GREEN CLIMATE FUND

Annex II
FEASIBILITY STUDY

Climate-resilient landscapes for sustainable livelihoods in northern Ghana

March 2025

Contents

Acronyms and abbreviations

AAESCC	Adaptation of Agro-Ecosystems to Climate Change
AAP	Africa Adaptation Programme
AFAWA	Program on Affirmative Finance Action for Women in Africa: Financing Climate Resilience Agricultural Practices in Ghana
AfDB	African Development Bank
ALP	Adaptation Learning Programme
AMCOW	African Ministers Council on Water
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CCA	Climate change adaptation
CCV	Climate change vulnerability
CEMC	Community Environmental Management Committee
CHANGE	Climate Change Adaptation in northern Ghana Enhanced
CRA	Climate-resilient agriculture
CHPS	Community Health Planning and Services
CSK	Climate Seed Knowledge
DA	District Assembly
DANIDA	Danish International Development Agency
DEMC	District Environmental Management Committee
DFATD	Department of Foreign Affairs, Trade and Development
DoA	Department of Agriculture
DRR	Disaster risk reduction
EbA	Ecosystem-based Adaptation
ECCU	Environment and Climate Change Unit
ECOWAP	Regional Agricultural Policy for West Africa
ECOWAS	Economic Community of West African States
EPA	Environmental Protection Agency
FASDEP	Food and Agriculture Sector Development Policy
FBO	Farmer-based organisation
GAIP	Ghana Agricultural Insurance Programme
GASIP	Ghana Agricultural Sector Investment Programme
GDP	Gross Domestic Product
GEMP	Ghana Environmental Management Project
GIZ	German Federal Ministry for Economic Cooperation and Development
GMA	Ghana Meteorological Agency
GMet	Ghana Meteorological Agency
GNI	Gross National Income
GOG	Government of Ghana
GRRIP	Ghana Rural Resilience and Innovations Project
GSGDA	Ghana Shared Growth and Development Agenda
GSIF	Ghana Strategic Investment Framework
GSIF	Ghana Strategic Investment Framework for Sustainable Land Management
GTZ	German Technical Cooperation
IFAD	International Fund for Agricultural Development
IIPACC	Innovative Insurance Products for the Adaptation to Climate Change
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
LFI	Local financial institution
MDAs	Ministries, Departments and Agencies
MESTI	Ministry of Environment, Science, Technology and Innovation
METASIP	Medium-Term Agriculture Sector Investment Plan
MoF	Ministry of Finance

MoFA	Ministry of Food and Agriculture
NAP	National Action Programme
NAP-CCD	National Action Programme to Combat Drought and Desertification
NCCAS	National Climate Change Adaptation Strategy
NCCP	National Climate Change Policy
NEP	National Environment Policy
NGO	Non-governmental organisation
NR	Northern Region
PDO	Programme Development Objective
PET	Potential evapotranspiration
PICS	Purdue Improved Crop Storage
RAINS	Regional Advisory and Information Network Systems
REMC	Regional Environmental Management Committee
RLSL	Resilient Landscapes for Sustainable Livelihoods
SARI	Savanna Agricultural Research Institute
SCCF	Special Climate Change Fund
SLWMP	Sustainable Land and Water Management Project
TAI	Trade Aid Integrated
TCP	Tree Crops Policy
ToT	Training of Trainers
TUDRIDEP	Tumu Deanery Regional Integrated Development Programme
UER	Upper East Region
UNDP CO	UNDP Ghana country-office
UNFCCC	United Nations Framework Convention on Climate Change
UWR	Upper West Region
VBA	Volta Basin Authority
VSLA	Village Savings and Loans Associations
WACDEP	Water, Climate and Development Project
ZECC	Zero Energy Cooling Chambers

1 Background of Ghana

1.1 Introduction to Ghana

The Republic of Ghana — hereafter referred to as Ghana — is a West African country situated along the Gulf of Guinea of the Atlantic Ocean (**Figure 1**). In March 1957, Ghana gained independence from colonial rule, becoming the first sub-Saharan country to do so. With a population of ~34.2 million people[1], Ghana is the 48th most populous country in the world. Over the next century, the country's population is projected to nearly triple in size, reaching ~73 million people by 2100[2]. Ghana covers an area of ~238,535 km^2 and is bordered by Burkina Faso to the north, Côte d'Ivoire to the west and Togo to the east (**Figure 1**). The administrative divisions of Ghana comprise 16 regions — divided into metropolitan, municipal and ordinary assemblies, forming a total of 216 districts (**Figure 1**).

Within the district level, several types of councils exist, including town and area councils, zonal councils and unit committees. For the purposes of this feasibility study — and for the climatic, agro-ecological, social development and economic reasons described in the sections below — the administrative regions of Ghana are partitioned into the northern regions (including the North East, Northern, Savannah, Upper East and Upper West Regions) and southern regions (including the Ahafo, Ashanti, Bono, Bono East, Central, Eastern, Greater Accra, Volta, Oti, Western and Western North Regions). Project sites are located in the North East, Upper East and Upper West Regions.

Several of these sixteen administrative regions were created in 2020 — the North East, Northern and Savannah Regions replaced the pre-2020 Northern Region, the Ahafo, Bono and Bono East Regions replaced the Brong-Ahafo Region, the Volta and Oti Regions replaced the pre-2020 Volta region, and the Western and Western North Regions replaced the pre-2020 Western Region. As much of the climate modelling work for this Feasibility Study occurred before the administrative changes, and because of a lack of statistics disaggregated by Ghana's current regions, the ten pre-2020 regions are frequently referred to in this document.

1.2 Climate profile

The climate of Ghana is primarily influenced by the annual north-south movement of the Intertropical Convergence Zone (ITCZ) across the country. The ITCZ is characterised by an area of calm winds that creates a boundary between the warm, moist winds of the West African Monsoon in the southwest of Ghana and the dry, hot and dusty winds (the Harmattan) in the northeast. The location of the ITCZ oscillates on an annual basis, reaching its northernmost extent from June to September and its southern-most extent from January to March (Figure 2). The movements of the ITCZ and West African Monsoon creates distinct temperature and rainfall regimes in northern and southern Ghana.

While the southern regions of Ghana experience a bimodal equatorial rainfall pattern that allows for two annual growing seasons — the major and minor growing seasons — the northern regions have a unimodal tropical monsoon that only allows for a single growing season each year, namely the major season (Figure 3). The two rainfall seasons of southern Ghana (Figure 3) correspond to the northern and southern passages of the ITCZ across the region. In the north, the single rainfall season occurs when the ITCZ is in its northern position and the dry season prevails when the Harmattan wind blows north-easterly. As a result of the

[1] In 2023; Available from http://data.worldbank.org/country/ghana
[2] United Nations Department of Economic and Social Affairs, Population Division – 2015 – World Population Prospects: The 2015 Revision.

unimodal rainfall pattern, the northern regions experience more dry months — a longer dry season — and higher rainfall seasonality than the southern regions (Table 1). The northern regions also receive less rainfall per annum than the southern regions (Figure 5; Table 1), ~300 mm less per year on average.

Figure 1. Administrative map of Ghana, showing the 16 administrative regions including the project Regions North East, Upper East and Upper West.

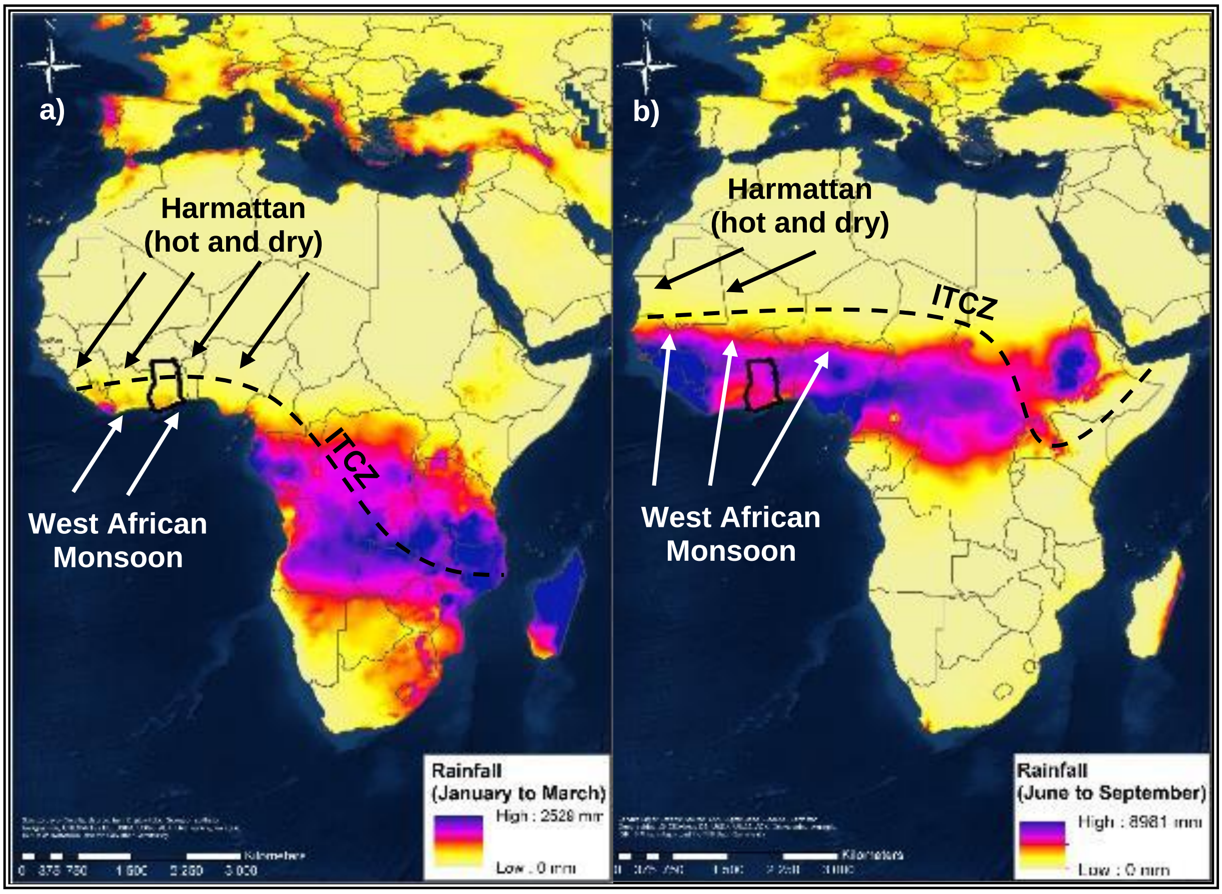

Figure 2. The interaction between Harmattan wind stream and West African Monsoon from: a) January to March; and b) June to September[3]. Ghana is shown in bold.

Across Ghana, mean monthly temperatures are highest from February to April (ranging from ~27℃ in the south to ~32℃ in the north) and lowest from July to September (~19℃ in the south to ~27℃ in the north) (Figure 4). While the mean minimum temperatures only vary slightly across the country (Figure 5; Table 2) because of the proximity of the equator and the absence of high-altitude areas, mean maximum temperatures differ substantially (Figure 5; Table 2). On average, in the northern regions, the mean maximum annual temperature is ~3℃ (10%) higher than the south (Figure 5; Table 2). Additionally, the northern regions experience high daily ranges in temperature and extreme temperature seasonality (Table 2). The high temperatures that occur from February to March in northern Ghana coincide with the dry season and the hot, dry Harmattan winds that blow in from the Sahara Desert.

Potential evapotranspiration (PET) — the amount of evapotranspiration that would occur if there were no limits on the available water supply[4] — varies across Ghana and is highest in the three northern regions (Table 3). As the northern regions also have the lowest mean annual rainfall, the annual moisture index — i.e. mean annual rainfall divided by PET — is lowest in the north (Table 3). With a mean annual moisture index of <0.50, the Upper East Region is considered the driest region of Ghana (Table 3).

[3] Rainfall data available from www.worldclim.org.
[4] Encyclopaedia Britannica. 2019. Potential evapotranspiration. Available at: https://www.britannica.com/science/potential-evapotranspiration. Accessed on 8 October 2019.

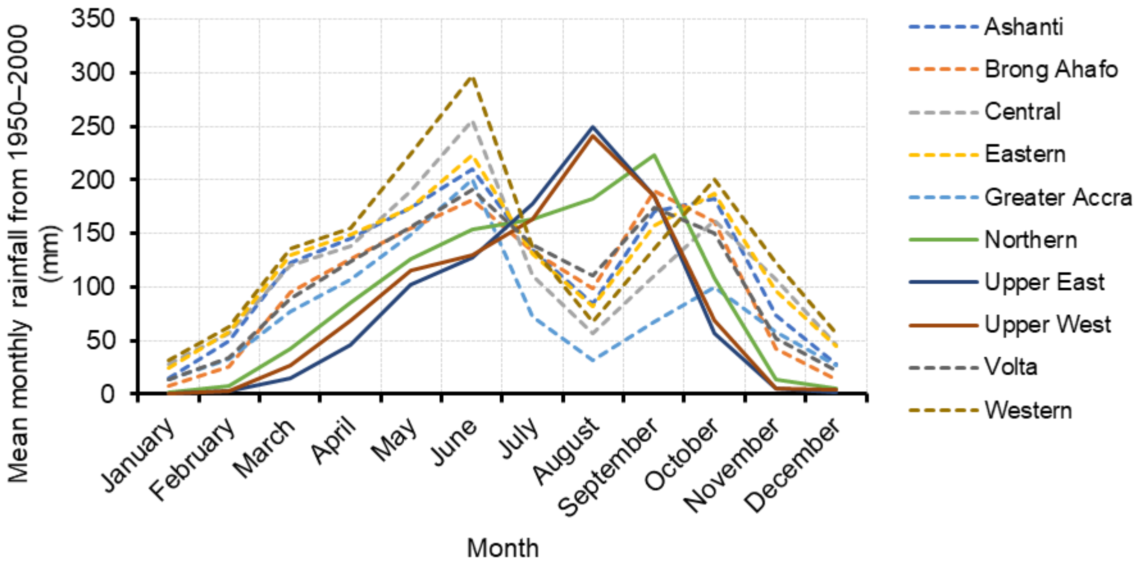

Figure 3. Current (1950–2000) mean monthly rainfall for the regions of Ghana. Bold lines indicate northern regions, whereas dashed lines represent southern regions[5].

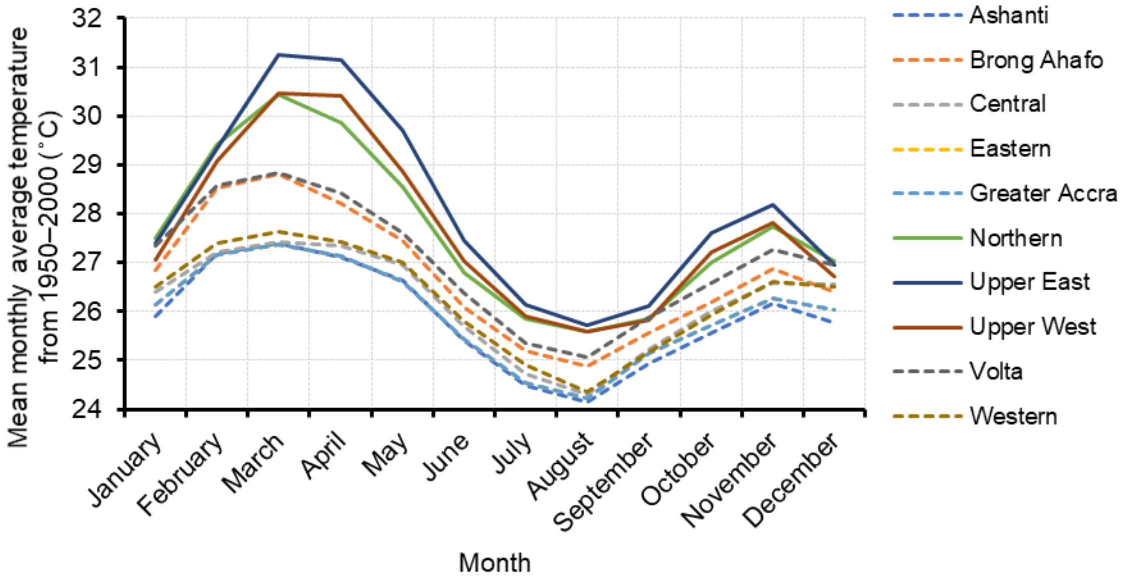

Figure 4. Current (1950–2000) mean monthly average temperatures for the regions of Ghana. Bold lines indicate northern regions, whereas dashed lines represent southern regions[6].

[5] Rainfall data available from www.worldclim.org.
[6] Temperature data are from www.worldclim.org.

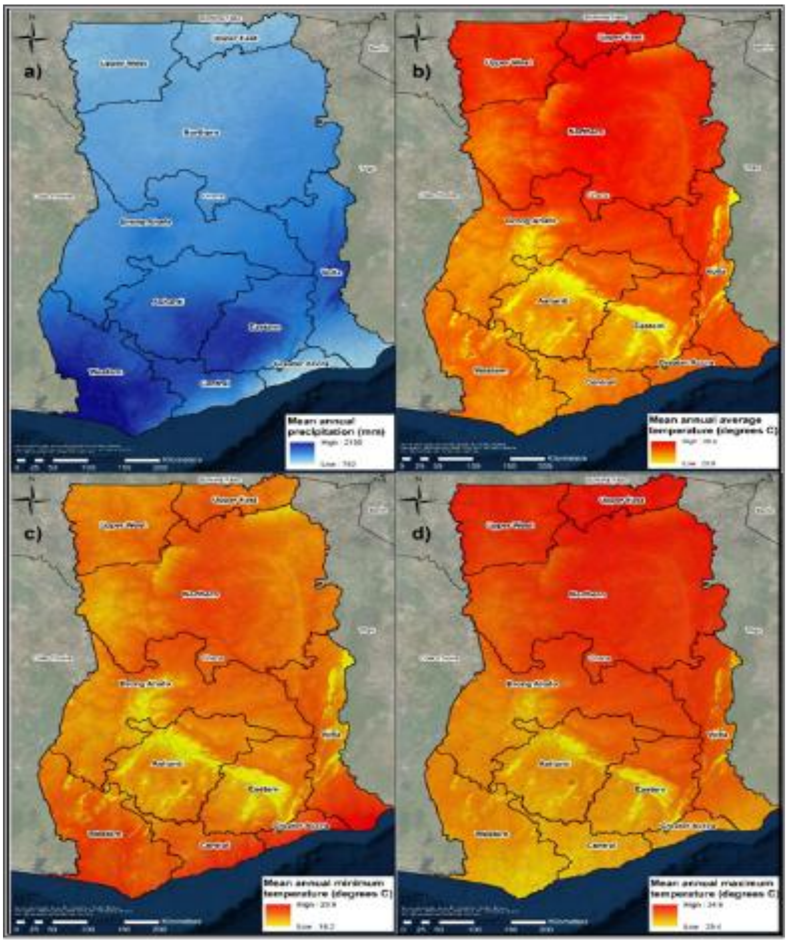

Figure 5. Maps of: a) mean annual rainfall; b) mean annual average temperature; c) mean annual minimum temperature; and d) mean annual maximum temperature for Ghana[7].

Table 1. Current (1950–2000) rainfall characteristics of the 10 regions of Ghana[8]. The colour scale relates to the values for each climatic variable. The bold border indicates the northern regions.

Administrative regions	Mean annual rainfall (mm)	Mean rainfall in wettest month (mm)	Mean rainfall in driest month (mm)	Mean number of dry months	Mean rainfall seasonality[9] (mm)
Ashanti	1,389	210	15	3	62.8
Brong Ahafo	1,230	198	7	4	64.9
Central	1,381	255	29	3	64.1
Eastern	1,454	223	25	3	59.7
Greater Accra	936	200	14	5	52.5
Northern	1,112	226	2	6	76.0
Upper East	970	249	1	7	82.7
Upper West	1,013	242	1	7	79.2
Volta	1,256	209	14	4	63.9
Western	1,624	296	31	2	76.0
Ghana	1,247	228	11	5	70.0

[7] All climate data are from www.worldclim.org.
[8] Climate estimates are based on the WorldClim database (www.worldclim.org).
[9] Rainfall seasonality is the standard deviation over monthly rainfall values.

Table 2. Current (1950–2000) mean temperature characteristics of the 10 regions of Ghana[10]. The colour scale relates to the values for each climatic variable. The bold border indicates the northern regions.

Administrative regions	Mean annual average temperature (°C)	Mean annual minimum temperature (°C)	Mean annual maximum temperature (°C)	Mean daily range in temperature (°C)	Temperature seasonality[11] (°C)
Ashanti	25.8	21.0	30.7	9.6	10.2
Brong Ahafo	26.7	21.6	31.2	10.3	12.4
Central	26.2	22.3	30.0	7.7	10.0
Eastern	25.9	21.1	30.9	9.8	9.8
Greater Accra	26.8	22.8	30.8	7.9	11.8
Northern	27.6	21.9	33.3	11.4	15.7
Upper East	28.0	22.0	34.2	12.2	18.1
Upper West	27.6	21.7	33.6	11.9	16.4
Volta	27.0	21.9	32.1	10.1	11.9
Western	26.2	22.2	30.3	8.1	10.2
Ghana	27.0	21.8	32.1	10.3	13.1

Table 3. Current (1950–2000) evapotranspiration and moisture index characteristics of the 10 regions of Ghana[12]. The colour scale relates to the values for each climatic variable. The bold border indicates the northern regions.

