Emerging Technologies for Climate Change Adaptation: A Case Study in Dangbe East District of Ghana

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AFRICAN TECHNOLOGY POLICY STUDIES NETWORK

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Abstract

The conversion of the kinetic energy in wind into electrical energy offers unique solution to the overall energy supply where resource exists as well as partial solution to the world's over dependence on exhaustible primary energy sources such as fossil fuel and their consequences which include climate change, extinction of aquatic life during spillages and so on. The coastlines of Ghana present significant wind potential which if properly harnessed could provide alternative livelihood opportunities and speed up climate change adaptation processes among those communities hard-hit by climate change effects.

To establish the technical and economic potential of wind resource for energy production and productive application, there is the need to investigate the baseline frameworks and use optimized wind energy tools to generate results for effective wind energy planning. Ground wind data search and analysis, overall energy situation and energy policy environment formed the core of establishing the technical potentials and economic opportunities of wind energy in the Dangbe East District.

A wind data analysis was done to establish the wind energy potential and a survey to identify innovative mechanisms adopted for building resilience and track changes in behavioural practices to adapt to climate change effect. Wind data covering a period of one year were analysed and interviews were conducted for a total of 360 small-scale farmers from 12 farming communities. Phenomenal changes in weather conditions and climate events observed by respondents include erratic and unpredictable rainfall patterns with poor distributions, high temperatures with hot sunshine conditions, drought and heavy precipitations/floods.

Key innovative technologies employed to adapt to climate change effects include soil management practices that reduce fertilizer use and increase crop diversification; promotion of legumes in crop rotations; use of quality seeds and integrated crop/livestock systems; avoidance of bush burning as well as burning crop residues; introduction of drought, flood and saline-tolerant crops and using improved, high yielding and drought resistant varieties. Less than 30% of farmers interviewed had relocated close to water bodies (River Volta), especially for minor season farming while 42% had diversified into other alternative livelihood options. Farmers strongly considered provision of irrigation services by government and non-governmental organisation, credit and availability of improved agro-technologies as well as education key in building resilience to climate change effects.

1. Introduction

1.1 Background Information

Climate change is the single most pressing issue facing the world today (IPCC, 2007). The poor are becoming increasingly vulnerable to the effects of climate change and their livelihoods are gradually being eroded. Millions of people are likely to be plunged into poverty and millions more will die of its effects. Ghana has just tasted its share of climate change related catastrophes: the 2007 energy crisis and the repeated patterns of droughts and floods in recent years are evidence of looming climate change catastrophes. Over the past five years, climate change and its effects have increasingly taken centre-stage in the Ghanaian development agenda. Various stakeholders have been working to address the effects of climate change. Adaptation strategies are localized in context and are gradually being developed to enable communities and individuals build resilience to the effects of the change. Undoubtedly, agriculture is rainfall dependent in Ghana. A drop in the annual precipitation rates therefore negatively affects agricultural production. Small holder and subsistence farmers in rural areas including those in Dangbe East District along the coastal plains are mostly affected often resulting in increasing seasonal poverty levels. One classical adaptation strategy that this project sought to explore is the use of renewable energy sources as an engine to push the drive for climate change adaptation among vulnerable rural communities along the coast of Ghana.

Wind energy can play a significant role in reducing greenhouse gas emissions, fostering sustainable economic development, enhancing energy security and accelerating adaptation to climate change where sustainable energy requirement is key. Wind resource in these rural communities could be harnessed to accelerate the adaptation process particularly in the use of new agricultural technologies for pre-production, production and post production practices. This resource could be used to develop irrigation potentials of the area. Ghana has an appreciable wind resource for power generation and the government is actively working to realize this potential. Energy is a primary requirement to drive every sector of the economy including rain-fed agriculture which is the mainstay livelihood channel for these rural communities. The Government of Ghana, through its Strategic National Energy Plan (SNEP), has set a goal to increase non-hydro renewable energy generation to 10% (~380MW) of the national generation capacity by 2020. To this end, the Government has launched initiatives to develop an appropriate regulatory and policy environment to stimulate and woo investment.

Specifically, the Ministry of Energy (MoEn) is currently preparing a renewable energy policy and regulatory framework and drafting a Renewable Energy Bill to facilitate commercial-scale application of renewable energy technologies. Preliminary wind resource assessments results give annual average wind speeds of ca 5.6 ms-1 at 12m in locations spread along the coastal areas. It is estimated that gross wind electric potential is ca 5.6GW according to the SWERA Project (Table 1). About 2.6GW can be tapped and developed for energy production.

Table 1: Wind Resource in Ghana at 50 m

Wind Resource Designation	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 mm/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Moderate	3	300 – 400	6.4 – 7.0	715	0.3	3,575
Good	4	400 – 500	7.0 – 7.5	268	0.1	1,340
Very Good	5	500 _ 600	7.5 _ 8.0	82	<0.1	410
Excellent	6	600 – 800	8.0 – 8.8	63	<0.1	315
Total				**1,128**	**0.5**	**5,640**

Source: SWERA_UNEP Project Report 2002. Assumptions: Installed capacity per km2 = 5 MW; total land area of Ghana = 230,940 km2

1.2 Problem Statement

Agriculture is the mainstay economic opportunity for many rural coastal communities in Ghana. Due to changing climatic conditions, the economy of these communities is experiencing low productivities resulting in diminishing living standards and rapid rural-urban migrations. The development of clean sustainable energy could stimulate and speed up the climate change adaptation processes and address the problems.

1.3 Objectives

The broader objective of the study is to examine the wind potential along the East Coast of Ghana, how it could be use to stimulate and promote climate change adaptation process and make investment opportunities more comprehensible to the quadruple helix, including policymakers, scientists, the private sector and civil society. The specific objectives are to:

> Identify and document effective indigenous and emerging technologies and innovations for climate change adaptation in the study area;

> Enhance behavioural changes towards climate change adaptation measures at individual and institutional levels in the study area;

> Build the capacities of farming communities in the study area to adapt to climate change impacts;

> Make policy recommendations for building climate change resilience at the state and national levels in Ghana;

- Conduct wind data search and analysis for the selected community based on best industrial practice to obtain data of good quality to stimulate and boost further exploration of wind energy potential in the area;
- Build capacity of five (5) ATPS members and/or allied institutions in the area of wind resource assessment with emphasis on the youth wing of the Ghana chapter of the ATPS;
- Raise awareness for investment in the environmentally sustainable energy generation for Ghana and entire West Africa region; and
- Engage communities through sensitization workshops to raise awareness of climate change and the need for alternative livelihood opportunities through wind energy.

1.4 Organization/Structure of the Paper

This report covers largely the wind resource potential and policy framework; and effective indigenous and emerging technologies and innovations for climate change adaptation in the Dangbe East District of Ghana. It covers the capacity building of farming communities toward behavioural change to climate change and adaptation strategies and the marketing of the wind potential to stimulate investment in further resource exploration.

2. Literature Review

Climate change is the single most pressing issue facing the world today (IPCC, 2007). The poor are becoming increasingly vulnerable to the effects of climate change and their livelihoods are gradually being eroded. Millions of people are likely to be plunged into poverty and millions more will die of its effects.

Ghana is no exception. Over the past five years, climate change and its effects have increasingly taken centre-stage in the Ghanaian development agenda. Various stakeholders have been working to address the effects of climate change. Adaptation strategies are localized in context and are gradually being developed to enable communities and individuals build resilience to the effects of the change.

Undoubtedly, Ghana's agriculture is rainfall dependent. A drop in the annual precipitation rates therefore adversely affects agriculture production. Small holder and subsistence farmers along the coastal regions are mostly affected often resulting in high poverty levels.

However, these coastal regions have proven moderate to excellent wind resource. The country records average wind speeds of about 5.6m/s at 12m in locations spread near and along the coastal areas. Studies have shown that regions of excellent wind regimes are the mountainous areas spread widely in the Volta, Northern and Eastern regions. Estimated 2.6GW of electrical energy can be derived from wind[1].

The interest in wind energy exploration for energy purposes in Ghana started in 1999 through the solar wind energy resource assessment (SWERA 1999-2002) project. The relatively high investment cost in wind and other renewable technologies coupled with energy storage difficulties accounts for the low uptake in many sub-Saharan Africa countries. In the coastal areas of Ghana where agriculture is predominantly mainstay economic activity, wind energy development offers utility-scale energy production and large-scale water storage for irrigation opportunities.The global annual installed wind capacity continues to register record highs. In 2009, a total of 37,466 MW new capacities were installed and the world cumulative installed capacity is 157,899MW. Ironically, Africa continues to be the region with the lowest wind energy penetration-most of its share come from the North and Middle East regions.

[1] *EC/SWERA 2002*

By the end of 2009, total installed capacity of wind power on the continent and the Middle East was nearly 900 MW mainly in North Africa and the Middle East. Sub-Saharan Africa SSA has not experienced any significant growth in wind power development. Africa's share represents less than a percent of the total global installed capacity. Regarding wind data availability, precise information about wind potential barely exists.

