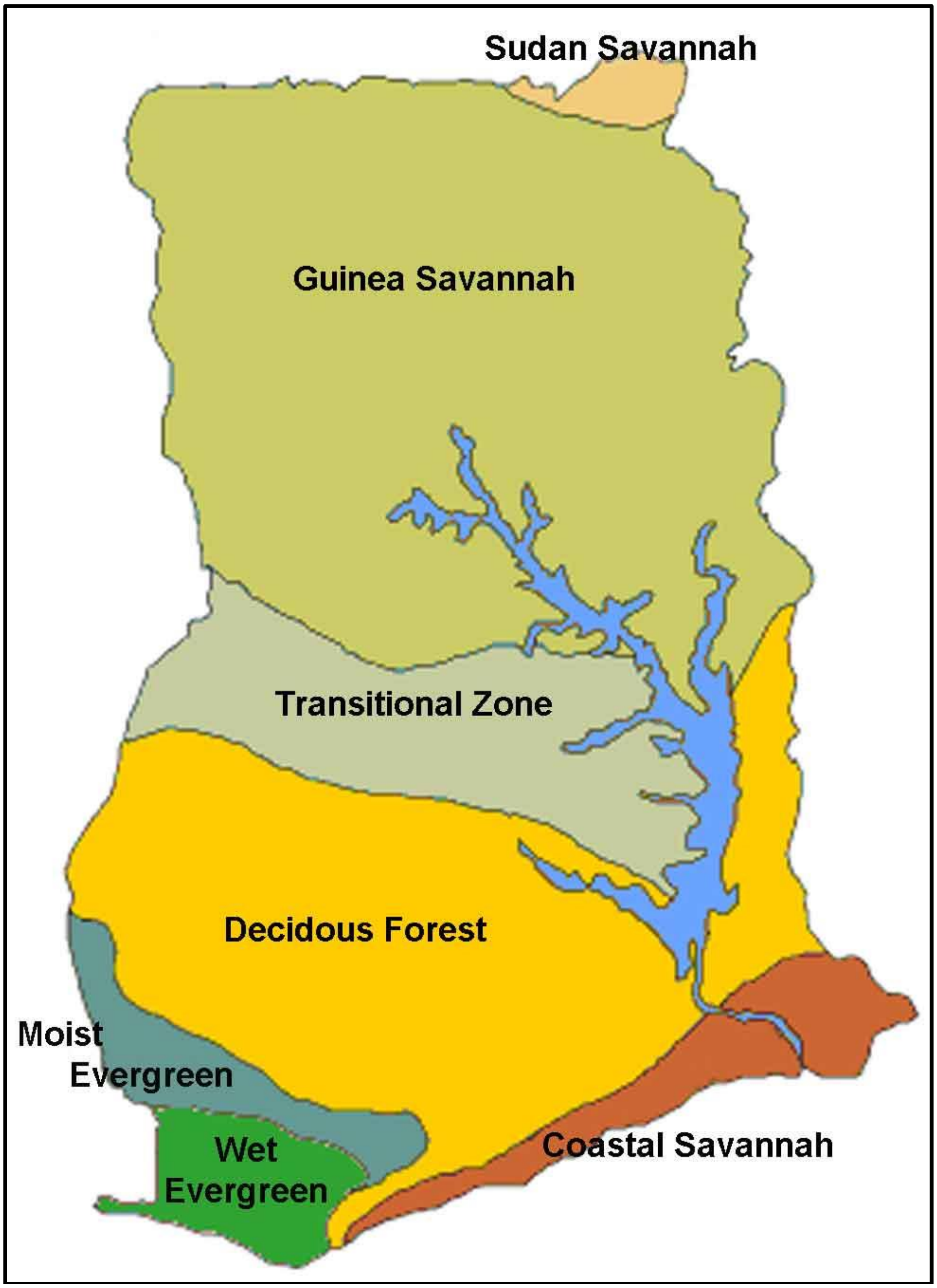
FIGURES

Figure 1. Map of Ghana's 10 administrative regions, regional capitals, national capital and adjacent countries.

