GHANA - Opportunity Assessment and Feasibility Study of Rainwater Harvesting for Agriculture in the Kwahu Afram

Vulnerability Assessment to Climate Change of agricultural communities in the Kwahu Afram Plains

Main Report

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Main Report

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AD	Administrative District
APADP	Afram Plains Agricultural Development Project
AFD	Agence Française de Développement
BP	Bank Procedure
CA	Conservation Agriculture
CDD	Consecutive Dry Days
CHPS	Community-based Health Planning and Services
CORDEX	Coordinated Regional Climate Downscaling Experiment
CSIR-WRI	Council for Scientific and Industrial Research-Water Research Institute
CSO	Civil Society Organisation
CWSA	Community Water and Sanitation Agency
DEM	Digital Elevation Model
EAR	Environmental Assessment Regulations
ECMWF	European Centre for Medium Range Weather Forecasts
EH&S	Environmental, Health & Safety
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ERA5	Global reanalysis climate data product from ECMWF
ESIA	Environmental and Social Impact Assessment
ESS	Environmental and Social Standards
ET	Evapotranspiration
EU-GAP	European Union Ghana Agriculture Programme
FAO	Food and Agriculture Organisation
FASDEP	Food and Agriculture Sector Development Policy
FGD	Focus Group Discussion
GCAP	Ghana Commercial Agricultural Project
GASIP	Ghana Agricultural Sector Investment Programme
GCF	Green Climate Fund
GHCN	Global Historical Climatology Network
GIDA	Ghana Irrigation Development Authority
GIIP	Good International Industry Practice
GMet	Ghana Meteorological Agency
GPRS	Growth and Poverty Reduction Strategy
GPS	Global Positioning System
GS	Ghana Standards
IFCo-op	Irrigation Farmers' Cooperative
IFC	International Finance Corporation
ILO	International Labour Organization
IPM	Integrated Pest Management
ISIMIP	Inter-Sectoral Impact Model Intercomparison Project
KAP	Kwahu Afram Plains
KAPND	Kwahu Afram Plains North District
KAPSD	Kwahu Afram Plains South District
KII	Key Informant Interview
LI	Legal Instrument
MCA	Multi-Criteria Analysis
MEL	Monitoring, Evaluation and Learning
MESTI	Ministry of Environment, Science, Technology and Innovation
METASIP	Medium Term Agriculture Sector Investment Plan

MoFA	Ministry of Food and Agriculture
MSDI	Ministry of Special Development Initiatives (now defunct)
NADMO	National Disaster Management Organisation
NAP	National Adaptation Plan
NARMAX	Non-linear Autoregressive Moving Average with exogenous Input
NBS	Nature-Based Solutions
NCCP	National Climate Change Policy
NDC	Nationally Determined Contributions
ND-GAIN	Notre Dame Global Adaptation Index
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NSSIP	National Small Scale Irrigation Programme
1V1D	One Village One Dam
OECD	Organisation for Economic Co-operation and Development
OP	Operational Policy
PFAG	Peasant Farmers Association of Ghana
PS	Performance Standards
RCM	Regional Climate Model
RDC	Rural Development Corporation
RCP	Representative Concentration Pathways
RMSE	Root Mean Square Error
SDG	Sustainable Development Goals
SPEI	Standardized Precipitation Evapotranspiration Index
SPIS	Solar Pumping Irrigation Systems
SRTM	Shuttle Radar Topographic Mission
SWAT	Soil & Water Assessment Tool
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use
WBG	World Bank Group
WIS	World Meteorological Organization Information System
WRC	Water Resources Commission
WUA	Water Users Association

EXECUTIVE SUMMARY

Study Context and Purpose

This Vulnerability Assessment Report is the third deliverable of the assignment funded by the Agence Française de Développement (AFD) Adapt'Action Facility for MESTI, MoFA and GIDA, aimed at assessing the opportunity and feasibility of rainwater harvesting for agriculture in the Kwahu Afram Plains (KAP). The objective of this report is to investigate the present and future climatic conditions of the KAP and assess the impact of climate variability and vulnerabilities to climate change of agriculture, water resources and socio-economic trends. Later studies and reports will assess the options for adaptation of rainwater harvesting and other intervention measures in the KAP.

Description of the Project Area and Socio-economic Situation

The KAP has a total land area of 5,436km^2, with major access routes by road and via ferries across the Volta Lake. The topography is generally undulating land (60 - 120 meters above sea level) and is drained by the Afram River in the west and south, the Volta Lake in the east and the Obosom River in the north, all of which are perennial, flowing throughout the year. The area is characterized as a savannah vegetation zone comprising the savannah transitional zone and woodland, with two main rainfall seasons occurring in April-July and August-November, and dry seasons between November and March, hot temperatures and high relative humidity throughout the year. Figure 1 shows the map of the Kwahu Afram Plains while Table 1 gives the population characteristics as at 2019.

Figure 1 - Project Area - Kwahu Afram Plains (North and South Districts)

Table 1 - Population Characteristics of the Kwahu Afram Plains (2019)

DISTRICT	Population	M/F Ratio	Growth rate	Density 2014	Distribution
KAPS	144,889	53.9% m 46.1% f	3.2 p.a	37.4/sq. km	75.4% rural
KAPN	127,117	53% m 47% f	2.4 p.a	48.0/sq. km	86% rural

The people in the KAP are primarily based in the rural areas and engaged in agriculture and are therefore significantly exposed to climate change impacts, such as temperature rises, declining rainfall, high annual and decadal rainfall variability and extreme climate events; these have been observed trends in the region and climate models project further increases and uncertainty in the future.

The construction of the Volta Lake in 1964 relocated people from villages along the River, whilst people from other parts of the country migrated to the KAP to seek opportunities in the agricultural sector. The main ethnic groups existing in the two districts are Ewes, Northern tribes, Dangbe, and Akans, and they are predominantly Christian, with a small proportion of Muslim and traditionalists.

Most schools in the area are based in temporary structures or in the open air (under trees) and lack basic facilities such as staff common rooms or accommodation, books and water, sanitation and hygiene (WASH) facilities. Based on the 2010 population and housing census, average rate of literacy in both districts is 58.3% of total population, lower than the national estimate of 74.9%.

Similarly, hospitals and other health facilities are inadequate for the growing population and understaffed by doctors and nurses, with the Doctor:Population ratio far below WHO standards (1:10,000) and Nurse: Population ratio below the national figure of 1:900.

Electrical power supply is frequently unstable, with consequences for business development in the district, and is concentrated in urban areas, with only 15% of rural areas benefiting from a connection to the national grid.

Land ownership is classified into two categories: state or public land and customary or private land. In the KAP, customary land is owned by the chiefs, clan or family heads, who hold them in trust for their subjects, whilst private land is held or acquired through direct purchase, rent, leasehold, share-cropping (Nnoboa) and gift. There are tensions among some groups with regard to access to land, land ownership and grazing land for herdsmen.

Present farm sizes range between 2-200 acres and the agriculture practised is mainly rainfed, with no large-scale, commercial or formal irrigation schemes present in the area and only supplementary irrigation utilised along the shores of the lake, where small pumps are used to extend the growing seasons. The assignment ToR envisaged developments at 12 scheme locations, each 80-100 ha, and a list of potential sites was provided developed during the inception stage. The total farmer population projected to benefit from a project in these 13 pre-selected sites is 14,433, composed of 7,928 (55%) males and 6,505 (45%) females, while the lessons learned and national guidelines to replicate rainwater harvesting systems for agriculture will be used by the beneficiary institutions (e.g. MESTI, MoFA and GIDA) in regional and district strategies and programmes to benefit larger populations.

Study Approach for Production of this Report

The approach of the study initially focussed on the four key areas of the climate, water resources, agriculture (for crops) and the socio-economics of the area, but this was later extended to include a livestock aspect, due to concerns raised during the inception stage.

The climatic analysis (fully detailed in the Climate Analysis Report) focuses on the three main meteorological variables of temperature, precipitation and wind, and their related indices. The Consultant's Team used station observation data from the Ghana Meteorological Agency (GMet) and interviews from the field missions, and Coordinated Downscaling Experiment (CORDEX) Regional Climate Models (RCMs) and driven by Global Climate Models (GCM) from the fifth coupled model Inter-comparison Project (CMIP5); two warming scenarios (e.g. RCP 8.5, high-warming and RCP 4.5, mid-warming). A reference period from 1979-2008 was used and projections for the near future (2006-2035), mid-century (2036-2065) and end of the 21st century (2066-2095) were modelled. The impacts of the present-day and projected climate variability and changes on agriculture, hydrology and socio-economic trends were then assessed.

The hydrologic analysis (fully detailed in Water Resources Report) considered the hydrology of the plains with a focus on catchment runoff estimation and implied impact of rainfall on Water Resources. Without available historical streamflow data for any of the rivers within the project area, the approach used was to estimate the surface runoff based on data from an adjacent catchment with similar characteristics, the Afram River, and two rainfall stations in the catchment, at Aframso and Ejura. Groundwater resources were also reviewed, based on borehole information for domestic water supplies in the area.

The agronomic analysis (fully detailed in the Agronomy and Livestock Report) discusses the present agricultural conditions, based on field visits to the project area and specific scheme sites, and data collection from existing sources, including present agricultural conditions, land use, crop yield and production, cropping pattern, farming practices, farm inputs and material and labour requirements, and crop budgets for the cultivation of crops in the project area. The analysis of information and data collated focused on a climate change vulnerability assessment, based on the present agricultural conditions in the KAP and at the selected sites.

The socio-economic analysis (fully detailed in Socio-economics Report) considered the socio-economic context with respect to the physical and natural environment, population and demographic characteristics, environmental and social issues, major economic activities and livelihoods, climatic hazards and vulnerability effects, irrigation management systems, land ownership in Ghana and the Afram Plains and gender and emerging trends. It was conducted through mainly qualitative methodologies and from a mix of primary and secondary data sources; field surveys employed a range of participatory methods for data collection, analysis and interpretation; a total of 12 Focus Group Discussions (FGDs), were held in six different villages/communities, three in each district. In-depth interviews were conducted amongst key informants, comprising of technical personnel engaged in agriculture, land use planning, gender, those engaged in innovative approaches in rural development and traditional leaders.

The livestock studies (also fully detailed in the Agronomy and Livestock Report) were added as additional work, following comments made during the inception stage and agreement with AFD; they focus on a preliminary baseline of

husbandry practices in the KAP, assessing the impacts of climate change on livestock activities, evaluating the vulnerability of livestock to climate change and establishing relationships between crops and livestock activities in the light of these changes. These would lead to the identification and formulation of livestock related activities for the project.

Summary of Key Findings

The main findings and conclusions of the studies are summarised as follows.

(i) Climate

Present-day

- Temperatures in the KAP increased since the 1980s and are higher by about 1°C in both the rainy and dry seasons, compared to the reference period of 1979-2008 (GMet data). The reference period as used in this context is the baseline period (i.e. the period relative to which anomalies are computed) and the assessment of past, current and future global surface temperature changes is done relative to this reference period.
- The frequency of both extreme hot nights and days have increased over the period 1980-2020, as compared to the reference period (1978-2008).
- GMet data reproduces the bi-modal nature of rainfall in all the weather stations in the KAP (1970-2020) and its vicinity – with a long rainy season over the 2nd trimester followed by a short dry season and short rainy season finishing in October-November (It is worth noting that interviews in the field had people claim the rainfall pattern had become uni-modal since 2018; according to stakeholders in the area, this new unimodal pattern is characterized by a late onset of the major rainy season coupled with early cessation of the rains).

Future

- Temperature in the KAP in the future period (2036-2065) is projected to increase by 1.3°C (RCP4.5) and 1.6°C (RCP8.5) compared to temperatures observed in the reference period (1979-2008).
- A higher frequency of heatwaves (e.g. 86 and 104 days in RCP4.5 and 8.5 respectively) and extreme hot nights will accompany the increase in temperature over the area.
- In the future period (2036-2065), the multi-model and project area mean precipitation in the rainy season is projected to increase by 2.8% (RCP4.5) and 4.1% (RCP8.5).
- The number of consecutive dry days could decrease by an average of 21 days in the KAP.
- Extreme wet events that could trigger flooding events are projected to increase by 1 day (RCP4.5) and 2 days (RCP8.5).
- Although precipitation change shows model disagreement, this is neither the case for the number of consecutive dry days nor extreme wet events in the rainy season.
- The frequency of days exposed to extreme wind events is also projected to increase, particularly in the dry season.

(ii) Hydrology

Present-day

- There are no historical flow data for the project area, so data from Afram River, an adjacent catchment with similar characteristics as the KAP, is

used to analyse the surface runoff capacity of the catchment.

- Catchment delineation using 30m SRTM DEM data is too coarse to segregate sub-tributaries for the proposed individual project sites, but impacts on total monthly flows for larger clusters of catchments are estimated.
- The extent of reservoir inundation at the proposed sites is yet to be developed and data on evaporation is not available, so the impact on reservoir storage for present and future scenarios could not be determined.
- Large impoundment areas produced by shallow reservoirs, due to the flat terrain in the KAP, and the potential risk of drying out as a result of increased evaporative losses, as well as the increased flooding risks from breaching, suggest that reservoir developments must be limited to stream channels and excavated dugouts where they are able to store sufficient water for irrigation and livestock water uses.
- Depths of groundwater boreholes in the KAP range from 35m to 128m across the two districts, with only 55% functional and yields limited to the domestic needs of the communities they serve (Anecdotal information given during the Adaptation Options Workshop suggested wells with discharges of 1,500 l/s, but attempts to clarify this did not yield any confirmation and it was considered erroneous).

Future

- The projected variations in streamflow for mid-century to century-end, range from reductions of up to 7% of current flows (using CCCma_CCCma-CanESM2 model and RCP 4.5 projection) to increases of over 30% of the current flows for the RCP 8.5 projection (Details can be found in the Water Resources Report).
- One implication is potentially reduced availability of irrigation water for agriculture, requiring sufficient storage capacity to be created to satisfy expected shortfalls.
- Alternatively, increased streamflows imply greater flood risks, especially for low-lying areas and communities, requiring adequate storage facilities to absorb these flows or protection measures to prevent or reduce flooding damage.
- Both have implications for adaptation and mitigation programs aimed at improved livelihoods for communities.
- Groundwater does not respond rapidly to climate variation, but over extended periods, reduced precipitation or high intensity rainfall tends to reduce infiltration to the aquifer, limiting groundwater availability (Aquifer recharge options may be explored, to channel excess flows that otherwise might cause flooding and improve water sources for irrigation of vegetable farms).

(iii) Agronomy

Present-day

- Interviews during the field missions indicate crop production is diverse, with farmers adopting different production techniques, but with the cultivation reduced to a single cropping season under mainly rainfed/upland conditions, and only a limited number of farmers growing

crops under irrigation, mainly along the shores of the Volta Lake.

- Harsh climatic conditions (i.e. drought, high temperatures and floods) and the associated pests, diseases and bush fires, as well as conflicts with livestock, place crops at increased risk and vulnerable to climate variability and change.
- Farmers' crop selections are limited by rainfall, duration of growing periods and cropping patterns, with annuals being the major crops grown (e.g. Cassava, Yam, Maize, Sorghum, Groundnut, Watermelon, Tiger Nut and Soya bean) and they are adverse to making investments and production changes for fear of crop failures; they sometimes abandon crop farming for alternative livelihoods, such as charcoal production that can further aggravate the climate change impacts.
- Current activities to address climate change mainly relate to conservation agriculture (e.g. Zero tillage, contour bonding, mulching, crop rotation, cover cropping).

Future

- Projected yields indicate a decrease for some of the crops currently grown in the project area (e.g. Cassava, maize, groundnuts, rice).
- Farmers' crop selection and cultivation techniques will be guided by climate vulnerability issues. They will select short duration crops rather than long duration crops due to the limited water availability. Based on the climatic suitability analysis and considering short, medium and long cycles, cashew is the most suitable for all three cycles, while maize is most suitable for medium and long cycles.
- Climate change will force more farmers to adopt irrigation for crop production and they will need to build capacity in appropriate practices and push for public and private investment in more formal irrigation systems to complement the existing informal schemes. Appropriate scheme design will enable cultivation of several crops at higher cropping intensities and increase crop yields. Scheme design should consider cropping patterns and crop-water requirements, as well as effective irrigation management for efficient irrigation scheduling.
- Farmer-Based Organisations (FBO) and Water User Associations (WUA) will be needed for sustainable management of the limited water resources and dissemination/ adoption of appropriate information, inputs and credit facilities, among others. Farmers will also need to undertake management of scheme facilities and maintenance of water infrastructure.
- The deteriorating condition of roads in the KAP and absence of crop storage infrastructure will continue to impact the storage and transport of agricultural inputs and farm produce, and magnify the frequent glut and price fluctuations, which directly affect farmers' incomes.
- Farmers may resort to more extensive use of farm machinery for cultivation, to reduce the time spent in labour-intensive activities, tractors or power tillers and other farm machinery would be required for land preparations and other farm activities such as harvesting. Improved extension activities and demonstration farms would build the

technical capacities of farmers along the crop production value chain.

(iv) Socio-economic

Present-day

- The combined effects of high levels of poverty, heavy reliance on rain-fed agriculture, high illiteracy rates (average 58.3% of total population), high fertility rate, poor transportation network and limited access to services such as credits, create a situation of high vulnerability to climate change in KAP North and South Districts.
- Agriculture employs as high as 72% of the labour force. 55.9% of urban households engage in agriculture.
- Kwahu Afram Plains South District has a poverty incidence rate of 59.7%, the highest in the Eastern Region, while the poverty incidence rate for Afram Plains North is 31.7%.
- Communities feel that the climate is changing, with the biggest climate-related hazards in the KAP districts being droughts, floods and storms, heavy rains and increase in temperature. These climate change impacts affect crops, livestock and human health, making access to water and pasture difficult, with impacts on crop productivity, animal health, food security, incomes and incidence of disease.
- The status of both districts as major migrant destinations and existing social and gender norms make women, migrant farmers, youth, people living with disabilities and children more vulnerable and most affected by the effects of the climate related hazards.

Future

- The outlook for the future effects of climate variability on the socio-economic context of Afram Plains depicts adverse effects on agricultural productivity, food security, incomes and employment.
- Trends like increasing population, limited diversification of the economy, practices such as excessive charcoal production and wood logging and emerging trends such as land "grabbing" will continue to increase the vulnerability of communities.

(v) Livestock

Present-day

- Decreased availability of forage and water has reduced the productivity and health of livestock, and triggered occasional herder-crop farmers conflicts, due to damage to crops and contamination of water bodies by livestock.

Future

- If appropriate climate smart policy interventions and technologies are not adopted, the worsened feed and water availability will have deleterious effects on livestock productivity and health, and trigger more frequent herder-crop farmer conflicts during livestock mobility in search of sustenance.

1 INTRODUCTION

1.1 Study Context

1.1.1 Background

Ghana is a country that is highly vulnerable to climate change, as indicated in the country's fourth National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020, and Ghana's ND-GAIN index of vulnerabilities to climate change and other global challenges. The National Communication specifies agriculture as one of the most exposed sectors to climate change, which also has a low adaptive capacity, especially in the Kwahu Afram Plains South District (KAPSD), while in the North District (KAPND) they have undertaken some agricultural activities to promote mitigation/adaptation to climate changes, such as Conservation Agriculture (CA) practices, including cover cropping in maize and mulching in cashew fields (Ref. District Annual Reports, 2020). Agriculture is linked with priority areas such as livelihood, water and land use and policies developed by the Government of Ghana (GoG) to address the challenges posed by climate change in these sectors are led by the Ministry of Food and Agriculture (MoFA) and the Ministry of Environment, Science, Technology and Innovation (MESTI), as well as other stakeholder bodies, such as the Ghana Irrigation Development Authority (GIDA) and Water Resources Commission (WRC).

The purpose of the Agence Française de Development (AFD) funded "Opportunity Assessment and Feasibility Study of Rainwater Harvesting for Agriculture in the Kwahu Afram Plains assignment" is to develop a bankable project proposal for this peninsula in the Volta River Basin bounded by the Volta Lake, the Obosum River and the Afram River and situated in the Eastern Region of Ghana (See Figure 2). In developing the proposal, both national and global targets will be considered[1] and the achievements of previous projects[2] will be built upon.

[1] To include, among others: the Paris Climate Agreement (2015), the Sustainable Development Goals, Ghana's fourth National Communication to the United Nations Framework Convention on Climate Change (2020), the National Climate Change Adaptation Strategy (2012) and National Adaptation Plan (2018), Nationally Determined Contributions (2015), the Irrigation Policy (2011), the National Climate-Smart Agriculture and Food Security Action Plan (2016-2020), and the Ghana Technology Needs Assessment (2012).

[2] For example, the Afram Plains Agricultural Development Project (AfDB, APADP, 2006-2013), One Village, One Dam initiative (Ministry of Special Development Initiatives) and the Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods (Adaptation Fund, 2016-2020).

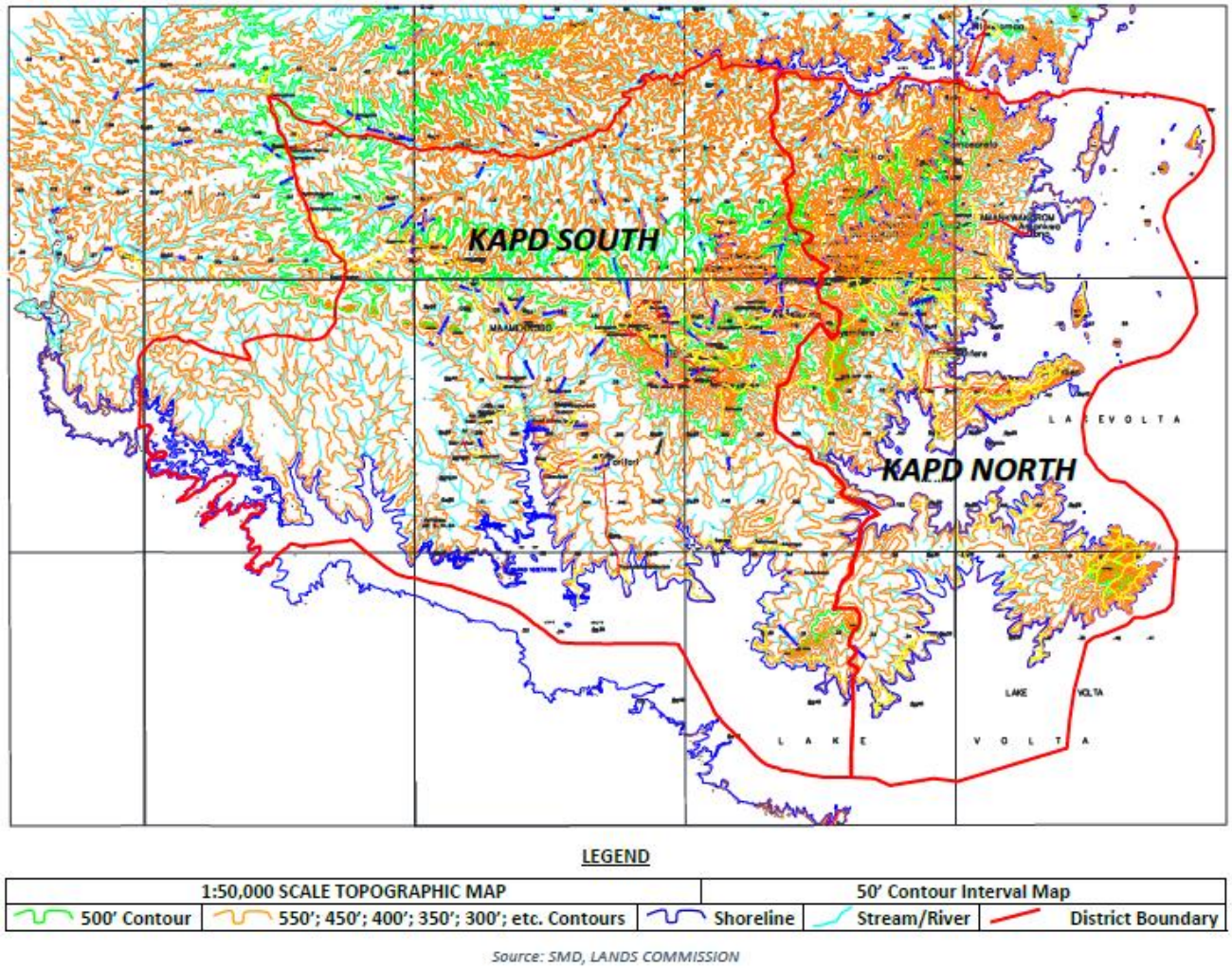


Figure 2 - Project Area - Kwahu Afram Plains (North and South Districts)

1.1.2 Aims

The aim of the project to be developed, is to ensure continuous access to high quality wholesome water for agriculture use throughout the year in a changing climate, through sustainable use of rainwater harvesting. This is to be accomplished by factoring in climate change impacts through analysis of vulnerabilities and the identification of robust adaptation options to ensure agriculture is resilient and livelihoods are sustainable in the long-term.

