Strengthening Innovations and Technology Dissemination for Sustainable Development in Cereals, Cocoa and Coffee Value Chains in Western and Eastern Africa

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REPORT ON

INVENTORY OF EXISTING AND EXPLOITABLE KNOWLEDGE AND TECHNOLOGIES ON COCOA AND MAIZE PRODUCTION IN GHANA

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Project Description

This project is on Strengthening Innovations and Technology Dissemination for Sustainable Development in Cereals, Cocoa and Coffee Value Chains in Western and Eastern Africa. It aims at building capacity in science, technology, and innovation in these regions to boost food security and socio-economic development. This is to be achieved by establishing three centers for innovation and technology dissemination (CITED) to effectively disseminate proven appropriate technologies in cocoa and cereal production in the study regions.

This project is under the ACP-EU Cooperation programme in Science and Technology II (S&T II) and is being implemented in Ghana, Ethiopia and Uganda by the University of Molise (UNIMOL), Italy; ARPA Moilse, Italy; Gulu University (GU), Uganda; Bioeconomy Africa (BEA), Ethiopia and the University of Energy and Natural Resources (UENR), Ghana. The University of Molise, Italy is the International Coordinating Partner as required by ACP-EU cooperation programme. The overall goal of the Project is to contribute to build and strengthen Science, Technology and Innovation (STI) capacities in the agricultural sector of Western and Eastern African countries to enhance food security and socio-economic development. The specific objectives are:

- Establishment of working partnerships among the participating institutions.
- Establishment of 3 Centers for Innovation and Technology Dissemination (CITED) in each ACP partner Country.
- Dissemination of successfully proven Appropriate Technologies in each ACP partner country.

Professors, researchers and post-graduate students of the African Universities are involved in the project and the key stakeholders are in maize, rice, cocoa and coffee sectors including farmers, farmers' associations, extension agents, traders, poor and disadvantage people living in rural areas of Ethiopia, Ghana and Uganda largely dependent on agriculture, wider farming community and users of research innovations.

Some of the principal outcomes of the project include:

1. Three centers for innovation and technology dissemination for sustainable agricultural production and food security at host universities established.
2. Improved knowledge, skills and attitude about various ATs that help to improve productivity and food security amongst 40 members of target groups.
3. Increased inter-institutional STI networking cooperation and collaboration among researchers, stakeholders, policy makers, technology distributors as well as end users from Africa and EU.
4. Improved ACP stakeholders networking capacity with institutions.
5. Increased awareness on the availability and use of successfully proven appropriate technologies in the rice, cocoa and coffee sectors.
6. Strengthened human resource capacity in developing collaborative research, technology transfer and knowledge exchange on best practices and procedures in sustainable maize, rice, cocoa and coffee value chain (i.e. trained and facilitated mechanics, blacksmiths and artisans to support dissemination of technologies).

The project is being implemented in several communities in the Brong Ahafo and Ashanti Regions of Ghana. The Ministry of Food and Agriculture, cocoa and maize farmers, artisans, processors and other practitioners in the cocoa and maize value chain have been identified as key stakeholders to benefit from training and the research outcomes of this project.

The objective of this baseline report is to provide an inventory of existing and potentially exploitable knowledge and technologies on the production of cocoa and maize in the Brong Ahafo and Ashanti Regions of Ghana.

2.0 Cocoa Production in Ghana

Cocoa is the dominant tree crop in Ghana and the main agricultural export commodity of Ghana and employs about 60% of the national agricultural labour force (Ntiamoah and Afrane, 2008). Cocoa is produced in six regions of Ghana namely: Western, Ashanti, Eastern, Central, Volta and Brong Ahafo. The Dutch missionaries planted cocoa in the coastal areas of the then Gold Coast (now Ghana) in 1815 and in 1857, the Basel missionaries planted cocoa at Aburi on small scale (Tweneboah, 2000; GRI, 2007). In 1876 Tetteh Quarshie, a Ghanaian, arrived from Fernando Po with the

Amelonado type of cocoa and started his farm at Mampong Akwapim in the Eastern Region of Ghana. His farm turned into nursery for all pioneering cocoa farms in Ghana. In 1886/87, the then governor of Gold Coast, Sir William Brandon Griffiths supported the cocoa industry by obtaining cocoa pods from Sao Tome and distributed seedlings to various farmers in the Akwapim area from a botanical garden he helped to establish near Aburi (Tweneboah, 2000).

The first export of 36.30 kg of cocoa beans from the Gold Coast was made in 1891 and by 1900, exports had increased to 540 tonnes (Tweneboah, 2000). By 1911, the Gold Coast was the leading cocoa producing nation in the world with 41,000 tonnes. The volume increased to 165,000 tonnes and at that time, Ghana accounted for 40% of world production (GRI, 2007). From 1930 to 1933 cocoa prices fell sharply which led to the imposition of a ban on further cocoa planting in some areas by local chiefs. There was a hold-up of cocoa sales for over six months by farmers during the 1937/38 main crop season and the burning of cocoa beans in some areas in protest against low prices (Tweneboah, 2000). However, there was a sharp rise in the producer price after 1947 but the cocoa swollen shoot virus which had been identified in the country in 1936 devastated several cocoa farms. The government then instituted a disease control programme in 1946 where the affected cocoa trees were felled.

Due to rapid expansion in cultivation, production reached 440,000 tonnes in 1960 increasing to a record 590,000 tonnes in 1964/65. Production fell sharply to 324,000 tonnes in 1976/77 and to a record low of 158,000 tonnes in 1983/84 when bush fires and drought destroyed a number of farms (GRI, 2007). Although Ghana was the world's largest cocoa producer in the early 1960s, by the early 1980s Ghanaian production had dwindled almost to the point of insignificance. The drop from an average of more than 450,000 tonnes per year to a low of 159,000 tonnes in 1983-84 was attributed to aging trees, widespread pests and disease attack, bad weather, and low producer prices. In addition, bush fires in 1983 destroyed some 60,000 hectares of cocoa farms, so that the 1983-84 crop was barely 28% of the 557,000 tonnes recorded in 1964-65. Output then recovered to 228,000 tonnes in 1986-87.

The current world's production is 3,607,000 tonnes and Cote d'Ivoire is the largest producer of cocoa in the world followed by Ghana. The respective metric tonnages are 1,308,000 for Cote d'Ivoire (RBD, 2009) and 710,638 for Ghana (MOFA SRID, 2009). The trend in cocoa production levels in Ghana from 1947 to 2010 are summarized in Table 1.

Table 1. Trend in cocoa production levels in Ghana from 1947 to 2010

Years	1947	1950	1960	1965	1970	1975	1983	1990	1995	2000	2005	2010
Production ('000 tonnes)	190	265	440	590	450	324	158	180	270	440	740	632.037

Source: Ghana Cocoa Board (2011)

2.1 Economic Importance of Cocoa in Ghana

Cocoa is the dominant tree crop in Ghana that accounts for 30% of Ghana's export earnings (ICCO AR, 2007) and employs about 60% of the national agricultural labour force. Cocoa production employs about 800,000 farm families spread over six of the 10 regions of Ghana and contributes about 70-100% of the annual household incomes of the Ghanaian cocoa farmers (Appiah, 2004; Ntiamoah and Afrane, 2008). In terms of agricultural Gross Domestic Product (GDP), cocoa contributed 11.24% and 11.50% in 2008 and 2009, respectively (MOFA SRID, 2010). Cocoa beans and products exported in Ghana from 2005 to 2009 seasons generated US$ 908.40 million to an estimated amount of US$ 1,865.98 million (ISSER, 2010). Ghana's export earnings on cocoa from 2000 to 2010 is summarized in Table 2.

Cocoa has been the mainstay of the Ghanaian economy for many years contributing about 6% to GDP (COCOBOD News, 2010) and about 11.5% to Agricultural GDP (SRID MOFA, 2009). It provides livelihood to 60% of the Ghanaian population and would continue for many years to come despite the discovery of oil in commercial quantities in the country. It is a major source of taxation to the government and over the years, cocoa has provided money for infrastructural development and for the education of the mass of the people. Records show that Ghana earned about $1.5 billion from cocoa receipts in the 2007/2008 cocoa year (COCOBOD News, 2010). Cocoa beans are used to make chocolate biscuits, cake and confectionary. In preparing cocoa powder, excess fat known as cocoa butter is expressed which is used in chocolate manufacture and other industrial processes such as in confectionary, margarine making and perfumery. Cocoa products feature prominently on the menu in many homes, restaurants and hotels. COCOBOD offers a lot of social incentives to Ghanaians through programmes like the scholarship scheme, pest and disease control, supply of subsidized fertilizers, provision of solar bore holes and solar street lights and the recent pension and housing scheme for cocoa farmers among others (COCOBOD News, 2010).