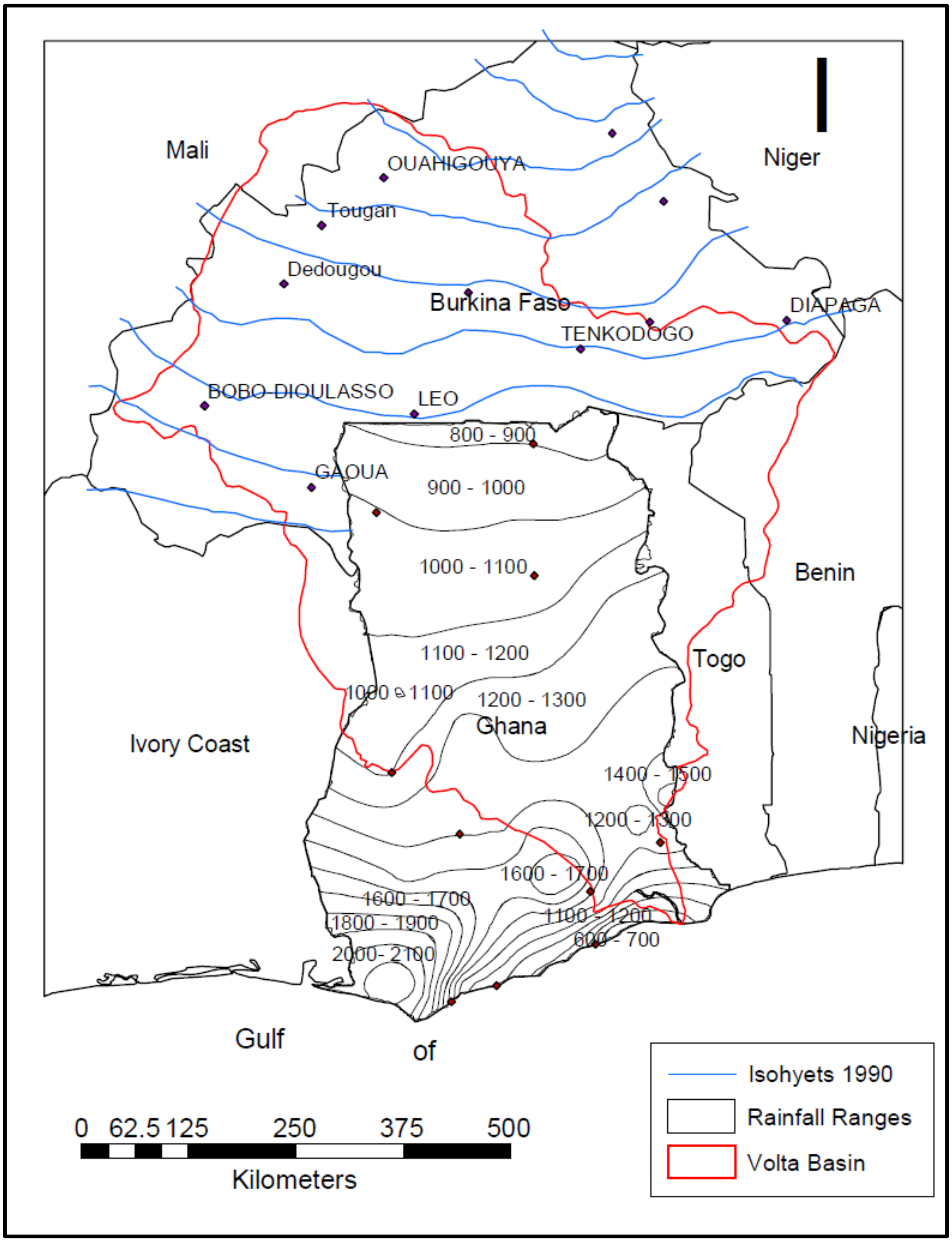
Source: CIA 2007 (https://www.cia.gov/library/publications/cia-maps-publications/Ghana.html)

Figure 2. Map of Ghana showing agro-ecological zones.