1.1.3 Objectives

The assignment objectives are as follows:

- To assess vulnerabilities to climate change and suggest options for adaptation of rainwater harvesting for agriculture
- To conduct feasibility study on the water harvesting potential and other adaptation measures for agriculture
- To develop a bankable project using the outcomes of the study.

The adaptation options to be considered include the feasibility of new infrastructures to ensure continuous access to water for agriculture; soft, low-regret and nature-based

solutions (NBS) that can address the low adaptive capacity in the Kwahu Afram Plains and enhance agricultural adaptation.

The assignment ToR envisaged developments at 12 scheme locations, each 80-100 ha, and a list of potential sites was provided during the inception stage. The total farmer population projected to benefit from a project in these 13 pre-selected sites is 14,433, composed of 7,928 (55%) males and 6,505 (45%) females, while the lessons learned and national guidelines to replicate rainwater harvesting systems for agriculture will be used by the beneficiary institutions (e.g. MESTI, MoFA and GIDA) in regional and district strategies and programmes to benefit larger populations.

1.1.4 Activities

The study comprises the following key activities:

- Activity 0 - Inception Mission
- Activity 1 - Climate Change assessment of the Kwahu Afram Plains, including identification of vulnerabilities and adequate adaptation options
- Activity 2 - Feasibility study on water harvesting potential in the Kwahu Afram Plains for agriculture
- Activity 3 - Development of a bankable project document for rainwater harvesting in the Kwahu Afram Plains for agriculture
- Activity 4 - Communication and capitalization.

1.1.5 Activity 1 - Climate Change Assessment

The objectives of the Climate Change Assessment (Activity 1) are to gather agronomic, climate, hydrological and socio-economic data and information to assess all vulnerabilities to climate change of the project area and to co-develop, in an inclusive manner, options to address the identified vulnerabilities, increase resilience and secure continuous access to water for agriculture in the project area.

The expected outputs from Activity 1 include:

- This report on the assessment of climate change impacts and vulnerabilities in the agriculture sector (Deliverable 2: Vulnerability Assessment Report)
- Suggested adaptation options, comprising a comprehensive range of agricultural practices and infrastructural investments, including rainwater harvesting to ensure continuous access to water for agriculture (Deliverable 3: Adaptation Option Report).

Deliverable 2 provides background, general description and an agro-economic analysis of the project area (Subtask 1-1) and analyses of the climate context and climate change impacts (Subtask 1-2), the water resources and their vulnerability to climate change (Subtask 1-3) and socio-economics of the area (Subtask 1-4). In addition, following feedback obtained during the inception stage, the methodology was modified to include livestock studies. The detailed information and analyses for each of the key areas of study are provided in a series of stand-alone Reports, as follows:

- Climate Analysis Report
- Water Resources Report

- Agronomy and Livestock Report
- Socio-economics Report

A separate report (Deliverable 3: Adaptation Options Report) identifies potential climate change adaptation options, to increase the resilience of Kwahu Afram Plain's water resources and of the agricultural communities depending on them, including water harvesting, as identified through participatory activities.

1.2 Description of the Project Area

1.2.1 Summary description of the KAP districts

Tables 2 to 5 provide a summary of characteristics for both KAPN and KAPS, including physical and natural environment, population and demography, environmental and social services/issues, and major economic activities and livelihoods, as provided in the detailed descriptions provided in the following sections.

Table 2 - Physical and natural Environment of the KAP

Indicator	KAPND	KAPSD
Size	2,341 km^2	3,095 km^2
Relief and drainage	Undulating between 60 - 120 meters	Undulating between 60 - 120 meters
Vegetation	Savannah vegetation zone	Savannah vegetation zone, but also comprises the savannah transitional zone and savannah woodland
Main rainfall seasons	April-July and August-November	March and Mid-November
Main dry seasons	November and late February	November and late March
Hottest days	In February and March (36.8^{0}C and 36.6^{0}C respectively)	
Coldest days	December and January (19.9^{0}C and 20.1^{0}C)	
Relative humidity	No data	68.2-71.6% in the dry season and 81.6-71.6% in the wet season
Major Soil group	Swedru-Nsaba-Offin Compound	
Soil vulnerability	The land is susceptible to wind erosion when the vegetation cover is removed. A combination of human activity, droughts and flooding events that occur in both districts have been cited as the cause of increased soil erosion.	
Geology	Principally Upper Voltarian sandstones	
Oil and gas	The districts are listed as having oil and gas deposit prospects (as part of the volta basin) and the Ghana National Petroleum Corporation (GNPC) has carried out a seismic survey to locate potential areas for commercial oil and gas drilling.	
Water Resources	Possesses groundwater resources that can be developed for water supply purposes, particularly in the rural communities, that are not served by pipe-borne water.	The Volta Lake, Afram River, Obosom River are located within easy reach of various towns and their environs, particularly providing the major towns of Ekye-Amanfrom and Bridge Ano with natural water resources.
Transportation	One central trunk road from Ekye-Amanfrom to Agordeke; a distance of 102.2 km	One central trunk road from Ekye Amanfrom to Tease and continues to Donkrokrom; a distance of 91.2 km

Table 3 - Population and Demography

Indicator	KAPND	KAPSD
Population	127,117	144,889
M/F ratio	53% m 47% f	53.9% m 46.1% f
Growth rate	2.4 p.a	3.2 p.a
Density 2014	48.0/sq. km	37.4/sq. km
Distribution	86% rural	75.4% rural
Migrants percentage	20.1%	32.1%
Ethnicity and religion	Ewes: 51.3%, Northern tribes: 40.1% Akans: 8.6%	Ewes: 66% Dangbes: 11%, Northern tribes: 13% Akans: 10%
Gender context; household	75.4% male headed 24.6% female headed	78.6% male headed 21.4% female headed
Incidence of poverty	Poverty incidence: 37.7% 70% of the people living in poverty in KAPND are female	Poverty incidence: 59.7%
Revenue GAP	Females are paid 30-40% less than men for comparable work	

Table 4 - Social Services/Issues

Indicator	KAPND	KAPSD
literacy rates for people from age 11 upwards	59.5%	57.1%
Male literacy rate	63.4%	50.4%
Female literacy rate	55.2%	49.6%
Health infrastructures	(1) hospital at Tease, three (3) health centres located at Ekye, Tease and Kwasi Fante and five (5) Community-based Health Planning Services (CHPS) compounds in communities	(1) Hospital at Donkorkrom and 29 CHPS Compounds
Doctor:Population ratio	1:21,529	1:30,000
Nurse:Population ratio	1:1,435	1:650

Table 5 - Major Economic Activities and Livelihoods

Indicator	KAPND	KAPSD
Agriculture	74.5% (65%m, 35%f)	77.2% (65%m, 35%f)
Service	11.5% (65%m, 35%f)	7.5% (65%m, 35%f)
Commerce	7.9% (40%m, 60%f)	5.3% (40%m, 60%f)
Industry	6.1% (70%m, 30%f)	10% (70%m, 30%f)
Markets	A major market in Donkorkrom and three other smaller ones in Bruben, Supom and Fasso Battor	Market outlets within the district include: Tease, Mama Krobo, Dome, Kwesi Fanti, Ekye Amanfrom
Access to credit	85% of farmers have no access to formal credit facilities	

1.2.2 *Physical and Natural Environment*

a. Location, Size and Accessibility

Kwahu Afram Plains North District (KAPND) has a total land area of approximately 2,341 km^2 and the Kwahu Afram Plains South District (KAPSD) is approximately 3,095 km^2. The area has two major road entrances: via Nkawkaw-Mpraeso-Bepong-Kwahu Tafo and Adawso, from which the Volta Lake Transport Company (VLTC) operates a ferry service across the three-kilometre-wide Afram River to Ekye-Amanfrom, and via Agogo in the Ashanti region's Sekyere Afram Plains, by road through Dome to Maame Krobo and then to Tease. See below maps of the districts indicating the major urban centres and access routes (Source: 2010 Population & Housing Census, District Analytical Reports for KAPSD and KAPND).

Figure 3 - Project Area: Kwahu Afram Plains South District

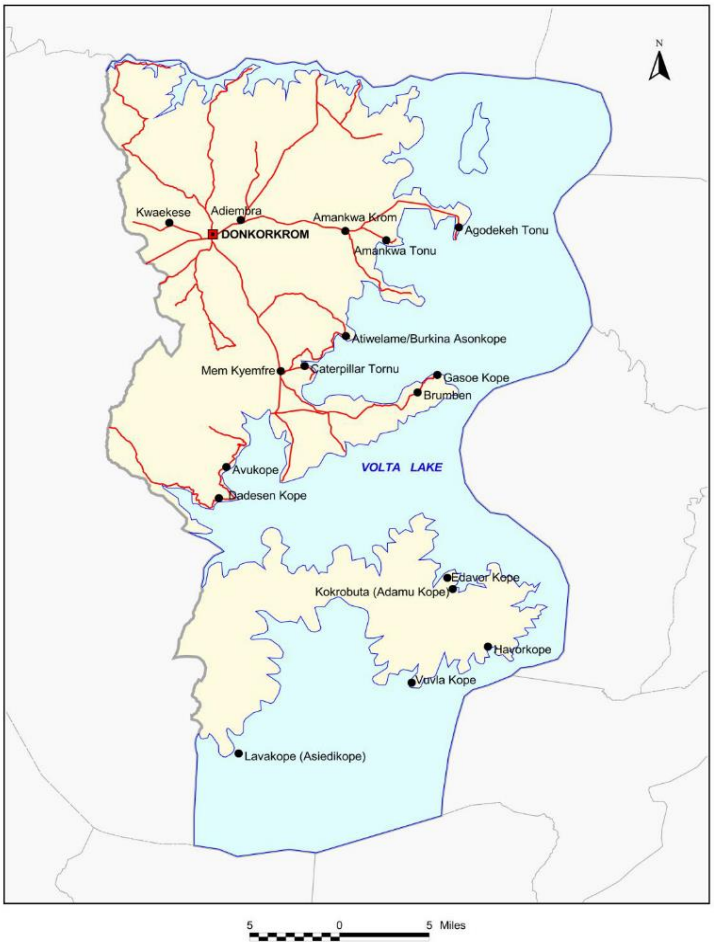


Figure 4 - Project Area: Kwahu Afram Plains North District

b. Transportation

Road and water transport systems are the two main types of transportation systems in the Kwahu Afram Plains North and South Districts. The KAPN district has about 690 km of feeder roads. However, only 270 km have been engineered and gravelled, and are in maintainable condition. There is one central trunk road in Kwahu Afram Plains North District, that is, from Ekye-Amanfrom to Agordeke; a distance of 102.2 km. The central trunk road in KAPS is from Ekye Amanfrom to Tease and continues to Donkrokrom; a distance of 91.2 km. It is worth noting that there are no roads to or in all the three Island communities and the area is difficult to access.

Ferries: The Volta Lake Transport Company (VLTC) provides ferry services on the Lake and currently operates one ferry in the Kwahu `Afram Plains South between Adawso and Ekye Amanfrom to the South District. It has a capacity of 360 tonnes. When using a single engine, it takes about 30 minutes to cross. The peak period in its service is during the yam and maize harvesting period (September--March), when up to six trips can be undertaken in a day.

Access to transportation infrastructure is important to the livelihood of residents of both districts and influences their vulnerability. Such infrastructure determines their access to markets and inputs.

c. Geology

The Kwahu Afram Plains lies in the Voltarian Sedimentary Basin, where the underlying geology consists almost entirely of sedimentary rocks. The geology is described as principally Upper Voltarian sandstones, consisting of course and fine-grained massive sandstones that are thin bedded, flaggy, impure, ferruginous or field spastic and locally inter-bedded with shales and mudstone.

d. Soils

The major soil group in the KAPN and KAPS districts is the Swedru-Nsaba-Offin Compound. Dominating this soil group is the Swedru series which are mainly red silty, well drained, deep gravel-free silty loams and silty-clay loams. The Nsaba series are yellowish red silty clay loam, moderately well drained, very shallow and rocky. The soils are suitable for the cultivation of both food crops (cassava, plantain, yam, cocoyam, maize) and cash crops (cashew, oil palm, citrus,) which are grown in the district. The land in this area is susceptible to wind erosion when the vegetation cover is removed. A combination of human activity, droughts and flooding events that occur in both districts have been cited as the cause of increased soil erosion. This has a negative effect on soil fertility and worsens the state of the limited road infrastructure in the district.

e. Relief and Drainage

The KAPND is generally undulating land which rises about 60 - 120 meters above sea level, with the only high ground in the Donkorkrom plateau. The district is drained by the Afram River in the west, the Volta Lake in the east and the Obosom River in the north which flow continually throughout the year and are used for both domestic and agricultural purposes. The KAPSD is also undulating, rising 60 - 120 meters above sea level, with Bonkrom the only elevated ground. The Afram River and the Volta River, which run continuously throughout the year and used for both domestic and agricultural purposes, drain the district to the south and east, respectively. There are also other intermittent streams in the area with underground water resources.

f. Vegetation and Climate

KAPND falls within the savannah vegetation zone, which is generally associated with a bimodal rainfall pattern; the major rainy season occurring in April-July and a minor from August-November (Profile KAPN 2016).

KAPSD also falls within the savannah vegetation zone, but also comprises the savannah transitional zone and savannah woodland, characterized by short deciduous trees and a ground flora of grass; it is also associated with two main rainfall seasons occurring in April and November, although the precise onset and cessation of the rainy season(s) varies across weather stations according to local precipitation.

Generally, the hottest months are February and March (36.8^0C and 36.6^0C respectively) while the coldest ones are December and January (19.9^0C and 20.1^0C). Relative humidity is generally high throughout the year, ranging between 68.2-71.6% in the dry season and 81.6-71.6% in the wet season (Profile KAPS, 2016).

Prior to the inundation of the Volta Lake, the Kwahu Afram Plains was a dense semi-deciduous forest area. The formation of the lake in the early 1960's witnessed major

changes in the population composition and structure of the area as well as the vegetation cover (APDO 2011). Present human activity continues to contribute to depletion of the vegetation. Key among these activities are charcoal production, wood logging, bush fires, clearing of land for agricultural purposes. The impact of climate variability on crop production has increased charcoal production as an alternative source of income. An increase in extreme climate events will exacerbate the use of coping mechanisms that will further deplete the vegetation and other ecological resources.

g. Water Resources

Towns in KAPND, such as Agordeke, Bruben and Suppom (Bridge Ano), are on the banks of large water bodies, like the Volta Lake, Afram River and Obosom River, which provides them with a plentiful natural water resource. These water resources also hold a huge potential for enhanced irrigation agriculture, fish farming, tourism (water sport) and water transport. More than half of the district's population depends on the Volta Lake and the Afram River for their source of drinking water and for domestic use, but these water bodies also carry debris and disease that can be harmful to the health of the people. The frequent reports of water borne related diseases is as a result of the unclean water sources. The district also has developed groundwater resources for water supply purposes, particularly in rural communities that are not served by pipe-borne water supply networks.

In KAPSD, the Volta Lake, Afram River, Obosom River are located within easy reach of various towns and their environs, particularly providing the major towns of Ekye-Amanfrom and Bridge Ano with natural water resources (District Profiles KAPS 2016). Droughts and heat events have been known to account for water scarcity for domestic and animal use for communities that rely on seasonal streams.

h. Oil and Gas

The districts are listed as having oil and gas deposit prospects (as part of the volta basin) and the Ghana National Petroleum Corporation (GNPC) has carried out a seismic survey to locate potential areas for commercial oil and gas drilling. Based on the Environmental Assessment Statement, the district has developed an Oil and Gas Plan (2019-2023) to address the environmental implications that are expected to arise. Exploration of this resource is yet to be undertaken. When this is fully exploited, it will have a significant effect on job creation (KAPS DMTDP 2019-2021). The two districts are already major migrant destinations and an increase in economic activity will attract more economic migrants to the location.

1.2.3 Population and Demography

a. **Demographic Characteristics**

The total population of the Kwahu Afram Plains North District is estimated at 127,117 (2019) people with interdental growth rate of 2.4 p.a. The growth of the population is mainly as a result of an increase in net migration and natural increase due to increase in fertility rate especially in the capital (Donkorkrom). The increase in net migration is as a result of the increase in economic activities which has made the district more attractive to people from the cities and other parts of the Country. The population is male dominated, the males represent 53% and the females constitute 47% according to the 2010 population census. The higher male population is because the district is a typical migrant destination. Most of the people in the district are migrants from the Kwahu South District, the Volta Region, Ashanti Region and Northern Ghana who were attracted to the area basically for employment in the agricultural sector. The increase in net migration to the district has both positive and negative consequences on the development of the district.

The district capital is gradually becoming an economic town due to the increase in economic activities such as the creation of new businesses to meet the increasing demands of the growing population. There has also been an increase in agricultural activities such as farming and animal rearing. The District has also become a preferred destination for hosting regional events. The population is scattered in about 280 towns, villages and hamlets spread over the 2341.3 sq. km land area. Majority of these Villages are on islands in the Volta Lake and its tributaries and can only be reached by boat or canoe. Owing to the widespread nature of the population, the district has a low population density of 48 persons per square kilometre. The district has only one urban settlement (Donkokrom) that has a population in excess of 12,000. (DMTDP 2018)

Using the growth rate of 3.2 from the 2010 Population and Housing Census data, the total population of the KAPS is projected at 144,889 (2019), consisting of 78,129 males (53.9%) and females 66,760 (46.1%). This gives a projected sex ratio of 117 males to every 100 females as against the regional ratio of 100 males to 96 females, representing a different situation from the national (95.2 males to 100 females) ratio. (DMTDP 2018)

Both districts are predominantly rural, based on the 2010 population and housing census, 75.4% and 86% of the population live in rural areas in the KAPS and KAPN respectively.

The table below provides a summary of the key demographic characteristics of the two districts.

Table 6 - Population Characteristics (2019)

DISTRICT	Population	M/F Ratio	Growth rate	Density 2014	Distribution
KAPS	144,889	53.9% m 46.1% f	3.2 p.a	37.4/sq. km	75.4% rural
KAPN	127,117	53% m 47% f	2.4 p.a	48.0/sq. km	86% rural

The growth of the population is mainly as a result of an increase in net migration and natural increase due to increase in fertility rate especially. Based on the 2010 population census, both districts have high total birth-rates, with KAPSD recording the highest rate for the entire region at 4.7. The KAPN district has a birth-rate of 4.2, the district with the lowest birth-rate in the region records a rate of 2.4. A high incidence of teenage pregnancies among young girls in the two districts has been determined as reason for the high fertility rates. Another unique trend in the demographic context of the two districts is the relatively high male population, which is actually a reverse of the male:female gender ratio nationally. The higher male population is due to the fact that the districts are typical migrant destinations mainly due to economic opportunities in the agriculture sector. Migrants constitute 32.1% of the population in KAPSD and 20.1% in KAPND.

Inter-regional regional migration is a key trend in both districts. Based on the 2010 population census, Ewes from the Volta region constitute 48.3% of migrants who were born outside the KAPS district and 32.9% for KAPND. Their migration to both districts was influenced by the inundation of their communities due to the construction of the Volta lake in 1962. Movement of people from the Northern part of the country to both districts is a strategy that is adopted to seek economic opportunities outside the unfavourable climatic conditions in their home regions. Migrants born outside Ghana represent 2.3% of the migrant population in KAPSD and 2.4% in KAPND.

b. Age and Sex Distribution

Both districts have a youthful population, the age group between 0-14 constitute 44.5% in KAPND and 26.8 in KAPSD. In KAPND 52.4%of the population is between 15-64 and 66.1% in KAPSD. These present opportunities for labour availability and need for provision of social services. Age dependency ratio is 91 for KAPND and 84.7 for KAPS.

The table over the page indicates the age and sex structure of the KAPN District. The trend for Kwahu Afram Plains South is similar.

Table 7 - Projected Age-Sex Distribution by Locality of Kwahu Afram Plains South District for 2017

Projected Population 2017				Projected Population 2021					Type of locality	
	Sex				Sex					
Age Group	Both Sexes	Male	Female	Age Group	Both Sexes	Male	Female	Sex ratio	Urban	Rural
All Ages	144,889	78,129	66,760	All Ages	164,674	88,798	75,876	117.0	40,467	124,207
0 – 4	23,590	12,125	11,465	0–4	26,811	13,781	13,031	105.8	5,975	20,836
5 – 9	20,384	10,564	9,820	5–9	23,167	12,007	11,161	107.6	5,408	17,760
10 – 14	17,684	10,025	7,659	10–14	20,099	11,394	8,705	130.9	5,393	14,706
15 – 19	14,048	8,153	5,895	15–19	15,966	9,266	6,700	138.3	4,878	11,088
20 – 24	11,607	5,948	5,660	20–24	13,192	6,760	6,433	105.1	3,623	9,570
25 – 29	11,175	5,737	5,437	25–29	12,701	6,520	6,179	105.5	3,064	9,637
30 – 34	9,787	5,096	4,692	30–34	11,123	5,792	5,333	108.6	2,838	8,285
35 – 39	8,685	4,621	4,063	35–39	9,871	5,252	4,618	113.7	2,389	7,482
40 – 44	7,441	3,982	3,459	40–44	8,457	4,526	3,931	115.1	1,833	6,625
45 – 49	6,073	3,472	2,601	45–49	6,902	3,946	2,956	133.5	1,534	5,368
50 – 54	4,759	2,787	1,972	50–54	5,409	3,168	2,241	141.3	1,225	4,184
55 – 59	2,709	1,611	1,097	55–59	3,079	1,831	1,247	146.9	652	2,425
60 – 64	2,167	1,267	900	60–64	2,463	2,463	1,023	240.8	563	1,899
65 – 69	1,151	726	425	65–69	1,308	825	483	170.8	276	1,032
70 – 74	1,566	866	701	70–74	1,780	984	797	123.5	355	1,426
75 – 79	933	548	385	75–79	1,060	623	438	142.3	186	874
80 – 84	569	281	288	80–84	647	319	327	97.6	143	503
85 – 89	334	184	150	85–89	380	209	170	122.7	68	311
90 – 94	154	91	63	90–94	175	103	72	144.4	35	140
95 – 99	73	44	29	95–99	83	50	33	151.7	27	56

Source: DPCU, KAPSDA, January 2021

c. Ethnicity and Religion

There are three main ethnic groups existing in the two districts. In KAPSD 66% of the population are Ewes, Dangbes constitute 11%, Northern tribes 13% and Akans 10%. In KAPND, the Ewes make up 51.3%, Northerners 40.1% and Akans 8.6%. This depicts the districts are both heterogeneous in terms of ethnicity. The Ewes are predominantly engaged in the fishing sector and also into crop production as a second income source, the Sissala's from Northern Ghana are mostly engaged in charcoal processing and other ethnics groups from Northern Ghana are into crop production. Nomadic cattle herding is carried out by Fulani herdsmen, some of whom have settled in the districts, but precise figures are not known, since they are nomadic. Both districts are predominantly Christian as they constitute 77.1% whilst the Muslims constitute 6.8% and the rest, which is 9.8 %, consists of traditionalists people

d. Gender Context

Contrary to what pertains in many locations in the country, the two Kwahu Afram Plains districts have the majority of the population being males. Based on population estimates for 2019, females constitute 46.1% and 47% for KAPSD and KAPND respectively. This trend is attributed to inter regional migration to the two districts. Most of the migrants are males, they leave their families in their home regions and send back remittances. Majority of households in both districts are male headed, from the 2010 population and housing census, 75.4% and 24.6% of households in KAPN were male and female headed respectively. The trend for KAPS is similar with 78.6% of households being male headed and 21.4% headed by women. Decision making in the male headed households is usually dominated by males while females contribute to the upkeep of the family including contributing to cater for feeding, education and health of the family.

Beyond the household level, there are gender disparities in participation in decision making at the community and district level. Based on a field survey by the KAPND, females constitute 20.1% of participants at community gatherings where community decisions are made and the rest 79.9% are males. At the district assembly level, a similar trend is reflected, in the KAPN district, there are six females out of a total of 45 district assembly members. In KAPSD, there are four females out of a total of 41 assembly members. To some extent, the differences in literacy levels is linked to the opportunity for people to take up such decision-making spaces. There is 8.2% difference in literacy rates in favour of men in KAPND and 0.8% difference in favour of men in KAPSD. A key contributing factor for limited educational attainment for girls is the high incidence of teenage pregnancy in the two districts, in 2019, KAPN recorded the highest teenage pregnancy rate in the Eastern Region. This often results in termination of girls' education with subsequent effects on other opportunities in life. Factors that have been linked to this phenomenon is the high incidence of poverty and the status of both districts as migrant destinations.

Statistics from both district assemblies indicate that males dominate in all key sectors of the economy except the commerce sector. In the agriculture sector, 65% of the people who are employed in that sector are male and 35% are female in both districts. Focus Group Discussions (FGDs) in both districts interrogated access to productive resources with both male and female farmers to determine the gendered differences. Due to the relatively low population density in both districts, both male and female farmers indicated

availability of land for agricultural purposes. Households usually have a family farm which is controlled by the male household head. The females take part in working on the family farm and take care of activities such as planting, fertiliser application, provision of water (eg. for agro chemical application), harvesting and marketing. The men play a major role in land preparation, agrochemical application and weeding. In addition to the family farm, females keep personal farms to serve as a source of income. This however comes with an additional labour burden for female farmers because they provide labour on both farms. The process for land acquisition is however more time consuming and expensive for female farmers because a female is required to have a male lead her through the process. The capital and labour requirements for preparing new ("virgin") agricultural lands are usually challenging for female farmers. Access to agricultural extension services is also limited for female farmers. All 24 agricultural extension agents in the two districts are male, this trend may limit women farmers' access to extension services, considering the fact that female extension agents are able to reach female farmers better. Female FGD respondents however reported having control over income that is made from their personal farms, most women cultivate vegetables, maize and legumes (groundnuts and cowpea).