Table 2. Ghana's export earnings on cocoa from 2000-2010

Crop Year	Export Earnings (US$)
2000/2001	139,945,542.30
2001/2002	171,581,081.40
2002/2003	380,652,258.10
2003/2004	621,008,756.30
2004/2005	487,971,361.00
2005/2006	577,736,177.60
2006/2007	630,132,143.20
2007/2008	759,321,155.40
2008/2009	1,367,424,000.00
2009/2010	1,581,762,856.00

Source: Ghana Cocoa Board (2011)

2.2 Health Benefits of Cocoa

The Mayans and the Aztecs thought of cocoa of having medicinal properties (Wood and Lass, 1985). In recognition of its multiple health benefits, they maintained its ancient Olmec name 'kakawa' meaning 'God Food' (Little, 1998; Addai, 2009). Natural cocoa powder contains the highest antioxidants and procyanidins compared to Dutch processed cocoa powder, unsweetened baking chocolate, semi-sweet chocolate baking chips, dark and milk chocolate (Addai, 2009). Cocoa beans contain a large number of phytochemicals which help the body cells resist damage and also inhibit the oxidation of the low density lipoprotein associated with heart disease. Consumption of cocoa which is a rich source of polyphenolic compounds is associated with a reduced risk of diabetes mellitus (Grassi *et al.,* 2006), dementias strokes and end-stage renal disease (Hollenberg, 2006). There is also reduced frequency of malaria illness in people who drink hot natural cocoa powder (Addai, 2009). Unlike tea and coffee, cocoa contains little caffeine which has little effect on the central nervous system and as such can be given to children without fear of sleeplessness (Weisburger, 2001). The moderate consumption of cocoa can prevent or cure a sickness like the plaque of the guts (Wood and Lass, 1985). Golden tree brand of milk chocolate produced in Ghana is non-acidogenic (Addai *et al.,* 2002).

However, cocoa processed into chocolate and other palatable beverages decreases its antioxidant content and perhaps removes other vital micronutrients necessary for its anti-malaria effect (Addai, 2009).

3.0 Maize Production in Ghana

In Ghana, maize is the largest staple crop and is the mainstay of the diet of the majority of Ghanaians, because it is the base for several traditional food preparations such as *banku, kenkey, tuozafi* etc. (Morris *et al*., 1999). Additionally, it represents the second largest commodity crop in the country, after cocoa (ISSER, 2012). Maize is also the main component for poultry and livestock feed. Maize accounts for 50–60% of the total cereal production in Ghana ISSER, 2012). The total average annual maize production in Ghana between 2007 and 2012 was 1.5 million MT (MoFA, 2012), which indicates that maize supply in Ghana has steadily been increasing over the past few years.

In terms of both harvest and sales value, maize is an important cash crop in Ghana. It is produced in all the ecological regions in Ghana, namely the Forest, Coastal Savannah, Forest Savannah transition, Guinea Savannah, Sudan Savannah and Sahel Savannah (Egyir, 2003). In the Ghana Living Standard Survey (GLSS, 2000), categorically, there are three ecological zones, the northern savannah, coastal savannah and forest zones. In the forest zone the climate is dominated most of year by moist air and conventional rainfall is frequent. The rainfall is usually between 1000 and 2000 cm per annum, falling in two seasons with only a short dry season of reduced rainfall between them. In Southern Ghana where this condition is prevalent two cropping seasons of maize are possible. The savannah areas may have two short rainy seasons and a pronounced intervening dry season, as in the coastal areas, or a medium, lengthy rainy season and a long dry season as found in most parts of Northern Ghana. Here there is only one season for maize production

Maize production also cuts across all the ten (10) regions of Ghana but the Eastern, Ashanti, Central, Brong-Ahafo and the Northern Regions are the five major maize growing areas in Ghana (SRID of MOFA, 2010). Maize is the largest staple crop cultivated in Ghana and contributes significantly to consumer diets. It is also used in the preparation of traditional dishes such as *tuozaafi, banku and kenkey*. Maize is produced mostly by small-scale farmers using simple hand tools such as hoe and cutlass. Very few commercial maize farms are in operation presently in Ghana (e.g Ejura Farms). The level of production on individual farms is very low, hence the need to increase productivity through science and technology.

Maize is the most important cereal crop on the domestic market in Ghana but its yield recorded by the Ministry of Agriculture in 2010 was 1.9 Mt/ha against an estimated achievable yield of around 2.5- Mt/ha (Ministry of Food and Agriculture, 2010). Table 4 shows the volume of maize production in Ghana from 2002-2010 in the 10 regions of Ghana (in metric tonnes). The total hectare of land under maize cultivation and tonnes production in Ghana from 2006 – 2010 is also shown in Table 3.

While there is no recent reliable data for maize used in animal feed, the COG estimates that 85% of all maize grown in Ghana is destined for human consumption and the remaining 15% is used for animal feeding sector (mainly poultry) (Grain and Feed Annual Grain Report, 2011). Thus, to meet the increasing demands of maize, farmers may have to adopt improved production and handling systems.

Table 3. Volume of maize production in Ghana from 2002-2010 (in Metric Tonnes)

Regions	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Western	86,520	86,520	159,622	72,135	73,210	75,406	77,553	-	74,191
Central	247,110	247,110	159,622	164,398	166,847	176,222	-	-	195,394
Eastern	218,900	244,000	241,621	206,467	209,542	227,505	280,806	303,400	380,505
Gt. Accra	2,610	2,610	2,714	2,103	2,134	2,775	-	-	3,584
Volta	58,630	58,630	53,868	47,577	48,286	49,978	72,858	-	93,887
Ashanti	187,000	193,920	183,032	161,816	164,226	169,383	182,848	186,830	253,374
Brong-Ahafo	295,680	295,680	281,267	358,259	363,595	381,435	402,688	-	510,172
Northern	79,050	79,050	74,566	96,717	98,157	88,037	131,857	-	202,316
Upper-West	60,710	60,710	60,801	47,422	48,128	40,104	55,223	-	96,018
Upper-East	20,370	20,370	14,650	14,496	14,712	8,756	27,528	51,143	62,256
Total	1,256,580	1,288,600	1,157,621	1,171,390	1,188,836	1,219,601			1871,695

Source: Statistics, Research and Information Directorate (SRID), MoFA (2002-2010)

4.0 Increasing Cocoa and Maize Production through Science and Technology

Having established that cocoa is Ghana's major export crop, and maize is also a key staple in the diet of majority of Ghanaians, it is imperative that production levels are increased to meet the increasing population growth in the country. The rapid population growth has brought extensive pressure on available arable lands as these lands are increasingly being used for human habitation, social infrastructural development and other economic activities such as mining. Consequently, new technologies that will help increase the yield per hectare need to be identified and disseminated to farmers to meet the growing demand. Furthermore, because majority of Ghanaian farmers are small scale peasant farmers with limited education, many of them will not voluntarily seek and adopt new technologies.

Technology plays an important role in agricultural production and impacts the lives of farmers in the whole world. Technical innovations such as ploughing, irrigation, milling, and other improved farming practices have helped to achieve food security throughout the history of mankind. In our modern time, technologies are readily available and innovations abound. However, these technologies may have some unknown risks when used indiscriminately without proper assessment. Generally, farmers and other stakeholders trust proven technologies which have been adapted for particular settings. However, new technologies can run the risk of being used only by the rich in the society to boost their incomes rather than ensuring food security. Such a practice can hamper the acceptance by small holder farmers, who traditionally are known to avoid risks (Global Forum on Food Security and Nutrition, 2010).

Certain factors have been known to affect the integration and adoption of new agricultural technologies in Ghana. Some of these include, age, educational level, farm size, access to information, land ownership, level of farm income and infrastructure, access to technology and availability of funds (km.fao.org/fsn). To have a positive and long term impact on food security and for broad acceptance by stakeholders, technologies need to be introduced with care and be readily adaptable to the demands of a particular setting, and must be easy to understand and use. Also, technologies need to take into account the socio-economic conditions of the community and/or current farming practices and their immediate benefits.

To effectively disseminate identified appropriate technologies, the following procedures would be followed:

- Several stakeholders in the cocoa and maize value chain (e.g. small scale farmers, researchers, Extension agents, policy makers, processors etc) would be identified and interviewed to discover what technologies they are currently employing
- Selection of effective available appropriate technologies that are not being widely used by farmers in the catchment areas through stakeholder workshop
- Demonstrate and educate identified farmers on the use of the selected appropriate technologies through field experimentation with key stakeholders
- Monitor and collect data on the impact of these appropriate technologies on the output of the farms. The above activities would be carried out with due consideration of existing natural resources, human resource capacity, farmer's needs and requirements, cultural norms and practices, as well as other socio-economic setup.
- Report findings as indicated in the project document.

5.0 Project Areas

Geographically, Ghana is situated between latitudes 4.7^0 S and 11.11^0 N and longitudes 3.3^0 W and 1.0^0E (Fig 1). The total land area is 23,853,900 ha. It has an arable land (agricultural) area of 13,628,000 ha out of which 12,000,000 ha is forest and fields. Ghana has a tropical climate with three distinct agro-ecological zones namely rainforest, transitional and coastal/guinea savannah. Annual mean rainfall is between 800 to 2,200 mm. The population stands around 24 m with 51% females and 49% males (2010 Population Census). Temperature range: Min: 18^0 C – Max: 38.0^0 C. Relative humidity range: 20% - 100% (Ghana Meteorological annual report, 2013).