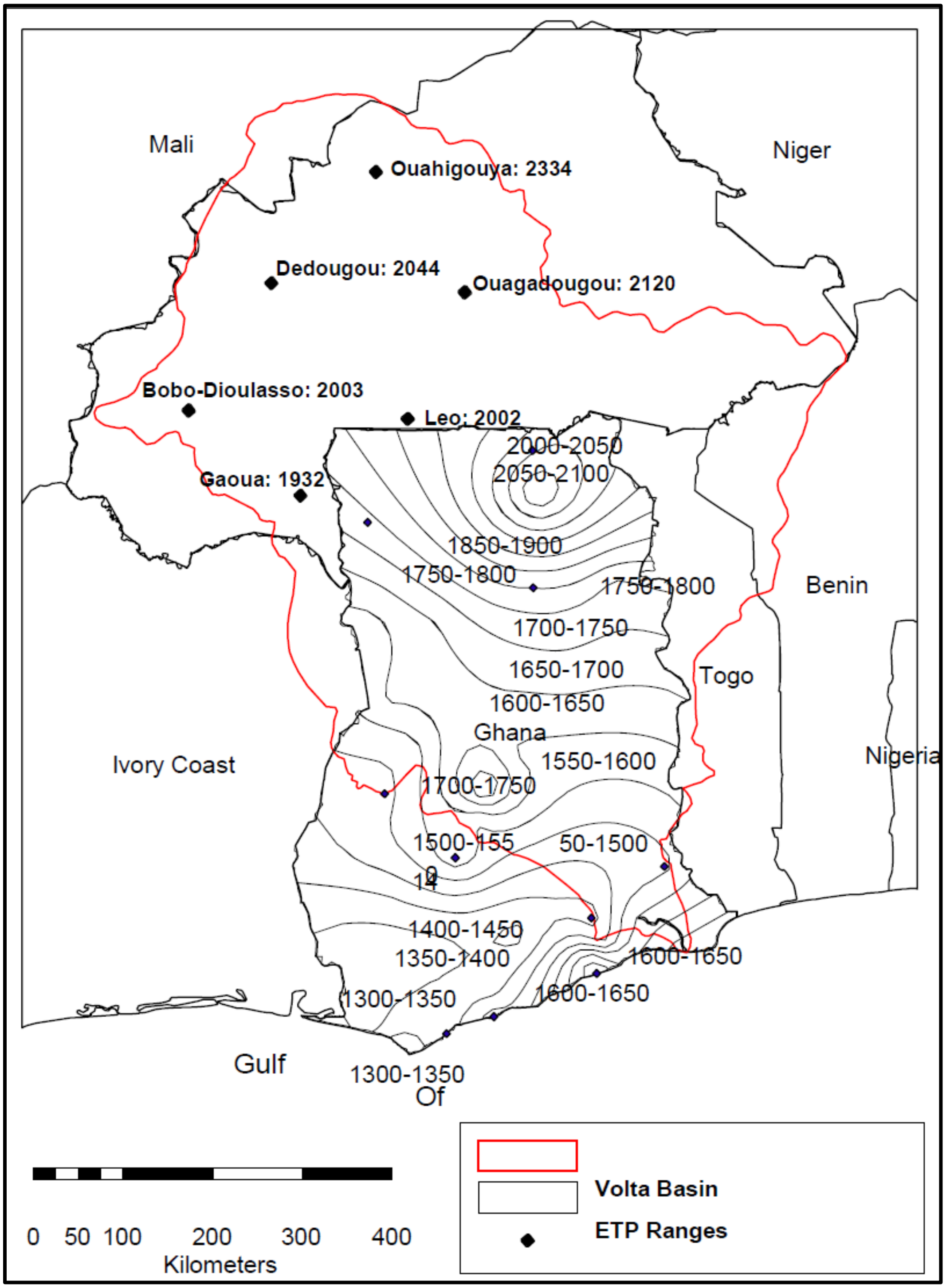
Source: Germer and Sauerborn 2008 (https://www.uni-hohenheim.de/respta/climate.php)

Figure 3. Annual precipitation ranges in Ghana.



