GHANA CCAFS SCIENCE POLICY PLATFORM

TECHNICAL REPORT

CLIMATE-SMART AGRICULTURAL PRACTICES IN GHANA

V. A. Botchway, K. O. Sam, N. Karbo, G. O. Essegbey, D. Nutsukpo,
K. Agyemang, R. Zougmore & S. Partey

December 2016

Correct citation:

Karbo Naaminong, Vincent-Ansah Botchway, George Owusu Essegbey, Kingsley Odum Sam, Delali Nutsukpo, Robert Zougmore and Mavis Akuffobea, 2016. Climate-Smart Agricultural Practices in Ghana. Technical Report www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

Cover page picture descriptions: The *pot* on the cover page is a climate-smart pot used to provide water for poultry within the local settings. The pumpkin *(Cucurbitae sp.)* which is beside the pot is a creeping plant that serves as a CSA cover crop to protect the surface of the soil and to enhance water conservation and microbial activities. *(Cucurbitae sp.)* The local name in Dagaare is Yoggvaar.

ISBN: 978-9988-2-2583-4

Abstract

The contribution of the agricultural sector to Ghana's economy has been dwindling in relative terms from a high of 39 per cent in 1990s to about 21 per cent in 2014 (ISSER, 2015). This reduction to the sector's GDP notwithstanding, sector continues to play a major role in the country's socio-economic growth. However, the sector is threatened by the effects of climate variability and climate change. There are already efforts being made at various levels to address this threat through the adoption and adaption of various technologies and practices. This paper profiles technologies and practices that respond to CSA principles and characteristics in the northern Guinea savannah and Forest agro-ecological zones of Ghana. Two regional workshops were held in Wa and Kumasi for the savannah and forest zones respectively. Over 200 participants consisting of farmers, NGOs, FBOs, MoFA directors and extension workers, traditional rulers, District Chief Executives, Academia and researchers were involved in the technology identification and profiling employing a matrix-ranking tool in the working groups at the various workshops. Participants identified 61 and 21 CSA technologies and practices in the Guinea Savannah and the Forest zones respectively and recommended scaling up of these technologies in the various zones. While the traditional rulers and farmers bemoaned the lack of synergy among the institutions involved in CSA and the lack of policy continuity, policy makers called for strengthening of collaboration between the stakeholders for CSA. The policy and decision makers further called on scientists to make CSA accessible at the farmer level through demonstrations and fact sheets for awareness creation and education and promised to support research and extension with the needed funds. Representatives of Academia and Research on their part pledged solutions that are sustainable and have climate change adaptation and mitigation effects for profit and the well-being of farmers.

Keywords
Agriculture, Climate-Smart Agriculture, Adaptation, Technology, Indigenous Knowledge, Ghana.

About the authors

Dr. Naaminong Karbo holds a PhD in Agriculture (Animal Nutrition and Feed Technology) - Timiriazev Agricultural Academy, Moscow, USSR, 1988. Alumini of the International Course in Development Oriented Research in Agriculture (ICRA), Wageningen, The Netherlands (1997). He is the immediate past Director of the CSIR-Animal Research Institute of Ghana with over twenty years of experience in agricultural research and development. Currently, a Chief Research Scientist on post-retirement contract in the CSIR and enjoys mentorship of young scientists and extensive collaborative research partnership programming with both local (Government and nongovernmental organizations) and the international research centers (ILRI, ICRISAT, ICARDA, etc.) under the CGIAR system. He is actively contributing to the Climate change, Agriculture and Food Security (CCAFS) West Africa programme in Ghana. He is Chairman of the Ghana CCAFS Science Policy Dialogue Platform and a member of the country Climate-smart agriculture profiling team. Earlier research project works covered the areas of protein and mineral nutrition in ruminants, smallholder crop-livestock integration and Animal-based Farming systems research.
Email : minongkordam@yahoo.com

Mr. Vincent Ansah Botchway holds M. Phil degree in Agricultural Administration and BSc degree in Agricultural Science. He is currently a Senior Research Officer and a member of CSIR-ARI Business Development Unit. He has relevant experience in agricultural projects and programme implementation and is the Secretary to the CCAFS Science-Policy Dialogue Platform of Ghana. He has been involved in implementing many scientific research projects under the Ghana Agricultural Subsector Improvement Programme (AgSSIP). He has extensive experience in evaluating Agricultural Project to ascertain the technical, economic and financial viability of projects. His specialties include Proposals and Business Development, Agribusiness and Research, Agricultural Marketing Analysis, Project analysis and appraisal.
Email: kingnavy@yahoo.co.uk

Dr. George Owusu Essegbey is the Director of the Science and Technology Policy Research Institute (STEPRI) of the Council for Scientific and Industrial Research (CSIR) in Ghana. With a PhD in Development Studies, he has conducted extensive research in Science, Technology and Innovation (STI) development especially in agriculture and industry. Climate change is one of his key thematic areas of research. Dr Essegbey is a leading member on the Core Team of the Ghana science-policy

dialogue platform. He provides critical policy research backstopping to the platform at all levels. He is currently leading the study team to develop the country CSA profile framework in Collaboration with CIAT. Dr. Essegbey has also executed assignments for agencies of the UN including the World Bank, UNESCO, WIPO and UNEP.
Email: goessegbey@csir-stepri.org or george_essegbey@yahoo.co.uk

Mr. Kingsley Odum Sam is a Socio-Economist and a Research Scientist at CSIR-Animal Research Institute of Ghana and holds an M. Phil. Degree in Agricultural Administration and B.Sc. Degree in Agricultural Economics from University of Ghana, Legon, Accra. He has progressive work experience in research and development with relevant exposure in both public and private sectors operations. Mr. Sam has extensive knowledge in project and research design and implementation. He has experience in M&E systems development and database management. He is a functional core team member of the Ghana CCAFS Science-Policy Dialogue Platform, serving as M&E Officer. Mr. Sam has previously had project and research engagements with USAID, Institute of Statistical, Social and Economic Research (ISSER) and Department of Agricultural Economics & Agribusiness all of University of Ghana, and Ghana AIDS Commission.

Email: kingsam704@yahoo.co.uk

Mr. Delali Kofi Nutsukpo is currently the Regional Director of the Department of Agriculture, Greater Accra Region of Ghana. Mr. Nutsukpo holds a Master of Philosophy degree in Soil Science from the University of Ghana, Post Graduate Certificate in Extension Coordination from Agriculture Academy, Odense, Denmark and Post Graduate Diploma in Organization Development from the University of Cape Coast, Ghana. Mr. Nutsukpo has during the last 25 years, been engaged in promoting improved land resources management within the food and agriculture sector in Ghana with emphasis on building capacity for effective extension service delivery. Before his current appointment, he was the Head of the Environment and Climate Change within the Ministry of Food and Agriculture and was responsible for facilitating the mainstreaming of environmental sustainability including climate change into sector policies, plans and programmes. Mr. Nutsukpo is the Vice Chairman of the Ghana science-policy dialogue platform on climate change, agriculture and food security, and brings national policy perspectives to the work of the platform. He has contributed to a number of publications related to Climate Change in Ghana including the National Climate Change Policy and the National Climate Smart Agriculture Action Plan.
Email: nutsukpodelali@gmail.com

Dr. Robert Zougmoré is an agronomist and soil scientist with a PhD in Production Ecology & Resources Conservation, University of Wageningen. He is based at ICRISAT Bamako where he currently leads the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS) in West Africa. His work focuses on the development of climate-smart agriculture technologies, practices, institutions and policies for better climate risk management in West Africa.
Email: r.zougmore@cgiar.org

Mavis Akuffobea is a Research Scientist at the Science and Technology Policy Research Institute (CSIR-STEPRI), Ghana. She holds MPhil in Sociology from the University of Ghana, Legon and BA Sociology and Law from Kwame Nkrumah University of Science and Technology. Over the past years, she has been involved in CSIR-STEPRI's collaborative research projects. Some of the projects include the Diffusion of Innovation in Low Income Countries (DILIC) and Rain Water Harvesting (RWH) for strengthening resilience to climate change impacts in Ghana. She is currently coordinating a European Union funded project titled "Multinational Enterprises in Emerging Markets (MNEmerge) – Exploring the role of multinational enterprises in addressing global development challenges".

Email: akuffobeamavis@csir-stepri.org or mavisakuffobea@gnail.com

Acknowledgements

The Authors are highly indebted for the technical and financial support of the Climate Change, Agriculture and Food Security (CCAFS) Program, West Africa Region, coming through the Ghana Science-Policy Dialogue Platform.

We acknowledge the contribution of the following for their presentations made during the workshops held in Wa and Kumasi respectively.

Mr. Dotse Samuel, CAN-Ghana

Mr. Benjamin M. Adjei, FAO, Accra

Dr. E. Techie –Obeng, EPA-Accra

Dr. Charles Domozoro, CSIR-ARI-Accra

Mr. Lawrence Ahia Armah, Ministry of Fisheries, Wa

Dr. Hans Adu Dapaah, CSIR-Crop Research Institute, Kumasi

Dr. Christopher Antwi, Department of Animal Science, KNUST –Kumasi

Mr. Alex Asare, Resource Management Support Centre, Forestry Commission, Kumasi

Dr. B. O. Antwi, CSIR-Soil Research Institute, Kumasi

Dr. Aliu Mahama, Department of Agric Mechanization, University of Ghana, Legon.

Table of Contents

List of Tables

List of Figures

Acronyms

AAESCC	Adaptation of Agro-Eco-Systems to Climate Change
ACIAR	Australian Centre for International Agricultural Research
AIBP	Agro- Industrial by- Product
ARI	Animal Research Institute
AUC	African Union Commission
AU	African Union
CAADP	Comprehensive Africa Agriculture Development Programme
CAN- Ghana	Climate Action Network- Ghana
CCAFS	Climate Change, Agriculture and Food Security
CCTWG	Climate Change Technical Working Group
CC	Climate Change
CCA	Climate Change Adaptation
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
CSA	Climate Smart Agriculture
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research, Ghana
COP	Conference of Parties
EPA	Environmental Protection Agency
FAOSTAT	Food and Agriculture Organisation Statistical Database
FAO	Food and Agriculture Organisation
FASDEP	Food and Agriculture Sector Development Policy
FBO	Farmer Based Organisation
FMNRT	Farmer managed natural regeneration of trees
FSIPs	Food Security Investment Plans
GDP	Gross Domestic Product
GMeT	Ghana Meteorological Agency
GHG	Green House Gases
GSGDA	Ghana Shared Growth and Development Agenda

GSS	Ghana Statistical Service
IFAD	International Fund for Agricultural Development
IK	Indigenous Knowledge
IPCC	International Panel on Climate Change
ISSER	Institute of Statistical, Social and Economic Research
LDCs	Least-Developed Countries
LWG	Live- Weight Gain
NEPAD	New Partnership for Africa's Development
METASIP	Medium Term Agriculture Sector Investment Plan
MESTI	Ministry of Environment, Science, Technology and Innovation
MAP	Months after Planting
MDA	Municipal and District Assemblies
MoFA	Ministry of Food and Agriculture
NAPAs	National Adaptation Programmes of Action
NCCP	National Climate Change Policy
NA	National Agriculture
NAMAs	Nationally Appropriate Mitigation Actions
NDPC	National Development Planning Commission
NGO	Non- Governmental Organisation
NTFPs	Non- Timber Forest Products
NRAC	Natural Resource Advisory Committee
ProVACCA	Promoting a Value Chain Approach to Climate Change Adaptation
PVS	Participatory Varietal Selection
QPM	Quality Protein Maize
REDD+	Reducing Emissions from Deforestation and forest Degradation
SARI	Savanna Agricultural Research Institute
SDC	Swiss Agency for Development and Cooperation
SRES	Special Report on Emissions Scenarios
SRID	Statistical Research and Information Directorate
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

CHAPTER ONE

1.0 Introduction

1.1 Climate Change and agriculture

Climate variability and change is an unpredictable occurrence and a threat to food security of millions of people worldwide. Projections to 2050 suggest both an increase in mean global temperatures and increase in weather variability with implications for the type and distribution of agricultural production worldwide. Climate change will also worsen the living conditions for many who are already vulnerable, particularly in developing countries including Ghana (IPCC, 2007). Conditions of drought and floods in northern Ghana for example, have been studied confirming the importance of addressing the real and potential impacts of climate change in agriculture (CRS, 2007).

Ghanaian agriculture is largely rain-fed with only about 4 per cent of the irrigation potential developed (FASDEP II). As the backbone of the national economy, agriculture provides employment for over fifty per cent of the population and over 70 per cent of the national food requirements. The impacts of global climate change (unpredictable rainfall, increasing temperatures, longer than expected dry periods etc.) are increasingly making Ghanaian agricultural production systems vulnerable. A climate Change vulnerability assessment of agriculture (EPA, 2010; Nutsukpo et al 2013) provides important information for consideration of policy makers in the agricultural sector.

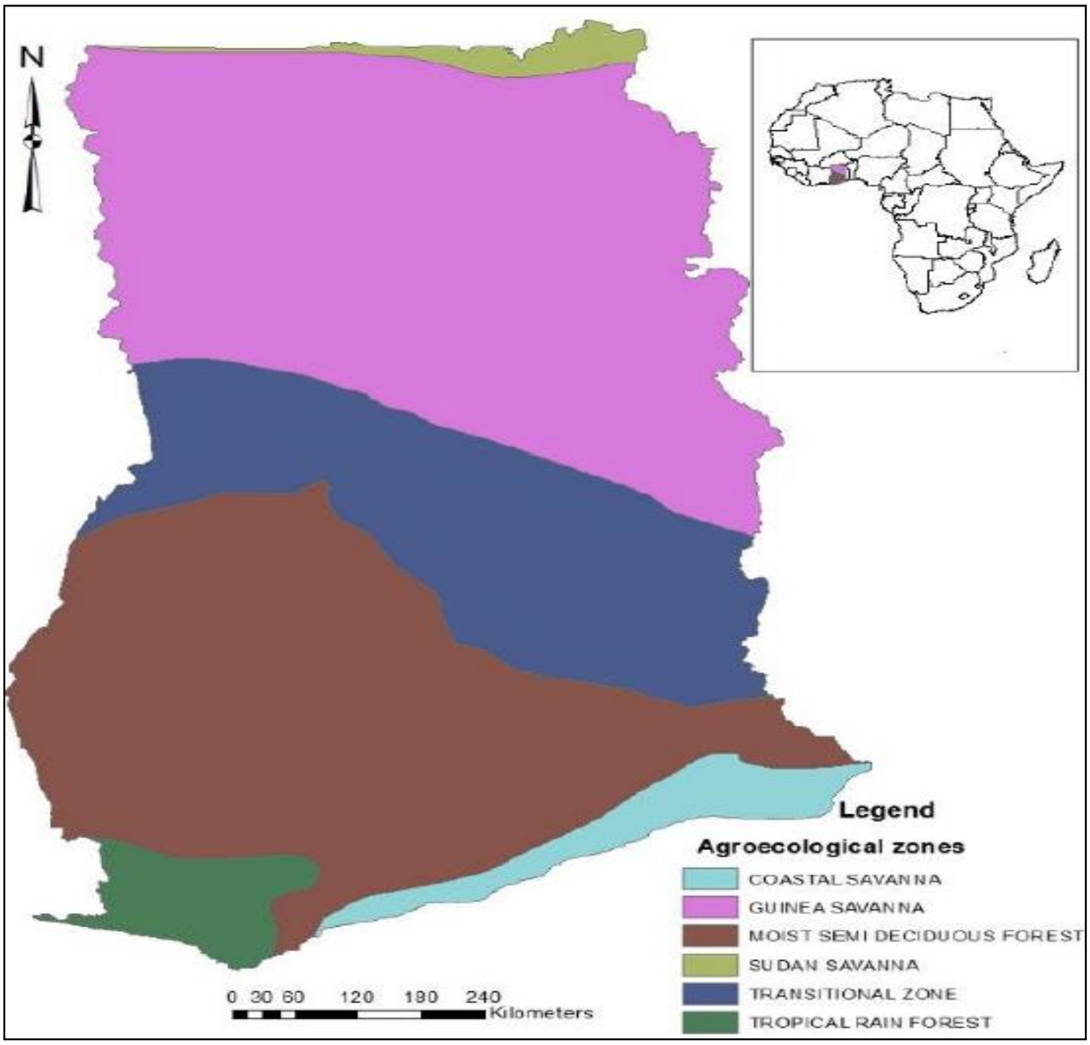
1.2 Changing agro-ecology and agricultural production

The major agro-ecological zones of Ghana are the Tropical Rain Forest, Moist Semi Deciduous Forest, Transitional zone, Coastal Savannah, Guinea Savannah and Sudan Savannah (as illustrated in Figure 1.1). The bimodal rainfall pattern in the Forest, ~~Derived~~ Transition and Coastal Savannah zones gives rise to major and minor growing seasons (Table 1.1). It is however not clear whether the number of growing days for the various seasons still holds for many areas. Pasture production in the Coastal Savannah Transition is failing due to disruption of the minor season rainfall pattern (Karbo, 2012). In the Sudan Savannah and Guinea Savannah the unimodal rainfall distribution results in a single growing season. The rainfall determines largely the type of agricultural enterprise carried out in each zone.

There is an increasing wave of human migration from north to south with corresponding anthropogenic effects on the ecology. For example, the Fulani herder groups are driving their cattle into Ghana more now than previously. The Savannah-Forest Transition and

Forest zones have become habitable for cattle production due to opening up of vegetation and the eradication of the tsetse fly, which is the vector of African *trypanosomiasis*. Increasing population is resulting in new settlements and expansion of old ones. These come along with increased level of socio-economic activities including crop farming and charcoal production which all increasing pressure on the already fragile ecology of the savannah zones.

Figure 1.1: Agro-ecological zones of Ghana



Source: Sidibé et al., 2016

Table 1.1: Characteristics of the agro-ecological zones of Ghana

Zone	Area ('000 ha)	Percent of total area	Mean annual rain (mm)	Growing period (days)	
				Major season	Minor season
Rain Forest	750	3	2,200	150-160	100
Semi Deciduous Forest	740	3	1,500	150-160	90
Transitional	6,630	28	1,300	200-220	60
Guinea Savannah	14,790	63	1,100	180-200	-
Sudan Savannah	190	1	1,000	150-160	-
Coastal Savannah	580	2	800	100-110	50

Source: SRID, 2001.

1.3 Human population, markets, climate change drivers and food consumption-production

Ghana's population distribution varies across the 10 administrative regions and ecological zones of the country. Currently a majority of50.1 percent of Ghana's population lives in urban areas with populations of 5,000 and above. A minority of 49.1 percent of the population lives in the rural communities (GSS, 2012). The urbanized nature of the population of Ghana has implications for value agricultural chain activities. Generally, human population growth is a key driving force for increased agricultural production to feed the growing population. Ghana's population by 2010 almost quadrupled from 6.653 million in 1960 to 24.26 million (GSS, 2012).

Agriculture contributes 22 percent of Ghana's Gross Domestic Product (GDP) with GDP growth of 5.7 percent (ISSER, 2015). It accounts for over 40 percent of export earnings while at the same time providing over 90 percent of the food needs of the country. Ghana's agriculture is predominantly smallholder, traditional and rain-fed.

About 50.6 percent of the labour force is engaged in agriculture. It is estimated that women constitute about 52 percent of the total labour force in agriculture and produce about 70 percent of the food crops (Duncan, 2004).

Domestic food production available for human consumption is 15,842,000Mt while the estimated national consumption is 9,518,000Mt leaving a surplus of 6,325,000Mt (SRID, 2007). It seems to suggest that there is a fairly reasonable level of food sufficiency. However, the increase in the food imports indicates the decrease in food sufficiency in the subsequent years. For example, in 2007 only 596 Mt of maize was imported into Ghana. However, in 2012 a total of 113,343 Mt of maize was imported into the country

(SRID, 2013). The situation with livestock production and consumption even more exposes the vulnerability of the country of food and nutrition security. In 2007, a total of the total livestock and poultry products imported was 111,248.9 Mt as against a total domestic production of 96,740Mt. However, in 2012, the total livestock and poultry products imported were 122,447.0 Mt as against a total production of 127,038Mt (SRID, 2012). From the data, there appears to be an increasing demand for livestock and poultry products. On the whole, there is the fundamental challenge of achieving food and nutrition security, which against the backdrop of the climate change impacts has become more complex.

Agriculture remains a major contributor to the economy although with a reducing rate over the years. For example, from about 39% in the 1990s contribution slides to about 22% in 2015 and with the services sector of the economy contributing almost 49.6% and industry 28.4% (ISSER, 2015; NDPC, 2014). In terms of employment, the sector is the most important; employing about 65% of the population, it has great impact on the key development goal of poverty reduction. Given its importance, every effort needs to be made to enhance productivity to ensure sustainability in the sector.

Figure 1.2 shows population projections by the UN Population office through 2050. The figure shows three scenarios for population growth rate for Ghana from a base value of about 24 million in 2010 (with the Ghana Statistical Service stating the population in 2010 more precisely as 24.6 million following the national population census). The high variant scenario projects Ghana's population to reach over 50 million by 2050, medium variant, 45 million and low variant less than 40 million. The low variant can be viewed as the best case scenario in terms of population growth whilst the higher variant depicts the worst case scenario. In all cases, the growth rates could be viewed as issues of concern. Even in the best case scenario, Ghana's population is depicted as doubling within a 40 year period. The implications of such a population growth rate for overall national development could be huge (Nutsukpo, et al 2013).