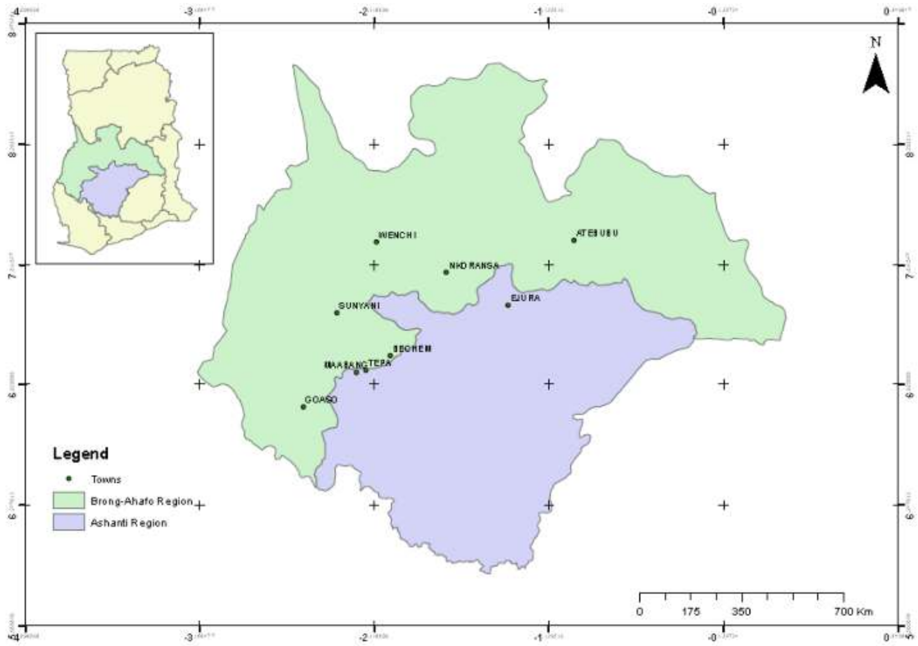

Fig. 1 Map of Ghana showing project areas

The inventory was carried out in several communities in the Brong Ahafo and Ashanti Regions of Ghana (Fig. 1; Table 4). The Brong-Ahafo Region is located in central part of Ghana, often considered ecologically as the transition zone between the northern savannah and the southern forest regions. It is bordered to the north by the Black Volta River and to the east by the Lake Volta, and to the south by the Ashanti region, Eastern and Western regions, and to the west by the Ivory Coast south-eastern border. Its administrative capital is Sunyani. The Brong Ahafo region has a population of about 3.5 million inhabitants (http://www.citypopulation.de/Ghana-Cities.html). Farms from some of the following towns and villages will be considered as part of the SATTIFS project; Wenchi, Nkoranza, Techiman, Atebubu, Bechem, and Goaso.

Geographically, the Ashanti Region occupies the south central of Ghana and bounded by the Brong Ahafo, Eastern, Central and Western Regions. It has a population of about 4.8 million residents, according to the Ghana Statistical Services' 2010 population and housing census. The capital of Ashanti Region is Kumasi. Projects in the Ashanti region are in the following towns/villages; Tepa, Maaban, and Ejura.

Table 4: Project Areas

Crop	Town
Cocoa	Goaso, Tepa, Maaban, Bechem
Maize	Techiman, Wenchi, Ejura, Nkoranza, Wenchi and Atebubu

6.0 Background Situation for Cocoa and Maize

6.1 Cocoa Situational Analysis

The government of Ghana has attempted to restructure cocoa production through market reforms (liberalization of domestic marketing of cocoa), improved seed and nursery development, improved cocoa varieties, better disease and pest control, integrated nutrient management and other measures like road construction and provision of social amenities in cocoa growing areas. For example, in 1983 farmers were provided with seedlings to replace trees lost in the drought and trees that were more than thirty years old (about one-fourth of the total number of trees in 1984). Until the early 1990s, an estimated 40 hectares continued to be added to the total area of 800,000 hectares under cocoa production each year. In addition, a major programme to upgrade existing roads and to construct 3,000 kilometres of new feeder roads was launched to ease the transportation and marketing of cocoa from some of the more neglected but very fertile growing areas on the border with Ivory Coast. Furthermore, the government tried to increase Ghana's productivity from 300 kilograms per hectare. New emphasis was placed on efficient and effective extension services, development of technologies such as early maturing cocoa varieties, improved pest and disease management, improved agronomic practices, nutrient management etc by the Cocoa Research Institute of Ghana (CRIG). These measures resulted in increased cocoa production to its highest level of 1 million tonnes in 2006 (CRIG, 2010), although this production level was not sustained.

In spite of this increase in production, Ghana's cocoa yield per hectare is still low by international standards. More importantly, only about 3% of cocoa farmers have adopted the full range of technologies developed by CRIG to increase productivity of cocoa.

6.2 Maize Situational Analysis

Maize is a staple in many Ghanaian diets, and is one of the more affordable foods on the local market. Domestic maize production seems to be meeting the local demand for human consumption. The maize supply in Ghana has been increasing steadily over the past few years with an average supply at 1.4 million MT over the period 2005-2010. However, human consumption is competing with the poultry industry and to a lesser extent the livestock industry. While there is no reliable data for maize used in animal feed, the Government of Ghana estimates that 85% of all maize grown in Ghana is destined for human consumption and the remaining 15% is used for the animal feeding sector (mainly poultry). Furthermore, with the promotion of the renewable sources of energy, maize as a source of biodiesel is being studied worldwide including Ghana and may soon increase local demand when farmers attempt to sell to fuel companies.

The share of smallholder farming on Ghanaian agriculture is significant especially for cassava, maize and cocoa production. More than 70% of Ghanaian farms are 3 ha or below. Maize together with cassava is present in the majority of Ghanaian household portfolios. For farms of up to two hectares, maize and cassava are also the most important crops. Their importance for food security for the smallholder farmers is also evident from the shares of commercialized product by holding size and crop. Given the current levels of commercialization by smallholder farmers any profitability analysis will have to take into account the share of product that is currently not commercialized (Ghana Statistical Service, 2007).

White maize consumption is projected to increase due to population growth and increasing per capita income (Table 4). Based on the most recent domestic production data, the shortfall between domestic production and domestic consumption would reach 267 000 Mt by 2015 if there is no significant productivity improvement (MOFA, 2011). This deficit will mostly affect consumers in urban areas and the poultry industry.

Table 5. Estimates on consumption of white maize produced in Ghana in 2006

MT	Production/Consumption	% of total consumption
1 189 000	Total national production (2006)	100%
675 000	Household consumption at a subsistence level	57%
150 000	Poultry and fish feed	13%
170 000	Formally imported for human consumption (wholesale)	14%
194 000	Informally imported for human consumption	16%

Source: WABS Consulting Ltd (2008)

Undoubtedly, there is great potential for Ghana to develop maize as a major export agricultural commodity. The climate and the soils in all the 10 regions of Ghana are suitable for maize production. In addition, several technologies along the maize value chain have been developed by research institutions in Ghana to enhance productivity. However, the mean yield of maize per hectare produced by smallholder farmers is very low and postharvest losses at farm level and during storage are extremely high averaging 30-50%. Low adoption of technologies is one of the key factors responsible for the rather low maize productivity and high postharvest losses along the value chain. There is the urgent need to remove the barriers that militate against adoption of technologies by resource poor farmers through more efficient and effective means of technology dissemination.

Plate 1: A small scale farmer in Nkoranza controlling weeds. Plate 2: This storage structure can store 15 bags of harvested maize

7.0 Knowledge

Ghana has an impressive human resource base in Agriculture including research scientists, senior faculty, agricultural extension officers, and field technicians. The Crop Research Institutes under the Council for Scientific and Industrial Research and the Cocoa Research Institute of Ghana under COCOBOD, and several public

Universities in Ghana have chalked many notable successes in technology development to increase maize and cocoa production in Ghana. They have contributed significantly to the development of improved and hybrid seed varieties which are high yielding and pest and disease tolerant. Additionally, many of Ghana's universities offer world class programmes in all aspects of agricultural sciences. While many of these professionals are not directly involved in farming activities, a significant number have demonstration farms, and others act as consultants and extension officers for the local farmers.

8.0 Methodology for the Inventory Survey

In order to gather information about the existing technologies available in the cocoa and maize value chains, two main research methodologies were employed. First, a literature review of reports, journal articles and books was conducted to determine the range of technologies that have been reported. Secondly, interviews with MOFA officials, COCOBOD and CRIG staff and research scientists, farmers, and other stakeholders (See Table 6) were conducted to find out their knowledge of existing technologies and to ascertain the scope of technology application in farming practices.

In the literature review, searches were done seeking specific information about technologies, processes, and practices used in cocoa and maize production over the years. An analysis of research finding publications, particularly in cocoa was conducted. Armed with this information the various district MOFA officers and some extension officers were interviewed. The interview questions were mostly open-ended – asking the officers to list the various technologies used in the maize and cocoa value chains. The open ended questions were broken down into the various cycles of crop production: land preparation, seed technologies, planting, weed and pest control, harvesting and processing for market, and storage practices

Locally, several technologies and improved practices are employed by some farmers. These technologies can found along the whole spectrum of the value chain of cocoa and maize. Among the seed technologies are development of disease resistant, drought resistant, and high yielding varieties of both crops. Researchers have also developed improved methods of nursing seedlings, land preparation, transplanting of seedlings, planting patterns, mulching, weed control, pruning, and fertilizer application to reduce losses and increase yield. Furthermore, better disease and pest control methods have been developed, including the use of synthetic pesticides and plant based pesticides. Better harvesting and processing methods have also been developed for both cocoa and maize. These include such technologies as harvesters, pod-breakers, fermentation processes, drying technologies, bagging, de-husking, and threshing.