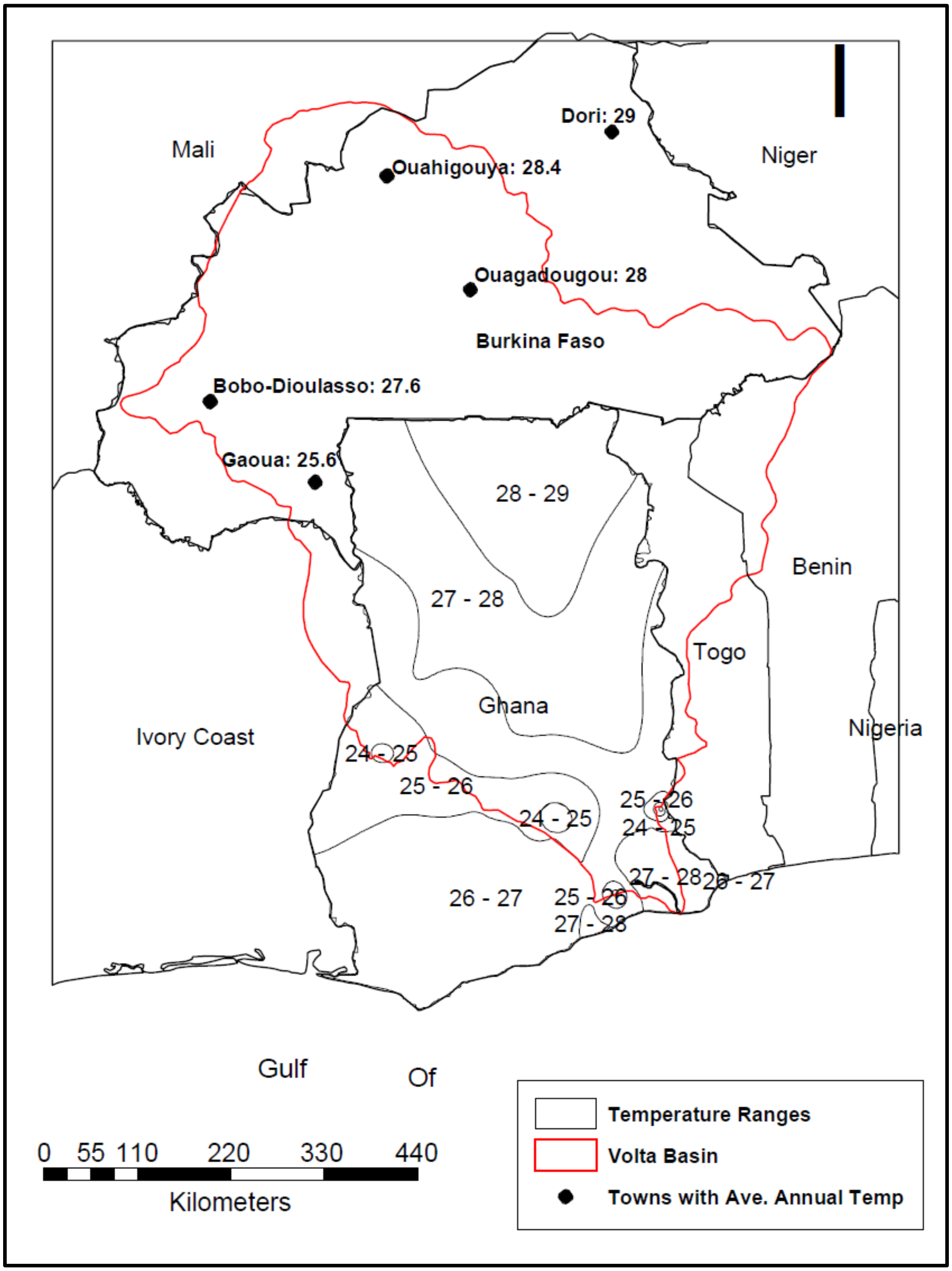
Source: Modified from Barry *et al.* 2005

Figure 4. Evapotranspiration ranges in Ghana.