Figure 1.2: Population projections for 2010 to 2050

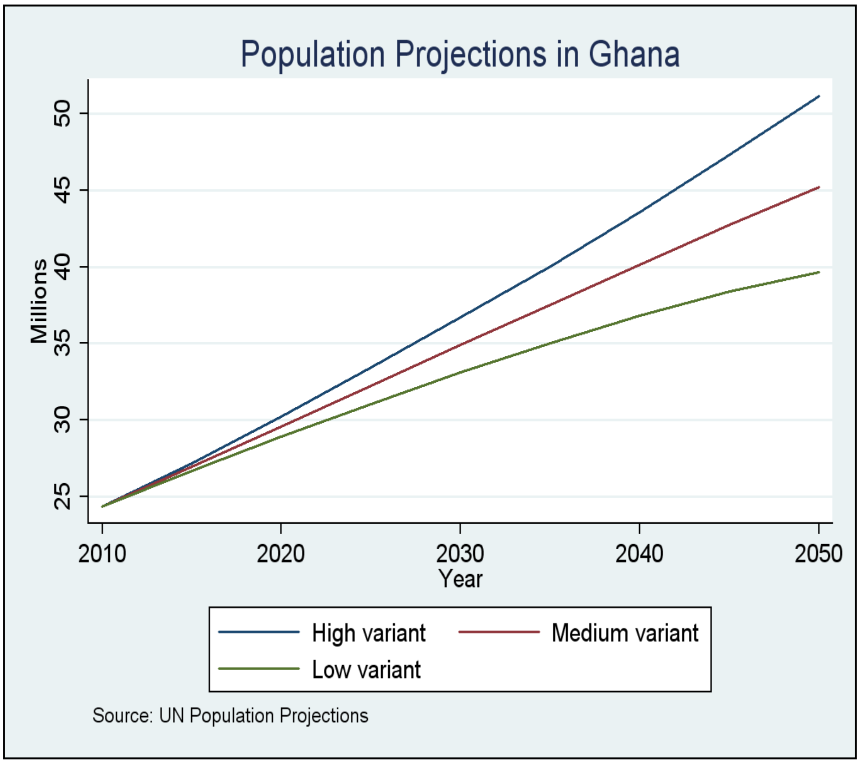


Table 1.2 shows key agricultural commodities in terms of area harvested, value of the harvest, and food for people (this last item was ranked by weight). Based on the area harvested, cocoa remains the most single important cash crop in Ghana. Cocoa is followed by two important staple food crops; cassava and maize. The three top crops accounted for over 50 per cent of area harvested under crops from 2006 to 2008. Whilst the three main crops mentioned are mostly located in the forest, transition and guinea savannah zones. Two ~~most~~ important crops (food and income) for the northern sector; ground nuts and sorghum rank 4th and 5th respectively. A comparison of Table 1.2a with Table 1.2b brings into focus the importance of other crops e.g. yams and plantains in terms of values of production. Whilst the areas harvested under these crops were lower (Table 1.2a), in Table 1.2b these crops were ranked higher (2nd and 3rd) because of the value of their production. Cocoa which ranked first in terms of the area harvested, is ranked 4th in terms of value of production. Cassava maintains its position of importance ranking 1st in terms of value of production. Cassava continued to maintain its 1st position on Table 1.2c in terms of quantity consumed (4,537,000 tonnes), followed by yams (2,433,000 tonnes) and plantain (2,250,000 tonnes) in the 2nd and 3rd positions respectively. The three crops were followed by a combination of other root and tuber crops. Maize features 5th on Table 3c with a total 899,000 tonnes and followed by rice with 513 thousand tones. The classification of food commodities based on quantities

consumed is an indication of the importance of the food commodities in diets of Ghanaians. Using the information presented by the three tables, cassava, yam, plantain, maize, and rice come up as the five most important crops produced and consumed in Ghana. In terms of the individual crop's contribution to medium to long term food security, maize and rice comes top because of their storability potential.

Table 1.2(a): Harvest area of leading agricultural commodities (thousands of hectares)

Rank	Crop	% of Total	Thousands of Hectares Harvested
	Total	100.0	6,310
1	Cocoa beans	26.6	1,678
2	Cassava	12.6	797
3	Maize	12.1	764
4	Groundnuts	7.4	470
5	Sorghum	5.3	333
6	Oil palm fruit	4.9	311
7	Plantains	4.8	301
8	Yams	4.7	299
9	Taro cocoyam	4.1	261
10	Millet	3.0	190

Source: FAOSTAT, 2013
Notes: All values are based on the three year average for 2006 through 2008.

Table 1.2(b): Value of production for leading agricultural commodities (millions of US$)

Rank	Crop	% of Total	Value of Production
	Total	100.0	6,695.6
1	Cassava	17.8	1,189.4
2	Yams	17.2	1,153.1
3	Plantains	15.1	1,014.3
4	Cocoa beans	10.3	689.7
5	Taro cocoyam	7.2	482.1
6	Groundnuts	5.5	368.3
7	Maize	5.2	349.9
8	Chillies and peppers	3.3	219.7
10	Rice	2.3	155.5

Source: FAOSTAT (FAO 2015)
Notes: All values are based on the three year average for 2005 through 2007.

Table 1.2(c): Consumption of leading food commodities (thousands of tons)

Rank	Crop	% of Total	Food Consumption
	Total	100.0	15,980
1	Cassava	28.4	4,537
2	Yams	15.2	2,433
3	Plantains	14.1	2,250
4	Other roots and tubers	8.0	1,286
5	Maize	5.6	899
6	Rice	3.2	513
7	Pelagic fish	2.7	426
8	Other vegetables	2.3	363
9	Oranges and mandarins	2.3	363
10	Wheat	2.1	332

Source: FAOSTAT (FAO)
Notes: All values are based on the three year average from 2003 to 2005.

In summary, the analysis of the growth in population as against the trends in food production and consumption point to the need for more scientific and technological approach to addressing food and nutrition security tied to more strategic policy initiatives especially under climate uncertainties. An important element in this is to ensure climate smartness in agricultural practices.

1.4 The Purpose of profiling

Climate variability and change effects are in most cases site specific. Technologies and practices to address climate variability and change must therefore aim to address site specificities and not one size fits all. The farming systems in a given agro-ecology therefore become important. The objective of this study was first, to create awareness, identify existing "climate smart" technologies and practices in the guinea savannah and forest zones of Ghana and rank them for ease of reference by extension workers reaching out to farmers and also to guide policy decision makers in agricultural investment decisions at local and national levels in response to detailed actions in the National Climate Change Policy (NCCP) under the Agriculture and Food Security Focus Area. In general, the output will contribute to CSA as an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change in Ghana.

1.5 Organisation of the document

The document is composed of five main chapters of which the first two provide the introduction and methodology used in assembling the data for analysis. Chapters 3 and 4 cover the existing knowledge, technologies and practices on CSA in the Guinea Savannah and Forest zones respectively and a general discussion of the findings. Chapter 5 presents the conclusions and some recommendations.

CHAPTER TWO

2.0 Methodology

2.1 Secondary literature review

Various literature sources were consulted to gain a broader understanding of the CSA concept. For example, the FAO Sourcebook, 2011 was found useful. Materials from the 3rd Global Conference on Agriculture Food Security and climate change held in Johannesburg, 2013 (African Alliance for CSA, 2013) and the Climate smart agriculture orientation and scaling up workshop in Nairobi, 2014 provided some insight in the design of the tools for this study.

2.2 Design and development of participatory profiling matrix

A multi-disciplinary team of 4 members composed of animal scientist, range ecologist, agribusiness and monitoring and evaluation experts from the core team of the Climate change, agriculture and food security platform of Ghana was tasked to develop a participatory profiling tool for the purpose. This was preceded by a presentation made to the platform core team to sensitize them and create awareness on climate-smart agriculture. The tool proposed a workshop environment with a working group of about 10-15 persons per group, identification and listing of the technologies and practices, and a matrix score sheet. The CSA technologies and practices that are applicable to the given agro-ecological zone were disaggregated by:

- Scope of technology
- Source/Origin
- Users of technology/practice
- Location/Community where practiced
- Usage by gender

The matrix score sheet contained various sieves of criteria with corresponding weight/ratings (1, 2, 3) according the Likert's scale. Each technology or practice was evaluated and scored (1=low and 3= high) using the following 11- point criteria:

- User friendliness
- Cost relating to technology application
- Responsiveness to temperature & rainfall variations
- Contribution to enhancing the environmental health (agro forestry)
- Ability to addressing land conservation (restoration of degraded lands)
- Degree of contribution to biodiversity
- Effect on productivity

- Capacity to reduce GHG emissions (carbon dioxide, methane, nitrous oxides, etc.)
- Ability to enhance integrated systems
- Scale of application (replicability)
- Sustainability regarding technology application

2.3 Regional Zonal Workshops

2.3.1 Selection of participants

Two separate one-day workshops were held in the Wa (guinea Savannah) and Kumasi (Forest) regional capitals of the Upper West and Ashanti respectively. The workshop participants were selected from stakeholders of different backgrounds. They cut across Policy and Decision makers, Traditional Authorities, Academia, Research Institutions, Civil Society including; NGOs, Farmer-Based Organisations, and Farmer Groups, and Individual Farmers whose activities are directly related to agriculture and the climate. From the districts 2 male and 2 female farmers, the District/Municipal/Metropolitan Directors of Agriculture and the District Chief Executives were specifically invited to participate. The Traditional Authorities who participated included the male chiefs and female chiefs (*Pognaa-mine*[1]) in order to address gender inclusiveness. Over 140 participants attended the two workshops.

2.3.2 Contextual Paper presentations

Resource persons were identified from within and without the CCAFS Platform made technical presentations to create awareness among participants and stimulate discussions on the National Climate Change Policy of Ghana and CSA technologies and practices in areas of Livestock, Crops and Fisheries. Soil and water management and Forest management were included during the forest zone workshop. The presentations focused on CSA technologies that have the potential of addressing farming issues within the Guinea Savannah and the Forest Agro-ecological zones under climate change.

The technical presentations were followed by group breakout sessions to identify and profile both indigenous and scientific CSA technologies and practices employing the tools that were developed and described in section 2.2 above.

[1] Dagaare word for female cheifs

2.3.3 Breakout Group Work

Four groups were formed to reflect the diversity of actors within agricultural value chains in the zones and present at the workshop. Generally, the participants were grouped in the following categories:

1. Academic and Research Institutions (Universities and CSIR)
2. Traditional Authorities and Farmers
3. NGOs and Farmer-Based Organisations
4. Policy and Decision Makers (Regional Coordination Council, District Assemblies, MoFA, EPA, Forest Commission).

The same task assignment was given to each of the groups in order to elicit diversity in outputs and provide space for comparative analysis across groups. This design further helped to bring out the technical, policy and institutional constraints pertinent to CSA in these functional groupings in the system. Each group was also tasked to list constraints and challenges associated with the application of the CSA technologies and practices identified and propose actions/solutions to address them. The group sessions were followed by plenary sessions during which results were shared, triangulated by groups and validated based on consensus building.

2.4 Data Analysis

The CSA identification and matrix ranking tools provided the needed data for both qualitative and quantitative analysis. Data on practices listed were first cleaned from double counting to arrive at the real number of practices enumerated by the various categories of stakeholders per zone in the study. There was analysis of the data to determine the proportions of the sources and users of the CSA practices. Simple arithmetic average values scored for the various CSA technologies and practices were used in the ranking to determine the order of most preferred visualized in tabular forms.

CHAPTER THREE

3.0 Technical Presentations

3.1 Concept of Climate Smart Agriculture

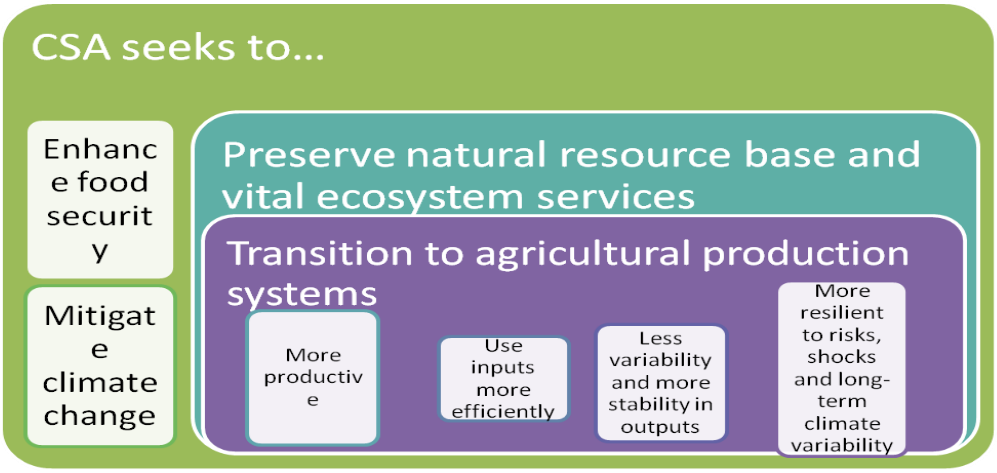
Introduction

Agriculture in developing countries must undergo significant transformation if it is to meet the growing and interconnected challenges of food insecurity and climate change (FAO, 2010). Global population however is expected to increase from 7 billion to more than 9 billion people in 2050 according to UNESCO, 2012. As a result, food production needs to be increased by at least 60% to ensure food security for everyone. In order to feed the continent's 900 million people, Africa needs its own food security and this can only be achieved through a uniquely African Green Revolution that recognizes that smallholder farmers are the key to increasing production, promotes change across the entire agricultural system, and puts fairness and the environment at its heart" (Kofi. A. Annan, 2010).

What is CSA?

Climate Smart Agriculture (CSA) is defined as "agriculture that sustainably increases productivity, builds resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals" (FAO 2015). Climate Smart Agriculture is an integrated approach, to achieve food security in the face of climate change (see diagram 1), while also mitigating climate change and contributing to other development goals. It focuses on the whole agriculture development chain (policies, practices and financing) and contributes to the achievement of sustainable development goals (FAO, 2015).

Diagram 1: Overview of CSA



Why Climate Smart Agriculture?

The World population is expected to reach 9 billion by 2050 and majority of the increases is expected to come from least and developing countries especially sub-Saharan Africa. There is the need to increase food production by 70 per cent above current levels and this cannot achieved through business as usual. Vulnerability of agriculture and food systems is most intense in countries where higher population increases are expected and the impacts of climate change are expected to further reduce productivity and lead to greater instability in the agricultural and food sectors in vulnerable countries. Climate change is exerting increasing pressure on natural resources resulting in environmental degradation hence the need for steps to cope with these conditions.

The agriculture sector is directly responsible for 14 per cent of global greenhouse gas emissions (23 per cent in Ghana) and a key driver of deforestation and land degradation (EPA, 2015). Sustainability of agriculture and food systems therefore require actions that will help cope with threats whilst limiting contributions to future climatic effects. The sector therefore has the potential of being an important part of the needed solutions. Capturing synergies that exist among technologies will ensure robust food systems and resilient production base.

The Concept of CSA seeks to increase sustainably productivity, strengthen farmers' resilience, reduce agriculture's greenhouse gas emissions and increase carbon sequestration and also strengthen~~s~~ food security and deliver~~s~~ environmental benefits.

CSA thus integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges, FAO sourcebook, 2013. It is composed of three main pillars:

1. sustainably increasing agricultural productivity and incomes;
2. adapting and building resilience to climate change;
3. Reducing and/or removing greenhouse gases emissions, where possible.

Some of the proven practical techniques and practices that support CSA are as follows;

- mulching,
- intercropping,
- conservation agriculture,
- crop rotation,
- integrated crop-livestock management agroforestry,
- Improved grazing, and improved water management
- Improved weather forecasting,
- more resilient food crops and
- risk insurance schemes.

The importance of CSA includes:

i. CSA addresses the complex interrelated challenges of food security, development and climate change, and identifies integrated options that create synergies and reduce trade-offs.
ii. The concept recognizes that these options will be shaped by specific country contexts and capacities as well as socio- economic and environmental situations.
iii. It also enables assessment of the interactions between sectors and the needs of different stakeholders, identifies barriers to adoption (especially for farmers), and provides appropriate solutions in terms of policies, strategies, actions and incentives.
iv. It seeks to create enabling environment through better alignment of policies, investments and institutions.
v. Creates opportunity for achievement of multiple objectives with the understanding that priorities need to be set and collective decisions made on different benefits and trade-offs.
vi. Prioritizes the strengthening of livelihoods (especially those of smallholders) by improving access to services, knowledge, resources (including genetic resources), financial products and markets
vii. It addresses adaptation and builds resilience to shocks, especially those related to climate change
viii. Considers climate change mitigation as a potential co-benefit, especially in low-income, agricultural-based populations
ix. Seeks to identify opportunities to access climate-related financing and integrate it with traditional sources of agricultural investment finance

A triple challenge for Agriculture is to:

- produce more food, in terms of quantity, quality and diversity, everywhere for everyone
- Adapt to Climate Change and increase Resilience
- Contribute to mitigate Climate Change

To address the multiple demands placed on agriculture, there is the need to create synergies between food security, adaptation and climate change mitigation. This is where the concept of CSA comes in.

What is new with CSA?

Climate Smart Agriculture is not a new Agricultural System, nor new set of practices. It aims to achieve food security and contributes to preserve natural resources. As such, it has very close links to the concept of sustainable intensification. It is a new approach, a way to guide the needed changes of agricultural systems given the necessity to jointly address food security and climate change. As a result, CSA shares all the objectives and guiding principles of the Green Economy and sustainable development approaches. The figure 3.1.1 below depicts some of the concepts and approaches before CSA concept and figure 3.1.2 shows the CSA links to previous approaches.

Figure 3.1.1: From farm-based to comprehensive development concepts

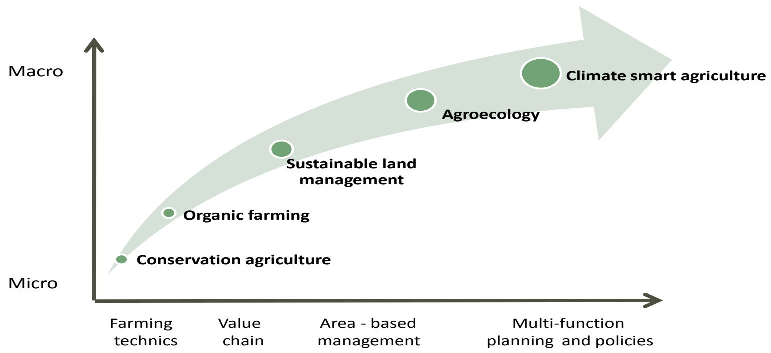
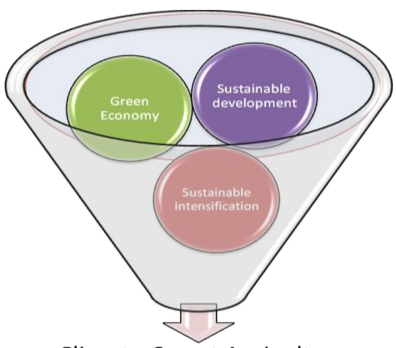


Figure 3.1.2: CSA links to previous approaches



CSA contributes to the achievement of economic, social and environmental goals (sustainable development goals). It lays heavy emphasis uses green economy's need for more resource use efficiency and resilience. Sustainable intensification: focuses on availability dimension of food security (CSA covers also accessibility, utilization and stability). Figure 3.1.3 summarizes the CSA opportunities in food systems, landscapes and services.