Several reasons account for the unprecedented low uptake of renewable energy technologies on the continent. In Ghana, policy incentives, political resolves and capacity largely account for the slow development and utilization of renewable energy.

2.1 About the District Surveyed (Dangbe East)

The Dangme East District is located in the Eastern part of the Greater Accra Region within latitudes 5°45 south and 6°00 north and from Longitude 0°20 west to 0°35 East. Dangme East district shares common boundaries with Central Tongu, South Tongu and Dangme West Districts at the north, east and west respectively. At the south is the Gulf of Guinea, which stretches over 45 kilometers (27.9 miles). The District covers a total land area of about 909 km2 (350 sq miles); about 28% of the total area of the Greater Accra Region. In terms of vegetational characteristics, the district is coastal savannah. A few stands of mangrove trees can also be found around the Songor lagoon and the tributaries of the Volta River where the soil is waterlogged and salty (Dickson & Benneh, 1980). Dangbe East district consists of both farming and fishing communities and forms part of the eastern coastal plains of Ghana. Heavy rainfall occurs between March and September with an average distribution of 750mm but also have extreme dry spells during the harmattan. Humidity is about 60% due to proximity to the sea, Volta River and other water bodies. In 2005, agriculture statistics on Dangme district by Ministry of Food and Agriculture (MOFA) estimated 8519 males and 4592 females farmer holders .

Figure 1: Map of Ghana Showing the Dangbe East District

3. Methodology

3.1 Review of EC / SWERA Wind Data

Wind data was collected using NRG Wind Explorer logger, NRG 40 anemometer and 200P wind vane (one each). The instruments were mounted on booms attached to tilt-up tubular towers (same or similar to NRG "Tall Towers"). A total of one year data was collected, reviewed and analyzed to determine basic wind parameters including annual average wind speeds, directional wind roses, shearing to hub height of 80m, determination of energy yield, etc.

Details are presented in the subsequent sections. Any other geophysical data from the measurement campaign was also obtained energy from the EC, reviewed for completeness and quality. It is important to note that this appraisal of the wind regime is for "prospecting" purposes only; the data set described in this report is far from being "bankable". It is important to understand and keep in mind the limitations of the existing data set for the study area. These include:

- Minimal instrumentation (i.e. no redundant sensors to confirm measurements, no sensors at multiple heights to determine wind shear) and Low tower heights;
- No temperature sensor (thus not possible to calculate pressure and density adjustments for energy yield estimates);
- Very rudimentary "NRG Wind Explorer" data logger (many of the detailed wind parameters that are captured as part of standard 'bankable' WRAs cannot be recorded) and lost or corrupted data;
- Missing or insufficient documentation trail and metadata for existing data.

3.2 Site Description

The Figures 2 presents photographs of the tower and site describing the topography of the region where the wind data was measured. Tables 2 and 3 present descriptions of the Dangbe East District which include the site coordinates and topography, access, extent and nature of habitation and/or cultivation.


Figures 2: Ada Foah

Table 2: WRA Site Descriptions

No.	Site Name	Coordinates		Anemometer height [m]	Measurement Period [date]	Topography	Access	Nature of habitation/ cultivation
		Lat	Long					
1	Ada Foah	05° 79N	00° 55E	12	Jun 99-Sept 00	Flat, low vegetative growth	Good access road and about 1 hour drive from Accra	Concentrated settlements fishing, crop farming

NB: The coordinates in Table 2 are those obtained from the Energy Commission. It is important to note that the EC mast location/coordinate is today in or close to settlements or very near the sea. Hence, the exact position is therefore generally not suitable for further investigation and development.

Table 3: Summary of Sites Description

No.	Name of Site	Altitude above sea level [m]	Anemo-meter Height [m]	Data period (months)	Annual mean wind speed [ms-1]	Wind speed @ 80m* [m/s]	Type of Tower	Recovery Rate (%)	Overall Data Quality	Remarks
1	Ada Faoh	N/A	12	16	5.3	7.6	Guyed Tower	90.9	Good	16 months of recorded data, Aug 99 data missing, tubular guyed tower.

* *Wind speeds at 80m based on assumed shear exponent of 0.16*

3.3 Methodology for Climate Change Adaptation Study

Farmer group identification and selection was done using pilot survey and focus group discussions (FGD). During the identification and selection processes, a total of 20 farmers (50% males and 50% females) divided into two groups comprising 10 farmers per group were purposively selected to engage in the discussions that were held in two communities: Sege and Kasseh in the Dangbe East district. A check list of questions was used to guide the discussions with the farmers. This was supplemented with pieces of information gathered through informal interviews with key informants in the farming communities. The following thematic areas were covered during the discussions:

Physical Characteristics

Rainfall regime/pattern
Soil type and characteristics
General whether pattern

Socio-economic Characteristics

Type of crops grown
Yield
Disease and pest

Adaptation Strategies

Visible changes in the climatic conditions in the last 5 to 10 years
Perceived reasons for changes
Adaptation measures adopted by community
Impact of adaptation
Technologies employed to mitigate the effects of the perceived changes

Training needs (Capacity building requirement topics)

Impact of training
Extension services
Training and technical assistance

The data was analysed to understand the basis of the issues raised by the discussants. The emerging trends of climate change effects identified by the discussants include:

> Erratic and unpredictable rainfall patterns with poor seasonal distribution;
> High temperatures with high sunshine intensity;
> Drought;
> Heavy precipitations/floods.

These phenomenal changes in weather conditions and climate dominated most of the discussions. A number of the discussants also mentioned acid rainfall and strong wind conditions which they say occur usually.

The discussants described some of the adaptation measures that are helping them cope with the situation as follows:

> Improved farm maintenance and cultural practices (timely planting, regular weeding, timely harvesting);
> Improved soil management practices (use of cover crops, mulching and application of organic manure);
> Varietals development (development of drought resistance varieties, high yielding varieties, disease resistant varieties);
> Additional livelihood options (cultivation of vegetables and fruits like okra and watermelon, fishing, petty trading etc.)
> Use of agro-chemicals;

- Use of neem extract to control pest and disease outbreaks and improved irrigation practices (Sinking tube wells for regular water supplies).
- Construction of drainage systems in the lowlands and construction of fence against sea breeze to limit the flow of saline water on cultivable lands.
- Application of organic manure, planting of cover crops and legume cultivation,
- Use of inorganic fertilizer and
- Tree planting.
- Ploughing across slopes (Tractor operators change the direction of ploughing to minimize soil erosion),
- Sacks are also filled with soil to block the passage of water; trenches are constructed on the ploughed fields.

Innovations/technologies adopted by farmers to contain drought conditions were largely irrigation, construction of wells for water storage, mulching to improve water holding capacity of soils, planting of soil covers crops, cultivation close to water bodies, cultural practices such as regular weed control, early ploughing and planting.

The discussants also stressed that pest and disease outbreaks are prevalent in severe drought conditions and also heavy precipitations (examples are leaf curl and blight diseases in tomatoes). The most commonly used innovations or technologies adopted to reduce impact of pest and disease outbreaks include:

- Use of agrochemicals (fungicides, pesticides)
- Use of “neem tree” extract
- Crop rotation
- Use of disease free seeds for planting
- Some farmers also mentioned nursing of maize seed before transplanting because rodents pick maize seeds sown directly. Maize seeds are nursed for 7-10days for the cotyledons to establish before transplanting.

According to farmers these strategies worked well except that the use of agrochemicals have some limitations like the health risks to users and also sometimes the efficacy is compromised by input dealers. Innovative technologies adopted to reduce effects from heavy precipitation

- Planting on raised beds
- Construction of drainage channels
- Early planting of crops
- Ploughing across slopes.

The discussants relate how sudden drought conditions often lead to crop failure and sometimes lower yields. Commonly used innovations/technologies by farmers interviewed to reduce effects of severe drought include:

- Storage of water for irrigation,
- Mulching and application of organic manure to improve water holding capacity of soils,
- Cultivation of short maturity crops and varieties as well as drought resistant crops and varieties.

3.4 Climate Change Adaptation Survey

Following the FGD pilot survey analyses, a structured survey tool was developed. Agricultural Extension Officers, AEOs from the District Agriculture Development Unit, DADU of the Ministry of Food and Agriculture were selected and trained to administer the tools in 12 selected communities in the study area. A total sample size of 360 farmers (82% males; 18% females with an average household size of 7) was interviewed in the Dangbe East District. This covered 12 community agricultural operational areas (Table 4). Thirty (30) farmers each were randomly selected for interview in each of the selected agricultural operational areas. The structured questionnaire was used for one-on-one interview. This was supplemented with pieces of information gathered through informal interviews with key informants in the farming communities. Secondary data was sourced mainly from the internet and in-house literature depot. Data collected was cleaned, validated and later analysed using SPSS version 16 and in MS Excel.