The incidence of poverty among females is high, it is estimated that 70% of the people living in poverty in KAPND are females. Estimates over an 8-year period shows that the increase in the number of poor rural females in the district is 17% higher than the increase in the number of poor males. (DMTDP, KAPND, 2015). The workload burden is highest for females, about 66% of female's work in the two districts is unpaid work (domestic work; childcare, cooking, laundry, cleaning, collecting water and fuel etc) compared to 25% of the male's work. Females are paid 30-40% less than men for comparable work (DMTDP, KAPND, 2015).

1.2.4 Social Services/Issues

a. Literacy and Education

Kwahu Afram Plains North District has a total of One hundred and six (106) public Schools and twelve (12) private Schools. Out of the total number of public Schools in the District, Primary Schools constitute almost 74%. Junior High Schools are made up of 22% whilst Senior High Schools and Technical and Vocational institutions constitute 4%. These facilities accommodate about 16,342 students in public Schools and 1,390 students in private Schools. Overall, about 90% of the structures lack basic facilities such as staff common rooms, workshops, ICT centres, teachers' accommodation, libraries and wash facilities. Equally important to note is the fact that about 68% of the Schools especially at the basic level are in temporal structures such as sheds/mud and in open air (under trees). Pre-Schools have the highest number of structures in temporal structures (73%). (KAPN Composite Budget 2019-2022). There are 207 schools in the KAPS with 203 being basic, 52 being J.H.S, 2 being SHS, 2 institutions functioning as vocational schools and a Technical Institute. These educational facilities exist to train and equip the pupils to reach their maximum mental, physical and even emotional potentials. However, the increasing numbers in population without equal increase in institutions of learning has gradually led to pressure on these facilities. This creates a development gap in the attainment of high educational standards in the District. (KAPS DMTDP 2014-2017)

Based on 2010 population and housing census data, literacy rates for people from age 11 upwards is 59.5% for KAPND and 57.1% for KAPSD. This is lower than the national estimated figure of 74.1%. In KAPND, 63.4% and 55.2% of the male and female population respectively are literate. In KAPSD, 50.4% of the male and 49.6% of the female population are literate. These figures are equally lower than the national literacy rates of 82.2 % and 68.5% for males and females respectively. Studies have proven that literacy levels have a direct link with people's adaptive capacity. Literacy levels affect access to new technologies and information, livelihood resources and opportunities for livelihood diversification.

b. Health

The infrastructure for health delivery in KAPSD consists of one (1) hospital at Tease, three (3) health centres located at Ekye, Tease and Kwasi Fante and five (5)Community-based Health Planning Services (CHPS) compounds in communities. The District has a Doctor:Population ratio of 1:21,529 as against the national average of 1:25,000. The Nurse:Population ratio is also relatively unfavourable (1:1,435) as against the national figure of 1:900. Due to the inadequacy of health facilities within the settlements in the district, most of the people patronize health services outside the settlements in which they live. About 59.9% of the population patronize health facilities outside the settlement they live whilst the other 40.1% patronize health facilities within the settlement they live. (KAPSD MTDP 2014-2017)

The KAPS District has one (1) Hospital at Donkorkrom and 29 CHPS Compounds. The District Hospital has a 300- bed ward including emergency ward, X-ray Department, Theatre, Medical Laboratory, Pharmacy Department, Mortuary, Out-Patient Department, Eye Clinic, Dental Clinic and a modern state of art Maternity Block. The District has a Doctor:Population ratio of 1:30,000. The Nurse:Population ratio of 1:650. (KAPND Composite Budget 2019-2022)

c. Electricity supply

Power supply is frequently unstable with recurrent outages; this has consequences on the development of businesses in the district. About 75% of the supply is concentrated in the urban areas whilst the rural areas enjoy only 15% of the services. Large number of peri-urban and rural communities are yet to be connected to the national grid. (KAP North and South, DMTDP 2017).

1.2.5 Major Economic Activities and Livelihoods

The major economic activities in both districts involve the agricultural sector (e.g. Crop production, agro-processing activities, animal rearing, fishing and fish farming), the industrial sector (e.g. Household industries, handicrafts/traditional crafts, modern crafts, small/medium scale manufacturing), as well as services and commerce.

Table 8 - Economic Activities

District	Agriculture	Service	Commerce	Industry
KAPSD	77.2% (65m, 35f)	7.5% (65m, 35f)	5.3% (40m, 60f)	10% (70m, 30f)
KAPND	74.5% (65m, 35f)	11.5% (65m, 35f)	7.9% (40m, 60f)	6.1% (70m, 30f)

a. Agriculture Sector

From the 2017 to 2021 District Medium Term Development Plans of the two districts, the economies of both districts are predominantly agrarian, agriculture employs as high as 72percent of the labour force. In the rural localities, seven out of ten households (75.5%) are agricultural households while urban households who engage in agriculture constitute 55.9 percent. The high interest in agriculture in the district is largely attributed to the vast fertile and arable lands, water bodies and weather conditions which support fishing, animal rearing and farming activities.

Most of these farmers are engaged in subsistence farming, producing just enough to meet the needs of the household. Despite the high level of crop production, most households still find it difficult in accessing the right blend of food which will enhance a proper balance diet. Farming households usually sell a portion of what is cultivated to meet other pressing needs, this leaves them with inadequate reserves to meet the food security requirements of the family.

b. Industrial Sector

Most industries in the two districts can be classified under small and medium scale Industries. The industrial activities are diversified, ranging from sawmilling where some levels of technological equipment are used to handicrafts and other craftworks which are produced using simple tools. These industries can be grouped under the following:

Table 9 - Number Employed In Industry (Average for both districts)

Sub-Sector	Percentage
Household Industries	27.7
Handicrafts / Traditional Crafts	29.8
Modern Crafts	10.6
Small / Medium Scale Manufacturing	31.9
Total	100

Household Industries

In this industry, family labour is used with the objective of providing basic needs, and augmenting the family income. The production methods are labour intensive, and there is no division of labour. Activities undertaken include palm oil and palm kernel oil extraction, cassava processing and basket weaving. Cassava processing is the most organized household industry in the districts. Some producers have formed cooperatives where members process their raw materials for a fee. Some private individuals have also acquired processing plants. Most settlements have either cassava processing or palm/kernel oil extracting industry or both. While these household industries are supporting income generation, their impact on the environment in terms of waste generation and disposal should be considered to ensure the proper disposal of their waste. The production of raw

materials for these industries is dominated by male (70%) whilst the processing aspect is dominated by females (80%).

Handicrafts and Modern Crafts

Handicrafts are produced by craftsmen who normally work alone with a few apprentices without much division of labour. Traditional tools and implements are used with little modernization. Activities here include blacksmith, and wood carvers. Modern crafts include car repairing, radio and television technicians, auto mechanics, electrical / gas welders, and woodworking shops. These activities are scattered all over the districts with high concentration in Donkorkrom and Tease the District capitals. A good number of youth who have acquired the skill for these sectors but are still unemployed due to the lack of capital to start their own business.

Small / Medium Scale Manufacturing

This category is capital intensive, this sub-sector employs 31.9% (both districts) of the labour force in the industrial sector. These industries use modern production methods and produce both traditional and modern products. These industries include the following: Food processing; distilling and blending alcohol; Sawmill; and furniture and fixtures. Most of these industries are located in residential areas and other areas not zoned for industrial activities.

c. Service Sector

The service sector has become an integral part of the districts' economy. It is currently the second highest sector which contributes significantly to the growth of the local economy and employs almost 14% of the districts' active labour force. The service sub sector has further been divided into two – formal and informal sectors.The formal sector which employs 15% of the labour force in the service sector comprising activities which require some form of formal training or skill and have their operations registered. These include activities such as governance, teaching, nursing and among others. The informal sector on the other hand does not require any specialized skill and mostly operates without necessarily being registered.

d. Markets and marketing of agricultural products

Every economy depends on the availability of effective markets for the sale and purchase of products that are produced and required. A key component of an effective market is the provision of decent infrastructure that provides market security for users. The KAPN district has only one major market in Donkorkrom and three other smaller ones in Bruben, Supom and Fasso Battor where farmers sell their products. Market price of food crops depends largely on the time of selling the crops. The prices are usually low just after harvesting (August and September) but the price shot up as the lean season draws closer. The prices are at the peak just before the farming season starts, that is between March and April when farm produce is scarce. The price of the food crops is usually determined by the market women or the middlemen who come to the district to buy food stuff. The local farmers therefore do not control the price of the farm produce. They are always at the mercy of the market women and middlemen. The inadequacy of modern storage and processing facilities and market infrastructure reduces the power of farmers to influence

market prices hence making them price takers instead of price makers. As a strategy, farmers have decided to undertake bulk marketing, they hope to develop contractual relations with produce buyers such as second cycle institutions, hospitals and poultry farmers to enable them bargain for better terms and conditions.

Existing data from the district assembly indicates that 71% of crop farmers sell their produce within the Kwahu Afram Plains South District. Market outlets within the district include (Tease, Mama Krobo, Dome, Kwesi Fanti, Ekye Amanfrom) this serves as an incentive for drawing farmers to sell their produce in the district. This ready market also aids in the prevention of post-harvest losses which would have occurred as a result of absence of storage facilities in the district.

e. Access to credit

Financial accessibility by farmers is crucial to the development of agriculture in every agrarian economy. This is needed for the purchase of agricultural inputs for farming. Such inputs include agro-chemicals, hiring of labour and buying improved planting materials. In the Kwahu Afram Plains North District, a survey that was conducted in 2014 revealed that 85% of the farmers have no access to credit. This could be attributed to the lack of collateral, fear of taking loans, lack of information on available credit facilities, absence of cooperatives. Areas where the banks have been successful with loan disbursement are areas of group loan facilities. Farmers who do not have access to credit facilities or enough money to finance their farming activities will be compelled to produce on subsistence basis. Financial institutions that operate in the districts include the Afram Community Bank, Agricultural Development Bank and non-Bank financial institutions like Dalex Finance. During Focus Group Discussions, farmers revealed that access to credit to undertake any meaningful investment is only limited to the local arrangement from a few market women who give agro-input credit and receive payment in kind usually at exorbitant rates.

1.2.6 Irrigation in the Afram Plains

a. **Current Practices**

“Agriculture is often misconstrued to be rainfall dependent; agriculture is water dependent and any form of investment in permanent water for agricultural purposes will enhance all year-round farming”- Moses Banfo, Director of Agriculture, Kwahu Afram Plains South District, Field Survey Data, June 2021.

Currently, the farmers in the plains practice one cropping season ranging between May and October/November each year with intermittent dry spells. This has drastically affected farm households which depend on agriculture for living. Irrigation farming is undertaken by farmers in order to sustain crop production under a water stress situation.

Draw-down Irrigation system – A practice where farmers access croplands close/ along the lake to undertake second (2nd) cropping between the months of November/December and February/March. This practice as the name suggests entails using the residual moisture of the water from the lake as the water draws back/resides with time during the dry season. During the rainy season, most farmlands along the lake are submerged but begin to recede when the rains cease in November. Crops mostly cultivated are; rice, vegetables (okro, pepper, tomatoes, among others). The farmers practice a system of

supplementary irrigation using the water pumping machines. This is usually the case due to inadequate moisture to support full maturity of the crops cultivated. Two out of the six sampled communities for this survey (Amankwa Tornu and Mem-Chemfre) are engaged in this system of irrigation.

This system of irrigation is considered informal because the farmer groups use infrastructure for water storage, conveyance and distribution provided from their own resources or with some external support other than the government. Currently about 500 acres of land under irrigation in ten (10) communities on okro, hot pepper and green pepper. (KAPND Agriculture Annual report 2019)

The majority of farmers who are currently engaged in irrigation are men; women's participation is constrained by the high capital investments require, for example for purchasing water pumps. The district departments of Agriculture and other stakeholders recognize the important role this irrigation system plays in sustaining production and incomes. Farmer groups involved in irrigation farming have therefore been supported through training on appropriate agronomic practices and provision of water pumping machines and other machinery. Both men and women farmers involved in the practice call for support with water pumps as most of them are unable to acquire them individually.

b. **Prospects for Irrigation development**

Based on the current changes observed in the pattern of rainfall, farmers consider alternative options of ensuring water availability is required to sustain their livelihoods. The prospect of farming along the shores of the volta lake is uncertain. The future of these systems (draw-down irrigation) is bleak given the recent policy debate regarding buffer zones, which intends to prohibit irrigation within a 50 m reach from a water body. (Regassa E. Namara et al., 2010). Farmers and stakeholders who were consulted during this study recommend the following in exploring options for ensuring water availability for farming:

- The topmost consideration should be aimed at water conservation measures to ensure that dry season farming within the plains is carried out uninterrupted. This should be complemented with a climate resilient cropping system.
- Promote harvesting of the excess rainwater which may require creating receptacles to hold the volumes of excess water during the rainy season. This could be linked to the one-district-one-dam initiative.
- Planting of trees (afforestation) and agroforestry aimed at retaining water in the soils over long periods.
- Develop climate-resilient cropping and livestock systems as well as crop varieties tolerant to flooding and drought.

1.2.7 Land Ownership in Ghana

Land ownership may be classified into two categories, namely, state or public land and customary or private land. Article 257 of the 1992 Constitution recognizes the following as customary or private owners – stools/skins, families, clans and individuals. These constitute 78 per cent of the total land area compared to 20% of land vested in the state for which compensation has been paid, and 2% vested in the President on behalf of the stools/skins, families and clans. It has been pointed out that the co-existence of customary

land tenure systems with formal legislation creates uncertainty in the administration of land rights. (Kasanga and Kotey, 2001).

Legally, there are five title categories regarding customary land, namely allodial, freehold, customary freehold title, leasehold, and others, such as sharecropping. Allodial title is held in trust with the family head and considered the highest form of land ownership. If an allodial rights holder gives or sells land, it is called freehold title. Most common in urban areas, the parties involved may agree that land tenure moves from customary to common law. Customary freehold title refers to tenure rights somebody holds on behalf of the stool or skin. Going back to the idea that the descendants of the first settlers have the right to use some of the stool land, if they cultivate it, these rights are conditional and indefinite. (https://landportal.org/book/narratives/2021/ghana)

a. Formal and Informal Land Sector Agencies

Public land is allocated through the Lands Commission or Regional Lands Officer. Under customary rule, land holders may sell, lease, mortgage or pledge their rights. However, the new owners must recognize the ownership of the stool or skin and agree to deliver any customary services. In addition, allodial and freehold title holders may lease land to individuals for a certain period of time for an annual rent. According to the constitution, foreigners are not allowed to own land but limits them to leaseholds of maximum 50 years. (https://landportal.org/book/narratives/2021/ghana)

One of the principal obstacles identified by the 1999 National Land Policy is the lack of effective coordination, consultation and cooperation among the land sector agencies. There is a maze of “formal” and “informal” institutions. The formal institutions are those which either have primary responsibility for land or are called upon to deal with land issues and disputes. The informal agencies refer to those agencies that have an indirect responsibility for dealing with land issues and disputes. The multiplicity of land agencies engaged in different but complementary processes regarding a single land transaction has led to the growth of centralized and bureaucratic structures, particularly in the collection of stool land revenue, transfers of customary land, title registration and planning control (Aryeetey et.al., 2007).

Table 10 - Land Sector Formal and Informal Agencies

Formal	Informal
i) Ministry of Lands and Natural Resources ii) Lands Commission iii) Survey Department iv) Land Title Registry v) Department of Town and Country Planning vi) Stool Land Administrator vii) Land Valuation Board viii) Land Administration Project Unit ix) Forestry Commission x) Regional Coordinating Councils xi) District Assemblies xii) Regional Lands Commission xiii) Stool Land Boundary Settlement Commission xiv) Joint Border Commissions and Minerals Commission	i) National House of Chiefs/Regional House of Chiefs/Traditional Councils/Individual Chiefs ii) Ghana Institute of Surveyors iii) Ghana Real Estate Developers Association iv) The Judiciary v) Ghana Bar Association vi) Environmental Protection Agency vii) National Association of Farmers and Fishermen viii) Ministry of Food and Agriculture ix) Commission for Human Rights and Administrative Justice

Source: Aryeetey et.al. 2007: 67

There have been several reforms aimed at rationalizing the agencies and enhancing the land administration and management systems; these efforts include the implementation of the Land Administration Project between 2004 and 2018. In 2020, a new land bill was adopted, the bill aims to consolidate and harmonize the 166 existing land-related laws in Ghana, regulate land use and acquisition and enhance effective land management.

b. Kwahu Afram Plains Land ownership

The Kwahu have been recognized as the traditional landowners of the Afram Plains which for a long time served as the hunting reserve for their chiefs who live on the Kwahu Plateau to the west of the plains. As a result, the Afram Plains remained virtually unpopulated until the 1920-30 when cocoa had become an important economic crop (Wallis 1953:24), and even then it was the forested patches of the plains that attracted the settlements (Boateng 1955: 161).

The construction of the Volta Lake in 1964 necessitated the relocation of an estimated 80,000 people from 740 villages along the banks of the Volta River into 52 government-sponsored townships (Lisa Westerhoff & Barry Smit, 2008). The Afram Plains is therefore inhabited by Kwahu's (indigenes) and Ewe (Settlers), with time people from other parts of the country migrated to the Plains mainly to seek opportunities in the agricultural sector. Generally, there are tensions among some groups with regard to access to land, land ownership and grazing land for herdsmen. Disputes have been between natives and settlers, chiefs and settlers, herdsmen and farmers and in a few cases, chiefs and chiefs Aryeetey et.al., 2011).

Land in the Kwahu Afram Plains is owned by the chiefs, clan or family heads who hold them in trust for their subjects. However, individuals also hold or acquire lands through direct purchase, rent, leasehold, sharecropping (Nnoboa) and gift. The fact that parcels of land can be inherited through parents or grandparents has led to problems of sale and resale of land with its attendant land litigations and chieftaincy disputes. This situation has also contributed to the rapid loss of farmlands with its attendant unemployment rate and subsequent migration. Land is vital in the development of agriculture and measures put in place to ensure effective administration of land resources go a long way to ensure agricultural development of a particular area.

Interactions with farmers, traditional leaders and stakeholders as part of this survey revealed that there are currently no existing conflicts in the proposed sites for the project except in Amankwa Turno in KAPN where some disagreements between the different chiefs in the community has resulted in a delay in receiving resettlement claims from the Volta River Authority.

There are two main form of tenure system in the Kwahu Afram Plains North district. The two systems are namely the sharecropping system and the sole proprietorship. In the sharecropping are the "Abunu and Abusa" systems. In the Abunu system the produce is shared equally between the farmer and the landowner or the financial sponsor of the production. In the Abusa system the proceeds from the farm are shared two thirds in favour of the farmer. But the most widely practised system in the district is the sole proprietorship. (Survey Data, June 2021)

Table 11 - Land ownership in the Kwahu Afram Plains Districts

Source	Percentage (%)
Long Lease (bought)	17.4
Lease	32.4
Inherited	21.7
Shared Family Property	12.4
Doma Yen Kye (Sharecropping)	1.8
Gift	14.3
Total	**100.0**

Source: Survey Data, June 2021

The table below presents land lease options in the 13 proposed sites for the project.

Table 12 - Land Lease options in proposed project sites

District	KAPSD
Location	**Lease Option**
Tease	Long term lease (> 10yrs. Traditional Authority-Nkwatia/Pitiko
Asukese	Long term lease (> 10yrs. Nkwatia and Abetifi Stool Land
Semenyia	Long term lease (> 10yrs
Faaso Krachi	Long term lease (> 10yrs. Nkwatia and Abetifi Stool Land
Forifori	Long term lease (> 10yrs.
Asayan	Long term lease (> 10yrs
Somsei	Long term lease (> 10yrs

District	KAPND
Location	**Lease Option**
Amankwa Turnu I	Long term lease (> 10yrs) Government(VRA) resettlement land.
Salepe-Awonakope	Long term lease (> 10yrs) Government(VRA) resettlement land.
Kamalo	Long term lease (> 10yrs) Nkwatia stool lands
Chemfre 1	Long term lease (> 10yrs) Government(VRA) resettlement land
Chemfre 2	Long term lease (> 10yrs) Government(VRA) resettlement land/ portion of the land is commercial land.
Kayera	Long term lease (> 10yrs) Nkwatia stool lands

c. Land; Gender and Emerging Trends

According to the constitution, women and men enjoy equal rights in accessing property. In practice, only 10%are female landholders and women have only secondary access to land through their spouses, sons or brothers. In patrilineal families, land is passed from father to son and from maternal uncles to their nephews in matrilineal communities, and as such, always remaining in male hands. For women it is thus highly important to maintain good relations with their male relatives. Under customary law the – usually male - family head is considered the custodian of the land. In addition, traditional gender norms and wide-spread discrimination limit the women's participation in public life and politics, including lineage, clan or stool meetings where most land-related decisions are made (https://landportal.org/book/narratives/2021/ghana).

The situation of women's access to land in the Afram Plains is not different from the general context described above. During FGDs, it was revealed that when women require lands for farming or investing in business, they rely on the men in their houses and where there are no men, they have to consult with another male relative to lead in the process. This results in delays and increases the cost of acquiring land for farming by women. It is recommended that land as a basic input for agriculture should be accessible to both men and women.

A key emerging trend related to land access that was highlighted by participants of this study is the increasing acquisition of large tracts of land (land grabbing) for agriculture, logging and other commercial activities. They indicate that a significant proportion of the citizens in the Afram Plains are migrants including some community chiefs. Investors showing interest in farmlands most often are given these lands without consideration of the present users of the land. The chiefs who are the custodians of the lands under the Kwahu stool lands superintend over these lands without any consultation with the community chiefs who live with the small-scale farmers in the districts. The situation is worsened by landowners who do not live in the catchment area, they sell or release land to prospecting investors without adequate notification of present users of the land. Farmers indicate that such land "grabbing" activities lead to displacement of smallholder farmers without adequate support or relocation.

1.3 Identified Sites

The assignment envisaged developments at 12 scheme locations across the project area, each 80-100 ha, and a list of potential sites was provided during the inception stage (Ref. Appendix 7, Inception Report, Deliverable 1). Initial consultations with the Agricultural Directors in the two districts had identified 24 potential sites for initial assessment (See Figure 5 below), which were visited and ranked according to selection criteria. This criteria ranked the sites based on the following considerations (Ref. Reconnaissance Survey in the Inception Report).

i) Local distribution within the area (to ensure district balance)

ii) Natural conditions (topography, soils, hydrology)

iii) Technical aspects (road network, accessibility, ease of construction, etc)

iv) Socio-Economic aspects (Willingness, existence of groups)

v) Agronomic aspects (state of land use, experience in irrigation)

vi) Marketing aspects

vii) Infrastructure aspects

Points were assigned to the various criteria for each site and ranked (details are outlined in the Reconnaissance Survey in the Inception Report). The final list of sites for detailed investigations is provided in the Table 13 below and indicates the most likely source of water to be proposed. These sites met the minimum requirements, notwithstanding a lack of soil and geology data required for detailed investigation and design. Additional site data would be required to ensure proper design of infrastructure and in the event that existing soil and geology data is inadequate, or expensive and time consuming to collect, appropriate designs may be developed on remedial or alternative engineering options.