Figure 3.1.3: CSA opportunities

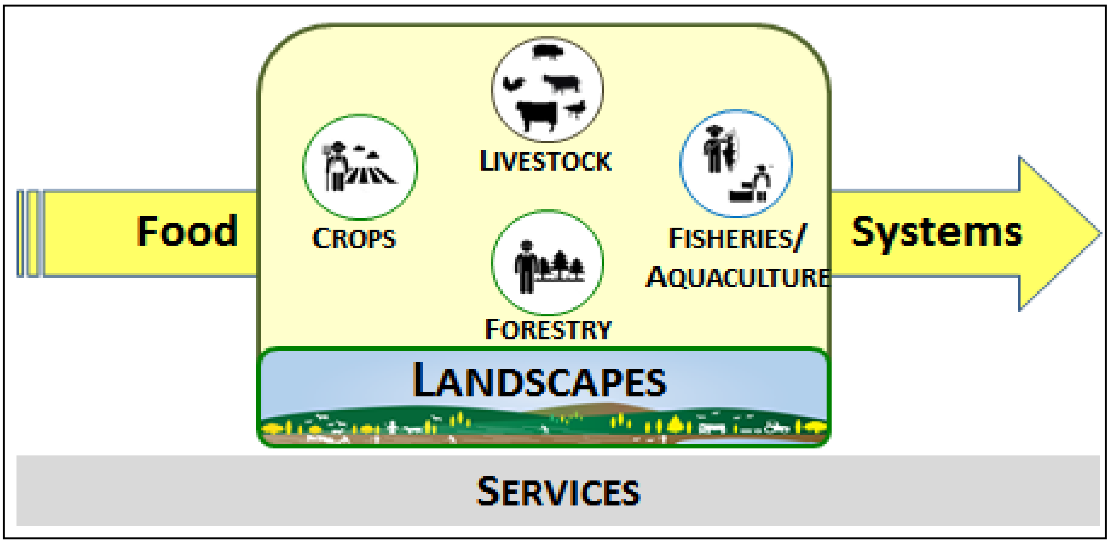


Fig 3.1.3a CSA opportunities in landscapes

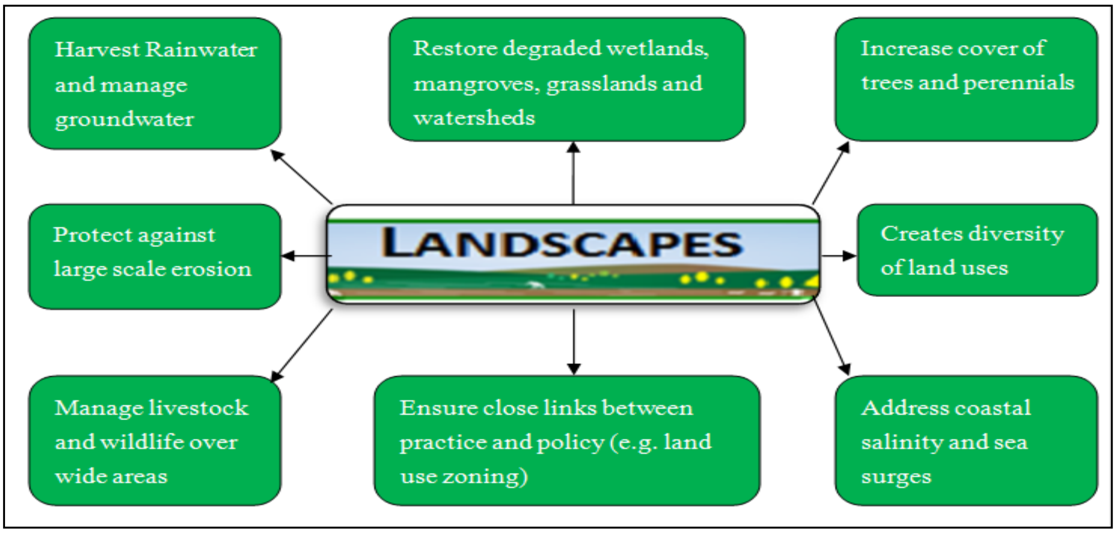


Fig 3.1.3b CSA opportunities in crops

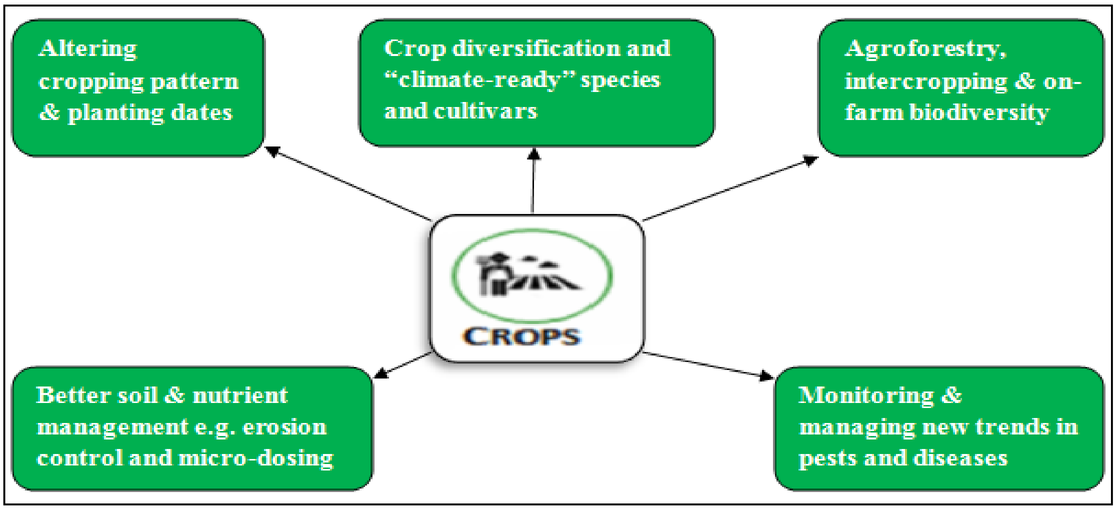


Fig. 3.1.3c CSA opportunities in livestock

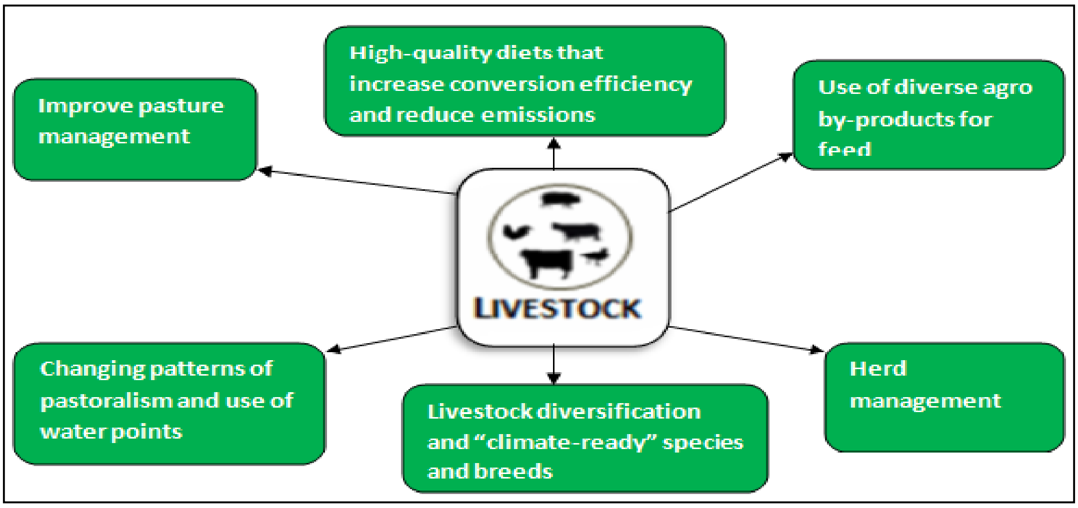


Fig 3.1.3d CSA opportunities in fisheries/Aquaculture

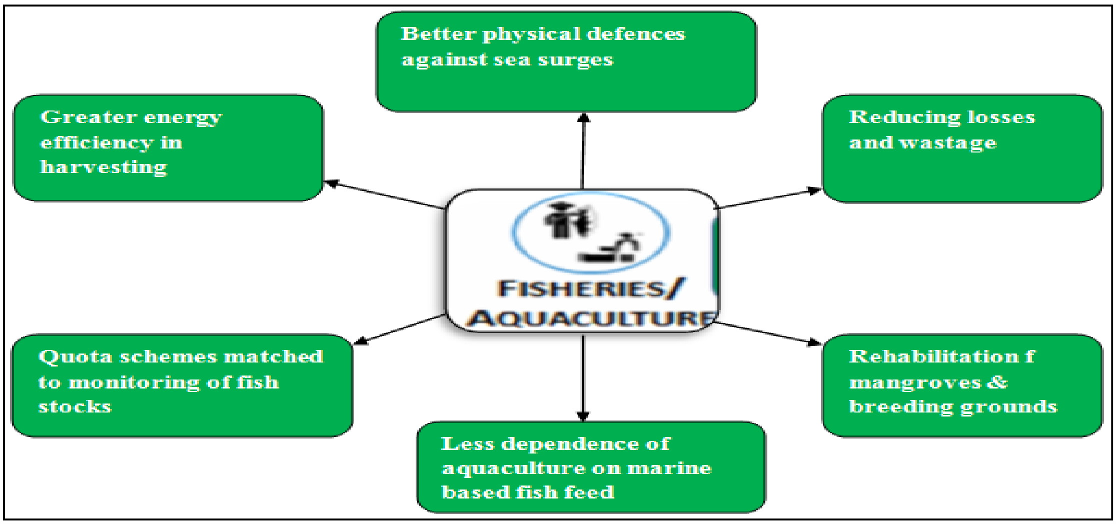


Fig3.1.3e CSA opportunities in food systems

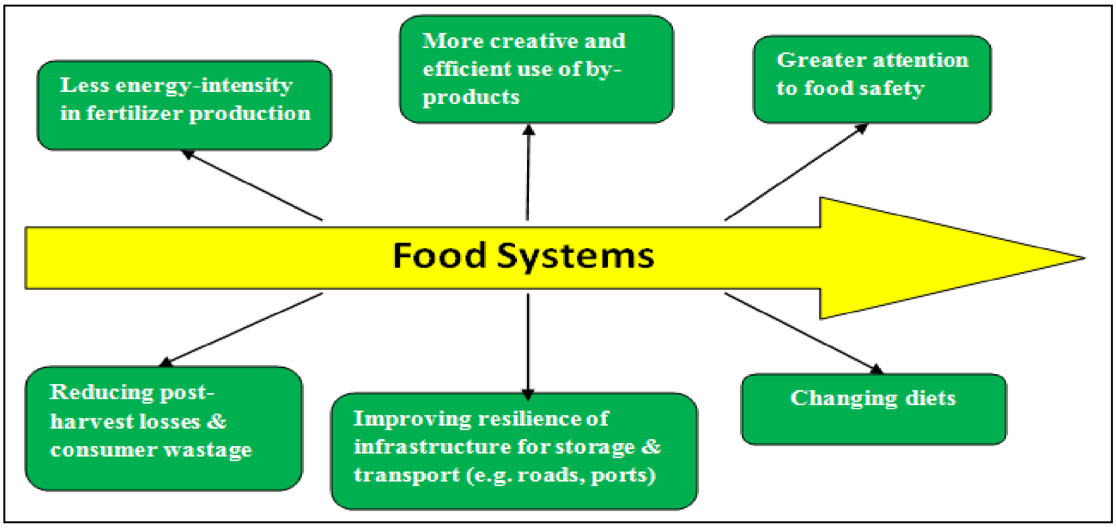
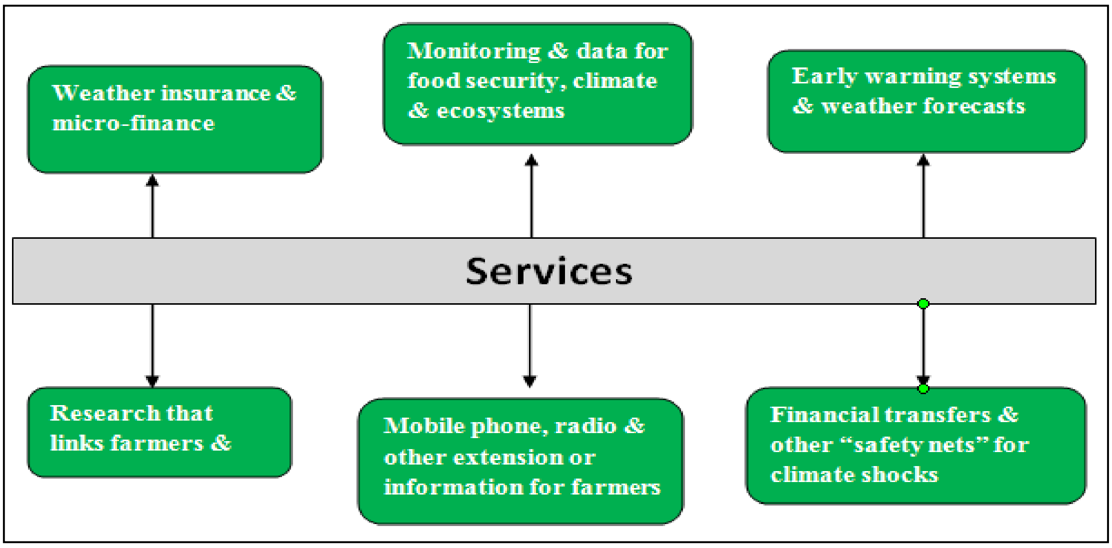


Fig 3.1.3f CSA opportunities in services



Conclusion

In a country like Ghana where the economy is heavily dependent on agriculture, development of the agricultural sector is the most efficient poverty reduction measure. To avoid solving a problem while exacerbating another, policy leaders should take an integrated approach to food security, poverty reduction and climate change.

Climate-smart agriculture is not a new agricultural system, nor a set of practices. It is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change. CSA therefore brings together practices, policies and institutions that are not necessarily new but are used in the context of climatic changes. It addresses multiple challenges faced by agriculture and food systems simultaneously and holistically and helps avoid counterproductive policies, legislation or financing.

3.2 Ghana National Climate Change Policy

Introduction

In the global context while climate change has become one of the defining contemporary international development issues, far less attention has been given to food security and climate change at the international level. Yet, these challenges are increasingly seen as being interdependent, shaped by a confluence of different pressures that converge within the agriculture sector such as population size and commensurate food demand are increasing, competition for food, land, water, energy, as well as carbon storage, is intensifying, degradation of natural resources is expanding. This makes solutions for climate change to become more urgent. At the UNFCCC COP16 in December 2010, the draft text on agriculture was not incorporated into the Cancun Agreements. Agriculture, however, already figured prominently in National Adaptation Programmes of Action (NAPAs) formulated by Least-Developed Countries (LDCs). The Challenge for Africa is that IPCC 2007, has projected an average temperature increase of 1.5 to 4° C in this century, higher than the global average. According to Jones and Thornton, 2009 moderate temperature rises, warming and drying could reduce crop yields by 10 to 20 percent by 2050 in Africa. In Sub-Saharan Africa, 250 million people went hungry in 2010, almost a third of the population. At the request of African leaders meeting at the thirteenth Summit of the African Union (AU), held in Sirte, Libya in 2009, African Union Commission (AUC)-NEPAD Agriculture-Climate Change Framework was prepared. An Investment Platform for African Climate Smart Agriculture was established to help make the Framework operational through mainstreaming CSA into CAADP National Agriculture and Food Security Investment Plans (NA&FSIPs). In Ghana, many economic areas and sectors are threatened by Climate change. Below is a GMeT historical data for 40 years for five agro-ecological zones in Ghana showing the future scenario for temperature and rainfall:

Table 3.2.1: Future scenario for temperature and rainfall

Year	Temperature Increase	Rainfall
2020	0.6 degrees Celsius	28% decreased
2050	2.0 degrees Celsius	10% decreased
2080	3.9 degrees Celsius	18% decreased

The effect of these climatic variables on key sectors is summarized in Table 3.2.2.

Table 3.2.2: Climate Change Effects on some key sectors of the economy

Sectors	Effects
Water Resources	• Lowest conversion factor of precipitation to run-off is 15% (average) • 30% decrease in run-off
Natural Resource Management & Biodiversity	• Species lost • Bush fires & • Fuel wood
Health	• Increase in malaria and Cerebrospinal meningitis (CSM)
Food Security	• Maize production decreasing by 7% by 2020 • Farming system along river banks will suffer • Cost of protecting important areas is estimated at USD 590.00

The National Climate Change Policy (NCCP) is to provide strategic direction and co-ordinate issues of climate change in Ghana. This surpasses 'traditional' climate change policy areas of adaptation and Mitigation. It emphasises ~~that~~ social development as key concern and as such cuts across sectoral areas.

Policy vision and objectives

The vision of the NCCP is to ensure a climate – resilient and climate – compatible economy while achieving sustainable development through equitable low – carbon economic growth for Ghana. The policy was designed to ensure sustainable socio – economic development pathway ~~of~~ for Ghana by dealing with the impacts of climate change. NCCP has three policy objectives: effective adaptation, social development and mitigation (MESTI, 2014).

These objectives were captured through a wide stakeholder base in order to ensure that appropriate systems are put in place to ensure success. Key Systemic Pillars considered in the policy are:

1. Governance and coordination
2. Capacity Building
3. Science, Technology and Innovation
4. Finance
5. International Cooperation
6. Information, Communication and Education
7. Monitoring and Reporting

1. Adaptation

Adaptation to climate change is crucial especially for the agricultural sector to help communities and the nation to reduce impacts through early warning, population or ecosystem-based resilience. This is driven by 4 thematic areas (interlaced with mitigation and social development measures) as follows:

- Energy and Infrastructure
- Natural Resource Management
- Agriculture and Food Security
- Disaster Preparedness and Response

2. Social Development

The Social development pillar considers the human impact of climate change in general taking into consideration the poor and vulnerable people as well as rural poor and vulnerable communities. It focused also on women, children, the aged and the physically challenged.

3. Mitigation

The mitigation pillar is focused on low carbon development activities, towards the reduction in GHG emissions and sequestration of GHGs among others. Some of the initiatives for achieving the objective include Green growth programmes, Nationally Appropriate Mitigation Actions (NAMAs) and REDD plus programme, etc.

Responsibilities of the Agriculture Sector

- Key Climate Change Unit in Government with representatives in NCCC, CCTWG);
- Collaborate with other Government, Non-Government, Civil Society Organizations, Private Sector and Development Partners;
- Responsible for policy formulation and coordination;
- Lead public organization for development of Food and Agriculture CC sector programmes;
- Hosts and operates the agriculture extension services

NCCP Further Endorses MOFA Decentralised Responsibilities

- National level - departments and technical directorates coordinate with regions (CC Task Force);
- Regional level - coordination and technical support to district offices;
- District level - provides extension services

  Two key policy documents are instrumental in the operations of MoFA namely:

- The National Food and Agriculture Development Policy (FASDEP II) and
- The investment plan - Medium Term Agriculture Sector Investment Plan (METASIP).

FASDEP II & METASIP

Both FASDEP II and METASIP emphasize on achieving an accelerated modernization of agriculture. Although the policies demonstrate very little concern for climate change and variability impacts, its pillars provide very good entry points for addressing challenges of climate change and variability

Policy/ programme areas

- food security and emergency preparedness;
- increased growth in incomes;
- Increased competitiveness and enhanced integration into domestic and
- international markets;
- sustainable management of land and environment;
- application of science and technology in food and agriculture development; and effective institutional coordination.

There are five prioritized policy areas of the NCCP (Themes and Strategic Focus Areas), which are:

1. Agriculture and Food Security
2. Disaster Preparedness and Response
3. Natural Resource Management
4. Equitable Social Development
5. Energy, Industrial and Infrastructural Development

The target is to have an effective adaptation response, reduction of GHGs emissions, and enhancement of carbon sinks as well as reduction of social impacts of climate change. Agriculture and Food Security thematic area of the NCCP focuses on the development of Climate Resilient Agriculture and Food Systems. Ghanaian agriculture production (crops and livestock) systems, are based on exploitation of natural resources. It is largely rain-fed, with persistence of hunting and fishing from natural water bodies. Therefore, issues on climate change and non-climate (soil degradation, land tenure arrangements and poor technology), are expected to have significant impacts on agriculture and food security.

Key Challenges that afflict the sector include:

- Limited basic infrastructure - roads, access to markets and storage facilities
- Crop failures due to weather variability and unpredictability
- Unsustainable agricultural practices
- Increasing incidence of disease and pests - changes in temperature and humidity
- High mortality rates of livestock,
- Declining fish catch,
- Destruction of fish breeding sites,
- Limited recycling of agricultural waste,

- Food insecurity and shortages due to reducing soil productivity
- Limited irrigation development and poor management
- Limited technology development for processing, transporting, handling and storage of crop produce, fish and livestock products
- Weak enforcement of environmental management for agricultural, land use and fishing activities

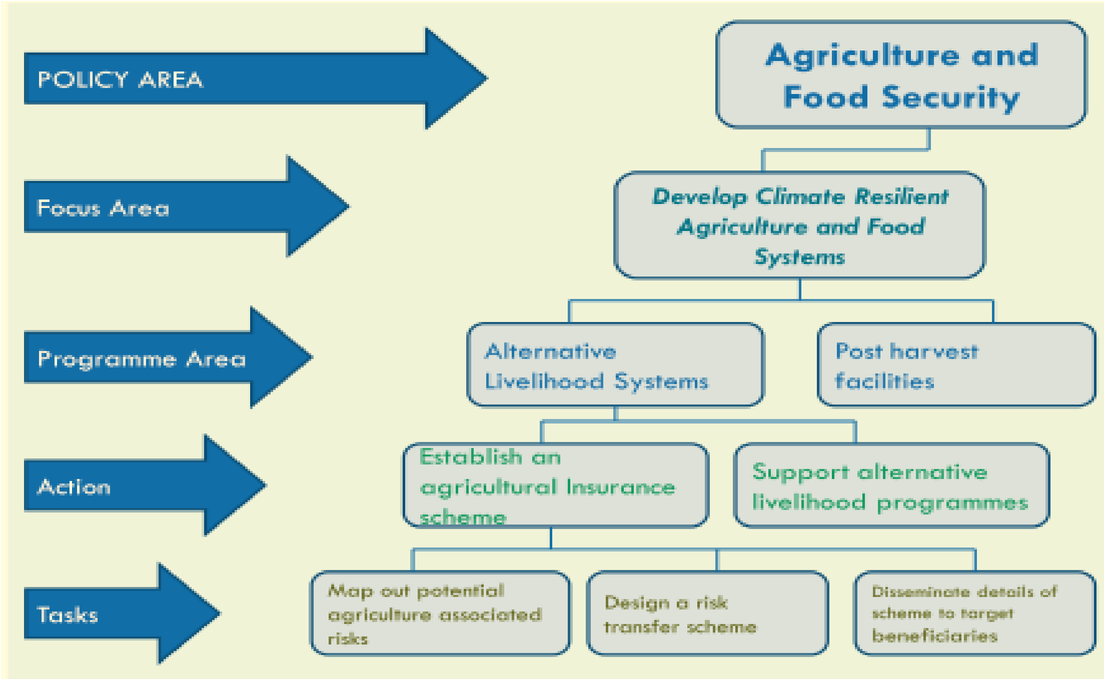
Climate Smart Agriculture Action Plan was developed to operationalize the implementation strategy of the Agriculture and Food Security thematic area of the NCCP. The objectives of the plan are to develop climate resilient agriculture and food systems for all agro-ecological zones and develop human resource capacity for climate resilient agriculture. These objectives are in recognition of the site-specific nature of CC effects and the decentralized governance/administration structure of Ghana.

The Climate Smart Agriculture Programme Areas are aligned with those of the NCCP as follows:

P1. Institutional capacity development for research and dissemination
P2. Develop and promote climate resilient cropping systems
P3. Adaptation of livestock production systems
P4. Support adaptation in fisheries sub-sector
P5. Support to water conservation and irrigation systems
P6. Risk transfer and alternative livelihood systems
P7. Improved post-harvest management
P8. Improved marketing policies

Figure 3 summarizes the Policy to Action processes.

Figure 3.2.1: Policy to Action



The NCCP policy has a number of specific programmes for addressing the critical sector policy actions necessary to achieve the desired objectives. These policy objectives can be achieved through the development of specific strategies and actions. The MDAs are expected to develop detailed time bound and budgeted implementation plans that would be linked to their operating strategies and work plans. As a strategy for the Agriculture and Food Security, sectoral policy objectives could be achieved through the development of specific strategies and actions that aim at mainstreaming climate change adaptation into sectoral policy planning and budgeting processes. There is the need as a country to develop and promote Climate Resilient Cropping Systems with the objective to enhance sustainable production and reduce climate related disasters. This is necessary on grounds that the sector is responsible for over 70% of the food needs of Ghana but our agriculture and food systems are rudimentary in nature, and climate dependent. In addition, in recent years, extreme climate events and climate variability have resulted in yield loses at farm and community level.

There is therefore the need to adapt to future climatic effects, define new cropping systems, new farming systems and improvement of existing ones etc. Proposed actions ~~of~~ for consideration as a nation include:

1. Research into climate resilient cropping systems
2. Document and promote appropriate indigenous knowledge and best practices
3. Upscale promotion of Sustainable Land Management including conservation agriculture and agro-forestry

For implementation, Multi Donor Budget Support (MDBS) is recommended as a mechanism for mainstreaming policy actions into sectoral plans and programmes for implementation by the various MDAs. An Inter-Ministerial Oversight Committee would be established to ensure linkages among implementing entities. There would be a Technical Secretariat which should be located at MESTI to coordinate and monitor the effective implementation of the policy, programme and plans. It also recommends that an intensive educational programmes and capacity building, especially training ~~is~~ for relevant ~~to~~ staff of MDAs.

Conclusion

In conclusion, Climate change was observed to be real and a challenge to national development and the NCCP document endorsed sectoral structures and policies of agriculture, responsible for development of climate resilient and agricultural systems. The MDAs are responsible for developing programmes and to mainstream Climate Change into sector planning and budgetary processes.

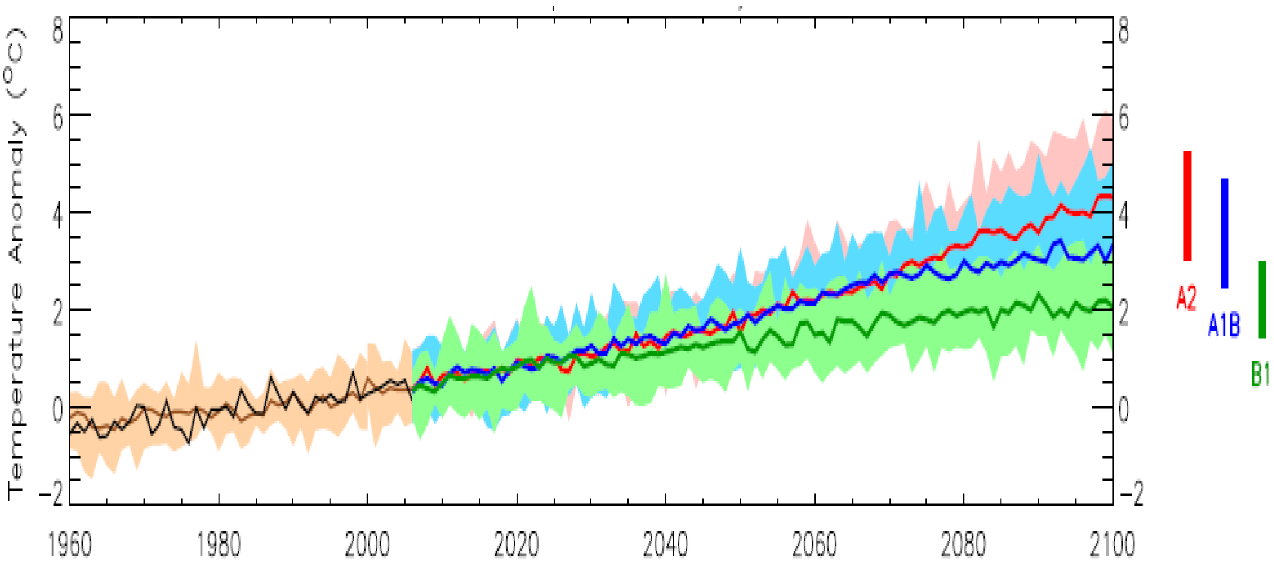
3.3 CSA Technologies and Practices Relating to Crops production in the Guinea Savannah and Forest Zones

Introduction

Climate change is a long-term shift in the climate of a specific location or region. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation.