Table 4: Operational Areas Surveyed

Operational Area	Communities Surveyed
AKJ	Hwakpo, Addokope, Ebeneza, Luhour & Nuhaley
AB	Faithkope, Manaikpo & Dogo,
DTA	Agbedrafoh, Adjumanikope, Toflokpo, Bornikope, Sege, Kpotsum & Koluedor
FA	Talebanya, Cesarkope, Tugakope, Agbenyegakope & Adodogdjikope
GA	Mangoase-Kenya, Dorgobom, English Kenya, Mangoase-Kenya & CeasarKope & Panya
IKB	Koluedov & Matsekope
ML	Asigbekope, Fantevikope, Atiadenyigba, Tojeh, Aditcherekope & Zuenor
MEO	Kadja Dornya, Tamatoku, Amanikope, Kadja Sega, Kadja Juam
MA	Tsrikopey, Gorm, Mensahkope, Obane, Attortorkorpey, Kenonya & MacCarthykope
PD	Songutsokpa, Ocansekope, Anyakpor, Adedetsekope & Totimekope
RW	Gbanave, Aborsikope, Amlakpo & Kopehem
SJJ	Korleykope, Kasseh, Bedeku & Kunyenya

4. Result & Findings

4.1 Wind Data Search and Analysis

This section presents the results of the wind data search and analysis for the Dangbe East District. It covers basically the wind resource assessment done by the Energy Commission and the market potentials for wind energy investment.

4.1.1 Wind Distribution and Direction

Wind distribution and directions are shown in Figures 3 and 4 respectively. The prevailing wind direction is south-west.

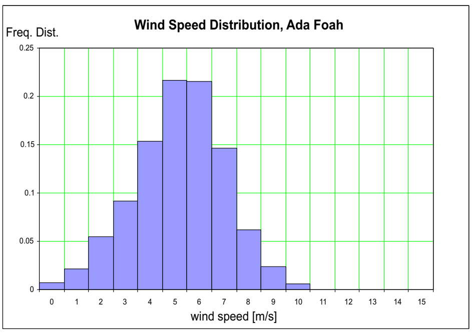

Figure 3

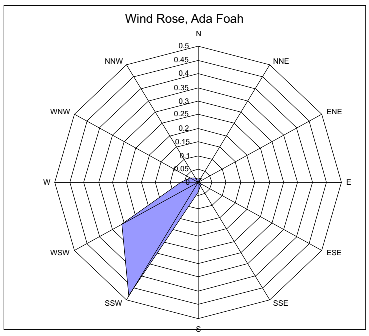

Figure 4

Table 5: Monthly Data Recovery Rate

		Monthly Data Recovery Rate				Sheared Wind Speed@ 80m	
	Month	Count	CountA	Rate%	Mean Speed @ 12m	0.16	0.2
1	Jun-99	209.0	4320	4.8%	4.6	6.3	6.8
2	Jul-99	4257.0	4464.0	95.4%	4.8	6.6	7.1
3	Aug-99	0.0	4464	0.0%	0.0	0.0	0.0
4	Sep-99	3943.0	4320	91.3%	5.7	7.7	8.3
5	Oct-99	4323.0	4464	96.8%	6.3	8.5	9.2
6	Nov-99	4320.0	4320	100.0%	5.0	6.8	7.3
7	Dec-99	4464.0	4464	100.0%	4.2	5.7	6.2
8	Jan-00	4464	4464	100.0%	5.1	7.0	7.5
9	Feb-00	4032	4032	100.0%	5.0	6.7	7.2
10	Mar-00	4464	4464	100.0%	5.8	7.9	8.5
11	Apr-00	75	4320	1.7%	9.2	12.4	13.4
12	May-00	4431	4464	99.3%	4.9	6.7	7.2
13	Jun-00	4320	4320	100.0%	5.6	7.6	8.2
14	Jul-00	4464	4464	100.0%	5.3	7.2	7.8
15	Aug-00	4464	4464	100.0%	5.2	7.1	7.6
16	Sep-00	93	4320	2.2%	5.3	7.2	7.8
	Overall Recovery	52323	70128	74.6%	5.3	7.0	7.5

Table 6: Simulation Results on Projected Annual Energy Output

		Hub Height 50 m		Hub Height 80 m	
		GE xle	V82	GE xle	V82
Capacity per turbine	MW	1.5	1.5	1.5	1.5
No. of turbines		1	1	1	1
Site capacity	MW	1.5	1.5	1.5	1.5
Ideal energy production	GWh/yr	4.0	4.0	5.1	5.2
Topographic efficiency1	%	101.9	102	101.5	101.6
Array efficiency1	%	100.0	100.0	100.0	100.0
Estimated gross annual energy output (AEO)	GWh/yr	4.1	4.1	5.2	5.3
Other Adjustments2		89.6%	89.6%	89.6%	89.6%
Estimated net AEO	GWh/yr	3.6	3.7	4.7	4.8
Estimated capacity factor (net)		27.7%	28.0%	35.5%	36.2%

Taken into account 10% wind farm, aerodynamic, electrical, operational and power curve losses and wind shear of 0.16 at hub height (50m) and (80m) respectively.

The wind resource was simulated for the determination of energy output. Interestingly, two kinds of a 1.5MW wind turbines were placed at the point (based on obtained coordinates) where the wind mast was sited. The modelling was done at two different heights of 50m and 80m using the General Electric GE xle and Vestas 82 turbines. Taking into account all uncertainty parameters, estimated net annual energy output, AEO are shown in the table 4.1. And this is very encouraging. Figures 5 and 6 show monthly average wind speeds distribution and recovery rate

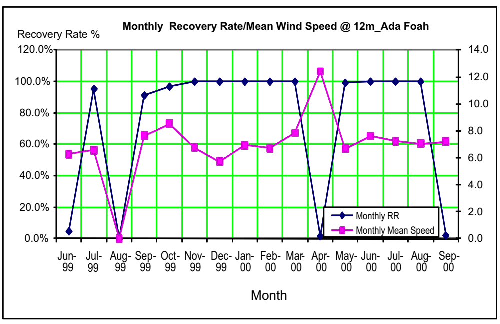

Figure 5: annual average

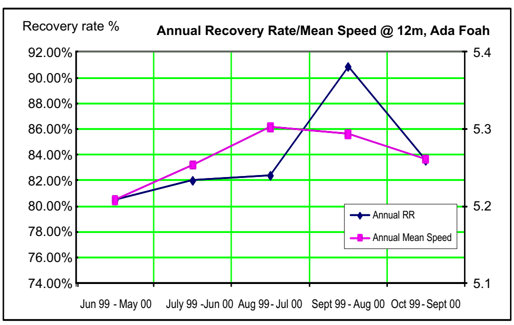

Figure 6: Recovery Rates

4.1.2 Suggested potential wind project site

Based on the quality of available wind data, terrain and other parameters such as grid networks, road infrastructure, etc., there are several spots stretching from Sege to Ada Foah that merit further investigation. Table 4.2 shows a summary of the average wind speeds of the point of measurement above 7 m/s at 80m hub heights while Table 7 presents the site that is suggested for further investigation as potential utility-scale wind project sites.

Table 7: Source of Wind Data for Potential Sites

Site Name	Measurement Period	Recovery Rate (%)	Annual mean wind speed @ 80m*	Turbulence intensity (%)	Remarks
Ada Foah	Sep 99-Aug 00	90.9	7.6	7.6	Good access roads, 11/33 kV grid extension exist, fairly good topography, not far from main industrial hub

**Based on assumed shear exponent of 0.16*

Table 8: Suggested Potential Project Site

Name of Site	Coordinates* (NAD 83)	Note
Tamino (closest wind data: Ada Foah)	05° 47´ 27 N 00° 33´ 14 E	Flat, exposed topography and excellent available land area for project development Site is 6km away from low/mediu m voltage distribution network and about 25km away from high voltage transmission and sub-station at Sogakofe The community is willing to lease small parcel for WRA and any size for future project development Conspicuous tree deformation by persistent wind Main obstacle to nearest high voltage transmission line is the Volta River, but a road bridge exists close to the SS at Sogakofe. The soil condition for anchor selection is sand+clay Site is about 1km away from the coast Main use of land is farming

** The coordinates shown are within a prospective project boundaries and represent preliminary suggested location where standard meteorological mast could be installed to confirm the wind resource and, if necessary, to provide 'bankable' data.*

Some of the potential wind spots are shown in Figure 7. The yellow are the potential sites investigated under the SWERA initiative and the purple colour show Meteorological sites for long term wind data.

Source: GPCo/TMT Energy 2010

Figure 7: Potential wind spots

4.2 Policy Environment

Undoubtedly, the renewable energy component of Ghana's energy mix is receiving remarkable attention in recent time. Through the Strategic National Energy Policy, SNEP, 10% of total energy (electricity) generation must come from Renewable Energy by 2010. There is currently a bill before cabinet for consideration and subsequent passage into law. To be able to inject renewable power into the country's grid system, grid reinforcement programs are also underway and new lines are being constructed to make interconnectivity cost effective. With these developments, the market outlook for renewable energy is positive. It is projected that wind energy would account for more than 70% of the 10% target. Land reforms are also underway to make access and acquisition of large land mass for utility-scale renewable energy power generation systems possible.