Administrative regions	Mean Potential Evapotranspiration (mm)[13]	Mean Annual Moisture Index[14]
Ashanti	1,662	0.82
Brong Ahafo	1,743	0.69
Central	1,502	0.88
Eastern	1,681	0.86
Greater Accra	1,540	0.58
Northern	1,862	0.58
Upper East	1,931	0.47
Upper West	1,893	0.51
Volta	1,741	0.70
Western	1,544	1.01
Ghana	1,750	0.70

1.3 Agro-ecological zones of Ghana

Spatial variation in climate — as well as soil properties — influences ecological processes across Ghana. Based on the climate- and soil-induced differences in vegetation, Ghana is divided into six agro-ecological zones (Figure 6). Savanna zones are found in the northern regions, while transition and forest zones are found in the southern regions.

[10] Climate estimates are based on the WorldClim database (www.worldclim.org).
[11] Temperature seasonality is the standard deviation over monthly temperature values.
[12] Climate estimates are based on the WorldClim database (www.worldclim.org).
[13] Potential evapotranspiration was calculated using Hargreave's 1985 method.
[14] The moisture index is calculated by dividing mean annual rainfall by potential evapotranspiration.

1.3.1 Sudan Savanna

The Sudan Savanna Zone is located in the north-eastern corner of Ghana, with the majority of the zone located in Burkina Faso and Mali. It is characterised by fire-swept short grasses interspersed with low-density woodland. Grass cover is low, and some areas of land are bare and severely eroded. The Sudan Savanna Zone receives the least rainfall of Ghana's agro-ecological zones (~940 mm per annum) and only one rainfall season.

1.3.2 Guinea Savanna

The Guinea Savanna Zone (or Interior Savanna Zone) is located north of the Transitional Zone and is the largest agro-ecological zone in Ghana, covering the northern half of the country. The zone is characterised by wooded grassland, consisting of a ground cover of grasses of variable height, interspersed with fire-resistant, deciduous, broad-leaved trees. In general, tree cover and height decreases from south to north along a gradient of decreasing rainfall. The Guinea Savanna Zone receives ~1,100 mm of rainfall per year, mostly during one rainfall season.

1.3.3 Transitional Zone

The Transitional Zone represents the transition from Guinea Savanna in the northern parts of Ghana to forest in the south. The tree species found in the Transitional Zone are similar to those in the forest zones further south and occur with grasses of tall and medium height. This zone is encroaching into southern forest zones as grassland replaces forest. Average annual rainfall is ~1,250 mm and generally occurs in two rainfall seasons.

1.3.4 Deciduous Forest

The Deciduous Forest Zone incorporates two forest types, namely moist semi-deciduous forest and dry semi-deciduous forest. It is further separated into two subtypes: the wetter inner zone and the drier fire zone. The opening of the forest canopy for farming has resulted in severe degradation of the original high forest of the fire zone. Invasion of savanna species into the Deciduous Forest Zone has resulted in the occurrence of clearings of savanna. Average annual rainfall is ~1,400 mm and occurs in two rainfall seasons.

1.3.5 Evergreen Forest

The Evergreen Forest Zone is located in the southwestern corner of Ghana. The forest types are wet evergreen — occurring in the south westernmost corner of the country — and the moist evergreen in the more northern parts. The Evergreen Forest Zone receives the most rainfall of the agro-ecological zones of Ghana — with an annual average of ~1,700 mm — occurring in two rainfall seasons.

1.3.6 Coastal Savanna

The Coastal Savanna Zone is located along a narrow belt parallel to the coast. It comprises a thin strip of vegetation along the seashore, mangrove vegetation associated with lagoons and coastal estuaries, as well as inland vegetation consisting of shrubs, grasses and scattered trees. Average annual rainfall is ~1,000 mm and occurs in two rainfall seasons. The rainfall in the southeastern corner of the zone is the lowest in Ghana.

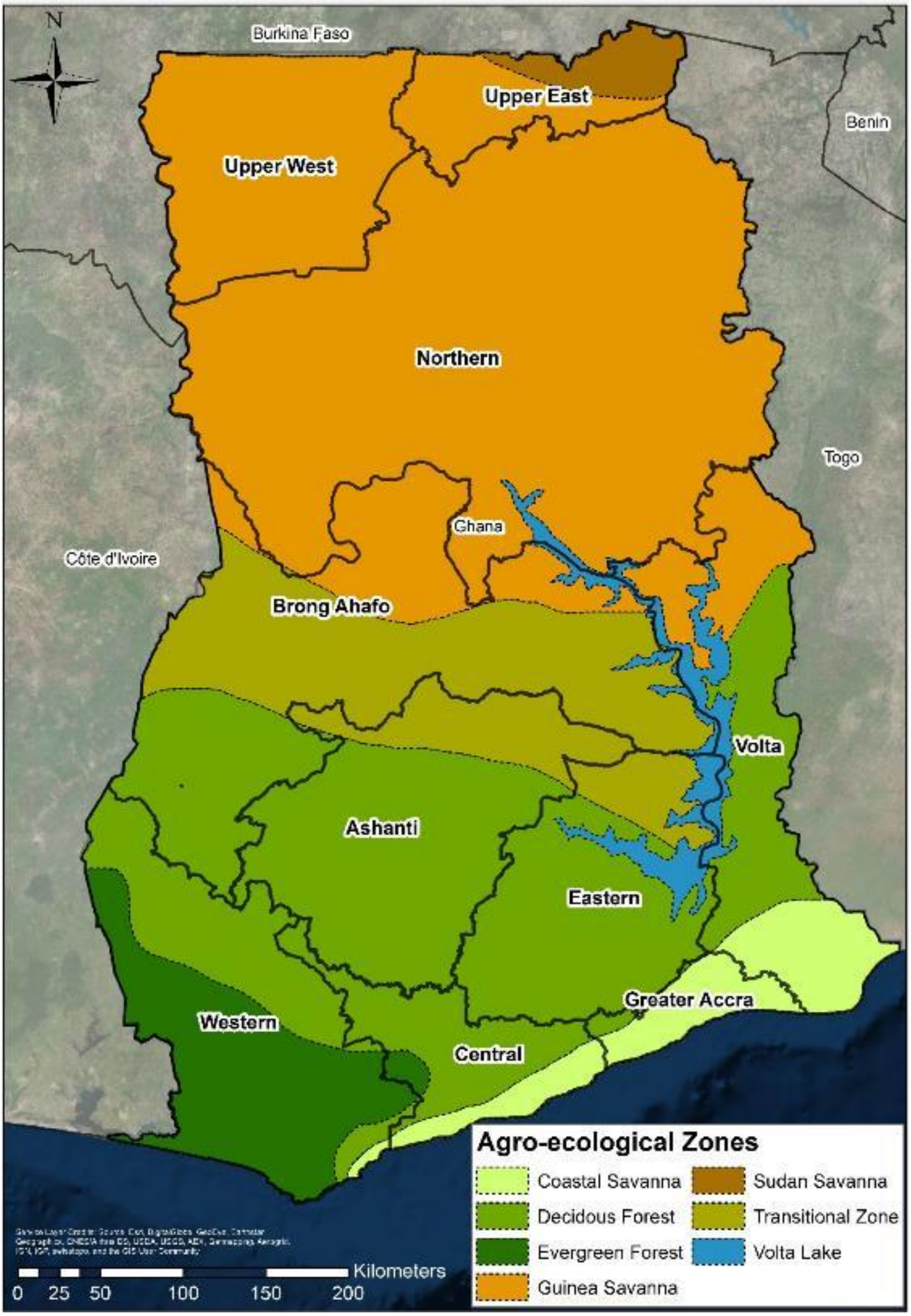

Figure 6. Agro-ecological zones of Ghana.

1.4 Economy, livelihoods, land degradation and poverty

1.4.1 Economic background

Ghana's economy has experienced consistent growth over the past five decades, with the Gross Domestic Product (GDP) increasing from ~US$1.2 billion in 1960 to a peak of ~US$24.8 billion by the end of 2024[15] . The enhanced growth observed during the period 2000–2011 allowed the country to attain lower-middle-income status in 2010 — a decade earlier than expected — with a Gross National Income (GNI) per capita of US$1,260[16]. Ghana's economic output has continued to rise, with nominal GDP reaching approximately GHS 331.2 billion by the end of 2024[17]. The country's real GDP grew by an average of 6.3% over the first three quarters of 2024 — a marked increase from 2.6% during the same period in 2023-driven by strong performances in both the oil and non-oil sectors[18]. For 2024, overall GDP growth is estimated at 5.7%, with non-oil GDP growing by 6.0%[19].

As one of the few countries in West Africa with lower-middle-income status, Ghana is considered an economic leader in the region and is an influential member of the Non-Aligned Movement, the African Union, the Economic Community of West African States (ECOWAS), Group of 24 and the Commonwealth of Nations.

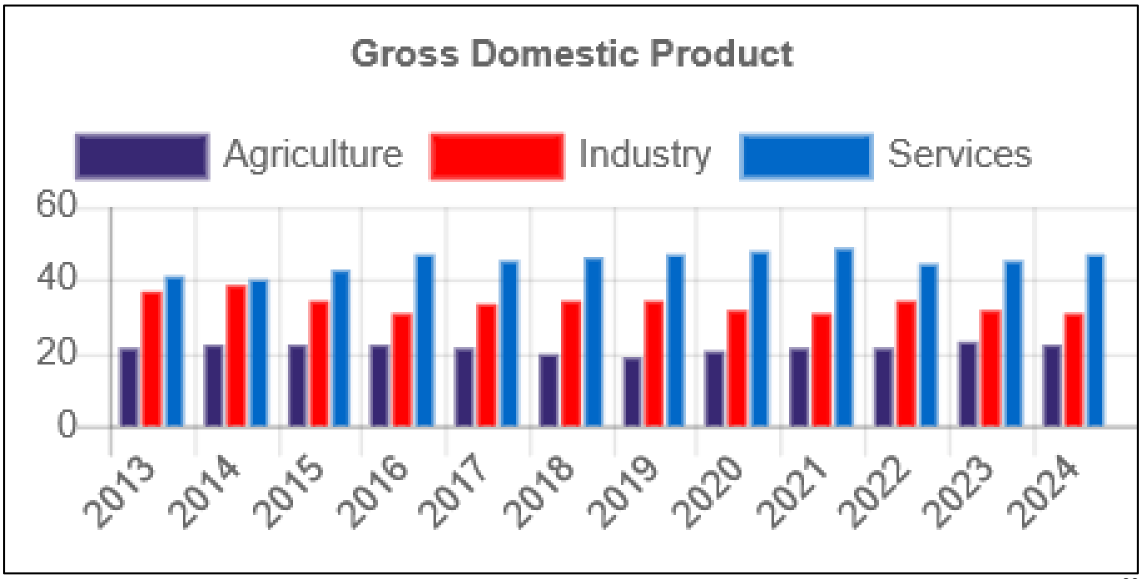

Figure 7. Ghana's sectoral share of GPD (agriculture, industry and services sectors) between 2013–2024[20].

As Ghana's economy matured over the past 50 years, there has been a noticeable shift from a primarily agrarian towards a services-based economy. The services sector has replaced the agriculture sector as the highest contributor to GDP, accounting for ~49% of the country's GDP in Q4 2024[21]. With increased exports in commodities such as gold, bauxite, manganese

[15] Bank of Ghana. 2025. Summary of Economic and Financial Data. Available at https://www.bog.gov.gh/wp-content/uploads/2025/03/Summary-of-Economic-and-Financial-Data-March-2025.pdf
[16] Calculated using the World Bank Atlas method.
[17] The Public Relations Unit, Ministry of Finance. 2024. Ghana's Economic Surge: Q3 2024 Growth Outpaces Expectations. Available at https://www.mofep.gov.gh/news-and-events/2024-12-12/ghanas-economic-surge-q3-2024-growth-outpaces-expectations
[18] The Public Relations Unit, Ministry of Finance. 2024. Ghana's Economic Surge: Q3 2024 Growth Outpaces Expectations. Available at https://www.mofep.gov.gh/news-and-events/2024-12-12/ghanas-economic-surge-q3-2024-growth-outpaces-expectations
[19] Bank of Ghana. 2025. Summary of Economic and Financial Data. Available at https://www.bog.gov.gh/wp-content/uploads/2025/03/Summary-of-Economic-and-Financial-Data-March-2025.pdf[19]
[20] Ghana Statistical Services,. 2024. Sectoral Share of GDP. Available at https://www.statsghana.gov.gh/gdpgraph.php?graphindicators=MTE4NzYxMzkxNi45NDI1/gpdgraph/49pp7266p8
[21] 21 Bank of Ghana. 2025. Summary of Economic and Financial Data. Available at https://www.bog.gov.gh/wp-content/uploads/2025/03/Summary-of-Economic-and-Financial-Data-March-2025.pdf

and diamond — and recently oil and gas — the industry sector has also surpassed the agriculture sector in terms of contribution to GDP, with a contribution of ~31% in Q4 2024.

The agriculture sector, however, still accounts for ~19% of GDP[22] and employs ~40% of Ghanaians compared with the ~41% provided by the services sector and ~19% by the industry sector[23]. The agriculture sector, therefore, remains an important source of income and employment in Ghana. The portion of the agriculture industry comprising crop production — with significant contributions from cocoa production — continues to be the single largest contributing subsector to the economy of Ghana, accounting for ~87% of agricultural GDP in Q4 2024[24].

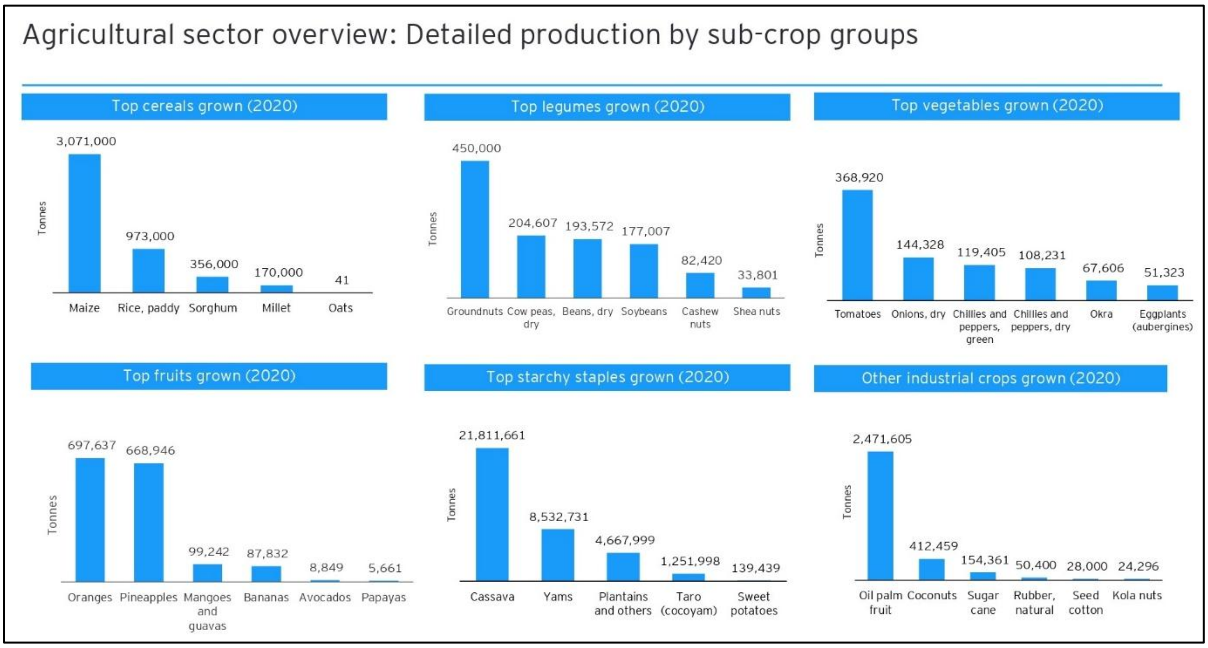

Figure 8. Ghana's agricultural sector production by sub-crop groups for 2020[25].

1.4.2 Agricultural and natural resource-based livelihoods

Approximately 155,000 km^2 (~65%) of Ghana’s total land area is classified as suitable for agriculture[26]. Of this land, 78,500 km^2 is under cultivation and only 300 km^2 is irrigated[27]. In 2022, the agricultural sector employed ~37% of the total labour force of Ghana (Table 4). Agriculture as a livelihood option is most popular in the northern regions of the country and least popular in Greater Accra (Table 4).

[22] Ghana Statistical Services. 2025. Statistical Newsletter: Gross Domestic Product Fourth Quarter 2024. Available at https://www.statsghana.gov.gh/gssmain/fileUpload/National%20Accounts/Newsletter_Quarterly_GDP_2024_Q4_March_2025%20Edition_GSS.pdf
[23] O’Neill A. 2025. Employment by economic sector in Ghana 2022. Statista. https://www.statista.com/statistics/447530/employment-by-economic-sector-in-ghana/
[24] Ghana Statistical Services. 2025. Statistical Newsletter: Gross Domestic Product Fourth Quarter 2024. Available at https://www.statsghana.gov.gh/gssmain/fileUpload/National%20Accounts/Newsletter_Quarterly_GDP_2024_Q4_March_2025%20Edition_GSS.pdf
[25] Ghana Investment Promotion Centre. 2022. Ghana’s Agricultural Sector Report. Available at https://www.gipc.gov.gh/wp-content/uploads/2023/03/Ghanas-Agriculture-Sector-Report-1.pdf
[26] CountryStat: Food and agriculture data network. Available from http://www.countrystat.org/home.aspx?c=GHA.
[27] Ibid

Table 4. Agricultural employment in Ghana[28]. The bold values indicate the project regions.

Administrative Region	Total labour force	Agricultural labour force	Agricultural relative to total labour force (%)
Ahafo	219,364	134,546	61.3
Ashanti	1,857,890	467,299	25.2
Bono	471,087	279,188	59.3
Bono East	509,691	302,501	59.4
Central	1,030,014	365,691	35.5
Eastern	1,095,588	388,831	35.5
Greater Accra	2,006,783	61,694	3.1
North East	**230,889**	**169,446**	**73.4**
Northern	768,423	436,797	56.8
Oti	331,900	239,199	72.1
Savannah	217,802	155,707	71.5
Upper East	**457,821**	**248,421**	**54.3**
Upper West	**303,785**	**166,772**	**54.9**
Volta	598,675	208,195	34.8
Western	784,883	290,885	37.1
Western North	330,729	229,122	76.2
Total	11,215,323	4,144,294	37.0

Cocoa is Ghana's principal agricultural export and is commercially produced in the forested areas of the Ashanti, Brong-Ahafo, Central, Eastern, Western and Volta Regions[29]. Ghana is the world's second-largest exporter of cocoa, having exported ~US$2,220 million worth of cocoa beans in 2010. However, cocoa production and exports reached a peak of $1.04 million tonnes in 2021 but has since declined – in 2024, cocoa output was measured at 650,00 – 700,000 tonnes and export revenues fell to $1.7 billion, the lowest in 15 years[30]. However, cocoa remains a major expert commodity, generating foreign exchange and employing around 800,000 farm families across 10 regions. It is Ghana's third-largest source of foreign exchange after gold and oil[31].

Cocoa production accounts for ~6% of the agricultural sector's contribution to Ghana's GDP and ~3% of overall GDP[32]. Approximately 80% of national agricultural output is produced by non-commercial, smallholder[33] farmers who rely on rudimentary technologies to manage their lands. These farmers cultivate a variety of food crops to meet their nutritional and income needs. Popular crops include: i) roots and tubers such as cassava, cocoyam and yam; ii) cereals like maize, millet, sorghum and rice; iii) legumes such as groundnuts and beans[34]; and iv) plantain. Ghana is the world's sixth-largest producer of cassava, producing nearly 25.6 million metric tons in 2022. Approximately 90% of Ghana's cassava crop is produced and consumed by smallholder farmers.

[28] Ghana Statistical Service. 2023. Ghana Annual Household Income and Expenditure Survey: Quarter 3 2022 Labour Statistics Report. Available at: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/AHIES%20QUARTER%203%202022%20LABOUR_STATISTICS_REPORT.pdf. Accessed on 8 April 2025.
[29] Ghana Statistical Service – 2011 – Ghana's Economic Performance in 2010.
[30] Taylor J, Beillard MJ & Galloway JD. 2025. Ghana - Cocoa Sector Overview – 2025. Available at https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Ghana+-+Cocoa+Sector+Overview+-+2025_Accra_Ghana_GH2025-0008.pdf
[31] Taylor J, Beillard MJ & Galloway JD. 2025. Ghana - Cocoa Sector Overview – 2025. Available at https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Ghana+-+Cocoa+Sector+Overview+-+2025_Accra_Ghana_GH2025-0008.pdf
[32] Taylor J, Beillard MJ & Galloway JD. 2025. Ghana - Cocoa Sector Overview – 2025. Available at https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Ghana+-+Cocoa+Sector+Overview+-+2025_Accra_Ghana_GH2025-0008.pdf
[33] Farms <2 hectares in size.
[34] Ministry of Food and Agriculture – 2011 – Agriculture in Ghana: Facts and figures.