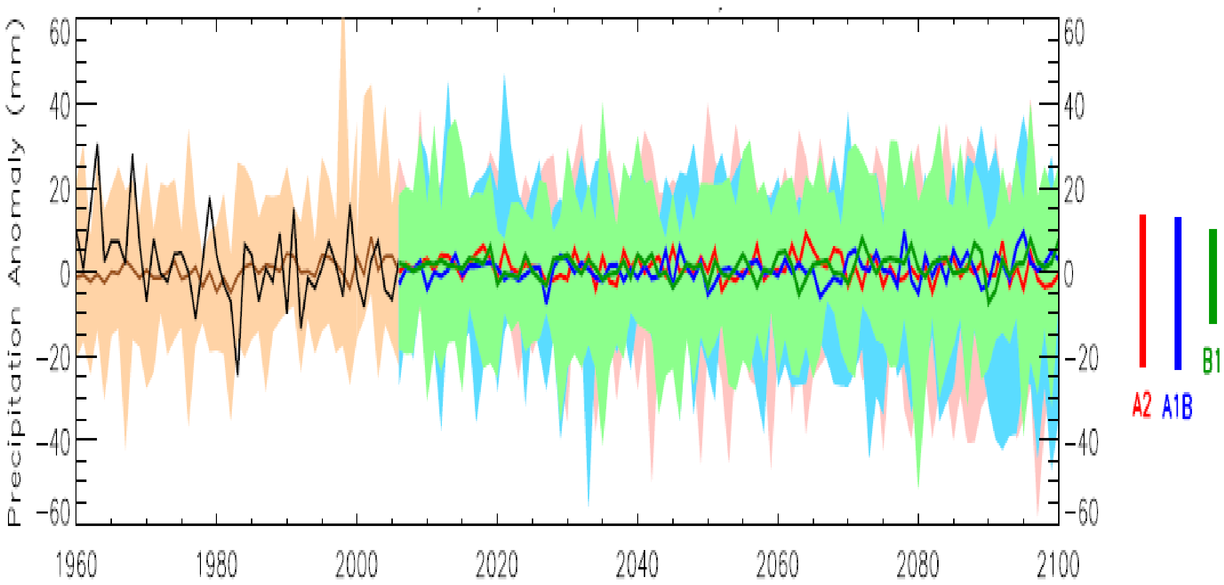
A change in the variability of climate is also considered climate change, even if average weather conditions remain the same. Evidence of Climate Change in Ghana is observed as changes in indicators of weather especially temperature and rainfall, for example the mean annual temperature has increased by 1.0°C since 1960, on an average rate of 0.21°C per decade (Figure 3.3.1). The rate of increase has been most high in April, May and June, around 0.27°C per decade. It has been generally more highest in the northern regions of the country than in the south.

Figure 3.3.1: Ghana Mean Temperature Anomaly Annual



In terms of rainfall, total annual rainfall in Ghana has had an overall decreasing trend in the period 1960 to 2006, with an average of 2.3mm per month (2.4%) per decade (Figure 3.3.2). Long-term trends are difficult to predict because annual rainfall in Ghana is highly variable on inter-annual and inter-decadal timescales.

Figure 3.3.2: Ghana Monthly Precipitation Anomaly Annual



Sea level rise and associated destruction of coastline are also major climatic change related issues. In Ghana, the ocean claims on the average 1.5 to 2 metres of Ghana's 539 kilometres coastline annually, with the most risky areas recording four metres.

- Projection of future climate in Ghana reveals that mean annual temperatures could increase by 1.0 to 3.0°C by the 2060, and 1.5 to 5.2°C by the 2090. The projected rate of warming is expected to be most rapid in the northern regions (interior savannah zones) of Ghana than the coastal regions. Projections of mean annual rainfall averaged over the country from different models (in the ensemble) project a wide range of changes in precipitation for Ghana. There is however no unanimity among the projections as to the direction (decrease or increase) of the expected changes. About half of the models project increases and half project decreases. Sea-levels in the coastal regions of Ghana is projected by climate models to rise by 0.13 to 0.43m under SRES B1, 0.16 to 0.53m under SRES A1B and 0.18 to 0.56m under SRES A2 by the 2090s, relative to 1980-1999 sea-level.

Productivity of major staple crops including maize, cassava and cocoyam are projected to decrease under future climatic change impacts. Yields of maize and other cereals are projected to reduce by 2.4% in 2020 and by 7% by 2050 whilst cassava production will decrease by 43% by 2080. Cocoyam production will decrease from 65.2% to 52.8% in 2080 (Mensah Bonsu, 2003). Table 3.3.1 shows some agriculture and non-agriculture climate-change impacts.

Table 3.3.1: Agriculture and Non-agriculture climate change impacts

Agriculture-Related Impacts	Non-Agriculture Related Impacts
i. Severe warming, floods, and drought may reduce Crop yields and can harm crops - Yield losses ii. Livestock may be at risk, both directly from heat stress and indirectly from reduced quality of their food supply. iii. Fisheries will be affected by changes in water temperature that shift species ranges, make waters more hospitable to invasive species, and change lifecycle timing. iv. Moderate warming and more carbon dioxide in the atmosphere may help plants to grow faster v. Climate change is already affecting diversity and productivity of forests and trees on farms through its impact on growing seasons, pest and disease outbreaks and tree population size & distribution.	i. A warmer climate is expected to increase both the risk of heat-related illnesses and death and worsen conditions for air quality. ii. Climate change will likely increase the frequency and strength of extreme events (such as floods, droughts, and storms) that threaten human safety and health. iii. Climate changes may allow some diseases to spread more easily and emergence of diseases and vectors. iv. Increased water stress will impact land areas twice the size of those areas that will experience decreased water stress.

vi. Weeds, pests and fungi thrive under warmer temperatures, wetter climates, and increased CO_2 levels. vii. Crop yields are expected to decline due to long-term changes in temperature and rainfall and increased climate variability. viii. The outcome may be higher food prices, along with chronic poverty and under-nutrition for farming households already battered by climate extremes such as drought and flood.	

Northern Ghana is generally characterized by dry deciduous to semi-arid climatic conditions. It has a uni-modal rainfall with high intensity rains, long dry season with high temperatures (high evapotranspiration). Soils are generally low in natural fertility (low organic matter) and highly erodible. It has high rate of weather related extreme events; floods and droughts. Climate Change is increasing pressures due to these natural phenomena on the agriculture and food systems. Some constraints identified to crop production in that part of the country include the following:

- Low farm productivity
- Poor husbandry practices including inappropriate land management
- Inadequate use of external nutrients
- Poor post-harvest management
- Weak market linkages and infrastructure including roads
- Inadequate access to financing

These problems can only be sustainably addressed using comprehensive approaches to development (CSA). Available CSA technologies for cropping systems will sustainably increase agricultural productivity and incomes, build resilience and the capacity of agricultural and food systems to adapt to climate change, and seek opportunities to reduce and remove greenhouse gases (GHGs) while meeting their national food security and development goals.

Therefore, the practice of CSA is based on the use of multi-technological approach – thus broader in context than soil conservation, fertility management, and/or forest management among others. Table 3.3.2 shows CSA technologies in the food crop sub sector in Ghana.

Table 3.3.2: CSA Technologies in the food crop sub-sector in Northern Ghana

Technology/Practice	Contribution to CSA	Remarks
Mulching	• Increases soil moisture content • Reduces direct evaporation and GHG emissions rate • Improves the capacity of the soil surface to intercept rainfall	Very useful in harsh environments with available mulching materials
Agroforestry	• Provides favourable micro-climate • Provides permanent cover • Improves soil structure and organic matter content • Increases infiltration • Enhances soil fertility • Reduces the need for mineral fertilizers • Reduces erosion in medium to long term • Betters rainwater management • Serves as carbon sink and increases carbon sequestration	Most suitable for environments that support tree growing. Species selection must be informed by local adaptability.
Inter-cropping	• Support soil fertility management • Ensures high percentage soil cover • Could reduce reliance on chemical fertilizers (cereal/legume) • Efficient use of water through improvement in infiltration • Intercropping cereals with legumes increases in both yield and total nitrogen content	Choice of associating crops is important in achieving the necessary synergies.
Chemical fertilizer	• Provides readily available forms of nutrients, supports plant growth, builds biomass, increases productivity, contributes to adaptation, mitigation and food security	It is important to address the four Rs (Right source, Right type, Right rate, Right place) in order to ensure efficiency
Organic amendment e.g. composting, animal manure etc.	• Provides plant nutrients • Improves soil structure-water storage and infiltration • Enhances soil carbon pool • Composting improve organic manure management-reduces GHA emissions • Support yield increases	Source and type of organic soil amendment is very important. Management of animal manure in particular has high benefit for CSA.
Cover cropping	• Reduces on farm erosion • Reduces yield (e.g. grain) losses due to pest attacks • Improves organic matter content • Improves soil health • Increases soil carbon content	Choice of material should consider, location, maturity period, utilization and biomass production

Water management and water harvesting	• Makes more water available to crops • Increase soil moisture content • Increased water use efficiency (yield per drop) • Supports crop production-supplementary irrigation • Can provide alternative source of employment	Water storage infrastructure should consider environment, purpose and population. Irrigation should consider most efficient methods.
Weather Forecasting	• Generally provides farmers with reliable weather information to make informed decisions. Thus, • Improve crop production planning (type and quantity of crops to grow) • Provides useful information for planning field operations e.g. fertilizer for the type, amount, timing and type of application of crop inputs • Improve crop field level investment decisions • Improve crop marketing and planning	Need to build capacity of local people for collection and analysis of data to generate needed information. Need to put in place communication mechanism to support dissemination of information generated.
Improved Crop varieties	• Increased yield , input (water, nutrient) use efficiency, tolerance to stress (flooding, dry spells pest and disease) conditions, tolerance, high biomass	The use of improved varieties must be supported with appropriate agronomic practices to achieve expected yields.

Several institutions in Ghana have for the past 54 years creditably discharged their mandate by generating research findings and technologies of relevance to climate change.

3.3.1 Climate Smart Technologies developed and disseminated for increased productivity and adaptation:

CSIR-CRI in focus.

The following are list of some selected CSA technologies developed by CSIR-CRI:

i. Development and promotion of high yielding, good quality crop varieties and traits (Micronutrients - e.g., Vitamin A, Iron, Zinc, Phosphorous).
ii. Development and promotion of the use of more disease and pest tolerant crop varieties
iii. Development of Phosphorous efficient and Nitrogen fixing crop varieties (cowpea, soybean)
iv. Participatory Varietal Selection (PVS)

v. Improved Farming systems
- crop residue management and mulching
- intercropping,
- conservation agriculture (No-till, cover crops),
- crop rotations incorporating legumes,
- integrated crop-livestock management,
- early planting,
- recommended planting distances integrated pest management practices,
- early harvesting to prevent rot and pest damage,
- agro-forestry, and
- improved water management

Major maize varieties released by CSIR-Crop Research Institute (CRI) are presented in Table 3.3.3.

Table 3.3.3: Maize varieties developed by CSIR-CRI

Variety	Year released	Special attributes
Obatanpa	1992	High Yielding QPM &Streak resistant
Mamaba	1996	High yielding QPM Hybrid
Golden Jubilee	2007	High yielding Yellow QPM
Abontem	2010	Extra early yellow QPM Drought and striga resistant
Ɔpɛaburoo	2012	High yielding Hybrid drought tolerant
Ɔwanwa	2012	High yielding yellow Hybrid

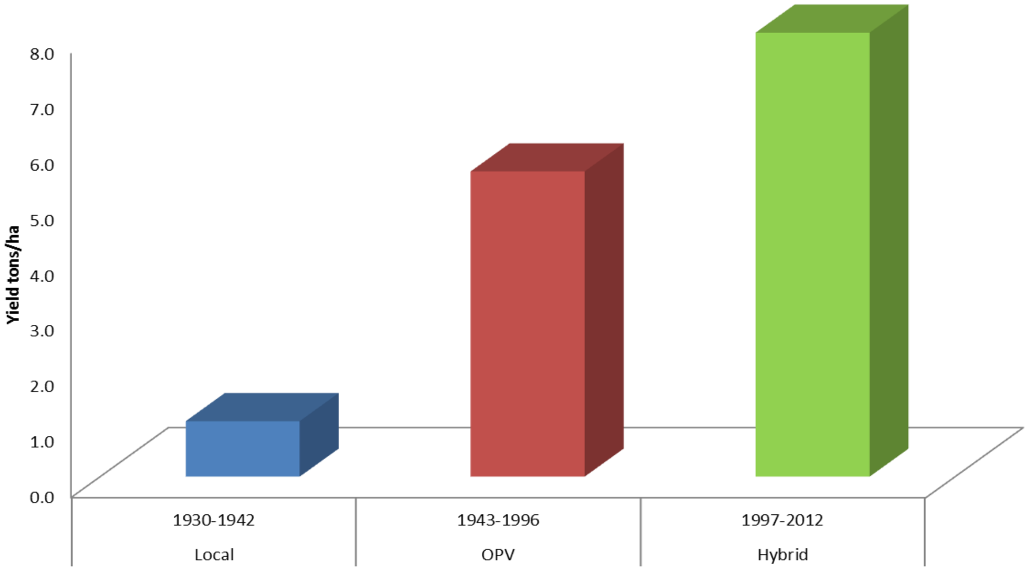
Figure 3.3.3 shows the yield of maize varities released by Crop Research Institute between 1930 and 2012. The hybrids which were released between 1997 and 2012, were observed to have the highest yield.

Other CSA activities undertaken include:

i. Development and promotion of early and extra-early maturing crop varieties which are high yielding

ii. Development of drought, heat and salinity tolerant crop varieties (e.g. Bambara groundnut, tomatoes, rice)

Figure 3.3.3: Potential grain yield of maize varieties released between 1930-2012



Rice Technologies:

i. Development and promotion of "**SAWAH**" technology in the inland valleys.

Sawah is a demarcated, bunded, puddled and levelled paddy field with water inlet and outlet in the valleys and therefore allows for effective management of periodic flooding and drought in the valleys and results in increased crop production. Rice fields with SAWAH technology illustrated.

Legumes types: Leguminous crops fix atmospheric nitrogen and thus enhance sustainable agriculture. Several high-yielding, diseases, pests and drought resistant/tolerant varieties of cowpea, groundnut and soybean have been released CSIR-CRI and CSIR-SARI as shown in the photos below. There is increase number of farmers using these improved varieties with recommended agronomic practices.

Table 3.3.4: Recently developed varieties of cowpea by CSIR-CRI

Name of variety	Year released	Special attributes
Hewale	2012	High yielding, white seed colour, brown hilum, tolerant to pests and diseases
Asomdwoe	2012	White seed colour, black hilum, moderately. tolerant to pests and diseases
Videza	2012	Dual purpose, medium maturing, white seed with black hilum

Pictures of Cowpea varieties released

Hewale Videza Asomdwe

Approximately 100 demonstration fields were organized with increased breeder seed production. Many farmers appreciated these varieties, seed companies and seed growers have shown strong interested.

Groundnut production in Ghana nearly also tripled in the last decade (168,200Mt in 1995 to 439,200Mt in 2004) primarily due to increases in the area under cultivation. Increased yields are mainly due to the deployment of improved crop varieties and dissemination of improved and sustainable cropping systems to farmers.

Bambara groundnut

Bambara groundnut (*Vigna subterranea* (L.) Verd) is an indigenous African legume considered as a complete balanced food. It is grown by subsistence farmers in Africa under traditional low input agricultural systems. It is an under-utilized, drought resistant crop grown in marginal and low-input environments with less sustained research input.

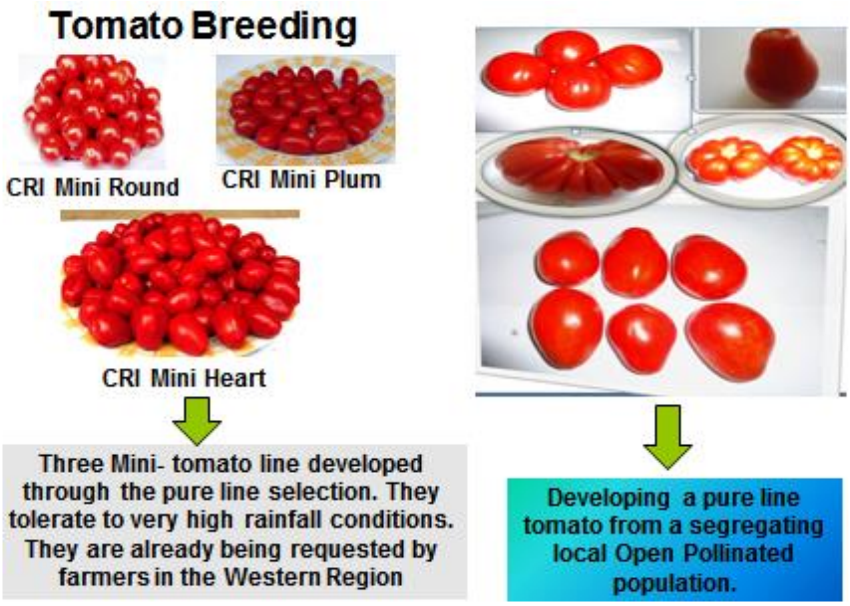
Early maturing, high yielding, highly nutritious, disease resistant varieties with reduced cooking time have been developed by CRI and yield levels based on evaluations were very encouraging.

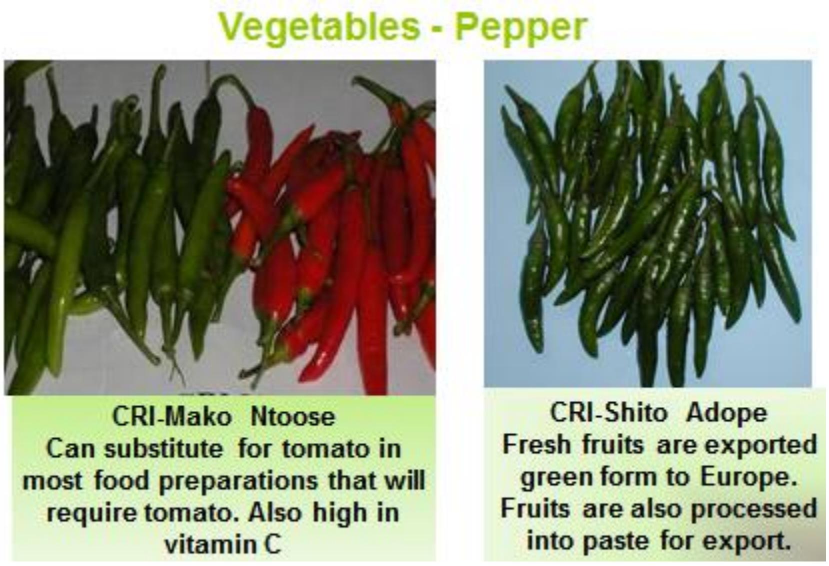
Efforts in the development of roots and tubers have also received fair share in terms of development and release of varieties. Cocoyam varieties developed such as *Gye Me Di* (Trust me) which is purple has a potential yield of 8.00mt/ha. Maturity Period is 15 MAP and has a high dry matter, ash and carbohydrate content of 58.22%, 2.73% and 48.19% respectively. It is mainly use for fufu, ampesi, eto, bread, confectioneries etc. Pictures of other relevant food crops developed, transferred and related activities are shown in subsequent pages.

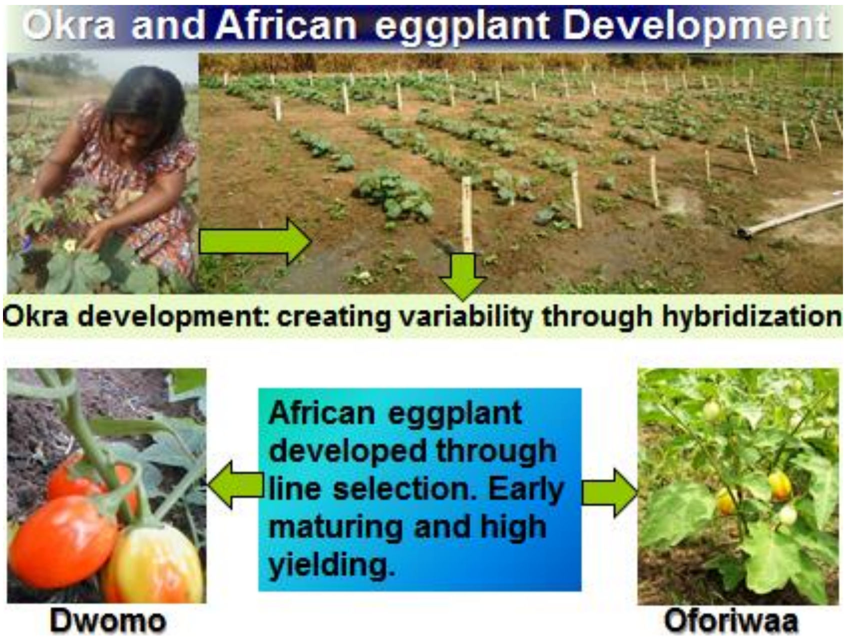
Cocoyam

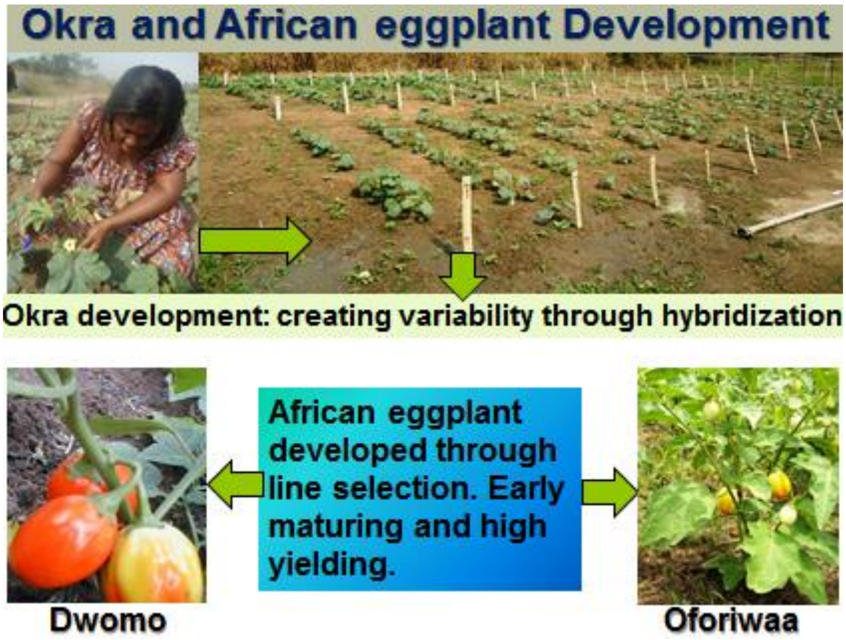
Breeding for tomato that can stand high rainfall conditions

Mini tomato growing in the middle of rainy season with no fungal problems.




Vegetables - Pepper
CRI-Mako Ntoose
Can substitute for tomato in most food preparations that will require tomato. Also high in vitamin C
CRI-Shito Adope
Fresh fruits are exported green form to Europe. Fruits are also processed into paste for export.