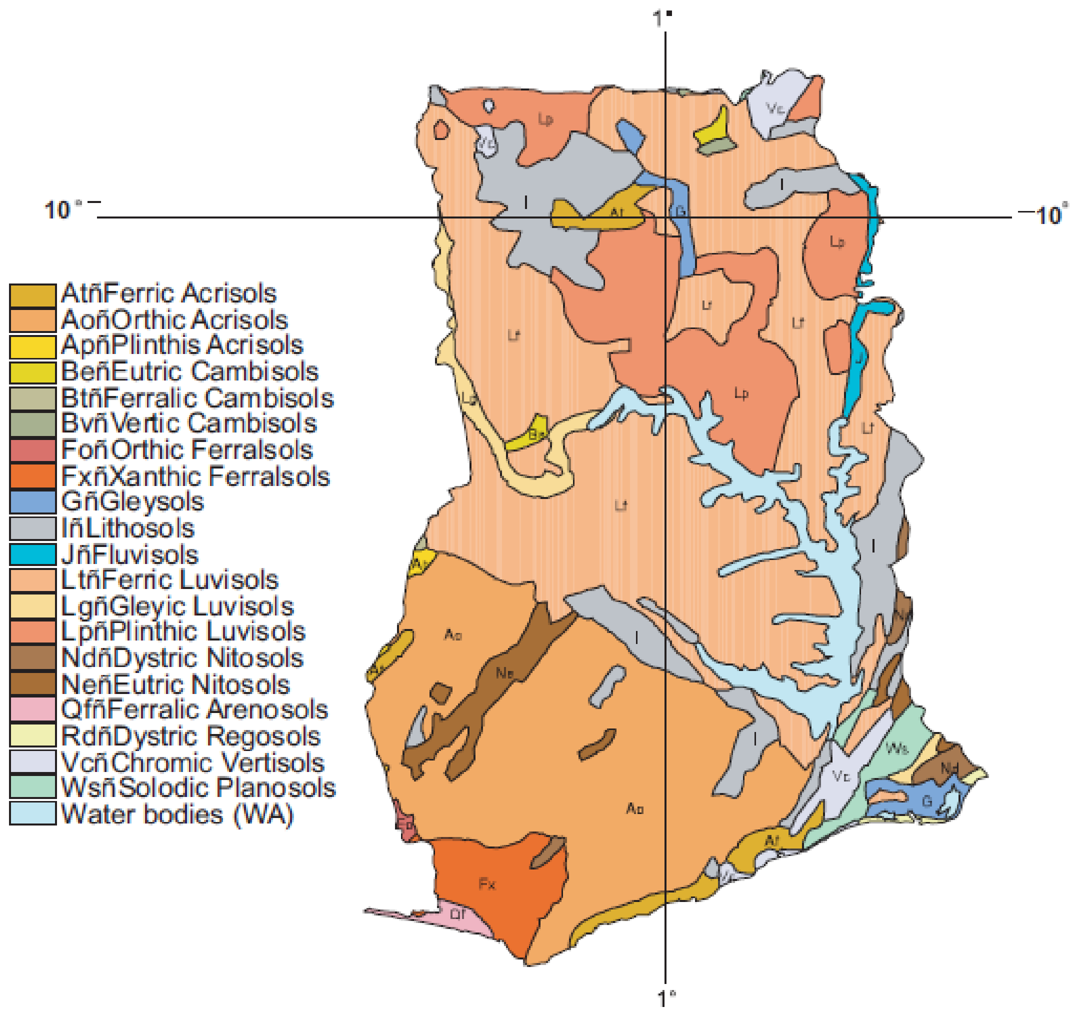
Source: Modified from Barry *et al.* 2005

Figure 5. Annual temperature ranges in Ghana.



Source: Modified from Barry *et al.* 2005

Figure 6. Dominant soils of Ghana.



Source: Modified from FAO 2005

TABLES

Table 1. Precipitation and growing seasons in Ghana by agroecological zone.

Agro-ecological Zone	Area (km^2)	Mean Annual Precip (mm)	Annual Precip Range (mm)	Major Rainy Season	Minor Rainy Season	Growing Period (days)	
						Major Season	Minor Season
Rain Forest	9,500	2,200	800 - 2,800	Mar-July	Sept-Nov	150 - 160	100
Deciduous Forest	66,000	1,500	1,200 - 1,600	Mar-July	Sept-Oct	150 - 160	90
Transition Zone	8,400	1,300	1,100 - 1,400	Mar-July	Sept-Oct	200 - 220	60
Coastal Savannah	4,500	800	600 - 1,200	Mar-July	Sept-Nov	100 - 110	60
Guinea Savannah	147,900	1,000	800 - 1,200	May-Sept		180 - 200	
Sudan Savannah	2,200	1,000	800 - 1,000	May-Sept		150 - 160	

Source: Data from Oppong-Anane 2006, and FAO 2005

Table 2. Average soil fertility status of seven administrative regions in Ghana.