The research work on the wind energy potential creates opportunities for the use of technologies and innovations for climate change adaptation especially to tackle the critical issues presented in the subsequent sections.

4.3 Emerging Indigenous Technologies and Innovations for Climate Change Adaptation

This section presents the findings of the effective indigenous and emerging technologies and innovations for climate change adaptation in the Dangbe East District of the Greater Accra Region, Ghana

4.3.1 Climate Change Effects

Climate Change Effects as perceived by respondents include erratic and unpredictable rainfall patterns with poor distributions, high temperatures with hot sunshine conditions, severe drought and heavy precipitations/floods. These phenomenal changes in weather conditions and climate events had been observed by over 80% of the sample interviewed over the past 10 years. Respondents had also experienced acid rainfall and strong wind (gust) conditions although very limited in occurrence. Table 9 presents details of percentage response to climate change effects by operational areas while Table 10 shows climate change effects on agriculture.

Table 9: Response to climate change effects

	% Responding to Climate Change Effects						
Operational Area	**Erratic and poor rainfall distribution**	**High Temp.**	**Drought**	**Floods/Heavy Precipitation**	**Hot Sunshine**	**Acid Rain fall**	**Strong Winds**
AKJ	100	46.7	100	96.7	50	-	-
AB	100	50	86.7	83.3	10	-	-
DTA	100	93.1	100	13.3	65.5	-	-
FA	93.3	100	100	3.2	100	6.7	-
GA	100	100	90.0	73.3	-	-	-
IKB	100	100	83.3	70.0	3.3	-	-
ML	100	90	100	6.7	3.3	-	16.7
MEO	100	100	100	13.3	-	-	-
MA	100	96.7	100	100	100	-	3.3
PD	100	100	100	100	100	-	83.3
RW	100	83.3	-	-	50	-	-
SJJ	100	100	3.3	43.3	20	-	-
Overall	**99.4**	**88.3**	**80.3**	**50.1**	**41.9**	**0.6**	**8.6**

Source: Survey compilation 2010. N=360; n =30/operational Area

Table 10: Climate Change Effect on Agriculture Enumerated by Respondents in the Surveyed Area

Climate change effects	Observed/experienced impacts on agriculture
Insufficient rainfall Erratic and unpredictable Long period of drought followed by excessive rainfall	Affects crop development, decreased yields; increased insect pest outbreaks cause delayed planting time in some communities. Insufficient rainfall when crops actually need water and too much water when the crops do not need that much water. Cassava root formation is negatively affected by climate change effect Fishing activities are reduced drastically Livestock production is negatively affected by climate change (lack of water and graze/feed)
High temperatures	There are heat waves associated with high temperatures. High temperatures cause bushfires, low yield and sometimes complete crop failure. High temperature disrupts activity of living organisms in the soil, low soil fertility which negatively affect crop development Crops wilt and die off especially tomatoes.
Heavy precipitation/ Floods	Damage to crops; soil erosion; inability to cultivate land due to waterlogging of soils A lot of pest and diseases emerged after heavy rains, heavy rains destroyed crops in the lowland areas The swampy areas are no longer in use. Excess water render the swampy areas unproductive; Not much value for vegetable production Heavy Precipitation caused rotting and dieback, root knots disease, flower abortion, cracks in water melon, nematode diseases and fungal diseases
Strong winds	Strong winds that come along with heavy rains caused flowers and fruits to abort or drop. Dropping of immature flowers, vegetables and fruits.
Severe Drought	Land degradation and soil erosion; lower yields from crop damage and failure; increased livestock deaths; increased risk of wildfire; loss of arable land
Sea levels increase	Salinization of irrigation water, estuaries and freshwater systems; loss of arable land and increase in alternative livelihoods Most uplands and arable lands have become saline and no more suitable for crop production

Source: Survey compilation 2010.

4.3.2 Opportunities and Constraints

Although climate change effects and impacts present diverse challenges to small-scale farmers, these farmers also appreciate some opportunities that come along with climate change. Climate Change opportunities listed by respondents can be categorized into improved farm maintenance and cultural practices (timely planting, regular weeding, timely harvesting); improved soil management practices (use of cover crops, mulching and application of organic manure,); varietal development (development of drought resistance varieties, high yielding varieties, disease resistant varieties); Additional livelihood options (cultivation of vegetables and fruits like okra and watermelon, fishing, petty trading etc.) use of agro-chemicals; use of “neem extract” to control pest and disease outbreaks and improved irrigation practices (Sinking tube wells for regular water supplies). Others are construction of drainage systems in the lowlands and construction of fence against sea breeze to limit the flow of saline water on cultivable lands. Table 11 presents percentage responses to opportunities emerging as a result of climate change effects and impacts. Most of these opportunities are innovations or improved technological packages extended to farmers to improve their local adaptive capacities to climate change impacts.

Table 11: Opportunities emerging from climate change effects

Operational Area	% Response to innovative opportunities created as a result of climate change effect								
	Use of fertilizer & Agro chemicals	High Yielding Seeds	Early maturing Varieties	Planting of leguminous crops	Use of drought Resistant crops	Application of organic manure	Planting of cover crops	Timely weeding	Timely planting
AKJ	20	23.3	13.3	10.0	3.3	26.7	10	30	26.7
AB	100	100	-	-	-	-	-	-	-
DTA	-	-	-	-	-	-	-	-	-
FA	96.8	96.8	-	-	3.2	-	-	-	3.2
GA	3.3	3.3	3.3	10.0	3.3	6.7	10	3.3	-
IKB	93.3	3.3	3.3	-	90.0	90	-	-	-
ML	13.3	20	90	-	93.3	13.3	-	-	3.3
MEO	76.7	-	3.3	-	3.3	76.7	76.7	-	-
MA	90	-	-	90.0	-	90	-	-	-
PD	100	96.7	96.7	-	-	100	-	-	-
RW	3.3	-	93.3	-	93.7	3.3	-	-	-
SJJ	93.3	-	6.7	-	10.0	93.3	-	-	-
Overall	**57.6**	**28.8**	**25.8**	**9.1**	**24.9**	**41.6**	**8.0**	**2.8**	**2.8**

Table 12: Opportunities emerging from climate change effects

Operational Area	% Response to innovative opportunities created as a result of climate change effect								
	Ploughing across slopes	Livestock Rearing	Use of Weather Forecast	Tractor Services	Row Planting	Early Maturing Crops	Vegetable & Fruit Cultivation	Irrigation services	High Food Prices
AKJ	6.7	-	-	-	-		-	-	-
AB	-	-	-	-	-		80	-	-
DTA	-	-	-	-	-		-	3.3	6.7
FA	-	3.2	3.2	6.5	6.5		-	-	-
GA	3.3	3.3	-	3.3	-		93.3	-	6.7
IKB	-	-	-	-	-		3.3	-	30
ML	-	3.3	-	-	-	6.7	6.7	6.7	-
MEO	-	-	-	-	-	6.7	-	23.3	3.3
MA	-	93.3	-	-	-		3.3	3.3	-
PD	-	30.0	-	-	-		-	100	-
RW	-	3.3	-	-	-		6.7	56.7	-
SJJ	-	-	-	-	-		-	10	-
Overall	**0.8**	**11.4**	**0.3**	**0.8**	**0.6**	**1.1**	**16.1**	**16.9**	**3.9**

Source: Survey compilation 2010. N=360; n =30/operational Area

Despite the appreciable exposure level to the above listed innovative and improved technological packages, there are challenges or constraints to their applications. As reported by Hazell and Wood (2008), agricultural systems may have considerable capacity to adapt to climate change, but there are challenges. The constraints and challenges include the high cost of production as a result of escalating input prices, high prices of food crops as farmers switch from food crops production to cash crops which contribute to market dependency for household food security (cultivation of vegetables and fruits over cereals and tubers), price threats from over-supply of certain crops, post harvest losses which aggravate poverty and health risks associated with agro-chemical applications. Others are availability and accessibility of organic manure on relatively large farms. As most farmers put it frankly animal droppings are not easily available; its application is also constrained when farm size is large. Some of the technologies are actually beyond the reach of resource poor farmers. Farmers lack the resources and money to enable them to apply corrective measures effectively and efficiently. Examples cited are high cost of irrigation facilities, high costs of double nursery establishment and cost of improved varieties.