Table 6. List of institutions and stakeholders Visited during the survey

Name of Place Visited	Type of Crop	Name of Contact Person	Contact Details
Sunyani 1. MOFA, District Officer 2. Regional Cocoa Board 3. GRATIS FOUNDATION	Maize Cocoa Technology Transfer	 Mr. Antwi Agyei	
Wenchi 4. District MOFA Officer 5. District National Service Farm Coodinator 6. District Extension Officer 7. Local Maize farmer	Maize	 Osei Adade, District Director, MOFA Halidu Haruna, National Service Mr. Ababio	 0209385947 0201447370 0208808078
Methodist University College 8. Dean	Technological innovations in Maize	Dean of College	0207984858
Techiman 9. MOFA, District Director 10. Extension Officer 11. Maize Farmer Group	Maize	 Mr. Effah Takyi Augustine Akonnor James Mahana	 0244941218 0244047286 0205561402
Nkoranza 12. District MOFA Officer 13. District Extension Officer 14. Local Maize Farmer	Maize	M. K.M. Ahiadu, District Director, MOFA Philip Datuah Gladys Abaa Jonathan Nsor	 0202235575 0202771038 0243557646
Atebubu 14. MOFA 15. District Extension Officer 16. Maize Farmer	Maize	 Eric Kontoma Lawrence Adomako Miller	 0208300792
Bechem 17. Cocoa Board Seed Development Office	Cocoa	Mr. Budu-Cocoa Nursery Division	0208184106
Goaso 18. Seed Development Office 19. A cocoa farmer	Cocoa	Evans Mortey-Cocoa Nursery Division Mr. Ayaama Francis	0242233134 0505203622
Tepa/Maaban 20. Cocoa Research Institute model Farm	Cocoa	PRO- CRIG	0208162424

21. Kuapa Cocoa Farmers' Association		Charles Adomako Baafi Anthony Owusu	0242685507 0246244503

9.0 Proven and Exploitable Technologies on Cocoa

9.1 Cocoa Varieties

There are four varieties of cocoa in Ghana, namely; Criollo, Amelonado, Trinitario and the Hybrid Seed. The hybrid varieties are been promoted for cultivation throughout the country. Hybrid seed gardens (nurseries) have been established in all the six cocoa growing regions in Ghana. In the Brong Ahafo Region the seed gardens are in Goaso, Sankore and Bechem. They supply improved hybrid (***akokorabedi***) variety which has the following advantages:

- Easy to establish
- Fruit bearing in two years
- High yielding
- Resistant to black pod and swollen shoot diseases
- Resistant to capsids (akate) pest

Plate 3: Cocoa hybrid pods, a) from seed farm and station

Plate 4: Rejected pods in Goaso seed

9.2 Best Agronomic Practices

9.2.1 Land Clearing and Shade Trees

In cocoa plantation, land clearing is conducted between the months of December and February, leaving desirable trees to provide shade. According to current research finding and practices, cocoa seedlings are to be planted at a distance of 3 m x 3 m for maximum yield. Plantain, cocoyam and cassava are planted to serve as temporary shades for the young cocoa plants, while in the forest regimes, 35-45 trees are left as shade trees per hectare (Table 5). This is further pruned to between 15-18 trees per hectare after the establishment of cocoa trees.

Table 7. Examples of desirable and undesirable trees in cocoa farms

Desirable shade trees	Local Name	Undesirable shade trees	Local Name
Terminaliaivorensis	Amire	*Ceibapentandra*	Onyina
Terminalia superb	Ofram	*Cola gigantean*	Watapuo
Albizia coriaria	Awiemfuosamina	*Cola chlamydantha*	Krabise
Entandrophragma angolense	Adinam, cedar	*Adansonia digitata*	Odadee
Funtumia elastic	Ofuntum	*Blighia sapida*	Akyewobiri
Alstonia bonei	Nyamedua	*Canthium glabriflorum*	Gyapam
Pycnanthus angolensis	Otie	*Musanga cecropoides*	Odwuma
Milicia excels	Odum	*Carapa procera*	Kwakuobise
Spathodea campulata	Kukuoninsuo	*Lecaniodiscus cupanoides*	Dwindwera
Ficusexaperata	Nyankyeren	*Myrianthus arboresus*	Nyankuma

9.2.2 Field Planting Patterns

The best time for planting cocoa is in May to July (the major rainy season). Seedlings should be watered a day before planting in rows of 3 m x 3 m, (10 ft x 10 ft) spacing. This gives 1,111 seedlings per ha or 435 seedlings per acre. There are two technologies employed in planting.

i) Technology 1 (Low Production Level)

Planting at stake with unspecified source of seeds, at irregular spacing, high density, infrequent weeding, little or no pruning, infrequent removal of mistletoe, infrequent disease and pest control, infrequent harvesting. Shade management is not normally practiced. Such technologies constitute 50% of national production giving an average yield of 250 kg. Per hectare.

ii) Technology 2 (Medium Production Level)

Planting in line at regular spacing with improved seeds from designated seed gardens, proper weed management, regular pruning and mistletoe removal, periodic shade management and pest and disease control about twice a year and frequent harvesting constitute 45% of total production yielding an average of 550 kg per hectare.

9.2.3 Planting Methods

a) Using nursed poly bags

b) Using seedlings raised on beds

c) Planting at stake,

Each of these methods has their advantages and disadvantages.

Plate 5: Using Poly bags

Advantages

- Better plant growth and establishment
- Higher survival rate
- Opportunity to establish healthy plant seedlings
- Seedlings tolerate adverse climatic conditions.

Disadvantages

- Require poly bags as a growing facility, making it expensive- procure topsoil, labor and polythene bags
- Transporting of seedlings to planting sites can be enormous.

Plate 6: Cocoa seedlings in poly bags. Plate 7: Cocoa seedlings transported to farms

b) Using seedlings raised on beds

Advantages

- Relatively high survival rate after transplanting
- Better seeding growth
- Reduce losses due to diseases
- Opportunity to be selective in establishing farms
- Minimize losses due to weeding
- Lower transportation cost than poly bags.

Disadvantages

- Require more labor for handling and seedling transportation
- Transplanting is weather dependent

c) Planting at Stake/Direct Planting

Plate 8: Cocoa planted at stake

Plate 9: Established farm planted at stake

Advantages

- More economical, requires no planting facility
- Reduces transportation cost

- Reduces transplanting shock
- Seedlings can better tolerate adverse conditions since they develop *in situ*.

Disadvantages

- May result in poor growth of seedlings due to competition from weeds.
- Seedlings exposed to rodents
- Little opportunity to select for uniformity
- Greater care is needed to prevent mechanical damage when weeding and may increase labor cost.

9.2.4 Mulching

This is essential for young cocoa plants during the first 2 years of establishment. Mulching helps to conserve soil moisture, promote soil organic activities, reduce impact of rain drops and slow down run offs. Mulching materials include dry grass, pseudo stems of plants. In termite infested areas a synthetic insecticide, Confidor solution is applied with water to the mulch.

9.2.5 Fertilizer Application

The application of fertilizers depends on the stage of plant growth, soil type and its fertility. Three types of fertilizers are recommended by the COCOBOD for cocoa as follows:

Conventional (inorganic) Fertilizers

i) Asaase Wura (NPK 0-22-18 +9CaO +7S + 6MgO)

ii) Cocofeed (NPK 0-30-20)

iii) Triple super phosphate (TSP; 46% P_2O_5) + Muriate of potash mixture (MOP; 60% K_2O)

iv) Ammonium sulphate (21%N)

Fertilizers are broadcast on the same plot for four consecutive years with 1-2 year break.

Foliar/Liquid fertilizers

These come in three formulations:

i) NP K 10:10:10 (balanced)

ii) NPK 20:2:4 (Nitrogen-rich) and

iii) NPK 6:0:20 (Potassium-rich)

These are applied at monthly intervals by way of broadcasting at the base of cocoa trees.

Organic Fertilizers

These are applied to reduce risk of environmental pollution. Examples include poultry manure, coco pod husk ash, compost etc.

All fertilizers are can be applied on young and old cocoa after 18 months on the recommendation by extension officers.

9.2.6 Pruning

This is done for both young and mature cocoa trees. Young seedlings are pruned within the 3rd and 4th year of establishment. Pruning is important for the following reasons;

- To provide shape to the plant
- Control mistletoes
- Improve air circulation
- Reduce quantity and cost on chemicals
- Opens canopy for adequate sunlight

9.2.7 Pests and Disease Control

The major pests and diseases of cocoa and their damage and economic importance have been identified and described (Table 8).