Region	Soil pH	OM (%)	Total N (%)	Available P (mg/kg soil)	Available Ca (mg/kg soil)
Greater Accra	5.4 – 8.2	0.1 – 1.7	0.05 – 0.9	0.8 – 144.0	14 – 470
Western	3.8 – 7.1	1.0 – 5.7	1.0 – 5.7	0.4 – 11.3	28 – 420
Ashanti	4.3 – 7.8	1.5 – 3.0	0.1 – 0.3	0.1 – 12.0	50 – 100
Brong Ahafo	3.5 – 6.7	0.3 – 1.7	No data	0.1 – 64.3	16 – 140
Northern	4.5 – 6.7	0.6 – 2.0	0.02 – 0.05	2.5 – 10.0	45 – 90
Upper West	6.0 – 6.8	0.5 – 1.3	0.01 – 0.07	2.0 – 7.4	52 – 152
Upper East	5.1 – 6.8	1.1 – 2.5	0.06 – 0.14	1.8 – 14.8	44 – 152

Source: Data from FAO 2005

Table 3. Principal crops produced in Ghana.

Group	Crops
Cereals	Maize, millet, sorghum, rice
Roots and tubers	Yam, cassava, cocoyam, sweet potato, taro
Legumes	Cowpea, Bambara nut, groundnut, soybean, dawa-dawa
Vegetables	Tomato, eggplant, onion, pepper, okra, cabbage, lettuce, carrot
Fruits	Papaya, avocado, mango, cashew, melon, plantain, coconut, banana, pineapple, orange, pawpaw
Industrial	Cocoa, oil-palm, rubber, coffee, cotton, tobacco, sheanut, cola nut

Source: Data from MOFA 2011, and FAO 2005

Table 4. Principal crops grown in agro-ecological zones

Zone	Cereals	Starchy crops	Legumes	Vegetables	Tree crops
High Rain Forest	Maize, rice	Cassava, cocoyam, plantain		Pepper, okra, eggplant	Citrus, coconut, oil-palm, rubber
Deciduous Rain Forest	Maize, rice	Cassava, cocoyam, plantain	Cowpea	Pepper, okra, eggplant, tomato	Citrus, oil-palm, coffee, cocoa
Transition	Maize, rice, sorghum	Cassava, cocoyam, plantain, yam	Cowpea, groundnut	Pepper, okra, eggplant	Citrus, coffee, cashew
Coastal Savannah	Maize, rice	Cassava	Cowpea	Tomato, shallot	Coconut, pineapple
Guinea Savannah	Maize, rice, sorghum, millet	Cassava, yam	Cowpea, soybean, groundnut, bambara	Tomato, pepper	Sheanuts, cashew
Sudan Savannah	Maize, rice, sorghum, millet	Sweet potato	Cowpea, soybean, groundnut, bambara	Tomato, onion	

Source: MOFA 2011, and FAO 2005

Table 5. Monthly climatic data for Tamale, Northern Region, Ghana.

Month	Mean Min Temp (^oC)	Mean Max Temp (^oC)	Mean Temp (^oC)	Mean Precip (mm)	Number of Wet Days (>0.1mm)	Mean RH (%)
Jan	20	35	27.5	4	1	19
Feb	23	37	30	12	1	21
Mar	25	37	31	48	4	31
Apr	25	35	30	88	7	46
May	24	34	29	112	10	54
Jun	23	31	27	146	12	63
Jul	22	30	26	142	13	66
Aug	22	29	25.5	198	15	69
Sept	22	30	26	231	19	69
Oct	22	32	27	92	12	57
Nov	22	35	29	14	2	39
Dec	20	35	27.5	3	1	27

Source: climatemps.com 2012-2013 (http://www.tamale.climatemps.com/)