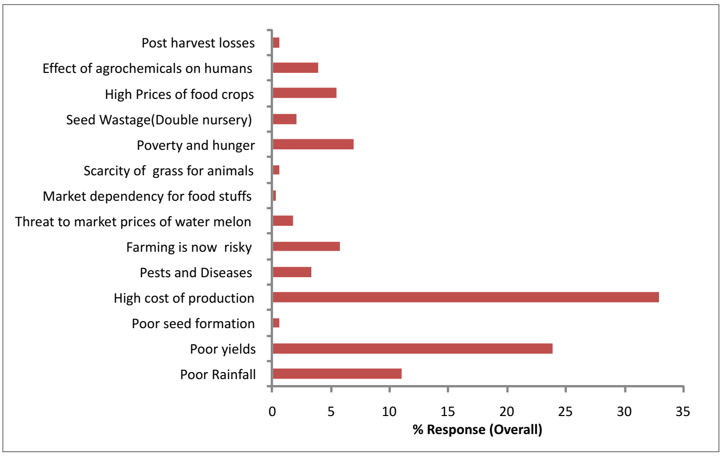

Figure 8: Constraints Due to Climate Change Effects

4.3.3 Mechanisms for building resilience/adaptation to climate change

Fussel (2007) defines adaptation to climate change, as measures which moderate the adverse effects of climate change through a wide range of actions that are targeted at the vulnerable system or population. A variety of adaptation options contribute to building resilience. Among these measures are: soil management practices that reduce fertilizer use and increase crop diversification; promotion of legumes in crop rotations; increasing biodiversity, the availability of quality seeds and integrated crop/livestock systems; promotion of low energy production systems; improving the control of wildfires and avoiding burning of crop residues; as well as promoting efficient energy use by commercial agriculture. Others are introducing drought, flood and saline-tolerant crops, improving breeding and farming techniques, developing local food banks for people and livestock, and improving local food preservation.

As elaborated in the earlier sections, climate change affected crop development and had caused decrease in productivity of both crops and livestock. Crops badly affected included vegetables only (44%) and vegetables and others like maize (56%). Therefore small-scale farmers need to build resilience/adaptive capacity to adapt to climate change impacts. Climate change effects are wide spread and interrelated. As shown in Table 13, climate change effects experienced by farmers interviewed include Pest & Disease outbreaks, changes in water availability, severe drought, and land degradation, reduction in arable lands, soil erosion and floods/heavy precipitation in decreasing order of importance.

Table 13: Percentage Response to Experience with Climate Change Effect

Operational Area	% Responding to Climate Change Effects						
	Land Degradation	Soil Erosion	Changes in water Availability	Pest & Disease outbreak	Floods/Heavy Precipitation	Severe Drought	Reduction in arable lands
AKJ	100	100	100	10	96.7	100	100
AB	50	73	86.7	96.7	83.3	86.7	40
DTA	33.3	63.3	70	76.7	13.3	100	
FA	100	100	100	100	3.2	100	100
GA	100	96.7	13.3	100	73.3	90	96.7
IKB	100	93.3	63.3	100	70	83.3	70
ML	20	100	96.6	96.6	6.7	100	90
MEO	100	-	100	100	13.3	100	100
MA	100	50	100	100	100	100	100
PD	100	93.3	100	100	100	100	100
RW	23.3	-	100	53.3		-	
SJJ	100	53.3	66.7	100	43.3	3.3	53.3
Overall	**77.3**	**68.7**	**83.1**	**93.6**	**50.1**	**80.3**	**70.9**

Source: Survey compilation 2010. N=360; n =30/operational Area

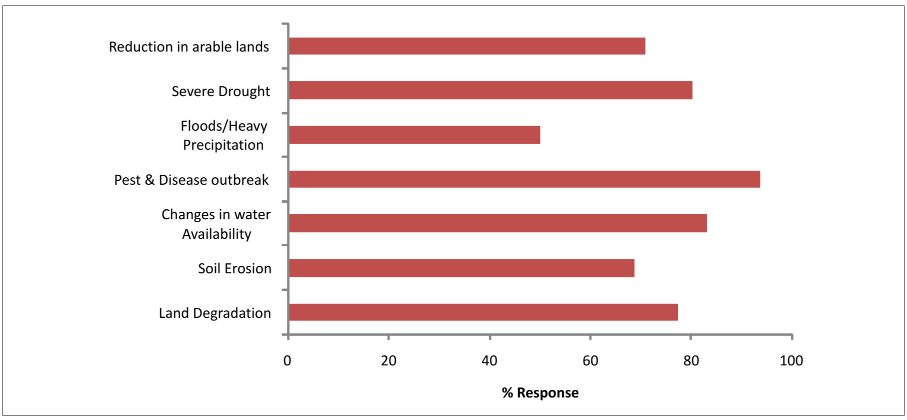

Figure 9: % Response to Experiences of Climate Change Effects

In the next section, details of adaptive options/innovative technologies adopted to build resilience to specific climate change effects in the district surveyed are presented.

4.3.4 Land Degradation

The literature suggests, many and complex linkages between agriculture and land degradation. Farming in areas of fragile soils, poor management of crop, soil and water interaction, and unsustainable exploitation of soil nutrients are some of the major causes of land degradation (Lal 1997). According to Wood et al (2000) only some 16% of croplands globally are inherently free of soil constraints, and that figure is as low as 6–7% in Southeast Asia and sub-Saharan Africa. However this survey focused on the climate change effects on land degradation and not causes from agricultural practices although the two are highly interlinked.

Table 14 presents emerging innovations/technologies adopted by farmers interviewed to reduce land degradation caused by climate change effects. The main innovations for land degradation adaptation are application of organic manure, planting of cover crops and legume cultivation, use of inorganic fertilizer and tree planting. According to the farmers interviewed, application of these innovations/technologies worked if well managed.

Table 14: Innovations/Technologies adopted to reduce land degradation

	% Responding to innovations to mitigate land degradation from climate change effects										
Operational Area	**Planting of cover crops**	**Tree planting**	**Organic Manure application**	**Stop cutting of trees & bush burning**	**Legume cultivation**	**Ploughing across slopes**	**Stop overgrazing**	**Farrows between fields**	**Fallowing**	**Crop Rotation**	**Inorganic fertilizer application**
AKJ	63.3	93.3	33.3	43.3	16.7	3.3	3.3	-	-	-	-
AB	-	-	50	-	3.3	-	-	10	17.2	-	-
DTA	6.7	3.3	3.3	-	-	33.3	-	10	-	-	-
FA	100	100	100	-	100	-	-	96.8	-	-	-
GA	100	-	100	-	100	6.7	-	6.7	3.3	6.7	100
IKB	100	3.3	96.7	20	96.7	-	16.7	3.3	6.7	3.3	96.7
ML	3.3	-	13.3	-	3.3	3.3	-	-	6.7	-	10
MEO	96.7	-	96.7	-	-	6.7	-	-	-	13.3	100
MA	93.3	96.7	96.7	-	-	-	-	-	-	-	96.7
PD	-	-	100	-	-	-	-	-	-	-	-
RW	20	-	23.3	-	20	20	-	-	-	-	23.3
SJJ	-	-	96.7	-	-	6.7	-	-	3.3	-	90
Overall	**48.8**	**24.9**	**67.6**	**5.3**	**28.5**	**6.6**	**1.7**	**10.8**	**3.1**	**1.9**	**42.9**

Source: Survey compilation 2010. N=360; n =30/operational Area

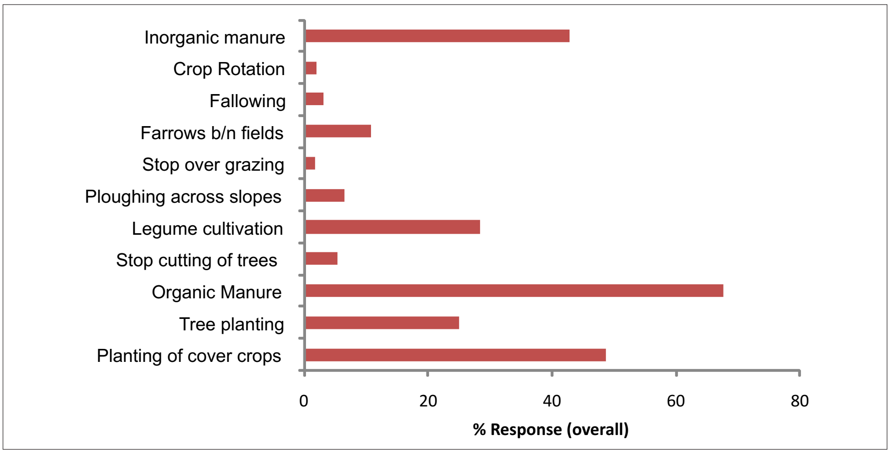

Figure 10: % response to Corrective Measures Against Land Degradation

4.3.5 Soil Erosion

Soil erosion is caused by a variety of factors including poor farming practices, deforestation, bush burning, and crop land encroachment into pastoral areas and over grazing. With particular reference to climate change effects, farmers interviewed adopted technologies such as ploughing across slopes (tractor operators have changed the direction of ploughing to minimize soil erosion), mulching and cultivation of cover crops. Sacks are also filled with soil (sand bags) to block the passage of water; trenches are constructed on the ploughed fields. Others are planting of trees along farm boundaries and application of mulch to the soil. It is not the entire field that is mulched. Usually, they are mulching around the plants and these are normally done during the early stages of the plants including transplanting. Fill sack with sand and place at the top edge of farm to prevent soil erosion. Table 15 presents details of innovations/technologies used among farmers interviewed in Dangbe East district.

