GHANA

TECHNOLOGY NEEDS ASSESSMENT REPORT

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TNA Project Team

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Dr. George Owusu Essegbey
Lead Expert
August 2012

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FOREWORD

Ghana has proven her commitment to cooperate with the international community to address the global challenge of climate change. In 1995, Ghana ratified the United Nations Framework Convention on Climate Change (UNFCCC). Ghana is also party to the Kyoto Protocol having acceded to it in 2003. Joining these conventions, represent the resolve of the nation to partner with other nations in mitigating or adapting to climate change.

In order to meet her commitments, Ghana has carried out a number of demand-driven studies, projects and programmes to address the adverse impacts of climate change.

Notable among them are, the formulation of the National Climate Change Policy, the adoption of a National Climate Change Adaptation Strategy (NCCAS) and Ghana Environmental Policy. It is in the context of these policies and programmes that Ghana accepted the implementation of the Technology Needs Assessment (TNA) Project under Climate Change Adaptation in 2011.

The TNA Project is a set of country-driven activities that identify and determine mitigation and adaptation technology priorities of countries facing the collapse of climate change. The overall goal of the TNA project is to enable countries to identify technologies and prioritize them to address their specific needs for climate change mitigation or adaptation. The specific objectives of the TNA project are:

- To identify and prioritize through country-driven participatory processes, technologies that can contribute to adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities;
- To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies;
- To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome barriers and facilitate the transfer, adoption and diffusion of selected technologies in the participant countries.

In order to achieve the above-stated objectives, appropriate processes were put in place. Ghana decided to focus on adaptation to climate change in the TNA Project and specifically on the agriculture and water sectosr.

A National Team was formed followed by a National Stakeholders Committee. The National Team comprised of the National Project Coordinator and three experts who led the preparation of the various reports. The National Stakeholders Committee was made up of relevant public and private institutions mostly in the water and agricultural sectors.

Series of stakeholders meetings were held in 2011, 2012 and the first quarter of 2013. During these meetings, stakeholders discussed and analyzed the various technologies in both the agricultural and water sectors. In all such meetings, the participatory approach methodology was used and this provided a very good environment for experts to exchange views.

During the last two quarters of 2012, a number of workshops were organized where various technical reports were produced. These reports were sent to the stakeholders for their comments. The inputs were later incorporated by the experts. The Technology Needs Assessment and Barrier Analysis Reports were the main outputs of the workshops.

It is my hope that the TNA report will stimulate further studies in the deployment and diffusions of environmentally sound technologies in other sectors of the economy where climate change impact is paramount. To achieve the above, the Environmental Protection Agency (EPA) will create the necessary national awareness among relevant institutions in the country.

Daniel .S. Amlalo
Executive Director
Environmental Protection Agency, Accra
20th March 2013

LIST OF ABBREVIATIONS

ADB	Agriculture Development Bank
COP 15	15th Session of Conference of Parties to UNFCCC
CREMA	Community Resources Management Area
CRI	Crop Research Institute of CSIR
CSIR	Council for Scientific and Industrial Research
CWSA	Community Water and Sanitation Agency
DTIE	Division of Technology Industry Economic of UNEP
EPA	Environmental Protection Agency
EST	Environmentally Sound Technology
FASDEP	Food and Agriculture Sector Development Policy
GEF	Global Environment Facility
GHG	Green House Gases
GM	Genetically Modified
GSGDA	Ghana Shared Growth and Development Agency
HWTS	Household Water Treatment and Safe Storage
ISSER	Institute of Statistical, Social and Economic Research
IWRM	Integrated Water Resources Management
KNUST	Kwame Nkrumah University of Science and Technology
MCA	Multi-Criteria Analysis
MDA	Ministries, Departments and Agencies
MEST	Ministry of Environment Science and Technology
METASIP	Medium Term Agriculture Sector Investment Plan
MWRWH	Ministry of Water Resources Works and Housing
MOFA	Ministry Of Food and Agriculture
NADMO	National Disaster Management Organisation
NCCAS	National Climate Change Adaptation Strategy
NCCC	National Climate Change Committee
NCCPF	National Climate Change Policy Framework
NDPC	National Development Planning Commission
NGOs	Non-governmental organisation
NREG	National Resource and Environmental Governance
O&M	Operation and Maintenance

PAS	Policy Advice Series
PCS	Post Construction Support
PEF	Private Enterprise Foundation
POU	Point of Use
PSC	Project Steering Committee
REDD	Reducing Emission from Deforestation and Forest Degradation
RO	Reverse Osmosis
R-PP	Readiness Preparation Proposal
STEPRI	Science and Technology Policy Research Institute of CSIR
STI	Science, Technology and Innovation
SODIS	Solar Disinfection
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UG	University of Ghana
UNEP	United Nation Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URC	UNEP Risoe Centre
WATSAN	Water and Sanitation Committee
WRC	Water Resources Commission
WRI	Water Resource Institute of CSIR
WSP	Water Safety Plans

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EXECUTIVE SUMMARY

Introduction

There is no gainsaying the fact that the achievement of the overall development goals of any country is intractably linked to its ecosystems and environmental conditions. In this regard, Ghana is committed to addressing the challenge of climate change from the local perspective even as it joins the international community to carry out the vital actions to meet the global challenge. In 1995, Ghana ratified the UNFCCC. Ghana is also a signatory to the Kyoto Protocol acceding to it in 2003. Over the years, the country has carried out a number of programmes and projects to address the climate change challenge. Various policy documents have been developed or are in the process of development to facilitate action by the relevant key stakeholders

One of the important policy documents Ghana has developed is the National Climate Change Policy Framework (NCCPF). The NCCPF aims at ensuring a climate resilient and climate compatible economy, while achieving sustainable development and equitable low carbon economic growth for Ghana. Related to the NCCPF is the strategic document on adaptation. The National Climate Change Adaptation Strategy (NCCAS) was finalized in 2011 and some key policy documents have been published. As stated in the Strategy, it is the blueprint formulated to guide the adjustment of Ghanaȁs economy to expected climactic stimuli and their effects. The overall goal is to ñenhance Ghanaȁs current and future development by strengthening its adaptive capacity with regard to climate change impacts and building the resilience of the society and ecosystemsò. In the short to medium term (2-7 years) NCCAS specifies targeted strategies to build national capacity to deal with climate change impacts and reduce vulnerability in key sectors, ecosystems, districts and regions of the country. For the TNA Project, Ghana selected the Agriculture and Water sectors for adaptation technologies.

The Institutional Arrangement for the TNA Project Implementation

Ghana has set up the appropriate institutional arrangement for the implementation of the TNA Project. It encompassed the TNA project team operating under the auspices of the Environmental Protection Agency (EPA), the Project Steering Committee and stakeholders workshops to solicit the inputs of the relevant organisations. The TNA project team comprises a Project Coordinator, an Assistant Project Coordinator, a Lead Consultant, Water Sector Consultant and Agriculture Sector Consultant.

Sector Prioritization

A national inception workshop was held to launch the Technology Needs Assessment (TNA) Project in Ghana. It was organised by the Environmental Protection (EPA) on 4thMay 2011 at the Coconut Grove Hotel, Accra and was attended by stakeholders and officers of UNEP Risøe and ENDA. The workshop was aimed at facilitating enhanced awareness and active engagement of a broader group of stakeholders on the TNA process and addressing relevant issues relating to the TNA process such as the choice of the sectors for the TNA. The twenty-two (22) participants who attended the workshop was drawn from the stakeholder organisations including the Ministry of Environment, Science and Technology, Ministry of Food and Agriculture, Water Resources Commission, Agricultural Development Bank, district assemblies and NGOs (EPA, 2011).

The workshop decided Ghana should focus on adaptation for the TNA given that enhancing resilience to climate change adaptation was a prime national challenge. When it came to the selection of sectors, three sectors were initially suggested, namely, water, agriculture and energy. Following discussions, the workshop decided on the Water and Agriculture sectors since a lot was already being done in the energy sector in respect of mitigation. More importantly, the water and agriculture sectors were at the base of Ghanaṓs socio-economic development. It was suggested that these sectors could be well dovetailed to ensure synergy. Additionally, the workshop suggested sub-sectors for consideration namely:

- Agric sub-sector: soil moisture conservation
- Water sub-sector: water harvesting, water shed management, water conservation, small scale irrigation etc. (EPA, 2011).

Technologies in these sub-sectors would then be included in those identified in the two sectors and taken through the technology prioritization process.

Adaptation to climate change is an important policy goal for Ghana. The choice for adaptation underscores the urgent need to put measures and strategies in place for countering the already manifest effects of climate change in the country. The two sectors are inter-linked as the availability of water in its various forms support agricultural practices; agricultural practices also stimulate efforts to ensure sustainable water availability. For Ghana, the negative climate change impact in the two sectors ï water and agriculture ï needs to be the effectively combated to assure and sustain the socio-economic development of the nation. Consensus on the selection of the two sectors came through discussion of the national development agenda and the priorities outlined for the prevailing socio-economic development efforts especially in relation to climate change. The criteria informing the selection of the two sectors include vulnerability to climate change, adaptive capacity and national priority based on development plans.

The Prioritization of Technologies

The Second Stakeholders Workshop was held from 20^{th} to 21^{st} December 2011. To prioritize the technologies for the Water and Agriculture sectors, the consultants gave presentations on the methodology highlighting the key objectives, principles and considerations, which should inform their activities. The main goal of adaptation is generally reducing vulnerability by increasing resilience to climate change impacts. To achieve this goal and related objectives, adaptation activities should be undertaken at the local level guided by appropriate national policies. The point was emphasized that, achieving the goal and objectives basically require technologies which were appropriate and feasible for the selected sectors. In each sector, there is a range of technologies which can be adopted for climate change adaptation. Given that resources to support technology adoption and diffusion are limited, there is the need to prioritize the technologies on pre-determined criteria.

Indeed the participants were taken through the Multi-Criteria Analysis (MCA) model, which the experts developed in Microsoft Excel, to facilitate the participatory process for prioritizing the technologies presented by the experts on the basis of agreed sets of criteria finalized at the workshop. The participants worked in two groups on the water and agriculture sectors respectively to prioritize the technologies and select four for each sector.

The Results of the Prioritization

At the end of the prioritization of the adaptation technologies for the two sectors, Integrated Climate Monitoring and Early Warning System was ranked among the top 4 for both sectors. Given that this technology is necessary for reducing vulnerability to climate change in all sectors it is proposed that it be automatically selected to stand on its own and not included in the top 4 technologies prioritized for the two sectors. The following then are the 4 top technologies for the respective sectors:

The Water Sector

I. Rainwater collection from ground surfaces.
II. Post construction support for community managed water systems.
III. Improving resilience of protected wells to flooding.
IV. Demarcation and Protection of Buffer Zones for water bodies.

The Agriculture Sector

I. Community Based Extension Model;
II. Water User Associations;
III. Integrated Soil Nutrient Management;
IV. Ecological Pest Management.

Conclusion

There are salient points coming from the results of the list of the 4 prioritized technologies. Firstly, the point about a community-based approach to providing technological solutions to climate change came out strongly in the prioritization exercise. In each of the sectors, there were community-based technologies. On the prioritized technologies for the water sector, the topmost being rainwater harvesting system highlights the concern of most people about the unnecessary ólossô of good natural water. Secondly, management-related technologies are vital to adaptation in the water sector. For the agriculture sector, the community-based extension model reflects the essence of having adaptation technologies of which the ownership will be community-centered. The two integrated systems ï the Integrated Climate Monitoring and Early Warning System and the Integrated Soil Nutrient Management ï underscore the importance of adopting systemic approach to adaptation in agricultural practices.

1 INTRODUCTION

1.1 Background

Technology Needs Assessments (TNAs) are a set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of countries to climate change. It is particularly relevant to the needs of developing countries. TNAs are central to the work of Parties to the United Nations Framework Convention on Climate Change (art. 4.5 UNFCCC). They present a unique opportunity for countries to track evolving needs for new equipment, techniques, services, capacities and skills necessary to mitigate Green House Gases (GHGs) emissions, enhance adaptation and reduce the vulnerability of sectors and livelihoods to climate change.

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Climate change is not just an environmental problem but it is developmental. It has both direct positive and negative impacts on the socio-economic well-being of the people. In order to ensure sustainable development, appropriate actions should be undertaken to address climate change impacts through the selection, development and deployment of environmentally sound technologies.

TNA development is a key component of the Poznan Strategic Programme on Technology Transfer supported by the Global Environment Facility (GEF). The GEF funding for the TNA project under the Poznan program is $9 million, with co-financing adding approximately $2.85 million. United Nations Environment Programme (UNEP) on behalf of the GEF is implementing a new round of TNAs with objectives that go beyond identifying technology needs narrowly. TNAs involve different stakeholders in a consultative process, enabling all parties to better understand their technology needs and prepare Technology Action Plans (TAPs) in a collective and coordinated manner.

The Division of Technology Industry and Economics (UNEP DTIE) in collaboration with the UNEP Risoe Centre (URC) provides targeted financial, technical and methodological support to assist 36 countries in conducting TNA projects. An initial round of 15 countries from Africa, Asia, Latin America and the Caribbean and Europe are being supported in the first round since early 2010. Additional 21 countries were selected in the last quarter of 2010.

The project has engaged a number of Regional Centres to support the TNA process in the countries. The Regional Centre for Africa is stationed in the Dakar, Senegal. The regional centres, in cooperation with URC, provide external support to the national TNA teams and Ghana is one of the selected countries to benefit from the project.

The overall goal of the TNA Project is to enable countries identify technologies and prioritise them to address their context-specific needs for climate change mitigation or adaptation. The specific objectives are:

- To identify and prioritize through country-driven participatory processes, technologies that can contribute to adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities;
- To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies;
- To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies in the participant countries.

1.2 The National Context and the Development Agenda of Ghana

Ghana is one of Sub-Saharan African countries with great potential for accelerated growth. Apart from its immense endowment in natural resources including minerals and crude oil, it has a fairly good human capital with a significantly high population educated at the secondary and tertiary levels. With the rebasing of the economy in 2010, Ghana became a middle-income country with a per capita GDP of $1,300. The challenge however is to enhance socio-economic development to ensure that the middle-income status reflects in the lives of the people given that poverty incidence is 28.6% as of 2005/6 (Government of Ghana, 2010, p.11). There is environmental degradation with a gradual loss of forest cover and the impact of climate change is already being felt in variability of climactic conditions with uncertain rainfall, drought, increasing temperatures and sea erosion. The overall challenge for Ghana, boils down to enhancing the national climate innovation system to facilitate the generation and adoption of technology, in response to climate change impacts (WWF, 2011).

The Ghana Shared Growth and Development Agenda (GSGDA) document provides the national framework for enhancing the countryĝs middle-income status socio-economically (Government of Ghana, 2010). In the medium term the GSGDA is designed to lay the foundation for the structural transformation of the economy through industrialization based on modernized agriculture and sustainable exploitation of Ghanaĝs natural resources. The process is to be underpinned by rapid infrastructural and human development and the application of Science, Technology and Innovation (STI). The GSGDA highlights key thematic areas that constitute the strategic focus of national development and these are:

- ensuring and sustaining macroeconomic stability;
- enhanced competitiveness of Ghanaĝs private sector;
- accelerated agricultural modernization and natural resource management;
- oil and gas development;
- human development, employment and productivity; and
- transparent and accountable governance.

The sector-specific policies and plans outline the national goals, priorities and mechanisms for implementing sector-specific agenda. In varying degrees, the sector-specific policies and plans are linked to the national priorities. Each of the policies also addresses climate change challenges either explicitly or implicitly. FASDEP II, the agricultural policy document notes the impact of climactic stresses on crop and livestock production; there are the fluctuations in food production in year to due to frequent variations in magnitude of rains during and between growing seasons. It therefore outlines specific strategies including for food security and emergency preparedness (MOFA, 2007). The Energy Policy underscores the point about the production and use of energy impact on the environment and global climate in varying degrees. The exploitation of biomass for energy results in deforestation and the use of fossil-based fuels contribute to climate change. It proposes strategies to address this (Ministry of Energy, 2009).

1.3 National Climate Change Adaptation Strategies

There is no gainsaying the fact that the achievement of the overall development goals of the country is intractably linked to its ecosystems and environmental conditions. In this regard, Ghana is committed to addressing the challenge of climate change from the local perspective even as it joins the international community to carry out the vital actions to meet the global challenge. In 1995, Ghana ratified the UNFCCC. Ghana is also a signatory to the Kyoto Protocol acceding to it in 2003. Over the years, the country has carried out a number of programmes and projects to address the climate change challenge. Various policy documents have been developed or are in the process of development to facilitate action by the relevant key stakeholders.

One of the important policy documents Ghana has developed is the National Climate Change Policy Framework (NCCPF). It was prepared through the participatory involvement of the all stakeholders including policy makers, regulators, researchers, farmers and environmentalists. The NCCPF aims at ensuring a climate resilient and climate compatible economy, while achieving sustainable development and equitable low carbon economic growth for Ghana. The NCCPF is provides a strategic contribution to achieving the overall goal of Ghana Shared Growth and Development Agenda (GSGDA).