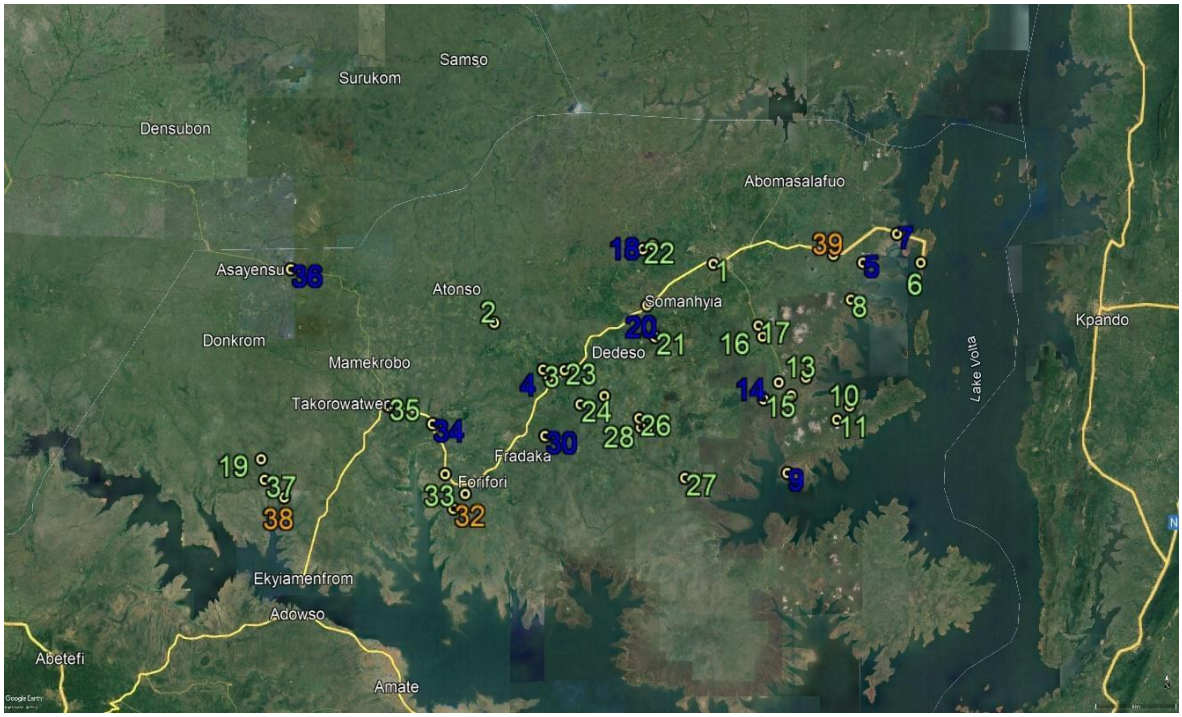


Figure 5 - Selection of Potential Sites for Project Developments

Table 13 - Selected Sites per District

Recommended Site	Site Assessment Score (Max 100)	Proposed Source of Water
Kwahu Afram Plains North (KAPND)		
Amankwa Tornu II (No.5)	75	Dugout / Pumping
Bruben (No.9)	71	Dugout / Pumping
Amankwa Tornu I (No.5)	71	Dugout / Pumping
Mem Chemfere 1 (No.14)	67.5	Dam
Mem Chemfere 2 (No.14)	66	Dugout / Dam
Teacherkope (No.7)	62	Dugout / Pumping
Kwahu Afram Plains South District (KAPSD)		
Forifori (No.33)	71	Dugout / Dam
Tease (No.4)	70	Dugout / Dam
Asayan/Asenyan Stream (No.36)	66	Dam
Semanhyia (No.20)	64.5	Dam / Dugout
Asukese/Asukesu II (No. 34)	60.5	Dam
Somsei (No.18)	58.5	Dam
Ata ne Ata (No.30)	58.5	Dam

2 APPROACH AND METHODOLOGY

2.1 Theoretical Framework and Concepts

The Intergovernmental Panel on Climate Change (IPCC, 2001 WG II) defines vulnerability as 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes'. Per this definition, vulnerability is a function of three factors which are exposure, sensitivity, and adaptive capacity. Exposure in AR4 is the magnitude and duration of the climate-related stress; sensitivity is the degree to which the system is affected by the climate related stress or extreme events; adaptive capacity refers to the system's ability to withstand or recover from the extreme events/damage. This definition is illustrated in the figure below.

Vulnerability can be measured using either a model-based approach (analysing impacts and mapping hotspots of affected subregions based on key issues of regional concern) or an indicator-based approach (using social, economic and environmental indicators). Analysis in the latter option is based on an examination of historical trends, a solid understanding of existing institutions affecting the current state of socio-economic development, and insight into local community responsiveness and resilience to external pressures (ESCWA, 2011); in this study, a model-based approach was used, supported by participative studies and socio-economic analysis to contextualise the findings.

Figure 6 shows the inter-play among the various aspects of the vulnerability assessment study. The climate variability and change analysis is directly related to hydrology (surface and ground water resources), agriculture (mainly agronomy) and socio-economic trends. The broken line also links to livestock, an aspect that was not initially incorporated in the assignment, but was added during the inception stage.

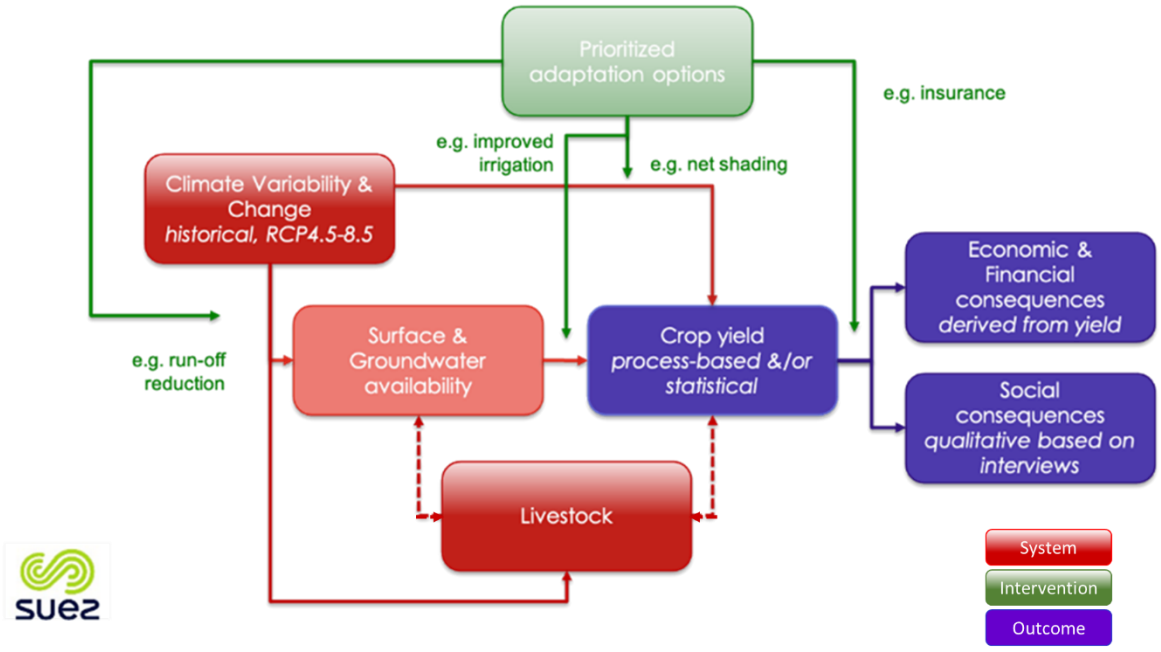


Figure 6 - Vulnerability Assessment Approach

These three aspects of the System impact on agriculture in the KAP as changes in crop yields, which have economic and financial consequences and social outcomes. The study's

approach modelled the statistical impacts on crop yields, deriving the financial and economic impacts from these changes, and assessed the social consequences based on qualitative analysis of stakeholder interviews.

2.2 Data Collection and Analysis

The following section details the study's approaches for data collection and analysis for each of the key sectors, with the summarised results provided in the following chapters. The full detailed analyses for each of these sectors are provided in separate reports, as follows:

- Climate Analysis
- Water Resources
- Agronomy and Livestock
- Socio-economics.

Following the Inception Workshop, held in April 2021, further meetings to consult with the key stakeholders continued through the subsequent data collection activities, to support the analysis, with minutes of these meetings and workshops recorded.

2.2.1 Climate Analysis

The climate analysis (Chapter 3) is based on the three meteorological variables of temperature, precipitation and wind, and related indices of trends and extremes. Past and present-day climatic conditions are explored using station observation data from the Ghana Meteorological Agency (Gmet), interviews from the field missions. The meteorological stations used are Donkorkrom (representing Kwahu Afram Plains North District, KAPND), Forifori (representing Kwahu Afram Plains South District, KAPSD) and two stations outside the KAP, but within the Kwahu area (The two stations are Abetifi, a hilly area, and Nkawkaw).

Projections rely on the Coordinated Downscaling Experiment (CORDEX):RCMs were driven by Global Climate Models (GCMs) from the fifth version of the Coupled Model Intercomparison Project (CMIP5). The RCMs are CCCCma-CanESM2 CanRCM4; ICHEC-EC-EARTH RACMO22T; MOHC-HadGEM2-ES RACMOT22T and CSIRO-QCCCE-CSIRO-Mk3 RCA4. The GCMs used are CanESM2, CSIRO-Mk3, EC-EARTH. Regarding the climate change projections, the two scenarios used in the study were the RCP 8.5 (high warming scenario) and RCP 4.5 (medium warming scenario). The reference period used is 1979-2008, near future is 2006-2035, mid-century is 2036-2065 and end of the 21st century is 2066-2095. In line with WMO recommendations, the periods are 30 years long. Both present-day and projections are analysed using a daily time-step.

The Table 14 below presents the parameters and sub-parameters analysed in this study and their respective sources and time periods.

Table 14 - Summary of Parameters Analysed, Sources and Time Periods

Parameter	Sub-parameter	Time period	Data source
Precipitation	Seasonal Rainfall	Historical: 1980-2020 Reference period: 1979-2008. Current and future period: 2006-2035; 2036-2065 and 2066-2095	Gmet weather stations and Regional Climate Model data Bias-corrected RCM ensemble in RCP4.5 & 8.5 scenarios
	Extreme wet events (R95pTOT)		
	Consecutive Dry Days (CDD)		
Temperature	Season mean temperature		
	Heat extremes (Tx90p)		
	Warm nights (Tn90p)		
Wind	Extreme wind speed (above 95th percentile)		

Full details of the climate change analysis and results can be found in the Climate Analysis Report.

2.2.2 Water Resources

The full details of the hydrological analysis can be found in the Water Resources Assessment Report, which was intended to be based on the collection and analyses of historical streamflow data, to estimate the effects of climate change on future flows, and assist with the selection of adaptation measures to ensure sustainable use of the water resources in the two KAP Districts. However, since no historical streamflow data was available for rivers in the KAP, the surface runoff capacity of the catchments to support agriculture has been estimated based on data from the Afram River, an adjacent catchment with similar characteristics. This was used to estimate flows for selected streams in the KAP according to the rational method, a relationship between the catchment runoff (Q, m^3/s), the runoff coefficient or specific yield (S, $m^3/s/km^2$) and the catchment area (A, km^2). Rainfall in the Afram River catchment is most closely represented by two rainfall stations, at Aframso and Ejura; data from which was used to estimate the runoff coefficient and translate the flows to the KAP catchments.

The impacts of climate change and the vulnerabilities of the water resources in the Kwahu Afram Plains are described in Section 4.1.

2.2.3 Agriculture

a. Agronomic studies

Full details of the Agronomic studies and analysis are covered in the Agronomy and Livestock Report and are based on the analysis of secondary data and information from existing reports (both published and unpublished) and media, through internet searches and provision of documents by the beneficiaries and stakeholders. This was supported by primary data collected and collated from site identification surveys conducted in May, 2021 and agronomic surveys in June, 2021. The agronomic survey was mainly undertaken by focus group discussions and semi-structured interviews with 10 farmer groups, each group of 10 farmers, randomly selected at each selected site; in all about 100 farmers were

involved in the group interviews, though other enthusiastic farmers also participated as onlookers.

The analysis of information and data collated focused on the climate change vulnerability assessment, based on the present agricultural conditions in the KAP and at the selected sites. The analysis also included crop selection approaches and climate change and crop vulnerability assessments using the Climate Adaptation in Rural Development (CARD)[3] assessment tool, based on on the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) Fast Track output, to access peer-reviewed modelling results for crop yields under climate change scenarios.

b. Livestock studies

Eleven communities, five in the KAPND and six in the KAPSD, were selected for the study, and livestock farmers and other actors in the value chain were identified with the help of the District Livestock Officers to take part in interviews. Rapid Rural Appraisal techniques were used to collect data for the study, including techniques such as observation, key informant interviews and group discussions. Available literature was also reviewed to generate information on the issues related to the study objectives. Subsequently, the perceptions of severity of climate change effects and vulnerability matrix assessment were adapted to elicit respondents' perspectives on future climate change.

Full details of the livestock studies methodology and results can be found in the Agronomy and Livestock Report, while the impacts of climate change and the vulnerabilities of livestock in the Kwahu Afram Plains are described in Section 4.3.

2.2.4 Socio-economic surveys

The socio-economic survey was conducted through mainly qualitative methodologies and from a mix of primary and secondary data sources. The survey employed a range of participatory methods for data collection, analysis and interpretation. Desk research involved the review of key documents related to Kwahu Afram Plains North and South District Assemblies' Medium Term Development Plans (2017-2021), agricultural profiles of the two districts, Afram Plains Development Organization's impeccable agricultural work spanning over 30 years, policy documents, published and unpublished documents sourced online about key socio-economic trends and practices in the KAP. As part of primary data collection, a total of 12 Focus Group Discussions (FGDs), were held in six different villages/communities (three in the north district and three in the south district) with separate groups for men and for women. Each FGD group was composed of 12 participants, as per standard FGD practices. A gendered approach was used to explore the dynamics of gender relations, shifts in gender relations, drivers of gender disparities in project's impacts. To add insight, in-depth interviews were conducted amongst key informants, consisting of technical personnel engaged in agriculture, land use planning, gender, those engaged in innovative approaches in rural development and traditional leaders.

[3] The original version of the tool was developed by the West and Central Africa Division of the International Fund for Agricultural Development (IFAD).
https://www.ifad.org/en/web/knowledge/-/publication/climate-adaptation-in-rural-development-card-assessment-tool

Full details of the socio-economic survey methodology and results can be found in the Socio-economics Report and the impacts of climate change and the socio-economic vulnerabilities in the Kwahu Afram Plains are described in Section 4.3.

3 CLIMATE ANALYSIS

3.1 Present Day Climate

This section introduces the results from the analysis of the data from the four weather stations provided by Gmet. The periods studied are in the near future (2006-2035), mid-century (2036-2065) and for the end of the 21st century (2066-2095) and are compared to the reference period (1979-2008). The analysis provides: current mean temperature and precipitation for the dry and rainy seasons (where relevant) and annually as well as recent changes in temperature, precipitation, heat extremes (TX90p), extreme wet events (R95pTOT) and consecutive dry days (CDD).

Figure 7 - Locations of Meteorological Stations

3.1.1 Temperature

The seasonal mean temperature anomalies have been predominantly positive throughout the last decades over Forifori and Nkawkaw since the 1980s until now. This is indicative of the prevailing heat in the Plains induced by climate change globally and potentially aggravated by deforestation in the area. The missing data in the Donkorkrom data does not enable a reasonable inference to be made. The mean seasonal temperature for Nkawkaw is the lowest among the three stations (Table 15).

Figure 8 provides the deviation from the mean period seasonal temperature at two stations in the Kwahu Afram Plains (Donkorkrom for the North District and Forifori for the South District) and two other stations outside the plains but in the Kwahu area (Abetifi and Nkawkaw); the plots are for the Dry and Rainy seasons.

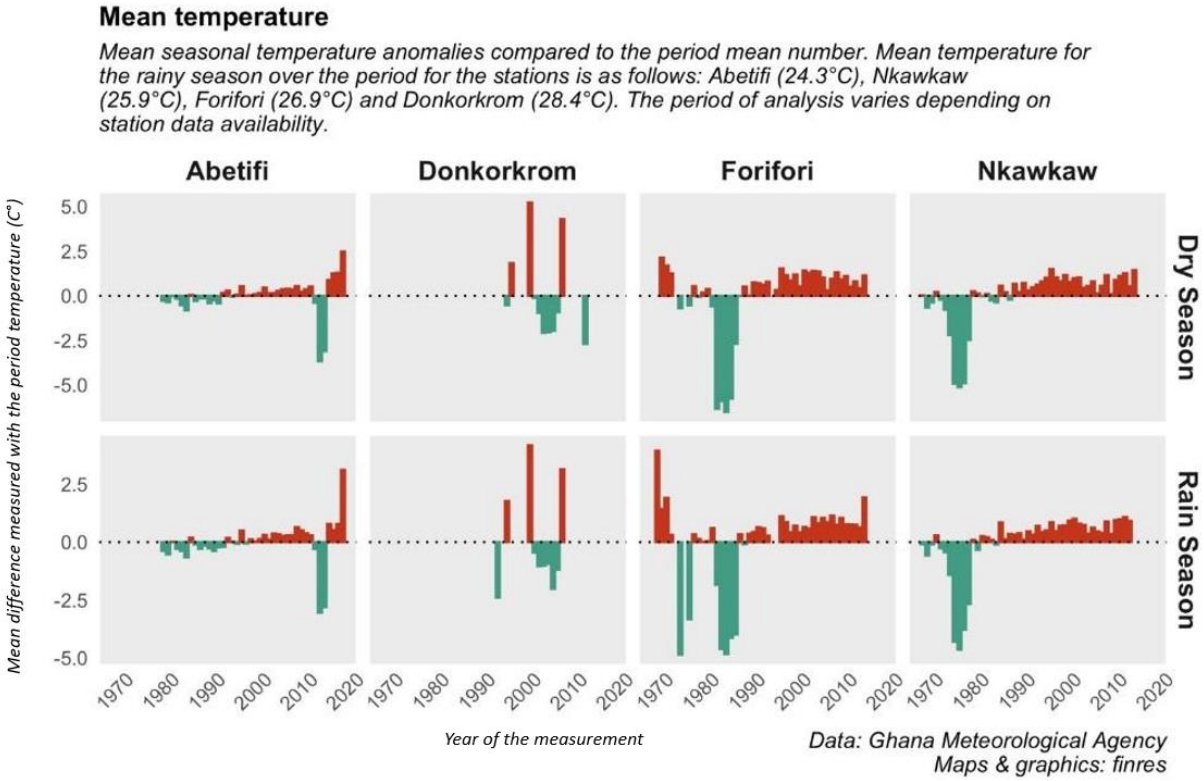


Figure 8 - Deviation from the Mean Seasonal Temperature (C°)

Table 15 summarises the mean seasonal temperature over the 1970-2020 period at Abetifi, Donkorkrom, Forifori and Nkawkaw meteorological stations.

Table 15 - Mean Seasonal Temperature over the Period 1970-2020

Station	**Mean temperature**	
	Rainy Seasons (April-October)	**Dry Season** (November to March)
Abetifi	24.3°C	25.0°C
Donkorkrom	28.4°C	30.3°C
Forifori	26.9°C	27.5°C
Nkawkaw	25.9°C	26.9°C

3.1.2 Precipitation

Precipitation in the Afram Plains generally follows a bimodal pattern, with the major rainy season starting by the month of April until July and the minor season from mid or late August to November. The onset of the rainy season is inferred using a method developed by Dunning et al., (2016). Therefore, the average onset and cessation of the rainy season(s) vary across weather stations according to local precipitation.

Figure 9 presents the mean daily precipitation (mm/day) for the 1970-2020 period at two stations in the Kwahu Afram Plains (Donkorkrom for the North District and Forifori for the

South District) and two other stations outside the plains, but in the Kwahu area (Abetifi and Nkawkaw). The bimodal nature of rainfall in the Kwahu area (KAP and vicinity) is well captured in the figure.

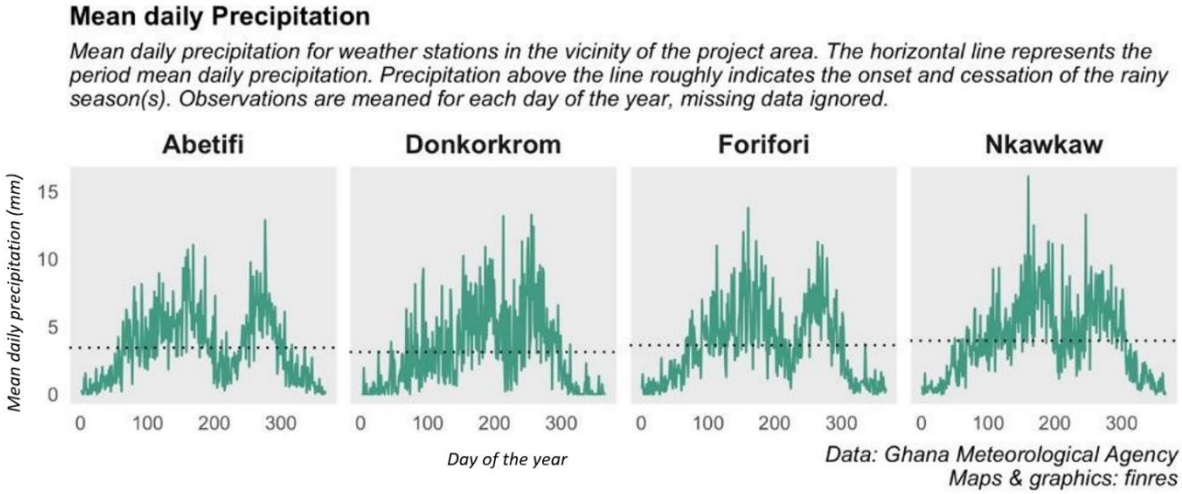


Figure 9 - Mean Daily Precipitation (mm/day) for the 1970-2020 Period

Table 16 presents the mean seasonal precipitation over the 1970-2020 period at Abetifi, Donkorkrom, Forifori and Nkawkaw meteorological stations. The data at the Abetifi station indicates total precipitation in the major rainy season is about 894 mm and falls to about 310 mm in the dry season. The figures for the three other stations are less reliable due to many gaps in the data.

Table 16 - Mean Seasonal Precipitation over the 1970-2020 Period

Station	Mean seasonal precipitation	
	Rainy Season (April-October)	Dry Season (November to March)
Abetifi	894 mm	310 mm
Donkorkrom	768 mm	125 mm
Forifori	1009 mm	221 mm
Nkawkaw	1039 mm	259 mm

For Abetifi, it is possible to distinguish a slight increase in the number of consecutive dry days over the rainy seasons between the 1970s and present-day. Again, for the other stations, precise inference is limited due to data availability.

3.2 Future Climate

This section focuses on the KAP and provides modelled results for temperature (seasonal trends and hazards), precipitation (seasonal trends and hazards) as well as the frequency of extreme wind speed. The timeframe of the analysis ranges from 2006 to 2095 with three periods of 30 years, not overlapping. Focusing more precisely on the Afram Plains, where

the investment is considered, it is observed that both trends and hazards related to temperature, precipitation and exposure to extreme wind events are projected to evolve in the future as a consequence of climate change.

3.2.1 Temperature

Temperature in the project area in the future mid-century period (2036-2065) is projected to increase by 1.31°C (RCP4.5) and 1.56°C (RCP8.5) compared to temperatures observed in the reference period (1979-2008). The most exposed places of the project area could face mean warming of up to 1.57°C and 2.02°C in the RCP4.5 and 8.5 scenarios, respectively. Figure 10 shows the seasonal temperature change (°C) under the high-warming scenario (RCP 8.5) for the dry season and rainy season during the 2020s, 2050s and 2080s (Data from the CORDEX database).

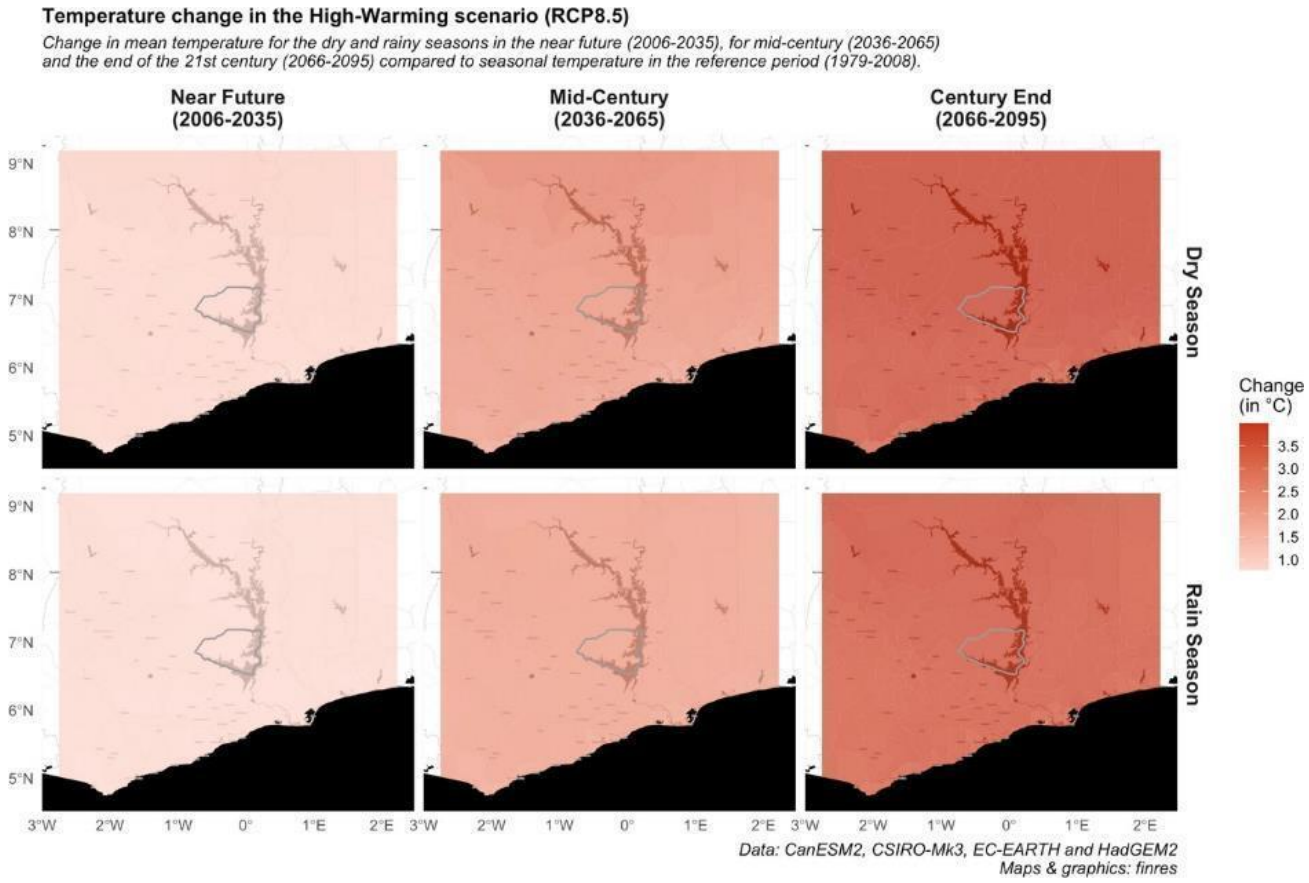


Figure 10 - Seasonal Temperature Change (C°) under the High-Warming Scenario (RCP8.5)

The seasonal temperature increases from the near future through mid-century to the end of the century (Figure 10). In terms of temperature, two types of hazards were analyzed: the frequency of warm days and nights.