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In the agricultural sector of Ghana, gender dynamics shape the responsibilities and contributions of men and women across numerous communities in northern Ghana. These dynamics are evident in the distinct division of labour, access to resources and the economic roles that men and women occupy within their respective communities. For example, in the Upper West Region, agricultural work in the Tuggoh community is divided along gender lines, with men taking on physically demanding tasks such as land preparation, while women focus on planting, sowing and compost production. Women also support men's work by collecting water and preparing food during land preparation activities. However, their involvement in certain types of crop cultivation, such as yams, is limited due to the physical demands of the task. Additionally, women are often responsible for selling agricultural produce at local markets, but they must first seek permission from their husbands or elders, highlighting the influence of gender norms on economic activities[35]. Section 5.1. in Annex 8: Gender Assessment and Action Plan provides a more detailed discussion of the intersection of gender and agriculture in the target areas.

The primary farming tools used by smallholder farmers are the hoe and cutlass, and mechanised farming is uncommon. Few smallholder farmers have access to irrigation infrastructure and as a result are highly dependent on rain for their livelihoods. Farmers in Ghana primarily use two farming systems to manage their agricultural land, namely bush fallow and continuous cropping[36]. The bush fallow system involves the rotation of land between natural vegetation and crops. Using this system, farmers cultivate an area of land for several years, then temporarily abandon the land and clear and cultivate a natural area. In Ghana, natural areas of vegetation are often cleared using slash and burn techniques. The abandoned land is left uncultivated for several years to allow the fertility of depleted soils to replenish naturally. In the past, this period of abandonment lasted approximately 15 years, allowing for natural regeneration of vegetation and an increase in soil quality. Recently, however — as a result of increasing human populations and a subsequent shortage of suitable land — the fallow period has shortened to less than five years[37]. Consequently, land degradation in Ghana is extensive and smallholder farmers are achieving significantly reduced crop yields compared with the past.

Contrary to the fallow system, the continuous cropping system is a technique that involves intense, long-term cultivation with no land rotation. Farmers may introduce mono- or polyculture techniques into the continuous cropping system, and livestock — including cattle, goats and chickens — are often integrated into farming activities. This practice is known as mixed crop-livestock production. Traditional fertilisers such as organic household refuse and livestock manure are often used to maintain soil fertility. In both the fallow and continuous cropping systems, augmenting incomes from farming through intercropping with cash crops and economically important trees is common. For the majority of smallholder farmers in Ghana, farming is both a source of food security[38] and household income.

Livestock farming plays a major role in the maintenance of food security and income-generation for smallholder farmers in Ghana. The important livestock industries in the country include: i) small ruminants — including goats and sheep; ii) cattle; and iii) pigs. Poultry (chicken) is also farmed[39] (Figure 9). Of these, the poultry industry, which is located

[35] Annex 7h: stakeholder engagement plan.
[36] Barry, B., E. Obuobie, M. Andreini, W. Andah, and M. Pluquet. 2005.The Volta River Basin: Comprehensive assessment of water management in agriculture. International Water Management Institute.
[37] Barry, B., E. Obuobie, M. Andreini, W. Andah, and M. Pluquet. 2005. The Volta River Basin: Comprehensive assessment of water management in agriculture. International Water Management Institute.
[38] Maize provides 20% of caloric intake in smallholder farming communities.
[39] http://www.fao.org/ag/agp/agpc/doc/counprof/ghana/Ghana.htm#4. RUMINANT LIVESTOCK SECTOR

predominantly in Ghana's southern region, has the highest rate of production[40]. In terms of livestock, production is distributed across the rest of the country as follows: i) cattle in the Northern Savanna zones; ii) pigs in the Accra and Ashanti Regions; and iii) sheep and goat production throughout all of Ghana[41].

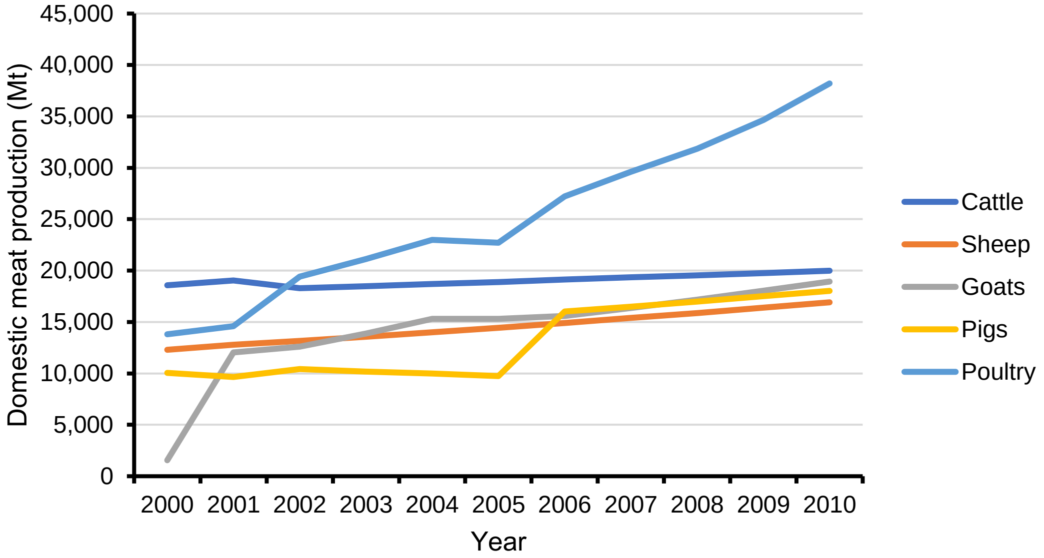

Figure 9. Domestic meat production in Ghana from 2000–2010[42].

Statistics show that 41% of Ghana's rural population keep some form of livestock. This implies that ~6 million rural households partly depend on livestock for their livelihoods[43]. Smallholder livestock production — particularly in the northern regions of Ghana[44] — is stimulated by increasing demand for meat and other livestock products. This increasing demand for livestock products in Ghana and the integration of the country's economy into global markets provides new opportunities to small-scale livestock producers[45]. Recent increases in livestock and poultry production (Figure 9) can be attributed to the Ministry of Food and Agriculture's (MoFA) productivity improvement interventions. Successful interventions include *inter alia* the supply of improved livestock breeds to farmers, sustainability of credit-in-kind projects — particularly those focused on pigs and small ruminants — and the cockerel programme[46,47]. In addition, investments in veterinary services — especially improved disease control mechanisms — and strengthened capacity of community livestock workers have ensured that the gains made by production interventions are sustained[48].

[40] http://www.letstalkagric.com/livestock-farming/livestock-farming-ghana-information-guide
[41] http://www.letstalkagric.com/livestock-farming/livestock-farming-ghana-information-guide
[42] Data are from: Ministry of Food and Agriculture – 2011 – Agriculture in Ghana: Facts and figures.
[43] Ghana Statistics Service (GSS). 2012. 2010 Population and Housing Census: Summary Report of Final Results. Sakoa Press Limited, Accra, Ghana. Available at: http://www.statsghana.gov.gh/docfiles/2010phc/Census2010_Summary_report_of_final_results.pdf
[44] Upper East, Upper West and Northern Regions.
[45] FAO. 2012. Livestock sector development for poverty reduction: an economic and policy perspective – Livestock's many virtues. Rome. Available at: http://www.fao.org/docrep/015/i2744e/i2744e00.pdf
[46] Programme run by the Ghananian Ministry of Food and Agriculture that supplies improved breeds of cockerels, vaccinated at day old against major poultry diseases, to selected beneficiary farmers at a subsidised price. The objectives of the programme are to enhance food security, increase intake of animal protein as well as the income earning capacity of rural dwellers particularly women with the view to reducing poverty among small scale poultry farmers. It is also designed to meet the country's meat deficit and introduce farmers into commercial poultry production.
[47] MoFA. 2014. Agric Sector Annual Progress Report. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/PUBLICATIONS/2016/02/27/Ministry+of+Food+and+Agriculture_APR_2014.pdf
[48] MoFA. 2014. Agric Sector Annual Progress Report. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/PUBLICATIONS/2016/02/27/Ministry+of+Food+and+Agriculture_APR_2014.pdf

Ghana currently produces only ~30% of its national demand for meat, of which northern Ghana supplies 70%[49]. The primary reason for the north's domination of the country's livestock product market is the good grazing available in the grassland areas of the Guinea Savanna agro-ecological zone, which is highly conducive to livestock farming[50]. Local meat production is supplemented by imports from neighbouring African states, as well as the Americas and Europe (Table 5).

Table 5. Ghanaian imports of livestock and poultry meat from 2000–2010[51].

	Year										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Beef	632	73	901	1,112	2,587	6,332	10,586	16,250	13,135	12,338	12,483
Poultry	9,548	6,808	20,752	34,108	40,357	42,288	47,794	66,791	93,258	69,080	72,418
Chevon	74	0	0	0	0	0	0	0	0	0	0
Mutton	237	478	1,285	2,122	2,053	3,641	4,839	6,887	5,961	6,153	4,903
Pork	358	1,166	7,738	9,882	7,756	10,287	13,291	10,552	5,487	3,150	3,039
Total	10,849	8,525	30,676	47,224	53,753	62,548	76,510	100,480	117,841	90,721	92,843

Apart from livestock farming, many smallholder farmers in Ghana supplement their household food supply and income with additional natural resource-based livelihood activities. Access to a livelihood source beyond rainfed agriculture and livestock provides smallholder communities in Ghana with year-round income. Additionally, the risks associated with farming are spread across multiple sources of income. For example, if crops are damaged or yields are low as a result of environmental hazards, farmers have another source of income available. These alternative livelihoods provide vital income diversification and access to cash during critical periods in areas where the risks of farming are high and rural savings, credit and insurance mechanisms are poorly developed or not available[52]. Consequently, it is estimated that 46% of households in Ghana operate non-farm enterprises — including those dependant on natural resources[53]. Examples of natural resource-based livelihoods include woodlots, fruit and nut cultivation, fish farming, beekeeping, snail breeding and mushroom farming (Table 6). The specificity of certain natural resource-based livelihoods to a specific area are influenced by the location, culture and resources in an area. For example, beekeeping is more common in forests than in savannas[54].

Table 6. Natural resource-dependent livelihoods in northern Ghana.

Category	Sub-category	Specific livelihood and description
Perennial crop farming	Woody products	Woodlots for pole, timber and fuelwood (including charcoal).
	Fruit orchards and cash crops	Mango (*Mangifera spp.*), cashew (*Anacardium occidentale*), shea nut (*Vitellaria paradoxa*) and cocoa (*Theobroma cacao*) for example.
Water resources	Fish farming	Tilapia, crabs and lobster.
	Fishing from natural waters	Artisanal (canoe) fishing
Agro-processing	Primary agro-processing	Processing of shea butter, gari (grated and dry-fried cassava), palm oil, fruit juice processing, cooking oil from peanuts,

[49] Amankwah K. 2013. Enhancing food security in Northern Ghana through smallholder small ruminant production and marketing. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/282342
[50] ICRA & NAES. 1993. Coping with uncertainty: Challenges for agricultural development in the Guinea Savanna Zone of the Upper West Region of Ghana. *Working Document Series 28.* Wageningen, The Netherlands.
[51] Data are from: Ministry of Food and Agriculture – 2011 – Agriculture in Ghana: Facts and figures.
[52] Reardon T. 1997. Using evidence of household income diversification to inform a study of the rural no-farm labour market in Africa. *World Development Report*. 25(5): 735–747.
[53] Mensah KK. 2014. Assessing the livelihood opportunities of rural poor households: a case study of Asutifi district. MSc. Thesis. Kwame Nkrumah University of Science and Technology, Kumasi. Available at: http://ir.knust.edu.gh/bitstream/123456789/7586/1/KYEREMEH%20KWAME%20MENSAH.pdf
[54] Ekpe EK, Hinkle RC, Quigley MF & Owusu EH. 2014. Natural resource and biodiversity conservation in Ghana: the use of livelihoods to support activities to achieve conservation objectives. *International Journal of Biodiversity Science, Ecosystem Services and Management*. 10(4): 253–261.

		dawadawa (a spice from seeds of *Parkia biglobosa*), fish processing and coconut oil.
Non-timber forest products (NTFPs)	Animal NTFPs	Beekeeping for honey and beeswax Rearing snails (*Achatina spp.*) and grasscutter (*Thryonomys swinderianus*) farming for meat.
	Mushroom farming	Oyster (*Pleurotus ostreatus*) and shiitake (*Lentinula edodes*) mushrooms.
	Plant NTFPs	Growing of prekese (*Tetrapleura tetraptera*) and black pepper (*Piper nigrum*) for spices; and *Thaumatococcus danielli* for the natural sweetener thaumatin.

The livelihoods of smallholder farmers in Ghana are deeply embedded within natural systems and rely on their continued capacity to provided goods and services. To ensure the sustainability of natural resource-based livelihoods in the country, it is necessary to proactively manage the systems that underpin them, as well as to implement policies and laws governing their use. For example, the Environmental Protection Agency (EPA) is in the process of reducing the production and sale of charcoal in Ghana, instead promoting the use of liquified petroleum gas[55]. This will help slow the rate of deforestation and preserve natural resources. Additionally, a shift from charcoal to liquid petroleum gas for cooking will reduce emissions of carbon dioxide, supporting Ghana's climate change mitigation strategies set out in the climate change policy of the country.

1.4.3 Land degradation

Natural ecosystems and agricultural land in Ghana have been severely degraded over the past few decades. With 69% of the total land area prone to severe or very severe land degradation, Ghana is well above the Sub-Saharan Africa average of 43%[56]. The main drivers of this degradation are *inter alia*: i) deforestation for wood and charcoal production, and clearing for agricultural activities; ii) wildfires to clear natural vegetation for agriculture; iii) overgrazing by cattle; and iv) soil erosion and fertility loss as a result of unsustainable farming practices (see Section 1.4.2 above). The magnitude of the effect of these drivers has increased over time as the population of Ghana has grown. By reducing the soil fertility of agricultural land and impeding the delivery of goods and services from natural ecosystems, land degradation can have severe negative consequences for Ghanaians. For example, soil erosion and deforestation are estimated to cost ~2% and ~5% of the national annual GDP, respectively[57]. This ~US$530 million loss per annum because of land degradation is equivalent to more than one-third of Ghana's annual Official Development Assistance. The effect of land degradation on poverty is also considerable. For example, soil loss is estimated to have increased the incidence of poverty by ~5% in 2015 compared with a scenario of zero soil loss[58]. Moreover, land degradation impedes the progression out of poverty, particularly in the five northern regions of the country.

1.4.4 Poverty and the north-south divide

The remarkable economic growth achieved in Ghana over the past decade (see section 1.4.1) resulted in millions of Ghanaians diversifying their livelihoods and rising out of poverty. As a result, Ghana achieved the Millennium Development Goal of halving levels of extreme poverty by 2015. However, this phase of economic and social development did not benefit the population evenly across the 16 regions of the country. While ~2.5 million people rose above

[55] http://www.ghanaweb.com/GhanaHomePage/business/Ghana-to-ban-charcoal-production-480659
[56] FAO, 2000.
[57] World Bank, DFID, ISSER, 2005.
[58] Diao and Sarpong (2007) Cost Implications of Agricultural Land Degradation in Ghana. International Food Policy Research Institute, Discussion Paper.

the poverty line[59] in the southern regions during the transition to lower-middle-income status, ~1 million descended into poverty in the north. Six years after achieving lower-middle-income status, the spatial disparity remains, with the three northernmost regions still having the highest poverty rates in the country (Table 7; Figure 10) and are home to approximately 2 million (~35%) of Ghana's ~5.8 million poor people (Table 7). Poverty depth and severity are also generally greater in northern than in southern regions (Table 7). In addition to lower economic activity and development[60,61] (Figure 10), northern Ghana also lags behind the south in terms of social development. Child mortality is relatively high in the north[62,63,64] (Figure 10), while data on indicators relating to education, sanitation, water, health, security and governance suggest that the northern regions have experienced less development compared with the southern regions[65] (Figure 10). The recent and rapid progress made in developing the southern regions of the country has not translated into better lives for most Ghanaians living in the north. This is also evident from the observation that large numbers of young northern Ghanaians are migrating south in search of economic opportunity[66].

1.4.5 Decentralised government in Ghana

The 1992 Constitution established the current decentralisation model and the Metropolitan, Municipal and District Assemblies (MMDAs). MMDAs are mandated the Act as the highest entities responsible for making and implementing local development plans in Ghana. The Act provides for the transfer of 5% of total national revenue to MMDAs for local level development. The 1992 Constitution also established the District Assemblies Common Fund (DACF), an inter-governmental funding scheme to transfer funds from central government to local government. In 2008, Central Government, through Parliamentary approval, increased the DACF to 7.5%. The Fund is administered by an Administrator who is appointed by the President of Ghana and approved by Parliament. The Fund allocation formula is based on 5 factors: need, equalising, responsiveness, service pressure and poverty. The DFCD represents between 23% to 53% of revenues received in the eight project Districts. Budget plans for these eight Districts and experience more widely shows that the DACF funds often arrive late. Inter-governmental transfers are the biggest source of funds for local authorities. Internally-generated funds make up a small percentage of revenue.

Ghana's local government structure is composed of Regional Coordinating Councils and different tiers of local government. RCCs were established to monitor, coordinate and evaluate the performance of the Assemblies. Assemblies are either Metropolitan (population over 250,000), municipal (one-town Assemblies with population over 95,000) or District (population over 75,000 and over). Sub-ordinate bodies of the Assemblies are the sub-Metropolitan Councils, Urban/Town/Area Councils which are established for settlements with population of between 5000 and 15000, and Area Councils are for settlements with populations below 5000. Unit Committees are the lowest tier in the structure, for settlements with populations of 1500 and lower.

Currently there are six Metropolitan, 56 Municipal and 154 District Assemblies in Ghana. The head of each District Assembly is the District Chief Executive who is nominated the State President and must receive the approval of two thirds of the District Assembly. Each District

[59] GH₵1,314 per person per year.
[60] Indicated by night light intensity.
[61] Mellander C., Lobo J., Stolarick K., Matheson Z. – 2015 – Night-time light data: a good proxy measure for economic activity? DOI: http://dx.doi.org/10.1371/journal.pone.0139779.
[62] Data were downloaded from: http://sheftneal9.wixsite.com/fse-data/download-data.
[63] Burke M., Heft-Neal S. and Bendavid E. – 2016 – Understanding variation in child mortality across Sub-Saharan Africa: A spatial analysis. The Lancet Global Health, 2016, Volume 4, Issue 12, e936-e945.
[64] ICF International (2004–2015) Demographic and Health Surveys (various) [Datasets]. Calverton, Maryland: ICF International [Distributor], 2015.
[65] UNICEF. 2015. Ghana's District League Table 2015.
[66] van der Geest K. 2011. North-south migration in Ghana: what role for the environment? International Migration 49. doi:10.1111/j.1468-2435.2010.00645.x.

has a Coordinating Director, as head of the government service. Each District Assembly also has a chairperson and is elected by at least two thirds of the members of the assembly. All elected assembly members represent single member wards and they are required to meet at least three times a year, Priorities that drive the District development agenda are set by executive committee. The District Chief Executive chairs the executive committee. The Executive Committee usually has a number of sub-committees. The Executive reports to the District Assembly.

Special committees – Regional Environmental Management Committees (REMCs)[67], and District Environmental Management Committees (DEMCs) – have been established within RCCs and DAs to deal with environmental matters. Regional Environmental Management Committees work with RCCs to ensure that environmental considerations are incorporated into strategic planning at the regional level while DEMCs work with DAs to integrate environmental management plans and projects into the District Medium-Term Development Plans (DMTDPs). These committees comprise representatives from each of the different government departments that are represented at the district level (including Agriculture, Forest Services, National Disaster Management, Fire Services, Gender, Social Development and Police amongst others). Regional EPA offices, with support from the regional Department of Agriculture offices, function as the secretariats for each REMC. District Departments of Agriculture offices are the secretariats for DEMCs.

Table 8 sets out the main population, budget performance and programme performance data for the eight Districts as reported in their programme-based budget reports.

[67] REMCs were established by the GoG during a decentralisation exercise and strengthened under the GEMP.

Table 7. A summary of poverty characteristics for the regions of Ghana[68]. Bold text indicates the regions containing project sites.