Related to the NCCPF is the strategic document on adaptation. The National Climate Change Adaptation Strategy (NCCAS) was finalized in 2011 and some key policy documents have been published. As stated in the Strategy, it is the blueprint formulated to guide the adjustment of Ghanaǿs economy to expected climactic stimuli and their effects (EPA & UNDP, 2011). The overall goal is to ñenhance Ghanaǿs current and future development by strengthening its adaptive capacity with regard to climate change impacts and building the resilience of the society and ecosystemsò. Thus it makes projections for the period 2010 to 2020. In the short to medium term (2-7 years) NCCAS specifies targeted strategies for to build national capacity to deal with climate change impacts and reduce vulnerability in key sectors, ecosystems, districts and regions of the country (EPA & UNDP, 2011). The following objectives are set to achieve the goal of the NCCAS:

- Improve societal awareness and preparedness for future climate change
- Enhance the mainstreaming of climate change into national development to reduce climate change risks

- Increase the robustness of infrastructure development and long-term investments;
- Enhance the adaptability of vulnerable ecological and social systems by increasing the flexibility and resilience of these systems;
- Avoid mal-adaptation by reversing the trends that increase vulnerability
- Foster competitiveness and promote technological innovation (EPA & EPA, 2011).

The relevance of climate change to Ghanaᦡ development strategies lies in the fact that, the countryᦡ economy relies heavily on climate sensitive sectors, namely agriculture, energy and forestry (EPA & UNDP, 2011, p.2). Agriculture is second to the services sector in its contribution to national output as illustrated in Table 1.1.

Table 1.1: Sectoral Contributions to National Output, 2006 – 2010 (% of Total in 2006 Constant Price)

Sector	2006	2007	2008	2009	2010
Agriculture	30.4	29.1	31	31.7	30.2
Industry	20.8	20.7	20.4	18.9	18.6
Services	48.8	50.2	48.6	49.5	51.1
Total	100	100	100	100	99.9

Source: ISSER, 2011

Even though currently the services sector is the main driver of the economy and contributes about 51% to national output, agriculture which is the second contributor with over 30% (ISSER, 2011) is the critical economic sector given that it employs the largest segment of the population. About 70% of the population depends directly or indirectly on agriculture (fisheries, crop and animal farming etc.) and the forest sector for both timber and non-timber forest products (EPA & UNDP, 2011). Its sensitivity to climate change implies that the necessary steps be taken to address the challenge. The energy sector is normally classified as a sub-sector of the industrial sector given that the generation of energy is primarily an industrial concern. However, energy is the driver for all the three sectors shown in Table 1. Energy is derived from biomass (woodfuel and charcoal), petroleum and electricity. In terms of total energy equivalence, biomass (fuelwood and charcoal) constituted 65.6%, petroleum products constituted 26.0% and electricity some 8.4% (Ministry of Energy, 2009). The very high energy equivalence of biomass is the result of the high reliance of the rural and peri-urban populations on biomass for domestic use and entrepreneurial activities. It means that the impact of climate change on any form of vegetation will generally affect energy supply to this large segment of the population. About 68.8% of the generated electricity is from hydro sources with the bulk (of about 59%) coming from the Akosombo hydro-electric dam (ISSER, 2011). Ghanaȏs vulnerability to climactic shocks in the energy sector was illustrated when in 2010, the water level in the Akosombo dam reached the peak of 84.45 metres for the first time in 20 years and there was the need for spillage of excess water from the reservoir (ISSER, 2011). Naturally, it affected human communities downstream along the banks of the Volta River.

However, the central challenge for Ghana in terms of the prevailing developmental challenges remains adaptation to deleterious climate change impacts. Meeting the challenge requires a multiplicity of strategies, initiatives and actions that include transformation of mindsets and attitudes. For example, with the support of the UNDP, it has produced a number of policy briefs in the Policy Advice Series (PAS) designed to increase the understanding and appreciation of policy makers and technocrats on climate change and development issues. The EPA in collaboration with the National Development Planning Commission (NDPC) and other public organizations executed the PAS project.

The collaboration among institutions and sectors is also critical for achieving goals. The mechanisms for action in various forms including policy formulation and implementation, monitoring and evaluation draw in several MDA, international organizations and non-governmental organizations. It transcends the hierarchy of governance structures. For example there is the Environmental Advisory Council at the Cabinet level comprising the Ministers of the following: Local Government; Lands and Natural Resources; Environment, Science and Technology; Finance and Economic Planning; Food and Agriculture. The Ministry of Environment, Science and Technology (MEST) hosts the National Climate Change Committee (NCCC) and the EPA which houses the National Climate Change Unit operates under the auspices of MEST. All these institutions have shared responsibility in addressing the climate change challenge in Ghana.

2 INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDERS INVOLVEMENT

2.1 TNA Team, National Project Coordinator and Experts

Ghana has set up the appropriate institutional arrangement for the implementation of the TNA Project. It encompassed the TNA team operating under the auspices of the Environmental Protection Agency (EPA), the Project Steering Committee and the relevant stakeholders.

The composition of the Project Steering Committee (PSC) was determined at the inception workshop held on 4th May 2011, in line with the project guidelines. It was decided that the PSC should have its membership drawn from the institutional representations of the National Climate Change Committee (NCCC) whose membership comprises representatives from organizations such as the Ministry of Finance and Economic Planning (MOFEP), Ministry of Health, Ministry of Energy, the National Disaster Management Organisation (NADMO) and Conservation Alliance (an NGO). In all, the PSC oversee the implementation of the project and work together with the TNA Project Coordinator to ensure political endorsement of the project based on agreed timelines. Serving on the PSC are the following**:**

- National TNA Project Coordinator;
- The three national experts;
- Representative of the Agricultural sector;
- Representative of the Water resource sector;
- Representative of Local government
- Civil society representation
- Representative of Ministry of Environment Science and Technology

Mr. K.Y Oppong-Boadi, the UNFCCC Focal Point at the EPA was appointed as the National TNA Project Coordinator. His responsibilities have been clearly spelt out in the project agreement. The TNA team as recommended at the inception workshop and subsequently constituted comprises:

- National TNA Project Coordinator;
- Agriculture sector expert;
- Water sector expert;
- Overall expert

- Assistant National TNA Project Coordinator

2.2 Stakeholders Engagement Process in the TNA

Ghanaôs TNA activities aimed at addressing Climate Change Adaptation effectively began after the signing of the Agreement in January 2011. The TNA global project started with the first round of countries in 2009. The TNA scoping mission was carried out in the country from 22-25 February 2010. During this period there were preparatory and information sharing meetings with various organizations and experts dealing with climate change in Ghana.

The EPA began the actual implementation of the project with the organization of the Inception Workshop on 4th May 2011 in Accra. The Inception Workshop was aimed at facilitating enhanced awareness and active engagement of a broader group of stakeholders on the TNA process while generating the feedback on the draft workplan. The workshop was attended by twenty-two (22) participants drawn from Ministry of Environment, Science and Technology, EPA, Ministry of Food and Agriculture, Agricultural Development Bank, and URC. (See Appendix 1 for list of participants.)

After the Inception Workshop a number of activities were carried out as part of the implementation of the TNA Project including the constitution of the Project Team, the appointment of the TNA Project Coordinator, the lead TNA Expert and two other experts. There was the selection of stakeholder institutions and sensitization of the key public institutions such as the Ministry of Environment, Science and Technology (MEST) on the TNA Project. A workplan was designed and finalized for the execution of the project as presented in Appendix 2.

The second workshop was organised from 20th to 21st December 2011 at the CSIR-STEPRI Auditorium in Accra, was in line with the fundamental principle of stakeholder engagement in identifying technologies for climate change adaptation, which is driving the TNA project. Stakeholders in the project areas will continually be drawn into the activities of the project especially as relates to producing the main deliverables e.g. the report on technologies for adaptation and the TAP. The workshop had the following specified objectives:

- Update stakeholders on the status of the project and obtain feedback on relevant stakeholders institutional activities;
- Present reports on the identified technologies for the two selected sectors namely, agriculture and water;
- Validate the list of technologies and criteria for prioritization;
- Prioritize through a participatory process the identified technologies using Multi-Criteria Analysis (MCA).

The Second Stakeholder Consultative Workshop was held under the chairmanship of Mr. E.O. Nsenkyire, the Chairman of the Ghana National Climate Change Committee. Participants came from the relevant stakeholder organizations including the universities, the ministries and NGOs. The full list of participants is in Appendix 1. Mr. E.O. Nsenkyire in his remarks stated that the evidence is clear of the potential threat posed by climate change to food and water security. Mr. Daniel Amlalo, the Ag. Executive Director of EPA, in his welcome address pointed out some of the phenomena which are indicative of the worsening negative impacts of climate change in Ghana including the devastating sea erosion being experienced on the coasts of Ghana and West Africa and the flooding in the city of Accra and other places resulting in the loss of properties worth over several billions Ghana cedis. However, globally several technologies are available for climate change adaptation, but there is the need to prioritize the technologies for Ghana. Such technologies should be durable, cost effective and feasible in the country's context. The TNA Project is therefore very important for addressing the country's climate change challenges.

The point was also emphasized at the Second Stakeholders Workshop that information sharing not only to the participants but also to the general public to create awareness of the impact of climate change was very vital. Adaptation to climate change is about people and how their attitudes and behaviours orientate towards solutions to the problems coming with climate change. There was need for people to know about the initiatives going on in climate change adaptation and how the country is proactively combating the negative impacts. The orientation of the populace towards the adaptation solutions will come with regular engagements with the stakeholders through these kinds of workshops and other modes of interactions. The TNA project is one of the projects enabling Ghana to be proactive about climate change adaptation. Stakeholders will continuously be engaged in the efforts to ensure adaptation nationally especially in the Water and Agriculture sectors. When the report was prepared by the experts, the stakeholders were given copies to comment on the report before finalization.

The engagement of stakeholders goes beyond having representations on committees and participating in meetings and workshops. Generally, participants in the TNA process and other related programmes can be broadly categorized into three. Firstly, there is the public sector category comprising policy makers, regulators and others in public office. The Ministry of Water Resources, Works and Housing, MEST, EPA and the Water Resources Commission belong to this category. The universities and research institutes e.g. University of Ghana, Crops Research Institute and Water Research Institute ï are also in the public sector category. The second category comprises private sector stakeholders including those in financial institutions (e.g. Agricultural Development Bank and Ecobank) and the Private Enterprise Foundation. The third category is made up of the non-governmental and international organisations such as CARE International. The respective functions of the stakeholders in the identifiable categories contribute to process. The academic stakeholders carry out the relevant studies and generate the knowledge base on which to act. The ministries and lead agencies such as the EPA provide the fulcrum for the execution of the process. It is important to see the engagement of stakeholders and diverse and all-emcompassing.

3 SECTOR PRIORITZATION

3.1 An Overview of the Expected Climate Change and Impacts, Sectors Vulnerable to Climate Change

The UNFCCC defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. In Ghana the evidence of climate change is visible in the various ecological zones and in the ordinary lives of the people. Adaptation to climate change is an important policy goal for Ghana. The choice for adaptation underscores the urgent need to put measures and strategies in place for countering the already manifest effects of climate change in the country.

A major sector vulnerable to climate change is agriculture. Based on a 20-year baseline climate observation, it is projected that yields of maize and other cereal crop, for example will reduce by 7% by 2050 (EPA, 2012). The impact on agriculture for Ghana is potentially damaging socio-economically. Increase in temperature, decrease in rainfall and its unpredictability is likely to jeopardize the employment of about 60% of the active population, the majority of whom are small scale rural farmers, resulting in unsustainable livelihoods. This poses negative consequences for food insecurity, poverty, health, education, gender equality and environmental degradation (EPA, 2012). In various parts of the country, there is manifest evidence of vulnerability. The destruction of livestock in Northern Ghana and other parts of the country due to floods in 2007 resulted in great loss of income to many households (Dittoh and Akudugu, 2012). Such losses increases the poverty incidence and livelihood insecurity.

3.1.1 Expected Climate Change Impacts in Ghana

Climate change effects in Ghana are mostly observable in terms of increasing rainfall variability and unpredictability resulting in reductions or total losses of crops and livestock. Additionally, floods are becoming more frequent with resultant loss of farms and lives in farming communities.
The agricultural sector is not the only sector where the impact of climate change is already being experienced in Ghana. Along the countryφs beach-line, the impact of climate change is being experienced as some coastal towns are already disappearing with sea erosion. A sea-level rise of 2.1 mm per year over the last 30 years, is currently resulting in estimated erosion up to 3 meters every

year. The data also indicates a rise of 5.8 cm, 16.5 cm and 34.5 cm by 2020, 2050 and 2080 respectively. It is not difficult to infer that by 2020 Ghana would be losing up to 81.3 m every year and the coastline would have receded by 465 m of seaside land to erosion. It will result in a loss of 1,110 sq. km land, placing about 132,200 people at risk (EPA, 2012).

Currently, coastal town such as Keta, Ada, Nungua, Winneba and some of the Gomoa towns and villages are all suffering from the impacts of the sea erosion. The government has to find resources to build sea defence walls. In spite of the huge costs involved, the sea defence walls appear not to be the complete solution. For example, the Keta sea defence wall only protects part of the Keta beach and already, the adjoining villages are suffering the onslaught of the sea. In Ada, the sea defence wall, which was initiated in 2011 can only protect a strip of the Ada beachline. Adaptation to the climate change impacts in whichever sector is therefore an important strategy for addressing the impacts.

Effective adaptation invariably depends on technology, which drive the implementation of the adaptation measures and strategies. The challenge for Ghana is to develop appropriate strategies to identify and promote technologies that address the climate change issues in the respective sectors of the economy (EPA and UNDP, 2010; WWF, 2011).

3.1.2 Sectors Vulnerable to Climate Change in Ghana

The three broad sectors of the economy namely agriculture, industry and services (as discussed in Section 1.3) are all vulnerable to climate change in varying degrees. Industry as a dependent on natural resources and agricultural inputs generally has some vulnerability. For example, in forestry where wood resources are crucial for the wood industry, climate change impact leading to forestation is a major challenge. In the services sector where tourism is a leading economic activity for Ghana, the impact on wild life and the beaches is a problem. However the most pronounced appears to be in the agricultural sector.

Indeed, the current sector policy and investment plan of the food and agriculture sector in Ghana (reference) identifies three pillars which provide entry points for climate change adaptation; these are food security and emergency preparedness, sustainable management of land and environment and application of science and technology in agriculture development, In addition, the national agriculture extension service is increasing its efforts at mainstreaming environmental management including climate change in its service delivery efforts.

Based on earlier vulnerability assessments (Environmental Protection Agency, 2000; Agyemang-Bonsu et al, 2009) a national climate change adaptation strategy was developed with the agriculture sector identified as one of the priority areas. A national climate change policy framework under preparation (MEST, 2011) also identifies the agriculture sector as priority sector for development of a sector climate change adaptation strategy. In addition to the above, a number of adaptation activities are on-going at various levels aimed at supporting rural and farming communities to build their resilience against future climate change effects.

The TNA stakeholders decided on the sectors to benefit from the climate change adaptation. Out of the range of sectors, Ghana settled on the two sectors of **Water** and **Agriculture**. The two sectors are inter-linked as the availability of water in its various forms support agricultural practices; agricultural practices also stimulate efforts to ensure sustainable water availability. For Ghana, the negative climate change impact in the two sectors ï water and agriculture ï needs to be effectively combated to assure and sustain the socio-economic development of the nation. Consensus on the selection of the two sectors came through discussion of the national development agenda and the priorities outlined for the prevailing socio-economic development efforts especially in relation to climate change. The criteria informing the selection of the two sectors include:

- Vulnerability to climate change;
- Adaptive capacity;
- National priority based on development plans;
- Socio-economic importance;
- Technological feasibility;
- Potential impact on large segments of the population.

The Food and Agriculture Sector Development Policy (FASDEP) is designed to achieve the transformation of Ghanaȏs agricultural activities for food security and self-sufficiency and for strengthening the base for industrialization through the production of industrial agro raw materials

(MOFA, 2007). The Medium Term Agricultural Sector Investment Plan (METASIP) also provides a broad investment framework with detailed cost projections to facilitate investment mobilization from public, donor and private sources (MOFA, 2010). The agriculture sector growth of averaging about 8% annually in the last five years shows the positive impact of the agricultural policies. The production of the staple foods e.g. maize, cassava, yam and plantain has enhanced national food sufficiency. However, the importation of food commodities shows the challenges for Ghanaös agriculture. Currently, rice is imported to the tune of about $500 million annually. The efforts to address the challenges in the agriculture sector depend on proactive initiatives to address the climate change challenges. The land for agricultural production of staple foods and cash crops must remain arable with sustainable sources of water to support production. The impact of climate change has been anticipated in some of the projections. Agricultural productivity especially in cereal production is likely to decline in the coming years in Northern Ghana as a result of uncertainties in the weather conditions from the impact of climate change. This trend will definitely have severe consequences on rural livelihood and the economy as a whole.

The National Water Policy also projects the vision of ensuring potable water supply to all human settlements irrespective of their location (Ministry of Water Resources, Works and Housing, 2007). Ghana is said to be on the way of achieving the MDG of halving the percentage of population with access to safe-drinking water by 2015. Available data indicates that the proportion of the Ghanaian population that uses improved drinking water has increased significantly from 56% in 1990 to 83.8% in 2008. Similarly the proportion of the urban population with access to improved drinking water has increased from 86% in 1990 to 93% in 2008, while that for rural population increased from 39% in 1990 to 76.6% in 2008 (National Development Planning Commission and United Nations Development Programme, 2010). The current drive of the Community Water and Sanitation Agency (CWSA) to supply water to rural and small town communities has greatly increased the pace of water provisioning outside of urban areas. However the reliance on water bodies such as lakes and rivers is under pressure as the changes in climactic conditions and human socio-economic practices are affecting these water bodies and undermining their sustainability.