- For the frequency of warm days (WMO-recommended TX90p), it is observed that these could increase by 86.4% and 104% on average in the project area, in the RCP4.5 and 8.5 scenarios, respectively.

- In relation with warm nights (WMO-recommended TN90p), a similar trend is observed, with a projected increase in their frequency. On average, an increase of 171 nights and 234 nights is expected for the mid-century (2036-2065).

3.2.2 Precipitation

In the mid-century (2036-2065), the multi-model and project area mean precipitation in the rainy season (period) is projected to increase across both districts by 2.8% (RCP4.5) and 4.1% (RCP8.5) compared to precipitation in the same season observed in the reference period (1979-2008). Figure 11 shows the percentage change in seasonal precipitation under the high-warming scenario (RCP 8.5) for the dry season and rainy season during the 2020s, 2050s and 2080s (data from the CORDEX database).

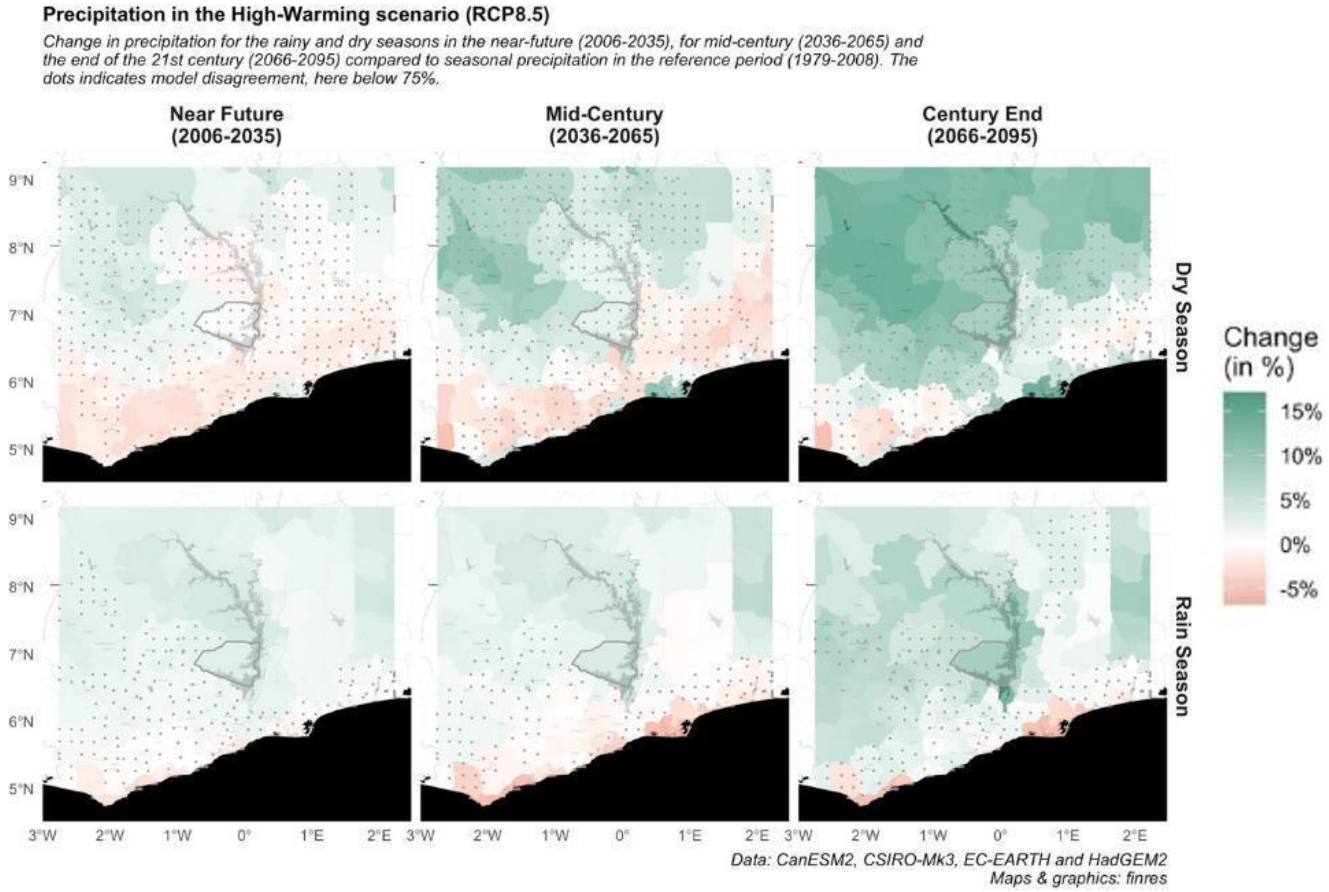


Figure 11 - Percentage Change in Seasonal Precipitation under the High-Warming Scenario (RCP 8.5)

The percentage change in seasonal precipitation shows an increase over the northern part of the domain and a decrease over the southern part (Figure 11). This is indicative of the local factors modifying climate change differently in the north and south. The magnitude of the increase over the northern sector is up to 15% during the dry season by the end of the century.

Two types of hazards are essential to analyse when it comes to precipitation: the number of consecutive dry days in the rainy season and the frequency of extreme wet events.

- For the number of consecutive dry days (WMO CDD), it is observed that these could decrease by 21 days (both scenarios) on average in the project area per year.
- In relation with extreme wet events (WMO R95pTOT), a different trend is observed, with a projected increase in their occurrence. On average, an increase of 1 day (RCP4.5) and 2 days (RCP8.5) is measured across models. The most significant increase in extreme wet events could range from about 1.5 to 2 days (RCP4.5 and 8.5 scenarios, respectively).

3.2.3 Wind

By mid-century (2036-2065), the multi-model mean number of days per year to which the project area is exposed to high wind speed is projected to decrease by -2.5 days (RCP4.5) and -2.9 days (RCP8.5) compared to daily wind speed measured in the reference period (1979-2008). The highest change according to climate models projects an average increase of 1.9 days (RCP4.5) and 4 days in the high-warming scenario. Figure 12 shows the seasonal change in the frequency of days exposed to wind speed above the 95th percentile of the reference period distribution under the high-warming scenario (RCP 8.5) for the 2020s, 2050s and 2080s (Data from the CORDEX database).

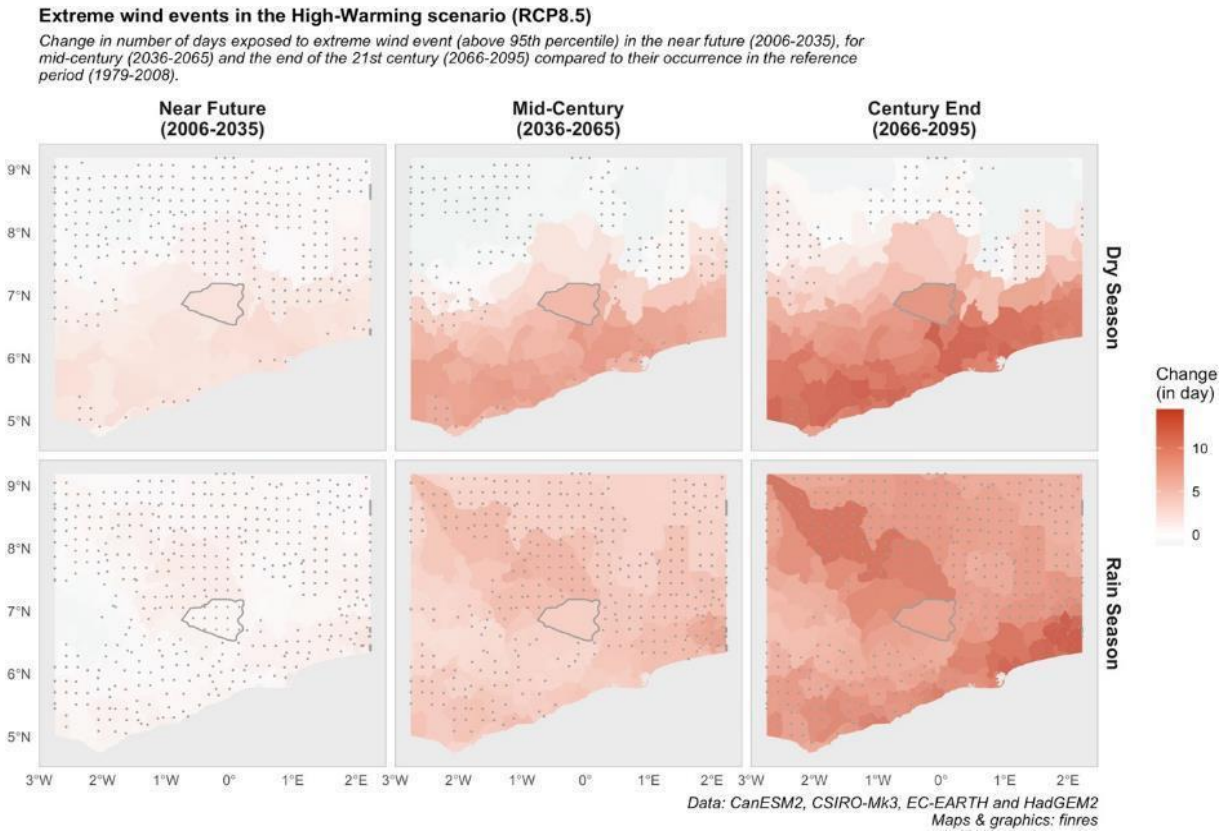


Figure 12 - Seasonal Change in the Frequency of Days Exposed to Windspeed

The frequency of days exposed to windspeed above the 95th percentile of the reference period is generally higher in the south than in the northern sector of the project area during the dry season.

According to the projections displayed in the report, by the end of the century the frequency would have increased by about 10 days compared to 5 days in the near future over the whole area during the rainy season (Figure 12).

4 CLIMATE CHANGE IMPACTS AND VULNERABILITY

4.1 Water Resources' vulnerability to climate change in the KAP

The objective of this part of the assignment was to assess the available water resources to be used for irrigation, as runoff from overland flow, in the streams of the selected catchments, or as groundwater in the sub-surface aquifers, in order to determine the sufficiency of the resources to support irrigation or other interventions/adaptations. In addition, the projected impact of climate variations on these resources were to be investigated.

In order to determine the current state of water resources in the districts, long-term historical data of daily or decadal flows would be required and analysed for any statistical trends, to estimate any decline or increase in flows. Low flow and high flow analyses of the data would also establish periods in which dependency on streamflow is adequate or otherwise for irrigation purposes and would be needed to design any proposed infrastructure for irrigation. However, such data is currently not available for the KAP, therefore an approach is described in full in the detailed hydrological analysis presented in the Water Resources Assessment Report, whereby the resources are estimated from data from a similar catchment, the Afram River.

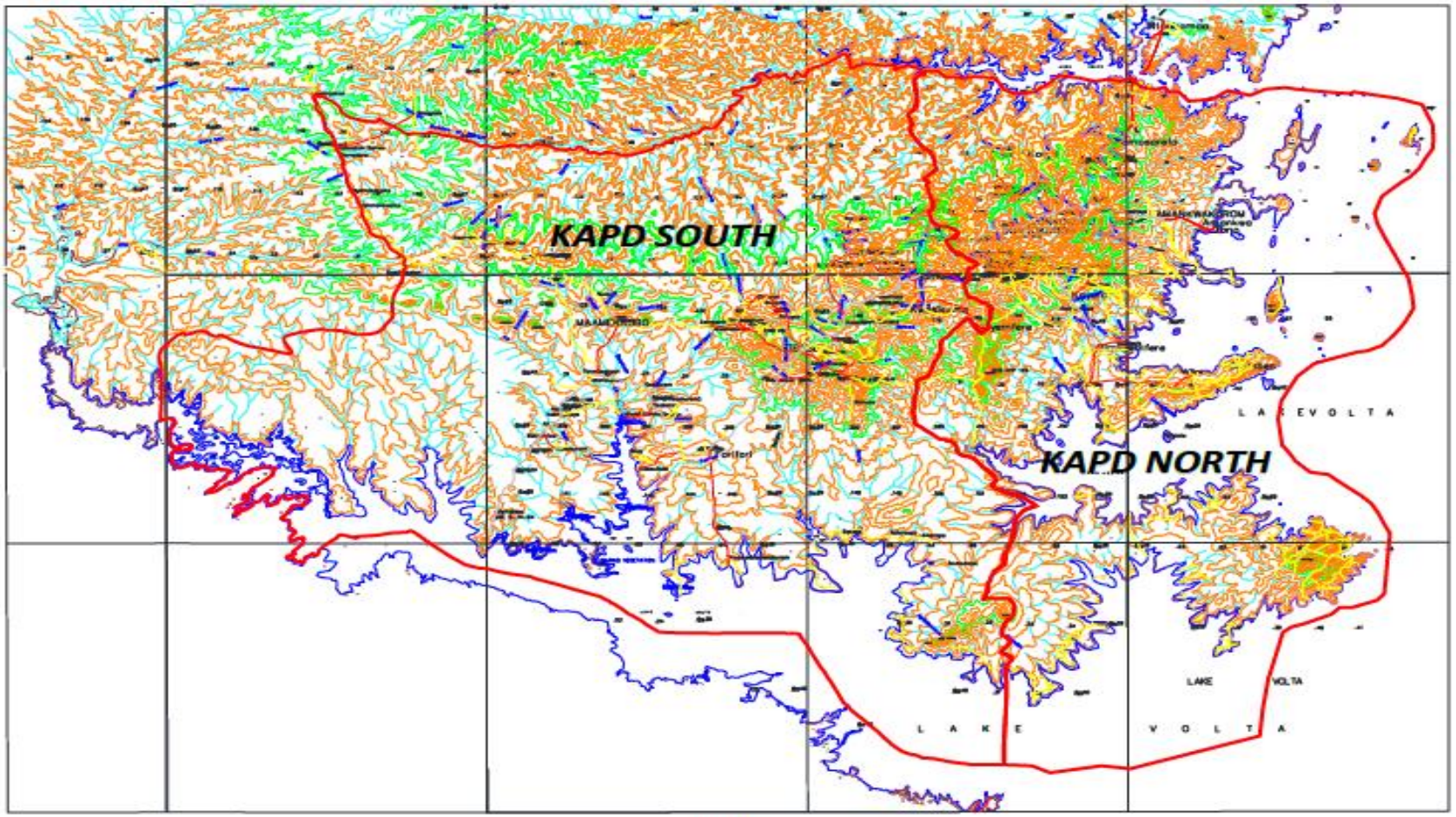
Similarly, existing data for groundwater resources is extremely limited.

4.1.1 Current situation

a. Hydrology of the Plains

The streams of the KAP are all ephemeral, flowing only during the rainy season and lasting at most for four months. The topography is generally flat, with gradual slopes producing flows that are relatively gentle. Valleys are wide in many catchments though stream channels are mostly narrow and shallow, except for a few in the south. None of the streams in the districts are gauged so no discharges have been recorded or archived.

The Afram River catchment adjoins the Kwahu Afram Plains districts. The catchment also empties into the Volta Lake at the south-south east boundary of the Kwahu Afram Plains South (KAPS) district. The two catchments, the Afram River and the catchments of the Kwahu Afram Plains, all fall within the forest-savannah transition ecological zone with similar vegetation, soil and climatic conditions. The slopes are steeper in the Afram River catchment compared to the slopes of the Kwahu Afram Plains, due to the passage through the Akwapim mountain range in the area. However, since the Afram River catchment has existing historical data, the assumption is that the ratio of runoff coefficient to rainfall for the catchment will be similar to that of the Kwahu Afram Plains by virtue of the fact that they fall within the same ecological zone and have similar vegetation, soil and climatic conditions. This assumption takes care of the relatively steeper slopes in the Afram River Catchment.



LEGEND

1:50,000 SCALE TOPOGRAPHIC MAP			50' Contour Interval Map	
500' Contour	550'; 450'; 400'; 350'; 300'; etc. Contours	Shoreline	Stream/River	District Boundary

Source: SMD, LANDS COMMISSION

Figure 13 - Topographical Map of the Kwahu Afram Plains North and South Districts

b. River Systems and Rainwater Runoff

The reference catchment is the Afram River basin whose discharges are measured at Aframso Sekyere in the Afram Plains North District. Summary characteristics (WARM 1998) of the catchment are presented in Table 17 below.

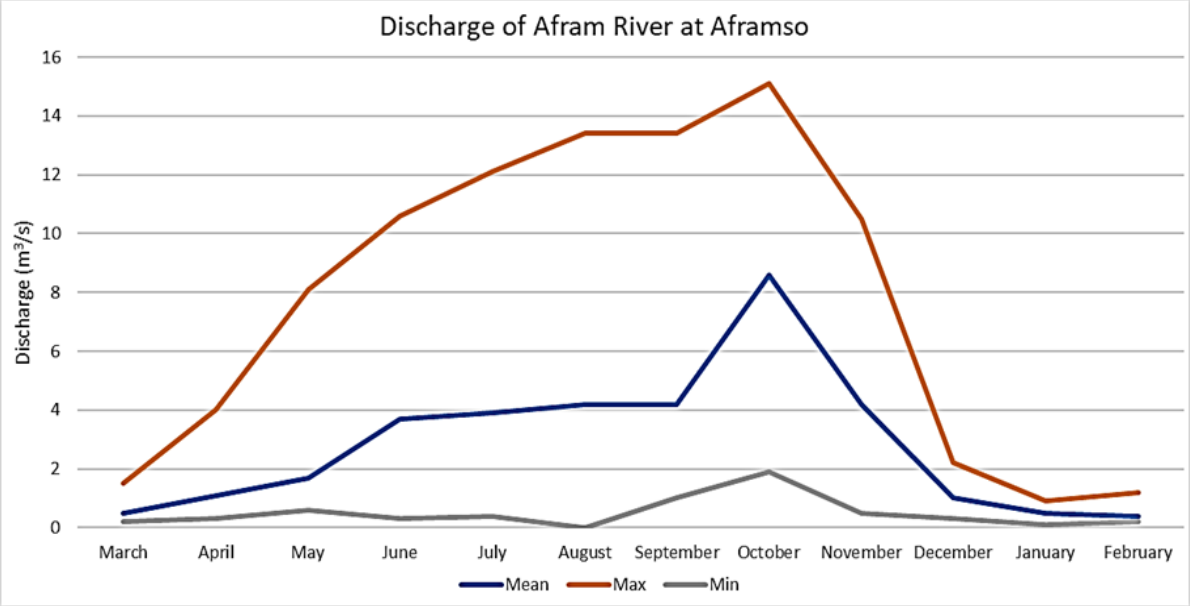


Figure 14 - Afram River Catchment Discharges at Aframso – graphical visualisation

Table 17 - Afram River Catchment Discharges at Aframso (Tabular version of Figure 14)

	March	April	May	June	July	August	September	October	November	December	January	February
	Discharges at Aframso : m^3/s											
Mean	0.5	1.1	1.7	3.7	3.9	4.2	4.2	8.6	4.2	1.0	0.5	0.4
Max	1.5	4.0	8.1	10.6	12.1	13.4	13.4	15.1	10.5	2.2	0.9	1.2
Min	0.2	0.3	0.6	0.3	0.4	0.0	1.0	1.9	0.5	0.3	0.1	0.2
	Runoff coefficient (Specific Yield) : $m^3/s/km^2$											
Mean	0.0016234	0.0035714	0.0055195	0.0120130	0.0126623	0.0136364	0.0136364	0.0279221	0.0136364	0.0032468	0.0016234	0.0012987
Max	0.0048701	0.0129870	0.0262987	0.0344156	0.0392857	0.0435065	0.0435065	0.0490260	0.0340909	0.0071429	0.0029221	0.0038961
Min	0.0006494	0.0009740	0.0019481	0.0009740	0.0012987	0.0001299	0.0032468	0.0061688	0.0016234	0.0009740	0.0003247	0.0006494

Notes: Area = 308 km^2

The duration of the data used is from 1967/68 to 1973/74.

Source : Water Resources Management Study (1998), Ministry of Works and Housing, Information "Building Blocks" Study. Part LL, Vol 2: Information in the Volta Basing System, Final Report, Nii Consult, May 1998

c. Rainfall-Runoff Relationship

All overland flow, runoff and river or stream flow, emanates from rainfall according to the hydrological cycle. Even when contributions such as seepage and springs add up to the

stream flow, rainfall remains the dominant contribution to stream flows. Flows may cease completely when rainfall is absent for a considerable length of time and when groundwater contribution also dwindles. At the time of the site visits (March/April 2021), all the streams were dry, but have been reported to flow following the onset of the rains (May/June 2021).

The project had initially envisaged the collection and analysis of historical discharge data; however, such data does not exist for the catchments. Estimating discharges from ungauged stations catchments is difficult as there are currently no universal approach applicable for predicting runoff at the catchment scale. Most of the knowledge applicable for processes that occur within the catchment has been derived at the "point" or laboratory scale (Blöschl G. et al, 2013). This study therefore used a simplified translational methodology as described in the methodology, to estimate the runoff from the catchments from projected rainfall derived from climate analyses. The outcomes, though not representative of actual flow, gives orders of magnitude that can be used as initial estimates for design of structures, incorporating additional factors of safety.

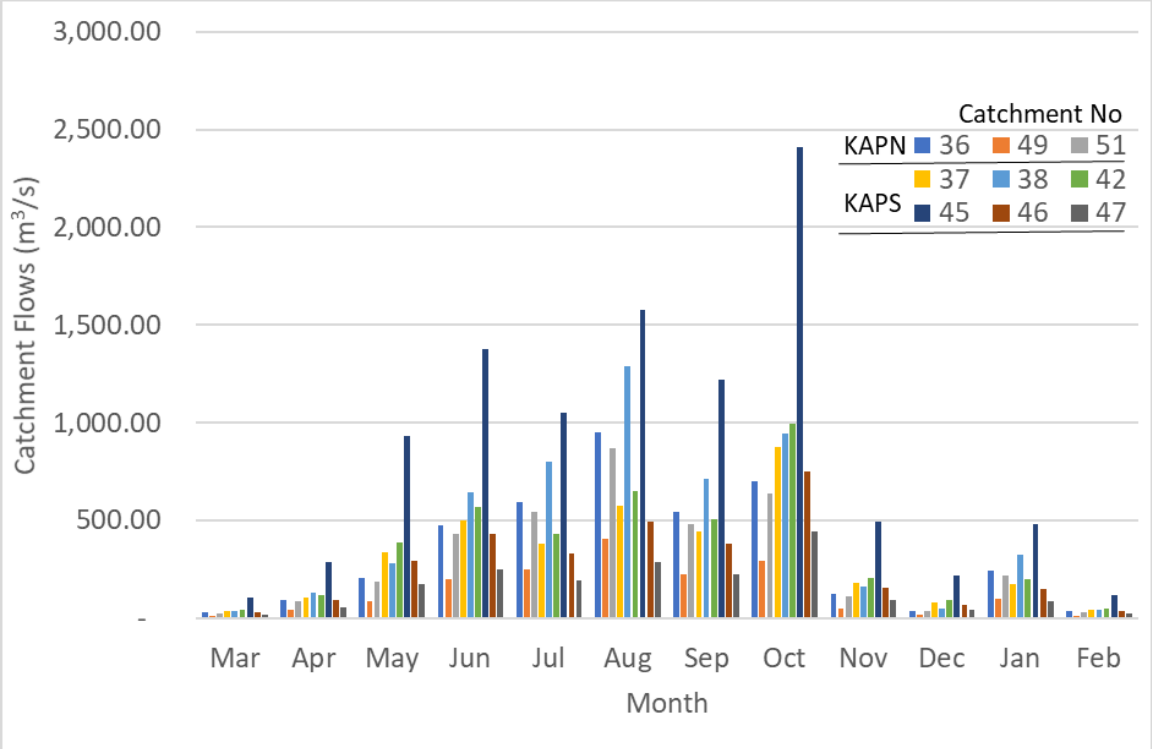


Figure 15 - Estimated Monthly Total Flows (or discharges) from Afram Plains Catchments

d. Evaporative Losses

Harvested rainfall, obtained through structural interventions for irrigation (e.g. dams, bunds or dugouts), will be directly impacted by the current and future climate, both in terms of the volumes of run-off collected and losses from the impoundment. Reservoirs lose water through seepage and percolation, dependent on the pedology and geology of the dam site and reservoir, but significantly through evaporative losses, which is directly related to the area of the impoundment and the climatic conditions.