Administrative regions	Total population	Multi-dimensional poverty index	Headcount	Headcount percentage (%)	Poverty intensity	Gini coefficient (%)[69,70]
Ahafo	564,406	0.262	303,086	53.7	48.8	49.4
Ashanti	5,440,910	0.151	1,822,705	33.5	45.1	37.3
Bono	1,208,593	0.180	466,517	38.6	46.6	49.4
Bono East	1,202,924	0.281	708,522	58.9	47.7	49.4
Central	2,859,898	0.198	1,232,616	43.1	45.9	42.0
Eastern	2,926,322	0.165	1,056,254	36.1	45.7	37.9
Greater Accra	5,456,027	0.095	1,200,326	22.0	43.2	37.6
North East	**659,828**	**0.396**	**511,434**	**77.6**	**51.0**	**38.8**
Northern	2,310,678	0.368	1,675,236	72.5	50.8	38.8
Oti	747,283	0.366	541,769	72.5	50.5	43.7
Savannah	654,010	0.391	506,831	77.5	50.5	38.8
Upper East	**1,301,212**	**0.341**	**891,329**	**68.5**	**49.8**	**57.6**
Upper West	**900,177**	**0.286**	**539,906**	**59.9**	**47.7**	**49.7**
Volta	1,658,726	0.198	711,771	42.9	46.2	43.7
Western	2,061,504	0.210	931,458	45.2	46.5	41.2
Western North	880,375	0.279	497,712	56.5	49.4	41.2
All of Ghana	30,832,873		13,597,472	44.1		44.0[71]
Project regions	**2,861,217**		**1,942,669**	**67.9**		
Other regions	27,971,656		11,654,803	41.7		

[68] Ghana Statistical Service. 2022. Ghana Annual Household Income and Expenditure Survey: Quarterly Multidimensional Poverty Report. Available at: https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/AHIES%202022%20Q1%20and%20Q2%20MPI_07102022.pdf. Accessed on: 7 April 2025.
[69] Ghana Statistical Service. 2015. Ghana Poverty Mapping Report. Available at: https://www2.statsghana.gov.gh/docfiles/publications/POVERTY%20MAP%20FOR%20GHANA-05102015.pdf. Accessed on: 7 April 2025.
[70] Gini values are dated to the most recent assessment by region in 2015, whereas the population and multi-dimensional poverty index values are more recent (2022). Moreover, in 2015 Ghana was administered using only ten of the 16 regions, necessitating aggregate values for regions that were formerly joined. The national Gini index given is from 2024.
[71] Statista. 2025. Gini index in Ghana from 2014 to 2029. Available at: https://www.statista.com/forecasts/1165084/gini-index-forecast-in-ghana. Accessed on: 7 April 2025.

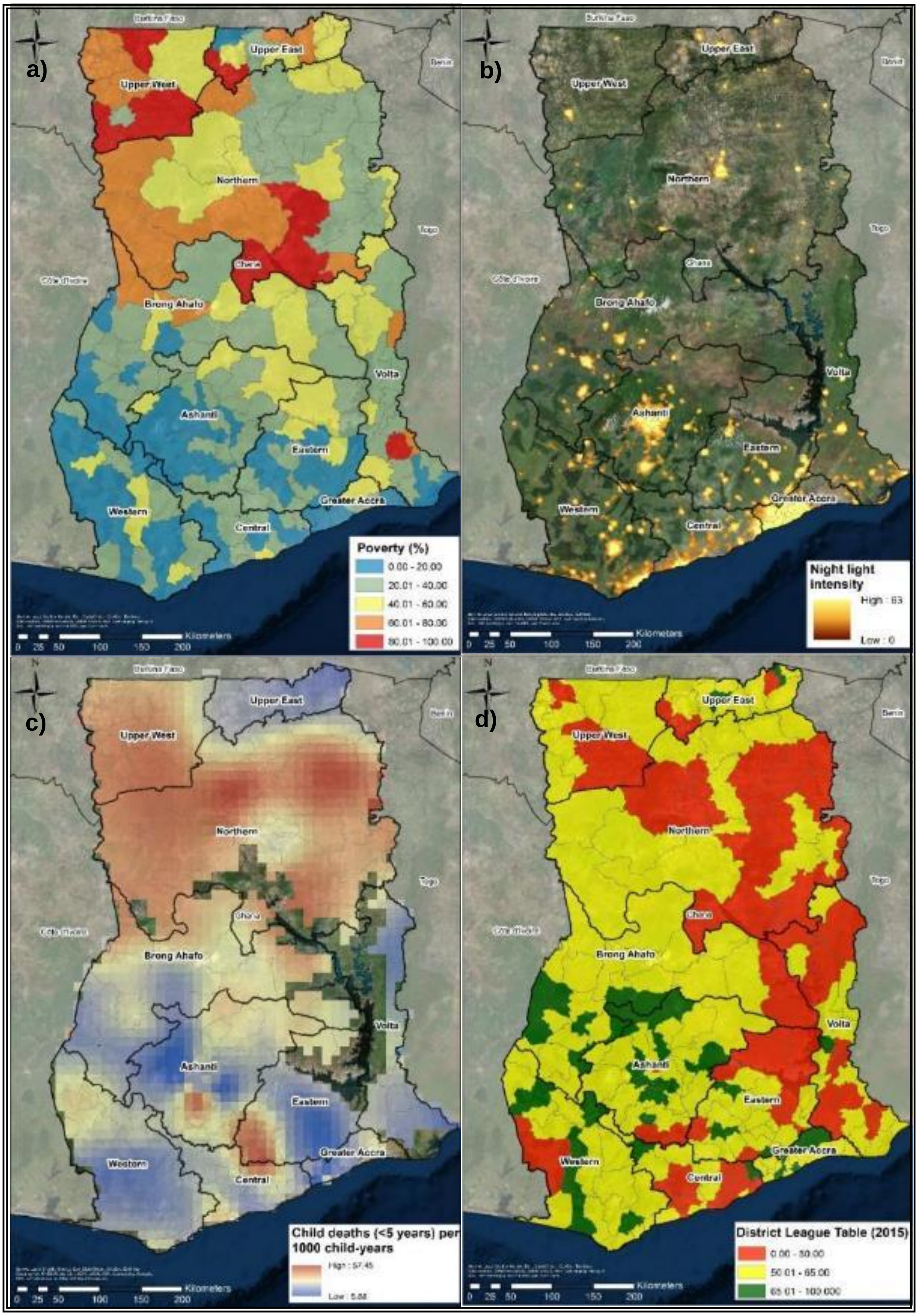

Figure 10. Maps of: a) district-specific poverty; b) night light intensity as an indicator of economic activity; c) mean child mortality from 2000–2010; and d) the District League Table for 2015.

Table 8. The main population, budget performance and programme performance data for the eight Districts

District Municipal Assemblies	Population (year of census or estimation)	Actual revenue (US$ equivalent)	Expenditure (US$ equivalent)	Expenditure relative to revenue (%)	Main achievements reported in budget plan	Main adaptation-related challenges reported in budget plan
Binduri[72]	79,237 (2024)	291,000	216,000	74.2	• Distribution of drought-resistant tree seedlings • Drilling of boreholes and road rehabilitation • Support for dry-season vegetable farming • Planting of cashew and mango seedlings • Climate change sensitisation for youth • Formation of Evergreen Clubs in schools • Development of disaster management plans and public education campaigns	• Insufficient Agricultural Extension Agents • Inadequate irrigation infrastructure • Land degradation and deforestation • Open defecation and poor waste management • Low community participation in disaster management • Limited support for disaster victims
Garu[73]	71,774 (2021)	298,000	349,000	117	• Use of early-maturing and drought-tolerant crops • Crop diversification to spread risk • Indigenous weather forecasting and resource practices • Community savings groups supporting household resilience	• Recurrent droughts causing crop failure and water scarcity • Flooding of low-lying areas and erosion from heavy rains • Windstorms damaging infrastructure and vegetation • Land degradation and desertification • Inadequate road and water infrastructure

[72] Office of the Binduri Municipal Assembly. 2024. Composite budget for 2025–2028. Programme-based budget estimates for 2025. Available at: https://www.mofep.gov.gh/sites/default/files/composite-budget/2025/UE/Binduri.pdf. Accessed on: 7 April 2025.
[73] Office of the Garu Municipal Assembly. 2023. Composite budget for 2024–2027. Programme-based budget estimates for 2024. Available at: https://mofep.gov.gh/sites/default/files/composite-budget/2024/UE/Garu.pdf. Accessed on: 7 April 2025.

						• Limited access to climate finance and insurance • Inadequate integration of climate issues into district planning
Jirapa[74]	91,279 (2021)	418,000	418,000	100	• Tree planting and seedling distribution for afforestation • Expansion of potable water access through boreholes and partnerships • Community sensitisation on early warning systems and disaster prevention • Sanitation campaigns and provision of cleaning tools	• Inadequate agricultural mechanisation • Inadequate access to quality and affordable water • Poor and inadequate disposal and management of waste • Inaccessible and high cost of farm inputs • Low level of Internal Generated Fund (IGF) mobilisation
Lambussie[75]	51,118 (2021)	275,000	418,000	152	• Supported 300 farmers with improved seeds and fertiliser • Provided 2 irrigation facilities to enhance dry season farming • Trained 70 farmers on climate-smart agriculture practices	• Inadequate Agricultural Extension Agents • Lack of early maturing and drought-resistant seeds • Inadequate mechanisation services • Poor road networks affecting access to farming communities
Lawra[76]	60,318 (2023)	475,000	475,000	100	• Rehabilitation of Goat Market Road at Babile • Community Health Planning and Services	• Erratic and inadequate rainfall • Flooding along the Black Volta

[74] Office of the Jirapa Municipal Assembly. 2024. Composite budget for 2025–2028. Programme-based budget estimates for 2025. Available at: https://www.mofep.gov.gh/sites/default/files/composite-budget/2025/UW/Jirapa.pdf. Accessed on: 7 April 2025.
[75] Office of the Lambussie Municipal Assembly. 2024. Composite budget for 2025–2028. Programme-based budget estimates for 2025. Available at: https://www.mofep.gov.gh/sites/default/files/composite-budget/2025/UW/Lambussie.pdf. Accessed on: 7 April 2025.
[76] Office of the Lawra Municipal Assembly. 2024. Composite budget for 2025–2028. Programme-based budget estimates for 2025. Available at: https://www.mofep.gov.gh/sites/default/files/composite-budget/2025/UW/Lawra.pdf. Accessed on: 7 April 2025.

					(CHPS) compound with mechanised borehole at Eremon Danko • New classroom infrastructure at Kuoli and Zambo Baagaun • Budget allocation to disaster prevention and climate resilience activities	• Bushfires and deforestation • Food insecurity • Environmental degradation • Loss of trees due to charcoal and firewood production
East Mamprusi[77]	194,022 (2023)	365,000	314,000	86	• Construction of classroom blocks with sanitation facilities at Nawuna and Tichirigitaba • Training of over 3,000 farmers in improved agricultural technologies • Increased agricultural extension coverage • Implementation of public education campaigns on disaster preparedness • Ongoing reforestation and soil and water conservation efforts	• Inadequate sanitation and limited access to potable water • Inadequate agricultural extension services • Insufficient adoption of agricultural technology • Insufficient logistics for disaster education and response • Inadequate environmental protection measures • Inadequate road network and limited infrastructure to support climate-resilient development
Wa West[78]	104,515 (2024)	619,000	500,000	81	• Support for dry-season gardening and livestock rearing • Tree planting to restore degraded areas • Borehole construction to improve water access	• Inconsistent rainfall and prolonged dry spells • Flash floods damaging roads and farmland • Reliance on rainfed agriculture

[77] Office of the East Mamprusi Municipal Assembly. 2023. Composite budget for 2024–2027. Programme-based budget estimates for 2024. Available at: https://mofep.gov.gh/sites/default/files/composite-budget/2024/NE/East_Mamprusi.pdf. Accessed on: 8 April 2025.
[78] Office of the Wa West Municipal Assembly. 2024. Composite budget for 2025–2028. Programme-based budget estimates for 2025. Available at: https://www.mofep.gov.gh/sites/default/files/composite-budget/2025/UW/Wa_West.pdf. Accessed on: 8 April 2025.

					• Promotion of sustainable farming practices and crop diversification	• Land degradation and deforestation from charcoal burning and bushfires • Water scarcity during the dry season • Limited access to extension services and climate information
Yunyoo-Nasuan[79]	58,598 (2024)	585,000	520,000	89	• Construction and furnishing of CHPS Compound with Nurses' Quarters at Kpanlori • Completion of 3-unit Nurses' Quarters at Jimbale • Furnishing of Model Senior High School at Nasuan • Increase in Open Defecation Free (ODF) communities to 67	• Inadequate funding for agricultural activities • Annual flooding destroying crops and limiting access to extension services • Inadequate motorbikes for Agricultural Extension Agents • High open defecation rates and poor sanitation coverage • Inadequate potable water supply
Total	710,861	3,326,000	3,210,000	97		

[79] Office of the Yunyoo-Nasuan Municipal Assembly. 2024. Composite budget for 2025–2028. Programme-based budget estimates for 2025. Available at: https://www.mofep.gov.gh/sites/default/files/composite-budget/2025/NE/Yunyoo_Nasuan.pdf. Accessed on: 8 April 2025.

2 Climate Change Vulnerability of the districts and regions of Ghana

2.1 Introduction

A climate change vulnerability (CCV) assessment was conducted to assess which regions of Ghana are most vulnerable to climate change impacts. The assessment used climate projections and available socio-economic data on risk and vulnerabilities to identify the most vulnerable districts and regions in Ghana. The identification of the most vulnerable districts and regions will assist in focussing the scope of the proposed project on the most affected areas and populations.

2.2 Climate change vulnerability

To effectively implement adaptation interventions that increase the resilience of people and natural systems to climate variability and change, it is first necessary to determine which people and systems are the most vulnerable to that variability and change. The Intergovernmental Panel on Climate Change (IPCC) defines climate change vulnerability (CCV) as "the degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes"[80]. Based on this definition, vulnerability is a function of the character, magnitude and rate of climate change variation to which a system is exposed, as well as the sensitivity and adaptive capacity of that system[81]. Within the CCV framework, four primary components determine to what extent a system is vulnerable to climate change (Figure 11):

- Exposure is the nature and degree to which a system is exposed to significant climatic variations[82].
- Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct or indirect[83].
- Potential impact is determined by a combination of exposure and sensitivity.
- Adaptive capacity is the ability of a system to adjust to climate change – including climate variability and extremes – to moderate potential damages, to take advantage of opportunities, or to cope with the consequences[84].

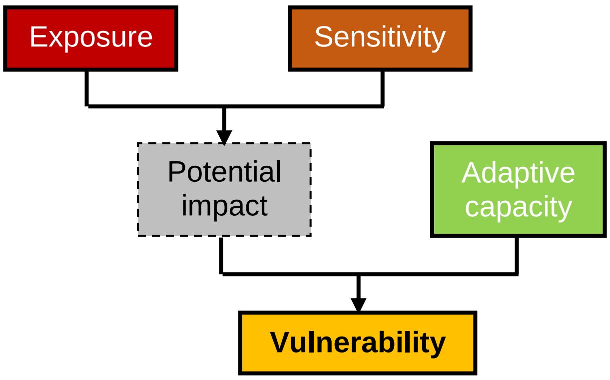

Figure 11. The four components of climate change vulnerability and how they interact.

[80] McCarthy JJ *et al.* eds. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, Uk.
[81] Ibid
[82] Ibid.
[83] Ibid
[84] Ibid

2.3 Methodology

A comprehensive assessment was undertaken to estimate CCV for the administrative districts of Ghana. Global and national datasets (Table 9) were used to generate parameters that relate to the components of CCV (see above). Exposure to climate change was divided into two subcomponents, namely: i) current/recent exposure to climate change and variability; and ii) predicted future exposure to climate change and variability. Three parameters relating to current variability/change in temperature and rainfall were used to quantify the current exposure of Ghana's districts (Table 9). For future exposure scores, nine rainfall and temperature parameters were split into a total of 36 sub-parameters to account for predicted medium- and long-term changes (2055 and 2085) under two different scenarios (RCP 4.5 and RCP 8.5) of future climate change (Table 9). Districts received a rank for every parameter and sub-parameter relating to exposure to current and predicted absolute changes in climate[85].

Sensitivity to current and future climate change was quantified as the percentage of the population per administrative region currently employed in the agricultural sector. It was assumed that people operating in this sector would be the most sensitive to changes in climate as the sector is inherently climate dependent. Employment information was only available at the regional level and, therefore, all districts within a region received the same sensitivity score in the assessment. No data were available to predict future sensitivity based on projected changes in agricultural employment. Therefore, it was assumed that sensitivity would remain relatively constant in the coming decades. Districts were ranked according to percentage agricultural employment, where a greater percentage suggested greater sensitivity to climate change[86].

The adaptive capacity of people within each district in Ghana was quantified using seven parameters relating to: i) economic activity; ii) education, sanitation, rural water availability, health, security and governance effectiveness; and iii) poverty (Table 9). As for exposure and sensitivity, each district received adaptive capacity ranks for each of the seven parameters[87]. No data were available to predict future adaptive capacity based on projected changes in economic activity, district development or poverty. Therefore, it was assumed that adaptive capacity would remain relatively constant in the coming decades.

District-specific exposure, sensitivity and adaptive capacity were calculated as the sum of the ranks of parameters divided by the maximum possible component score. District-specific CCV was calculated using the IPCC equation:

CCV = (**Exposure** x **Sensitivity**) – **Adaptive Capacity**.

The resulting CCV scores range from -1 (low vulnerability) to 1 (high vulnerability). See Table 10 for a simplified illustration of how CCV was calculated for the districts of Ghana.

[85] See Table 4.1 for a description of the ranking methodology.
[86] Ibid
[87] Ibid

Table 9. Description of the parameters used to calculate Climate Change Vulnerability for the administrative districts and regions of Ghana.

Component	Parameter	Rationale and data description	Ranking methodology
Current/recent exposure to climate change and variability.	1. Variation in annual average temperature[88]	• Provides a measure of current temperature variability. • Calculated as the current district-specific standard deviation over monthly average temperature values.	Greater variation = higher exposure ranking
	2. Variation in mean annual rainfall[89]	• Provides a measure of current rainfall variability. • Calculated as the current district-specific standard deviation over monthly average rainfall values.	Greater variation = higher exposure ranking
	3. Changes in mean annual rainfall[90, 91]	• Current and/or recent changes in rainfall would affect *inter alia*: i) the frequency and intensity of climatic hazards such as droughts and floods; ii) agricultural productivity; iii) ecosystem function; and iv) human health. • Calculated as the absolute district-specific change in rainfall as measured by a linear trend from 1981–2016.	Greater absolute change = higher exposure ranking
Predicted future exposure to climate change and variability[92, 93, 94, 95].	4. Percentage change in mean annual rainfall	• Future changes in rainfall would affect *inter alia*: i) the frequency and intensity of climatic hazards such as droughts and floods; ii) agricultural productivity; iii) ecosystem function; and iv) human health. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean annual rainfall.	Greater absolute percentage change = higher exposure ranking
	5. Percentage change in rainfall variability	• Future changes in rainfall variability (seasonality) would affect *inter alia*: i) the frequency and intensity of climatic hazards such as droughts and floods; ii) agricultural productivity; iii) ecosystem function; and iv) human health. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) rainfall variability.	Greater absolute percentage change = higher exposure ranking

[88] Data are from: www.worldclim.org; Hijmans, R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965–1978.
[89] Ibid.
[90] Data are from the CHIRPS v2.0 dataset, available at http://chg.geog.ucsb.edu/data/chirps/.
[91] Funk C., Peterson P., Landsfeld M., Pedreros D., Verdin J., Shukla S., Husak G., Rowland J., Harrison L., Hoell A., Michaelsen J. 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Scientific Data 2, 150066. doi:10.1038/sdata.2015.66 2015.
[92] All future climatic predictions were calculated using an ensemble of 10 general circulation models downscaled using five regional climate models. Four sub-parameters were produced, including percentage change by: i) 2055 under RCP 4.5; ii) 2055 under RCP 8.5; iii) 2085 under RCP 4.5; and iv) 2085 under RCP 8.5. This accounted for medium- and long-term changes under two different scenarios of future climate change.
[93] Current climate data are available at www.worldclim.org; Hijmans, R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965–1978.
[94] Future climate data are available at www.york.ac.uk/environment/research/kite/resources/; Platts P.J., Omeny P.A., Marchant R. 2015. AFRICLIM: high-resolution climate projections for ecological applications in Africa. *African Journal of Ecology* 53, 103-108.
[95] Exposure to sea-level rise, salt water intrusions and/or coastal erosion was not considered in this assessment. This was to ensure that all parameters were comparable across Ghana and were not region-specific.