3.2 Process and Criteria of Prioritization of the Sectors

The national inception workshop held to launch the Technology Needs Assessment (TNA) Project in Ghana provided the forum for deciding on the water and agriculture sectors. It was organised by the Environmental Protection (EPA) on 4thMay 2011 at the Coconut Grove Hotel, Accra and was attended by stakeholders and officers of UNEP Risøe and ENDA. The workshop was aimed at facilitating enhanced awareness and active engagement of a broader group of stakeholders on the TNA process and addressing relevant issues relating to the TNA process such as the choice of the sectors for the TNA. The twenty-two (22) participants who attended the workshop was drawn from the stakeholder organisations including the Ministry of Environment, Science and Technology, Ministry of Food and Agriculture, Water Resources Commission, Agricultural Development Bank, district assemblies and NGOs (EPA, 2011).

The workshop decided Ghana should focus on adaptation for the TNA given that enhancing resilience to climate change adaptation was a prime national challenge. When it came to the selection of sectors, three sectors were initially suggested, namely, water, agriculture and energy. Following discussions, the workshop decided on the Water and Agriculture sectors since a lot was already being done in the energy sector in respect of mitigation. More importantly, the water and agriculture sectors were at the base of Ghanaôs socio-economic development. It was suggested that these sectors could be well dovetailed to ensure synergy. Additionally, the workshop suggested sub-sectors for consideration namely:

- Agric sub-sector: soil moisture conservation
- Water sub-sector: water harvesting, water shed management, water conservation, small scale irrigation etc. (EPA, 2011).

Technologies in these sub-sectors would then be included in those identified in the two sectors and taken through the technology prioritization process.

Adaptation to climate change is an important policy goal for Ghana. The choice for adaptation underscores the urgent need to put measures and strategies in place for countering the already manifest effects of climate change in the country. The two sectors are inter-linked as the availability of water in its various forms support agricultural practices; agricultural practices also stimulate efforts to ensure sustainable water availability. For Ghana, the negative climate change impact in the two sectors ï water and agriculture ï needs to be the effectively combated to assure and sustain the socio-economic development of the nation. Consensus on the selection of the two sectors came through discussion of the national development agenda and the priorities outlined for the prevailing socio-economic development efforts especially in relation to climate change. The criteria informing the selection of the two sectors include vulnerability to climate change, adaptive capacity and national priority based on development plans.

Again even in the two sectors of water and agriculture, decisions have to be made in respect of the technologies to address the climate change adaptation challenges. This necessarily requires a process of identification and prioritization of the technologies. The identification and prioritization of technologies demand a certain level of expertise. The two sector consultants therefore carried out the exercise to prepare for Ghana, lists of adaptation technologies for the two sectors. The consultantsô participation in the GEF African Regional Workshop on Technology Needs Assessment (TNA) project organized in Navaisha, Kenya, from 28th to 30th June, 2011, enhanced their expertise in the process. The Regional Workshop was geared towards resourcing the TNA teams of the various countries with the knowledge and tools in selecting the requisite technologies for climate change adaptation and mitigation. Participants were given access to climate change databases like Climate Techwiki, guidebooks and other technical support to enable them carry out the technology identification and facilitate the prioritization with stakeholder participation. The sector consultants therefore prepared the list of adaptation technologies using these resources and their own knowledge of the sectors in consultation with the TNA project team members. Similarly, the consultants also prepared the criteria for prioritization of the technologies.

At the Second Stakeholders Workshop held to prioritize the technologies for the Water and Agriculture sectors, the consultants gave presentations on the methodology highlighting the key objectives, principles and considerations, which should inform their activities. The main objective of adaptation is generally reducing vulnerabilities by increasing resilience of human populations living in communities and ecosystems experiencing severe impacts of climate change. To serve these purposes, adaptation activities should be undertaken at the local level guided by appropriate national policies. This overall objective calls for technologies appropriate and feasible for adaptation in the sectors.

Technology is normally defined as a piece of equipment, technique, practical knowledge or skills for performing a particular activity. The list of technologies for each sector broadly divides into three types - soft technology, orgware and hard technology. These types of technologies work complementarily to achieve the desired results though they are distinctively different from one another. Still whether as hardware, orgware or software or in whatever form, technologies are critical for the implementation of the relevant adaptation options in any given national context. The overriding objective of the climate change technology adaptation is not merely addressing adaptation to climate change impacts but also to ensure sustainable development.

A Multi Criteria Analysis (MCA) was used in prioritizing the adaptation technologies identified by the experts. The MCA was implemented in Microsoft Excel by the TNA team using guidelines in ñMulti-criteria analysis for the identification of national adaptation strategiesò ï a resource provided by the Regional Centre, ENDA. The participants were taken through the MCA model, to facilitate the participatory process for prioritizing the technologies presented by the experts. The use of the MCA was necessary given the different national development priorities and the different stakeholder perspectives. Before going into the actual prioritization process using the MCA, the participants had a session to critically review the list of criteria at the group levels (water and agriculture) and make changes where necessary. Generally decisions to make changes were arrived at by consensus with the experts facilitating discussion. The discussions focused on among other issues:

- The reduction or eradication of poverty;
- The apparent bias for crop agriculture in the identification of technologies;
- The need for the consideration of the national development agenda;
- Health and sanitation considerations;
- The role of biotechnology in the adaptation options and the issue of acceptability of products;
- The predominance of technologies identified from the TNA Guidebook Series in the lists of technologies presented to participants;

- The connectivity between the hardware, software and orgware technologies.

3.3 Inventory Current Status of the Technologies in Water and Agriculture

Table 2 shows the list of the water and agriculture technologies presented for prioritization. The sector consultants prepared the list on the basis of their knowledge of these technologies in the two sectors and with reference to the climate techwiki database. The full details of the descriptions and the current status of the technologies in the country are in the Appendix 3.

Table 3.1: List of identified Technologies for the Water and Agriculture Sectors

Water Sector Technologies	***Agriculture Sector Technologies***
1. Sub-surface storage and use (Artificial groundwater recharge and groundwater dams).	1. Integrated Climate Change Monitoring and Early Warning System
2. Household water treatment and safe storage (HWTS)	2. Climate Insurance
3. Improving resilience of protected wells (boreholes and hand-dug wells) to flooding.	3. Sprinkler and Drip irrigation
4. Increasing the use of water-efficient fixtures and appliances.	4. Rainwater harvesting
5. Leakage management, detection and repair in piped systems	5. Slow-forming terraces
6. Post-construction support (PCS) for community-managed water systems	6. Conservation tillage
7. Rainwater collection from ground surfaces (e.g., Small community dams and dugouts, check dams)	7. Integrated soil nutrient management
8. Rainwater harvesting from roofs	8. Crop Diversification and New Varieties
9. Water reclamation and reuse (waste-water recycling)	9. Biotechnology
10. Water safety plans (WSPs) ï river catchment level	10. Ecological Pest Management
11. Desalination	11. Seed and Grain Storage
12. Demarcation and Protection of Buffer Zones for water bodies (Rivers, Reservoirs, Wetlands, etc.)	12. Selective Breeding via Controlled Mating
13. Flood hazard mapping and warning systems.	13. Livestock Disease Management
14. Flood-proofing	14. Mixed Farming
15. Climate Change Monitoring System.	15. Agroforestry
	16. Farmer Field Schools

	17. Community Based Extension
	18. Forest User Groups
	19. Water User Associations

Source: Expertôs descriptions of technologies from Climate TechWiki (2011) http://climatetechwiki.org/taxonomy/term/292

The emergence of orgware technologies in the list is an interesting development. Water User Associations and Forest User Groups are organizational frameworks for managing natural or available resources. In the discussing the respective resources such as water, the issue of how collective responsibility for the management and exploitation of the resources came to be highlighted. These are organizational frameworks and yet important as any of the hardware or software technologies listed in Table 2.

Table 2 presents all the technologies taken into the prioritization exercise. The analysis of the current status shows that the technologies are at various levels of diffusion in Ghana. All the technologies are known and in the respective sectors they have been used in one form or the other to address specific concerns. Generally, these technologies represent a range of technologies which over the years have shown potential and relevance in the national efforts to address specific challenges in the sectors. The prioritization to identify the top-most technologies was therefore vital in determining which ones to concentrate on in the climate change adaptation efforts.

4 TECHNOLOGY PRIORITIZATION FOR THE WATER SECTOR

4.1 An overview of possible adaptation technology options in the Water Sector and their adaptation benefits.

The participants were divided into two groups for Water and Agriculture respectively on the basis of their backgrounds. The groups went through the sessions of discussion and prioritization using the MCA Model and produced a final list of criteria and water technologies. Handouts giving descriptions of the technologies were prepared and distributed to participants at the workshop. Each group discussed and agreed on weights in the scoring based on their competence, knowledge and experience, fine-tuning the prioritization of the technologies. How the weights reflect in the scoring are shown in the tables of scores for the prioritization exercise for the water and agriculture sectors respectively. At the end of the exercise, they came up with the top four adaptation technologies for the sector for implementation using the MCA model. This section details the prioritization for the water sector.

Integrated Water Resources Management (IWRM) was agreed upon by the Water Sector Group as the framework under which any adaptation technologies in the sector would be implemented. This framework has been recommended in the Ghana National Climate Change Adaptation Strategy, featured prominently in the Ghana National Water Policy and vigorously promoted by the Water Resources Commission of Ghana (WRC). The WRC is the national agency tasked with ensuring the sustainable management, development and use of the countryôs fresh water resources. IWRM framework for adaptation to climate change impacts implies (GWP, 2000):

- Implementation of a Climate Change Monitoring System.
- Improved knowledge of water resources and water demand.
- Cross-sectoral collaboration.
- Improved access to information systems and increased awareness of climate change information.
- Maintenance or strengthening of biological diversity and environmental integrity.
- Improved equity including gender equity.
- Building of formal and informal institutions and social networks for IWRM.

* Support for improved climate modeling and forecasting to provide the basis for informed decision making.
* Implementation of adaptation strategies that also include traditional knowledge.
* Interactions between policy makers, researchers, WRM practitioners and communities so that IWRM technologies and planning processes are developed in partnership, responding to the needs of users and integrating their knowledge.
* Improved water governance
* The river basin as the unit for IWRM.

The various adaptation technologies in the water sector were identified and agreed upon through stakeholder consultation. These are presented in details in Appendix 3. They are intended to address climate change impacts of reduced water availability, increased incidence of extreme events such as droughts and floods and water quality degradation.

4.2 Criteria and process of technology prioritization

The criteria used in prioritizing the technologies are presented in Table 4.1. They have been classified as benefits (advantages) or costs (disadvantages) derived from implementation of the technologies. All criteria were discussed and accepted by the water sector group at the stakeholder workshop for technology prioritization for adaptation.

A photograph of the water sector group: The Water Sector Expert, Dr. Barnabas Amisigo who is standing, is guiding the process.

For each adaptation technology the group scored the benefit criteria on a scale of 1 ï 5 with one being the least benefit and 5 the highest derived from the technology for the criterion. It was difficult determining actual costs for the only cost criterion so in the end the group decided to use a scoring system of 1 ï 5 with 1 being the least cost and 5 the highest cost involved in implementing the technology. In the few cases where the group could not agree on a score by consensus, a majority decision was taken. Scores were entered in an appropriately designed Excel sheet, the scores sheet (Table 4.2). A standardization excel sheet was then used in which all scores were standardized on a scale of 0 ï 1, averaged across all criteria for each technology and the technologies ranked (Table 4.3). For the benefit criteria 0 represented least benefit while 1 the highest benefit. On the other hand, for the cost criterion, the standardization was implemented such that 0 represented highest cost (most negative) and 1 the least cost (least negative).

The determination of scores by the group was done on the basis of extensive discussion, more precisely debates, taking account of the advantages and disadvantages the implementation of the technology will have based on each criterion and the relevance of the criterion under consideration either in accentuating the advantage or the disadvantage. The group discussion resolved issues of the difficulty in weighing one criterion over the other in respect of the selected technologies. This same situation pertains to the agriculture sector.

Table 4.1: Criteria for Prioritizing Adaptation Technologies in the Water Sector.

Criteria	Brief Description of Criteria	Classification of Criteria
1. Poverty Reduction of Vulnerable Groups	Potential impact of technology on poverty reduction among vulnerable groups, e.g. Women, children, the disabled, the aged. (Improved incomes, improved nutrition, improved health, etc)	Benefit
2. Socio-Economic Benefit for Country	Potential of technology to contribute positively to the economy of the country as a whole.	Benefit
3. Investment cost (as estimated by the participants)	The actual investment costs of the technologies are not known. Participants therefore discussed the estimated costs on the basis of their knowledge and experience with the facilitation of the experts.	Cost (disadvantage)
4. Environmental Benefit	Potential to support ecosystems and enhance environmental integrity	Benefit
5. Contribution to Increased Resilience and of Adaptive Capacity of Communities, Vulnerable Groups and Ecosystems	Potential to increase resilience of vulnerable groups, eg add to options available to them, adjust to, increase their ability to 'buffer climate change disturbance'	Benefit
6. Improvement in Health and Sanitation	The extent to which the technology contributes to improved health status and sanitation of the community towards wealth creation.	Benefit

Criteria	Brief Description of Criteria	Classification of Criteria
7. Community participation in management	Potential of technology to enhance/increase community participation in the planning, implementation management and ownership of the systems introduced by the technology.	Benefit
8. Women's participation in management	Potential of technology to enhanced/increased participation of women and other vulnerable groups in the planning, implementation and management of the systems introduced by the technology.	Benefit
9. National Development Priority	Extent to which technology has been included in the National Development Agenda e.g. Ghana᾿s Shared Growth and Development Agenda (GSGDA).	Benefit
10. Stakeholder Acceptability	Extent to which technology is culturally and socially acceptable - considerations of indigenous knowledge and practices.	Benefit
11. Endorsement by Experts	Extent to which experts recommend the technology, e.g., as feasible, desirable, implementable, manageable	Benefit

Source: Expert᾿s analysis

This standardization sheet had links to the scores in the scores sheet and contained the necessary formulas for standardizing the scores and ranking the technologies. No manual entries were made in this sheet as it was designed to perform the ranking automatically as the scores sheet was being completed. The four highest ranked technologies were then selected for the next stage of the TNA process.

4.3 Results of technology prioritization

Table 4.2 shows the actual scores agreed upon by the water sector group for the technologies against the criteria. The criteria that are benefits and the only one that is a cost are also indicated in the table. The higher the score for a benefit criterion, the greater the beneficial attributes of the technology as potrayed by that criterion. On the other hand, the bigger the score for the cost criterion, the higher the disadvantage of the technology, As shown in the table all scores ranged from 1 to 5.

The standardized scores and prioritized technologies are presented in Table 4.3. The table shows the unordered technologies, criteria, standardized scores, average scores and the ranks. The table shows clearly that all standardized scores were in the range 0 ï 1. For the benefit criteria, 0 means the least benefit while 1 means the greatest benefit. For the cost criterion, 0 means the least cost (desirable) while 1 means the highest cost (undesirable). As indicated by the ranks in the table, the 4 technologies ranked the highest (with ranks 1 ï 4) are :.

1. Climate Change Monitoring System.
2. Rainwater collection from ground surfaces.
3. Post construction support for community managed water systems.
4. Improving resilience of protected wells to flooding.

These were selected for the next stages of the TNA process.