Table 8: Major Pests and Diseases of Cocoa and their control

Disease	Control Method
Swollen shoot	Cut down infected diseased trees and replant
Black pod	a. Pruning regularly to reduce shade. b. Using chemicals to spray in May/June every year to stop germination of fungal spots.
Thread blight, charcoal pod rot, root rot, cushion gall and mealy pod diseases are other minor diseases.	Using fungicides approved by COCOBOD.
Mistletoe	a. Providing shade trees b. Cutting infected branches.

	c. Chemicals are being tested.
Pests	**Control Method**
Cocoa capsids	Shade management, use of approved insecticides
Cocoa Mealybugs	Cultural practices, use of approved insecticides
Shield bugs	Cultural practices, use of approved insecticides
Termites	Cultural practices, use of approved insecticides
Grasshoppers	Cultural practices, use of approved insecticides
Rodents	Cultural practices (e.g. trapping, weeding)

An effective method of controlling the key pests and diseases that attack cocoa is the application of synthetic pesticides. There are three approved insecticides for the control of pests and diseases in cocoa (Table 9.).

Table 9. List of approved insecticides for cocoa by CRIG

Trade Name of insecticide	Active ingredient	Dosage
Akate Master	Bifenthrin	500 ml/ha
Actara	Thiomethoxam	85 ml/ha
Confidor	Imidacloprid (200 SL)	150 ml/ha

All these chemicals are used under the supervision of extension officers from nursery to mature plants. In some cases, for the production of organic cocoa, Aqueous Neem Seed Extract (ANSE) is the only botanical insecticide used



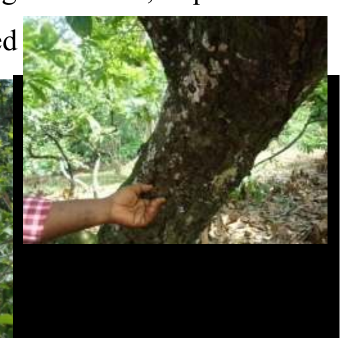

Plate 10 a: Cocoa capsid on a pod Plate10b & 10c: Mistletoe and an aged cocoa tree at Maaban and Bechem COCOBOD demonstration farms respectively.

10. Postharvest Management

Harvesting and postharvest management in cocoa are important practices that determine the quality of cocoa beans among other factors. To a large extent harvesting, fermentation and drying of cocoa beans in West Africa are carried out under traditional methods with little mechanization. All post-harvest management monitoring on cocoa is done by the Quality Control Division of the Ghana Cocoa Board. The quality of cocoa is determined by four fundamental factors: purity or wholesomeness, yield of cocoa nib, uniformity and flavour and functional potential. The highest quality bean is expected to possess these criteria for assessment by the manufacturer (CRIG, 2010). There is also the ‘Code of Practice’ accepted internationally which covers inspection, sampling, testing, bagging, storage and infestation of cocoa beans found in the 7 volumes of Codex Alimentarius.

10.1 Harvesting

There are generally two cocoa cropping seasons in a year in West Africa in particular, the main crop in October-March and the light-crop in May-August (CRIG, 2010). Harvesting is done every 2-4 weeks when the pods are ripe and yellow in colour. However, for farmers who apply fertilizers, harvesting weekly or every two weeks is not uncommon. Regular harvesting ensures that pods of about the same level of maturity are harvested. The pods should not be overripe, otherwise germination of beans will take place and the pods may be desiccated, damaged by rodents or predisposed to disease infection. Harvesting is done by cutting the stalk fruit with a knife as close as possible to the pod to avoid causing injury to the tree. Pods on stem and branches within reach are harvested with a cutlass while those on branches higher up in the cocoa canopy are harvested with sickle-shaped knives on long poles (Plate 11a). It is important to ensure that the cushions carrying the flowers and immature fruits are not damaged during harvesting. During harvesting, sorting is done to remove diseased pods and those damaged by rodents and other pests. The healthy pods are gathered and picked to a central breaking point in the farm. Generally, harvesting and breaking of cocoa for fermentation in Ghana are communal operations where farmers in a village assist each other.

Plate 11: Harvesting of cocoa pods with a sickle in Ghana

10.2 Breaking of Pods and Fermentation of Cocoa Beans

The breaking of cocoa pods is normally done within 2-3 days after harvest. The pods can be broken using either a wooden club or cutlass. If not done with caution cutlasses may injure the cocoa beans inside the pods. Wooden clubs are therefore recommended for pod breaking to ensure bean quality. Having broken the pods, the beans are scooped out of the pods by hand and the husk and placenta are discarded. To maintain bean quality, all germinated, discoloured (mostly black) and diseased beans or foreign materials such as pieces of husk, placenta fragments should be removed from the scooped beans.

Cocoa beans are embedded in a sweet, white mucilaginous pulp, which serves as a substrate for fermentation which begins immediately the pods are broken. Cocoa fermentation is one of the stages in postharvest processing that defines the ultimate product quality. Good quality cocoa beans depend not only on their variety and growth environment but also on the quality and efficiency of fermentation. The cocoa pods are broken open after harvest and the wet freshly beans piled on and covered with plantain or banana leaves. A maximum of 500 kg weight of fresh beans (about 10 medium sized basketfuls) should be fermented in a single heap on banana or plantain leaves spread out in a circular form. The other parts of the leaves are then folded to cover the heap at the centre. Most of the beans in Africa (especially Ivory Coast and Ghana) go through wet fermentation. The degree of fermentation in cocoa is assessed by a random sample of fermented and dried beans. If the cotyledon is salty, and then it is totally unfermented, and if it is completely or partially purple, then the bean is under-fermented. Completely brown cotyledon means the bean is thoroughly fermented (CRIG, 2010).

Raw freshly harvested cocoa beans have an astringent and unpleasant flavour. It is therefore necessary to ferment to obtain the desired organoleptic characteristics of good-tasting and good-flavour chocolate. Fermentation helps to break down mucilaginous pulp surrounding the beans, causes death of cotyledon and triggers the biochemical changes inside the beans that contribute to reducing bitterness and astringency and results in the development of flavour precursors. Cocoa fermentation is a spontaneous process and occurs in two stages namely anaerobic and aerobic. The process is exothermic and requires access to air in order to be successful.

A number of factors affect the fermentation process. These include the type of cocoa, ripeness of the pods, storage of pods before breaking, quantity of beans and pulp during fermentation, rate of turning of the fermentation mass, duration of fermentation and climatic factors and diseases that affect the pods. Over-ripening of pods can cause germination of the beans. Harvesting immature, damaged and diseased pods produces poor quality beans for fermentation. The time between harvesting and pod breaking affects fermentation and the ultimate bean quality. Storing the pods for more than six days can cause the pulp surrounding the beans to dry up. During the rainy season the pulp and beans may contain more water and this can affect the aeration of the fermenting mass and bean acidity. Turning enhances the aeration of the fermenting mass and ensures even distribution of temperature and oxygen.

Plate 12: Cocoa pods ready for cracking

Fermentation of raw cocoa beans begins when the heap of cocoa beans is covered and should proceed for six continuous days and it is caused by microbial succession involving yeasts, lactic acid bacteria and acetobacter. If possible the heap of cocoa beans should be turned every other day (i.e. at two days intervals) to ensure even fermentation. Six days fermentation would develop the basic cocoa bean aroma, and the bitter and astringent of the bean would be reduced significantly. The purple colouration of the original beans due to the presence of anthocyanins in the cotyledons would also have changed to brown or purple brown. Beyond six days fermentation, the testa covering the cotyledons becomes brittle and is prone to invasion by moulds. Further fermentation would lead to breakdown of proteins to produce "ammonia gas" and off-flavours which are not desired in the manufacture of chocolate.

10.2.1 Methods of Fermentation

Several different fermentation methods namely heap, box, basket, tray and heap are used around the world with heap, basket and box fermentation being most widely used.

Heap fermentation is the simplest and practiced mostly in West Africa in small farms and in Ghana cocoa fermentation by this method dominates. The method does not need any permanent structure and is well suited for family holdings with a small production. The weight of the wet cocoa beans should not be less than 90 kg for good and effective fermentation. In heap fermentation the seeds are placed on a carpet of banana or plantain leaves and these are placed on a bed of branches of cut trees which help the surplus liquid to drain away easily. The mat of leaves should be punctured with a pointed stick to create drainage holes for easy drainage of the pulp. The heap of cocoa beans is covered with more leaves when the heap is complete and the leaves are held in place by pieces of wood or small (Plate. 13). Covering the heap protects the fermenting cocoa beans from surface drying, mould growth and helps to maintain the heat generated within the heap. The size of the fermenting heap varies from 300-500 kg of beans. Generally, the heaps are fermented 5-6 days but in Ghana farmers are advised to ferment for 6 days turning the heap twice on the second and fourth days to allow adequate aeration and also to ensure uniform fermentation of the beans in order to obtain the required chocolate flavour

Plate: 13. A heap of fresh beans on plantain leaves and covered heaps for fermentation

Basket fermentation is similar to the heap fermentation is simple and is used on small-holder farms. There is no definite size for the baskets which usually hold about 10-15 kg wet beans. The baskets are first lined with fresh plantain leaves before placing the wet beans in them. They are then covered with more leaves which are held in place with small logs (Plate 14). The sweating drain from the sides and the bottom of the baskets and air also passes through the sides and the bottom. The fermenting mass is turned by transferring the beans from one basket to the other.