Component	Parameter	Rationale and data description	Ranking methodology
	6. Percentage change in mean rainfall of the wettest month	• Future changes in rainfall in the wettest month would affect agricultural productivity during the most vital period of the growing season. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean rainfall in the wettest month.	Greater absolute percentage change = higher exposure ranking
	7. Percentage change in the number of dry months	• Futures changes in the number of dry months would affect agricultural productivity through changes to the length of the growing season. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) number of dry months where a dry month is a month with moisture index <0.5.	Greater absolute percentage change = higher exposure ranking
	8. Percentage change in mean annual average temperature	• Futures changes in annual average temperature would affect *inter alia*: i) agricultural productivity; and ii) ecosystem function. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean annual average temperature.	Greater absolute percentage change = higher exposure ranking
	9. Percentage change in mean annual minimum temperature	• Futures changes in annual minimum temperature would affect *inter alia*: i) agricultural productivity; and ii) ecosystem function. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean annual minimum temperature.	Greater absolute percentage change = higher exposure ranking
	10. Percentage change in mean annual maximum temperature	• Futures changes in annual maximum temperature would affect *inter alia*: i) agricultural productivity; and ii) ecosystem function. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean annual maximum temperature.	Greater absolute percentage change = higher exposure ranking
	11. Percentage change in mean potential evapotranspiration	• Future changes in potential evapotranspiration would affect *inter alia*: i) agricultural productivity; and ii) ecosystem function. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean potential evapotranspiration.	Greater absolute percentage change = higher exposure ranking
	12. Percentage change in mean moisture index	• Future changes in the moisture index would affect *inter alia*: i) agricultural productivity; and ii) ecosystem function. • Calculated as the district-specific absolute percentage difference between predicted future (2055 & 2085) and current (1960–2000) mean moisture index.	Greater absolute percentage change = higher exposure ranking

Component	Parameter	Rationale and data description	Ranking methodology
Sensitivity to current and future climate change	13. Percentage of the population employed in the agricultural sector[96]	• The agricultural sector is considered one of the most sensitive sectors to climate change. Therefore, the assumption was made that the percentage of people working in the agricultural sector in each district would be a good indicator of how sensitive people in that district are to climate change. • Employment data were only available at the regional level. Therefore, all districts within a region have the same percentage employment in the agricultural sector.	Larger percentage employed in the agricultural sector = higher sensitivity ranking
Adaptive capacity	14. District League Table score[97]	• The DLT incorporates measures of education, sanitation, rural water availability, health, security and governance effectiveness to assess development across Ghana's 216 districts. These factors are considered good indicators of the capacity of private citizens and local governments to adapt to a changing climate[98].	Lower score = lower adaptive capacity ranking
	15. Night-time light intensity[99]	• Night-time light intensity is a good proxy for economic activity[100]. • Economic development and activity is an effective measure of adaptive capacity as it relates to the ability of people to diversify their livelihoods and incomes when and if necessary.	Lower value = lower adaptive capacity ranking
	16. Percentage of the population under the poverty line[101]	• People under the poverty line are assumed to have reduced capacity to adapt to climate change as they have less financial resources to moderate damages and/or take advantage of the benefits of climate change. • District-specific estimate of the percentage of people below the poverty line of GH₵1,314 per person per year.	Greater percentage = lower adaptive capacity ranking
	17. Number of people under the poverty line[102]	• The number of people under the poverty line accounts for the number of people with reduced adaptive capacity. • District-specific estimate of the number of people below the poverty line of GH₵1,314 per person per year.	Greater number = lower adaptive capacity ranking
	18. Poverty Depth[103]	• Poverty depth is used in addition to percentage poverty to measure adaptive capacity. Where the percentage poverty parameter considers all people below the poverty line equally poor, poverty depth measures the intensity of poverty.	Greater depth = lower adaptive capacity ranking

[96] Data are from: Ministry of Food and Agriculture. 2010. Agriculture in Ghana: Facts and Figures.
[97] Data are from: UNICEF – 2016 – District League Table 2016: Calling for central government to better target district support.
[98] GIZ – 2014 – A framework for climate change vulnerability assessments.
[99] The Visible Infrared Imaging Radiometer Suite (VIIRS) data are from U.S. National Oceanographic and Atmospheric Administration (NOAA).
[100] Mellander C., Lobo J., Stolarick K., Matheson Z. 2015. Night-Time Light Data: A Good Proxy Measure for Economic Activity? PLOS One. https://doi.org/10.1371/journal.pone.0139779.
[101] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.
[102] Ibid.
[103] Ibid.

Component	Parameter	Rationale and data description	Ranking methodology
		• District-specific average poverty gap in the population as a proportion of the poverty line.	
	19. Poverty Severity[104]	• The square of district-specific poverty gaps to give greater attention to the needs of the poor.	Greater severity = lower adaptive capacity ranking
	20. Gini coefficient[105]	• District-specific measure of inequality.	Greater Gini = lower adaptive capacity ranking

Table 10. Simplified example of the method used to calculate district-specific Climate Change Vulnerability.

		Exposure			**Sensitivity**		**Adaptive capacity**			
District	Region	Predicted change in mean annual rainfall[106] (ranking)	Predicted change in mean annual average temperature (ranking)	Score	% agricultural employment (ranking)	Score	% below the poverty line (ranking)	District League Table (ranking)	Score	**CCV**
Adansi North	Ashanti	5.91% (2)	16.14% (2)	0.67[107]	43.8 (2)	0.67[108]	18.4 (2)	58.61 (2)	0.67[109]	**-0.22**[110]
Accra Metropolis	Greater Accra	1.84% (1)	14.56% (1)	0.33	10.5 (1)	0.33	2.6 (3)	65.03 (3)	1.00	**-0.89**
Wa East	Upper West	8.85% (3)	17.03% (3)	1.00	73.2 (3)	1.00	83.8 (1)	54.96 (1)	0.33	**0.67**

[104] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.
[105] Ibid.
[106] By 2085 under RCP 8.5.
[107] [Rainfall change rank (2) + Temperature change rank (2)] / [Max. possible rainfall change rank (3) + Max. possible temperature change rank (3)] = 0.67
[108] [% agricultural employment rank (2)] / [Maximum possible % agricultural employment rank (3)] = 0.67
[109] [% below poverty rank (2) + District League Table rank (2)] / [Max. possible % poverty rank (3) + Max. possible District League Table rank (3)] = 0.67
[110] [Exposure score (0.67) * Sensitivity score (0.67)] - [Adaptive capacity score (0.67)] = -0.22

2.4 Results

The CCV assessment revealed that the vulnerability of Ghana's districts generally increases from the coast[111] into the transition zone and the northern savannas (Figure 13)[112]. On average, the Upper West Region is the most vulnerable region in the country (Figure 12). The 10 districts with the highest CCV scores were all from the Upper West Region (Figure 13)[113], and Wa East was the most vulnerable district to climate change with a CCV of 0.68. Wa East's neighbouring district – and the home of the regional capital, Wa Municipal, had the lowest CCV in the Upper West Region. The Northern and Upper West Regions were the second and third most vulnerable regions, respectively (Figure 12). In the Northern Region, the Sawla-Tuna-Kalba District on the borders of Côte d'Ivoire and Burkina Faso had the highest CCV. Garu Tempane on the Togolese border had the highest climate change vulnerability in the Upper East Region. The three least vulnerable regions were the Greater Accra (average CCV = -0.78), Ashanti (-0.61) and Central Regions (-0.51) (Figure 12). The four districts with the lowest CCVs were all in the Greater Accra Region, and the La Dade Kotopon District had the lowest CCV (-0.95) in Ghana (Figure 12)[114].

Based on the results of the CCV assessment, it is evident that climate change adaptation interventions are required to enhance climate resilience in the northern regions of Ghana. As a result, the subsequent sections of the feasibility study will focus on the northern regions of Ghana.

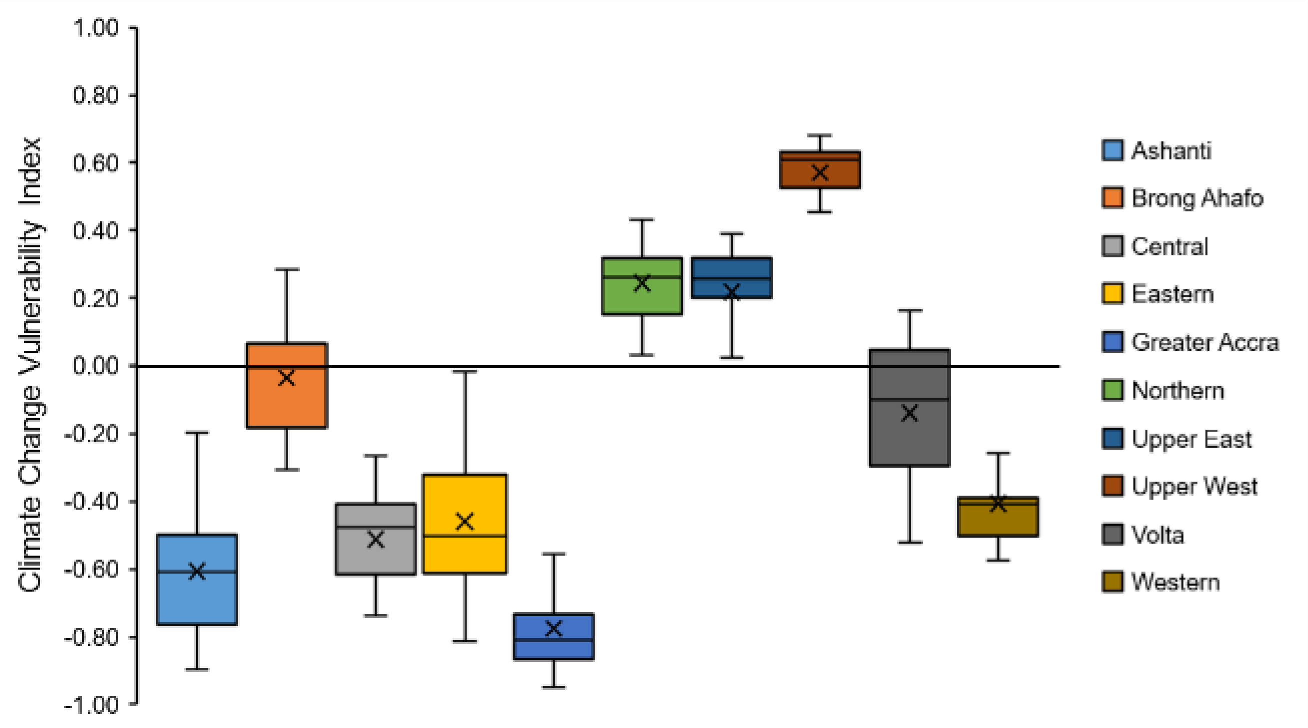

Figure 12. District Climate Change Vulnerability scores aggregated at the level of administrative regions. "Xs" are mean values.

[111] Although exposure to coast-specific climate impacts (e.g. sea level rise) were not considered in this assessment (see above).
[112] See Table S1 in Supporting Information for all CCV results.
[113] Ibid.
[114] Ibid.

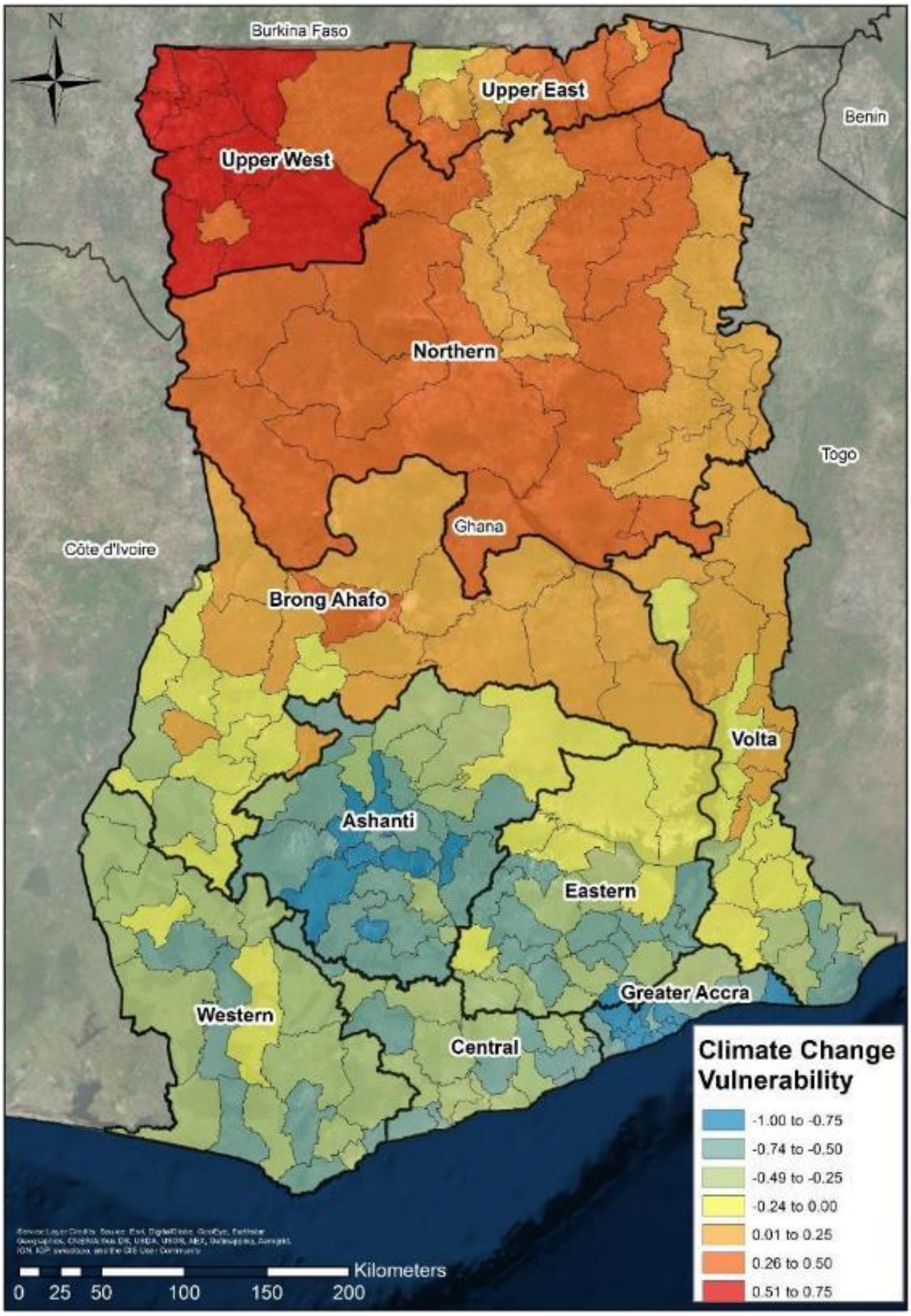

Figure 13. Climate Change Vulnerability scores for Ghana's 216 districts[115].

[115] See Table S2 in Supporting Information for district-specific exposure, sensitivity, adaptive capacity and Climate Change Vulnerability scores.

3 Baseline conditions in northern Ghana

3.1 Introduction

The results of the climate change vulnerability assessment (see Section 2) demonstrate that the northernmost region of Ghana is the most vulnerable in the country. This region – hereafter referred to as northern Ghana – should, therefore, be a priority target for climate change adaptation interventions. This chapter focusses on northern Ghana — providing details on the geographical context, socio-economic situation, and status of smallholder farming and agroecological systems.

3.2 Physical and geographic context

Northern Ghana comprises the three northernmost administrative regions of Ghana, including the Upper West Region (UWR), Upper East Region (UER), and Northern Region (NR)[116]. The three regions — which cover ~40% (~100,000 km^2)[117,118] of Ghana's total land area — are bound to the west by Cote D'Ivoire, to the east by Togo, to the north by Burkina Faso, and to the south by the Brong Ahafo and Volta regions (Figure 14). The topography across northern Ghana consists of gently rolling plains that range between 180 and 300 m above sea level in altitude[119]. Vegetation consists of short, deciduous, widely spaced, fire-resistant trees, which do not form any closed canopy and a ground cover of grasses of varying heights[120]. The area is drained by the Volta River system which includes the White Volta, Black Volta, Oti, and Darka Rivers[121].

The three regions comprising northern Ghana are divided into 52 districts. The UWR covers ~13% (~18,000 km^2) of the total land area of Ghana and is the seventh-largest region in the country. It contains 11 districts consisting of one municipal and ten ordinary districts (Figure 14)[122]. The UER — which occupies ~2.7% (~9,000 km^2) of Ghana's total land area — is the second smallest of Ghana's ten administrative regions and contains 13 districts made up of two municipal and 11 ordinary districts (Figure 14)[123]. The NR covers ~31% (~70,000 km^2) of the country's total area and is the largest of Ghana's ten regions. It comprises 28 districts, 19 of which are ordinary while eight are municipal and one is metropolitan (Figure 14)[124].

[116] Awedoba AK (ed). 2014. *The peoples of northern Ghana*. National Commission on Culture. Accra.
[117] Mosello B, Adamtey R, Obuobie E (eds). 2017. *Making water infrastructure investment decisions in a changing climate. A political economy study of river basin development in Ghana*. Overseas Development Institute. London.
[118] Alhassan SI, Shaibu MT, Kuwornu JKM, Damba OT. 2018. Factors influencing farmers' awareness and choice of indigenous practices in adapting to climate change and variability in northern Ghana. *West African Journal of Applied Ecology* 26: 1-13.
[119] The World Bank 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a sustainable land and water management project. Sustainable Development Department, Africa Region.
[120] Karbo N, Agyare WA. 2002. Crop-livestock systems in northern Ghana. *Improving crop-livestock systems in the dry savannas of West and Central Africa*. Ibadan: IITA.
[121] Acheampong D, Balana BB, Nimoh F, Abaidoo RC. 2018. Assessing the effectiveness and impact of agricultural water management interventions: the case of small reservoirs in northern Ghana. *Agricultural Water Management* 209: 163-170.
[122] USAID 2017. Documenting various sustainable land and water technologies into forms that can be used for extension service provision: The experience of Northern Ghana. Feed the Future Ghana Agricultural Policy Support Project (APSP). Accra: United States Agency for International Development (USAID).
[123] Ibid.
[124] Ibid.

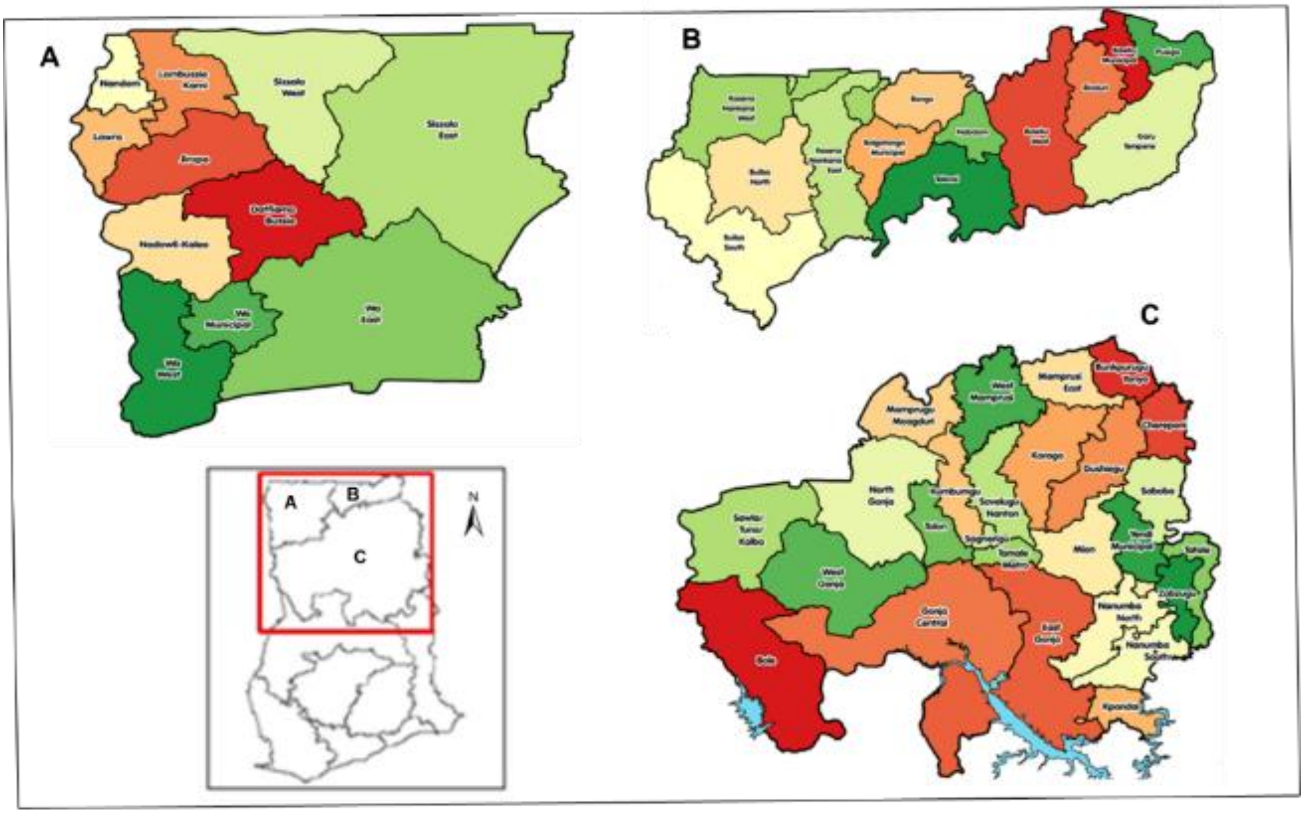

Figure 14. Map showing the (A) Upper West, (B) Upper East and (C) Northern regions of Ghana and their districts[125]

3.3 Socio-economic context

3.3.1 Economy

While Ghana's southern regions have experienced a significant reduction in poverty since 1992, the UER, EWR and NR have made comparatively little economic and development progress (see Section 1.4.4). The Ghana Statistical Service estimates that poverty rates in the northern parts of the country are approximately two times higher than the national average of 28%[126]. Approximately 3 million people (~50% of the population)[127] in northern Ghana live below the poverty line.