Okra and African eggplant Development
Okra development: creating variability through hybridization
African eggplant developed through line selection. Early maturing and high yielding.
Dwomo
Oforiwaa



3.3.2 Climate Smart Technologies Applied/developed by CSIR-CRI for Mitigation (GHG Reduction)

GHG emissions from agriculture are mainly due to three gases: carbon dioxide (CO_2), methane (CH_4) from rice cultivation, and nitrous oxide (N_2O) from fertilizer application. Broad mitigation measures at CSIR-CRI include:

i. Agricultural biotechnology – molecular techniques and tissue culture
ii. Cover crop technology – Mucuna, cowpea, groundnut help manage soil fertility, soil quality and water.
iii. Fertilizer management technologies – Type, required amounts of fertilizer, time of application
iv. Zero-tillage, Conservation tillage – Zero tillage is an agriculture technique which encourages planting in mulch instead of "slash and burn" and increases the amount of water and organic matter (nutrients) in the soil and decreases erosion
v. Sprinkler and drip irrigation
vi. Methane mitigation (Rice) using reduced tillage.

3.3.3 Climate Smart Technologies Applied by CSIR-CRI for Food Security

Climate smart technologies for ensuring the achievement of food security and the Millennium Development goals for poverty reduction include:

i. Development of the seed industry (e.g., QPM – Obatampa, cowpea, rice, etc.) has provided increased job opportunities and incomes for millions of farmers, seed growers, seed distributors, and grain sellers

ii. Enhancement of the nutritional status of farm households and the general public, particularly children, through the utilization of high and stable yielding, nutritionally superior and consumer-preferred varieties.
iii. Promotion of community-based seed production that allows farmers to borrow and pay back seeds to a common seed pool at affordable prices.
iv. Cowpea with high Zinc, Iron and Calcium.
v. Orange flesh sweet potato high in vitamin A.
vi. Bio-fortification of maize, rice and sweet potato with high lysine and tryptophan.

Field Level Interventions to promote CSA Practices in Ghana

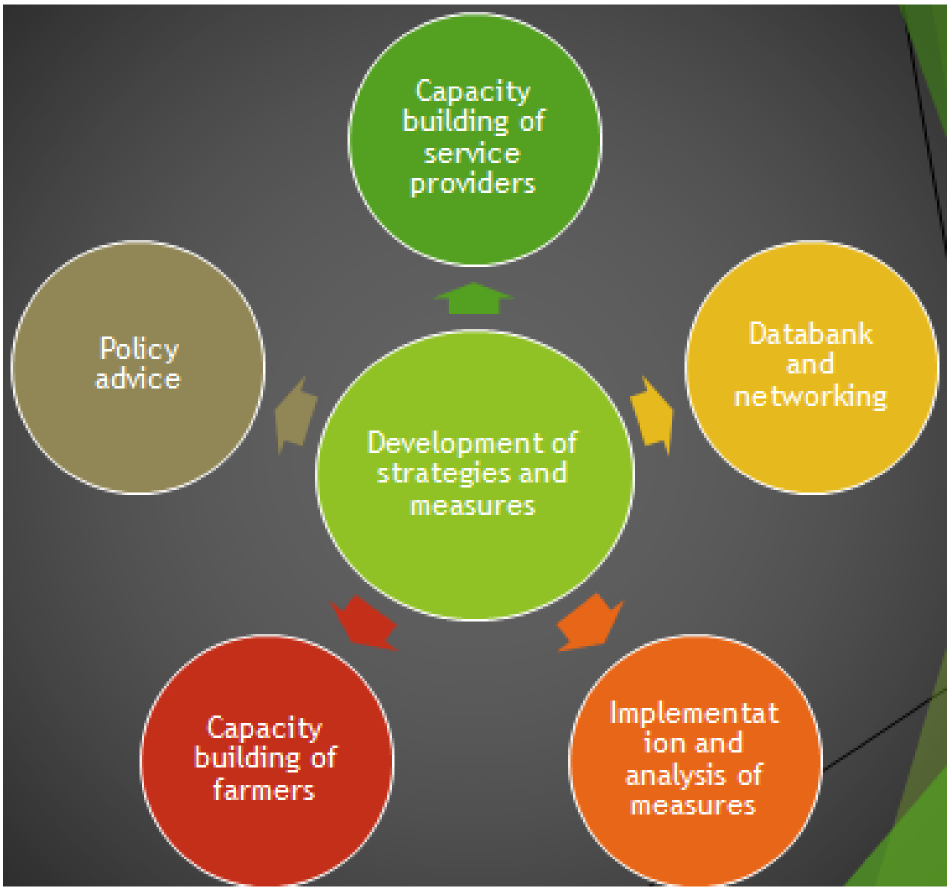
The Adaptation of Agro-Eco-Systems to Climate Change (AAESCC) Project is a collaborative project between Governments of Ghana and Germany). The project is being implemented in Northern and Brong Ahafo regions. The objective of AAESCC is to reduce climate related yield losses for the farmers and incorporate the results of the activities into agricultural sector policy on adapting land use systems to climate change. Major implementating organisations are GIZ and MoFA through the Regional and District structures; in collaboration with institutions such as EPA, GMet, CSIR, and national consultants who are contracted for specific tasks. The duration of the project is 5 ½ years (July 2012 – December 2017). The expected outputs from the project are highlighted by figure 3.3.4 for which development of strategies and measures is key.

AAESCC (2): Project intervention locations

The field activities of the project are implemented in 16 communities in the Northern and Brong Ahafo regions (4 districts, 8 communities per each region. The project is aimed at reaching 600 farm household (300 in each region). Major activities carried out since AAESCC Project (2) implementation includes the following:

- Climate change awareness creation
- Use of GPS in area measurement and coordinate picking
- Land and water management interventions
- FM Radio broadcasting in local languages
- Mobile weather forecast
- Establishing field demonstrations
- Community resource mapping
- Soil and water conservation measures
- Use of PRA for baseline survey
- Field visits by MoFA staff, Accra to assess project performance

Figure 3.3.4: AAESCC Areas of intervention and expected results (2)



On-farm Demonstration of Drought/*Striga* Tolerant Maize Varieties by CSIR-SARI (2)

On-farm demonstrations were carried out in 16 communities in the Northern and Brong-Ahafo regions using drought/striga tolerant varieties by CSIR-Savannah Research Institute (CSIR-SARI). The main objectives of the demonstration were to:

- Increase production and productivity of maize per unit area by adopting recommended scientific and sustainable management practices in maize production using drought and striga tolerant varieties.
- Reduce poverty, improve food security, income and livelihoods of small-scale resource poor farmers in Ghana's savannah and transition zones

Some scenes from the demonstration fields (2)

Demonstration field at Famisah

Demonstration field at Naniik

Demonstration field at Blema

Demonstration field at Baasari

AAESCC Project: Mobile weather forecast (2)

The main objective of this activity was to assist farmers to effectively plan using available weather information. Ignitia Limited a private entity is the service provider and over 600 farmers in project communities have signed up for the mobile weather forecast.

Farmers receive weekly (5 times per week) weather forecast through text messages on their phones irrespective of network. The weather text message contains symbols/pictures (for illiterate farmers), numbers and text (for literate farmers). All the farmers have received training on the text interpretation.

MoFA staff interacting with farmers to know their perception about the project (2)

Lailai, Atebubu district

Kwayasi, Pru district

Famisa, Chereponi District

Jilik No.1, Bunkpurugu – Yunyoo

Farmers' perception about usefulness of weather forecast

According to the farmers, mobile weather forecast is very useful because '***it enables us to plan farming activities***'. Farmers have expressed willingness to pay for that service when project is over. '*We have subscribed to certain programmes and activities that do not contribute anything meaningful to our agricultural activities why won't we subscribe to something that will provide us information on rains'*, said farmers at Famisa, Chereponi district. A farmer who is not under the AAESCC project and would like to sign up with the Ignitia weather forecasting can do so by texting START 455 to MTN at the cost of 8 pesewas Ghana Cedis per text.

Major Challenges to Implementation of Climate Smart Agriculture Research in Ghana

Some of the major challenges to the implementation of Climate Smart Agriculture Research in Ghana have been summarized as follows:

i. Inadequate Funding

ii. Weak Research-Policy Linkages: Because research is Donor driven areas of focus are not adequately linked with Government Priorities
iii. Weak institutional structures and arrangements – weak linkages between extension service providers and research Institutes due to funding constraints
iv. adoption rate of some of the improved varieties by farmers not significant for some crops.

Conclusion

Climate change impact is increasingly becoming severe. Long-term projections indicate that crop yields could fall by up to 50% by 2020. Net revenues from crops could drop by as much as 90% by 2100. It is envisaged that small-scale farmers will be mostly affected. There is therefore the need to develop more CSA technologies to increase productivity, adapt to and mitigate the effects of climate change and ensure national food security. Though faced with challenges like funding, poor research-policy linkages among others, there is the need to continue to sustain agricultural production by employing science and innovation to boost productivity, reduce poverty and address climate change in Ghana by developing climate-smart agriculture technologies. There is the need for integrated efforts to ensure achievement of goals. Strong policy instruments to empower research and development are also key.

3.4 Climate-Smart Agriculture Technologies and Practices Relating to Livestock Production

Introduction

It has been estimated that World food requirement by the year 2050 will be double that of 2010. A significant part of this requirement will emanate from the developing countries, on account of increased human populations, disposable incomes and urbanization. Meat consumption is also expected to increase by 26kg and 32kg in 2030 and 2050 respectively. A marked gap will continue to exist between developed and developing countries. Global production levels will more than double 580 -1043 Million tonnes (FAO, 2006). Livestock make a necessary and important contribution to global calorie and protein supplies. These however need to be managed carefully to maximise this contribution. Livestock are valued and will continue be consumed in increasing amounts. Meat, milk and eggs are valuable sources of easily digestible protein and essential micronutrients. The choice of production systems and good management practices are important for optimizing the protein output from livestock. Buffer against economic shocks and natural disasters are equally important.

The impacts of climate change on livestock are difficult to quantify due to the sector's uncertain and complex interactions between agriculture, climate, the surrounding environment and the economy. Increased temperatures, shifts in rainfall distribution and increased frequency of extreme weather events are expected to adversely affect livestock production and productivity around the world. Adverse impacts are reflected in Table 3.4.1. The table shows the direct result of increased heat stress and reduced water availability on livestock. Indirect impacts on livestock include reduced quality and availability of feed and fodder, the emergence of livestock disease and greater competition for resources with other sectors.

Table 3.4.1: Direct and indirect impacts of climate change on livestock production systems

	Grazing system	Non-grazing system
Direct impacts	• Increased frequency of extreme weather events • Increased frequency and magnitude of droughts and floods • Productivity losses (physiological stress) due to temperature increase • Change in water availability (may increase or decrease, according to region)	• Change in water availability (may increase or decrease, according to region) • Increased frequency of extreme weather events (impact less acute than for extensive system)
Indirect impacts	• Agro-ecological changes and ecosystem shifts leading to : -alteration in fodder quality and quantity -change in host-pathogen interaction resulting in an increased incidence of emerging diseases. -disease epidemics	• Increased resource prices (e.g. feed, water and energy) • Disease epidemics • Increased cost of animal housing (e.g. cooling systems)

CSA strategies for dominant livestock production systems

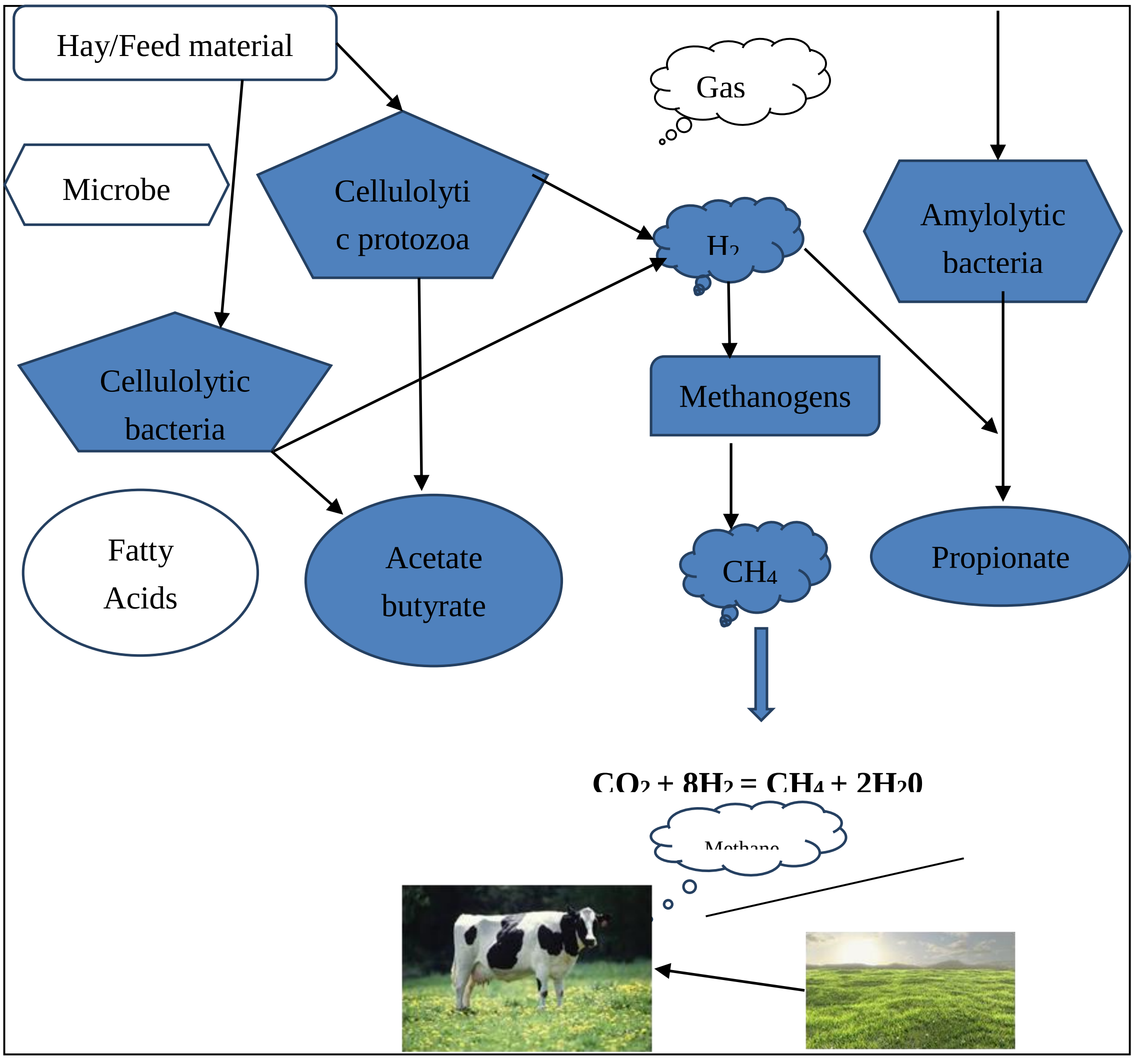
CSA strategies for dominant livestock production systems can be classified as land based systems, mixed systems and landless systems.

Land based systems: The main mitigation options could be reduction in enteric CH_4 emissions and CO_2 removals through soil carbon sequestration and manure management options. Figure 3.4.1 shows the schematic presentation on the production of methane.
Grazing management and benefits could be optimized by balancing and adapting grazing pressures on land, increasing grassland productivity and delivering adaptation and mitigation benefits. The influence of optimal grazing is variable and is highly dependent

on baseline grazing practices, plant species soils and climatic conditions (smith *et al*., 2008). Carbon sequestration stemming from reduced grazing pressure according to Conant and Paustian, 2002 stops land degradation and rehabilitates degraded lands. The intensities of enteric emissions are also lowered and give wider choice of forage for animals to select more nutritious forages. This will lead to more rapid rates of live weight gains, restored degraded grassland, improved soil health, better water retention, increased resilience of the grazing system to climate variability and reduced pressure stemming from reduced number of animals.

As a strategy for grazing management, rotational grazing can be practiced. This can be adjusted to the frequency and timing of livestock grazing needs and better matches needs with availability of pasture resources. It allows for maintenance of forages at a relatively earlier growth stage, enhances the quality and digestibility and improves productivity of the system. It also reduces CH4 emissions per LWG (Eagle *et al* 2012). It is more suited to manage pasture systems but investments are required for fencing, watering points and it is also labour intensive.

Figure 3.4.1: Schematic methane production



Pasture management and nutrition

Pasture management measures involve the cultivation of improved varieties of pasture. Typically, there is the replacement of native grasses with higher yielding and more digestible forages, including perennial fodders, pastures and legumes. It leads to carbon sequestration, improves farm productivity and reduces enteric emissions. As benefits and tradeoffs, fertilization, cutting regimes and irrigation practices may enhance productivity, improve soil carbon, pasture quality and animal performance. Fertilization may involve trade-offs between lower CH_4 and higher N_2O emissions (Bannink *et al* 2010). Net effect of GHG emissions here may be negative on grazing lands (Eagle *et al.* 2012). Forage quality may be improved by chemical and/or mechanical treatments and ensiling. With increasing variability of climatic conditions there may be increase in periods where forage quality falls short of animal demand; supplementary feeding becomes essential.

Animal Breeding

Breeding to select more productive animals, enhances productivity and lower CH_4 emissions intensities. There is evidence that cross-breeding programmes can deliver simultaneous, adaptation, food security and mitigation benefits. Cross Breeds developed with local breeds can be tolerant to heat stress, adapted to poor nutrition, disease & parasite resistance. Adaptation to climate change may involve switching livestock species. Making use of locally adapted breeds and crossing them with more productive breeds, while selecting desired traits is one of the breeding strategies.

Animal and herd management, disease control and feeding management

In all livestock production systems, there are number of animal and herd management options that can enhance productivity, improve feed conversion efficiency and reduce enteric emissions intensities. Better nutrition, improved animal husbandry, the regular maintenance of animal health and the responsible use of antibiotics can improve reproduction rates, reduce mortality and reduce the slaughter age. These measures would therefore have an effect on output produced for a given level of emission. Management of disease risks is important in the era of climate change, as there may be an increase in the emergence of gastro – intestinal parasites due to climate change (Wall & Morgan, 2009). Breeding more disease resilient animals is one approach to addressing this issue.

Vaccines

Even for low-input extensive systems with little human intervention, vaccines for methanogens (microorganisms that produce methane as a metabolic by-product in low-oxygen conditions) in the rumen are a potentially useful mitigation option for ruminants in land-based grazing systems. More research and development is however needed in this area before it can be ready for wide spread adoption.

Early warning systems and insurance

The use of weather information to assist rural communities in managing the risks associated with rainfall variability is a potentially effective (preventive) option for climate change adaptation. However, there are issues related to the effectiveness of climate forecasts for livestock management that still need to be addressed.

Livestock insurance schemes that are weather-indexed (i.e. policy holders are paid in response to 'trigger events' such as abnormal rainfall or high local animal mortality rates) may also be effective where preventive measures fail (Skees and Enkh-Amgala, 2002). There may be limits however to what private insurance markets can do for large vulnerable populations facing covariate risks linked to climate change (UNDP, 2008).
Where risks are unacceptably high for the private sector, public-private partnership approaches to index-based livestock insurance could play an important role. Indexed insurance schemes based on satellite imagery are being piloted in several areas, including Ghana.

Agroforestry practices

Agroforestry is an integrated approach to the production of trees and non-tree crops or animals on the same piece of land. Agroforestry is important for climate change because in terms of mitigation it contributes to carbon sequestration, improved feed and consequently reduced enteric methane. In the case of adaptation, it improves the resilience of agricultural production to climate variability by using trees to intensify and diversify production and buffer farming systems against hazards. Shade trees reduce heat stress on animals and help increase productivity. Trees also improve the supply and quality of forage, which can help reduce overgrazing and curb land degradation.

Mixed systems

Because they serve multiple purposes, mixed livestock systems, if well managed, may be among the most promising means of adapting to climate change and mitigating the contribution of crop and livestock production to GHG emissions. There are a number of agronomic techniques and livestock management practices, that have proven to be effective in delivering multiple benefits (food security, and improved climate change mitigation and adaptation).

Integrated soil-crop-water management

Soil and water are intrinsically linked to crop and livestock production. An integrated approach to soil and water management is vital for increasing efficiency in the use of resources, adapting to and mitigating climate change, and sustaining productivity.

Increasing the organic content of the soil through conservation tillage, the soil's water holding capacity increases, and make yields more sustainable and reduces erosion.
Key technologies include:

- Minimum or zero tillage;
- Erosion control;
- The use of crop residues (mulching) to conserve soil moisture; and improved soil cover through cover crops

By increasing water infiltration, reducing evaporation and increasing storage of rainwater in soils, many crop management practices (e.g. mulching, green manures, conservation tillage and conservation agriculture) will help land users in areas projected to receive lower levels of precipitation adapt to climate change.
Promoting the capture of carbon in the soil also mitigates climate change. Soil management practices that limit soil compaction, reduce tillage and retain crop residues, lower the potential for N_2O losses, and increase soil carbon. In addition, managing pests including weeds, and diseases using technologies such as the 'pull-and-push technology' can contribute to improving the availability of food and improve animal feed in crop-livestock systems (Lenné and Thomas, 2005).

Water use efficiency and Management

In coming decades, water management will be a critical component ~~for~~ of adapting to climate change as well as socio-economic changes. Practices that increase the productivity of water use (crop output per unit water) may have significant climate change adaptation potential for all land production systems
Some adaptation techniques and approaches proposed by FAO, 2011 include cultivation of crop varieties with increased resistance to extreme conditions; irrigation techniques that maximize water use; adoption of supplementary irrigation in rain-fed systems and water-efficient technologies to harvest water; and the modification of cropping calendars (timing or location). Strategies for improving livestock-water productivity in mixed Crop-Livestock systems include feed management (e.g. improving feed quality, increasing feed-water productivity, enhancing feed selection, strengthening grazing management); water management; and animal management (e.g. increasing animal productivity and health).

Sustainable soil management

Carbon sequestration in soils has the potential to mitigate climate change and bolster climate change adaptation (Pascal and Socolow, 2004). As a climate-smart strategy it involves creating a positive carbon budget in soils and ecosystems by using residues as mulch in combination with no-till farming and integrated nutrient management (i.e. the appropriate application of both synthetic and organic fertilizer). Soil carbon sequestration delivers numerous ancillary benefits by improving soil quality and other ecosystem services. These benefits include:

- Restoration of degraded soils, through increases in soil organic carbon pools,
- Improves productivity which helps foster food security and improves nutrition,
- Improves efficiency in the use of nitrogen and potassium,
- Improves water quality through a greater control of non-point source pollution (Lal, 2009).

Feed Management

Crop residues can represent up to 50% of ruminant diets in mixed farming systems (Herrero *et al.,* 2008). These are inexpensive feed sources but have low digestibility, deficient in crude protein, minerals and vitamins. They limit productivity and increase CH_4 emissions. Increasing digestibility of rations (improving quality, or supplementing with concentrates) reduce emissions.

CSA practices in mixed systems

This involves the use of improved grass species and forage legumes. Animal productivity can be improved by using a multidimensional approach for improving the quality and thereby the utilization of food-feed crops. This can also lead to a reduction in animal numbers, lower feed requirements and reduced GHG emissions (Blümmel *et al., 2009).* The better we feed cow the less methane per kg of milk they produce.

Diversification to climate-resilient agricultural production systems

The diversification of sensitive production systems can enhance adaptation to the short- and medium-term impacts from climate change. In parts of southern Africa, reductions in length of growing period and increased rainfall variability are leading to conversions from mixed crop–livestock systems to rangeland-based systems, as farmers find growing crops too risky in marginal environments (Thornton *et al., 2009).* Changing the mix of farm products (e.g. Proportion of crops to pastures) is an example of a farm-level adaptation option. Farmers may reassess the crops and varieties they grow, and shift from growing crops to raising livestock, which can serve as marketable insurance in times of drought. They may also introduce heat-tolerant breeds that are more resistant to drought.