At this stage, the climate change analysis suggests increased temperatures and wind speeds, resulting in higher evaporative losses from impounded water bodies.

e. Groundwater Resources

Groundwater resources are available in the two districts but are mainly for domestic use in the communities in which they have been dug. Pumping tests conducted on a borehole in Donkorkrom by the Community Water and Sanitation Agency from 29th to 30th March 2021, for instance delivered a steady 120 l/min for 24hrs resulting in a drawdown of 8.35m. The volume of 172.80m^3 is barely enough to meet the domestic needs of the community even though the recovery of the wells was good. A similar borehole at Mem Chemfere delivered a steady 50 l/m for 24h resulting in a drawdown of 12m. The recovery over an 8 h period resulted in a residual drawdown of 0.06m. These (recovery) indicate that sustainable delivery of water for domestic use of the communities is feasible but will not be able to sustain additional demands like irrigation supply. Additional boreholes may be provided at the irrigation sites for agricultural use only but their abstraction would be limited to the prevailing maximum rates. The use of overnight storage tanks to store pumped water to be used for irrigation at night may be worth investigating. At best, groundwater could be used to supplement irrigation water during periods within the growing season, when surface water is not adequate.

4.1.2 Impacts of Changing Weather Patterns

In order to assess the sustainability of the project to meet its purpose, the effect of projected climate on the water resources of the Afram Plains was investigated. The discharge of streams will predominantly be affected by the projected changes in rainfall amounts, the extent of evaporation of reservoir water surfaces, and to a reduced extent, static water level and yields of groundwater aquifers. Future flows of the streams under the various climate change scenarios are thus generated.

The variations in annual streamflow range from -7% to +30% of current flows (see the Water Resources Assessment Report). This is based on results of different climate models (same as for climate analysis) and the expected projections from each in terms of current, mid-century and century end projections (same as for climate analysis).

The reduced inflows have the propensity to affect yields and areas under cultivation, particularly impacting crops with high water demands. Excess flows could lead to flooding in the low-lying agricultural lands, communities and infrastructure, which could impact the livelihoods and safety of residents.

Groundwater usually does not respond rapidly to climate variation due to the relatively long lag time in accumulation of aquifers from rainwater percolation.

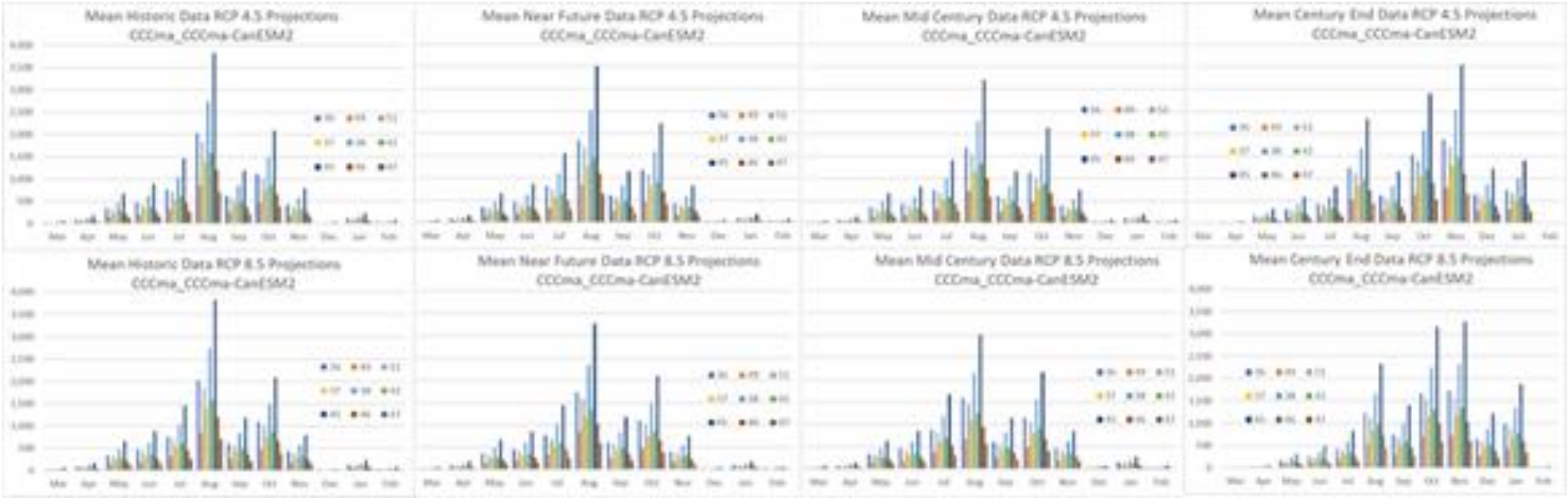


Figure 16 - Projected Flows under CCCma_CCCma-CanESM Climate Scenarios in the KAP

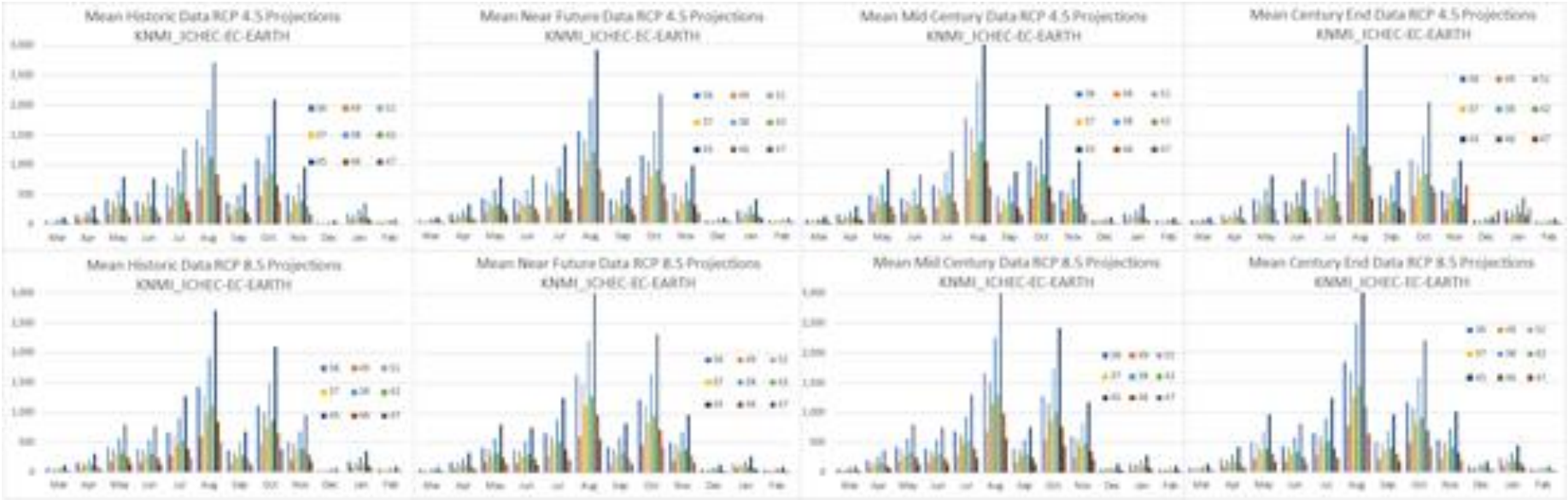


Figure 17 - Projected Flows under KNMI_ICHEC-EC-EARTH Climate Scenarios in the KAP

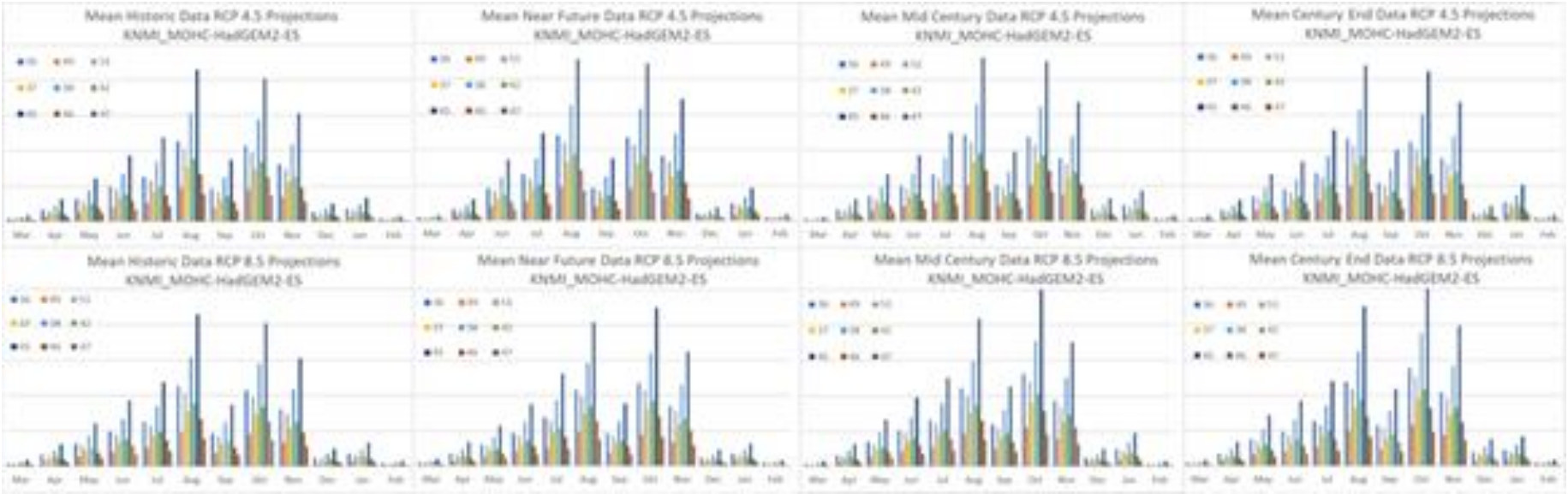


Figure 18 - Projected Flows under KNMI_MOHC-HadGEM2-ES Climate Scenarios in the KAP

Figure 19 - Projected Flows under SMHI_CSIRO-QCCCE-CSIRO-Mk3-6-0 Climate Scenarios in the KAP

The effect of future rainfall on flows of the KAP districts were graphically plotted as shown in the Figures above. The flows are derived from future rainfall as calculated from equivalent climate expectations using the various climate models described in the climate section of the report. Variations of flows from the historic data for near future, mid century and century-end projections show that flows could decrease by up to 0.9 through 7% for the near future to mid century projections, and increase by up to 1.4 through 30.5% for the century-end projections.

Across the entire KAP region, the end century projected flows are generally towards higher flows except for one model (SMHI_CSIRO-QCCCE-CSIRO-Mk3-6-0 using both RCP 4.5 and RCP 8.5 projections). The projections for increased flows have the capacity to promote flooding in the low-lying agricultural lands, communities and developed infrastructure that could impact the livelihoods and safety of residents. The reduced inflows have the propensity to affect yields and total areas under cultivation. It could also affect crops with high water demands. Details are outlined in the Water Resources Assessment Report.

4.2 Crop Farming's Vulnerability to Climate Change in the KAP

4.2.1 Agronomic Context of the KAP

Agriculture is the mainstay of the project areas economy. It employs about 80% (75%m, 25%f) of the total employed labour force of which 87.2% are engaged in subsistence farming and 12.8% in agroindustry (APADP, 2006). According to ADADP, majority of the farmers (94.1%; 75%m, 25%f) are into crop farming with the remaining 5.9% practicing mixed farming, which is a farming system that includes the cultivation of crops and rearing of livestock. Crop farming is the dominant agricultural activity and involves growing crops such as food crops (maize, yam, cassava, rice, grain legumes and vegetables such as pepper, okra, garden eggs (*Albemuscus esculentus*, a vegetable crop in Ghana, etc.) and tree crops (e.g. cashew, orange and oil palm, APADP, 2006). Poor rainfall and high temperatures are climate factors that affect agricultural productivity in the KAP and contribute to the low crop yields and production in the farming landscape. The vagaries of the weather mostly, has reduced cropping intensities in KAP to almost a single cropping per year under upland mainly rain-fed conditions. The practice of irrigation is marginal and constitutes the informal irrigation system where farmers use mechanized water pumps for pumping water from the nearby Volta Lake for irrigating their crops.

a. Crop production in KAP

Land

Most of the agricultural lands in the districts are stool lands owned by four traditional stools namely, Nkwatiahene, Bokruwahene, Abetifihene and Petikromhene. Other lands were seeded to the Volta River Authority and such lands were given to resettled communities that were removed from their land during construction and filling of the Volta Lake. Land in the districts is suitable for agricultural production. About 90% of farm holdings have less than 2 hectares in size, although there are some large farms (rice and maize) and plantations particularly for cashew, oil palm, and mango (tree crops).

Crop types

The major crops (crops that majority of the farmers grow) in Kwahu Afram Plains Districts include annuals (Cassava, Yams Maize, Sorghum, Groundnut, Watermelon, Tiger Nut and Soya bean) in addition to dry season vegetables (including pepper, Okra, garden eggs, Onion, Carrot, Cabbage, Lettuce and tomatoes) and perennial tree crops including Mangoes, Cashew and Oil palm (KAPN, 2021, and KAPS district annual reports, 2020, 2021). Crop production is mainly rain-fed apart from some vegetables that are produced by the informal irrigation using motorised pumps at communities along the Volta Lake.

Table 18 - Crop yield in tons per hectare (t/ha) and average farm size in hectares (ha)

Crop	Amankwa Tornu	Salepe/Ak	Mem Chemfere	Kamalo	Asayan	Asikesu Ii	Tease	Koranten(Somsei)	Forfori/Fk	Semanhyia	Average Farm Size (ha)	Ave (t/ha)
Maize	1.5	3	1.35	1.5	3.4	1.5	2.7	1.35	4.1	1.5	**2.46**	**0.88**
Yam	0	0	0	0	8.5	20	20	11	10	20	**0.98**	**14.9**
Cassava	12.5	0	11.5	9.3	25	0	12.5	15	0	2	**0.68**	**12.4**
Rice	5	3.7	0	0	3.0	0	0	0	0	0	**0.3**	**3.9**
Groundnut	1.2	0	0	0.9	0.63	0.75	0	2.5	0.9	0.9	**0.68**	**1.1**
Tiger nut	0	0	0	0	0	1.3	0	0	0	0	**0.24**	**1.3**
Okro	1.6	11.5	10.5	2.2	0	0	0	0	0	0	**0.36**	**6.45**
Pepper (dry)	1.5	2	0.8	0.8	0.7	0	0.75	0	1.8	0	**0.74**	**1.19**
Watermelon	0	0	0	0	6.0	0	0	0	0	0	**0.24**	**6.0**
Beans	0	0	0	0	0	0	0	0	1	0	**2.46**	**1.0**

Irrigation

Informal irrigation is practised along the fringes of Volta Lake covering a total of about 1,325 hectares among 53 communities.

The level of informal irrigated vegetable production output is slightly higher than within some formal irrigation schemes. Women's participation in the irrigated vegetable activities is high about 70%, representing the proportion of women farmers in the informal irrigated vegetable production sector in the KAP. The 70% women population constitute the proportion of the total number of farmers (men and women) who are into vegetable cultivation in KAP.

b. Agricultural Support Services

Agricultural Support Services in KAP are provided by the Extension Services Department, Agricultural Engineering Services Department both of the Ministry of Agriculture, Agro-chemical distribution agencies, Research Institutions, Universities and Non-Governmental Organisations (NGOs). However, the Extension Services Department serves as the linkage between these Support Service Organizations and the farmer. The survey on Extension activities covered the district offices of the department of agriculture in the district capitals at Donkorkrom and Tease. The district extension unit is mostly headed by the District Agricultural Extension Officer who normally are University graduates.

4.2.2 Crop Farming Vulnerabilities

The objective for this part of the assignment was to analyse and identify crop-specific climate vulnerability: Analysis of crop irrigation requirements (i.e. impacts of insufficient rainfall or high evapotranspiration), cropping pattern (crop cycles) and crop calendars (i.e. impacts of onset and cessation changes), examples of crop failures / poor harvests in recent years and their causes (i.e. climatological extreme weather or other agronomic causes).

Present cropping patterns have been analysed, which will be developed further in the Adaptation Options Report and in later deliverables into proposed cropping patterns, crop calendars and crop rotations for implementation at specific proposed sites under the project. Similarly, crops that require lots of water will only be proposed where soils are suitable.

Both present and proposed crops with potentially high farm-gate value (e.g. maize, cassava and cashew) were identified and the processing requirements for added value to other crops was assessed.

Finally, a crop vulnerability assessment was undertaken, using selected criteria to produce a vulnerability/impact matrix and the Climate Adaptation in Rural Development (CARD) assessment tool. The full detailed agronomic analysis is presented in the Agronomy and Livestock Report.

a. Farmers' Perceptions of Climate Variability

This section is the perception of the inhabitants of the KAP, based on statements given during the field interviews with farmers and the MIS officer (e.g. the Management Information System Officer from the KAPN: Bonsu, 2021 personal communication; Agronomy and Livestock Report). The information illustrates the consequences of recent extreme climate events on crop production. The present-day rainfall is very erratic and unpredictable. The normally bi-modal rainfall pattern in the project area has now almost become uni-modal. According to Bonsu and the District Director of the Ministry of Agriculture, this observation started within the past three years (i.e. 2018) and thus, the cropping season has also narrowed to one season. The end of the minor rainy season which normally occurs in November (in the first week of November in 2018 and 2019) sometimes occurs earlier, for example mid-October as happened in 2020. This statement could be supported by data analysis. However, only one GMet station, Donkorkrom, is present in KAPN and missing data at the station did not allow for further analysis. The ensuing drought resulted in failure of entire crops on the field. During 2020 and early part of 2021, the rains started in March for the major rainy season and yams, cassava and groundnut were planted for the major season cropping. However, in the middle of the year (i.e. April/June), the rains did not come and so caused severe damage to crops through drought. Yam vines were scorched, cassava cuttings were dried out of water and died and groundnut became stunted, wilted and died. The seed yams germinated but later got scorched and died. During the milking stage of yams, the milking activity which is done to facilitate production of seed yams, was not done as there were no rains. Therefore, seed yam production was reduced in the districts causing reduction in yam production and loss of revenue. Farmers that produced a few yam seeds could also not expand their farm sizes due to scarcity of seed yam that occurred during the period under review.

Focus on the community Perceptions about Risks and shocks

The information in this section was obtained during the socio-economic field survey. Seventy two (72) participants, who were consulted during 12 focus group discussions, including farmers, traditional leaders and local government representatives, indicated that the Kwahu Afram Plains used to practice three cropping cycles of farming, as indicated in Table 19 below. The agronomic survey also undertook group-focused interviews and discussions with 10 farmer groups, each group comprising 10 farmers randomly selected at each site.

Table 19 - Cropping Cycle Supported by Rainfall Pattern in the Plains Before the early 1980s

Cropping cycle	Period
First cycle	February to May
Second Cycle	May to August/September
Third Cycle	October to January

Source: Field survey data (June 2021)

Currently, the plains' farmers practice one cropping cycle ranging between June/July and October/November each year with intermittent dry spells. Farmers also reported the weather is now hotter and periodic heat waves are experienced. Respondents expressed strong linkages between climate related events and key livelihood(s) especially farming. Drought, inadequate rains and too much rain were reported to have adverse impact on crop yields. Farmers in the Asayansu community in KAPS reported that they experience unpredictable onset and cessation of rains, the onset period has shifted (from Mar/Apr to Jun/Jul), high temperatures cause yams and other tubers to get rotten and there has been increased incidence of pest and diseases. Farmers are also of the perception that human activity such as bush burning, charcoal production and logging of trees contribute to worsening the situation. In response to the question about time frame for observed climate events, respondents referenced the period between 1982 – 1983, as the beginning of the current trend of climate events they witnessed.

During focus group discussions, participants were requested to recall periods when climate events were experienced in the location. Across almost all the communities, participants referenced bushfires that accompanied droughts between 1982-1985, the bushfires resulted in widespread destruction of the vegetation. Cocoa farms were destroyed, farmers had to cut down the stumps of the cocoa trees and replanted with crops and cashew. The vegetation can no longer support the cultivation of cocoa. In 2007, the KAPS and KAPN districts experienced floods which resulted in loss of lives and properties. Regarding more recent events, they indicate that a drought that was experienced in 2020 resulted in the absence of rainfall in July and August which affected farmer's ability to cultivate crops for the minor season.

A study on climate change and food security in Afram Plains, with findings as presented in the detailed and main reports, indicated participants reported a delay in the onset of the major rainy season in recent years, with little or no heavy rainfall occurring until the month of July and occasionally heavy rainfall in August that saturates farmland and causes several

crops to fail. Additionally, the community members have observed a trend in which the bi-modal rainfall pattern is being replaced by a unimodal pattern. There is a late onset and an early cessation of the rains. Furthermore, significant climatic events recorded from the memory of the participants include the following (Codjoe and Owusu, 2011):

- January–July 1976: Very hot weather conditions
- 1983–1984: Drought—A year long of bush fires
- October–December 1989: Very hot weather conditions
- 1991: Lots of rains throughout the year
- 1995: About 40 days of intensive rains
- 2004: Very cold winds experienced during March–April (Easter) and November–January was very cold
- 2005: Cold periods resulting in animal deaths
- August 2006: 1 week of intensive rains
- 2007: Lots of rain in August and September.

Most households in the Afram Plains districts are subjected to a number of disasters, which may be caused by nature or influenced by human activity. Natural disasters such as flooding, drought, and pest infestations are the most common disasters in the districts. Human-Induced Disasters also include: domestic fire, bushfire and accidents on the road. The Socio-economics Report outlines disaster-prone areas (meteorological and non-meteorological) in both districts and the likely number of people who will be impacted.

b. Projected Impacts of Climate Change

Figure 20 shows a decrease in the percentage yield in some selected crops in West and Central Africa under the RCP8.5 emission scenario (around 4^{o}C global warming by 2100). The tool used is the Climate Adaptation in Rural Development (CARD) assessment tool that enables easy access to peer-reviewed modelling results for crop yields under climate change. The original version of the tool was developed by the West and Central Africa Division of the International Fund for Agricultural Development (IFAD)[4].

The data used in the tool is based on the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) Fast Track output. Figure 20 contains five (Beans, Cassava, groundnuts, maize and rice) out of the ten crops cultivated in the scheme areas (Table 18). In the absence of specific modelling results for the KAPN area, Figure 20 should be considered a guide before further data is available for the specific soils at the proposed sites.

[4] https://www.ifad.org/en/web/knowledge/-/publication/climate-adaptation-in-rural-development-card-assessment-tool

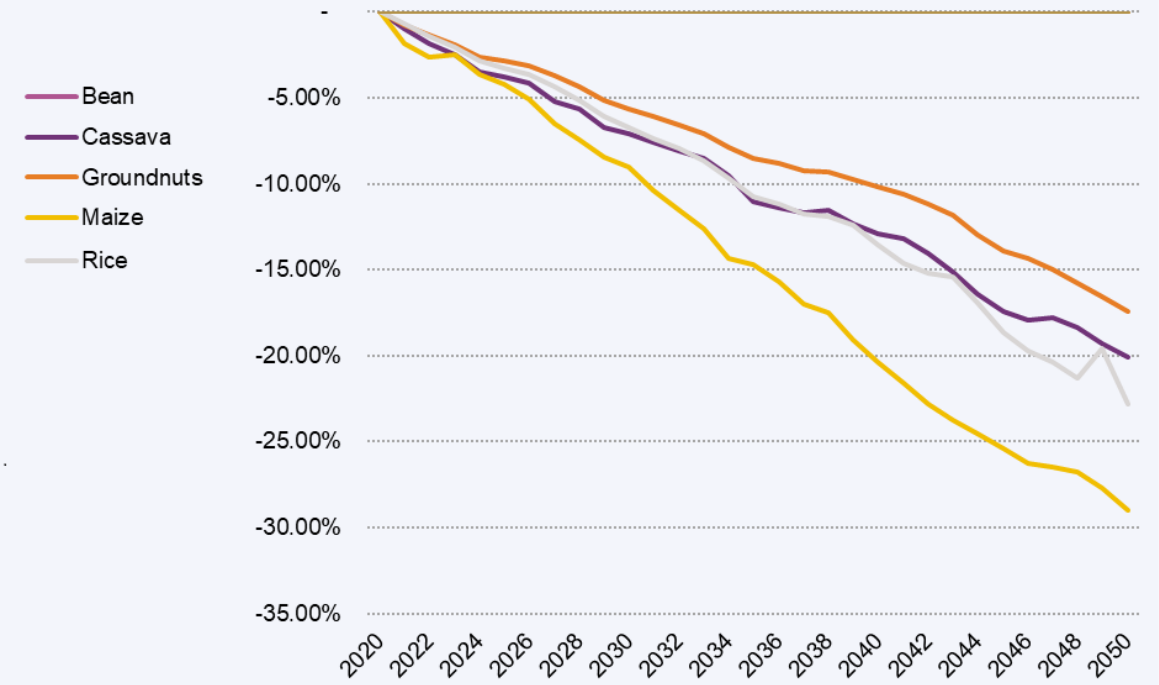


Figure 20 - Effects of Climate Variability and Change on Yield and Use of Existing Tools

(e.g. IFAD.org/CARD : Climate Adaptation In Rural Development Assessment Tool – International Fund for Agricultural Development)

Climate suitability is predicted for each crop by modelling the effects of mean annual temperature (MAT) and total annual precipitation (TAP) on yield while controlling for the effects of various agricultural (e.g. irrigation and fertilization), socio-economical (e.g. gross net product and human development index), soil and topographic factors (Mahaut et al., 2021). Crop area corresponds to the fraction of total, available cropland devoted to each crop.