Table 4.2: Actual scores for each water sector technology against the criteria

Technology	Critera (scores from 1 to 5 for each criterion; the higher the score the more benefit for the criterion except for investment cost where the higher the score the less the benefit for the critierion)									
	Poverty Reduction of Vulnerable Groups	Economic Benefit for Country	Investment cost (US $)	Environmental Benefit	Increased Resilience and Adaptive Capacity of Vulnerable Groups	Improvement in Health and Sanitation	Community participation in management	Women's participation in management	National Development Priority	Stakeholder Acceptability	Endorsement by Experts
	benefit	benefit	cost	benefit	benefit	benefit	benefit	benefit	benefit	benefit	benefit
1. Sub-surface storage and use.	4	4	4	3	3	3	3	2	3	4	2
2. Household water treatment and safe storage (HWTS).	3	1	2	2	4	4	2	4	4	4	4
3. Improving resilience of protected wells to flooding.	3	3	2	1	4	4	2	4	4	5	4
4. Increasing the use of water-efficient fixtures and appliances.	1	4	3	3	1	2	2	3	4	2	3

Technology	Critera (scores from 1 to 5 for each criterion; the higher the score the more benefit for the criterion except for investment cost where the higher the score the less the benefit for the critierion)										
	Poverty Reduction of Vulnerabl e Groups	Economic Benefit for Country	Investment cost (US $)	Environmental Benefit	Increased Resilience and Adaptive Capacity of Vulnerable Groups	Improvement in Health and Sanitation	Community participation in management	Women's participation in management	National Development Priority	Stakeholder Acceptability	Endorsement by Experts
	benefit	**benefit**	**cost**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**
5. Leakage management , detection and repair in piped systems.	1	4	4	2	1	3	3	1	4	4	5
6. Post-construction support (PCS) for community-managed water systems.	2	2	2	1	4	3	5	5	4	5	5
7. Rainwater collection from ground surfaces. (small dams)	4	4	3	3	3	2	4	4	5	4	4
8. Rainwater harvesting from roofs.	3	3	4	2	4	4	2	3	5	4	5

Technology	**Critera (scores from 1 to 5 for each criterion; the higher the score the more benefit for the criterion except for investment cost where the higher the score the less the benefit for the critierion)**										
	Poverty Reduction of Vulnerabl e Groups	**Economic Benefit for Country**	**Investment cost (US $)**	**Environmental Benefit**	**Increased Resilience and Adaptive Capacity of Vulnerable Groups**	**Improvement in Health and Sanitation**	**Community participation in management**	**Women's participation in management**	**National Development Priority**	**Stakeholder Acceptability**	**Endorsement by Experts**
	benefit	**benefit**	**cost**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**
9. Water reclamation and reuse. (waste-water recycling)	3	3	4	4	3	3	2	2	1	1	2
10. Water safety plans (WSPs).	2	3	4	5	3	3	2	2	5	2	5
11. Desalination.	2	1	5	1	1	1	1	1	1	1	1
***12.* Demarcation and Protection of Buffer zones for water bodies.**	2	4	4	4	2	4	4	4	5	2	5
13. Flood warning systems.	3	3	4	3	4	3	4	3	4	4	4
14. Flood-proofing.	3	3	4	3	3	3	1	1	1	1	2

Technology	Critera (scores from 1 to 5 for each criterion; the higher the score the more benefit for the criterion except for investment cost where the higher the score the less the benefit for the critierion)										
	Poverty Reduction of Vulnerabl e Groups	**Economic Benefit for Country**	**Investment cost (US $)**	**Environmental Benefit**	**Increased Resilience and Adaptive Capacity of Vulnerable Groups**	**Improvement in Health and Sanitation**	**Community participation in management**	**Women's participation in management**	**National Development Priority**	**Stakeholder Acceptability**	**Endorsement by Experts**
	benefit	**benefit**	**cost**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**	**benefit**
15. Climate Change Monitoring System.	4	4	4	5	4	3	4	4	5	4	5

Table 4.3: Standardized Scores and Ranks of Technologies in the Water Sector

Technology	Criteria											
	Poverty Reduction of Vulnerable Groups	Economic Benefit for Country	Investment cost (US $)	Environmental Benefit	Increased Resilience and Adaptive Capacity of Vulnerable Groups	Improvement in Health and Sanitation	Community participation in management	Women's participation in management	National Development Priority	Stakeholder Acceptability	Endorsement by Experts	Average Score	Rank
1. Sub-surface storage and use.	1.000	1.000	0.333	0.500	0.667	0.667	0.500	0.250	0.500	0.750	0.250	**0.58**	**9**
2. Household water treatment and safe storage (HWTS).	0.667	0.000	1.000	0.250	1.000	1.000	0.250	0.750	0.750	0.750	0.750	**0.65**	**8**
3. Improving resilience of protected wells to flooding.	0.667	0.667	1.000	0.000	1.000	1.000	0.250	0.750	0.750	1.000	0.750	**0.71**	**4**
4. Increasing the use of water-efficient fixtures and appliances.	0.000	1.000	0.667	0.500	0.000	0.333	0.250	0.500	0.750	0.250	0.500	**0.43**	**12**

Technology	Criteria											
	Poverty Reduction of Vulnerable Groups	Economic Benefit for Country	Investment cost (US $)	Environmental Benefit	Increased Resilience and Adaptive Capacity of Vulnerable Groups	Improvement in Health and Sanitation	Community participation in management	Women's participation in management	National Development Priority	Stakeholder Acceptability	Endorsement by Experts	Average Score	Rank
5. Leakage management, detection and repair in piped systems.	0.000	1.000	0.333	0.250	0.000	0.667	0.500	0.000	0.750	0.750	1.000	**0.48**	**11**
6. Post-construction support (PCS) for community-managed water systems.	0.333	0.333	1.000	0.000	1.000	0.667	1.000	1.000	0.750	1.000	1.000	**0.73**	**3**
7. Rainwater collection from ground surfaces. (small dams)	1.000	1.000	0.667	0.500	0.667	0.333	0.750	0.750	1.000	0.750	0.750	**0.74**	**2**
8. Rainwater harvesting from roofs.	0.667	0.667	0.333	0.250	1.000	1.000	0.250	0.500	1.000	0.750	1.000	**0.67**	**6**

Technology	Criteria											
	Poverty Reduction of Vulnerable Groups	Economic Benefit for Country	Investment cost (US $)	Environmental Benefit	Increased Resilience and Adaptive Capacity of Vulnerable Groups	Improvement in Health and Sanitation	Community participation in management	Women's participation in management	National Development Priority	Stakeholder Acceptability	Endorsement by Experts	Average Score	Rank
9. Water reclamation and reuse. (waste-water recycling)	0.667	0.667	0.333	0.750	0.667	0.667	0.250	0.250	0.000	0.000	0.250	**0.41**	**13**
10. Water safety plans (WSPs).	0.333	0.667	0.333	1.000	0.667	0.667	0.250	0.250	1.000	0.250	1.000	**0.58**	**10**
11. Desalination.	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.03**	**15**
12. Demarcation and Protection of Buffer zones for water bodies.	0.333	1.000	0.333	0.750	0.333	1.000	0.750	0.750	1.000	0.250	1.000	**0.68**	**5**
13. Flood warning systems.	0.667	0.667	0.333	0.500	1.000	0.667	0.750	0.500	0.750	0.750	0.750	**0.67**	**7**
14. Flood-proofing.	0.667	0.667	0.333	0.500	0.667	0.667	0.000	0.000	0.000	0.000	0.250	**0.34**	**14**
15. Climate Change Monitoring System.	1.000	1.000	0.333	1.000	1.000	0.667	0.750	0.750	1.000	0.750	1.000	**0.84**	**1**

Source: Result of Stakeholders Analysis

Table 4.4: Results of Sensitivity analysis for water sector

Technology	Criteria											
	Poverty Reduction of Vulnerable Groups	Economic Benefit for Country	Investment cost (US $)	Environmental Benefit	Increased Resilience and Adaptive Capacity of Vulnerable Groups	Improvement in Health and Sanitation	Community participation in management	Women's participation in management	National Development Priority	Stakeholder Acceptability	Endorsement by Experts	Average Standardized Score	New Rank
3. Improving resilience of protected wells to flooding.	3*	3	2	1	4	4	2	4	4	5	4	0.71	4
	3	*3*	*3*	*3*	*4*	*4*	*3*	*4*	*4*	*5*	*4*	*0.75*	*4*
6. Post-construction support (PCS) for community-managed water systems.	2	2	2	1	4	3	5	5	4	5	5	0.73	3
	2	*2*	*2*	*2*	*4*	*3*	*5*	*5*	*4*	*5*	*5*	*0.76*	*3*
7. Rainwater collection from ground surfaces. (small dams)	4	4	3	3	3	2	4	4	5	4	4	0.74	2
	4	*4*	*3*	*3*	*3*	*3*	*4*	*4*	*5*	*4*	*4*	*0.77*	*1*
15. Climate Change Monitoring System.	4	4	4	5	4	3	4	4	5	4	5	0.84	1
	4	*4*	*4*	*4*	*4*	*3*	*4*	*4*	*4*	*4*	*4*	*0.77*	*1*

* Scores and ranks in black type are original scores and ranks (from Tables 4.2 and 43). Those in blue are the modified scores and resulting ranks for the sensitivity analysis.

4.4 Sensitivity analysis

Sensitivity analysis was carried out after the prioritization to determine whether rankings change significantly for small changes in the scores. Small modifications in the scores were made for selected technologies and criteria and the change in rankings compared with the original rankings. Results of such an analyses are presented in Table 4.4 for the 4 technologies with the highest original rankings. The top row for each technology in the table are the original scores and rankings while the bottom are the new ones. The scores changing for the analysis are highlighted in the same colour for a technology. The results indicate slight modification in ranking with only the technology ranked 2 previously now ranked 1, at the same level with the one originally ranked 1.

Climate change Monitoring System has also been selected as an adaptation technology for the Agricultural sector by the sector group. Indeed, this technology is necessary for adaptation in all sectors ï energy, fishery, coastal, etc. This is because knowledge of the continuously evolving climate system and impacts would be required for the appropriate adjustments in the implementation strategies of adaptation options for all sectors. This would ensure that adaptation is undertaken as a continuous iterative process taking into consideration current objective circumstances and projected future conditions based on sound scientific evidence.

Therefore, it is proposed that Climate Change Monitoring Systems should stand alone and automatically selected as adaptation technology for the water and other sectors. An additional technology can then be selected to be the 4th technology so that the following would be the final 4 selected technologies for the water sector only:

1. *Rainwater collection from ground surfaces.*
2. *Post construction support for community managed water systems.*
3. *Improving resilience of protected wells to flooding.*
4. *Demarcation and Protection of Buffer Zones for water bodies.*

5 TECHNOLOGY PRIORITIZATION FOR THE AGRICULTURE SECTOR

5.1 An overview of possible adaptation technology options in Agriculture Sector and their adaptation benefits

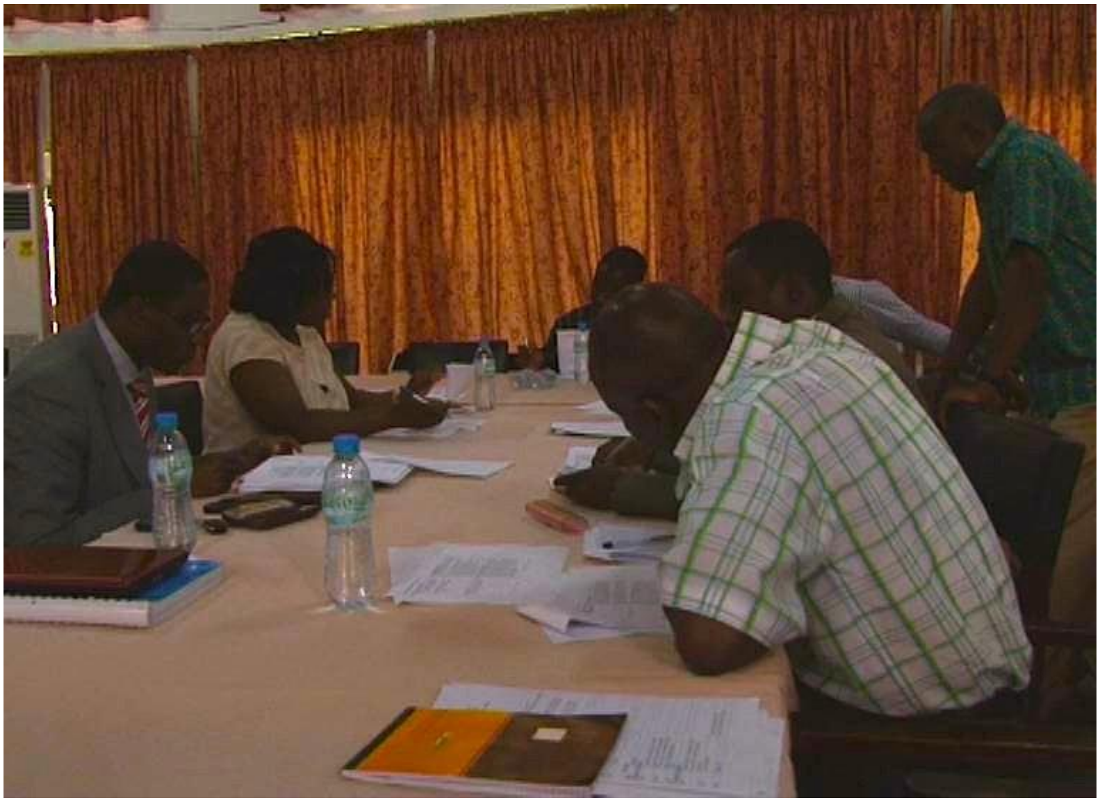
The Food and Agriculture sector in Ghana as indicated in the introductory sections of this report, is a major contributor to Gross Domestic Product through the provision of food, employment and source of livelihoods for majority of rural dwellers. Despite its contribution to national development over the years the sector remains basically under developed with majority of operators at the small-scale level using rudimentary and labour intensive means of production. Additionally, production is mainly rainfall dependent with only 4 per cent of irrigation potential developed in the country.

Ghana as most sub-Saharan African countries is highly vulnerable to Climate Change putting further pressure on its agriculture and food systems.

Based on on-going activities and information available in literature relating to adaptation technologies the following technologies were selected for discussion and prioritization by stakeholders. Whilst the title of some of the technologies might not be what is commonly used in Ghana, the most widely used terminologies are adopted to provide an international understanding.

5.2 Criteria and Process of Technology Prioritization

In the Agriculture Sector Group, MCA was also used for ranking and prioritization of the listed technologies. Following the methodology of the TNA, the Agriculture Sector expert prepared the list of criteria and presented it to the stakeholders for discussion and revision.



A photograph of the agriculture sector working group: The Agriculture Sector Expert, Mr. Kofi Delali Nutsukpo who is standing, is guiding the process.

The final list of criteria is presented in Table 5.1 below:

Table 5.1: Criteria for Prioritization of Adaptation Technologies in the Agriculture Sector

Criteria	**Description of criteria**	**Classification of criteria**
1. Maintenance or strengthening of biological diversity and environmental sustainability	extent to which the technology conserves and strengthens biological diversity and promotes environmental sustainability	Benefit
2. Facilitation of access to information systems and awareness of climate change information.	Extent to which the technology enables and facilitates (i) access to information about climate change and the uncertainty of future conditions, (ii) integration of information from seasonal and weather forecasting and early warning systems into decision-making	Benefit

Criteria	Description of criteria	Classification of criteria
	processes, and (iii) strengthening information systems in general (and with local knowledge more specifically).	
3. Investment cost.	Cost of implementing the technology	Cost
4. Support for water, carbon and nutrient cycles and stable and/or increased productivity.	Extent to which the technology (i) supports natural life cycles (nutrients of soil and water) and thus, conserves adequate biological conditions for future production; (ii) enables farmers Adaptation Decision-making and Prioritisation of Technologies for Climate Change Adaptation ï Agriculture Sector 32 to produce enough for self-consumption (to achieve food security), (iii) improves crop quality and productivity; (iv) improves crops quality and (v) is of easy dissemination and replication.	Benefit
5. Income-generating potential, cost-benefit analysis and contribution to improved equity.	Extent to which the technology: (i) Strengthens existing productive systems; (ii) Increases the amount of information about variations of prices of inputs and final products in the different months of the year. (iii) Reduces transaction costs of productive and commercial activities, for example, transportation costs, credit and rural insurance costs, costs incurred due to theft, among others.(iv) Does not generate influence, power and natural resource management inequities, which could be the source of social conflicts that obstruct the development of productive activities.	Benefit
6. Respect for cultural diversity and facilitation of inter-cultural exchange.	Extent to which the technology (i) respects cultural diversity, (ii) allows for an intercultural dialogue and the incorporation of ancient and local knowledge, and (iii) is understandable and easily applied by farmers in their current context.	Benefit
7. Potential for integration into regional and national policies and up-scaling.	Extent to which the technology is integrated coherently into regional and national policies and can be scaled-up for wider implementation.	Benefit
8. Building of formal and informal institutions and social networks.	Extent to which they strengthen formal and informal institutions, such as government ministries, civil society organisations and community-based organisations by building capacity for planning and execution of	Benefit

Criteria	Description of criteria	Classification of criteria
	adaptation strategies. Also level of support for civil society to form social networks and participate in decision-making processes.	

Source: Based on Stakeholders Analysis

5.3 Results of Technology Prioritization

Going by the methodology for the prioritization, the group was facilitated by a chairman with a sector expert providing the necessary technical insight into each technology during the discussions.

A similar procedure as adopted in the water sector was followed in scoring, ranking and prioritizing the agriculture sector technologies. The criteria were also classified as to benefit and cost (Table 5.1). For each criterion, a scale of 1 to 5 was used for scoring each technology (Table 5.2). Each technology was discussed by the group taking account of the national context. Each individual member of the group then provided a score for the technology. The average of the individual scores was then adopted as the group score. The scores were then converted into standard scores of between 0 and 1 (Table 5.3). The average standard scores of the technologies were used to do an initial ranking of the technologies. A second ranking of the technologies was done by inclusion of a weighting factor to prioritize the technologies. The results of the prioritization are also shown in Table 5.3.