In most cases, these practices in mixed farming systems deliver multiple benefits. However, before long-term benefits can be reaped, there are some trade-offs that need to be made in the short term with respect to emissions, productivity and food security. Despite the long-term benefits, poor subsistence farmers may not be willing or able to accept the short-term losses associated with some of these practices.

Landless systems

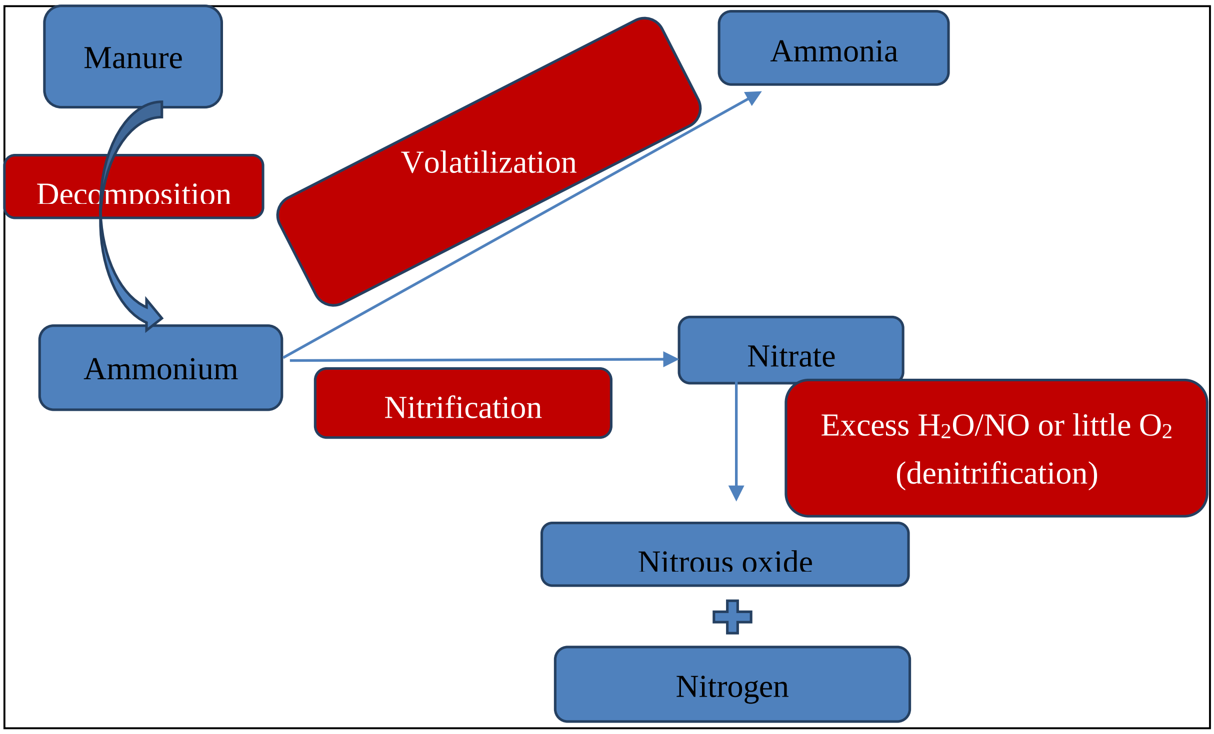
Climate-smart options are also available for intensive systems (Gill *et al., 2009; UNFCCC, 2008).*

These options mainly relate to manure management (pig, dairy, and feedlots) and enteric fermentation (dairy and feedlots). Because these systems are generally more standardised than mixed and grazing systems, there are fewer applicable options.

Improved waste management

Most methane emissions from manure derive from swine and beef cattle feedlots and dairies, where production is carried out on a large scale and manure is stored under anaerobic conditions. Green House Gas mitigation options include the capture of CH_4 by covering manure storage facilities (biogas collectors). The captured CH_4 can be flared or used as a source of energy for electric generators, heating or lighting. Energy generated in this way can offset CO_2 emissions from burning fossil fuels. Figure 3.4.2 shows the energy generation process from manure.

Figure 3.4.2: Generation of energy from Manure



(Bio-digester installed at ARI, picture by courtesy Dr. N. Karbo)

Benefits from waste management are that manure application practices can also reduce N_2O emissions. It improves livestock diets, as well as feed additives and can substantially reduce CH_4 emissions from enteric fermentation and manure storage (FAO, 2006a). Figure 3.4.3 summarises the enteric fermentation process as occurred in the ruminants. Energy-saving practices have also been demonstrated to be effective in reducing the dependence of intensive systems on fossil fuels.

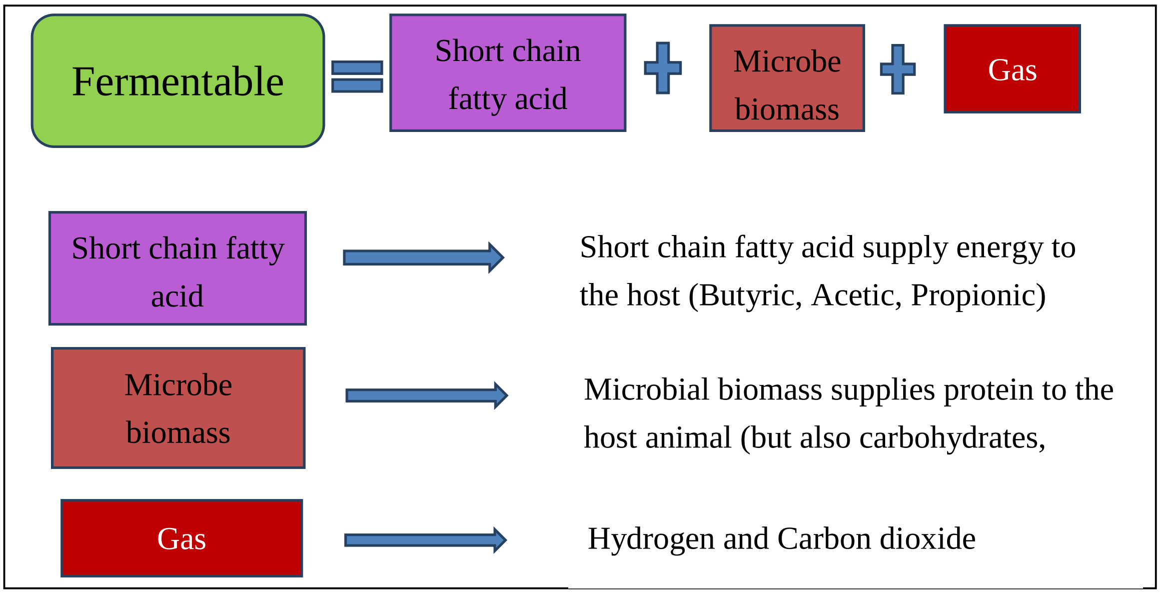
Improved Feed conversion

Carbon dioxide emissions associated with feed production, especially soybean, are significant (FAO, 2006). Improved feed conversion ratios have already greatly reduced the amount of feed required per unit of animal product. However, there is significant variation between production units and countries. Further progress is expected to be made in this area through improvements in feed management and livestock breeding. Reducing the amount of feed required per unit of output (e.g. beef, milk) has the potential to both reduce GHG emissions and increase farm profits.

Increased feed efficiency can be achieved by developing breeds that grow faster, more hardy, gain weight more quickly, or produce more milk, and improved herd health. Better veterinary services, preventive health programmes and improved water quality can also increase feed efficiency.

Shifting to feed resources with a low-carbon footprint is another way to reduce emissions, especially for concentrated pig and poultry production systems. Examples include feed crops that have been produced through conservation agriculture practices or feed grown in cropping areas that have not been recently extended into forested land or natural pastures. The use of AIBPs as feed is also important.

Figure 3.4.3: Enteric Fermentation



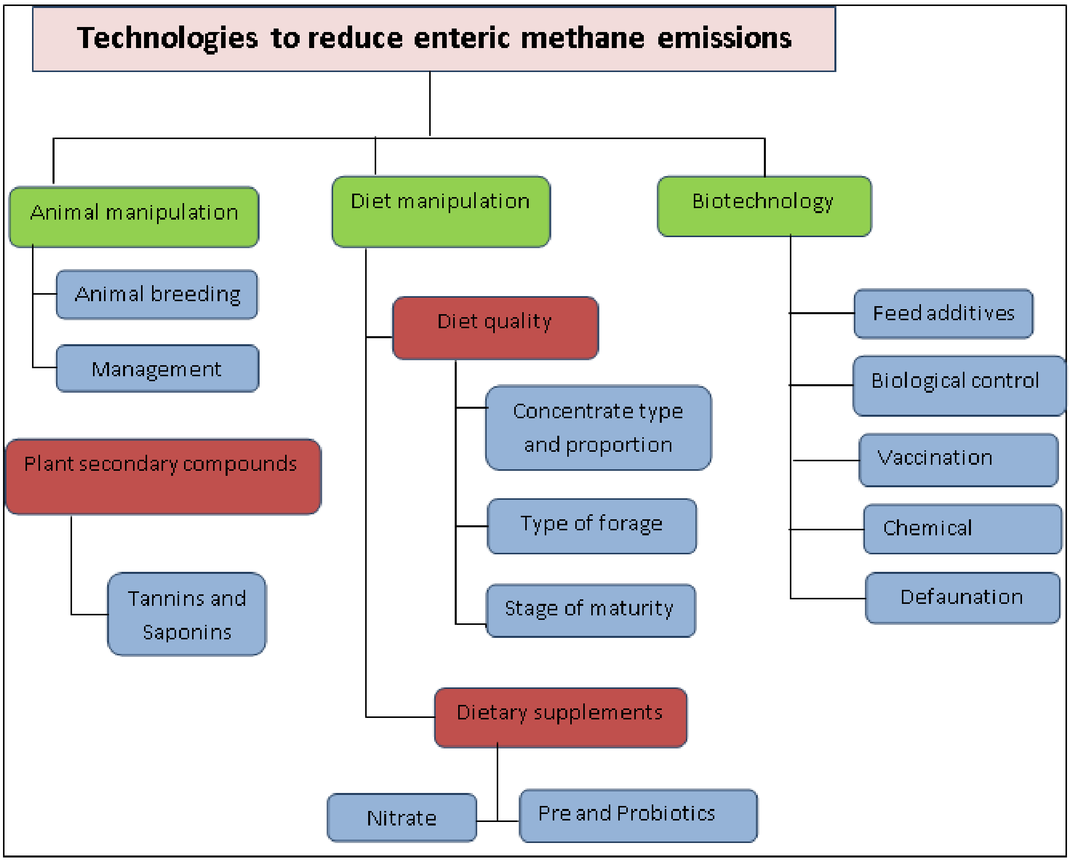
Mitigation strategies to reduce enteric methane emissions are summarized by figure 3.4.4.

Improving energy use efficiency

Landless systems generally rely on greater amounts of fossil fuel energy than mixed and grazing systems (Gerber *et al., 2011: FAO, 2009b).* Improving energy use efficiency is an effective way to reduce production costs and lower emissions. Dairy farms are seen as having great potential for energy use efficiency gains. Energy is used for the milking process, cooling and storing milk, heating water, lighting and ventilation. Cooling milk generally accounts for most of the electrical energy consumption on a dairy farm in developed countries. Cows are milked at temperatures around 35 to 37.5 degrees Celsius.

Milk store at 3-4 degrees Celsius (keeps bacteria load low). Refrigeration systems are usually energy-intensive and require energy conservation technologies such as Heat exchangers cooled by well water, variable-speed drivers on the milk pump, refrigeration heat recovery units and scroll compressors. These technologies can reduce GHG emissions, especially in countries where the energy sector is emission intensive.

Figure 3.4.4: Enteric methane emissions



Building resilience along supply chains

Landless livestock systems rely on purchased inputs. Climate change contributes to increased price volatility of these inputs, especially feed and energy, which increases the financial risks for stakeholders involved in the livestock supply chain. This is especially true where commodity stocks of inputs are kept at a minimum throughout the supply chain and buffering options against price hikes are limited. In addition, the changing disease patterns caused by climate change can quickly affect landless systems that heavily rely on transport in the supply chain.

Resilience can be achieved either by allowing chains to overcome the crisis or by creating the conditions for quick recovery after the crisis. There is little experience developed in this area however, greater coordination among the different stakeholders involved in the supply chain, insurance schemes, buffers and stocks may contribute to a greater resilience of supply chains that rely on landless livestock systems.

Conclusion

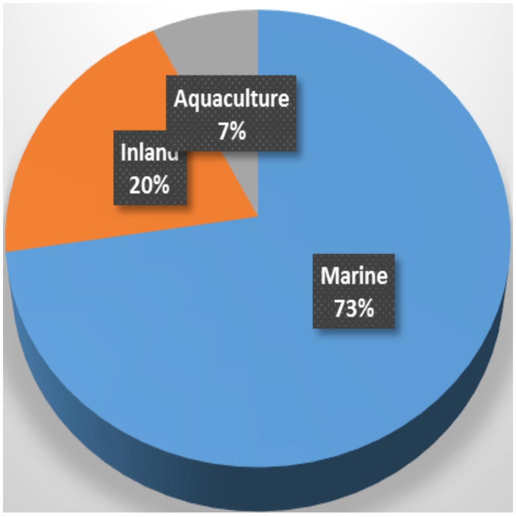
Livestock can make a large contribution to climate-smart food supply systems. The sector offers substantial potential for climate change mitigation and adaptation. Mitigation options are available along the entire supply chain and are mostly associated with feed production, enteric fermentation and manure management. Mitigation strategies in the local context could be the use of Lipids (palm kernel cake or powder), browse plants good feed improvement program, urea treatment and precision feeding that reduces nitrogen in manure or efficient nitrogen utilization. Capacity building for livestock breeders is also key as part of the adaptation Strategies. Livestock's role in adaptation practices relates to organic matter and nutrient management (soil restoration) and income diversification. Livestock make key contributions to food security, especially in marginal lands where it represents a unique source of energy, protein and micronutrients. The contribution of the livestock sector to food security could be strengthened, particularly in areas where current levels of consumption of livestock products are low.

3.5 Climate-Smart Agriculture Technologies and Practices Relating to Fisheries and Aquaculture

Introduction

The importance of Fisheries & Aquaculture in Ghana cannot be overemphasized. Agriculture potential and contribution to GDP is estimated at 35% of which fisheries contribution to GDP is 2-5 %. The subsector provides about 60% of national animal protein requirement and provides 10% direct and indirect employment. Annual national protein requirement is 1,062,194 MT and whilst annual production is estimated at 434,120.32 MT, (marine contributes 73%, Inland 20%, and Aquaculture 7% (Figure 3.5.1)) leaving an annual deficit of 628,074 MT. Fish imports alone stood at 150,700 MT valued at $135,118,500.77 and Fish export is 56,626.25mt valued at $209,795,314.

Figure 3.5.1: Contribution of Marine, Inland & Aquaculture Sub-sector to total Fish



Fisheries Resources

Ghana fisheries resources covers 550 Km marine coastline from Half Assini to Aflao (EEZ of 24,300 km^{2}). These include 50 lagoons, Volta Lake (covering an area 900,000 ha); coastline of 5,000 km, rivers, dams and dugouts. Aquaculture has over 5,000 fishponds; 2,500 fish cages and 76 pens. The challenges are that fish stocks are under intensive pressure and are rapidly declining. According FAO, about 84 % of world's fisheries are over-exploited, fully exploited, or depleted and this presents a major concern for all stakeholders. In Ghana, our weak wild fish cannot meet demand and therefore aquaculture is the hope to bridge the gap. Trending the fisheries sub-sector's Gross Domestic Product (GDP), its contribution between 2008 and 2013 were 2.7%, 2.5%, 2.3%, 1.7%, 1.6% and 1.5% respectively. The clear indication therefore is that the sub-sector has been experiencing a progressive decline in its contribution to agricultural GDP over the past six years. The decline could be attributed to low value fish catch by fishermen, consistent unfavorable climatic conditions (such as higher sea-surface temperature, lower salinity and lower upwelling index), human factors (such as light fishing, use of unapproved fishing gears, use of dynamite in fishing etc.). Table 3.5.1 shows some of the important indicators and performance of the sub-sector.

Table 3.5.1: Summary of Important Performance Indicators of the Fisheries Commission for 2012 and 2013

	2012	2013
Average Annual Sea Surface Temperature	26.1 ^{o}C	26.2
Average Annual Salinity	33.30	33.2
Annual Upwelling Index	24.20	23.1
Total Annual Fish Requirement	1,036,336mt	1,062,194mt[1]
Annual Fish Production	456,147.56mt	434,120.32
Annual Marine Fish Production	333,697.00mt	314,867.57
Annual Inland Fisheries Production	95,000.00mt	86,740.75
Aquaculture Production	27,450.56mt	32,512.00
Fish Imports	181,824.62mt	150,700.61mt
Value of Fish Import (FOB)	$158,974,508.86	$135,118,500.77
Fish Exports	62,984.07	56,626.25mt
Value of Fish Export	$209,246,963	$209,795,314
Fish Self Sufficiency (%)	56.0% of Annual Requirement	49.7%
Total Number of Vessels Licensed to Fish	129	138
Number of Newly Registered Vessels	14	16
Total Number of Quayside Inspections of Vessels	944	1,034
Total Number of Vessels Arrested For Infringing on Laws	14	8
New Ponds Constructed	189	139
Total Surface Area of Ponds Constructed	30.065 ha	-
New Cages Developed	753	11
Total Number of Fingerlings Produced	79,380,269	130,127,500

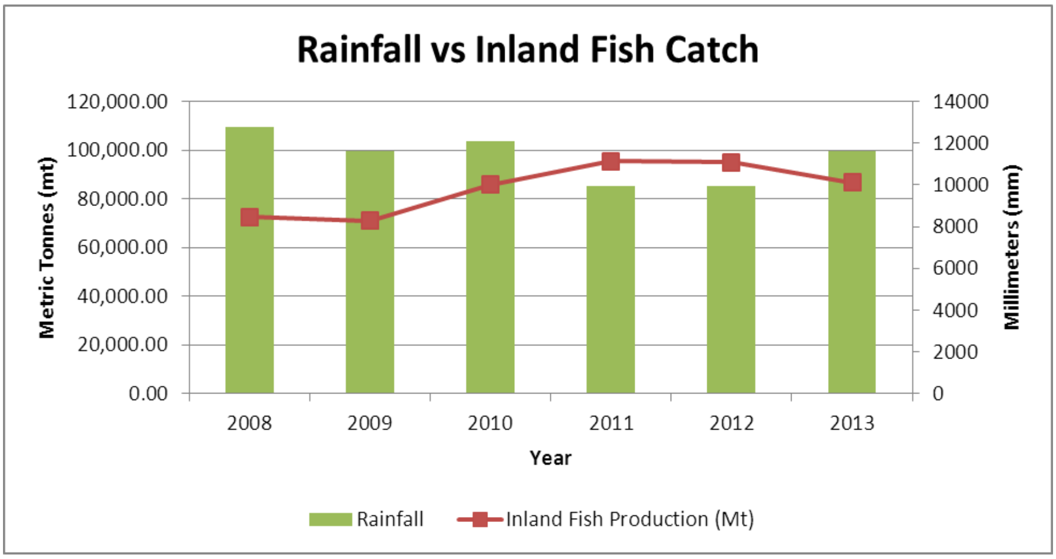
Climate change processes and impacts on fish production

The impacts of the accumulation of Green House Gas (GHG) in the atmosphere and water relate to a number of physical phenomena. Gradual changes in water temperature, acidification of water bodies, changes in ocean currents, rising sea levels are some physical changes that affect ecological functions within aquatic systems/ecologies.

Changes in rainfall causes a spectrum of changes in water availability ranging from droughts and shortages, floods, reduce water quality, saline water further upstream in rivers, rising sea level threatens inland freshwater and aquaculture. Changing rainfall patterns and water scarcity impact on river and lake fisheries and aquaculture production. Figure 3.5.2 show the relation between rainfall and inland fish catch. Higher rainfall in the tropics is expected to enhance the quality and quantity of freshwater fish habitats by improving river flows and the connectivity between river channels.

At the onset of the rainfall water bodies become more turbid, water surface becomes cooler and fishes move to the surface and can easily be caught by the fishermen. When the rainfall intensifies the fishes move to the bottom of the river body and hide making them unavailable.

Figure 3.5.2: Relationship between Rainfall and Inland Fish Catch



Integration of climate change into fisheries management and CSA Innovations

Some mitigation measures that could be used to integrate climate change into fisheries management include:

- Increase monitoring of stocks and maintain basic fish sampling.
- Ensure that fisheries' interests, including the need for conservation of resources, are taken into account in the multiple uses of coastal zones and are integrated into coastal area management, planning and development.

- Conduct climate change risk assessments for native fisheries to identify species and populations that are at risk, and include potential economic losses and the costs of adaptation measures.
- Ensure that land and water resource managers at the state and local levels integrate adaptation options into planning, programs and practices.

Reducing the impact of invasive species is one of the options. There is the need to promote the health of native populations, which gives them a better chance to compete successfully. Strengthening rules for cleaning and transporting boats and fishing gears to reduce invasive species outbreaks, increase research into new techniques for controlling/managing invasive species and increase monitoring and control of invasive plant and aquatic species are important options for consideration. There is also the need to develop regulations aimed at preventing future incursions of exotic and invasive species.

The construction of floating cages is important since it can adapt to changing water resource opportunities.

The introduction of saline or shock tolerant fish species and the use of quality fingerling and brood stock are important. The use of indigenous species, short duration and fast growing species that can combat seasonal variations in livelihood returns is important. The use of efficient feed conversion species is also important.

Enhancing the adaptive capacity in terms of productive livelihood (new income opportunity) option for fish farmers, women and poor households, will lead to better nutrition (livelihood diversification). There is the need to also to implement insurance scheme in this sub-sector.

Conclusion

Improving management of individual fisheries and ecosystems to build climate resilience is important. The use of science-based approach to better target protection and management actions by establishing temperature ranges and maximums and other water quality ranges for resource management are important. There is the need to review existing legal, regulatory and policy frameworks that govern protection and restoration of fisheries habitats, and identify opportunities to improve their ability to address climate change impacts. Basing conservation and management decisions for fisheries on the best scientific evidence available, and consideration of traditional knowledge of the resources and their habitat, including current and future environmental, economic and social factors are very important issues.

Also the integration of sustainable fisheries management into local land planning and development regulations and supporting initiatives to reduce commercial fishing in already stressed fisheries; (lightly fished stocks) are likely to be more resilient to climate change impacts than those heavily fished are necessary. There is the need to strengthen and enforce laws that govern fisheries and also identify water-rights options that protect fish and wildlife. Preventing overfishing and rebuilding depleted fisheries is important. Maintaining fisheries above biomass levels to produce maximum sustainable yields; since it will ensure more resilient populations under changing environmental conditions.