Two primary reasons have been advanced to explain the disparity in poverty rates and economic development between northern and southern Ghana, namely different climate regimes and British colonial rule[128,129]. Northern Ghana has a single short wet season, while the south has two[130]. In addition, northern Ghana falls within the southern fringe of the West Africa Sahel and as a result is much drier than southern areas of Ghana (see Section 1.2)[131]. As a result, agricultural productivity in northern Ghana is low, resulting in food insecurity, low

[125] Antwi EK, Otsuki K, Saito O, Obeng FK, Gyekye KA, Boakye-Danquah J, Boafo YA, Kusakari Y, Yiran GA, Owusu AB. 2014. Developing a community-based resilience assessment model with reference to Northern Ghana.
[126] Baah AKE. 2017. Subsistence farmers' perceptions of pluralistic agriculture extension in northern Ghana. PhD, Walden University, Minneapolis.
[127] Poverty data extracted from: Ghana Statistical Service – 2015 – Ghana Poverty Mapping Report.
[128] Nyantakyi-Frimpong H, Bezner-Kerr R. 2015. The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. *Global Environmental Change* 32: 40–56.
[129] Ibid.
[130] Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
[131] USAID 2017. Documenting various sustainable land and water technologies into forms that can be used for extension service provision: The experience of Northern Ghana. Feed the Future Ghana Agricultural Policy Support Project (APSP). Accra: United States Agency for International Development (USAID).

income and high poverty levels among smallholder farmers in the region[132,133]. British colonial rule — from 1874 to 1957 — set northern and southern Ghana on divergent development trajectories[134]. While the colonial government supported intensive infrastructural development in southern Ghana, northern Ghana remained neglected and was regarded as a source of labour for export-oriented economies in the south[135]. This trajectory of unequal economic development extended into the post-independence period[136]. After independence in 1957, state policy and planning in Ghana continued to embrace the same regional bias, thereby perpetuating the spatial disparity in development[137]. Early post-colonial state policies continued to favour the extraction of natural resources[138]. As northern Ghana has low resource endowments, little government revenue flowed into the region, resulting in limited transport and marketing infrastructure, input and credit availability, agricultural extension, and other rural services[139].

In addition to the north-south development gap, there is a notable gap in poverty levels between rural and urban areas. Poverty levels in rural areas (37.9%) are far higher than those in urban areas (10.6%), with the gap growing over the past two decades[140]. There is also a gendered pattern between poverty levels and employment in Ghana. Although the unemployment rates in Ghana are only marginally higher for women than men (~6.2% compared to ~5.4%)[141], women's employment is often concentrated in low-income activities[142], including unpaid family labour and small household farms. As a result, women's control over their income is precarious and poverty rates among working women are generally higher than those of working men. This challenge is compounded by the gender wage gap of 0.75, with women earning 75 cents to the dollar compared with men[143]. This ranks Ghana at 26th out of 144 countries in terms of the gender wage gap. However, in terms of overall economic participation and opportunity, Ghana ranks much higher at 30th place, with a gender gap index of 0.805. Section 3 in Annex 8: Gender Assessment and Action Plan which provides further details on the factors influencing economic and social development in Ghana.

3.3.2 Population

The population density in northern Ghana is low compared to the national average (~80 people km^{-2}) and the southern parts of the country (Figure 15)[144]. The spatial distribution of population density in northern Ghana, however, varies markedly[145]. The UER is densely populated — particularly around Bolgatanga and Bawku — while the UWR has areas of dense population (around Wa, Nandom and Lawra) amidst a generally low population density[146]. The NR has a

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[132] Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
[133] Kudadze S, Imoru A, Adzawla W. 2019. Farmer's perception on irrigation farming and the factors influencing access to and size of irrigable lands in Northern Region, Ghana. *Asian Food Science Journal* 8: 1-14.
[134] Nyantakyi-Frimpong H, Bezner-Kerr R. 2015. The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. *Global Environmental Change* 32: 40–56.
[135] Ibid.
[136] Ibid.
[137] Ibid.
[138] Ibid.
[139] Ibid.
[140] Cooke E., Hague. & McKay A. 2016. The Ghana Poverty and Inequality Report. Available at: https://www.unicef.org/ghana/Ghana_Poverty_and_Inequality_Analysis_FINAL_Match_2016(1).pdf
[141] World Bank. Ghana – Gender Data Portal. Available at: http://datatopics.worldbank.org/gender/country/ghana
[142] Heintz J. 2005. Employment, Poverty and Gender in Ghana. Practical Economy Research Institute. Working Paper Series 92.
[143]Schwab K, Samans R, Zahidi S, Leopold T.A, Ratcheva V, Hausmann R & Tyson L.D. 2016. The Global Gender Gap Report. World Economic Forum, Geneva.
[144] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[145] Dietz T, Millar D, Dittoh S, Obeng F, Ofori-Sarpong E. 2004. Climate and livelihood change in North East Ghana. In: Dietz A, Ruben R, Verhagen A editors. *The Impact of Climate Change on Drylands, with a Focus on West Africa*. *Environment and Policy Series*. Dordrech/Boston/London: Kluwer academic Publishers. p. 149–172.
[146] Ibid.

generally low population density (except around the town of Tamale)[147]. The low population density in northern Ghana is mostly attributed to outmigration[148]. Large numbers of people migrate from northern Ghana to the more developed southern regions in search of work in the mining sector, plantation economy or urban areas (see Section 1.4.4)[149]. Despite this outmigration, population densities in northern Ghana have more than doubled (UER, UWR) or tripled (NR) since 1960[150].

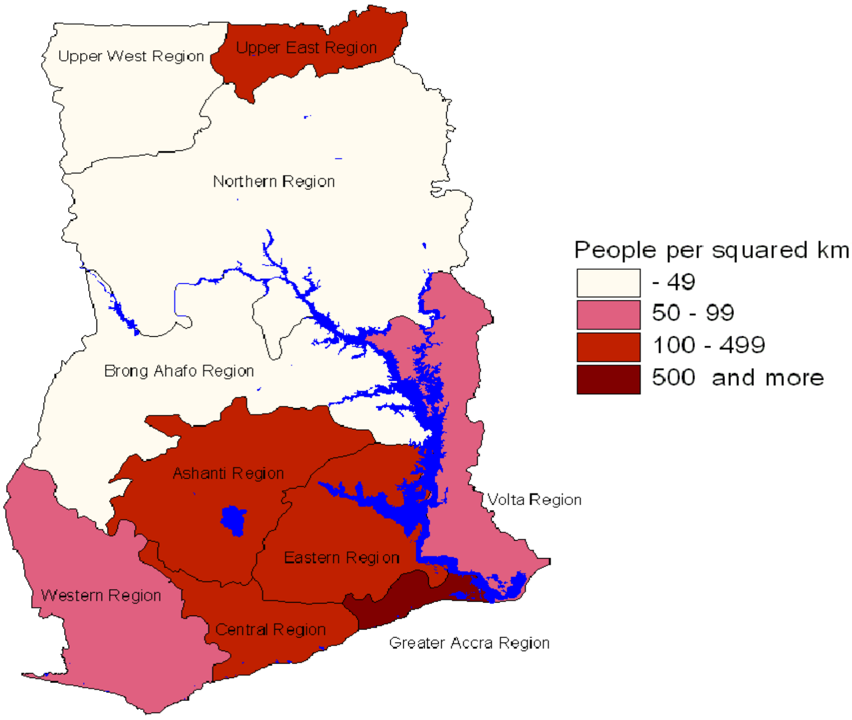

Figure 15. Population density across the ten regions of Ghana[151].

3.3.2.1 *Ethnic minorities*

The project regions of Ghana are home to as many as 70 distinct ethnic groups, each contributing to the region's social and cultural diversity. The dominant ethnic group in all three project regions is the Mole-Dagbani, comprising ~53, 73, and 78% in the North East, Upper East and Upper West Regions, respectively (**Table 11**). The Gurma group is the second most common ethnic group in the North East Region (~29%), whereas the Grusi is second in the Upper East and Upper West Regions (~15 and 18%, respectively)[152]. Other notable groups include the Akan, Ewe, and Mande, although they make up smaller proportions of the population in these regions. While each group is distinct in language, customs and history, they are deeply integrated across and within communities, with intermarriage, shared

[147] Dietz T, Millar D, Dittoh S, Obeng F, Ofori-Sarpong E. 2004. Climate and livelihood change in North East Ghana. In: Dietz A, Ruben R, Verhagen A editors. *The Impact of Climate Change on Drylands, with a Focus on West Africa*. *Environment and Policy Series*. Dordrech/Boston/London: Kluwer academic Publishers. p. 149–172.
[148] USAID 2017. Documenting various sustainable land and water technologies into forms that can be used for extension service provision: The experience of Northern Ghana. Feed the Future Ghana Agricultural Policy Support Project (APSP). Accra: United States Agency for International Development (USAID).
[149] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[150] Stanturf JA, Warren ML, Charnley S, Polasky SC, Goodrick SL, Armah F, Nyako YA. 2011. Ghana climate change vulnerability and adaptation assessment. *Washington: United States Agency for International Development*.
[151] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[152] Ghana Statistical Service. 2013. 2010 Population and Housing Census – National Analytical Report.

livelihoods and social networks creating cohesive bonds. In the context of Ghana, while ethnicity is a considerable factor in shaping identity it does not generally result in persecution or differential treatment of minority groups, as communities tend to prioritise collaboration and cooperation in everyday interactions. For example, communities that were consulted during the development of the proposed project constituted as many as 6 different ethnic groups, with traditional leadership structures[153] indicating similar diversity.

Table 11. Ghanaians by major ethnic group and region, 2021[154].

Ethnic Group	North East	Upper East	Upper West
Akan	9,5	1,3	1,4
Ewe	0,4	0,2	0,2
Ga-Dangme	0	0,1	0,2
Grusi	2,6	14,8	18,3
Guan	0,2	0,1	0,4
Gurma	29,2	3,5	0,2
Mande	4,2	6,6	1,3
Mole-Dagbani	53	72,5	77,7
Others	0,9	0,9	0,3

The Fulani are an Indigenous People within northern Ghana, known for being nomadic pastoralists. As a transnational Indigenous People found throughout West Africa, their pastoralist practices often bring them into contact with sedentary agricultural communities, sometimes leading to conflicts over land and water resources. As a result of their transhumance movements, Ghanaians view the Fulani as foreign and have historically been excluded from official national plans and projects. Nonetheless, this group forms a considerable component of the country's socio-economic environment. Section 1.2.3. in Annex 6 the Indigenous Peoples Planning Framework provides a more detailed discussion on the social environment of the target areas.

3.3.3 Agriculture

Agriculture is the backbone of most ethnic groups in northern Ghana and most communities practice small-scale subsistence agriculture, selling any excess produce either through farming co-operatives or on a sole basis at nearby markets. The Mole-Dagbani, for example, are known for cultivating staple crops such as maize, millet, yams and sorghum. These crops are integral to the food security of households, particularly during lean periods when food reserves from the previous season run low. Among these groups, crop production is a gendered activity. Men are typically responsible for clearing and ploughing the land, while women contribute to planting, weeding and harvesting. In recent years, women have also gained prominence in the cultivation of vegetables — which are often grown for both consumption and sale in local markets. In addition to crops, the Mole-Dagbani also engage in animal husbandry, rearing sheep, goats and poultry to complement their farming activities. Section 3.3. in Annex 6C: Ethnic Minority Planning Framework provides a more detailed discussion of gender roles in livelihood practices in the target areas.

- **Smallholder farming**

[153] For example, a council of elders supporting the chieftaincy or a unit committee.
[154] Ghana Statistical Services. 2024. Population major ethnic group by Ethnicity and Geographic Area. Available at: https://statsbank.statsghana.gov.gh/pxweb/en/PHC%202021%20StatsBank/PHC%202021%20StatsBank__Population/ethnic_table.px/table/tableViewLayout2/. Accessed on 8 April 2025.

Agriculture in northern Ghana is dominated by smallholder farmers — who constitute more than 80% of the economically active population in the region[155,156]. The smallholder farmers — who farm on small farms ranging in size from 0.5 to 2 ha — are mostly subsistent, producing primarily for home consumption with little produce sold in the market[157,158,159]. Most of the farmers use simple tools such as hoes and fire for clearing vegetation and depend on family labour for farm operations[160,161]. Animal traction is utilised heavily in some parts of northern Ghana — for example, ~50% of smallholder farmers in the UWR and UER use bullocks for ploughing[162]. The major crops produced by smallholder farmers in northern Ghana include: i) cereals — including maize, rice, millet and sorghum; ii) root and tuber crops — including cassava, yam and sweet potatoes; iii) vegetables — including pepper, tomato, onions, okra, leafy vegetables and garden eggs; iv) pulses and nuts — including shea nut, cashew nut, dawadawa and tamarine; and v) fruits (mango)[163]. The low level of technology used by smallholder farmers limits the total area cultivated in the region[164].

- **Rainfed agriculture**

Most smallholder farmers in northern Ghana depend on rain-fed agriculture as irrigation infrastructure is limited[165,166]. As a result, agriculture in the region is highly seasonal, with only one crop grown per year during the single wet season[167,168]. Planting is usually conducted at the onset of the rains in April/May and harvesting in September (Figure 16). Harvesting ends at the latest in December, by which time the bulk of the household's food supply has usually been harvested and stored in granaries (Figure 16)[169]. Wet season crop production — and also the local household's primary food stockpile — is mainly based on millet[170]. Other crops grown during the wet season in northern Ghana include cereals (sorghum, guinea corn, rice and maize) and legumes (groundnuts, Bambara beans and cowpea)[171].

155 Sumani JBB. 2018. Exploring perceptions of the potential of agricultural insurance for crop risks management among smallholder farmers in northern Ghana. DPhil, Antioch University, New England.
156 Darko E, Atazona L (eds). 2013. *Literature review of the impact of climate change on economic development in northern Ghana. Opportunities and activities*. Overseas Development Institute.
157 Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
158 Mustapha S, Mohammed T, Abukari I. 2017. Application of multinomial logistic to smallholder farmers' market participation in northern Ghana. *International Journal of Agricultural Economics* 2: 55-62.
159 Etwire PM, Al-Hassan RM, Kuwornu JK, Osei-Owusu Y. 2013. Smallholder farmers adoption of technologies for adaptation to climate change in Northern Ghana. *Journal of Agricultural Extension and Rural Development* 5: 121–129.
160 Mustapha S, Mohammed T, Abukari I. 2017. Application of multinomial logistic to smallholder farmers' market participation in northern Ghana. *International Journal of Agricultural Economics* 2: 55-62.
161 Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
162 Ibid.
163 Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
164 Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
165 Wossen T, Berger T, Swamikannu N, Ramilan T. 2014. Climate variability, consumption risk and poverty in semi-arid Northern Ghana: Adaptation options for poor farm households. *Environmental Development* 12: 2–15.
166 Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
167 Wossen T, Berger T, Swamikannu N, Ramilan T. 2014. Climate variability, consumption risk and poverty in semi-arid Northern Ghana: Adaptation options for poor farm households. *Environmental Development* 12: 2–15.
168 Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
169 Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
170 Ibid.
171 Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.

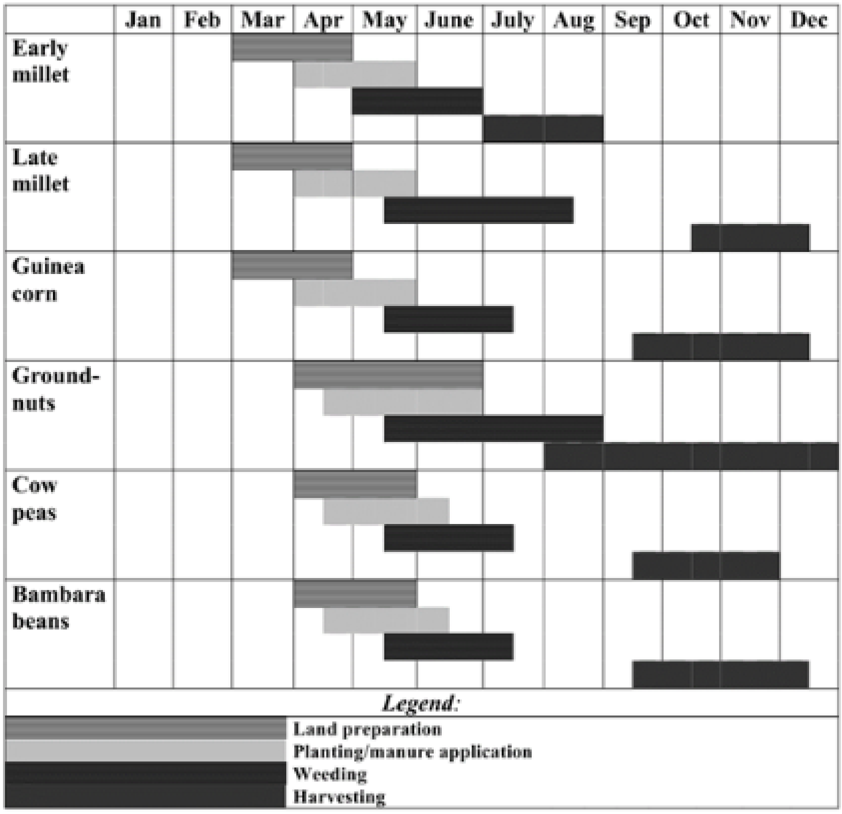

Figure 16. Cropping calendar for selected crops grown during the wet season by smallholder farmers in northern Ghana[172].

Dependence on rainfed agriculture is limiting smallholder agricultural production in northern Ghana by restricting farmers to cultivating during the single short wet season. This is particularly the case in the Guinea Savanna zone, where seasonal variation in rainfall has historically been most extreme[173]. Moreover, dependence on rainfed agriculture limits agricultural production by exposing it to the variability and unreliability that characterise rainfall patterns in northern Ghana[174]. Rapid population growth (see Section 3.3.2) is also contributing to limited agricultural yields in northern Ghana by reducing the amount of available arable farmland and hindering productive traditional farming methods[175,176,177]. For example, the practice of shifting cultivation — in which exhausted farmland is left fallow for five to 15 or more years until soil fertility is restored — has historically been the dominant agricultural system in northern Ghana[178,179]. Population growth has caused increasing pressure on farmland, resulting in the reduction of long fallow periods from five to 15 years to only about

[172] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[173] Fagariba C, Song S, Baoro SKGS. 2018a. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West District. *Sustainability* 10: 1484.
[174] Asante FA, Boakye AA, Egyir IS, Jatoe JB. 2012. Climate change and farmers' adaptive capacity to strategic innovations: The case of northern Ghana.
[175] Antwi-Agyei P, Dougill AJ, Stringer LC, Codjoe SNA. 2018. Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. *Climate Risk Management* 19: 83–93.
[176] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[177] Brown O, Crawford A. 2008. Climate change: A new threat to stability in West Africa? Evidence from Ghana and Burkina Faso. *African Security Studies* 17: 39–57.
[178] Diao X, Sarpong DB. 2011. Poverty implications of agricultural land degradation in Ghana: an economy-wide, multimarket model assessment. *African Development Review* 23: 263–275.
[179] Sumani JBB. 2018. Exploring perceptions of the potential of agricultural insurance for crop risks management among smallholder farmers in northern Ghana. DPhil, Antioch University, New England.

two to three[180,181,182]. The decrease in fallow periods — an essential form of soil fertility restoration in smallholder farming systems in northern Ghana — has led to severe mining of soils, thereby depriving them of nutrients, resulting in declining crop yields and food insecurity[183,184]. In densely populated areas, population growth has even led to permanent or semi-permanent use of farmland, resulting in considerable declines in soil fertility and crop production[185,186].

- **Irrigated agriculture**

Although most cropping in northern Ghana is conducted during the wet season, a small number of smallholder farmers carry out dry-season farming using water collected from shallow wells, dams, dugouts and small reservoirs[187]. Small reservoirs and dugouts are also extensively used for livestock watering[188]. Although groundwater is used to some extent for irrigation, over 80% of the groundwater extracted in northern Ghana is used for drinking and other domestic purposes[189]. Groundwater supplies water to over 60% of rural households in northern Ghana (e.g., 78% in the UWR) [190]. Groundwater extraction in most basins in northern Ghana is still less than 5% of the average annual groundwater recharge[191]. Hydrological models running under various scenarios — such as increased population, expanding water extraction and decreased rainfall — indicate that groundwater abstraction in the region will remain less than the recharge rate into the foreseeable future[192].