Crop suitably could be estimated based on the EcoCrop method using temperature and rainfall during the growing period to determine a suitability index that varies between 0 and 1. Total suitably was calculated by multiplying temperature and rainfall suitability. A grid cell was considered suitable for a crop if the suitability was greater than or equal to 0.55, following the standard of using 0.5 as 'marginal' for crop growth (Chapman et al., 2020).

The climate suitability values are from 0 to 1 with 1 being the most suitable. The information in Figure 20 is based on the ensemble mean of the CanESM2, CSIRO-MK3, EC-Earth and HadGEM2 CMIP5 Global Climate Models. The results are used only as a guide as the GCM resolution is very coarse. Figures 21, 22 & 23 contains maize, groundnut, cassava and cashew which are crops grown in the scheme areas (or sites). The model data used for the figures are for the globe (West Africa, Ghana or KAP) and averaged over the period. As the climatic suitability is based on both the precipitation and temperature suitability, the focus is on the climatic suitability figure. Under both mid-warming (RCP 4.5) and high-warming (RCP 8.5) scenarios, cashew is most suitable for all three cycles while maize is most suitable for medium and long cycles.

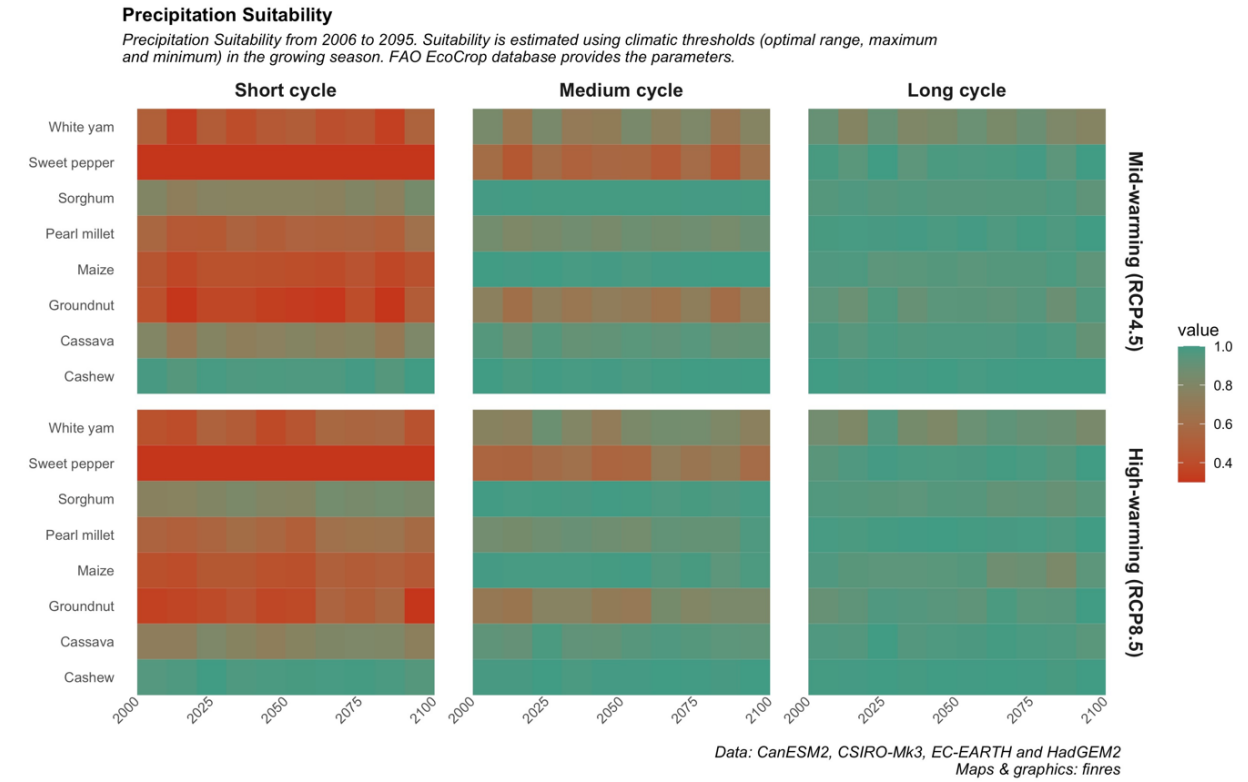


Figure 21 - Suitability of Crops to Current and Future Climates (Precipitation)

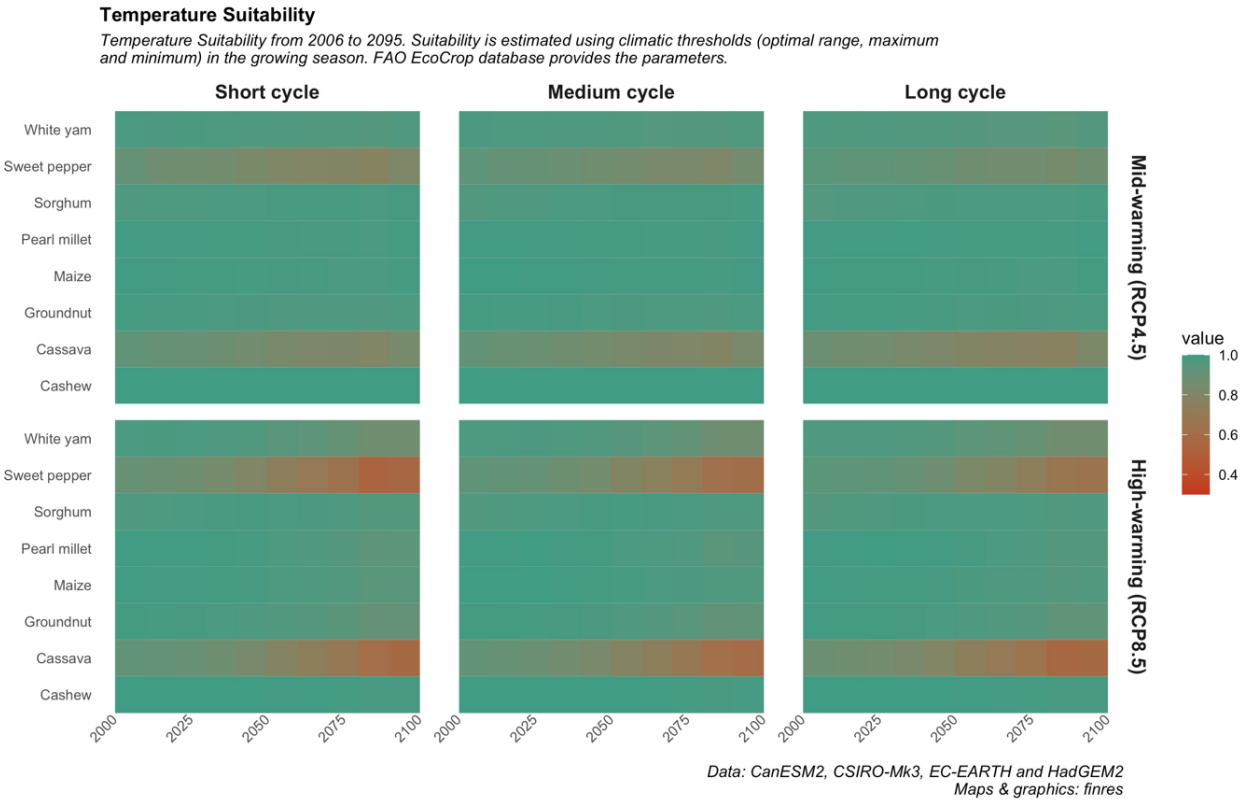


Figure 22 - Suitability of crops to current and future climates (Temperature)

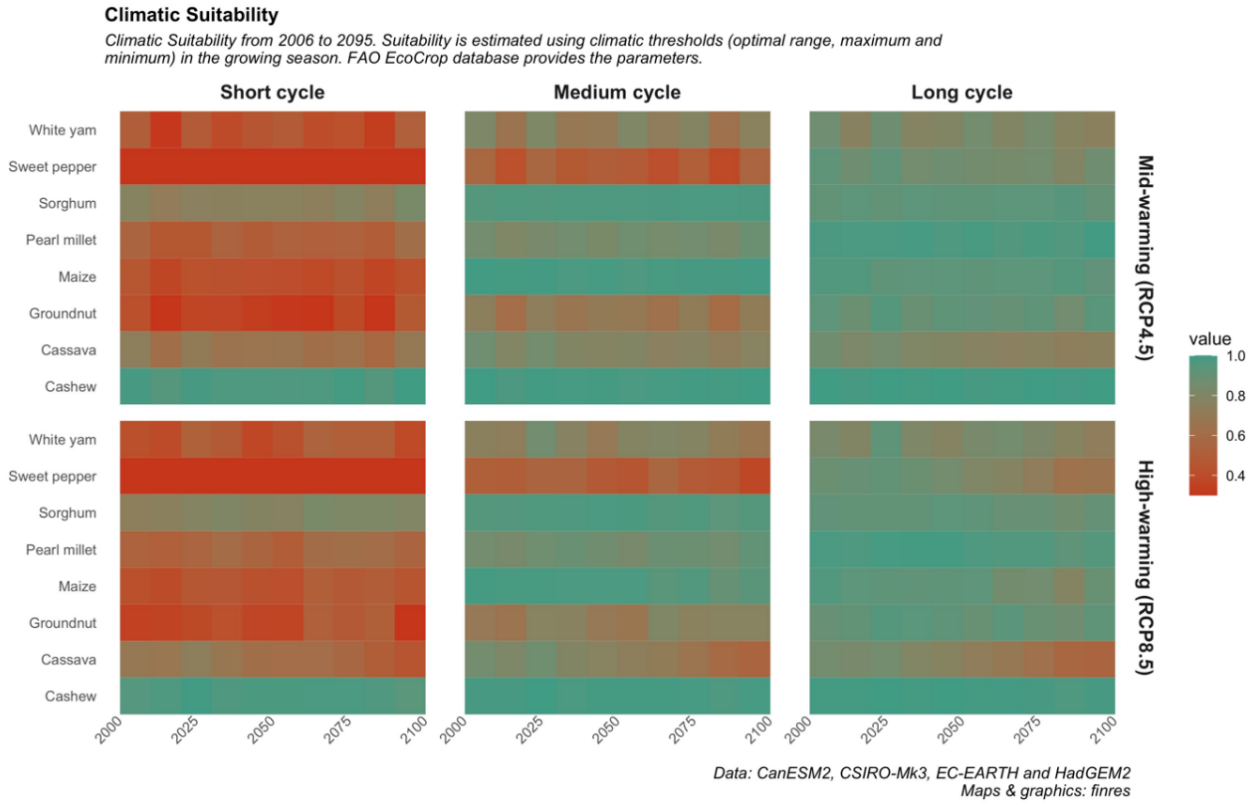


Figure 23 - Suitability of Crops to Current and Future Climates (Climate Suitability)

c. Crop Vulnerability to Climate Change

The following crops were selected by the farmers (Table 20), based on farmers' perceptions of each crop suitability and resilience to climate change impacts.

Table 20 - Crop Selection and reasons for ranking

Selected Crop	Reasons for Ranking
Maize	High patronage, good farmer experience, good returns, source of food, can be easily planted on upland, good storage
Rice	High cropping intensity, Good farmer experience, good market, major source of food, good storage
Vegt. (Okro, pepper)	Early harvest, Key food ingredient, small land requirement, good market, quick returns
Groundnut	High returns, do well in intercrops, early maturing
Watermelon	Quick market, high price, good income, ready market
Sweet Potato	Ready market, part of food staple, high price

The reasons for selecting the crops were scheme specific and dependent on the perceptions of each group of farmers Though several crops lend themselves to processing

for value addition (e.g. maize, cassava, yam, watermelon, tiger nut) farmers in KAP have little or no knowledge for their use.

d. Conservation Agriculture (CA) in the Project Area

From interviews with the North District Director of Agriculture, conservation agriculture is being emphasized as a measure to adapt to the effects of climate change in the project area. Two Conservation Agriculture practices were noted to have been carried out including Cover Cropping in Maize and mulching in Cashew fields. Table 21 gives more information about the status of the practices.

Table 21 - Crops under Conservation Agriculture Practices in KAPN

Crops	Total Cropped Area (acres)	Conservation Agriculture		Yield (MT/ha)	
		Area (acres)	%	Conservation	Non-conservation
Maize	250	118	47	Cover cropping	1,582
Cashew	520	520	100	Mulching	609

A total of five conservation practices had been carried out as shown in Table 22 to demonstrate to farmers how to prevent their crops from wilting and dehydration during the dry periods in order to keep the crops green and to maximize yield as well as conserve moisture in the soil and to prevent soil erosion of nutrients.

Table 22 - Conservation Agriculture Demonstration in KAPN

Conservation System	Target Number of Demonstrations	Actual Number of demonstrations	Beneficiaries		
			Total	Male	Female
Zero tillage	300	240	1,072	756	316
Contour bonding	8	4	256	116	140
Mulching	120	110	911	665	246
Crop rotation	25	22	890	603	287
Cover cropping	4	3	284	178	106

The 2020 annual reports, from field visits and monitoring by the District Agriculture Departments, indicate 45.6% of farmers have adopted crop rotation practices; 78.3% mulching, 83.9% zero tillage, while 87.5% have adopted practicing cover cropping which is highly recommended in maize and Cashew fields. It has been proposed to add on other conservation practices such as growing of Mucuna spp as cover crop and green labelling.

Table 23 - Conservation Systems Adopted in scheme areas

Conservation Systems	Types of Crops	Beneficiaries		Total	Number Adopted		Total	Percentage Adoption %
		Male	Female		Male	Female		
Crop rotation	Yam	641	191	832	213	167	380	45.6
Mulching	cashew	136	21	157	102	21	123	78.3
Zero tillage	Maize	116	140	256	94	121	215	83.9
Cover cropping	Cashew	211	192	403	188	165	353	87.5
Intercropping	Groundnut	60	38	98	56	35	89	9 0

Source: KAPN District Agriculture 2020 Annual report

4.3 Livestock Farming's Vulnerabilities to Climate Change in the KAP

4.3.1 Livestock Context of the KAP

With respect to livestock, the initial formulation of the study had a strong focus on crops. However, livestock is an important issue and was raised several times during stakeholder consultations and at the inception workshop and it was agreed that it should be given greater prominence in the studies. The full detailed livestock analysis is presented in the Agronomy and Livestock Report.

Livestock farming is the second most important agricultural activity after crop farming in the Kwahu Afram Plains Districts. There were of 342,522 and 411,120 animals of different species reared by 16,254 and 12,644 keepers with an average of 21 and 32 animals per keeper in the North and South Districts respectively in 2010 (GSS, 2014a; GSS, 2014b). The types of animals reared include sheep, goat, cattle, pigs and poultry. The systems employed in the rearing of animals are mainly the intensive system where animals are kept in a confined area and fully fed and semi-intensive where animals are allowed to go out during the day and brought indoors in the evening. About 60% of the farmers who practice mixed farming employ the semi-intensive system, with the remaining 40%, comprising mainly commercial poultry, pig and micro-livestock farmers getting into the intensive system of rearing animals. Extensive system applies to transhumant practice, particularly during the dry season.

Conflict between farmers and herdsmen have been reported in the Kwahu Afram Plains area. The destruction of crops by cattle during their search for forage is a major cause of conflicts. Also, the competition for water between human and animals leads to conflicts. Thus, it became crucial that the study consider both crops and livestock demands for water as a scarce resource in most parts of the area.

The KAP has benefited from the Afram Plains District Agriculture Development Projects (APADP, 2008 - 2013), which had a livestock component that covered fodder bank construction and breed improvement. There are no new projects except some attempts by the Ghana Cattle Ranching Committee to revive and maintain the fodder banks.

The approach has been described in Chapter 2 and is provided in further detail in the Agronomy and Livestock Report. Eleven communities, five in the KAPND and six in the KAPSD, were selected for the study, and sixty-five respondents were identified with the help of the District Livestock Officers to take part in interviews, comprising livestock farmers and other actors in the value chain (including four butchers who were also farmers; 24 females and 41 males). Additionally, four Department of Agriculture Development Officers and the Wawase Cattle Ranch Manager were interviewed. Rapid Rural Appraisal techniques were used to collect data for the study, including observation, key informant interviews and group discussions. The perceptions of severity of climate change effects and vulnerability matrix assessment were adapted to elicit respondents' perspectives on future climate change; the farmers noted that climate change is seriously affecting their yields production and ultimately impacting on their incomes and livelihoods.

4.3.2 Climate Change Effects on Livestock

The effect of climate change on key productivity indicators in livestock production and effects on disease incidence, occurrence of transhumance and conflicts were tracked over the last 30 years. Generally, the effect of climate change on productivity parameters (weight gain, milk yield, and livestock mortality) have become increasingly severe in both the Afram Plains North and South Districts.

The communities assessed the vulnerability of livestock resources to hazards including drought, floods, and bush fires, and in both districts, feed resources were perceived to be most vulnerable followed by water and diseases. The vulnerability of water resources and diseases appear to be more prominent in the North than in the South.

Considering the trend of climate change effects in the last 30 years, the key informants' perceived increasing severity of future climate change effects on livestock productivity. feed and water availability for transhumance livestock and conflicts between farmers and herders. Livestock weight gain is expected to be negatively affected due to reduction in feed availability. Reduced feed intake and heat stress are expected to reduce milk yield. Increased temperature and reduced among livestock. Increased temperature and reduced rainfall are expected to lead to increased disease outbreak. This together with with lower resistance to diseases resulting mainly from inadequate feed availability will lead to higher mortality, particularly among the young. The search for increasingly scarce feed by both transhumance and local livestock will result in damage to crop fields and contamination of most community water sources thereby precipitate in increased crop farmer - herder conflicts.

a. Farmers' Adaptation Responses

In community group discussions, climate smart animal agriculture practices were identified and scored in order of importance, as a basis for ranking in the various communities and each district. In the Kwahu Afram Plains South District, veterinary prophylaxis was perceived as the most important practice, with pasture management and use of water-points ranked second and third respectively. In the Kwahu Afram Plains North District, veterinary prophylaxis was also ranked first, but this was followed by supplementary feeding and pasture management, in that order. The use of water points was only ranked fifth in the North, which appears contradictory given that water resources were considered

quite vulnerable, but may be explained by the use of lake water when boreholes dry up in the dry season.

b. Relationship Between Livestock and Crops

The Kwahu Afram Plains area experiences regular conflict between farmers and Fulani herdsmen. There are four fodder banks, two each in the KAPN (Amankwa and Mem Chemfere) and KAPS Districts and they are located in well fenced ranches (One fodder bank in each district has been converted to a ranch to hold community cattle and there are ten dugouts located in the fodder banks to collect water). However, the destruction of crops by cattle is a major issue related to the competition for water and pasture lands and the study should consider both crops and livestock demands for water as a scarce resource in most parts of the area.

There are some common input resources for livestock and crop production, with some outputs in turn becoming inputs for other production processes (e.g. manure as fertilisers and crop residues as livestock feed). Climate change in the form of increased drought and environmental temperature will reduce the availability and quality of the yield of crops such as maize, sorghum and soya bean, as well as crop residues and pasture; this in turn will reduce feed availability for livestock and hence decrease manure production for crop fertilization.

4.4 Socio-Economic vulnerabilities to climate change in the KAP

4.4.1 Socio-economic assessment

The socio-economic analysis includes information from a field survey. The survey was designed to:

- Establish the existing socio-economic baseline conditions of the Afram Plains North and South Districts
- Examine the existing institutional arrangements and power dynamics in irrigation development and management in the districts
- Determine existing and potential land tenure and natural resource access rights issues including past and present conflicts and the implications for the project
- Examine the potential direct and indirect implications of the project on the socio-economic context
- Identify the effect of past and future effects of climate events on the socio-economic conditions in the districts
- Assess gender dynamics in the districts and implications for the project and adaptive capacity in general.

The study approach and detailed survey methodology are covered in Chapter 2 and more detailed in the Socio-economics Report. The socio-economic context within the KAP is described in detail in Chapter 1 and also at the beginning of the Socio-economics Report .

4.4.2 Land context in Kwahu Afram Plains

The Kwahu have been recognized as the traditional landowners of the Afram Plains which for a long time served as the hunting reserve for their chiefs who live on the Kwahu Plateau to the west of the plains (Wallis 1953:24). The construction of the Volta Lake in 1964

necessitated the relocation of an estimated 80,000 people from 740 villages along the banks of the Volta River into 52 government-sponsored townships (Lisa Westerhoff & Barry Smit, 2008). The Afram Plains is therefore inhabited by Kwahu's (indigenes) and Ewe (Settlers). With time people from other parts of the country migrated to the Plains mainly to seek opportunities in the agricultural sector. Generally, there are tensions among some groups with regard to access to land, land ownership and grazing land for herdsmen. Disputes have arisen between natives and settlers, chiefs and settlers, herdsmen and farmers and in a few cases, chiefs and chiefs (Aryeetey et.al., 2011).

Land in the Kwahu Afram Plains is owned by the chiefs, clan or family heads who hold them in trust for their subjects. However, individuals also hold or acquire lands through direct purchase, rent, leasehold, sharecropping (Nnoboa) and gift. The fact that parcels of land can be inherited through parents or grandparents has led to problems of sale and resale of land with its attendant land litigations and chieftaincy disputes. This situation has also contributed to the rapid loss of farmlands which results in unemployment and subsequent migration. Land is vital in the development of agriculture and measures put in place to ensure effective administration of land resources go a long way to ensure agricultural development of a particular area. Interactions with farmers, traditional leaders and stakeholders as part of this survey revealed that there are currently no existing conflicts in the proposed sites for the project except in Amankwa Turno in KAPN where some disagreements between the different chiefs in the community has resulted in a delay in receiving resettlement claims from the Volta River Authority.

There are two main forms of tenure system in the Kwahu Afram Plains North district. The two systems are namely the sharecropping system and the sole proprietorship. In the sharecropping are the "Abunu and Abusa" systems. In the Abunu system the produce is shared equally between the farmer and the landowner or the financial sponsor of the production. In the Abusa system the proceeds from the farm are shared two thirds in favor of the farmer. But the most widely practised system in the district is the sole proprietorship. (Survey Data, June 2021)

The situation of women's access to land in the Afram Plains is not different from the general context of limited access to land by women in Ghana. During FGDs, it was revealed that when women require lands for farming or investing in business, they rely on the men in their houses and where there are no men, they have to consult with another male relative to lead in the process. This results in delays and increases the cost of acquiring land for farming by women. It is recommended that land as a basic input for agriculture should be accessible to both men and women.

A key emerging trend related to land access that was highlighted by participants of this study is the increasing acquisition of large tracts of land (land grabbing) for agriculture, logging and other commercial activities. They indicate that a significant proportion of the citizens in the Afram Plains are migrants, hence they do not own the lands they cultivate on, the owner of the land can sell it to an investor without prior notification to them. Investors showing interest in farmlands most often are given these lands without consideration of the present users of the land. The chiefs who are the custodians of the lands under the Kwahu stool lands superintend over these lands without any consultation with the community chiefs who live with the small-holder farmers in the districts. The situation is worsened by landowners who do not live in the catchment area, they sell or

release land to prospecting investors without adequate notification of present users of the land. Farmers indicate that such "land grabbing" activities lead to displacement of smallholder farmers without adequate support or relocation.