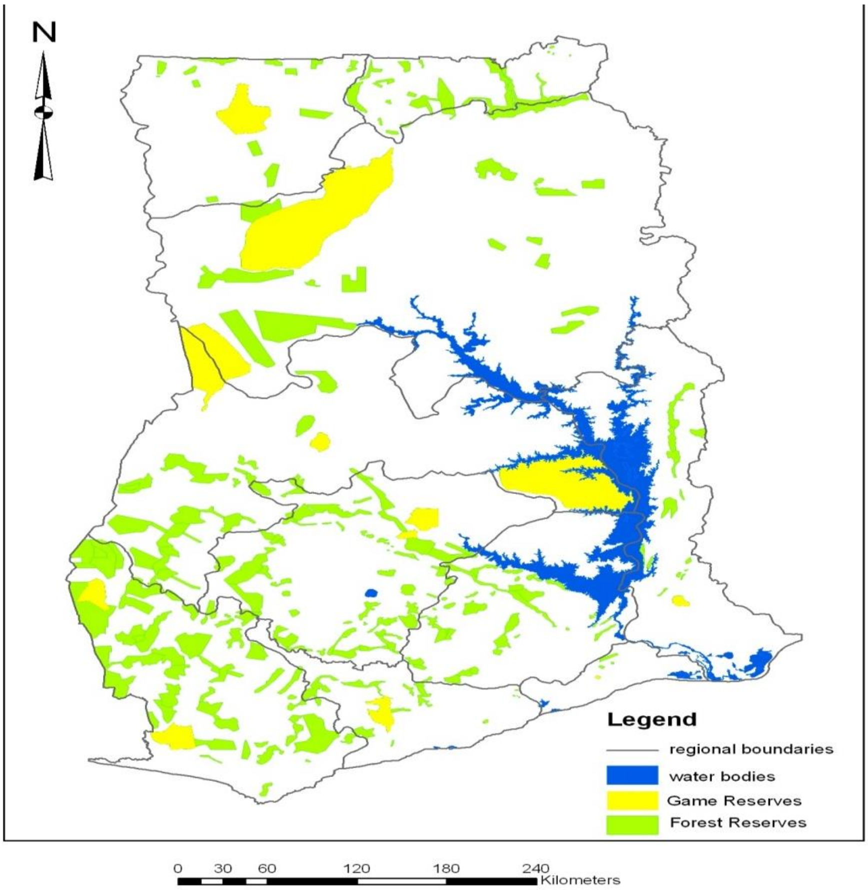
3.6 CSA Technologies and Practices Relating to Forest Management

Introduction

Rapidly increasing population (2.6%) which has increased ten folds since the beginning of 20th Century cannot be overemphasized. There has been extensive expansion of agricultural lands using low technology systems in order to feed the increasing population. Today there is widespread degradation of farmlands making most areas to lie waste (Table 3.7.1). The original endowment of extensive forest resources (hfz) is now reduced from 8.2 million ha to approximately. 1.6 million ha. High dependence on low-productive natural forests for timber supply has also led to over-exploitation and consequent forest degradation. Annual bush fires (set for fresh pasture, etc.) also lead to massive Carbon emission into the atmosphere. Deforestation and forest degradation contribute approximately 18% of Carbon emission. The consequence is the climate change with resulting impacts of erratic rainfall, extreme temperatures, floods, low productivity, etc. The National Policy on Climate Change, NRAC, REDD+, ProVACCA, FIP, etc. were all introduced to address these impacts.

Figure 3.7.1 shows the forest reserves in Ghana with the legends describing existing water bodies, game and forest reserves.

Figure 3.7.1: Forest Reserves Map of Ghana



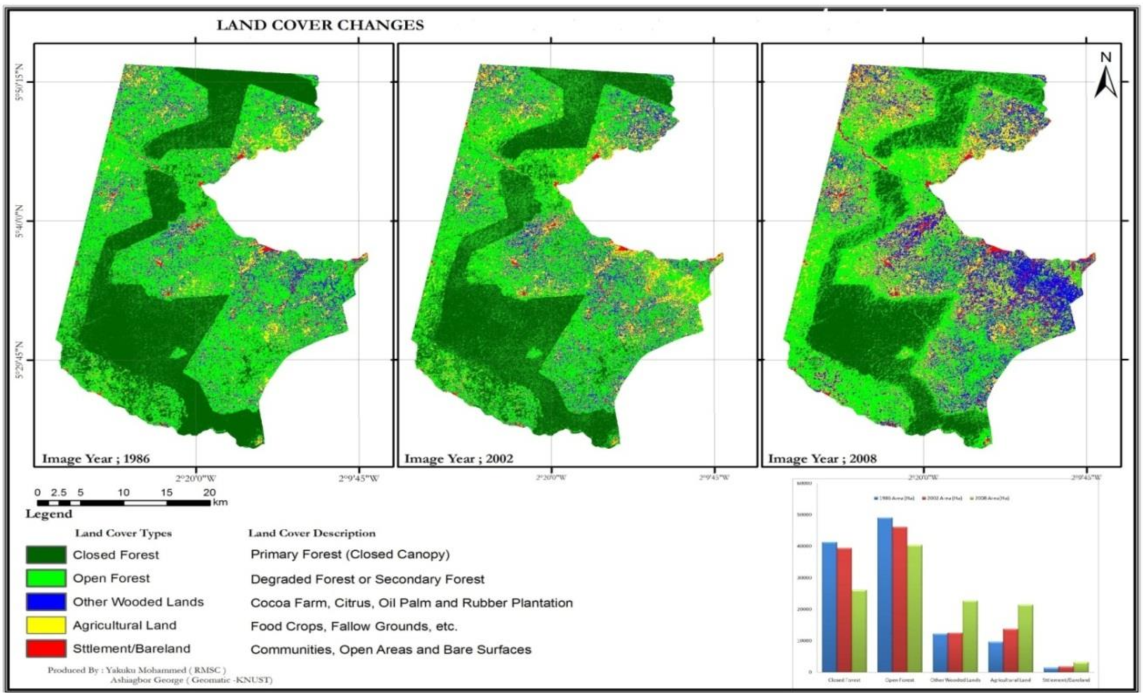
Picture shows a typical Modified Taungya farming system in Ghana.

Table 3.7.1 shows the high forest zone and land area outside forest reserves in Ghana.

Table 3.7.1: High Forest Zone Land Area Outside Forest Reserves			
Region	**Land area (m ha)**	**Area off-reserve**	**Percentage**
Ashanti	2.44	2.08	85
Central	0.95	0.76	80
Western	2.25	1.57	70
Eastern	1.89	1.71	91
Brong Ahafo	0.99	.77	79
Total	8.54	6.92	81

The figure 3.7.2 shows the forest cover change with the light green legend showing the open forest which represents degraded forest or secondary forest. It reveals that the close canopy forest is given way to other wood lands coupled with increasing agricultural lands (food crops and fallow grounds) and rapid settlement (communities, open areas, bare surfaces).

Figure 3.7.2: Forest Cover Change (Asenanyo FR & Off FR Time Series Analysis)



Enabling Factors for Agriculture and Forest/Tree Integration

Ghana possesses competitive advantage in tree growing; because it has good climate, good soils with approximately 50 per cent of population being rural. Farmers in Ghana have been exposed to tree crop plantation culture and over 1 million ha of cocoa plantations; oil palm, citrus, woodlots etc. Farmers now link forest/tree conservation or growing to adequate rainfall, improved soil fertility, Non-Traditional Forest Products supply, etc. Indigenous tenure arrangements exist to govern tree crop growing and several viable approaches also exist for agriculture landscape restoration. Table 3.7.2 shows an example of trees and crop integration approaches in Ghana.

Table 3.7.2: Trees and crop integration approaches

Land use type	Approx. Area (m ha)	Suitable Planting Type	Species recommended
Acheampong (degraded farmlands)	1.41	Woodlots	Fast growing exotics with later introduction of indigenous
Food crops	1.21	Boundary & dispersed	Indigenous
Cocoa	0.98	Dispersed	Indigenous
Natural forest	0.67	Enrichment planting	Indigenous
New farms	0.50	Flexible	Both exotics and indigenous
Grassland	0.50	Woodlots	Fast exotics resistant to wildfires
Secondary forest	0.17	Enrichment planting	Indigenous

Integration continued

Planting Options	**Description**	**Trees per ha**
Woodlots	Trees in pure stands with canopy closure at full establishment	1100-2500
Boundary	Tress planted in multiple or single rows (e.g., Australia) along farm boundaries at 2 to 4 m intervals	100 – 400
Dispersed	Trees planted at regular or irregular intervals at wide spacing (25m) to allow continuous cropping	25
Alleys	Tree are planted widely (10m x 2.5 m) and crops grown in-between	400

CSA Innovations:

Some of the CSA innovations introduced include:

Modified Taungya System

Under the modified Taungya system, tree cropping (cocoa, etc.) is grown adopting the 'Taungya' system of agriculture crops at initial stages. The modified Taungya was introduced as viable partnership system for improved success of forest plantation established. There is joint ownership between government (investors), landowners and (landless) farmers. This system is based on a tree share ratio of for instance 40: 40: 15: 5.

With this system, there are no land encroachments and some of the advantages include bush fire prevention, wealth creation, improved Non-Traditional Forest Products (NTFPs) such as bush meat supply. This leads to improved environmental conditions in terms of climate, microclimate, watershed, carbon, etc.

Benefits of tree crop integration in agriculture systems

- Source of income when on pension and in old age;
- Provides security against adverse crop failure;
- Storage of wealth and environmental conservation;
- Multi-purpose use of products in terms of provision of fuel wood, plants for livestock browsing, availability of medicinal herbs, fruits, etc.

Key challenges are that most farmers in degraded landscapes are migrants with strict tenure arrangements restrictive to tree planting. Land access and tenure is most hindering factor in tree planting, lack of easy access to seeds and seedlings, inadequate extension support are some other challenges indicated.

It was concluded that there is the need to create awareness and provide incentives to deserving farmers for the adoption of climate smart agriculture during national farmers' day award ceremony, etc. Conservation of existing trees on farms and adoption of agroforestry/Woodlot systems is important. Facilitation of tenure arrangements to promote tree planting culture and the provision of logistics and technical support by agriculturists, foresters and scientists are also very crucial as well as continuous research on integrated agriculture and tree systems in terms of ecology, economics, social, etc. Link up with ongoing EPA, MOFA and Forestry Programmes such as ProVACCA, REDD+, FIP, CCAFS, etc. to promote synergies. There is the need to formulate organizational policies and plans for climate smart approaches in all operational activities.

3.8 Climate Smart Agricultural Mechanization and Modernization of Agriculture in Ghana

Introduction

Climate involves issues related to temperature, humidity, pressure, rainfall, solar, wind, dust, etc. To be smart about the changes of these in any geographical area is to adapt and avoid making such factors change further. Agricultural mechanization involves the use of tools or machines to aid human labour to increase agricultural production economically and ensure Environmental protection. Agricultural mechanization, which is divided into four special areas such as crop, livestock, irrigation and post-harvest are in the frontline of climate change and therefore, climate change smart principles are very important to the application especially in crop, livestock and post-harvest. Modernization is the application of Technology (Hard or processes) in Agriculture for higher production or productivity. Modernized agriculture can be defined as maximizing production from a minimum input of resources. In crop production, the resources are land, labour, plant material and post-harvest management of produce. Livestock is also linked to breeds, feed, health and post-harvest management of livestock products. The major and common denominator of the above systems of production is engineering and for that matter mechanization. This is supported by the fact that Countries that are said to be modernized have a great input of engineering.

Agricultural Mechanization in any Country is assessed with the number of tractors employed in production or technology used in the entire production line of commodities in that country. The intended objectives of agricultural mechanization here, are thus not confined to land and labour productivity alone, but include its consequent impact on poverty reduction and human development.

It is on record (MOFA-FASDEP - 2002) that Ghana has a total land area of approximately 24 million hectares of which 57% (13.7 million hectares) is suitable for agriculture and 8 million hectares convenient for mechanical powered machines. Less than 20 % of this area is cultivated. The Ghanaian agricultural sector consists of food crops, livestock and fisheries. Without significant improvement in agriculture’s performance, the long-term goal of the country cannot be achieved as projected in national Vision documents. To achieve this target on a sustainable basis, the additional growth in agriculture has to be derived from rapid increases in production and productivity of farm labour through the interplay of all the agricultural technologies such as Agricultural Mechanization activities.

Climate Change effect and interventions in Agricultural Mechanization

The climatic conditions such as temperature, pressure, humidity and many others have great influence on the effectiveness of the performance of the internal combustion engine of a tractor. Some researchers (Kuznesov 1987) have come out with some ranges on the temperature and pressure influence on power development as stated in Table 3.8.1. This means any specification output power of a diesel engine will reduce by 2.2% if there is a temperature change at every 10 ºC. Pressure changes accounts for some similar changes in output power of engines.

Table 3.8.1: Engine power development % depending on the change of temperature of air and pressure

No.	Factor and Condition.	Petrol	Diesel
1.	Temperature changes at every 10 ºC in the range of 10 – 60 ºC	1.8	2.2
2.	Pressure changes at every 10mm Hg and not below 60mm Hg	1.35	1.35

The effect of dust on engines

Dust in the air affects the work of automobiles and others with internal combustion system for different purposes due to wear of machine aggregates and machine parts. Dusty conditions depend on so many factors like the season, type of road or soil, weather, wind direction, movement intensity, etc. Dusty air is characterized by the weight of dust in a cubic meter of air. Generally, air with less than 1mg/m^3 is accepted technically as clean air. European roads have reduced soil dust to about 0.00025 – 0.001 g/m^3. On rough roads the condition of dust in the air ranges 0.4 – 0.45 g/m^3 but when crawlers are moving in a convoy the soil dust ranges 1.25 – 2.0 g/m^3 (Kuznesov 1987). Research have proven that where dust ranges 0.8 – 1.2 g/m^3 then clarity is lost. Averagely for different conditions of automobiles exploitation it should not exceed 1.4 and for crawlers it should not be more than 2g/m^3. In the big cities dust should not exceed 0.00025 – 0.0084 g/m^3. As seen from the references above it is very important to avoid using or working under dusty condition. But one cannot avoid dusty conditions at work, it is necessary to take the following recommendation as a corrective measure in maintenance schedule. The servicing here is mainly referred to as change of oil. Smart servicing is recommended in Table 3.8.2 looking at the relativity and half (1/2) or one third (1/3) or one quarter (1/4) the number of hours required for servicing if your location is in a dusty area such as Ghana.

Table 3.8.2: A Smart Comparative servicing length of different parts of a tractor in a dusty area.

Part of A Tractor	Servicing length (Hours)	
	Normal condition	Dusty condition
Engine	3000	1500 ($^{1}/_{2}$)
Clutch	3000	800 – 1000 ($^{1}/_{3}$)
Gear box	4400	1000 – 1600 ($^{1}/_{4}$)

Climate Smart practices in Crop and Livestock production

Rainfall affects the condition of the soils that is worked on and as such, affects the tillage machines. Soil mechanics almost exclusively has been receiving attention in research fields and applied to the problem of designing tillage machinery. The main objectives of tillage that serves crops and livestock are to prepare a seedbed suitable for the growth of the crop or fodder, leave the soil in a condition to absorb, retain moisture and to improve aeration, add humus and fertility by incorporating plant residue, manure or seed into the soil and influence subsequent mechanize practices. These objectives are only achieved by certain implements such as soil condition and some approaches, which are crucial for smart tillage operations. These include:

- Tillage Implements and selection
- Soil friction and moisture content for ploughing
- Methods of Smart tillage for Soil and Moisture Conservation

Tillage Practices

It is the process of the working ~~of~~ the soil loose to provide favourable conditions for agricultural purposes. Tillage is further classified into two main groups namely: **Primary and Secondary Tillage.** There are certain groups of implement that fall in the various tillage classes but it can be found out that sometimes some of the secondary tillage equipment is used for primary tillage purpose.

The Mouldboard plough and the Disc plough are among the implements mostly used for tillage. The disc plough does the same activity as the mouldboard but they are different in construction. The disc plough mostly three concave disc that work the soil whiles the mouldboard plough has its main parts as the mouldboard component for handling the soil and the share for cutting the soil.

Whiles the disc plough can work so well on virgin fields full of stumps and rocks, the mouldboard plough cannot work well under such conditions. But it has the advantage of wider options of depth of cut for ploughing, optional ploughing objectives and does not dilute the top soil. Studies conducted by Mahama (1997) on the tubular fixed bottom disc plough shows it can leave unploughed land when used (Figure 3.8.1).

Table 3.8.3 shows the various depths of cuts and the percentage of profile left unploughed. Maximum depth of cut for disc diameters of 66 cm and 55 are calculated as 22cm and 18cm respectively. The more a disc will be worn, the greater the unploughed land. Ahn (1977) reported that the average topsoil depth of West Africa sub-region is around 15 cm. This suggests that the disc plough works beyond the top soil hence burying the productive topsoil after ploughing.

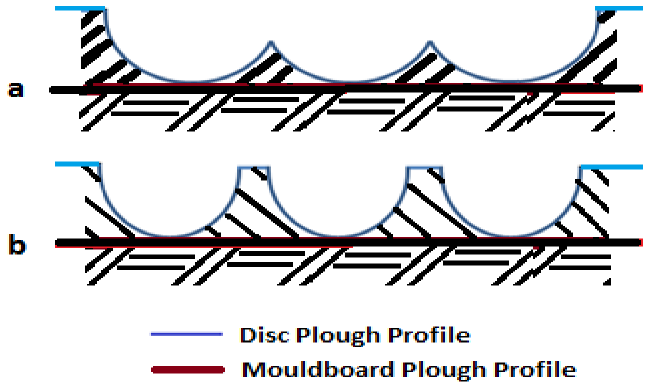


Figure3.8.1. Cutting profiles of soil after the pass of tubular Disc and Mould board ploughs

Table 3.8.3: Untouched land Percentage with varied disc diameter and depth of cut

Disc Diameter D cm	Untouched land 'η' percent at varied depth			
	10cm	**15cm**	**20cm**	**25cm**
66	65.4	42.2	31.7	25.4
60	75.0	50.0	37.6	30.1
55	92.7	61.8	46.4	37.0

Rainfall intensities are very high with little protection from vegetation or residues. Kamal and Kassin (1975) reported that about 60% of rain drops at Samaru in Nigeria are over 3mm in diameter and energy of 35.77 J/m^2. Out of 1091mm yearly average rainfall, 635 mm was said to be erosive power with a load of 24.18 J /m^2. Highly erosive rain of this type in the tropics especially in Ghana obviously subjects the soil to a very severe test on ploughed lands especially with disc ploughs with the profile illustrated in Figure 3.8.1.

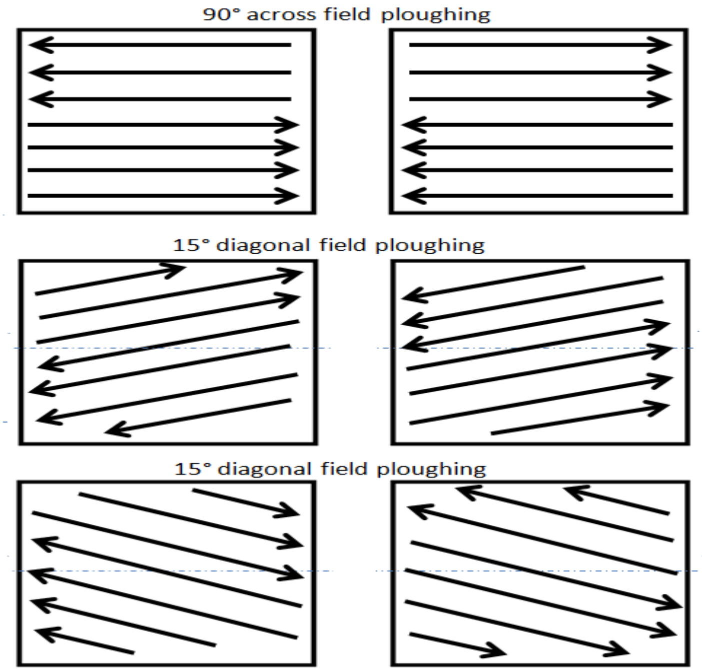


Figure 3.8.2. Options of ploughing traffic for change in subsequent year's field operation.

Smart tillage Operations

From the above discussions the following climate smart tillage operations are recommended.

- Determine the appropriate moisture content for tillage
- Use the appropriate tillage implement.
- Keep records of previous ploughing traffic to vary the next traffic (Figure 3.8.2)
- Use a well-trained tractor operator and not a tractor driver

Climate Smart Mechanization on Livestock

The following section elaborates on some of the issues and their corresponding smart mechanization alternatives or remedies.

Large Ruminant Husbandry and the Environment

The provision of housing for large ruminants is needed due to the effects the absence of proper housing can have on the environment. Some of these effects are not readily visible but become worse with time. Indiscriminate grazing by large ruminants destroys vegetation. It is reported that about 70% of available vegetation can be eaten by livestock when grazing on the field in a free range system. Continuous effect of free range is loss of vegetation which in-turn affects the climate.

Another important but ignored component is soil compaction on the fields with free range systems. It is estimated (Mahama, 1994) that the average pressure under the feet of a cow is 6 - 13 t/m^2. This will create serious compaction issues for wet soils when livestock is allowed to graze on such a field. To put this in perspective, the average pressure under the tracks of a pick-up truck is about 35 t/m^2 whiles the acceptable compaction pressure is about 2.8 t/m^2 (Daum, 2015). As such the provision of adequate housing for large ruminants will seriously help conserve the environment.

Watering Systems

Watering has been very vital in livestock production for poultry and ruminants. However, the most critical is that of the ruminants. The practice in Ghana is mainly free range ~~of~~ feeding which normally starts in the morning to evening. Water source have not been located to the convenience of the herdsmen and therefore the greater part of the fodder eaten by the ruminants is expended in the search for water or to water sources. This could have been directed to the growth and maintenance of the ruminants. Another smart watering system is the use of wind pumps for lifting water from boreholes on farms or grazing fields and for livestock watering systems. This provides regular water supply and a renewable energy source.