Agricultural yields from irrigated agriculture in northern Ghana are mostly low relative to investment costs due to poor management and maintenance of infrastructure — rendering irrigation in the region generally unprofitable[193]. This, however, does not apply to vegetable irrigation which — despite being mostly small-scale and supported by low input levels — is generally profitable[194]. Smallholder farmers with bucket irrigated vegetable gardens make an average profit of ~US$160-200[195] per year. Pump farmers, on average, earn a profit of US$450-580[196] per year. Smallholder farmers engaged in vegetable gardening usually use shallow groundwater harvested from wells and dugouts to irrigate vegetable gardens established along dry riverbeds[197]. The water for irrigation is usually fetched manually with

[180] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[181] Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
[182] Diao X, Sarpong DB. 2011. Poverty implications of agricultural land degradation in Ghana: an economy-wide, multimarket model assessment. *African Development Review* 23: 263–275.
[183] Boakye-Danquah J, Antwi EK, Saito O, Abekoe MK, Takeuchi K. 2014. Impact of farm management practices and agricultural land use on soil organic carbon storage potential in the savannah ecological zone of Northern Ghana. *Journal of Disaster Research* 9: 484-499.
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[185] Fagariba C, Song S, Baoro SKGS. 2018a. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West DistrictIbid. 10: 1484.
[186] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[187] Mul M, Obuobie E, Appoh R, Kankam-Yeboah K, Bekoe-Obeng E, Amisigo B, Yaw Logah F, Ghansah B, McCartney M Water Resources Assessment of the Volta River Basin.
[188] Ibid.
[189] Ibid.
[190] Ibid.
[191] Namara RE, Horowitz L, Nyamadi B, Barry B (eds). 2011. *Irrigation development in Ghana: Past experiences, emerging opportunities, and future directions*. Ghana Strategy Support Program (GSSP). Accra.
[192] Ibid.
[193] Akuriba MA, Haagsma R, Heerink N, Dittoh S. 2018. Irrigation governance and performance: the case of smallholder irrigated agriculture in northern Ghana. *Semanticscholar.org*.
[194] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[195] Ibid.
[196] Ibid.
[197] Ibid.

buckets, but some smallholder farmers use motor pumps[198]. The average size of manually irrigated vegetable gardens is ~0.06 ha, while those under pump irrigation are on average ~0.2 ha[199]. However, despite the economic promise of irrigated vegetable gardening, the proportion of smallholder farmers in northern Ghana that practice it is small[200]. The majority (~80%) of smallholder farmers in the region depend solely on rain-fed crop agriculture[201].

- **Livestock rearing**

In addition to cultivating crops, smallholder farmers in northern Ghana also rear livestock such as cattle, goats, sheep, chicken and guineafowl[202,203]. Livestock rearing — which is carried out on a minor scale compared to crop farming — is regarded as an insurance investment and ex-ante coping strategy in times of a sudden need[204,205]. Furthermore, livestock are used in wide parts of northern Ghana to: i) pay the bridal dowry; ii) provide food for important social events such as funerals; and ii) source cash to buy farm inputs such as seeds, pesticides and fertilisers[206]. Lastly, livestock — particularly cattle — also have a very high cultural value for smallholder farmers, as they symbolise social status[207]. The use of livestock for food is generally low in northern Ghana as meat forms a small part of the typical Ghanaian diet[208]. However, for some smallholder farmers in the UER and UWR, household food security relies more on livestock than on crop farming[209]. In these areas, livestock is reared to supply food for household consumption[210,211]. Smallholder farmers in northern Ghana depend on natural pasture as the primary source of forage for livestock production (see Section 3.4)[212].

Although higher than the rest of the country, livestock numbers per smallholder farmer in northern Ghana are modest and generally fail to satisfy household requirements[213]. As a result, live animals (especially ruminants) are imported into the region from neighbouring countries and meat from either Europe or America to meet local demand (see Section 1.4.2)[214]. Livestock production in northern Ghana is mainly being limited by overgrazing, which is causing a decline in the quality of grazing land through the replacement of palatable perennial grasses, legumes and herb species with unpalatable annual species[215,216]. The sedentarisation of pastoral communities is driving the widespread overgrazing in northern

198 Ibid.
199 Ibid.
200 Abdul-Razak M, Kruse S. 2017. The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Climate Risk Management* 17: 104–122.
201 Ibid.
202 Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
203 Alhassan SI, Shaibu MT, Kuwornu JKM, Damba OT. 2018. Factors influencing farmers' awareness and choice of indigenous practices in adapting to climate change and variability in northern Ghana. *West African Journal of Applied Ecology* 26: 1-13.
204 Mul M, Obuobie E, Appoh R, Kankam-Yeboah K, Bekoe-Obeng E, Amisigo B, Yaw Logah F, Ghansah B, McCartney M Water Resources Assessment of the Volta River Basin.
205 Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
206 Ibid.
207 Ibid.
208 Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
209 Darko E, Atazona L (eds). 2013. *Literature review of the impact of climate change on economic development in northern Ghana. Opportunities and activities*. Overseas Development Institute.
210 Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
211 Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
212 Konlan SP. 2018. Availability and utilization of feed resources in small ruminant production among smallholder farmers in northern Ghana. DPhil, University For Development Studies.
213 Government of Ghana 2015. Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods. Project proposal to the Adaptation Fund.
214 Adzitey F. 2013. Animal production in Ghana - an overview. *Journal of World's Poultry Research* 3: 1-4.
215 Avornyo FK, Zougmore R, Partey S, Tengan K. 2019. Candidate fodder trees and shrubs for sustainable ruminant production in northern Ghana. *Livestock Research for Rural Development* 30: 1-8.
216 The World Bank 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a sustainable land and water management project. Sustainable Development Department, Africa Region.

Ghana[217]. The reliance by most smallholder farmers in northern Ghana on natural pastures as the primary source of forage for their livestock accentuates the adverse effects of overgrazing on livestock yields[218]. Although some smallholder farmers supplement forage from natural pastures with cereal crop residues and low-quality rangeland hay, most farmers lack the means to transport bulky crop residues[219,220]. As a result, livestock production in northern Ghana is based mainly on low-quality forage in degraded natural pasture that limits livestock productivity because of its lower dry matter content, digestibility and nutritive value[221].

Livestock diseases are also limiting livestock production in northern Ghana by reducing livestock performance and causing mortalities in some cases. Major livestock diseases in the region include: i) Contagious Bovine Pleuro-pneumonia; ii) the main zoonoses —including Tuberculosis, Brucellosis, Anthrax and Rabies; iii) Foot and Mouth Disease; iv) Trypanosomosis; and v) tick-borne diseases — including Dermatophilosis, Babesiosis, Anaplasmosis and Heartwater — which are particularly acute and cause high mortalities in exotic cattle and their crosses. In small ruminants, "Peste des petits ruminant", mange and internal parasites are the major diseases. In poultry, major epidemics of Newcastle Disease and Gumboro are common. In pigs, mange and internal parasites predominate. The privatisation of veterinary services has led to the suspension of free government programs in eliminating livestock diseases. As a result, the number of livestock in northern Ghana has dwindled because of the high cost of veterinary services[222]. Therefore, many rural households have lost an important source of wealth, which acts as a source of investment and coping mechanism to extreme climate events and other stresses[223].

- **Additional livelihoods**

Few smallholder farmers in northern Ghana rely solely on crop farming and livestock rearing for their food security and livelihoods[224]. In addition to crop farming and livestock rearing, these farmers engage in a range of off-farm activities to generate additional income — primarily to buy groceries but also to meet other expenditures like clothing or school fees[225]. Depending on the location or market environment, social status and the agricultural income situation, off-farm activities conducted by smallholder farmers in northern Ghana range from the collection of firewood or NTFPs for sale to food processing like the brewing of pito[226] or small-scale trading activities[227]. NTFPs are collected from surrounding woodlands for trade by smallholder farmers in northern Ghana (see Section 3.4)[228]. Traded NTFPs include Dawadawa, shea, baobab, kazuge and yellow berries[229]. Berries, wild fruits and vegetables, as well as nuts are harvested by women and children year-round and represent an income supplement during the dry season (March to June) when food is scarce and there are few farming activities taking

[217] Republic of Ghana 2000. Ghana: Northern Savanna Biodiversity Conservation Project. Ministry of Lands and Forestry in collaboration with the Ministry of Health.
[218] Avornyo FK, Zougmore R, Partey S, Tengan K. 2019. Candidate fodder trees and shrubs for sustainable ruminant production in northern Ghana. *Livestock Research for Rural Development* 30: 1-8.
[219] Karbo N, Agyare WA. 2002. Crop-livestock systems in northern Ghana. *Improving crop-livestock systems in the dry savannas of West and Central Africa*. Ibadan: IITA.
[220] Avornyo FK, Zougmore R, Partey S, Tengan K. 2019. Candidate fodder trees and shrubs for sustainable ruminant production in northern Ghana. *Livestock Research for Rural Development* 30: 1-8.
[221] Ibid.
[222] Yaro JA. 2013. *Building resilience and reducing vulnerability to climate change: Implications for food security in Ghana*. Friedrich-Ebert-Stiftung, Ghana Office.
[223] Ibid.
[224] Darko E, Atazona L (eds). 2013. *Literature review of the impact of climate change on economic development in northern Ghana. Opportunities and activities*. Overseas Development Institute.
[225] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[226] Locally brewed beer.
[227] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[228] Sulemana A. 2017. Management and use of non-timber forest products (NTFPs) as climate change adaptation strategy in Lawra District, Ghana. MPhil, University of Ghana, Accra.
[229] Ibid.

place[230,231]. Petty trade, mostly by women, is an additional source of income in most low-income households. In some communities, traditional crafts like the weaving of baskets, pottery or the making of special ropes for animal husbandry are a source of considerable additional income[232]. Smallholder farmers in northern Ghana also migrate to the south in search of work during the dry season when agricultural production comes to a seasonal halt[233]. These off-farm activities, however, generally bring in low income such that most smallholder farmers in northern Ghana largely depend on subsistence rainfed farming for their livelihoods[234].

3.4 Agro-ecological systems

A typical smallholder agroecological system in northern Ghana consists of scattered homesteads and rainfed agricultural plots within a matrix of fallowed farmland and natural woodland (Figure 17)[235,236]. Two distinct kinds of agricultural plots — compound and bush farms – occur within this matrix[237]. Compound farms (sieman) are located closely around homesteads and are usually cropped every year (Figure 17)[238]. Often, a small portion of compound land is cultivated by the women of the homestead, who generally establish gardens in which they grow additional produce like tomatoes and other vegetables like okra[239]. Where compound farms are not cropped, the area is reserved as grazing for small ruminants. On the other hand, bush farms are situated further from homesteads and are cultivated using a traditional bush fallow system which involves abandonment and reuse of exhausted fields after fallow periods (Figure 3.4)[240].

Traditionally, bush farms in many parts of northern Ghana were left to fallow for periods of up to 5 to 15 years[241]. However, fallow periods have decreased significantly in recent years in response to increased population pressure (see Section 3.3.2)[242]. As a result, fallow periods have been reduced to about two to three years in many areas in northern Ghana, while cultivation has become permanent in areas with high human populations (see Section 3.3.3.2)[243,244]. Like with uncultivated compound farms, abandoned bush farms in fallow are used for livestock grazing and NTFP collection. Smallholder farmers in northern Ghana maintain parkland agroforestry systems, characterised by the deliberate retention of mainly economically valuable and multipurpose trees such as Shea (*Vitellaria paradoxa*), Dawadawa (*Parkia biglobosa*) and Kapok (*Ceiba pentandra*) on compound and bush farmlands[245]. The

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[230] Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
[231] Ibid.
[232] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[233] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[234] Darko E, Atazona L (eds). 2013. *Literature review of the impact of climate change on economic development in northern Ghana. Opportunities and activities*. Overseas Development Institute.
[235] Songsore J. 1996. Population growth and ecological degradation in northern Ghana: Myths and realities. *Research reviews* 12: 51-66.
[236] Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
[237] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[238] Ibid.
[239] Ibid.
[240] Sumani JBB. 2018. Exploring perceptions of the potential of agricultural insurance for crop risks management among smallholder farmers in northern Ghana. DPhil, Antioch University, New England.
[241] Ibid.
[242] Diao X, Sarpong DB. 2011. Poverty implications of agricultural land degradation in Ghana: an economy-wide, multimarket model assessment. *African Development Review* 23: 263–275.
[243] Ibid.
[244] Republic of Ghana 2000. Ghana: Northern Savanna Biodiversity Conservation Project. Ministry of Lands and Forestry in collaboration with the Ministry of Health.
[245] Mul M, Obuobie E, Appoh R, Kankam-Yeboah K, Bekoe-Obeng E, Amisigo B, Yaw Logah F, Ghansah B, McCartney M Water Resources Assessment of the Volta River Basin.

farmers harvest shea nut from their farmlands as well as from shea trees found in agricultural plots elsewhere in the community[246].

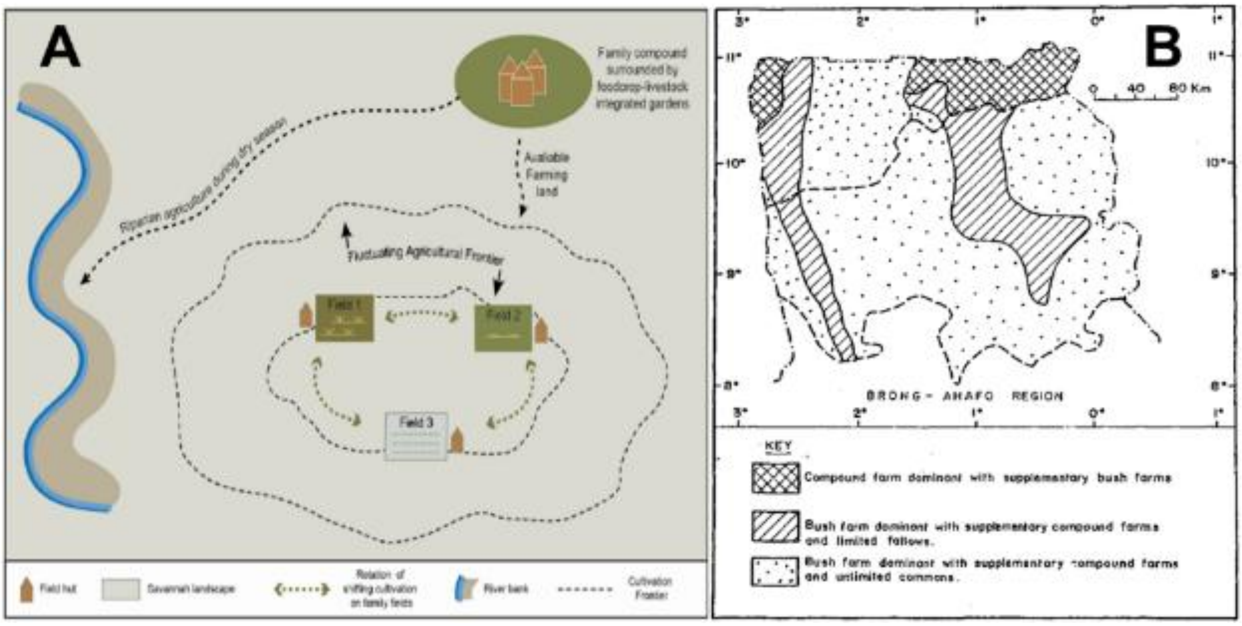

Figure 17. Schematic representation of (A) a typical smallholder agroecological system and (B) the distribution of agroecological regimes across northern Ghana[247,248].

Woodlands are thought to have covered ~94% (~9.4 million ha) of northern Ghana at the beginning of the last century[249]. However, much of the woodlands have been degraded by human activities to the extent that only a few small patches remain as sacred groves[250]. As a result, the matrix of woodland and abandoned/grazing lands in which smallholder agriculture is undertaken in northern Ghana is generally degraded[251]. Despite their current condition, woodlands and abandoned/grazing land provide smallholder farmers in northern Ghana with important ecosystem services such as fruits, wild meat, medicine, nuts, fibre, as well as soil stabilisation, flood mitigation and water filtration[252,253]. Food products collected from surrounding woodlands include shea fruit (*Vitellaria paradoxa*) — the nuts of which are processed to produce butter, honey, mushrooms (*Agaricus*), wild fruits such as sibisibi (*Lannea acida*), dawadawa (*Parkia biglobosa*), baobab fruit (Adansonia) and gaa (*Diospyros mespiliformis*)[254]. Baobab, Dawadawa, shea trees and *Acacia* are all-year-round sources of food because of their resistance to drought and fire[255]. Local communities also collect medicinal plants from forests such as neem tree leaves (*Azadirachta indica*), which are extracted and used to alleviate the symptoms of malaria, and moringa leaves (*Moringa*

[246] Gebremariam GG. 2018. Sustainable Agricultural Practices (SAPs) in Northern Ghana: impacts on welfare, environmental reliance, and agricultural land expansion. PhD, Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn.
[247] Songsore J. 1996. Population growth and ecological degradation in northern Ghana: Myths and realities. *Research reviews* 12: 51-66.
[248] Boateng P. 2017. Land access, agricultural land use changes and narratives about land degradation in the savannahs of Northeast Ghana during the pre-colonial and colonial periods. *Social Sciences* 6: 1-36.
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[250] Aniah P, Kaunza-Nu-Dem M, Ayembilla JA. 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. *Heliyon* 5: 1-25.
[251] Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
[252] Gebremariam GG. 2018. Sustainable Agricultural Practices (SAPs) in Northern Ghana: impacts on welfare, environmental reliance, and agricultural land expansion. PhD, Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn.
[253] Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
[254] Ibid.
[255] Sulemana A. 2017. Management and use of non-timber forest products (NTFPs) as climate change adaptation strategy in Lawra District, Ghana. MPhil, University of Ghana, Accra.

oleifera) and paw leaves (*Carica papaya*) which, when brewed together, soothe stomach-aches[256]. The bark of the sibi sibi tree (*Lannea acida*) is chewed to help childbirth[257]. Grasses, ropes and sticks are mostly collected by women for roof thatching, basket weaving and making fishing gear[258]. Smaller trees and shrubs are often cleared for firewood, some of which is processed into charcoal[259]. During the dry season, livestock grazing is dependent on woodland shrubs and trees[260].

The capacity of agroecological systems in northern Ghana to supply ecosystem services such as NTFPs, forage, soil stabilisation and water storage to smallholder farmers is declining[261,262,263]. This decline is mainly driven by rapid population growth, which is increasing the demand for food, firewood, timber, and farmland, resulting in the degradation and clearing of natural pastures and woodlands[264,265]. For example, the widespread clearing of woodland cover in response to increasing population pressure has resulted in more widespread exposure of soil to erosion in many areas in northern Ghana[266]. The increase in erosion has, in turn, resulted in — among other things — enhanced siltation and sedimentation of water bodies in northern Ghana, reducing their water holding capacity[267,268]. Land use projections suggest that farmland in northern Ghana will continue to expand into pasture and woodland ecosystems at a rate of 4.2% per year[269].

[256] Mul M, Pettinotti L, Amonoo NA, Bekoe-Obeng E, Obuobie E (eds). 2017. *Dependence of riparian communities on ecosystem services in northern Ghana*. International Water Management Institute (IWMI). Colombo.
[257] Ibid.
[258] Ibid.
[259] Ibid.
[260] Ibid.
[261] Fagariba CJ, Song S, Soule SKG. 2018b. Livelihood economic activities causing deforestation in northern Ghana: Evidence of Sissala West District. *Open Journal of Ecology* 08: 57–74.
[262] Boakye-Danquah J, Antwi EK, Saito O, Abekoe MK, Takeuchi K. 2014. Impact of farm management practices and agricultural land use on soil organic carbon storage potential in the savannah ecological zone of Northern Ghana. *Journal of Disaster Research* 9: 484-499.
[263] Etwire PM, Al-Hassan RM, Kuwornu JK, Osei-Owusu Y. 2013. Smallholder farmers adoption of technologies for adaptation to climate change in Northern Ghana. *Journal of Agricultural Extension and Rural Development* 5: 121–129.
[264] Martey E, Kuwornu JKM, Adjebeng-Danquah J. 2019. Estimating the effect of mineral fertilizer use on land productivity and income: Evidence from Ghana. *Land Use Policy* 85: 463-475.
[265] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[266] Martey E, Kuwornu JKM, Adjebeng-Danquah J. 2019. Estimating the effect of mineral fertilizer use on land productivity and income: Evidence from Ghana. *Land Use Policy* 85: 463-475.
[267] Government of Ghana 2015. Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods. Project proposal to the Adaptation Fund.
[268] Yaro JA. 2013. *Building resilience and reducing vulnerability to climate change: Implications for food security in Ghana*. Friedrich-Ebert-Stiftung, Ghana Office.
[269] Boakye-Danquah J, Antwi EK, Saito O, Abekoe MK, Takeuchi K. 2014. Impact of farm management practices and agricultural land use on soil organic carbon storage potential in the savannah ecological zone of Northern Ghana. *Journal of Disaster Research* 9: 484-499.

4 Climate change in northern Ghana

4.1 *Introduction*

This section presents information on observed and predicted climate change in northern Ghana — including the occurrence of climate hazards and extreme events. Details on the methods used to model future climate change in the region are also provided.

4.2 Recent climate trends

4.2.1 Rainfall trends

Annual rainfall in Ghana shows considerable inter-annual and inter-decadal variation (Figure 18). This variability makes it difficult to detect long-term changes in national and local rainfall[270]. For example, no statistically significant change in mean annual rainfall for Ghana was evident during the period 1950–2012 (**Figure 18**). For the northern regions of Ghana, specifically, changes in rainfall were likewise insignificant (Table 12). Even at a very fine scale (i.e. 25 km^2), significant changes over the past several decades in mean annual rainfall were rare in Ghana with only a few areas in the UER and UWR exhibiting significantly increased rainfall from 1981–2016 (Figure 19).