Plate 14: Basket fermentation

Box fermentation requires a fixed volume of cocoa and is associated with large cocoa plantations especially in the Ivory Coast. This is done in large, perforated boxes made of local hardwood (Plate 15). The holes at the bottom of the boxes allow the sweating from the pulp to drain down and air to enter. To ensure efficient drainage of the sweating, the boxes are always raised above the ground level and placed over a drain. The boxes are normally raised in tiers so that turning is done by moving beans from a higher box into a lower one. The boxes are of variable sizes but they should be large enough to take about 1000 kg wet beans (1.2 x 1.2 x 1.2 m). The beans are placed in top box and covered with a few layers of plantain leaves. This method reduces labour in turning beans. Heat is conserved in the box by covering the wet beans with banana or plantain leaves or polythene sheet. To facilitate uniform fermentation the beans are turned after 48 hours with a second turning done after another 48 hours. Fermentation is allowed to continue for another 48 hours or until the temperature begins to fall and the odour of ammonia develops, where the fermentation could be considered to have been completed. In comparing the heap and box fermentation methods, the pH, temperature and aeration are more consistent in the heap method, although there is no difference in cocoa quality.

Plate 15: Examples of box fermentation

Tray fermentation: In this method about 90 kg wet beans are placed in wooden trays of 1.2 x 0.9 x 0.1 size (Plate 16). The trays have battens or mats fixed at the bottom. About 6-12 of such trays are stacked one over the other with an empty tray kept at the bottom to allow for aeration and drainage of the sweating. Beans in the top-most tray are covered with banana leaves. After 24 hours of setting the stacked trays, they are covered with gunny sacks to conserve the heat that develops. There is no need for turning and fermentation will be completed in 3-5 days. This method allows aeration of the fermenting mass without having to turn and ensures better and more even fermentation. Efforts are being made to encourage cocoa farmers in Ghana to adopt the tray system to improve quality of fermented beans. Chocolate produced from heap and tray - fermented cocoa beans have shown differences in their key odorants.

Advantages of tray fermentation over the heap method

- More homogenous fermentation
- Better aeration – increased acetic acid concentration and lower levels of moulds
- Reduced loss of cocoa beans
- Better quality of the beans – higher price
- Less labour –intensive

Plate16: Tray fermentation

10.3 Drying of Cocoa Beans

Freshly fermented cocoa beans must be dried immediately to avoid being rotten. The moisture content of the freshly fermented beans is about 60% and must be reduced to at least 7.5% for safe storage and shipment to its ultimate destination. Drying reduces the bitterness and astringency of cocoa by oxidizing polyphenols to insoluble tannins and also developing the chocolate colour of well fermented cocoa beans. After fermentation, the beans are carried to the drying area and spread thinly on raised mats. Drying should not be done on a bare floor or asphalt roads. The beans must be stirred frequently to pick out germinated, flat and black beans, placenta and any foreign materials.

There are many drying techniques used by farmers ranging from the natural sun drying to the artificial hot air technique. Currently, the direct sun drying is the most widely used method in West Africa and Latin America. This method is most widely used especially by smallholders due to its simplicity, low cost and requires only renewable and abundant direct sunlight. In West Africa, the beans are dried on mats raised above ground level, (Plate 6) on wooden boards or on concrete floors. The thickness of the layer of the beans on the drying mat should range between 5 and 7 cm. The duration for sun drying depends on the weather and may normally last between one and two weeks. During drying, defective beans and foreign matter are picked and also beans which stick closely together are separated. The beans are covered every evening to protect them from possible showers and dew. Sun drying produces the best quality beans because during sun (slow) drying acetic acid, which is volatile, evaporates through the shells. Lactic acid, which is non-volatile, is partly transported by water from the bean to the shell. There is also the oxidation (browning) of polyphenols resulting in the reduction of astringency and bitterness. More flavour forming reactions also occur during sun drying

In countries where artificial drying or forced air dryers are used, the beans dry too quickly that some of the chemical reactions which started during the fermentation are stopped, thereby preventing the escape of the remaining acids in the bean resulting in acidic and astringent flavours in the cocoa. On the other hand, when the drying is too slow, moulds will develop and penetrate the testa to cause off-flavours. Continuous drying of cocoa beans artificially at 40 °C gives the best quality cocoa although, drying the beans at 60 °C does not adversely affect the quality. Artificial hot air drying method is normally associated with beans of weaker flavour quality, higher acidity, insufficient browning, smoke contamination and case hardening.

Mechanical drying is generally not recommended because it is expensive; there is danger of smoke contamination and high acid retention in the beans.

10.3.1 Sun drying methods

After six (6) days of fermentation, cocoa beans are collected and taken home for drying on mats spread out on platforms. The mats, made of palm fronds, are woven with raffia strings such that very small beans drop through the fronds, as an initial "cleaning" to obtain homogeneous sized beans. The beans are spread out in the morning, turned and cleaned during the day and heaped at night or in the event of rainfall. Drying should last for at least six (6) days in sunny dry weather, during which placenta is removed, bean cluster are separated and smaller beans are picked to ensure that the produce is as homogeneous in size as possible (Plate 17). Broken and damaged beans are also picked and discarded. The beans are regularly turned over to ensure even and thorough drying. Drying period may increase beyond six days in periods of dull or moist weather. When it rains during the day, the beans must be covered to protect them from the rains. Uncover the beans early in the morning or immediately after the rains. The beans are dry when they produce a 'cracking' sound after pressing them lightly in the fist. Fire should not be made under or close to the beans during drying as it will give the beans a bad taste or smell. Well –fermented and well-dried beans are generally brown in colour.

Plate 17: Sun drying of cocoa beans

Another sun drying of cocoa beans method practiced in certain countries such as Cote d'Ivoire and Cameroon is drying on concrete floor which may be fenced to keep out domestic animals and poultry. Drying on wooden floors with movable roofs, known as "boucans" is practiced in Trinidad and "barcacas" in Brazil, and on large cocoa plantations in Central and South America. Other sun drying method found in Central and South America is drying on movable trays which can be pushed under a fixed roof. Several layers of tray may be pushed under a fixed roof.

10.3.2 Artificial drying

This depends on transfer of heat into the cocoa beans and the movement of water vapour from the bean to the surrounding air. Moisture must first be driven off the surfaces of the cocoa beans before moisture from inside the testa and cotyledons migrates to the surface to the beans for drying out. Dryers in Cameroon and Equatorial Guinea depend on conduction of heat from wood fire. Others in Brazil and Samoa depend on convection currents of natural air heated by warm air in a flue, to heat the cocoa. Smoke is thus excluded. Artificial drying is fast and may last up to three days, but it is expensive, leads to acidic produce and also has the risk of wood smoke contaminating the cocoa beans.

10.4 Control of Bean Quality

This is not done by farmers but by trained professional field staff of COCOBOD located in key cocoa producing regions in Ghana to provide services which include representative sampling for laboratory tests. Cocoa laboratory analysis includes the following:

1. Physical entomological assessment.
2. Chemical assessment for essential oils.
3. Moisture content to assess aflatoxin.
4. Microbiological assessment though pH of beans
5. Fat content and pesticide residue testing.

11.0 Proven and Exploitable Technologies on Maize

11.1 Maize Varieties

The Crop Research Institute of the Council for Scientific and Industrial Research (CSIR) has developed several varieties of maize seeds in Ghana. The characteristics of commercial maize varieties released by the CSIR and for which seed may be available from certified seed growers and registered seed outlets are listed in Table 7. The full season (115-120 days) and the medium maturing (105-110 days) varieties normally give the highest yields, followed by the early (90-95 days) and extra-early (75-80 days) maturing varieties. The early and extra-early varieties must be planted at higher densities if their full yield potential is to be realized (Table 7).

Currently, the most popular recommended varieties are Obatanpa (open-pollinated variety or OPV) and Mamaba (hybrid). The two are quality protein maize (QPM) varieties and, hence have superior nutritional quality compared to the normal maize varieties such as Dodzi, Dorke SR, Abeleehi and Okomasa. Quality protein maize varieties are, therefore, highly recommended for human consumption and livestock feeding.

Table 10. Characteristics of commercial maize varieties*

Variety	Type of Variety	Grain colour/Texture	Plant height	50% silk (days)	Maturity days	Average Yield	
						Tons/ha	**Bags/acre**
Obatampa	QPM OPV **	W. dent ***	175	55	105	**4.6**	**18**
Mamaba	QPM hybrid	W. flint	185	55	105	**6.0**	**24**
Okamasa	Normal OPV	W. dent	198	59	120	**5.5**	**22**
Abeleehi	Normal OPV	W. dent	157	53	105	**4.6**	**18**
Golden Crystal	Normal OPV	Y. dent/flint	200	55	110	**4.6**	**18**
Dorke-SR	Normal -OPV	W. dent	174	52	95	**3.8**	**15**
Dodzi	Normal OPV	W. dent	149	47	80	**3.4**	**15**

*Agronomic data are averages from station variety trails conducted at 8-10 locations in Ghana.
** OPV=Open-pollinated varieties or composites
***W=White or Y= Yellow grain colour
QPM=Quality Protein Maize


Plate 18: Fertilizing (mamba Variety) on a Maize Farm with Urea in Ejura

A few newer varieties have been introduced on the Ghanaian farming landscape. These are PANA- 53 and Pioneer varieties. According to farmers in Atebubu the PANA-53 is a high yield and draught resistant variety. However, their first and only experience with the Pioneer was not very favourable since it appeared most of the seed supplied to them were not viable. As a result they were unable to give a fair assessment of it.