SOLAR ENERGY (Renewable Energy)

- Use of Solar Inverter power for lighting in poultry houses and ruminants
- Taking advantage of solar energy for drying

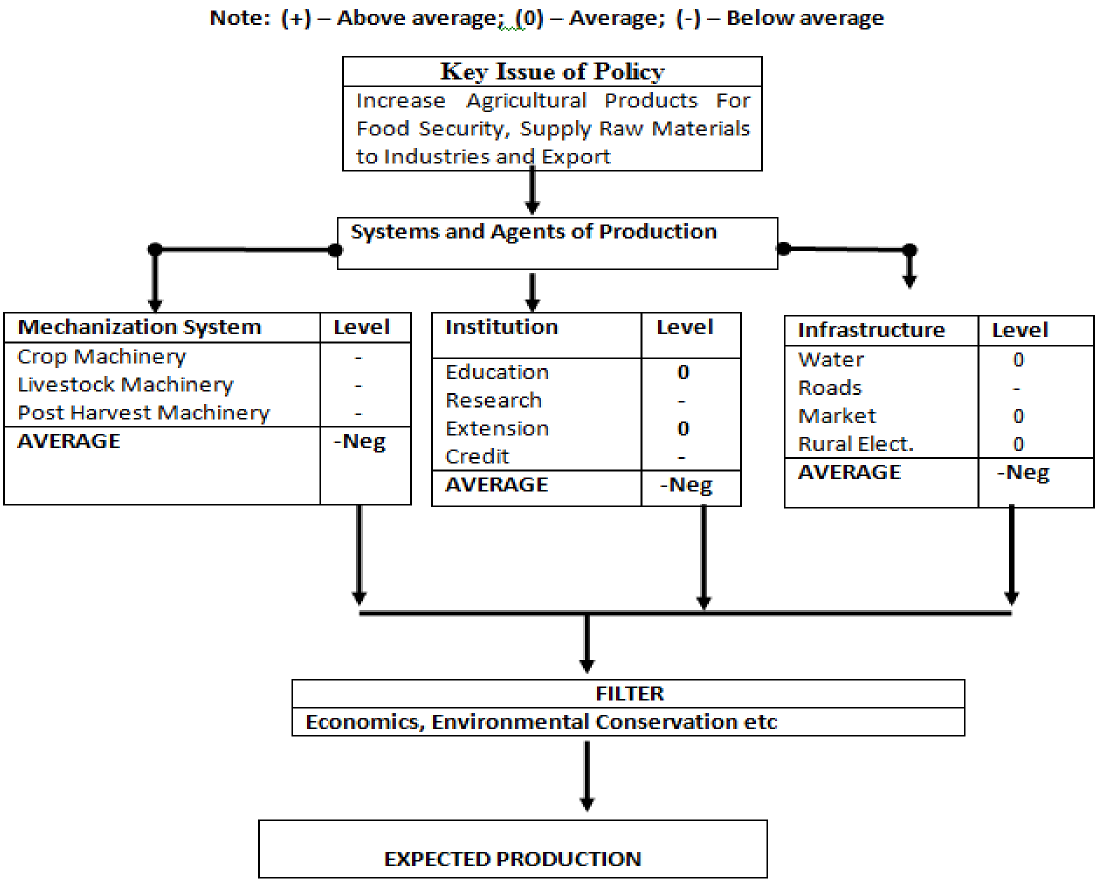
Use of Solar Inverter power for lighting in poultry houses

Light in the pens of birds will increase feeding time and will influence greatly the growth rate of the birds and prepare them for market early. This is evident with the broiler production. Here, the Agricultural electrical engineers have their role to play in promotion of production.

Taking advantage of solar energy for drying

Solar drying technology will offer an alternative source of energy for processing agricultural produce (root and tubers, fruits and vegetables) in clean, hygienic and sanitary conditions to national and international standards at very low cost. It saves energy, time and occupies less area, improves product quality, makes processing more efficient and protects the environment. Solar drying technology can be used in small-scale food processing industries to produce hygienic, good quality food products. At the same time, this can be used to promote renewable energy sources as an income-generating option. Further, this solar technology will ideally be suited for women since they can place the load in the dryer and then get on with their other numerous household tasks (Seidu *et al*, 2008). Solar drying which takes place in an enclosed ventilated area is able to do away with all the problems associated with the traditional open sun drying and bring about sustainable income and food security. The matrix shown in Fig. 3.8.3 illustrates the policy being implemented through a category of farmers with access to the appropriate power sources in mechanization systems, institutions and other infrastructure to achieve the appropriate results. Improving or building up the systems, institutions and infrastructure will have to filter through the conservative practices and economics to get results that will be sustainable with growth. It is clear from the estimates that Ghana is still far from modernising Agriculture.

Figure 3.8.3: A matrix of Modernizing Agriculture through Mechanization input in Ghana



Conclusion

Climate change involves issues related to temperature, humidity, pressure, rainfall, solar, wind, dust, etc. To be smart about the changes of these in any geographical area is to adapt and avoid making such factors of climate change further affect negatively. Agricultural Mechanization has been one of the main pillars of any accelerated agricultural growth and has a direct correlation with the kind of energy used in agriculture. The analyses showed that Ghana is still far from modernized agricultural production. Measures of climate change that need to be taken to ensure that farmers also have access to a level of mechanization technology appropriate to their circumstances for agricultural production are also discussed for policy makers and professionals. For Smart Agricultural Modernization to take its rightful place in the development of agriculture in Ghana, strategies, which cut across all the technologies based on agricultural mechanization and other labour saving technologies should be developed and pursued.

CHAPTER FOUR

4.0 Profiling of CSA practices by Researchers, Farmers, Development workers and Policy decision makers

4.1 Profiling of CSA technologies and practices in the Guinea savanna Agro-ecological Zone of Ghana

There was great similarity in the CSA technologies and practices identified between the stakeholder categories in the study and probably demonstrate a sense of good knowledge by participants of the existing practices in the agro-ecology. A total of 61 technologies and practices were listed by all the groups. However, when double counting was accounted for between the groups, the figure was brought down to 53. The top twenty-six practices, the farmer category using them and the location/scale of practice was characterized and presented in Table 4.1.1.

Table 4.1.1: CSA technologies and practices, type of users and scale/location of practice in the Guinea savannah area

CSA Practice	Type of Farmer User			Location/Scale of Practice
	Smallholder	Medium	Large	
Farmer Managed Natural Resource Tree Regeneration (FMNRTR)	✓	-	-	Projects Lawra, Nandom
Conservation agriculture	✓	-	-	Projects Lawra, Nandom, Bawku
Agroforestry	✓	-	-	Whole Region
Mulching	✓	-	-	Whole Region
Weather forecast	✓	-	-	Whole Region
Mixed farming	✓	✓	-	Whole Region
Bee keeping	✓	-	-	Whole Region
Crop rotation	✓	-	-	Whole Region
Tie ridging	✓	-	-	Whole Region
Half moon and Zai	✓	-	-	Lawra, Jirapa, Nandom
Community led bush fire control	✓	-	-	Lawra, Nandom Jirapa
Stone bunding	✓	-	-	Yaga, Tugo Doggoh zones
Earth bunding	✓	-	-	
Ridging along contours		-	-	Whole Region
Composting	✓	-	-	Whole Region
Strip cropping	✓	-	-	

Tree planting (agroforestry and plantations)	✓	-	-	Whole Region
Supplementary feeding-livestock	✓	-	-	Whole Region
Manuring	✓	-	-	Whole Region
Fodder banking	✓	-	-	Whole Region
Minimum tillage	✓	-	-	Whole Region
Cross breeding and selection-livestock	✓	-	-	Region wide
All male tilapia culture	✓	-	-	Busa, Guo location
Gill netting	✓	-	-	Whole Region
Crop-livestock integration	✓	-	-	Region wide
DT maize	✓	✓	✓	Region wide

Most of the identified practices by the various stakeholder categories were observed to focus on addressing soil fertility > Crops > Water > Livestock > Aquaculture in that order. Limited focus in the scope was given to information technology. The CSA practices were found to be gender neutral in their use but were largely used by smallholder farmers. The ranked preference for CSA practices in the savannah was in the order of Farmer managed natural regeneration of trees (FMNRT) > Agro-forestry > Mixed farming > Mulching = Bee keeping, etc. The cost sieve in the criteria was a decider in the observed differences in pooled scores. Least rated technologies and practices in the savannah area included: Drip irrigation, proper storage, insurance, local level by-laws, combined use of mineral and organic fertilizers, Essoko information dissemination and climate resilient varieties. Costs, capacity to reduce greenhouse gases, the sustainability and scale of application limitations accounted for their low rating.

There was diversity in the top-three ranked CSA practices by the various stakeholders in the given agro-ecology. Table 4.2 shows the stakeholder category CSA choice variability and the factors limiting their use.

Table 4.1.2: Stakeholder best three rated choices of CSA technology/practices and factors limiting use in the Guinea Savannah zone

Stakeholder Category	Choice of CSA practice	Factors limiting use
1. Traditional authorities, farmers and extension	1.1 Agro forestry 1.2 Mulching 1.3 FMNRT	Cost Scale, cost and user friendliness Scale, cost
2. Research and Academia	2.1 FMNRT 2.2 Conservation agriculture	Scale User friendliness, cost, scale

	2.3 DT maize= Ethno veterinary	
3. NGO and FBO's	3.1 Mixed farming 3.2 Bee keeping 3.3 Crop rotation=FMNRT	Cost, scale Cost, GHG Scaling, cost
4. Policy decision makers	4.1 Bee keeping 4.2 Stone 4.3 Zai=compost=Tree planting	Cost Scale, biodiversity Scale, sustainability

A query for the sources of the technology and practices showed that in general indigenous knowledge (IK) accounted for 35.4% compared to 64.6% from formal research. On specific technologies and practices the contribution from IK sources dropped by 10.4 percentage points with the formal research accounting for 75% of such technologies. The technologies and practices in the present study credited solely to IK included: Community-led bush fire control, contour ploughing, FMNRT, organic fertilizers, and local level by-laws. Formal research was credited with the following: All male tilapia breeding, composting, Zai, drip irrigation, talking book, cover cropping, alley cropping, cage fish farming, proper storage systems, chemical fertilizer, DT and striga tolerant maize, integrated soil fertility management, crop-livestock integration and intensive smallholder pig production.

The use of CSA technologies and practices in the guinea savannah area was found to be largely 86.6% smallholder farm types compared to medium and or large (Table 4.1.3). However, DT Maize was patronised by all the farm type enterprises. Gill netting practice was found to be practised by men. It was revealed by the stakeholder categories in the study that all the CSA technologies and practices were patronised by both men and women in the zone.

Table 4.1.3: Proportion (%) of Farmer type using CSA technologies and practices by stakeholder categories in Guinea savannah zone

Group	Number of CSA practices	% Farmer Type.		
		Smallholder	Medium	Large
1. Traditional Authority, farmer and extension	19	100	0	0
2. Research and Academia	7	71.4	14.3	14.3
3. NGO and FBO	16	75.0	6.3	18.5

4. Policy decision makers	19	100	0	0
Average	-	86.6	5.2	8.2

Constraints and Suggested solutions:

A litany of constraints limiting CSA adoption and spread was enumerated by participants to include the following:

- Finance constraints and cost implications
- Poor logistical support from …????
- Labour intensiveness of CSA technologies and practices
- Lack of knowledge and education
- Lack of law enforcement (legislation)
- Lack of commitment and bad attitudes
- Lack of enforcement by traditional authorities
- Absence of land use policy to support CSA adoption
- Low AEA to farmer ratio
- Lack of collaboration with implementers of programmes
- Ineffective implementation of government policies
- Lack of information dissemination attributable to insufficient MoFA Extension officers
- Poor access to relevant information
- Weak collaboration between NGOs and the developing partners.
- Weak collaboration with development partners
- Inadequate stakeholder empowerment
- High illiteracy level of farmers

Proposed solutions for action to promote the practice of CSA were identified to include the following:

- Laws should be enforced
- Traditional laws must be enforced
- Support traditional authorities to enforce laws
- AEAs should be educated on CSA and the technologies/practices
- Target AEA employment and provision of support
- Logistical support for MoFA staffs to support the labour intensity of CSA
- Traditional rulers must call for the incorporation of land policy in the NCCP
- Collaboration between MoFA extension officers and farmers
- We need to continue what we are doing to strengthen platform activities
- Translate material in local languages

4.2 Profiling of CSA in Forest Agro-ecological zone of Ghana

Three stakeholder categories, namely research and academia; traditional authority, farmers and NGOs; and the policy and decision makers were used in this work. A total of 21 CSA technologies and practices were identified, listed and profiled. In terms of the scope the focus of the practices was similar to the observations found in the guinea savannah zone and was in the order of soil fertility > crops > water > livestock >aquaculture. Least attention was given to information technology.

The top ten practices, the farmer enterprise type using them and the location/scale of practice is characterized and presented in Table 4.2.1.

Table 4.2.1: CSA technologies and practices, type of users and scale/location of practice in the Forest area

CSA Practice	Type of Farmer User			Location/Scale of Practice
	Smallholder	Medium	Large	
Trees on farms (e.g. cocoa)	✓	✓	-	Cocoa farming communities
Cover cropping		✓	-	Common all over
Slash without burn	✓	✓	-	Common all over
Riparian vegetation conservation	✓	-	-	Widely
Modified Taungya	✓	-	-	Degraded forest reserves
Improved varieties	✓	✓	✓	Whole Region
Conservation Agriculture	✓	✓	-	Widely
Integrated soil fertility management	✓	✓	-	Ejura, Wenchi, etc
Agro-forestry	✓	✓	-	Widely
Crop intensification	✓	✓	✓	Ejura, Atebubu

The CSA practices were found to be gender neutral as both men and women farmers used the 21 technologies and practices listed. A new trend however, emerged in the type of farms applying CSA. There was a strong presence of both the smallholder and medium scale farmers in the use of CSA. All the three types of farm enterprises patronised improved varieties, crop intensification, use of agro-industrial by-products for feed and zero-grazing. The overall ranking appeared to favour Cover cropping=Slash without burning>Trees on farmers>Conservation agriculture > modified taungya = improved varieties/breeds in that order. Costs, scale of application and emissions were critical decider-sieves of concern in the ratings. Least rated practices in this zone included fish-cage culture and non-timber forest products for similar reasons. It therefore appears cost effectiveness of the technologies and practices, the ease of application and the benefits derived from the technologies and practices positively influenced the ratings for possible adoption.

There was diversity in the top-three ranked CSA practices by the various stakeholder categories in the Forest zone. Table 4.2.2 shows the stakeholder category CSA choice variability and the factors limiting their use.

Table 4.2.2: Stakeholder category order of choices of CSA practices and factors limiting use in forest zone.

Stakeholder Group	Choice of CSA practice	Factors limiting use
1. Farmers, Traditional rulers and NGOs	1.1 Cover cropping= slash non-burn 1.2 Trees on farms 1.3 Riparian conservation.	- Productivity Cost
2. Research and Academia	2.1 Conservation Agriculture 2.2 Modernised taungya 2.3 Agro forestry = ISFM	Scale and cost Cost and scale Cost, scale
3. Policy and decision makers	3.1 Improved varieties and breeds 3.2 Improved livestock housing = Manure application	Cost and GHG GHG, scale

In terms of the sources of the existing technologies and practices identified, the study showed that in general indigenous knowledge (IK) accounted for 50% and equal to that from formal research. The percentage contribution for specific technologies and practices listed was also same but distinct in content. The technologies and practices in the present study credited solely to IK included: Agro-forestry, fodder conservation, Taungya, tree on farms, riparian vegetation conservation, slash-no-burn, manuring and inter-cropping. Formal research was credited with the following: Cover cropping, crop intensification, cage fish culture, Trellis for minimum staking, improved varieties, zero-grazing, pasture fodder, and improved animal housing.

The use of CSA technologies and practices in the forest area was found to be largely dominated by the smallholder and medium farm type enterprises (Table 4.2.3).

Table 4.2.3: Proportion (%) Farmer type using CSA Technologies and practices by stakeholder categories in Forest Zone

Group	Number of identified CSA practices	% Farmer Type		
		Smallholder	Medium	Large
1. Farmers Traditional Authority and NGOs	4	50.0	50.0	0
2. Research Academia	10	56.2	37.5	6.3
3. Policy and decision makers	8	44.4	33.3	22.3
Average	-	50.2	40.3	9.5

Constraints and Suggested solutions

Bulleted below are some of the constraints enumerated to be associated with the climate smart technologies and practices:

i. Uncoordinated information/views on the technologies and practices
ii. Limited right by farmer to economic trees on their farms
Limited access to extension services
iii. No synergy between various policy formulation institutions
iv. No continuity in policy

Solutions advanced by stakeholders that could improve adoption and spread of CSA technologies and practices included:

- Available and affordable Technologies at farmer level
- More demonstrations on farms should be established to demonstrate to the farmers about the technologies and practices by research and extension
- Strengthen collaboration among the stakeholders
- Fact sheet should be made available
- Policy level will support research and extension in terms of funding
- Farmer level transfer the technologies and practices that are sustainable and has close climate change adaptation and mitigation
- Compelling cage culture with bi-valves to clean the system
- Research and extension level innovative ways of practicing cage culture, among others which lead to climate change adaptation and mitigation
- Policy level zoning areas to ensure carrying capacity is not exceeded

CHAPTER FIVE

5.0 Conclusion and Recommendations

5.1 Trends in development of CSA practices (indigenous and scientific knowledge systems)

CSA integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges (FAO, 2010). It is composed of three main pillars namely:

- Sustainably increasing agricultural productivity and incomes;
- Adapting and building resilience to climate change;
- Reducing and/or removing greenhouse gases emissions, where possible.

However, the fundamentals are in the way the technical/technology, Institutions and Policy are blended creating the congenial environment for the practice to deliver the desired outcomes.

5.2 Role of actors in promotion of CSA practices

Policies and laws need strengthening to deal appropriately with climate change issues e.g. Bush fires, migrant herders and other conflicts. Strengthening of CCA platforms at all levels (local assembly, regional and national) for science-policy dialogue could prove rewarding from the institutional innovation end point. Indeed, this calls for concerted action by actors and stakeholders including; producers, marketers, and input dealers/service providers, associations and other influential individuals along a given value chain. The need for partnerships and (north-south and south-south) Alliances for CSA to bridge knowledge gaps and mobilize resources to improve ~~the~~ financial investments for climate-smart agriculture research and development without which our producers may remain at high risk of being uncompetitive cannot be over-emphasized.

5.3 Research and Policy Implications

- Support private sector participation in the delivery and funding of climate smart agriculture extension services to farmers ensuring inclusiveness of smallholder men and women farmers.
- Encourage co-production and management of climate smart agriculture innovations by scientists and local indigenous knowledge systems
- Development of human resource capacity and equipment to effectively prosecute climate smart agriculture in the country through partnerships and alliances locally and globally.
- Develop framework for CSA research prioritization, co-ordination, networking, monitoring, evaluation and learning.

- Over haul the research-extension-farmer-input dealers' linkage systems for greater delivery of extension on CSA technologies and practices.
- Formulate policy on regionalization of climate smart agriculture technologies and practices by ecological zones in the country
- Conduct more in-depth case studies of the identified and prioritized technologies, integrated systems practices for scaling up and out.
- Policy environment creating needed incentives for business investments in CSA, enhancing markets and trade across borders (south-south and north-south).
- Institutions creating awareness; aligning CSA technologies and practices in agricultural sector action plans to respond appropriately to the national climate change policy (NCCP) document.

5.4 Recommendations

The following recommendations were made in connection with the promotion of CSA in Ghana:

- Current efforts by Forestry sector to replant degraded forest reserves should include Farmer managed natural regeneration of trees enhancing natural biodiversity capacities of identified protected areas towards increasing their ecotourism potentials.

- Weather/climate information is important in enabling farmers adapt to current weather events; the food and agriculture sector operators should consider forging closer relations with the Meteorological Agency to make weather information more relevant and useful (timeliness and scale of forecast) to farmers.

- The scaling up of CSA practices on landscape is recommended for the studied zones. The transfer of some practices such as cover cropping, conservation agriculture across zones could be direct. However, others may require test validation to adapt.

- Formal and informal institutions may need to go into alliances to promote climate smart agriculture. Unfavorable policies observed by stakeholders limiting CSA practices should be addressed to promote adoption and adequate investments

- More profiling activities of CSA will be needed to cover the country to unearth indigenous knowledge for scientific fine tuning by research.

- Targeting agricultural mechanization for CSA is required.

References

Ahn, P. M. 1977. Soil Factors Affecting Rain-Fed Agriculture in Semi-Arid Regions with Particular reference to the Sahel Zone of Africa. Proceedings of an International Symposium on Rain-Fed agriculture in Semi-Arid Regions, Riverside California-Vorvallis Oregon, pp 1281 - 1667.

Boamah J. K. 2006. Agricultural Engineering Policy in Ghana and its effects on Agricultural Development. "Engineering Ghana's Agriculture and Health for Economic Progress" 3rd National Conference on Agricultural Engineering, 1- 4 August. KNUST. Kumasi. Ghana. pp. vi-xiv. ISSN O855-708X

Daum, D. R. 2015. Soil Compaction and Conservation Tillage (Crops and Soils). Retrieved August 5, 2015, from http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/soil-compaction-and-conservation-tillage

Duncan, B.A. (2004) *Women in Agriculture in Ghana,* Friedrich Ebert Foundation, Accra

EPA. 2015. *Ghana's First Biennial Update Report,* Environmental Protection Agency (EPA), Accra.

GSS (2012) 2010 Population and Housing Census – Summary of Final Results, Ghana Statistical Service (GSS), Accra.

International Panel on Climate Change (IPCC), 2007. Fourth Assessment Report

Karbo, N. (2012) "Livestock and Climate Change: The Case of Ghana", A Presentation at the 6th Africa Agriculture Science Week, July 2012, Accra.

ISSER (2015) The State of the Ghanaian Economy in 2014, Institute of Statistical, Social and Economic Research (ISSER), University of Ghana, Legon.

Kamal, J. M, Kassin, A. H. 1975. Energy Load and Instataneous Intensity of Rainstorms at Samaru Northern Nigeria. IITA Workshop on Soil Conservation and Management in Humid Tropics. Ibadan.

Kuznesov L. C. 1987. Exploitation of machine-tractor pool in conditions of tropical and sub tropical. Published by UDN. Moscow (in Russian)

Mahama, A.A.; Mensah, E. 1997 - The Use of Some Tillage Implements & Soil Degradation in Ghana// Efficient Soil and Water Management: A Prerequisite for

Sustainable Agriculture (Proceedings of the 14th and 15th Annual General Meeting of the Soil Science Society of Ghana). Soil Science Society of Ghana, pp. 185-189.

Mahama, A.A, Seidu, J. M. 1994 - Energy Cost and the Environment in Agriculture in Ghana.// Journal of Energy Research and Technology. National Science Tech. Press. CSIR, ACCRA Vol.6 Page 61...66.

Mensah-Bonsu, A. (2003). Migration and Environmental Pressure in Northern Ghana. Ph.D Dissertation, Vrije Universiteit, Amsterdam, November, 2003.

Ministry of Food and Agriculture - Ghana 2002. Food and Agriculture Sector Development Policy. Delaram Publishing Ltd. Accra.

Ministry of Food and Agriculture, 2008. Food and Agriculture Sector Development Policy (FASDEP II)

Ministry of Environment, Science, Technology and Innovation (MESTI), 2014, *National Climate Change Policy,* Accra: Ministry of Environment, Science, Technology and Information.

NDPC (2014) Ghana Shared Growth and Development Agenda (GSGDA) II, 2014 – 2017, National Development Planning Commission, Accra

SRID. 2001. Agriculture in Ghana. Facts and Figures. Ministry of Food and Agriculture, Statistical Research and Information Directorate, Accra, Ghana.

SRID. 2007. Agriculture in Ghana. Facts and Figures. Ministry of Food and Agriculture, Statistical Research and Information Directorate, Accra, Ghana. 25pp.

SRID. 2013. Agriculture in Ghana. Facts and Figures. Ministry of Food and Agriculture, Statistical Research and Information Directorate, Accra. Ghana.

Seidu,J. M., Tevor. W.J, Kotei, R, A. A.Mahama and R.S. Amoah. 2008. Suitability of locally constructed solar dryers for vegetable drying. Journal of Ghana Science Association**.** Sonlife Press & Services, Accra Vol. 10 (1) pp50-58.

Sidibé, Y., Williams, T.O. and Kolavalli, S. 2016. Flood Recession Agriculture for Food Security in Northern Ghana: Literature review on extent, challenges and opportunities. Working Paper. IFPRI, Washington, USA.