4.4.3 Kwahu Afram Plains households' vulnerabilities to climate change

a. Exposure of households to climate risks

Kwahu Afram Plains North and South districts are highly exposed to the effects of climate variability, key events include; unpredictable onset and cessation of rains, floods, drought and increase in temperature. For instance, residents in both districts report that, over the past three years, the bi-modal rainfall pattern has almost become unimodal. Although G-Met data produces a bi-modal rainfall pattern, perhaps the distribution of rainfall does not support a double cropping cycle for farmers. Based on the climate analysis, temperature in the both districts is reported to have increased since the 1980s by about 1°C in both the rainy and dry seasons. The frequency of extreme hot days and nights have also increased. The projected future climate also reflects exposure of both districts to climate variability. Temperature is projected to increase by 1.3°C, a higher frequency of heatwaves is expected and extreme wet events that can trigger flooding are projected. Both districts have island communities and they are the locations that are most exposed to flooding. In KAPSD, Ekye-Amanfrom, Forifori, Digya Island and Dodi Island have been identified by the district assembly as the flood prone locations. In KAPND, the flood prone communities are; Dwarf Island, Ntonaboma, Mem-Chemfere, Amankwa – Tornu, Agordeke – Wodidiada, Digya Island, Dodi Island.

b. Sensitivity of households to climate risks

Over 70% of residents in both districts depend on agriculture as a source of livelihood, a sector that is highly sensitive to climate variability. In the case of Kwahu Afram Plains, the majority of farmers depend on rainfall for production. Farmer groups who were met during the survey of proposed project sites bemoaned the fact that depending on rainfall for agricultural purposes has become a perennial challenge. Most crops planted during the major season this year (2021), could not mature due to the absence of rains. In addition to crop cultivation, animal husbandry and fishing are equally sensitive. The fishing sector is affected by increase in temperature and drought, these result in a drop in the water level at the lake and drives the fish into deep waters. Sensitivity of the animal husbandry sector is influenced by the effect of droughts on availability of forage and water for livestock.

The soils in the district are known to be susceptible to erosion when exposed, heavy rainfall events and strong winds have contributed to erosion of soils, hence affecting fertility of the soils. Soil erosion also negatively affects the limited road infrastructure that exists in both districts and this makes locations in the districts inaccessible. These transportation limitations adversely affect commerce and access to essential services such as health care.

c. Households' adaptive capacity to climate risks

Adaptive capacity is KAPSD and KAPND is assessed based on the ability of residents to adjust to the impacts of the extreme climate events they are exposed to. The analysis which has been made based on a number of key variables which include financial, social and physical capital reflect a low adaptive capacity in both districts. The incidence of poverty in both districts is high at 59.7% for KAPSD (highest in Eastern Region) and 31.7%,

this reflects a limitation in economic resources to be able to invest in adaptation efforts. For example, replanting on the field to take advantage of the rains in the minor season when a drought causes crop failure during the major season. The incidence of poverty is higher among rural women in both districts, for instance a study of the poverty trend in KAPND by the District Assembly revealed the increase in poverty among rural women was 17% higher than that of men. (DMTDP, KAPN, 2015).

Another key determinant of adaptive capacity is literacy rates, this is essential in skills acquisition, information regarding access to inputs services and technology. Both districts have literacy rates that are relatively lower than the national average. The literacy rates for KAPND and KAPSD are 14.6% 17% lower than the national average. Within the districts, the literacy rates for males are higher than females, there is a difference of 8.2% and 0.8% in KAPND and KAPSD respectively. This depicts a relatively lower adaptive capacity for females in both districts.

Access to technology has also been assessed as a link to adaptive capacity. In view of the focus on the agriculture sector, this review has focused on access to agricultural mechanization services. There is minimal use of mechanization services in both districts, the hoe and cutlass continue to serve as key farming equipment. The reported form of mechanization service used is ploughing with the use of a tractor or power tiller. During the 2020 cropping season, 1,005 male and 311 female farmers had access to mechanized ploughing service in KAPND. In KAPSD, 1,800 male and 1,300 female farmers used the same (2020 Agric Department Progress Reports- KAPND and KAPSD). Across both districts, there are more male farmers who have used mechanized ploughing services than female farmers. Different explaining factors have been mentioned, such as limited financial ability to pay for tractor services, and the fact that mechanization service providers prioritize large scale farmers who are mostly male. During FDGs female farmers indicated that the limited availability of mechanization services such as threshers places workload burden on them during harvesting and processing of grains and legumes.

The age dependency ratios for both districts are relatively higher than the national average based on the 2010 population census. The ratio for KAPND is 91 and 84.7 for KAPSD against a national average of 76. This means that in both districts the persons in the active age group (15-64) take care of more people in the age dependent group (0-14 and 65+). This trend puts pressure on the income and resources of the working population hence limiting the ability to save to address any urgent needs that may arise in future.

Access to credit is also a key determinant of adaptive capacity, credit plays an essential function in supporting investments in livelihood activities, livelihood diversification and responding to sudden emergencies. Only 15% of farmers have access to formal credit and this is skewed in favour of males. Farmers resort to alternative arrangements with family, friends and private individuals for credit.

Farmer networks and other forms of social groupings are important in building the adaptive capacity of people. These offer opportunities for support/assistance in time of need, learning and sharing. In both districts there are crop/sector specific Farmer Based Organisations (FBOs) that farmers belong to. In KAPSD there are a total of 101 FBOs composed of 2,083 males and 1,005 females. In KAPND, there are 102 FBOs with a membership of 900 males and 645 females. These FBOs serve as platforms for learning and

provision of support such as labour. Considering the large farmer population in both districts, it is important to support the establishment and strengthening of additional FBOs and encourage more female participation. NGOs in both districts have also supported the establishment and management of village savings and loans associations in some communities and these groups enable members to save and borrow from their savings.

Measures that are taken by farming households to adapt to negative effects of climate related hazards on crop production include; adoption of early maturing seed varieties. The consultations revealed that the adoption of early maturing seed varieties was high for males compared to females. This can be attributed to the generally low access to production inputs and information by female farmers. The practice of mixed farming has also been highlighted by farmers as a strategy that is adopted to manage the risk of crop failure, hence most households keep livestock and poultry to supplement crop production. The practice of residual moisture irrigation along the shores of the Volta Lake is used as an option for crop production for communities that are closer to the lake. Farmers who are unable to afford the cost of replanting after their crop has failed resort to selling their labour to other farmers, this practice was reported to be very common among migrant farmers.

d. Economic and Food Insecurity Derived from Agricultural Vulnerability

Majority of households in the Kwahu Afram Plains Districts meet their income and food security needs through livelihood activities in the agriculture sector. The agronomic analysis which has been reported in earlier sections of this report identified maize, yam, rice, cassava, groundnut, cowpea and vegetables (pepper, okra) as the crops that are most sensitive to the effects of the climate related hazards in the districts. Maize is the most common crop in the districts, it is cultivated for both food and income by both male and female farmers and across all ethnic groups in the districts. Yam is equally grown for food and income and mostly cultivated by migrants from Northern Ghana and Krachi's. Cowpea, groundnuts and vegetables (okro, pepper) are mostly cultivated by female farmers, for instance they constitute 70% of vegetable producers in informal irrigation sites across both districts. They exercise the greatest control over income generated through the production of these crops. As in the case of maize, rice and cassava are fairly cultivated across ethnic groups and gender.

The reduction in maize production results in limited availability for household consumption and income losses that affect ability to purchase food and meeting other household needs. The effect on yam production hits migrant farmers the hardest and results in significant income losses since yam production serves as a key income earner for the migrant households. Production losses on legumes and vegetables leave female farmers the most affected, a greater proportion of these crops is sold to generate income to purchase food and other basic needs. Other pre-existing factors such as their limited access to extension information, a more challenging land acquisition process and limited access to credit puts female farmers and female headed households in a more vulnerable position. It is also important to note that beyond losses to climate related hazards, vegetable farmers lose income due to their inability to transport their harvest to the market on time as a result of the poor transportation infrastructure in the districts.

In the livestock sector, feed resources have been identified as the most vulnerable followed by water. These contribute to reduction in productivity with the attendant effects on income and animal sourced foods for households. Another effect of the feed and water stress situation is the competition between crop farmers and transhumance livestock herders over these resources which results in crop damage and conflicts.

The fishing sector is a major income source for a segment of the population who live along the water bodies and it is a sector that is dominated by the Ewes. The sector also serves as a source of animal based protein for residents. During FGDs, it was revealed that during periods of drought, there is low fish catch because the water level of the lake drops and the fishes move into deep waters. This drives fishes into deep waters. A reduction in fish catch adversely affects income and food security for households that depend on this sector. Males are engaged in actual fishing which is estimated as 55% of the fishing value chain. Females undertake the processing and marketing related components and this is valued to constitute 45% of the value chain (APADP 2006).

Since the economies of both districts are primarily agro based, activities in the commerce sector primarily revolve around agricultural products. Marketing of these agricultural products therefore requires a good transportation network. However, heavy rainfall events worsen the state of poor road network that exists in the districts, this makes it difficult for farmers and traders to transport products to the markets. This situation is worsened by limited storage infrastructure. Females constitute 60% of people who are engaged in the commerce sector in the two districts. The poor transportation infrastructure serves as a big challenge to that sector of the economy and affects incomes of both farmers and market actors. It is also important to emphasize the effect of poor transportation and storage infrastructure on food safety, especially for perishable products such as vegetables and tubers.

Access to clean and safe water is an essential component of food security, there are communities in both districts that depend on perineal streams for water for domestic use. These streams dry out due to increased evaporative losses due to drought and high temperature. This places a workload burden on women and girls to source for alternative options of water for domestic use.

When the household farm yield drops, it is women who will explore, identify and execute alternative sources of food for the family and they will increase their contribution to the family budget. In times of flood they are those who bear the burden of ensuring the safety and security of children and family property, and in times of climate related health issues such as malaria, diarrhoea and Cerebral Spinal Meningitis (CSM), it is them who will provide the needed Care to affected children and even adults.

In response to a question about which gender was hardest hit by climate related hazards in the agriculture sector, all female FGDs and 45% of respondents of male FGDs were of the view that women are the most affected. Reasons cited include the fact that, when the household farm yields and income to purchase food drop, it is women who are faced with the increased responsibility of finding alternative sources of food for the family.

It is also important to note that the Afram Plains districts play a key role in food availability for other districts and regions that rely on what is produced in the Plains, hence reduction in food production has a spillover effect on other parts of the region and country. For

instance, the Minister of Agriculture attributed the maize shortage that has been experienced in the country this year to droughts that affected maize production in the Kwahu Afram Plains Districts and other major maize producing districts in 2020[5].

e. Vulnerability of the Health Sector

The most critical climate change issue the districts are facing in the health sector is flooding and its accompanying consequences on disease prevalence. The most common disease that threatens the lives of people in the districts is Malaria, and the periods of heavy rainfall events have been linked with increase in the incidence of Malaria. The other effects of flooding on health are contamination of water sources resulting in diarrhoea, and skin diseases are also prevalent when there is flooding. The poor nature of roads in the districts also affect timely access to health care facilities by patients, including pregnant women, during periods of flooding. Appendices in the Socio-economics Report gives the top ten causes of out-patient department (OPD) attendance in KAPS during 2020.

[5] https://www.modernghana.com/news/1101501/agric-minister-blames-low-yields-of-maize-in-2020.html

5 CONCLUSIONS AND KEY FINDINGS

5.1 Climate Change Trends

Historical and Present-day climate trends:

- Arguably, the temperature change in the Afram Plains has been positive since 1980s. The temperature in both the rainy and dry seasons are higher in the Afram Plains that in the surrounding areas (GMet data).
- With regards to rainfall, the GMet data reproduces the bi-modal nature of rainfall in the KAP (using GMet data from 1970-2020) but interviews during the field missions had people claim the bimodal rainfall pattern has virtually become unimodal especially since 2018.
- Late onset of the major rainy season coupled with early cessation of the rains.

Future climate trends:

- Temperature in the project area is projected to increase under RCP4.5 (mid-warming) and RCP8.5 (high-warming) scenarios, respectively by 1.3°C and 1.6°C
- Precipitation is projected to increase over the northern part of the area and decrease over the southern part. In the future period (2036-2065), the multi-model and project area mean precipitation in the rainy season is projected to increase by 2.8% (RCP4.5) and 4.1% (RCP8.5).
- The number of consecutive dry days is projected to decrease under both scenarios over the project area by an average of 21 days in the KAP.
- A higher frequency of heatwaves (e.g. 86 and 104, in RCP4.5 and 8.5, respectively) and extreme hot nights will accompany the increase in temperature over the area.
- Extreme wet events that could trigger flooding events are projected to increase by 1 day (RCP4.5) and 2 days (RCP8.5).
- By mid-century (2036-2065), the number of days to which the project area is exposed to high wind speed is supposed to decrease under both scenarios with regards to the reference period of 1979 to 2008.
- The frequency of days exposed to windspeed above the 95th percentile is generally higher in the southern than in the northern sector of the project area. By the end of the century, the frequency will increase over the whole area.

5.2 Climate change impacts, Adaptive capacity & Vulnerabilities

5.2.1 Water Resources' vulnerability to climate change

Present-day vulnerability:

- There are no historical flow data for the project area. Thus, data from Afram River, an adjacent catchment with similar characteristics as the Kwahu Afram Plains, is

used to analyse the surface runoff capacity of the catchment in order to obtain reasonable information for irrigation development in the plains.

- Catchment delineation using thirty-metre SRTM DEM data is too coarse to segregate sub-tributaries on which proposed irrigation schemes are planned. Thus, the total monthly flows for the various catchments in the Kwahu Afram Plains is not precise and based on larger clusters of catchments. It was thus not possible to obtain flows for the sub-catchments.
- Additionally, the extent of inundation of proposed schemes are yet to be developed. Data on evaporation of the plains as well as the adjoining Afram River catchment is also not available. The impact of evaporation on reservoir storage for present day and future scenarios could not be determined.
- Potentially, the large impoundment areas produced by shallow reservoirs, due to the flat terrain in the KAP, and the potential risk of drying out as a result of increased evaporative losses, as well as the increased flooding risks from breaching, suggest that reservoir developments must be limited to stream channels and excavated dugouts where they are able to store sufficient water for irrigation and livestock water uses.
- Average depths of the boreholes range from 35m to 128m across the two districts. Out of a total of 58 boreholes dug to date (time of filed missions), 32 boreholes (55.17%) are functional, 24 boreholes (41.38%) are dry, 1 borehole (is marginally functional and another 1 borehole 1.72%) is salty. Even though some information on irrigation wells with discharges of about 1,500 l/s and depths of about 120m have been obtained during the MCA Adaptation Workshop, locations and additional information including their use and functionality could not be obtained because the participant who gave the information could not be reached after many tries.

Future vulnerability:

- The variations in streamflow for mid-century to century end as projected by the range of climate projections and their attendant impact on hydrology are expected to range from reductions of up to 7% of current flows, to increases of over 30% of the current flows (see the Water Resources Report). The implications are for reduced irrigation water for agriculture that require that sufficient storage to be created to satisfy these expected shortfalls. Increased flows imply flood expectations, especially for low-lying areas and communities, which may also be attenuated by adequate storage facilities, to absorb these flows and prevent or reduce flooding downstream. This has implications for adaptation and mitigation programs that could inure to improved livelihoods for the communities.
- Groundwater usually does not respond rapidly to climate variation due to the relatively long lag time in accumulation of aquifers from rainwater percolation. Over extended periods however, reduced precipitation or high intensity rainfall resulting from climate change impacts, has the tendency of reducing the infiltration of water into the aquifer thus reducing groundwater availability. It is useful to explore aquifer recharge options for channelling excess flows that otherwise could

cause flooding. This will improve the static water levels of aquifers and allow for additional water sources for irrigation of vegetable farms.

5.2.2 Crop Farming's Vulnerability to Climate Change

Present-day vulnerablity:

- Interviews during the field missions indicate crop production is diverse, with farmers adopting different production techniques, but with the cultivation reduced to a single cropping season under mainly rainfed/upland conditions, and only a limited number of farmers growing crops under irrigation, mainly along the shores of the Volta Lake.
- The major crops grown in Kwahu Afram Plains Districts are annuals (Cassava, Yam, Maize, Sorghum, Groundnut, Watermelon, Tiger Nut and Soya bean)
- Harsh climatic conditions (i.e. drought, high temperatures and floods) and the associated pests, diseases and bush fires, as well as conflicts with livestock, place crops at increased risk and vulnerable to climate variability and change.
- Farmers' crop selections are limited by rainfall, duration of growing periods and cropping patterns, with annuals being the major crops grown (e.g. Cassava, Yam, Maize, Sorghum, Groundnut, Watermelon, Tiger Nut and Soya bean) and they are averse to making investments and production changes for fear of crop failures; they sometimes abandon crop farming for alternative livelihoods, such as charcoal production that can further aggravate the climate change impacts.
- Current activities to address climate change mainly relate to conservation agriculture (e.g. Zero tillage, contour bonding, mulching, crop rotation, cover cropping).

Future vulnerability:

- Projected yields indicate a decrease for some of the crops currently grown in the project area (e.g. Cassava, maize, groundnuts, rice).
- Farmers' crop selection and cultivation techniques will be guided by climate vulnerability issues; they will select short duration crops rather than long duration crops due to the limited water availability - Based on the climatic suitability analysis and considering short, medium and long cycles, cashew is the most suitable for all three cycles, while maize is most suitable for medium and long cycles.
- Climate change will force more farmers to adopt irrigation for crop production and they will need to build capacity in appropriate practices and push for public and private investment in more formal irrigation systems to complement the existing informal schemes; appropriate scheme design will enable cultivation of several crops at higher cropping intensities and increase crop yields - Scheme design should consider cropping patterns and crop-water requirements, as well as effective irrigation management for efficient irrigation scheduling.
- Farmer-Based Organisations (FBO) and Water User Associations (WUA) will be needed for sustainable management of the limited water resources and dissemination/adoption of appropriate information, inputs and credit facilities,

among others - Farmers will also need to undertake management of scheme facilities and maintenance of water infrastructure.

- The deteriorating condition of roads in the KAP and absence of crop storage infrastructure will continue to impact the transport of agricultural inputs and farm produce, and magnify the frequent glut and price fluctuations, which directly affect farmers' incomes.
- Farmers may resort to more extensive use of farm machinery for cultivation, to reduce the time spent in labour-intensive activities; tractors or power tillers and other farm machinery would be required for land preparations and other farm activities such as harvesting - Improved extension activities and demonstration farms would build the technical capacities of farmers along the crop production value chain.

5.2.3 Livestock Farming's Vulnerability to Climate Change

The study set out to generate baseline information on husbandry practices, assess the impacts of climate change on livestock feed, health and productivity, and evaluate the vulnerability of livestock to climate change. It was also to establish the effect of climate change on livestock activities, relationships between crops and livestock activities and the human/social consequences of the relationships between crops and livestock activities in KAPN and KAPS. The findings and the implications for investment in livestock activities in the districts are presented in this section.

Present-day livestock's vulnerability:

- The people of KAPN and KAPS belong to diverse ethnic groups. However, three ethnic groups, Akans, Ewes and Krachis were in the majority. Most of the livestock, in particular, are owed by members of these ethnic groups as well as the settled Fuanis, while herding is undertaken by Fulanis.
- On average, livestock farmers had over twenty years of experience in livestock keeping. Cattle, sheep, goat and poultry were the livestock species mostly kept, and cattle, sheep and pigs were the animals considered most important.
- Livestock rearing was prominent in the farming system in both districts and had significant implications for crop production. The production system was predominantly semi-intensive.
- Few farmer-herder conflicts were reported in the districts, particularly in KAPS. Occasionally, when they occurred it was due to crop damage or contamination of water bodies among others.
- Feed resources available to livestock included forages, crop residues, maize and cassava.
- There were no grazing reserves in the districts. However, two fodder banks had been converted into community cattle ranches, one in each district.
- Available water sources included bore - holes, pipe - borne water, the lake, rivers and streams.

- Health care infrastructure for livestock and veterinary care personnel in the districts were inadequate.
- Demarcated mobility corridors with water resources were not available, as such some cattle were herded close to crop farms with some veering into the farms and destroying crops.
- Climate change effects have worsened progressively over the last 30 years. Feed resources were found to be the most vulnerable followed by water. Drought was the most influential hazard in both districts, and bush fire was the second most influential hazard in KAPN.
- Climate change effects were expected to increase in severity in future if nothing is done to mitigate the effects.
- The top adaptation option in livestock production wtaas veterinary prophylaxis, and the prominence of water points use as an adaptation option differed in the two districts, being higher in the north than in the south.
- Animal rearing had both negative and positive impacts on the communities. Livestock generated money for use in crop farming and vice versa. Livestock provided manure for crop farming, while the droppings sometimes contaminated water bodies rendering them less safe for human use. The animals also damaged crops while searching for forage.

Future livestock's vulnerability:

- The two fodder banks not yet converted into ranches should be rehabilitated to hold community cattle. The broken down fences in the fodder banks should be mended and appropriate gates secured. The overgrown portions should be slashed to reduce the bush encroachment and pasture developed, dug-outs are to be de-silted, cattle holding areas set up and demarcated into camps of varying sizes to hold cattle herds.
- Establish grazing reserves with requisite facilities to provide feed and water to both cross-border and domestic transhumant cattle. Demarcated corridors of about 100 meters wide with water points to the grazing reserves should be provided to prevent straying of animals into crop farms thereby causing immeasurable financial loss to the farmers with associated humanitarian, social and health effects. Similarly, when animals have alternative water sources, they are less likely to use water sources patronised by humans and pollute them.
- Adequate veterinary personnel should be provided and interventions put in place to facilitate access to veterinary care since it is a key mitigating measure to counteract the increasing severity of animal diseases due to climate change.
- Boreholes usually dry up in the dry season; therefore, more sustainable sources of water should be provided in the communities for livestock use by exploiting water from the existing major water bodies such as the lake, rivers and streams. These will provide livestock with water year round and prevent contamination of community water bodies.

5.2.4 Socio-economic vulnerabilities to climate change

Present Day vulnerabilities:

- Both districts are highly dependent on the agriculture sector for livelihood security, the sector employs as high as 77.2% of the labour force in KAPSD and 74.5% in KAPND. On the average 55.9% of urban households in both locations engage in agriculture. Incidentally, livelihoods in this sector are the most at risk from the negative effect of climate related events. Males dominate in all key sectors of the economy except the commerce sector which has the majority of people engaged in that sector being female.
- The incidence of poverty in both districts is quite high, KAPSD records the highest incidence rate in the entire region at 59.7% whilst the rate for KAPND is 31.7%. Comparatively, the incidence of poverty is higher among females, for instance it is estimated that 70% of the people living in poverty in KAPND are females.
- Literacy rates in both districts are lower than the national average, with a rate of 59.5% for KAPND and 57.1% for KAPSD which is lower than the national estimated figure of 74.1%. Across gender, the literacy rate for males is higher in males than in females, for instance there is an 8% difference in favour of males in KAPND. This has an implication on women's ability to take up opportunities in the formal sector, take up leadership positions and participate in training activities.
- Current population density rates are low hence both male and female farmers indicate land availability for agricultural purposes. In addition to supporting cultivation on the family farm which is usually controlled by the male household head, most females keep personal farms to serve as a source of income. This however comes with an additional labour burden for female farmers because they provide labour on both farms. The workload burden is highest for females, about 66% of female's work in the two districts is unpaid work (domestic work; childcare, cooking, laundry, cleaning, collecting water and fuel etc) compared to 25% of the male's work. Females are paid 30-40% less than men for comparable work.
- The emerging trend of acquisition of large tracts of land (land grabbing) for agriculture, logging and other commercial activities is cited as having a negative effect on land security for agricultural purposes especially for migrant farmers.
- Heavy rainfall events worsen the state of poor road network that exists in the districts, this makes it difficult for farmers and traders to transport produce to the markets, resulting in post-harvest and income losses.
- In addition to crop cultivation, animal husbandry and fishing are equally sensitive to climate related events. The fishing sector is affected by increase in temperature and drought, these result in a drop in the water level at the lake and drives the fish into deep waters.
- The reduction in maize production results in limited availability for household consumption and income losses that affect ability to purchase food and meeting other household needs. The effect on yam production hits migrant farmers the hardest and results in significant income losses since yam production serves as a key income earner for the migrant households. Production losses on legumes and

vegetables leave female farmers the most affected, a greater proportion of these crops is sold to generate income to purchase food and other basic needs. Other pre-existing factors such as their limited access to extension information, a more challenging land acquisition process and limited access to credit puts female farmers and female headed households in a more vulnerable position.

- The analysis of adaptive capacity based on key variables such as financial, social and physical capital reflects a low adaptive capacity in both districts. Almost all these key variables are skewed in favour of men.

Future vulnerabilities:

- Trends like increasing population, limited diversification of the economy, practices such as excessive charcoal production and wood logging and emerging trends such as land "grabbing" will need to be addressed to contribute towards improving the adaptive capacity of residents of the two districts.
- Farmers in the Afram Plains are currently exposed to double climate change linked water stress situations. Agricultural production is affected by limited access to water due to late onset of rains and intermittent dry spells. The second situation they encounter is when there is excess water due to heavy rainfall events. Adaptation options should therefore consider both scenarios.
- The age dependency ratios for both districts are relatively higher than the national average based on the 2010 population census. The ratio for KAPND is 91 and 84.7 for KAPSD against a national average of 76. With existing high total fertility rates in both districts future climate related disruption of livelihood activities will further increase the dependency rate.
- Water harvesting infrastructure/technologies will not be successful at improving adaptive as a stand-alone intervention. There is a need to coordinate with other institutions to provide other requisite facilities e.g. improvements in the road network to facilitate movement of goods and services.
- As a key migrant destination, the two districts will continue to attract migrants especially when more economic opportunities are created. It is important to put in place measures to ensure the negative effects of migration is checked eg. high teenage pregnancy rates in both districts is attributed to migration. It is also important to ensure livelihood security of migrants for instance putting in place mechanisms that will ensure security of land tenure.

6 APPENDICES

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