11.2 Planting Patterns

The recommended planting calendar is given in Table 7. These planting dates are based on the establishment of the rains in each agro-ecological zone. However, the experience of farmers in each area is the best guide. Experience over the years indicates that planting as early as possible after the rains have the following advantages:

- Highest yield
- Lower incidence of streak virus disease
- Benefit from higher soil fertility
- Lower incidence of birds and rodent damage
- More days of sunlight.

Locally, farmers use a cutlass, planting stick or hoe to plant, making 5-7 cm deep holes in the soil. They cover seed with soil and firm with their foot. Deep planting and firming soil prevent seed removal by birds and rodents. In clay soils or soils that crust easily, planting is done by making 2-3 cm deep holes in the soil. Farmers make sure that the seeds are in good contact with the soil. Table 9 gives the recommended spacing for planting maize. Approximately 20 kg of seed are needed to plant one hectare (or 8 kg for 1 acre).Inorganic fertilizers are the most widely used after planting.

11.3 Cropping Systems

The full potential of a maize variety can only be realized within sustainable cropping systems that optimize the use of plant growth resources in space and over time, while maintaining or improving on soil condition and the environment. The maize-legume rotations, maize-mucuna relay, maize-cassava intercrop, and maize-legume intercrops are recommended, (CSIR). It is also recommended that planting fields are rotated with cowpea every two years (Table 13).

Table 11. Recommended Planting Calendar for the Major Agro-Ecological Zones

Agro-Ecological zones	Planting Period	Recommended Variety Early planting Late planting	
Major Season			
Forest	Early Mar-End of Apr	Okomasa, Mamaba, Obatanpa	Obatanpa, Abeleehi, Mamaba
Transition	Mid. Mar.-End of Apr	Okomasa, Mamaba Obatanpa	Obatanpa, Abeleehi, Mamaba
Coastal Savannah	End of Mar-End of Apr	Okomasa, Mamaba	Abeleehi, Dorke SR
Guinea Savannah	End of May-End of June	Okomasa, Mamaba, Obatanpa	Obatanpa, Mamaba, Abeleehi, Dorke SR
Minor Season			
Forest	Mid July-Early Sept	Mamaba Obatanpa	Dorke SR, Obatanpa Mamaba, Abeleehi
Transition	Mid July-Early Sept	Mamaba Obatanpa	Obatanpa, Abeleehi Mamaba, Dorke SR
Coastal Savannah	Mid July-Mid Aug	Mamaba, Obatanpa, Dorke SR, Dodzi	NA

Table 12. Recommended Plant Spacing for Maize

	Okomasa Golden Crystal	**Obatanpa Mamaba, Abeleechi**	**Dorke SR Dodzi**
Spacing			
Between rows	90 cm	80cm	75 cm
Within rows	40 cm	40 cm	40 cm
POPULATION*	56,000	62,500	76,000

*** Expected population (plants/ha) when two seeds are planted per hill.**

Table 13. Spatial arrangement for maize-cowpea intercrop

M	**cp**	**cp**	**M**
M	**cp**	**cp**	**M**
M	**cp**	**cp**	**M**
40cm	**20cm**	**40cm**	

11.4 Fertilizer Application

Inorganic fertilizers, NPK are applied at planting. About 100 kg of NPK and 50 kg of Sulphate of Ammonia per acre, and 150 kg of NPK and 100 kg of sulphate of Ammonia per acre at 4 weeks. Guidelines for fertilizer application for maize at recommended spacing in the different ecological zones are shown in Table 14.

Table 14. Fertilizer Guidelines for Maize at recommended spacing in Ecological zones

			Starter Fertilizer (15:15:15 Or 20:20:0)				**Side Dress 4-5 WAP****			
Agro-Ecology	**Cropping History**	**Maize Type**	**Bags/ Acre**	***Plants/ Milk Tin 90**	**80**	**75**	**Bags / Acre**	**Plants / Milk Tin 90**	**80**	**75**
Coastal savannah	Land fallowed for 5 years or more	All	1	60	68	72	1	60	68	72
Coastal savannah	Land fallowed for less than 5 years or continuously cropped	All	2	30	34	36	1	60	68	72
Forest	Land fallowed for 5 years or more	All	**NO FERTILIZER RECOMMENDED**							
Forest	Land fallowed for less than 5 years or cropped the previous year	All	1	60	68	72	1	60	68	72
Transition	Land fallowed for 5 years or more	All	**NO FERTILIZER RECOMMENDED**							
Transition	Land fallowed for less than 5 years or cropped the previous year	All	1	60	68	72	1	60	68	72
Transition and Forest	Land continuously cropped	Open pollinated	2	30	34	36	2	30	34	36
		Hybrid	3	20	23	24	3	20	23	24
Guinea savannah	Land fallowed for less than 5 years or cropped the previous year	All	1	60	68	72	1	60	68	72
Guinea savannah	Land continuously cropped	All	2	30	34	36	2	30	34	36

****Plants per milk tin refer to the number of plants that can be fertilized with the small ideal milk tin size (170ml), if recommended plant populations are adopted. The first number is for full season varieties such as 'Okomasa' planted* in 90cm rows*, the second for medium/early maturing varieties such as 'Obatanpa' planted in 80 cm rows and the third is for extra early maturing varieties planted in 75 cm rows.***Weeks after planting**

Experts recommend, and many of the farmers interviewed also admitted to adapting crop rotation practices on the maize farms. Several farmers planted cowpea, groundnuts, or yams in alternate years in place of maize on their farms. This ensures that the legumes replenish the nitrogen content in the soil and thus keep the fertility relatively higher for a longer period of time.

11.5 Weed Control

Weeds are controlled with herbicide Glyphosate before planting and post planting weeds are controlled with 2-4 D weedicides. Most of the small scale farmers also control weeds by thrashing with cutlass and hoes. Apparently farm labour costs have been soaring in all regions, and so these farmers admitted that using weedicides were cheaper alternative to hoeing or other manual weeding methods, which is their preferred choice of weed control.

One of the most problematic parasitic weeds affecting the coastal and Guinea savannah regions of Ghana is *Striga.* It attaches itself to the root of the crop and is very difficult to control once it has established itself. It is recommended that farmer's rotate their maize crops with other non-susceptible crops like cotton, groundnuts, and some varieties of soybean. These crops causes what is known as suicidal germination of *Striga,* because even though they germinate, they are unable to attach to their roots so that it dies naturally. Furthermore, well fertilised maize is unaffected by *Striga* so fertilisation with Nitrogen is recommended in locations where it is a problem.

Plate 19: Weedicides for controlling weeds in the maize farms

11.6 Pests and Diseases

The most serious disease affecting maize in Ghana is the maize streak virus disease. It is generally observed in late plantings in the major season and during the minor season. Early disease symptoms consist of very small, round, scattered spots in the youngest leaves. Fully elongated leaves develop chlorosis with broken yellow streaks along the veins, contrasting with the dark green colour of normal foliage. The best control for streak is to plant the recommended improved varieties that are all tolerant/resistant to the disease. Other major diseases of maize are maize rust, maize smut, leaf blight, and downy mildew (Table 15). The major pests of maize in Ghana are maize stem borers, the Larger Grain borers and grain weevils (Table 16).

Table 15. Diseases, symptoms and cultural control measures for maize

Disease of Maize	Symptoms or Damage	Cultural Practice
Maize Streak Virus	Most important disease of maize. Can be recognized by the long white streaks on the maize leaves, interrupted by yellow and white sections. The development of plants infected by this disease is seriously affected; the growth of the plants is stunted and they look pale. Transmitted by maize leaf hoppers (*Cicadulina* sp.) Green streaks along the leaf interrupted by yellow to white streaks. Plants are stunted.	• No known direct control • Rogue young infested plants and destroy (e.g. Feeding to animals) • Use streak resistant varieties (Certified varieties are resistant to the disease).
Maize rust, *Puccinapolysora*, *P. sorghi*	Minor disease. Pustules on leaves and stems bearing dusty masses of spores.	• Partial control obtained by early planting and use of high yielding varieties • Avoid cropping the same land with maize after a severe attack • Remove and destroy affected plants.
Leaf blight *Helminthosporium turcicum* and *H. maydis* (*Setasphaeriaturcica*)	Minor disease. Spindle shaped elongated necrotic lesions on the leaf blade.	• Rarely serious disease • No chemical control required
Maize smut *Ustilago maydis*	Occasional disease. Tumour –like galls form on any above ground plant part. The galls that replace the kernels are covered with greenish –white, papery tissue. Cob and seeds are inflated; kernels are filled with grey spores.	• Can be avoided by using clean certified seeds • Avoid injury to plants and maintain well-balanced soil fertility • Use resistant/tolerant varieties • Rogue out diseased plants and bury

		• Do not over fertilize with (Nitrogen)
Downy mildew, *Peronosclero sporasorghi(Sclerospora graminicola)*	Occasional disease Dwarfing or shortening of the upper internodes. Poorly formed ears. Suckering or proliferation of axillary crown buds in seedlings or inflorescence where the modified leaf-like inflorescence?	• Use improved varieties • Rogue diseased plants • If heavy attack is experienced in unfavourable weather, use appropriate fungicides for control