Table 5.2: Actual scores for each agriculture sector technology against the criteria

Technology	Criteria (scores from 1 to 5 for each criterion; the higher the score the more benefit for the criterion except for investment cost where the higher the score the less the benefit for the criterion)							
	Maintenance or strengthening of biological diversity and environmental sustainability	Facilitation of access to information systems and awareness of climate change information.	Investment cost	Support for water, carbon and nutrient cycles and stable and/or increased productivity.	Income-generating potential, cost benefit analysis and contribution to improved equity	Respect for cultural diversity and facilitation of inter-cultural exchange	Potential for integration into regional and national policies and upscaling.	Building of formal and informal institutions and social networks.
	benefit	benefit	cost	benefit	benefit	benefit	benefit	benefit
1. Integrated National Climate Change Monitoring & Early Warning System	5	5	5	5	5	5	5	5
2. Climate Insurance	1	3	4	1	4	2	5	4
3. Sprinkler and Dripping Irrigation	3	2	5	4	5	2	5	5
4. Rain water harvesting	5	2	3	4	4	1	5	1
5. Slow-forming Terraces	3	3	4	4	4	3	5	1
6. Conservation Tillage	5	3	5	5	5	5	5	2
7. Integrated Soil Nutrient Management	5	3	3	5	5	5	5	3
8. Crop Diversification and New varieties	5	3	5	5	5	4	5	3

Technology	Criteria (scores from 1 to 5 for each criterion; the higher the score the more benefit for the criterion except for investment cost where the higher the score the less the benefit for the criterion)							
	Maintenance or strengthening of biological diversity and environmental sustainability	Facilitation of access to information systems and awareness of climate change information.	Investment cost	Support for water, carbon and nutrient cycles and stable and/or increased productivity.	Income-generating potential, cost benefit analysis and contribution to improved equity	Respect for cultural diversity and facilitation of inter-cultural exchange	Potential for integration into regional and national policies and upscaling.	Building of formal and informal institutions and social networks.
	benefit	benefit	cost	benefit	benefit	benefit	benefit	benefit
9. New Varieties through Biotechnology	5	5	5	5	5	3	5	2
10. Ecological Pest Management	5	5	4	5	5	4	5	2
11. Seed and Grain Storage	4	5	4	1	5	5	5	5
12 Selective Breeding via Controlled Mating	3	3	4	2	4	2	3	3
13. Integrated Livestock Disease Management	3	2	3	2	4	2	5	2
14. Mixed Farming	4	3	3	4	4	4	3	2
15. Agro-forestry	4	3	3	4	4	3	3	3
16. Farmer Field Schools	4	5	5	4	5	5	5	5
17. Community Trained Extension Agents	5	5	3	5	5	5	5	5
18. Community Forest Management Groups	5	5	3	4	4	5	4	5
19. Water User Associations	5	5	3	3	5	5	5	5

Table 5.3: Standardized Scores and Ranks of Technologies in the Agriculture Sector

Technology	Criteria									
	Maintenance or strengthening of biological diversity and environmental sustainability	Facilitation of access to information systems and awareness of climate change information.	Investment cost	Support for water, carbon and nutrient cycles and stable and/or increased productivity.	Income-generating potential, cost benefit analysis and contribution to improved equity	Respect for cultural diversity and facilitation of inter-cultural exchange	Potential for integration into regional and national policies and upscaling.	Building of formal and informal institutions and social networks.	Average Score	Rank
1. Integrated National Climate Change Monitoring & Early Warning System	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	**0.88**	**3**
2. Climate Insurance	0.000	0.333	0.500	0.000	0.000	0.250	1.000	0.750	**0.35**	**18**
3. Sprinkler and Dripping Irrigation	0.500	0.000	0.000	0.750	1.000	0.250	1.000	1.000	**0.56**	**12**
4. Rain water harvesting	1.000	0.000	1.000	0.750	0.000	0.000	1.000	0.000	**0.47**	**15**
5. Slow-forming Terraces	0.500	0.333	0.500	0.750	0.000	0.500	1.000	0.000	**0.45**	**16**
6. Conservation Tillage	1.000	0.333	0.000	1.000	1.000	1.000	1.000	0.250	**0.70**	**10**
7. Integrated Soil Nutrient Management	1.000	0.333	1.000	1.000	1.000	1.000	1.000	0.500	**0.85**	**4**
8. Crop Diversification and New varieties	1.000	0.333	0.000	1.000	1.000	0.750	1.000	0.500	**0.70**	**10**
9. New Varieties through Biotechnology	1.000	1.000	0.000	1.000	1.000	0.500	1.000	0.250	**0.72**	**9**

Technology	Criteria									
	Maintenance or strengthening of biological diversity and environmental sustainability	Facilitation of access to information systems and awareness of climate change information.	Investment cost	Support for water, carbon and nutrient cycles and stable and/or increased productivity.	Income-generating potential, cost benefit analysis and contribution to improved equity	Respect for cultural diversity and facilitation of inter-cultural exchange	Potential for integration into regional and national policies and upscaling.	Building of formal and informal institutions and social networks.	Average Score	Rank
10. Ecological Pest Management	1.000	1.000	0.500	1.000	1.000	0.750	1.000	0.250	**0.81**	**5**
11. Seed and Grain Storage	0.750	1.000	0.500	0.000	1.000	1.000	1.000	1.000	**0.78**	**7**
12 Selective Breeding via Controlled Mating	0.500	0.333	0.500	0.250	0.000	0.250	0.000	0.500	**0.29**	**19**
13. Integrated Livestock Disease Management	0.500	0.000	1.000	0.250	0.000	0.250	1.000	0.250	**0.41**	**17**
14. Mixed Farming	0.750	0.333	1.000	0.750	0.000	0.750	0.000	0.250	**0.48**	**13**
15. Agro-forestry	0.750	0.333	1.000	0.750	0.000	0.500	0.000	0.500	**0.48**	**13**
16. Farmer Field Schools	0.750	1.000	0.000	0.750	1.000	1.000	1.000	1.000	**0.81**	**5**
17. Community Trained Extension Agents	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.00**	**1**
18. Community Forest Management Groups	1.000	1.000	1.000	0.750	0.000	1.000	0.500	1.000	**0.78**	**7**
19. Water User Associations	1.000	1.000	1.000	0.500	1.000	1.000	1.000	1.000	**0.94**	**2**

Source: Agric sector group analysis

5.4 Sensitivity analysis

As for the water sector, sensitivity analysis was also done for the agriculture sector with similar results as for the water sector; rankings of the technologies are not very sensitive to changes in criteria scores.

At the end of the process the following were the first 4 prioritized technologies (as shown in Table 5.3):

1. *Community Based Extension Model;*
2. *Water User Associations;*
3. *Integrated Climate Monitoring and early warning system;*
4. *Integrated Soil Nutrient Management.*

Following the case made for *Integrated Climate Monitoring and early warning system* as being common and critical to all sectors, it is proposed that it be automatically selected to stand alone so that the next highest ranked technology could be included to make the final top 4 technologies as:

1. *Community Based Extension Model;*
2. *Water User Associations;*
3. *Integrated Soil Nutrient Management.*
4. *Ecological Pest Management*

6 CONCLUSION

There are salient points coming from the results of the list of the 4 prioritized technologies. Firstly, the point about a community-based approach to providing technological solutions to climate change came out strongly in the prioritization exercise. In each of the sectors, there were community-based technologies. On the prioritized technologies for the water sector, the topmost being rainwater harvesting system highlights the concern of most people about the unnecessary ölossô of good natural water. Secondly, management-related technologies are vital to adaptation in the water sector. For the agriculture sector, the community-based extension model reflects the essence of having adaptation technologies of which the ownership will be community-centred. The two integrated systems ï the Integrated Climate Monitoring and Early Warning System and the Integrated Soil Nutrient Management ï underscore the importance of adopting systemic approach to adaptation in agricultural practices. In fact the Integrated Climate Monitoring and Early Warning System also placed highly in the prioritization of the water sector. This is to be expected since climate change monitoring system is vital to the planning and implementation of adaptation strategies.

Indeed for the water sector, Integrated Water Resources Management (IWRM) was considered to be a key framework under which any adaptation technologies in the sector would be implemented. This framework has been recommended in the Ghana National Climate Change Adaptation Strategy, featured prominently in the Ghana National Water Policy and vigorously promoted by the Water Resources Commission of Ghana (WRC). The IWRM framework for adaptation to climate change impacts demands the implementation of a Climate Change Monitoring System, improved knowledge of water resources and water demand, cross-sectoral collaboration, improved access to information systems and increased awareness of climate change information, among other things (GWP, 2000). The technologies prioritized and listed in this report should therefore provide the foundation for technological solutions in adaptation to climate change.

After the technology prioritization exercise in both the Water and Agriculture Sectors along with the respective MCA, the Climate Change Monitoring System emerged as a priority technology in both sectors. It is proposed that Climate Change Monitoring Systems should stand alone and automatically selected as adaptation technology for the water and other sectors. An additional technology can then be selected to be the 4^{th} technology so that the following would be the final 4 selected technologies for the respective sectors:

(a) Water Sector Prioritized Technologies:

1. *Rainwater collection from ground surfaces.*
2. *Post construction support for community managed water systems.*
3. *Improving resilience of protected wells to flooding.*
4. *Demarcation and Protection of Buffer Zones for water bodies.*

(b) Agriculture Sector Prioritised Technologies:

1. *Community Based Extension Model;*
2. *Water User Associations;*
3. *Integrated Soil Nutrient Management.*
4. *Ecological Pest Management*

The point also needs emphasis that information sharing not only to the participants but also to the general public to create awareness of the impact of climate change is very vital. There is need for people to know about the initiatives going on in climate change adaptation and how the country is proactively combating the negative impacts. The TNA project is one of the projects enabling Ghana to be proactive about climate change adaptation. Stakeholders will continuously be engaged in the efforts to ensure adaptation nationally especially in the Water and Agriculture sectors. The stakeholders involvement is particularly important for the formulation and implementation of the Technology Action Plan, which is meant to address the technology needs of climate change adaptation in Ghana.

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Appendix 1: List of Participants of 1st and 2nd National Stakeholder Workshops

A. Participants of the 1st Inception Workshop of the TNA Project held on 4th May 2011 at the Coconut Groove Hotel

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1. Charles Ekpe (NADMO)	1. Henry Alhassan (ADB)
2. Ebenezer Mensah (KNUST)	2. Kwame Agyei Frimpong (UG)
3. Christine Young Adjei (WRC)	3. Daniel Dzissem (PEF)
4. Longman Attakumah (MWRWH)	4. Baba Tuahiru (CARE)
5. Roland Asare (CSIR-STEPRI)	5. Stephen Awuni (CSIR-STEPRI)
6. David Annan (EPA)	6. Regina Sagoe (CRI)
7. Oppong-Boadi (EPA)	7. Daniel Tutu Benefor (EPA)
	8. Kwadwo Tutu (UG)
	9. Quaronica Q. Quartey (ACTIONAID)

Appendix 2: Proposed Workplan of Ghana TNA Project

Act. no.	Activity							
	Year	2011				2012		
	Month	1-3	4-6	7-9	10-12	13-15	16-18	19-21
4.1	Appoint a TNA Coordinator and Establish the National TNA Committee							
4.2	Organise Stakeholders							
4.3	Develop a detailed draft work plan							
4.4	Identify institutions for data and expert support							
4.5	Hold National Inception Workshop and finalize the work-plan based on stakeholders feedback and contract consultants							
4.6	Participate in Regional Workshops (a) Capacity Building workshops (b) Experience Sharing Workshop							
4.7	Prioritizing Sectors and Technologies							
4.8	Prepare the prioritized technologies report (TNA report)							
4.9	Carry out market assessment-analyse barriers and develop an Enabling Framework for deployment and diffusion of prioritized technologies							
4.10	Prepare a Technology Action Plan (TAP)							
4.11	Seek political endorsement and integration of the TAP into national energy policy/ development plans							
4.12	Conduct techno-economic appraisal and develop proposals for a few selected projects							
4.13	Prepare and submit the Final Report							

Appendix 3: Inventory of Technologies in the Water and Agriculture Sectors

Technology	Current Status of Technologies
Water Sector Technologies	
1. Sub-surface storage and use (Artificial groundwater recharge and groundwater dams).	Artificial groundwater recharge is currently not practiced in Ghana though the technology is recommended as adaptation to water shortage and excessive surface evaporation in the Ghana National Climate Change Adaptation Strategy (NCCAS). Groundwater dams such as sand dams are also not formally used though farmers in the northern parts of the country access water naturally stored in the sands of dry river beds for dry season irrigated agriculture. Sub-surface storage technologies improve the yields in areas where aquifer levels are low or groundwater extraction is excessively high. They can also be employed to conserve and store excess surface water for future requirements. Evaporation losses and risk of contamination of the stored water are drastically reduced for water stored underground. They contribute to adaptation by making water of relatively high quality available for productive and other uses in the dry season or periods of drought.
2. Household water treatment and safe storage (HWTS)	Household water treatment such as filtration (using cloth material) and boiling is practiced in certain rural communities in Ghana. In areas suffering from guinea worm infestation filtration of drinking water obtained from dams and dugouts has been promoted as a means of controlling the problem. Recently, water purification tablets such as OASIS 1000 are being sold in some parts of the country using non-piped water as from rainwater harvested from roof tops. This is not widespread yet, however. Household or point of use (POU), drinking water treatment and safe storage provides a means to improve the quality of water for those with unsafe drinking water by treating it in the home. Popular treatment technologies include chemical disinfectants, biological sand filters and solar disinfection (SODIS) or ultraviolet disinfection. These technologies have been shown to improve the microbiological and, in some cases, the chemical quality of drinking water and to reduce diarrheal disease. HWTS enhances the resilience of households dependent on unsafe water sources such as streams, dugouts and ponds.
3. Improving resilience of protected wells (boreholes and hand-dug wells) to flooding.	Boreholes and hand-dug wells are the main source of potable water supply in the rural areas of Ghana. Their numbers are still woefully inadequate. Some of the existing ones have concrete protection against contamination from flood waters. Protecting wells against floods has been a major adaptation option considered in the country following persistent seasonal floods in the Volta Basin of the country that tended to pollute

Technology	Current Status of Technologies
	water sources including wells. Increasing access to groundwater is a key strategy for household water supply (both potable and non-potable) during drought. Therefore, drought relief programs in rural areas typically incorporate drilling or deepening of tubewells and/or boreholes. The key vulnerabilities of wells during flooding are: (1) ingress or infiltration of contaminated waters; (2) lack of wellhead access due to flood waters; and (3) collapse of unlined hand dug wells when soil becomes saturated. Protected wells can potentially provide a water supply that is highly resilient to flooding and ensure that clean water is available to communities during dry periods.
4. Increasing the use of water-efficient fixtures and appliances.	This has been recommended in the NCCAS as an adaptation option to conserve water but no strategies have been put in place nationally to vigorously promote it, as is the case for energy conservation through the use of energy saving lamps and appliances. The use of water efficient appliances and fixtures in homes, institutions and businesses can contribute greatly to water conservation efforts. The technology thus enhances water use efficiency and contributes to adaptation to water shortage or reduced water availability.
5. Leakage management, detection and repair in piped systems	Also recommended in the NCCAS as part of a water conservation strategy. The national water supply company, GCWL, is developing its capacity to implement this technology. Leakage in distribution systems is a major problem for water utilities throughout the world. In developing countries common causes of leakage, in addition to aging pipes, include poor network design and construction, damage to exposed pipes, and leakage at poorly sealed connections. Management, detection and repair of small leaks in a distribution system are critical functions of system operation and maintenance, but are often neglected. Leak management methods can prevent or reduce leakage volume and leak detection technology can improve the ability of water utilities to respond quickly and repair leaks. The technologies contribute substantially to water conservation and its sustainable use.
6. Post-construction support (PCS) for community-managed water systems	Many aspects of this technology have been adopted by the Community Water and Sanitation Agency (CWSA) as a means of ensuring sustainability in community-managed rural water supply systems. Communities are assisted to form Water and Sanitation (WATSAN) Committees and given the necessary technical, book-keeping and other training to equip them to better manage the communitiesô water systems. However,

Technology	Current Status of Technologies
	these committees often lack the necessary financial resources to undertake prompt maintenance of the systems they manage, particularly in repairs of broken down borehole pumps. PCS can increase the success and sustainability of community-managed water systems, including ñdemand-drivenò, community-managed ones. PCS is typically carried out through government programs, municipalities, multilateral donors, and various NGOs and include: ÅTechnical training for water system operators. ÅFinancial and accounting assistance (e.g. setting tariffs). ÅAssistance with maintenance, repairs and finding spare parts. Assistance with finding external funding for operation and maintenance (O&M), expansion or repairs. ÅAssistance with assessing the sufficiency of supply for expansion or in the case of drought. PCS can empower community water committees and operators to access the financial, management and technical resources that enable utility-managed supplies to prepare for and adapt to adverse precipitation conditions.
7. Rainwater collection from ground surfaces (e.g., Small community dams and dugouts, check dams)	This is major adaptation intervention to make water available to communities in the dry season, particularly in the drier northern regions of Ghana. Several such systems exist in the country for domestic water supply, dry season agriculture and livestock watering but these are woefully inadequate at present. The technology has been recommended in the NCCAS and is very high on the governmentôs development policy and agenda. Rainwater collection from ground surfaces are typically used in areas with seasonal rainfall to ensure that adequate water is available during the dry season. The water stored in these surface reservoirs is available in the dry period for irrigation, livestock watering and domestic needs. Experience in Ghana and elsewhere has shown that properly managed community dams are a big relief to communities vulnerable to water shortage in the dry season. Major environmental benefits of such reservoirs include the replenishment of nearby groundwater reserves and wells and the nourishment of neighbouring ecosystems.
8. Rainwater harvesting from roofs	Recommended in the NCCAS and given prominence in both the national water policy and the governmentôs development agenda as an important technology to increase water availability in households, public institutions and communities in general. The Ministry of Water Resources, Works and

Technology	Current Status of Technologies
	Housing is currently promoting the technology. Though used in various forms in some parts of the country, the technology is yet to be widely adopted as a water resources management strategy. Rainwater collection from rooftop catchments is a very old technology practiced in many countries. It is an important viable technical option for supplementing household and institutional water supply. Rainwater collection is easy to manage and contributes to householdsô adaptation to inadequate water supplies or availability.
9. Water reclamation and reuse (waste-water recycling)	Water reclamation or recycled water, is the treatment or processing of wastewater to make it reusable with definable treatment reliability and meeting appropriate water quality criteria while water reuse is the use of treated wastewater (or reclaimed water) for a beneficial purpose. Sustainable and safe approaches to meeting increasing water demand with municipal wastewater include: • Substituting reclaimed water for applications that do not require potable water. • Augmenting existing water sources and providing an additional source of water supply to assist in meeting both present and future water needs. • Protecting aquatic ecosystems by decreasing the diversion of freshwater, as well as reducing the quantity of nutrients and other toxic contaminants entering waterways. The technology is an example of an Environmentally Sound Technology (EST) because it protects the environment, results in less pollution, utilizes resources in a more sustainable manner, allows its waste and products to be recycled, and handles residual wastes in a more acceptable manner than the technologies for which it substitutes. It is recommended in the NCCAS but is currently not seriously adopted or promoted.
10. Water safety plans (WSPs) ï river catchment level	Not formally adopted as a water management strategy in the country though some aspects of it are being promoted by the Water Resources Commission (WRC) in its IWRM activities in river basins. The WRC is the government agency tasked to ensure the sustainable management, development and use of the water resources of Ghana, including the granting of water abstraction licenses. Water Safety Plans (WSPs) are a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. They enable identification of threats to water