Table 15: Innovations/Technologies adopted to reduce Soil Erosion

	% Responding to innovations to mitigate soil erosion from climate change effects							
Operati-onal Area	**Planting of cover crops**	**Mulching /organic manure**	**Plant Immedia-tely After Ploughing**	**Plough Across Slopes**	**Construct Trenches**	**Planting of Deep Rooted Crops**	**Planting of Trees**	**Mixed Farming**
AKJ	80	73.3	16.7	56.7	10	6.7	16.7	-
AB	63.3	3.3	-	10	70	3.3	-	-
DTA	10	13.3	3.3	33.3	10	-	-	-
FA	100	100	-	100	-	-	-	100
GA	96.7	96.7	-	36.7	96.7	-	-	-
IKB	90	90	-	3.3	13.3	-	-	-
ML	24.1	17.2	3.4	75.9	6.9	-	3.4	-
MEO	-	-	-	-	-	-	-	-
MA	-	16.7	-	26.7	3.3	-	50	-
PD	93.3	93.3	-	60.0	6.7	-	53.3	-
RW	-	-	-	-	-	-	-	-
SJJ	43.3	6.7	-	6.7	-	-	-	-
Overall	**50.3**	**42.8**	**1.9**	**34.2**	**18.1**	**0.8**	**10.3**	**8.6**

Source: Survey compilation 2010. N=360; n =30/operational Area

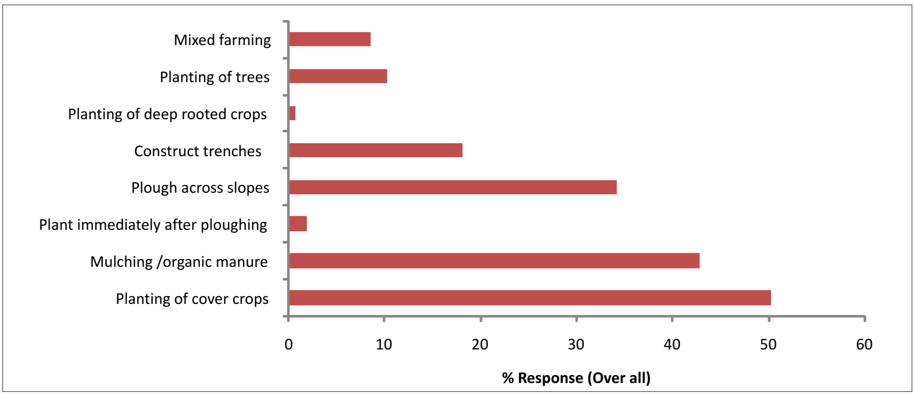

Figure 11: Measures to Mitigate Soil Erosion

4.3.6 Changes in Water availability

Innovations/technologies adopted by farmers to contain changes in water availability were largely makeshift irrigation, construction of wells for water storage, mulching to improve water holding capacity of soils, planting of soil covers crops, cultivation close to water bodies, cultural practices such as regular weed control, early ploughing and planting as shown in Table 16. Water availability is also improved by de-silting of surface wells.

Table 16: Innovations/Technologies adopted to reduce changes in water availability

	% Responding to innovations to mitigate changes in water availability from climate change effects									
Operat-ional Area	**Const-ruction of wells**	**Double ploughing**	**Soil Cover**	**Constru-ction of trenches**	**Regular Weed-ing**	**Early Planting**	**Mulch-ing/ Organic manure**	**Irrig-ation**	**Early Plough-ing**	**Cultivate Close to Water Bodies**
AKJ	23.3	80	46.7	30	16.7	13.3	70	10	-	-
AB	-	-	73.3	3.3	16.7	-	73.3	10	-	-
DTA	30	-	-	-	-	-	-	10	-	-
FA	-	96.8	71	-	93.5	-	80.6	-	87.1	-
GA	3.3	-	-	-	-	-	-	13.3	-	-
IKB	60	-	3.3	6.7	-	-	10	50	-	-
ML	-	-	6.9	-	-	10.3	10.3	31	-	3.3
MEO	-	-	3.3	-	-	6.7	10	10	-	-
MA	93.3	-	3.3	-	-	3.3	100	93.3	-	-
PD	100	3.3	-	-	-	-	-	100	-	-
RW	16.7	-	100	-	100	100	100	96.7	-	-
SJJ	6.7	-	-	3.3	-	-	-	20	-	-
Overall	**27.8**	**15.3**	**25.8**	**3.6**	**19.2**	**11.1**	**38.1**	**36.9**	**7.5**	**0.3**

Source: Survey compilation 2010. N=360; n =30/operational Area

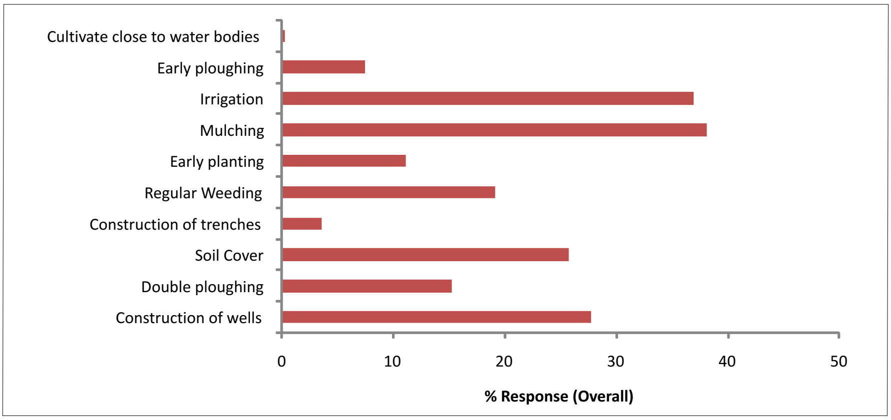

Figure 12: % response to Innovations to Check Changes in Water Availability

4.3.7 Pest and Disease outbreaks

From farmers interviewed, pest and disease outbreaks are prevalent in severe drought conditions and also heavy precipitations (examples are leaf curl and blight diseases in tomatoes). In decreasing order of importance, the most commonly used innovations or technologies adopted to reduce impact of pest and disease outbreaks include the use of agrochemicals (fungicides, pesticides), use of "neem tree" extract, crop rotation and the use of disease free seeds for planting as well as hygiene practices on farms. Table 17 presents details of innovations used to fight pest and disease outbreaks. Some farmers also mentioned nursing of maize seed before transplanting because rodents pick maize seeds sown directly. Maize seeds are nursed for 7-10 days for the cotyledons to establish before transplanting.

According to farmers these strategies worked well except that the use of agrochemicals have some limitations like the health risks to users and also sometimes the efficacy is compromised by the input dealers.

Table 17: Innovations/Technologies adopted to reduce the effect of Pest and Disease outbreaks

	% Responding to innovations to check pest & disease outbreaks from climate change effects								
Operational Area	**Use of Agro-chemicals**	**Spray Soapy Water**	**Use Neem Tree Extract**	**Crop Rotation**	**Plant Disease Resistant Varieties**	**Use of Disease Free Seeds**	**Timely Planting**	**Fallo-wing**	**Removal of Affected Crops**
AKJ	86.7	3.3	23.3	40	30	30	6.7	3.3	20
AB	96.7	-	13.3	13.3	-	16.7	-	-	-
DTA	73.3	-	-	-	-	-	-	-	6.7
FA	100	-	100	-	-	-	-	-	-
GA	100	-	100	-	3.3	3.3	-	-	-
IKB	100	-	100	3.3	-	-	-	-	-
ML	86.2	-	3.4	44.8	20.7	24.1	-	-	3.4
MEO	100	-	-	-	-	-	-	-	-
MA	100	26.7	96.7	96.7	-	-	-	-	-
PD	100	-	100	100	50	50	-	-	6.7
RW	53.3	-	-	-	-	-	-	-	-
SJJ	100	-	-	2.3	3.3	-	-	-	-
Overall	**91.4**	**2.5**	**45**	**25**	**8.9**	**10.3**	**0.6**	**0.3**	**3.1**

Source: Survey compilation 2010. N=360; n =30/operational Area

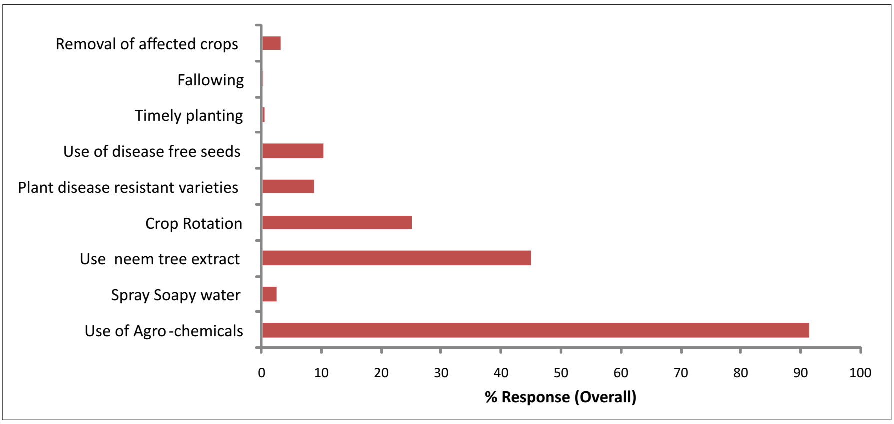

Figure 13: % Response to Innovations to Check Pest & Disease Outbreak

4.3.8 Heavy Precipitation/floods

Heavy precipitation causes soil erosion, damage to crops, pest and disease outbreaks as well as waterlogged of soils. Adaptive innovative technologies include the raising of plant beds, construction of drainage channels and gutters, timely planting of crops, farming at hilly areas and ploughing across slopes. Construction of surface wells and sinking of tube wells. Cultural practices to prevent excessive rainfall interference are practiced. Most farmers interviewed did not have any adaptive measures against heavy precipitation. Farmers therefore relocate their farming activities if possible. Table 18 gives indication of the technologies adopted to prevent effects of heavy precipitation.