Table 16: Major pests of maize

Pests of maize	**Symptoms or Damage**	**Recommended Cultural Practices and Direct Interventions**
Stem borers, *Sesamiacalamistis, Eldanasaccharina, Busseolafusca*	Major pests of cereals. Larvae damage leaves and bore holes or funnels into stems resulting in ''Dead hearts'' (enabling you to pull off the last leaves easily) and stalk lodging. Boring into maize stems disrupts the flow of nutrient fluids from the roots to the upper part of the plant and weakens the stems, so they lodge or collapse with the slightest wind. Larvae attack the cob and damage seeds/grains.	• No resistant varieties to stem borers available • Do not plant maize in stem borer prone areas especially forest zone. Plant other crops in minor season to escape stem borers • Intercropping with pulses in alternative rows (cowpeas, groundnuts etc. reduce stem borers infestation) • Embark on stalk management in dry season, cut and destroy stalks • Spray with an appropriate insecticide • Natural enemy of stem borers includes predatory ants and some parasitic wasps.
Larger Grain Borer (LGB), *Prostephanus truncatus*	Major pest of maize. Grub and beetle feed in seeds. Eggs are laid unto the grains; infestation can be brought from field to store. Unshelled maize in storage is milled into flour and destroyed.	• Shell maize early after harvest • Storage hygiene to be observed • Divide produce for long –term (3months) storage ; treat only maize for long-term storage • Use proprietary storage pesticides • Introduce exotic beetle (Teretriusnigrescens) for biological control of Larger Grain Borers (LGB). • Harvest maize early to reduce field to store infestation • Use phosphide according to manufacturer's recommendations
Greater Grain Weevils, *Sitophilus oryzae, S. zeamais*	Major pests of maize. Grub and weevil feed in seeds. Maize grain heavily weeviled, loses much of the grain content	• As for LGB ,except bio-control

11.7 Threshing

Hand threshing using sticks, tarpaulin or bare ground, bam-bam boxes are common). Processing to add value and increase shelf life of maize is done traditionally to minimize post harvest losses. There is the introduction of mobile threshing machines that are hired out to maize farmers by co-operative farmers' groups.


Mechanical mobile threshing machines

Hand shellers **Mobile maize thresher for hiring in Wenchi**

Plate 20: Hand and Power Threshers

11.8 Maize Drying and Storage

As a dry cereal, when properly dried, treated and stored, maize can last for several months. One of the most critical post-harvest problem maize farmers' faces is the development of mould, which is facilitated by the presence of extra moisture in the crop. Consequently ensuring that the grain is adequately dried before placing in storage is crucial. Several types of open air cribs, wood cribs, and solar dryers are available and in use by Ghanaian farmers. The poor peasant farmer, however, is often unable to afford quality crib and storage and thus is compelled to sell their produce quickly and cheaply to prevent post-harvest losses. Some of the farmer's who were interviewed also indicated that they continue to plant some of the old varieties of maize because they tend to store and keep for longer periods without going bad. The new protein infused varieties like Obatanpa are particularly susceptible to weevils and other pests after harvest.

There are two options in the storage, either the maize are shelled and stored in jute or poly propylene sacks or can be stored in dehusked or undehusked ears. Traditional rural storage facilities include: Open area storage, granaries, barns, cribs, pots, pits, baskets, platforms, bags, jars, gourds. Modern facilities include: Warehouses, metallic silos, GrainPro cocoons, improved barns, supper grain bags, triple bags (PICS), and zero fly bags and narrow cribs (Plates 21-22). Several maize drying technologies are used by farmers (Plates 23).

Crib holding maize

Hous ... ead ... rat ... storing
... ize
Plate 2 ... lo ... us

a b c

Process of Bagging Maize: a. Place the Super bag as a liner inside an existing storage bag. Fill bag with dry grain or seed c. Remove excess air and twist, fold plastic over and seal with either strong rubber bands or tape

Plate 22: Grain super bagging

11.8.1 Drying maize domestically



Drying on road side **Drying on Tarpaulin** **Open air drying in the h**


Open air drying in th




Solar Dryers

Plate 30: Different ways of drying maize in Ghana

12.0 Brief Discussion on Environmental Conditions

12.1 Cocoa

The production of cocoa can damage the environment depending on the practices of the farmers and other actors along the cocoa value chain. Cocoa farming also contributes to deforestation, which at present is approximately 5% per annum in Ghana. By clearing land in these forests, farmers decrease the biodiversity and interactions between the organisms which naturally live in these areas. Many wildlife habitats are destroyed and the plant species diversity is drastically reduced. Nutrients begin to leach out of the soil due to poor irrigation and inadequate

soil protection, which can increase the erosion of the soil. The more intense the farming practices are, the more damaging they are to the ecosystem. Cocoa farming becomes a destructive circle as farmers wear out the soils and cut further into the forest to obtain fresh land. All of these processes stress the cocoa trees and result in lower yields, giving the opposite effect to what the farmers expect from these practices. http://www.cocoafarming.org.uk/ Cocoa_farming_bw_v8_uk.pdf
Because cocoa requires a very particular ecological environment to thrive, futures expansion is threatened by the rapid expansion of human habitation. On the other hand, indiscriminate forays into existing forests have contributed to the rapid destruction of the remaining forest cover in Ghana. As a result, it is important that newer varieties of cocoa be developed that can thrive in other ecological zones.

The irresponsible use of pesticides by some farmers poses several hazards including toxic residues in cocoa beans, contamination of water bodies, destruction of beneficial non-target organisms, poising of applicators, development of resistance in certain pests and environmental pollution.

12.2 Maize

Maize is a versatile crop that does well in all the ecological zones in Ghana. Some regions even have three or more growing seasons. Although maize farmers may not have a clear understanding of climate change, they are among the first in perceiving and reacting to environmental changes. It has been observed that the effects of decreasing rainfall, with emphasis on changes in the regularity, length, intensity and timing of rainfall; increasing air temperature, increasing sunshine intensity and seasonal changes in rainfall pattern hamper profitable maize production (Kluste *et al.,* 2013). Changes in the onset and cessation of rain have had a negative impact on maize production and this poses a serious threat to household food security since maize is a staple food of most Ghanaians.

Maize farmers are also aware of the interacting effect between bad management practices and changes in climate. For instance, deforestation and clearing of vegetation is considered a major factor that increases soil erosion. Maize thrives well in many soils in the tropics. However, because of the economic returns, many farmers are encroaching on the forest reserves to cultivate their maize.

Furthermore, the use of agricultural chemicals close to the rivers and streams create hazards for the environment, especially water pollution. Consequently, effective and efficient adaptation of control measures is promoted by extension officers to educate key stakeholders, especially farmers in environmentally friendly maize production systems to enhance their resilience and flexibility in their farming practices.

13.0 Technology Development and Transfer

13.1Gratis Foundation

The team sought to find out how technologies are developed and disseminated in the country. It was observed that several hardware were being manufactured locally by local artisans, but one organisation that is spearheading the research, development, and transfer of appropriate technologies in several sectors in Ghana is the GRATIS Foundation. The core activities include: Research and design, technology implementation through the manufacture of Agri-agro processing, Waste Management Equipment, spare parts, teaching and learning through training in employable trades and courses, machining, welding and fabrication, radio and television electronics, motor vehicle mechanics, secretarial studies, information and communication technology. Gratis also provides technical support through Equipment application, installation, repair and maintenance services. The Regional Office in Sunyani has been able to assist local farmers and farmers' groups to acquire agro-processing machines for maize. The organization is capable of designing and manufacturing various equipments to specification, and training artisans for specific jobs.

14.0 Summary of Technologies

The summary of technologies that have been identified in cocoa and maize production systems are shown in Table 16.

Table 16. Summary of Technologies in Cocoa and Maize

COCOA TECHNOLOGIES				
Seed	**Growing**	**Disease and pest control**	**Harvesting**	**Postharvest Management**
• Improved	• Land preparation	Chemical	• Sickles/harvesters	• Fermentation

cocoa varieties • Nursery management	• Transplanting • Planting patterns • Mulching • Weed control • Pruning • Fertilizers • Inorganic • Organic	• Akate Master • Actara • Confidor Organic Neem tree extract	for harvesting • Pod- breakers	• Drying Bagging
MAIZE TECHNOLOGIES				
• Improved varieties of maize and seed development technologies	• Land preparation • Mechanical Seeders • Planting patterns • Weed control • Fertilizers	Chemical • Karate Organic • Intercropping with cassava crop rotation with cowpea/mucuna • Removal of grasses and other susceptible plants	• Sickles/harvesters for harvesting • Harvesters	• Drying technologies • De husking • Threshing and Bagging • Storage facilities

15.0 Conclusion

Cocoa and maize are economically important crops in Ghana for revenue generation and attainment of food security, respectively. Several proven technologies have been developed to increase the productivity of both crops in Ghana. However, as a result of the prevailing economic, educational, socio-cultural, institutional and infrastructural constraints, many smallholder farmers in the rural communities are unable to take advantage of novel technologies and innovations to increase production. The introduction, application and utilization of agricultural technologies in maize and cocoa production should be a collaborative effort of the state and community actors who will be supported by capable and well-organized extension services and other service providers. Many novel and valuable agricultural innovations become lost to communities as a result of inadequate information, poor dissemination and application. It is of categorical imperative that a more effective and efficient technology dissemination platforms are developed to empower farmers to adopt these appropriate technologies to increase crop productivity and yields.

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