Technology	Current Status of Technologies
	safety during any and all steps in the catchment, transport, treatment and distribution of drinking water, as opposed to the traditional techniques which rely on treatment and end-product testing to ensure water safety. When implemented successfully, the WSP approach can ensure that water quality is maintained in almost any context and improvement in the resilience of both human and natural systems.
11. Desalination	Not yet popular in Ghana though reverse osmosis (RO) techniques are increasingly being used to extract potable water from boreholes with saline water. Due to the high costs involved in implementing RO techniques, the technology is at present being undertaken mainly in commercial ventures such as the production of bottled water for sale. Currently, desalination is not being promoted as a national strategy. Desalination is the removal of sodium chloride and other dissolved constituents from seawater, brackish waters, wastewater, or contaminated freshwater using thermal processes or membrane processes such as reverse osmosis. The aim is to increase the fresh water supply base and could be a major adaptation measure to water unavailability, particularly in arid regions.
12. Demarcation and Protection of Buffer Zones for water bodies (Rivers, Reservoirs, Wetlands, etc.)	Recommended in the NCCAS and promoted strongly as a national policy. The WRC has developed a Riparian Buffer Zone policy accepted by both government and parliament. This policy is being implemented slowly the WRC in selected river basins of the country. Buffer zones refer to the existence of physical areas that separate either two ecological systems or an ecological system from other land uses or that border a water body. The creation and protection of buffer zones for water bodies are intended to control adverse human induced activities in the vicinity of the bodies, protect, regenerate and maintain the native/ established vegetation in the zones to improve water quality, maintain the functionality of the water bodies and ensure the sustenance of the ecological and socio-eonomic functions of the zones. Therefore, Riparian Buffer Zones support and maintain both natural (ecological) and human (socio-economic) systems.
13. Flood hazard mapping and warning systems.	Currently being promoted nationally. The World bank is currently assisting the WRC to develop a Flood Warning System for the White Volta Basin that experiences persistent seasonal flooding from torrential rainfall and dam operations upstream in Burkina Faso. Flood hazard mapping is an exercise to define those areas which are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of flooding. It acts as an information system to enhance our understanding

Technology	Current Status of Technologies
	and awareness of flood risk A flood warning system is a way of detecting threatening events in advance. This enables the public to be warned en masse so that actions can be taken to reduce the adverse effects of the event. As such, the primary objective of a flood warning system is to reduce exposure to flooding. Flood warnings are a highly important adaptive measure where protection through large scale, hard defences, is not desirable or possible. The technology considered here is for floods from storms as opposed to from sea level rise.
14. Flood-proofing	Not seriously promoted nationally, though some individuals in flood prone areas particularly in cities such as Accra practice some form of it. The primary objective of flood-proofing is to reduce or avoid the impacts of flooding upon structures and is an important adaptive measure. This may include elevating structures above the floodplain, employing designs and building materials which make structures more resilient to flood damage and preventing floodwaters from entering structures in the flood zone, amongst other measures.
15. Climate Change Monitoring System.	Recommended in the NCCAS and recognized by government as an important technology for sustainable development in all sectors of the countryǒs economy particularly in the energy (hydropower production), water supply, agricultural and fisheries sectors. The framework for adopting this technology comprehensively is yet to be formulated. It is critical to provide access to information about expected climate changes which should clearly explain the uncertainty involved in estimating future impacts. Monitoring climate change, forecasting impacts and using early warning systems to disseminate data to a range of stakeholders from the national to the local level are all vital components to successful long-term adaptation planning and implementation. A climate change monitoring system integrates satellite observations, ground-based data and forecast models to monitor and forecast changes in the weather and climate. The better the information available, the more climate can be understood and the more accurately future conditions can be assessed, at the local, regional, national and global level. This has become particularly important in the context of climate change, as climate variability increases and historical patterns shift.
Agriculture Sector Technologies	
1. Integrated Climate Change Monitoring and Early Warning System	There is no integrated climate change monitoring and early warning system currently in Ghana. However, there is limited dissemination weather information across the country. Some NGOs in the Northern regions have established a learning platform for gathering, analysis and sharing of information to

Technology	Current Status of Technologies
	inform planning at community level
2. Climate Insurance	This is a new concept in Ghana but identified within the FASDEP as an important scheme for addressing climate risk. It is currently being piloted in the Northern Region using maize as a focus commodity
3. Sprinkler and Drip irrigation	Sprinkler irrigation is an old technology in Ghana but its use is not wide spread. Compared to sprinkler irrigation, drip irrigation is new and its use is limited to the horticultural industry. Drip irrigation is being used successfully to produce Mango in the Northern regions of Ghana.
4. Rainwater harvesting	Rainwater harvesting is a well known technology with wide application in the savannah regions. The most common structures are the dams and dugouts. Water Resources Commission (WRC) is currently piloting underground storage tanks in flood prone areas in the Northern Region.
5. Slow-forming terraces	This group of technologies are being promoted and adopted widely in various agro-ecological zones and landscapes. They are however most common in the Northern savannah zones and sloppy landscapes.
6. Conservation tillage	The promotion and adoption of conservation tillage started late 1990s. Among the various aspects of conservation, no-till is the most widely adopted and being used in most parts of the country with the highest concentration in the forest and transition zones.
7. Integrated soil nutrient management	Also referred to as integrated soil fertility management in Ghana, it has been widely promoted. There is availability of capacity for effective transfer to farmers. However the use of the technology is low compared to use of single nutrient sources.
8. Crop Diversification and New Varieties	There is increased introduction of new varieties of existing crops due to increased research and development of improved varieties. The adoption and use of these new and improved varieties are however below average.
9. Biotechnology	Biotechnology is not a new technology in Ghana and its use is increasing in crop variety development including rapid multiplication of vegetatively propagated crop species e.g. pineapples and plantain.
10. Ecological Pest Management	Ecological (Integrated) Pest Management has been introduced into farming systems in Ghana and adopted as an alternative to conventional pest management approaches. It has currently been expanded to include improved crop husbandry practices and called integrated crop management.
11. Seed and Grain Storage	Community seed and grain storage is not well established as a technology although farmers at household level practice various types of traditional storage methods. Recently, there were discussions about developing community based seed systems that would respond to farmersô groups and community needs.
12. Selective Breeding via	Controlled mating is being promoted as a good animal

Technology	Current Status of Technologies
Controlled Mating	husbandry practice for maintenance of stock/herd quality. The adoption and use of the technology is however on the lower side due to the prevalence of extensive livestock production systems.
13. Livestock Disease Management	Livestock Disease Management is a major component of livestock extension service provision. This is supported by disease surveillance and mass vaccination programmes. Farmers are trained to undertake regular preventive actions to control diseases in their stock.
14. Mixed Farming	Mixing farming is not practiced on any appreciable level in Ghana although most farming households keep one type of farm animal or the other, there is little or no effort to actually integrate the crops and animal components.
15. Agroforestry	Agroforestry was introduced in the late 1990s as an important land management technology with emphasis on alley cropping and woodlots. Acceptance and use of the technology was varied across the different agro-ecological zones. The technology is still being promoted under various land improvement projects.
16. Farmer Field Schools	Farmer Field Schools have been adopted in Ghana as an alternative technology dissemination and adoption approach. It is widely used by research institutes and projects for involving farmers in problem identification, and analysis, and testing and adaption of technologies.
17. Community Based Extension	The community based rural agricultural extension model was introduced in Ghana to complement the efforts of veterinary services because of shortage of staff. The practice has been expanded to include other technical areas including crop agronomy. It is also being practiced to promote climate adaptation in parts of the Northern region by CARE International, an NGO. The use of model is however not on a large scale.
18. Forest User Groups	The concept of Forest User Groups is being practiced by the Wildlife Division of the Forestry Commission under the name Community Resource Management Area (CREMA) for the conservation of wildlife and other natural resources. It has been widely piloted and found to have the potential for regeneration of biodiversity among others. The approach is currently being used for the restoration of the Gbele Game Reserve
19. Water User Associations	A Water User Association is a unit of individuals that have formally and voluntarily associated for the purposes of cooperatively sharing, managing and conserving a common water resource. The objective of a WUA include; conservation of water catchments; sustainable water resource management; increase availability of water resources; increase the usage of water for economic and social improvements and development of sustainable and responsive institutions. The WUA can contribute to climate change adaptation by providing a cooperative mechanism through which impacts of climate

Technology	Current Status of Technologies
	change on water resources can be monitored and water users and decision makers can be empowered to manage and allocate water resources with a consideration for climate change The concept of Water User Associations was introduced in Ghana as major step towards involving farmers of irrigation facilities in the management of schemes and allocation of water rights. This became necessary when it was realised that farmers were not concerned with good management and maintenance of the schemes and government alone could not handle it. Since its introduction the concept has been found to be workable and has led to improvements in management of irrigation facilities especially small-scale schemes for farmers.

Appendix 4: Technology Factsheets for the Water Sector

Technology: Rainwater collection from ground surfaces	
Technology characteristics	
Introduction	This technology covers collection, storage and use of rainfall that lands on the ground as opposed to collection from roofs. In many water-poor areas, small-scale runoff collection infrastructure can contribute greatly to the volume of freshwater available for human use. This is especially true in arid and semi-arid regions, where the little rainfall received is usually very intense and often seasonal. Because of this, runoff and river flows can be abundant for brief periods and non-existent throughout the rest of the year, as is the case in Northern Ghana. Rainwater collection from ground surfaces is typically used in areas with seasonal rainfall to ensure that adequate water is available during the dry season. The technology consists essentially of collecting flows from a river, stream or other natural watercourse (sometimes called floodwater harvesting). This technique often includes an earthen or other structure to dam the watercourse and form ñsmall reservoirs.ò Another flood water harvesting technique is "Check-dams." These are small barriers constructed of rock, gravel bags, sandbags, etc, across the direction of water flow on shallow rivers, streams and other natural small water channels for the purpose of water harvesting, for erosion and sediment control. The small dams retain excess water flow during the rains in a small catchment area behind the structure. Collection of rainfall from ground surfaces utilizing ñmicro-catchmentsò to divert or slow runoff so that it can be stored before it can evaporate or enter watercourses is another technique. However, micro-catchments are often used to ñstoreò water as soil moisture for agriculture and are rarely used for water supply for other purposes. Rainwater collection from ground surfaces contributes to climate change adaptation at the community level by providing a convenient and reliable water supply during seasonal dry periods and droughts.
Institutional and organizational requirements	Policies, legislation and institutional capacity are needed to address conflicts and externalities that can result from to rainwater collection. The ñdemand-driven, community-managedò model that has worked for small drinking water supplies is likely to work small reservoir systems as well.
Operation and maintenance	Operation and maintenance for community-owned systems are straight forward. Appropriate post construction support systems would be required to enable communities undertake proper and

Technology: Rainwater collection from ground surfaces	
Technology characteristics	
	timely maintenance of small reservoirs such as repairing and re-enforcing eroded embankments and to ensure sustainability.
Endorsement by experts	Small reservoirs have been endorsed by experts as a means of ensuring the continuous availability of water in the dry season for rural communities, particularly for irrigated agriculture and livestock watering.
Adequacy for current climate	Very suitable for both current variability and future climate change. It empowers communities to adapt appropriately to seasonal and short duration rainfall conditions now and in the future.
Size of beneficiaries group	The technology is targeted to communities or clusters of communities and not few individuals.
Disadvantages	The main disadvantage is cost of construction of robust water collection systems. Also, if systems are not demand-driven they could malfunction as the critical element of ownership would be missing.
Capital costs	
Cost to implement adaptation options	These are made up of construction costs and expenditures on training beneficiary communities to properly operate and maintain the systems. Construction and implementation costs of rainwater collection projects depend on many factors including the type of collection systems and the scale and location of the project. Construction costs of a small reservoir system could exceed US $50,000.00.
Additional cost to implement adaptation option, compared to ñbusiness as usualò (extra storage capacity)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Reduces the current high vulnerability of communities in arid and semi-arid regions to impacts of climate variability and change
Economic benefits Employment	 Creation of jobs to support operation and maintenance of water systems and to provide training to users/households.
Investment	.
Public and private expenditures	Expenditure on food imports could be reduced.
Social benefits Income	 Ensuring availability of water in communities would reduce household expenditure on more expensive potable water sources

Technology: Rainwater collection from ground surfaces	
Technology characteristics	
	such as from water tankers and bottled water. The water can also contribute to productive and economic livelihood through irrigation and maintenance of livestock.
Learning	Training elements from capacity building in operation and maintenance Improved health improves school attendance
Health	Contributes to water availability and eliminates dependence of communities on unimproved water sources. Systems also used for irrigation, for example, could result in improved nutritional status of beneficiary communities. These will result in improved health for households including women and children.
Environmental benefits	Groundwater recharge is an added benefit of unlined reservoirs; stored water will infiltrate permeable soils during storage and eventually reach the groundwater table.
Local context	
Opportunities and Barriers	Increased agricultural productivity, the potential for year-round water supply, and decreased time spent collecting water provide strong incentives to communities considering rainwater collection. Increased opportunities for ground-level rainwater collection should arise when rainfall is highly variable or seasonal, agricultural productivity is clearly hindered by dry periods, and alternative water supplies are distant, such as is the case for northern parts of Ghana. Barriers include the potential for adverse hydrological impacts downstream and the need for adequate capacity to assess these impacts. However, the environmental and hydrological impacts of small reservoirs have been reported to be minor. Additionally, surface storage can lead to parasite/vector breeding, algal blooms and poor water quality, particularly in small reservoirs fed by agricultural runoff.
Market potential	The technology is relevant and, though a bit expensive has market potential in the arid and semi-arid regions.
Status	Small reservoirs and check dams are already being used in various communities in Ghana, is promoted by the Ministry of Water Resources, Works and Housing, Ministry of Agriculture and NGOs. Their numbers are currently inadequate and many of the existing ones are poorly maintained due to lack of resources.

Technology: Rainwater collection from ground surfaces	
Technology characteristics	
Timeframe	The implementation can start now. Communities could be assisted in adapting to climate variability now while preparing for adaptation to climate change impacts in the future.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

Technology Fact Sheet for Adaptation

Technology: Post-construction support (PCS) for community- managed water systems	
Technology characteristics	
Introduction	The community that can adequately manage its own water supply system over the long term without any form of external assistance is the exception rather than the rule. Post-construction support (PCS) can increase the success and sustainability of community-managed water systems. This is even true for those systems that are implemented according to all the currently recognized best practices of the ñdemand-driven, community-managed model. PCS is typically carried out through government programs, municipalities and other bodies that provide community-managed water systems. Types of PCS include, but are not limited to: • Technical training for water system operators • Technical and engineering support, including provision of technical manuals • Financial and accounting assistance (e.g. setting tariffs) • Help with settling disputes (e.g. bill payment or water sources) • Help with maintenance, repairs and finding spare parts • Assistance in finding external funding for O&M, expansion or repairs • Assistance in assessing the sufficiency of supply for expansion or in the case of drought • Start-up capital for emergency system repairs • Household visits to residents to discuss water system use. PCS contributes to climate change adaptation at the community level through: (1) Diversification of community water supply (2) Promotion of water conservation, and (3) Increased resilience to water quality degradation. PCS can empower community water committees and operators to access the financial, management and technical resources that enable utility-managed supplies to prepare for and adapt to adverse precipitation conditions. PCS facilitates community ownership, management and

Technology: Post-construction support (PCS) for community- managed water systems	
Technology characteristics	
	maintenance of water systems, promotes women participation in their management and improves system performance and sustainability.
Institutional and organizational requirements	Four basic PCS institutional models: • Centralized Model: where support services are provided by a government agency or ministry operating from a centralized point, directly engaging with community management structures in rural areas. • Deconcentrated Model: under which support services are provided by a central government agency operating, with a degree of autonomy, through regional or departmental level offices. • Devolution Model: where the authority and responsibility for provision of support services is transferred from a central government agency to a decentralized tier of government, usually at the municipal level. • Delegated Model: where the responsibility for provision of support services is delegated from a central or local government agency to a third party, which could be an NGO, a private sector company or a relevant user association Regardless of the model, it is important that: • The roles and responsibilities among PCS staff are defined. • Community water committees understand clearly which operation, maintenance and administration tasks are the responsibility of the community. • The respective roles of all stakeholders are recorded and disseminated.
Operation and maintenance	Operation and maintenance consists primarily of training for community members, especially with respect to system management and protection of water quality. Budgets would also be required to support field visits to communities by field staff of the supervising and monitoring agency. Monitoring and evaluation of PCS systems would be required in order that the necessary adjustments in their operation are promptly made to ensure sustainability.
Endorsement by experts	PCS is widely recognized by experts as a means of ensuring the continuous operation of community owned and managed water system.
Adequacy for current climate	Very suitable for both current variability and future climate change. It empowers communities to adapt appropriately to adverse rainfall conditions now in the future.