Table 18: Innovations adopted to reduce the effects of Heavy Precipitation

	% Response to innovations to check heavy precipitation from climate change effects						
Operational Area	Use of cover crops	Crop Rotation	Mulching/ Organic Manure	Construction of Drainage/gutters	Leveling of Fields	Ploughing Across Slopes	Leave Land to Fallow
AKJ	73.3	2.3	70	26.7	20	6.7	-
AB	-	-	-	66.7	-	-	-
DTA	-	-	-	10	-	3.3	-
FA	-	-	-	3.2	-	-	-
GA	-	-	6.7	-	-	-	-
IKB	40	-	46.7	30	-	3.3	-
ML	-	-	-	3.3	-	3.3	-
MEO	-	-	6.7	6.7	-	-	-
MA	-	-	96.7	100	-	-	-
PD	70	-	-	100	-	-	100
RW	-	-	-	-	-	-	-
SJJ	-	-	-	26.7	-	-	-
Overall	**15.2**	**0.3**	**18.8**	**33**	**1.7**	**1.4**	**8.3**

Source: Survey compilation 2010. N=360; n =30/operational Area

4.3.9 Severe Drought

Severe drought conditions as a result of climate change effects cause land degradation, soil erosion, increased risk of bush fires, loss of arable lands, crop damage and lower yields, sometimes complete crop failure. Commonly adaptive innovations/technologies used by farmers interviewed include storage of water for irrigation, mulching and application of organic manure to improve water holding capacity of soils, cultivation of short maturity crops and varieties as well as drought resistant crops and varieties. Other innovative adaptation strategies are the use of water satchel rubber under crops as a check against severe drought. However most farmers considered drought as natural and seasonal occurrence and therefore are not encouraged to apply adaptive measures. At the community level tree planting on farmlands is encouraged to reduce severe drought impact.

Table 19: Innovations/Technologies Adopted to Reduce the Effects of Severe Drought

Operational Area	% Response to innovations against severe drought from climate change effects										
	Planting Drought Resistant Varieties	Early Planting	Cultivation of short duration crops	Timely weeding	Timely Planting	Timely Harvesting	Mulching/organic Manure	Cultivating Drought Resistant Crops	Irrigation /Store Water in Trenches	Fallowing	Earthing Up
AKJ	76.7	66.7	33.3	16.7	46.7	3.3	33.3	43.3	10	3.3	3.4
AB	-	-	-	-	-	-	6.7	-	50	-	-
DTA	-	-	-	-	3.3	-	6.7	-	50	-	-
FA	-	-	100	-	-	-	100	-	-	-	-
GA	-	-	-	-	-	-	-	-	-	-	-
IKB	-	-	-	-	3.3	-	83.3	-	83.3	-	-
ML	40	3.3	53.3	-	3.3	-	6.7	70	46.7	-	-
MEO	-	-	-	-	-	-	-	-	-	-	-
MA	-	3.3	-	3.3	3.3	-	100	-	76.7	-	-
PD	-	-	-	-	-	-	-	-	100	-	-
RW	-	-	-	-	-	-	-	-	-	-	-
SJJ	-	-	-	-	-	-	-	-	-	-	-
Overall	**9.7**	**6.1**	**15.8**	**1.7**	**5.0**	**0.3**	**28.3**	**9.4**	**34.6**	**0.3**	**0.3**

Source: Survey compilation 2010. N=360; n =30/operational Area

4.3.10 Reduction in Arable lands

About 71% of the farmers had experienced reduction in arable lands due to multiple stresses from climate change effects. Reduction in arable lands is also caused by salt seepage into lands. Innovations/technologies adopted to maintain reduced arable lands include correct planting techniques (row planting), use of organic manure and crop rotation as well as use of inorganic fertilizer and planting of high yielding varieties since farm expansion strategies are constrained. Farmers are also educated to minimize grazing activities.

Table 20: Innovations/Technologies Adopted to Maintain Reduced Arable Lands

	% Response to innovations /technologies adopted due to reduction in arable lands				
Operational area	**Correct Planting distance**	**Use of organic manure and crop rotation**	**Use of Inorganic Fertilizer**	**Ploughing with Vegetation**	**Planting of High Yielding Varieties**
AKJ	43.3	90	80	23.3	36.7
AB	0	40	30	0	0
DTA	0	0	0	0	0
FA	0	100	0	100	100
GA	0	76.7	96.7	0	0
IKB	53.3	70	63.3	0	0
ML	0	33.3	33.3	0	0
MEO	0	100	100	0	0
MA	6.7	100	100	0	0
PD	0	100	100	0	0
RW	0	0	0	0	0
SJJ	3.3	40	40	0	0
Overall	**9.7**	**64.7**	**53.5**	**10.5**	**11.6**

Source: Survey compilation 2010. N=360; n =30/operational Area

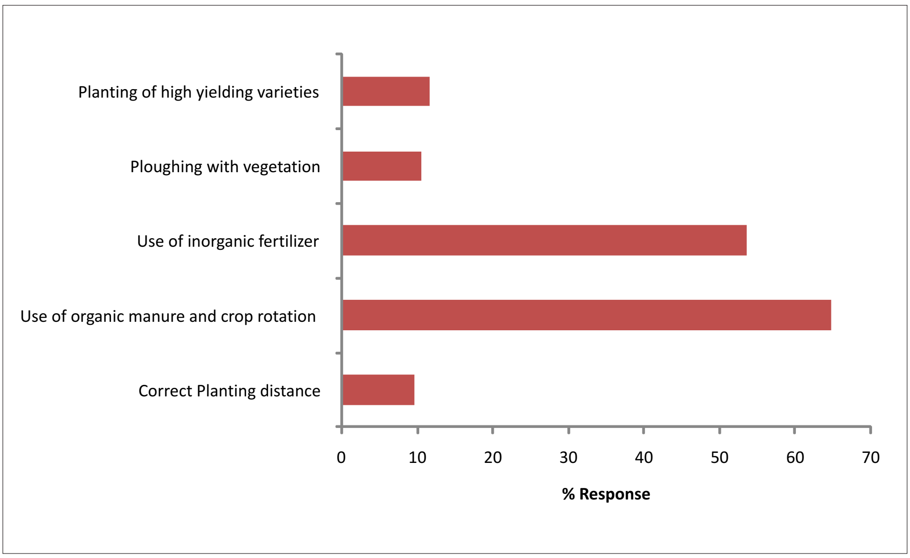

Figure 14: Innovations/Technologies Adopted to Manage Reduced Arable Land

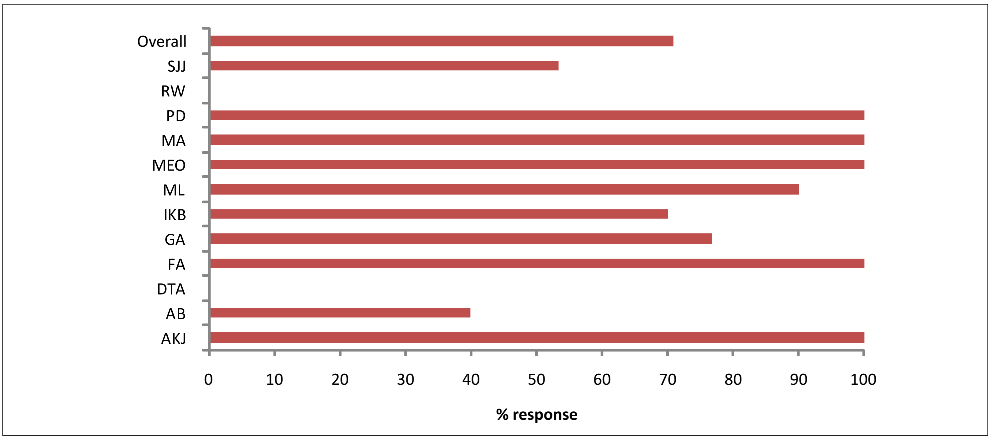

Figure 15: % Response to Reduction in Arable Lands by Operational Area

4.4.1 Changes in Behavioural Practices to Adapt to Climate Change

In many cases people will adapt to climate change simply by changing their behavior. This may involve relocation and/or changing occupation. Often farmers affected by climate change effects and impacts will employ different forms of technologies such as new irrigation systems or drought-resistant seeds which are considered 'hard technologies', or 'soft' technologies, such crop rotation patterns. In most situations a combination of hard and insurance schemes or soft technologies are employed. Farmers interviewed in the district had either relocated their farms and/or diversified into alternative livelihood options. None had changed occupation completely since they explained that farming is part of their culture. As some farmers put it 'farming is the only occupation we have there is no other alternative'. However changes in crop type cultivated were observed. Currently most farmers cultivate crops that do not need much water for growth like water melon. Less than 30% of the farmers interviewed had relocated close to water bodies (River Volta), especially for minor season farming. Farmers relocated to fertile lands and also moved to Yeiji (in the middle belt regions of Ghana) to fish in addition to farming (seasonal migrants). Farmers relocate when there is flood or heavy precipitation but come back later (after a while; leave the land to fallow). Farmers relocate from marshy areas to higher grounds