Technology: Post-construction support (PCS) for community- managed water systems	
Technology characteristics	
Size of beneficiaries group	PCS is targeted to communities or clusters of communities and not few individuals.
Disadvantages	The benefits of PCS are primarily medium-term to long-term and are often difficult to quantify. If not demand-driven could lead to system malfunction as the critical element of ownership would be missing.
Capital costs	
Cost to implement adaptation options	These costs include salaries, office overhead, training costs, and a substantial transportation budget for field staff to travel to rural communities. Cost per community system established = USD 150/annum Total costs (3 000 units)= USD 450 000/annum
Additional cost to implement adaptation option, compared to ñbusiness as usualò (extra storage capacity)	Additional cost per unit = USD 50/annum Total additional costs = USD 150 000/annum
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	
Economic benefits Employment Investment Public and private expenditures	 Creation of jobs to support operation and maintenance of water systems and to provide training to users/households. Can create investments in production of items such as pump parts. Reduce public and private expenditures associated with completely broken down water systems.
Social benefits Income Learning Health	 Ensuring availability of water in communities would reduce household expenditure on more expensive potable water sources such as water tankers and bottled water. The water can also contribute to productive and economic livelihood purposes, especially the water system could be used for irrigation and livestock watering. Training elements from capacity building Improved health improves school attendance Contributes to water availability and eliminates dependence of communities on unimproved water sources. Better managed systems for irrigation, for example, could result in improved

Technology: Post-construction support (PCS) for community- managed water systems	
Technology characteristics	
	nutritional status of beneficiary communities. These will result in improved health for households including women and children. In general, can result in stronger social cohesion in beneficiary communities.
Environmental benefits	PCS could result in water availability for the environment and protection of water bodies from proper water systems management and water conservation.
Local context	
Opportunities and Barriers	There exists national agencies in many countries such as Ghana and NGOs that provide some support to community managed water systems. These can be scaled up with further sources of funding. The effectiveness of PCS requires education of key stakeholders and a reliable source of funding.
Market potential	The technology is small-scale, proven and less capital-intensive. It has market potential nationwide.
Status	PCS is already being undertaken in various communities in Ghana, promoted by the Community Water and Sanitation Agency of Ghana and NGOs. This need to be improved, strengthened and applied country-wide.
Timeframe	The implementation can start now. Communities could be assisted in adapting to climate variability now while preparing for adaptation to climate change impacts in the future
Acceptability to local stakeholders	PCS is acceptable to local stakeholders.

Technology: Improving resilience of protected wells to flooding.	
Technology characteristics	
Introduction	Increasing access to groundwater is a key strategy for household water supply (both potable and nonpotable) , particularly in rural communities. Access to groundwater is critical during drought. Therefore, water supply schemes and drought relief programs in rural areas typically incorporate drilling or deepening of tubewells and/or boreholes. Protected wells can potentially provide a water supply that is highly resilient to flooding. However, improper design and construction can make them vulnerable during flooding. The key

Technology: Improving resilience of protected wells to flooding.	
Technology characteristics	
	vulnerabilities of wells during flooding are: (1) ingress or infiltration of contaminated waters; (2) lack of wellhead access due to flood waters; and (3) collapse of unlined hand dug wells when soil becomes saturated. Protected wells can include tubewells, boreholes and hand-dug wells. The salient features of all protected wells include the following: (1) a concrete apron to direct surface water away from the well; (2) a sanitary seal (normally clay, grout, and concrete) that extends at least 1-3 m below ground to prevent infiltration of contaminants; and (3) a method to access water that enables it to be sealed following use. The technology includes ñsanitary surveysò of wells to identify key vulnerabilities related to flooding. In addition to protection of wells currently used for drinking water, sealing abandoned wells is also essential to protecting groundwater quality in flood zones. If an abandoned well in not properly sealed, floodwaters that inundate the abandoned well are likely to contaminate both shallow and deep groundwater. Flooding can lead to contamination of drinking water wells and can also prevent physical access when floodwaters are high enough. Protecting wells against flooding is an effective mechanism to reduce the vulnerability of communities during flood events.
Institutional and organizational requirements	A training or certification program may be necessary for those carrying out sanitary surveys of wells in flood-prone areas. Some institutional capacity is necessary to determine if, where and how public funds should be allocated for constructing or retro-fitting wells.
Operation and maintenance	Mainly maintenance of installed and protected systems.
Endorsement by experts	Endorsed by experts.
Adequacy for current climate	Very suitable for both current variability and future climate change. It empowers communities to adapt appropriately to seasonal flooding that could result in contamination of or temporary lack of access to wells.
Size of beneficiaries group	Households and communities.
Disadvantages	The main disadvantage is cost, particularly if new wells drilled.

Technology: Improving resilience of protected wells to flooding.	
Technology characteristics	
Capital costs	
Cost to implement adaptation options	Cost of constructing and protecting one borehole may be up to US $15,000. Protecting an existing well be cost up to US $5,000.00
Additional cost to implement adaptation option, compared to ñbusiness as usualò (extra storage capacity)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Reduces the vulnerability of flood-prone communities increased flooding from climate change.
Economic benefits	
Employment	Employment for technicians undertaking ñsanitary surveysò and artisans for construction works.
Investment	Initial investment may be high but maintenance is simple and less expensive.
Public and private expenditures	Reduces public expenditures on resettling communities displaced due to lack of access to flooded wells.
Social benefits	
Income	Ensuring availability of good quality water in flooded communities would reduce household expenditure on more expensive potable water sources such as from water tankers and bottled water.
Learning	Training of local artisans and communities as a whole in maintaining the systems put in place.
Health	The technology ensures continuous access of communities/households to uncontaminated water during floods thereby contributing to improved health of households..
Environmental benefits	Groundwater is protected from contamination.
Local context	
Opportunities and Barriers	Communities that are frequently flooded with temporary lack of access to their wells would certainly be willing to invest in flood-proofing. However, those with alternative (e.g. piped) water supplies may be less likely to demand/ less willing to invest in flood-proofing wells.
Market potential	
Status	Some protected wells already exist in several rural communities.

Technology: Improving resilience of protected wells to flooding.	
Technology characteristics	
	The technology is being promoted by the CWSA and some NGOs in Ghana.
Timeframe	The implementation can start now. A large number of communities are already vulnerable to well contamination from frequent floods, especially in the northern parts of the country.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

Technology: Demarcation and Protection of Riparian Buffer Zones	
Technology characteristics	
Introduction	Human induced activities such as uncontrolled logging and mining activities, human settlements, urbanization, livestock populations, and poor agricultural practices have degraded the vegetative cover at headwaters and along the banks of many river systems and other surface water bodies. These poor and unsustained management practices are jeopardizing the physical quality of the environment, the hydrological and ecological support systems and the livelihoods of local inhabitants around these water bodies. These activities have further exposed most of Ghanaȏs rivers and water bodies to the vagaries of the weather, and may as a result, account for the many streams and rivers, which used to be perennial, but are now experiencing periodic drying up. The creation and protection of Buffer Zones for water bodies are intended to control these human induced activities in the vicinity of the bodies, protect, regenerate and maintain the native/ established vegetation in the zones to improve water quality, maintain the functionality of the water bodies and ensure the sustenance of the ecological and socio-economic functions of the zones. Buffer zones refer to the existence of physical areas that separate either two ecological systems or an ecological system from other land uses or that border a water body. The functional aspect of Riparian Buffer Zones can be categorized into natural (ecological) and human (socio-economic) services.
Institutional and organizational requirements	A decentralized institutional and organizational arrangement, preferably at the river basin level, would be required to design and implement the technology. Such an institutional framework would require the involvement of the various stakeholders who depend one way or the on the resources of the basin.
Operation and maintenance	While the implementation and management of the technology at the

	local level would actually be done by the local body of stakeholders, such as the river basin board in Ghana, the whole system must be coordinated by a designated National body such as the Water Resources Commission (WRC).
Endorsement by experts	The technology is endorsed by national experts
Adequacy for current climate	The technology seeks to improve the functionality of rivers and other water bodies and maintain ecological support systems and environmental integrity of the bodies. Therefore, it is suitable for current climate.
Size of beneficiaries group	The technology is beneficial to riverine communities and the country as a whole.
Disadvantages	Disadvantages include the high cost of implementing and maintaining the zones, particularly as this technology is implementable nationwide.
Capital costs	
Cost to implement adaptation options	Costs are high and could exceed US $.
Additional cost to implement adaptation option, compared to ñbusiness as usualò	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change by ensuring the availability of the hydrological and ecological support systems for the socio-economic well-being of beneficiary communities and the country at large.
Economic benefits	
Employment	Jobs would be created for the local communities not only in the creation of the buffer zones (growing trees) but also in the policing and protection of the zones.
Investment	Local communities could also invest in growing fruit trees as part of the buffer and harvest the fruits later for extra income.
Public and private expenditures	Reduce public and private expenditures on climate related disaster management such as flooding from rivers overflowing the banks.
Social benefits	
Income	Buffer zones would maintain the integrity of river systems and their environment and ensure that local communities could continue to depend on the systems for their livelihood support. For example, buffer zones could provide indigenous plants of diverse species that are traditionally harvested for medicine and building materials and also support fish populations traditionally caught as an important food item in many fishing communities.
Learning	Training elements from capacity building in creation and maintenance of the zones at various levels

Health	The technology could help reduce health risks associated riverine floods and water shortage from drying rivers.
Environmental benefits	The technology protects the environment and maintains its integrity.
Local context	
Opportunities and Barriers	A buffer zone policy has already been formulated by the WRC of Ghana and due to be adopted. In addition, the WRC has established River Basin Boards in some river basins of the country for their management including creation of buffer zones. Barriers include the high cost and the reluctance of some communities to give up farming and other detrimental activities such as illegal small scale gold mining in the zones. .
Market potential	
Status	Ghana already has a WRC with River Basin Boards for the integrated water resources management of the basins.
Timeframe	The implementation can start now.
Acceptability to local stakeholders	The technology is acceptable to a wide spectrum of local stakeholders.

Appendix 5: Technology Fact Sheets for the Agriculture Sector

Technology: Community-based extension	
Technology characteristics	
Introduction	The community based rural agricultural extension model is based on the idea of providing specialised and intensive technical training to identified people in rural communities to promote a variety of technologies and offer technical services with support and review from an extension organization. The model is demand- based in that the service provider is contacted by farmersô groups or community to provide specific information and related service. The community based extension model can contribute to climate change adaptation through the training of service providers in climate data collection; analysis and dissemination within their areas of operation to enable communities select appropriate response strategies. The community based rural agricultural extension model was introduced in Ghana to complement the efforts of veterinary services in addressing livestock health problems in the absence of adequate qualified staff. The practice has since been expanded to include other technical areas including crop agronomy. It is also being used to promote climate adaptation in parts of the northern region by CARE International, an NGO. The use of model is however remains on pilot basis with limited coverage.
Institutional and organizational requirements	The role out of the community-based extension model requires a well established and experienced extension service at the national and regional level with qualified staff to role out. This is necessary for the supervision and technical support required by the community agents.
Operation and maintenance	As a community ï based model, its operation will basically be at the districts and community level. There will be the need for regular on the job training and refresher courses for the agents to enable them deliver efficient services. The model will also require regular reviews towards improving its general operation
Endorsement by experts	The community based extension model is endorsed as an important alternative and supplement to nation-wide extension services especially under circumstance of high farmer to extension agent ratios.
Adequacy for current climate	The model is very relevant for addressing current climate change effects at the community level since it provides opportunity for local leadership in problem identification, analysis, selection of relevant technologies for addressing to current climate variability and future climate change.
Size of beneficiaries group	The technology has the potential of increasing access to extension services by a lot more farmers and in a timely manner.
Disadvantages	A major disadvantage of the model is the probability of rolling out

	poorly trained agents. Another disadvantage could be inadequate supervision and technical support from the main extension service.
Capital costs	
Cost to implement adaptation options	The model aimed at reducing cost of extension service provision. Costs are therefore expected to be low and will depend on the coverage area.
Additional cost to implement adaptation option, compared to ñbusiness as usualò (extra storage capacity)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change through increases in access to technical services by farmers for implementation of other adaptation technologies e.g. li8vestock management, soil and water management etc.
Economic benefits	
Employment	The implementation of the model will create on site jobs for people within their own communities.
Investment	Requires low investment when compared to training and use of regular extension staff
Public and private expenditures	Reduce public and private expenditures on climate related disaster management through its support to building community resilience.
Social benefits	
Income	Source of extra income for4 the community extension agents whilst supporting increases in household incomes at the community level.
Learning	Creates opportunity for increased group and individual learning at community level
Health	The technology has the potential reducing health risks within communities through improved flow of information and training.
Environmental benefits	Community based extension model would assist in producing environmental benefits through the promotion and training of farmers on technologies that support environmental sustainability.
Local context	
Opportunities and Barriers	The current national extension policy provides for multiplicity of extension service providers hence is an opportunity for rolling out the technology by either public or private sector extension services. A major barrier is absence of the right caliber of people from various communities to be trained and appointed. Additional to this is the high rate of rural urban migration which could lead to high turnover of trainees. .
Market potential	This is a non-market technology

Status	Both the government extension service and NGOs are piloting the technology in some selected areas for specific purposes
Timeframe	The implementation can start now.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

Technology: Water User Associations	
Technology characteristics	
Introduction	A Water User Association is a unit of individuals that have formally and voluntarily associated for the purposes of cooperatively sharing, managing and conserving a common water resource. The objective of a WUA include; conservation of water catchments; sustainable water resource management; increase availability of water resources; increased usage of water for economic and social improvements and development of sustainable and responsive institutions. The WUA can contribute to climate change adaptation by providing a cooperative mechanism through which impacts of climate change on water resources can be monitored and water users and decision makers can be empowered to manage and allocate water resources with a consideration for climate change. The concept of Water User Associations was introduced in Ghana as major step towards involving farmers at irrigation facilities in the management of schemes and allocation of water rights. This is necessary for effective and efficient management and maintenance of the schemes in collaboration with government. Since its introduction the concept have been found to be workable and has led to improvements in management of irrigation facilities especially small-scale schemes.
Institutional and organizational requirements	The success of the use of the technology depends on the development of an organizational structure including leadership roles and responsibilities, financial management rule and procedures. The structure must be supported by a constitution or an operational manual provides for leadership accountability and financial auditing.
Operation and maintenance	The technology can be implemented at local (community) river basin levels. The operations of WUAs will need to be supported by necessary technical support by appropriate agency.
Endorsement by experts	The technology has been endorsed as appropriate for effective management of water resources as a climate change adaptation measure.
Adequacy for current climate	WUAs are relevant for addressing current climate change effects at the

	community and water basin levels since it provides opportunity for local leadership in management and conservation of water resources including water use rights which is important for addressing to current climate variability and future climate change.
Size of beneficiaries group	The technology has the potential of increasing access to water resources for multiple user groups and over longer periods
Disadvantages	A major disadvantage of the model is the risk of poor management structures and unclear roles and responsibilities of the WUAs. Additionally, undue political influences could limit the effectiveness of WUAs in the performers of their duties.
Capital costs	
Cost to implement adaptation options	The major cost associated with WUAs is that needed for initial capacity building activities (technical support, organizational development, initial operational cost etc.). The total cost for developing and operationalizing one WUA will not exceed US$100,000.
Additional cost to implement adaptation option, compared to ñbusiness as usualò (extra storage capacity)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change through effective management of water resources that results in increased productivity of water.
Economic benefits	
Employment	The technology supports employment at the community through ensuring availability of water for off season farming activities.
Investment	Requires low investment for capacity building of WUAs
Public and private expenditures	Reduce public and private expenditures on climate related disaster management through its support to building community resilience.
Social benefits	
Income	Provides source for extra income for farmersô groups through increasing water availability for production. WUAs can also develop market cooperatives that ensures effective marketing of membersô produce
Learning	Creates opportunity for increased group and individual learning at group and community level
Health	The technology has the potential reducing health risks within communities through improved management of water resources that supports improvement in water quality.
Environmental benefits	WUAs are essential part of Integrated Water Resource Management that ensures sustainable use of water resources.

Local context	
Opportunities and Barriers	The current national water policy provides for participation of various stakeholders management of water resources using IWRM approach. Additionally there are number water basin management boards that are collaborating with different stakeholders to achieve improved management of water resources. The Ghana Irrigation policy also recognizes the important role of WUAs in the effective and efficient management of schemes. A major barrier could be the lack of commit of government to support the initial capacity development of these WUAs and also put in the necessary regulatory framework to ensure their effective management .
Market potential	This is a non-market technology
Status	The technology is being used to management a number of water facilities across the country with success.
Timeframe	The implementation can start now.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

Technology: Integrated Soil Nutrient Management	
Technology characteristics	
Introduction	Also referred to as integrated soil fertility management, the technology aims making efficient use of both synthetic and natural plant nutrient sources to enhance soil fertility towards improving and preserving soil productivity. The success of INM relies on the appropriate application and conservation of nutrients and transfer of knowledge to farmers. The technology enables the adaptation of plant nutrient and soil fertility management within a farming system to site specific characteristics; an important ingredient for climate change adaptation. Integrated soil fertility management in Ghana, has been widely promoted. There is availability of capacity for effective transfer of the technology to farmers. However the use of the technology is low compared to use of single nutrient sources.
Institutional and organizational requirements	The technology requires a well resourced research and extension organization for its effective promotion and use. In additional there is the need for appropriate extension approaches and methodologies that provides opportunity for farmer experimentation and adoption of technology.
Operation and maintenance	The technology can be promoted using existing research, extension and farmer linkages for technology dissemination. This however needs to be supported by effective capacity building at various levels to support

	operations at farmer level.
Endorsement by experts	The technology has been endorsed as appropriate for effective management of soil resources for increased and sustainable productivity a necessity for climate change adaptation.
Adequacy for current climate	Integrated Soil Nutrient Management is relevant for addressing current climate change effects at farmer level. Its effectiveness will however be enhanced with combination with other related technologies.
Size of beneficiaries group	The technology has the potential of increasing the number of farmers achieving improved yields from their farms.
Disadvantages	A major disadvantage of the technology is the inadequacy of available organic nutrient sources.
Capital costs	
Cost to implement adaptation options	The technology will contribute to cost associated with use of soil nutrients on farmersô field. It will however require some level of invest for packaging aspects of the technology, awareness creation, training of extensionists and farmers; and demonstrations. It will require about US$ 1,000,000 to be effectively disseminated and adopted.
Additional cost to implement adaptation option, compared to ñbusiness as usualò (extra storage capacity)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change through improvements in soil resources and increases in productivity.
Economic benefits Employment	The technology can contribute to generation of employment at the community level sales of transformed organic sources e.g. compost
Investment	Requires low investment in tools and equipment; and training of farmers for transforming organic sources into easily usable forms.
Public and private expenditures	Reduce public and private expenditures in terms of expenditure on the use of inorganic soil nutrients.
Social benefits Income	Could provide a source of extra income for individuals and groups from sales of transformed organic materials into organic soil nutrients e.g. compost
Learning	Creates opportunity for increased group and individual learning at group and community level
Health	The technology could provide opportunity for reducing health risks within communities from improved sanitation achieved from processing of waste.

Environmental benefits	Integrated Soil Nutrient Management will contribute to reduction in the use of inorganic fertilizers hence reduce dangers of water pollution from poor handling and over use of chemical fertilizer.
Local context	
Opportunities and Barriers	The major opportunity for rolling out technology lies in the fact that farmers are already using one form of soil nutrient or the other. Additionally most farmers keep one type of livestock or the other as part of farming activities. The major barrier has is the limited integration of crops and animal production systems at the farmer level .
Market potential	The technology could create a market for organic soil nutrients
Status	The use of the technology ie below average across the country.
Timeframe	The implementation can start now.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

Technology: Integrated Climate Change Monitoring and Early Warning System	
Technology characteristics	
Introduction	This technology combines a National Climate Change Monitoring System, a Seasonal to Interannual Prediction System and a Decentralised Community-run Early Warning System to provide comprehensive, wide range and distributed information for implementation of appropriate adaptation measures against the impacts of climate variability and change across a range of spatial scales. For countries to understand their local climate better and thus be able to develop scenarios for climate change, they must have adequate operational systematic observing networks, and access to the data available from other global and regional networks. These systems enable the integration of national early warning systems, GIS mapping of vulnerable areas, meteorological information on flooding and droughts, as well as the mapping of disease outbreaks. In this way, they provide indicators for monitoring the impacts of climate change and facilitate disaster preparedness and adaptation planning. It is critical to provide access to information about expected climate changes which should clearly explain the uncertainty involved in estimating future impacts. Monitoring climate change, forecasting impacts and using early warning systems to disseminate data to a range of stakeholders from the national to the local level are all vital components to successful long-term adaptation planning and implementation. A climate change monitoring system integrates satellite observations, ground-based data and forecast models to monitor and forecast changes in the weather and climate.

	A Seasonal to Interannual Prediction System allows for a forecast of weather conditions for a period of three to six months ahead. Seasonal forecasts are based on existing climate data; in particular, on sea surface temperatures, which are then used in ocean-atmosphere dynamic models, coupled with the synthesis of physically plausible national and international models. Modern and science-based systems facilitate seasonal forecasting. Predicting climate seasonal anomalies requires the use of complex coupled atmosphere-ocean models. Knowledge of climatic variability can lead to better decisions in water resources management and agriculture, regardless of geographical location and socio-economic conditions; the technology can therefore increase preparedness and lead to better social, economic and environmental outcomes. An Early Warning System (EWS) is a set of coordinated procedures through which information on foreseeable hazards is collected and processed to warn of the possible occurrence of a natural phenomenon that could cause disasters. Decentralised community systems, usually operated by a network of volunteers employing simple equipment to monitor meteorological conditions and operate radio communication networks. Operators of decentralised community meteorological stations report the information to a local forecasting centre where the data is analysed and then communicated back to the community network. The demand for community-led systems is increasing due to lower operational costs and the need for local forecasting and monitoring of climate variability and potential disasters. EWS technology designed as a climate change adaptation strategy must therefore be capable of forecasting a number of climatic events that correspond to different time scales such as three to four months of advance warning of a drought and a few hours of advance warning of torrential rain, hail and floods. The main disadvantage of an integrated climate monitoring system is the cost. Not just the capital required to purchase, install and/or operate all the necessary equipment, but also the ongoing costs of maintaining the equipment and ensuring accurate collecting of data, building and maintaining databases, making sure that data is correctly interpreted and, ultimately, ensuring that relevant information is communicated to the appropriate people in a timely fashion.
Institutional and organizational requirements	While an integrated climate monitoring system may be managed and coordinated by the designated National Meteorological or Hydrometeorological Service (NMHS), decentralized systems involves a participatory, cross-disciplinary research approach that brings together institutions (partnerships), disciplines (such as climate science, agricultural systems science, rural sociology, and many other disciplines) and people (scientists, policy makers and direct beneficiaries) as equal partners.
Operation and maintenance	An integrated climate monitoring system is itself a network of regional and local monitoring resources, but the whole system must be managed and coordinated by the designated National Meteorological or Hydrometeorological Service (NMHS). The NHMS should also share

	climatic data readily with other relevant national and international organizations, as well as with researchers.
Endorsement by experts	The integrated technology is endorsed by national experts
Adequacy for current climate	It empowers stakeholders at all levels, from national to local, to plan adequately to adapt to current climate variability and future climate change.
Size of beneficiaries group	The technology is beneficial countrywide and across all sectors.
Disadvantages	Disadvantages include the high cost of implementing and maintaining the systems and the requirement for highly trained and skilled personnel across many disciplines and down to the local level to collect, analyse, interpret and disseminate hydrometeorological data and information.
Capital costs	
Cost to implement adaptation options	Costs are high and could exceed US $6,000,000.00.
Additional cost to implement adaptation option, compared to ñbusiness as usualò (eg. Fully decentralized system)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change by making critical weather and climate information available in a timely manner for adaptation planning.
Economic benefits	
Employment	Creation of jobs for people in a wide range of disciplines ï climate scientists, meteorologists, agric scientist, socio-economists, support operation and maintenance of water systems and to provide training to users/households and communities.
Investment	.
Public and private expenditures	Reduce public and private expenditures on climate related disaster management.
Social benefits	
Income	Ensuring availability of weather and early warning information to communities in a timely manner would not only help reduce loss of property and livelihoods in extreme events such as floods and droughts but would also enable communities plan their agricultural and agribusiness activities in a manner that would enhance their incomes..
Learning	Training elements from capacity building in operation and maintenance of systems at various levels
Health	The early warning systems in particular would enable people prepare for extreme events such as flooding and drought and reduce health

	risks associated with them.
Environmental benefits	Good and reliable climate and weather information would assist in environmentally sustainable development.
Local context	
Opportunities and Barriers	Scientific weather monitoring and short term forecasts (a few days) are already being undertaken in Ghana. As ñtraditional indicatorsò of weather (e.g., bird and animal movement, the date and quantity of the first rains, the special forecasting knowledge of diviners and religious leaders, etc) become more unreliable, due largely to climate change, local communities previously relying on such indicators would embrace more and more the scientific systems. Barriers include the high cost, given that there are many competing demands for national resources and the possibility of providing information that the public cannot understand and make use of. Also, local communities that rely on ñtraditional indicatorsò for weather and seasonal forecasting may be resistant to the new technology. .
Market potential	Market potential exists in the supply of basic monitoring equipment.
Status	Ghana already has a Meteorological Agency in charge of a wide network of weather monitoring stations throughout the country.
Timeframe	The implementation can start now.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

Technology Factsheet: Ecological Pest Management (EPM)	
Technology characteristics	
Introduction	Ecological Pest Management (EPM) is an approach to increasing the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production. Also know as Integrated Pest Management (IPM), this practice can be ñdefined as the use of multiple tactics in a compatible manner to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, animals, plants and the environment. IPM is thus ecologically-based pest management that makes full use of natural

	and cultural processes and methods, including host resistance and biological control. IPM emphasises the growth of a healthy crop with the least possible disruption of agro-ecosystems, thereby encouraging natural pest control mechanisms. Chemical pesticides are used only where and when these natural methods fail to keep pests below damaging levelsò (Frison et al, 1998; 10). Conventional, chemically based pest-management strategies encourage short-term solutions that can be harmful to the environment and to human health. Broad-spectrum chemicals also are ineffective against some pest problems. EPM is based on a broad knowledge of the agro-ecosystem, the range of species of living organisms in the ecosystem, their interactions and the outcomes of those interactions. On any given farm, crops are interacting with all types of living organisms including bacteria, insects, nematodes, ruminants, which are also in dynamic interaction. The knowledge of these interactions constitutes the basis of EPM. The overall goal of EPM is to achieve ecological sustainability whilst maximizing the economic gains of agriculture. It comes with a conscious effort to maintain the equilibrium in the ecology of the agricultural or farming systems. The goal is achieved broadly on the principle of ensuring the generation and transfer of knowledge to the farmers on their respective ecological systems and promoting the application of such knowledge.
Institutional and organizational requirements	Structures that enable farmers to organise themselves so as to jointly implement the proposed solutions are also required. Collective action can increase the successful development and implementation of EPM. Farmersô cooperation can help reduce the costs of EPM implementation. In addition, better linkages between research and extension, more extension services, monitoring services and private consultants can lead to better coordination and feedback processes. Strong efforts in the area of communication with farmers are required so that they appreciate the benefits of applying this approach. Communication should be primarily focused on showing the range of advantages of this technology in comparison with other available options (such as longer-term sustainability and no environmental damage). Public sector agencies, such as ministries of agriculture and environment, should lead on these initiatives.
Operation and maintenance	The key components of an EPM approach are: 1. Crop Management: Selecting appropriate crops for local climate and soil conditions. Practices include: • Selection of pest-resistant, local, native varieties and well adapted cultivars; • Use of legume-based crop rotations to increase soil nitrate availability thereby improving soil fertility and favourable conditions for robust plants that better face pests and diseases; • Use of cover crops, such as green manure to reduce weed infestation, disease and pest attacks; • Integration of intercropping and agro-forestry systems; • Use of crop spacing, intercropping and pruning to create conditions unfavourable to the pests. 2. Soil Management: maintaining soil nutrition and pH levels to provide the best possible chemical, physical, and biological soil habitat for crops. Practices include:

	• Building a healthy soil (soil relatively free of fungi, bacteria and insects, with basic nutrients (nitrogen, phosphorus, and potassium) in optimal level and with acidity or alkalinity levels (pH level) that make them available for crops) structure according to the soil requirements of the different plants (such as deep/shallow soil levels or different mineral contents); • Using longer crop rotations to enhance soil microbial populations and break disease, insect and weed cycles; • Applying organic manures to help maintain balanced pH and nutrient levels. Adding earthworm castings, colloidal minerals, and soil inoculants will supplement this. Microbes in the compost will improve water absorption and air exchange; • Soil nutrients can be reactivated by alleviating soil compaction; • Keeping soil covered with crop residue or living plants; • Cultivating for weed control based on knowledge of the critical competition period; • Managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests. 3. Pest Management: using beneficial organisms that behave as parasitoids and predators. Practices include: • Releasing beneficial insects and providing them with a suitable habitat; • Managing plant density and structure so as to deter diseases; • Managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests. IPM strategies can exist at various levels of integration. Note that integration at all four levels are not common (Frison et al, 1998, p. 11).
Endorsement by experts	EPM is endorsed by national experts
Adequacy for current climate	EPM enables the farmer to work with other critical stakeholders especially scientists and extension workers at all levels, from national to local, to adapt to current climate variability and future climate change.
Size of beneficiaries group	The technology is beneficial primarily to farmers, consumers and other stakeholders in the locality of its application, countrywide and globally.
Disadvantages	There are very strong pests for which the “biological controller” has not yet been identified (i.e. an insect that destroys it). When these pests emerge it is common for producers to turn to pesticides. EPM is not easy to implement and requires substantial knowledge and monitoring for the combined components of the system to produce success. Perhaps the biggest drawback to the EPM approach is that biological control is not a “quick fix”. In most cases, biological controllers will take several years to successfully establish a population and begin making a significant contribution. In addition, no single biological controller works in every situation. A controller that works well in one soil type, for example, may not work at all in another soil type. In the long run, more than one type of biological controller may have to be used to achieve uniform control across a variety of different situations and land types.
Capital costs	
Cost to implement adaptation options	The cost of implementing EPM in the identifiable ecological regions and nationwide can be high. For example, one such programme

	implemented in Nicaragua implemented involving seventy local service providers (such as NGOs, producer organisations, technical service providers, government extension agents), trained over 300 extension agents. These extension agents in turn trained over 8000 farmers but probably reached at least 15,000 farmers through collaborators applying the techniques to farmer groups not directly attended by the programme. The combined cost of the training programme was about US$ 6.6 million over five years (Guharay et al, 2005)
Additional cost to implement adaptation option, compared to ñbusiness as usualò (eg. Fully decentralized system)	The fully decentralized system of implementation for Ghana suggests the extension of EPM across the 110 districts of the country. Costs will be high in training agricultural extension officers and organizing training sessions for the relevant farmers.
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	EPM contributes to reduction of vulnerability to climate change by strengthening ecosystemic resilience and stability. The impact of pest attacks on farm yields are reduced and enables farmers to harvest appreciable crops.
Economic benefits	
Employment	Where large numbers of farmers are trained in EPM farming practices, there is sustainability of farming in the respective agro-ecological zones. In Ghana where about 65 per cent of the population are supposed to be employed in agriculture-related activities, sustainability is an important issue to address.
Investment	Investment in implementing EPM programmes can be high depending on the scale of implementation. However, with the EPM approach, farmers can avoid the costs of pesticides as well as the fuel, equipment and labour used to apply them. A 22-year trial comparing conventional and organic corn/soybean systems found that organic farming approaches for these crops use an average of 30 per cent less fossil energy (Pimentel et al, 2005). Although this can cause a slight drop in productive performance, the risk of losing an entire crop is reduced dramatically.
Public and private expenditures	EPM reduces public and private expenditures on climate related crop losses. The reduction in the use of pesticides can also lead to increase in yields. This is the case when there are specific controllers for a determined pest, for example, in West Africa the introduction of the wasp has been a spectacular control of the slug of cassava, thus saving the staple food crop for millions of Africans (FAO, 1996).
Social benefits	
Income	On the average, farmersô incomes are the lowest in Ghana especially for those in the Northern parts of the country. Cash crop farmers e.g. cocoa and oil palm farmers are known to be earning higher incomes. The implementation of EPM is likely to enhance the incomes of farmers as they harvest higher yields of their crops.
Learning	EPM depends greatly on knowledge impartation to farmers and all those involved in the production component of agriculture value chain. Training is a necessity for capacity building in operation and maintenance of systems at various levels.
Health	There are benefits coming with the practice of EPM. Farmersô minimal

	use of pesticides impacts positively on their health. The residual traces of pesticides in foods produced from farms where there have been excessive applications of pesticides will be reduced with EPM.
Environmental benefits	Effectively planned and executed EPM programmes lead to invaluable environmental benefit. There is reduction in chemical pollution coming with pesticide use in farming. The ecological balance of agro-ecosystems is better sustained with EPM practices.
Local context	
Opportunities and Barriers	In Ghana, the barriers to implementation of EPM are generally in line with what are already known. The agricultural system in Ghana shows the typical constraints of a developing African economy and some of the technical and socio-cultural barriers are more pronounced. The major constraints to the development and adoption of EPM programmes fall into four categories: 1. Technical: lack of studies and complexity of EPM; 2. Economic: competing simplicity and apparent efficacy of chemicals; lower prices for EPM-produced goods (cosmetic damage); high cost of selective pesticides; lack of fiscal policy that favours EPM over pesticide use; high perceived risk if spraying is not carried out; failure to consider long-term advantages). A major obstacle to the implementation of this technology is that farmers generally prefer commercial pesticides because they are easier to apply and manage 3. Institutional (poor linkages between research and extension; lack of extension services, monitoring services, private consultants) 4. Educational (lack of understanding of EPM by farmers/extension, lack of EPM specialists) (Frison et al, 1998; 16-17). EPM is complex and for farmers to understand and adopt EPM strategies they frequently have to change their whole pest control philosophy (Frison et al, 1998; 21). There is also a common misconception that pesticides are essential for high yields. This is not necessarily the case. However, there are opportunities for implementation. In agricultural production systems where the environment is relatively free of polluting elements (such as pesticides), and pests and diseases are becoming progressively more aggressive, conditions for EPM development are better. This is because there is no need to óclean ô the environment first in order to conduct research into which biological controllers are required. When EPM is used, farmers can benefit from the opportunity to sell their goods as healthy organic products that can fetch a higher market price.
Market potential	The Ghanaian farmer is ready to learn. Already the concept has been implemented in some parts of the country with some successes such as in the cocoa industry where organic cocoa is being exported. EPM has potential.
Status	Ghana already has some experiences in EPM implementation. The Ministry of Food and Agriculture and other stakeholders such as the agricultural research institutes and universities have implemented EPM

	programs.
Timeframe	The implementation of EPM can start now.
Acceptability to local stakeholders	EPM is acceptable to local stakeholders.

Source: Based on expertôs knowledge and information in the climatetechwiki (http://climatetechwiki.org/content/ecological-pest-management-0)