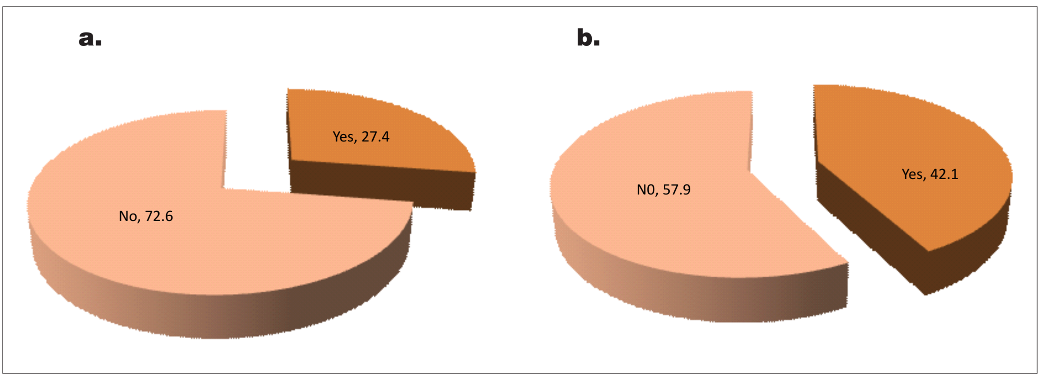

Figure 16: a. Have You Relocated Your Farm; b. Have You Diversified Your Economic Activities

Majority (97.5%) indicated that their farmlands could not have supported crop development but for the application of improved agricultural practices. Corrective measures applied include organic manure (92%), use of inorganic fertilizer (90%) and Crop rotation (28%).

Diversified economic activities include fishing, mushroom cultivation, livestock rearing, grasscutter rearing, salt mining and bee keeping. Others are petty trading, artisanal jobs, gari processing, hairdressing and soap making, basket weaving, bricks making. Some farmers migrate to urban centres in search for off-farm jobs.

4.4.2 Organizational Innovation

The most effective adaptation approaches in developing countries, as highlighted in UN Framework Convention on Climate Change (UNFCCC) meetings, are those that address a combination of environmental stresses and factors. Strategies, policies and programmes that are most likely to succeed need to link with coordinated efforts aimed at alleviating poverty, enhancing food security and water availability, combating land degradation and soil erosion, reducing loss of biological diversity and ecosystem services. Indeed farmers interviewed had benefited from organizational support from various government and non-governmental agencies/organizations. Such organizations currently operational in the district includes Ministry of Food and Agriculture (MOFA) and Adventist Relief Agency (ADRA); both operational in almost all the communities surveyed and involved in technology dissemination. Others are forestry department (into afforestation programmes), Wildlife (wildlife conservation), the media (Radio Ada) and other projects mostly involved in food security issues. Unfortunately, the Ministry of Energy was not mentioned although it has a major role to play since building resilience to climate change requires a dependable source of energy. However, a check with the Renewable Energy Directorate of the Ministry of Energy showed that there are plans to rollout utility scale wind energy project in the Dangme East district to help speed up the processes of addressing the impact of climate change and improve livelihoods in the district.

Table 21 gives a summary of institutions/organizations supporting farmers to build resilience to climate change effect and food security threats.

Table 21: Summary of Organisations/Institutions supporting farmers to build resilience to Climate Change Effects

Name of Organis-ation	Operatio-nal Area	Innovation/ Services	Description	Advantages	Disadvantages
Forestry Department	MA PD	Tree planting	Planting of allies Woodlots Boundary trees	Improves soil fertility Fuel wood Reduction in boundary disputes	Tree planting is constrained by land tenure system Some farmers do not own land Land tenure system does not make it favourable to most farmers in the area
ADRA	Almost all the communit ies surveyed	Planting of Fruit trees Supply of tree seedlings	Planting of fruit trees like mangoes and cashew in allies Woodlots establishment Group formation for effective support	Security for old age Fuel wood	-do- Shattering of tree seeds Lack of market for cashew
MOFA	All communit ies surveyed	Extension delivery	Dissemination of improved agricultural practices through Field demonstrations Trails Field days Records keeping Nursery Management	Evidence of effective technologies and enhanced technology adoption	Logistics for effective extension delivery inadequate Compost takes too long to decompose Improved seeds are too expensive Dug-out too expensive to contruct Manure not readily available Organic manure speeds weed growth Staking of tomates difficult Agrochemicals dangerous to health Carting of manure is cumbersome/bulky Correct planting distance (Row planting) is time consuming
Radio Ada AFRI & Christian Aid GTV/TV3	MA PD GA MA IKB	Dissemination of information on innovative technologies and market prices Information on the Weather	Weekly programmes on improved technologies AFRI/Christian Aid is an NGO that fund radio programmes in the interest of farmers	Educate alot of farmers	NA

4.4.3 Suggestions from farmers

Table 22 presents suggestions by farmers interviewed concerning climate change effects and adaptation.

Table 22: Suggestion from farmers about climate change issues

Suggestions	Percentage Response
Provision of irrigation facilities only	42.0
Availability of inputs, irrigation facilities and subsidies	13.0
Irrigation and credit facilities	12.1
Afforestation and irrigation	9.9
Public Education on climate change	7.6
Provision of alternative livelihoods	5.6
Supply of electricity to reduce high cost of fuel used for irrigation	3.4
Improved agricultural practices(organic manure application, use of resistant varieties, early planting)	2.3
Provision of Tractor Services	1.1
Regular weather forecast	0.6

Other suggestions are bulleted below;

> MOFA should encourage water melon cultivation it helps maintain soil moisture

> De-silting of blocked and silted tributaries so that water can flow

> Reduction in arable lands also caused by salt invading lands; something has to be done about salt lands

> Land Degradation- education on the effect of cutting down trees for charcoal burning

> Use of LPG instead of charcoal,

> Application of cow dung and bat fecal matter

> Increase use of organic manure and less of agro-chemicals and inorganic fertilizers

> Development of sustainable irrigations infrastructure

5. Conclusions & Recommendations

The District has fairly flat topography, low vegetative growth, relatively good infrastructure and sufficient land mass for wind energy development and agriculture. At 80m, the area has sheared annual wind speed of 7.6m/s (based on available rudimentary wind data). The predominant wind direction is south-west.

Land mass around the site where data was collected has reduced in size as a result of persistent sea erosion and new settlements. As a result, the development of utility scale wind energy project is technically impossible within the measurement site.

However, towards the South-Western part of the Dangbe East (Pute,Alavanyo and Tamino) where agricultural and fishing are mainstay economic activities, there is sufficient land area that can support utility scale wind energy project.

As a matter of interest, since wind resource is site specific, the identified areas with good wind resources should be properly demarcated and protected. This will help monitor and control the uncoordinated use of potential wind sites for other economic activities in the district.

A wind energy project in the district would stimulate the development of the agriculture potential. For instance, during idle times, the energy from the wind could be used to pump water from the lower Volta River (naturally flowing into the sea) into reservoirs for irrigation.

From the situational analysis of the climate change effects on agricultural practices in Dangbe East district of Ghana, most farmers are challenged by the high cost involved in adaptation of innovative technologies to build resilience. Linked to constraints posed by climate change effects are opportunities mostly in the form of improved agro-technologies and economic diversification. Some adaptation measures disrupt traditional food production systems thereby compromising their community and household food security. Farmers strongly recommended provision of irrigation services, availability of improved agro-technologies and education as key in building resilience to climate change effects. The use of irrigation facilities and other agro-technologies is very energy-dependent. Where there is potential for the generation and application of wind energy, it has to be exploited. To promote climate change strategies, efficient agro-technological improvement need to be strengthened substantially in Ghana as well as efficient interface between policy-makers, researchers and the farming community through regular dialogue and institutional support.

The emerging agricultural production trend suggests that staple foods such maize and cassava in the district are under intense stress and could pose food security challenges. Dialogues with the farming communities to scale up some of the innovative technologies has to be strengthened substantially as well as efficient interface between policy-makers, researchers and other supporting institutions.

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