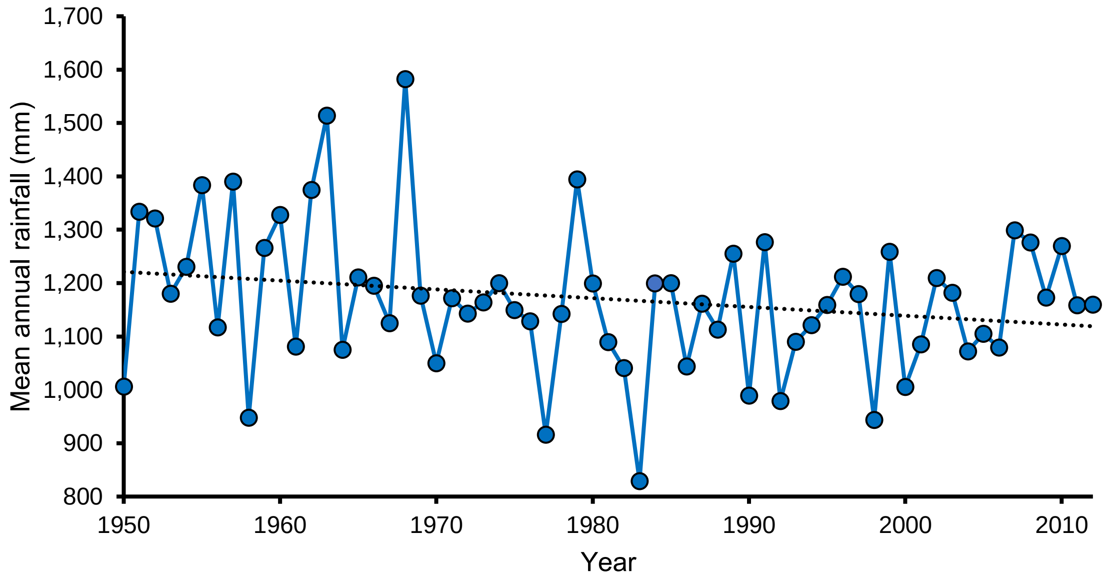

Figure 18. Change in annual rainfall for Ghana from 1950 to 2012. The dashed line is a nonsignificant linear trend line (y = -1.65 + 4430; R^2 = 0.05; p = 0.08).[271]

[270] Government of Ghana. 2015. Ghana's Third National Communication to the UNFCCC
[271] Data are from http://sdwebx.worldbank.org/climateportal/index.cfm.

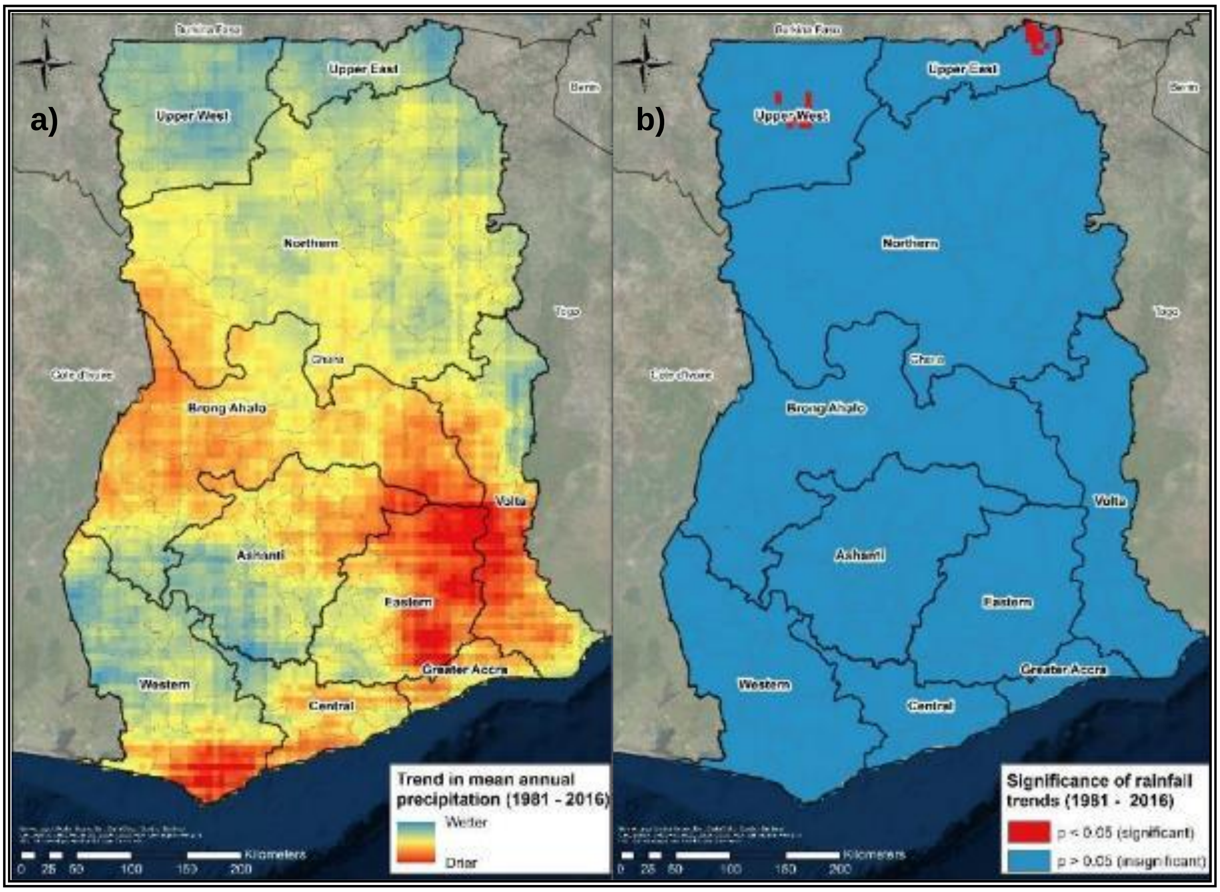

Figure 19. Maps showing: a) linear trends in mean annual rainfall per pixel (25 km^2) across Ghana from 1981 to 2016; and b) their statistical significance[272,273].

Table 12. Mean slopes of linear trends in rainfall from 1981 to 2016 for the northern regions of Ghana. The colour scale relates to the magnitude and direction of the slope of the linear trend. Significance values are provided within brackets. Data are from the CHIRPS v2.0 dataset.

Region		Mean slope of linear trend (p-value)
Northern		0.53 (0.73)
Upper East		2.31 (0.26)
Upper West		2.18 (0.26)

While historical trends suggest only minor changes in total annual rainfall in northern Ghana, a significant change in rainfall pattern is evident. Examining CHIRPS data on average monthly rainfall over the past four decades (Figure 20), there is evidence of a reduction in the amount of rainfall during the early wet season (~-8mm April, ~-8mm May, ~-17mm June ~-9mm July, ~-12mm August in the 2010 decade) and an increase during the late wet season (~+5mm September and ~+17mm October in the 2010 decade). This observation is supported by recent research that found that rainfall in northern Ghana has become increasingly erratic with

[272] Rainfall data are from the CHIRPS v2.0 dataset, available at http://chg.geog.ucsb.edu/data/chirps/.
[273] Funk C., Peterson P., Landsfeld M., Pedreros D., Verdin J., Shukla S., Husak G., Rowland J., Harrison L., Hoell A., Michaelsen J. 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data* 2, 150066. doi:10.1038/sdata.2015.66 2015.

the start of the wet season becoming more difficult to predict[274,275,276]. In the past, the wet season started in April and ended around late September or early October[277]. However, in recent times, the wet season starts in June or July with extremely heavy rainfall in September or October that often results in floods that destroy crops, life and properties or ends abruptly resulting in drought conditions[278,279]. This is indicative of a shortening of the historical rainfall season.

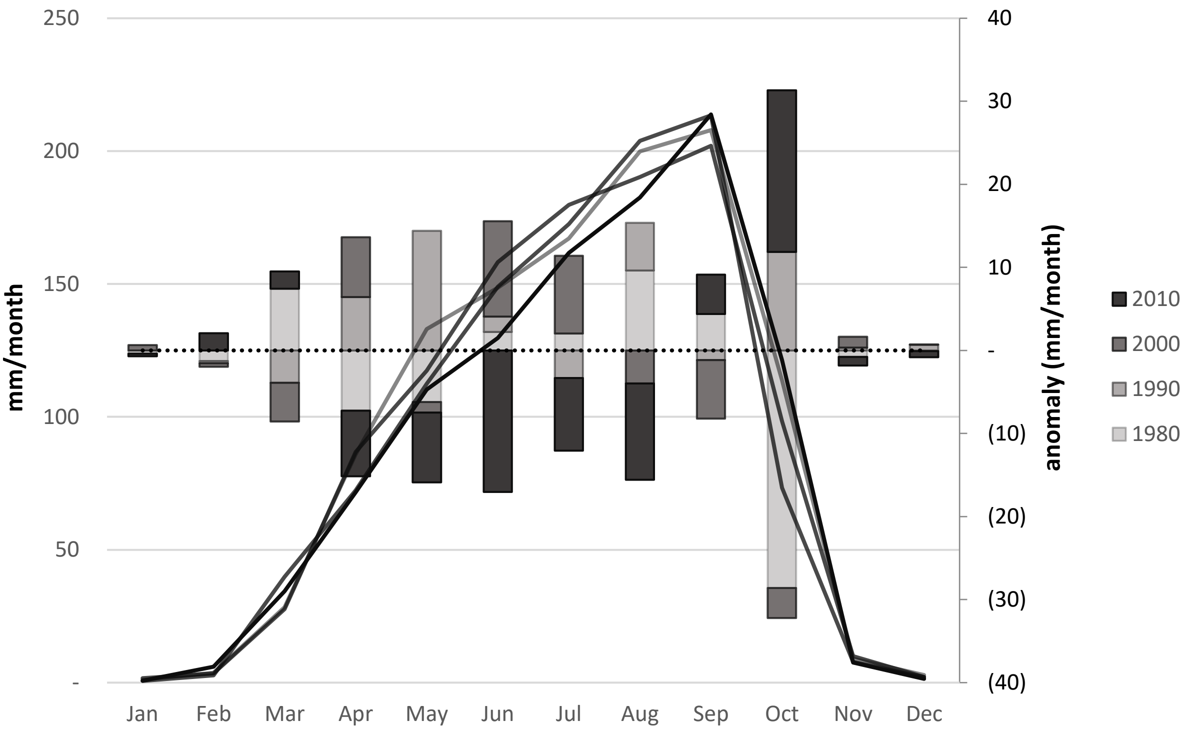

Figure 20. Decadal monthly precipitation profiles (lines) and monthly precipitation anomalies (bars) for the three northern regions of Ghana.

Changes in rainfall pattern have also included an increase in the frequency of large rainfall events. While lower rainfall days usually contribute the majority of total rainfall days, flood risk increases with an increase in the frequency of higher rainfall days. Examining the frequency of occurrence of rainfall magnitude days over the past four decades using CHIRPS data, there has generally been a decrease in the number of lower rainfall days and an increase in the number of higher rainfall days (Figure 21).

[274] Lacombe G, McCartney MP, Forkuor G. 2012. Drying climate in Ghana over the period 1960-2005: Evidence from the resampling-based Mann-Kendall test at local and regional levels. *Hydrological Sciences Journal* 57: 1-16.
[275] Akudugu MA, Alhassan A-R. 2012. The climate change menace, food security, livelihoods and social safety in Northern Ghana. *International Journal of Sustainable Development and World Policy* 1: 80–95.
[276] Kankam-Yeboah K, Amisigo B, Obuobi E. 2011. Climate change impacts on water resources in Ghana. *Ghana and Unesco 2009/2010, 65–69. Accra: Ghana National Commission for UNESCO/Ministry of Education*.
[277] Ibid.
[278] Ibid.
[279] Ibid.

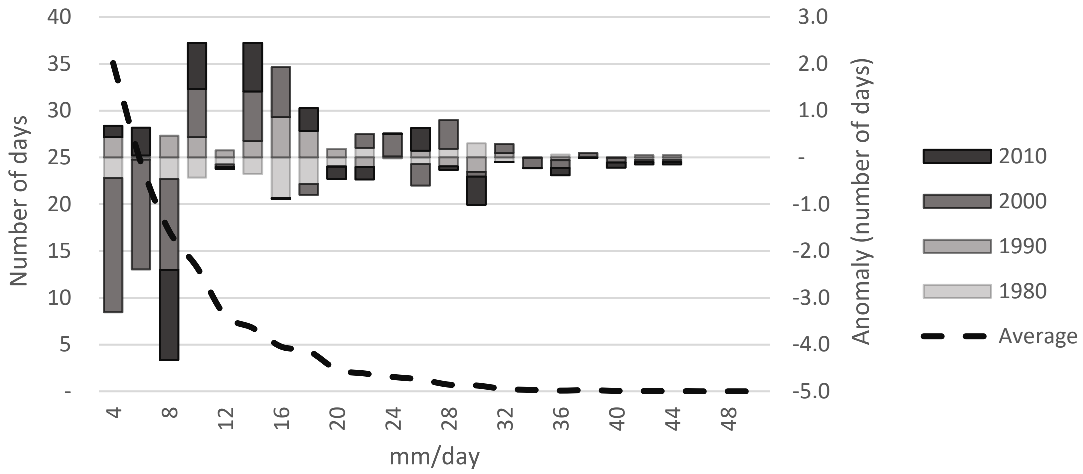

Figure 21. Precipitation event occurrence profile (average line) and event magnitude shifts (bars) for the three northern regions of Ghana

This increase in the number of higher rainfall days is also reflected in an overall increase in the magnitude of 90th percentile precipitation events over the past ~40 years (Figure 22). 90th percentile precipitation events represent the largest rainfall events, and changes in their volume are indicative of a shift towards more or less extreme events in the precipitation profile. The observed increased magnitude of 90th percentile precipitation events in northern Ghana, therefore, indicates a trend towards an increased occurrence of extreme rainfall events.

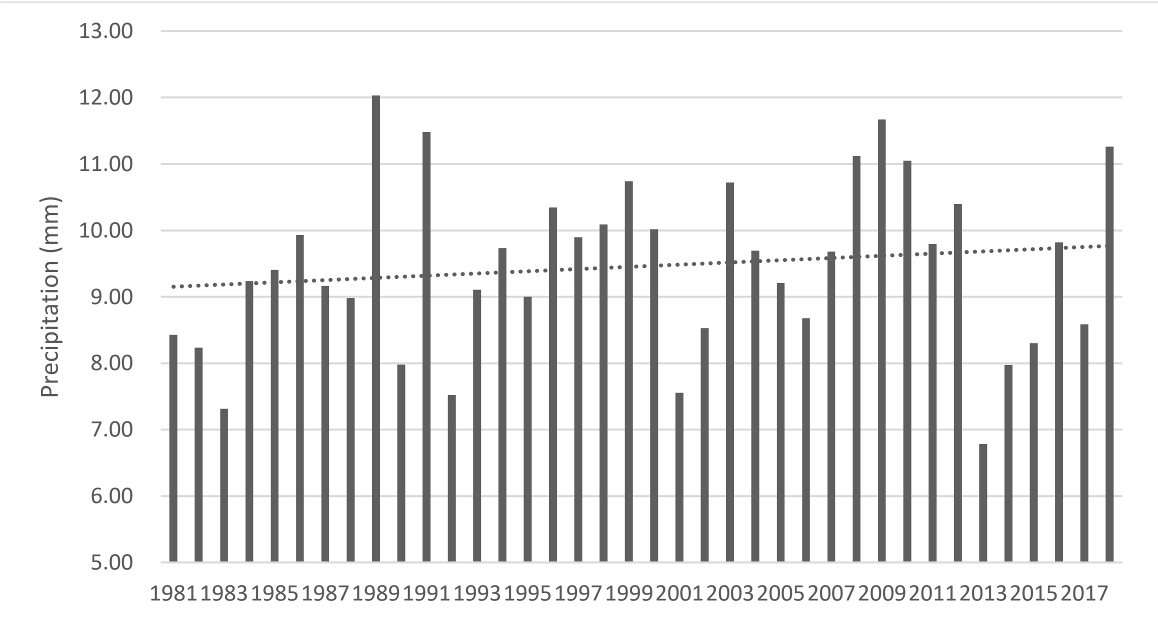

Figure 22. Magnitude of 90th percentile precipitation events in northern Ghana. 90th percentile precipitation events represent the largest rainfall events, and changes in their volume are indicative of a shift towards more or less extreme events in the precipitation profile.

Overall, observed rainfall data for northern Ghana indicate that while there has been little change in average annual rainfall, the wet season has been shortening while the rainfall pattern has become more erratic with an increased frequency of higher rainfall events.

4.2.2 Temperature trends

While detection of observed long-term changes in rainfall is challenging from a statistical perspective, the long-term changes in temperature in Ghana are unambiguous (Figure 23). From 1950 to 2012, the mean annual temperature of Ghana has risen by ~1℃, representing an average rate of increase of ~0.14℃ per decade (Figure 23). Increases in temperature have been most rapid during April, May and June (~0.27℃ increase per decade) and in the northern regions of the country[280]. Indeed, mean annual temperatures in the northern Sudan Savannah ecological zone have increased from 28.1°C in 1960 to 29.0°C in 2000[281]. The frequency of hot days and nights has also increased[282]. Between 1960 and 2000, the average number of hot days and nights per year has increased by 48 (an additional 13.2%) and 73 (an additional 20%), respectively[283]. Similarly, and for the same period, the average number of cold days and nights[284] per year decreased by 12 and 18.5, respectively[285].

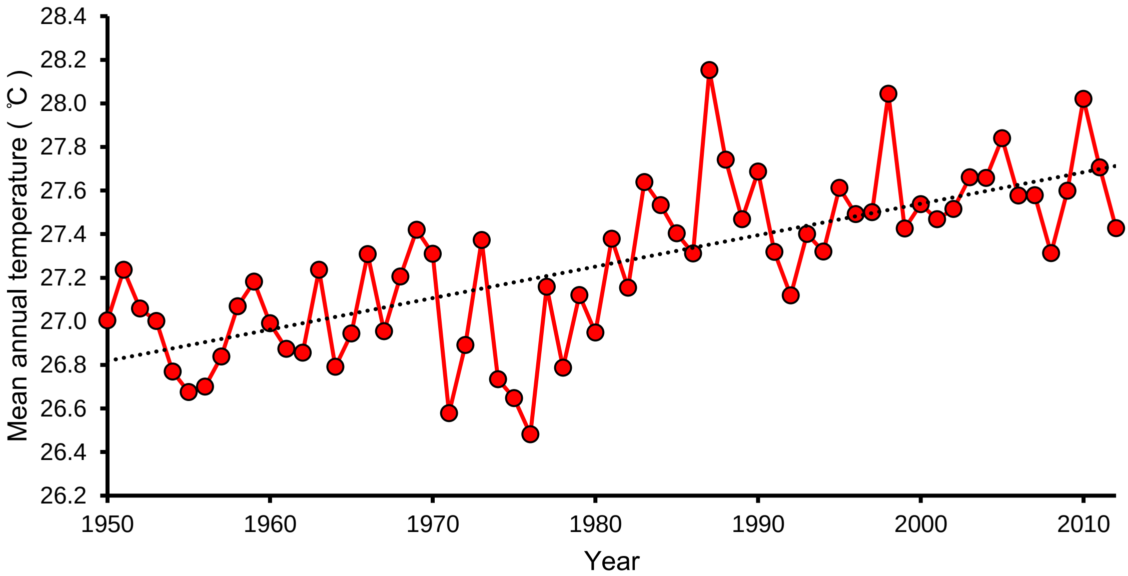

Figure 23. Change in annual temperatures for Ghana from 1950 to 2012. The dashed line is a significant linear trend line (y = 0.01 – 1.33; $R^2 = 0.50$; $p < 0.01$).[286]

4.2.3 Recent climate hazards and extreme events

Ghana — and particularly northern Ghana — has been adversely affected by numerous extreme events (Figure 24). These include at least three droughts and nineteen floods (Table 13), which have cumulatively affected over 16 million people and resulted in at least 444 deaths – excluding the undocumented numbers of deaths resulting from droughts. Floods, in particular, have become increasingly frequent over the past 30 years (Table 13).

[280] McSweeney C., New M., Lizcano G. 2010. UNDP Climate Change Country Profiles: Ghana. UNDP Climate Change Country Profiles, School of Geography and Environment, University of Oxford, Oxford, United Kingdom. Available from: http://country-profiles.geog.ox.ac.uk.
[281] Government of Ghana 2015. Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods. Project proposal to the Adaptation Fund.
[282] The temperature threshold for a hot (cold) day in any region or season is defined by the daily maximum (minimum) temperature which is exceeded on the 10% warmest (coldest) of days in the standard climate period (1970-99).
[283] McSweeney C., New M., Lizcano G. 2010. UNDP Climate Change Country Profiles: Ghana. UNDP Climate Change Country Profiles, School of Geography and Environment, University of Oxford, Oxford, United Kingdom. Available from: http://country-profiles.geog.ox.ac.uk.
[284] The temperature threshold for a hot (cold) night in any region or season is defined by the daily minimum (maximum) temperature which is exceeded on the 10% warmest (coldest) of days in the standard climate period (1970-99).
[285] McSweeney C., New M., Lizcano G. 2010. UNDP Climate Change Country Profiles: Ghana. UNDP Climate Change Country Profiles, School of Geography and Environment, University of Oxford, Oxford, United Kingdom. Available from: http://country-profiles.geog.ox.ac.uk.
[286] Data are from http://sdwebx.worldbank.org/climateportal/index.cfm.

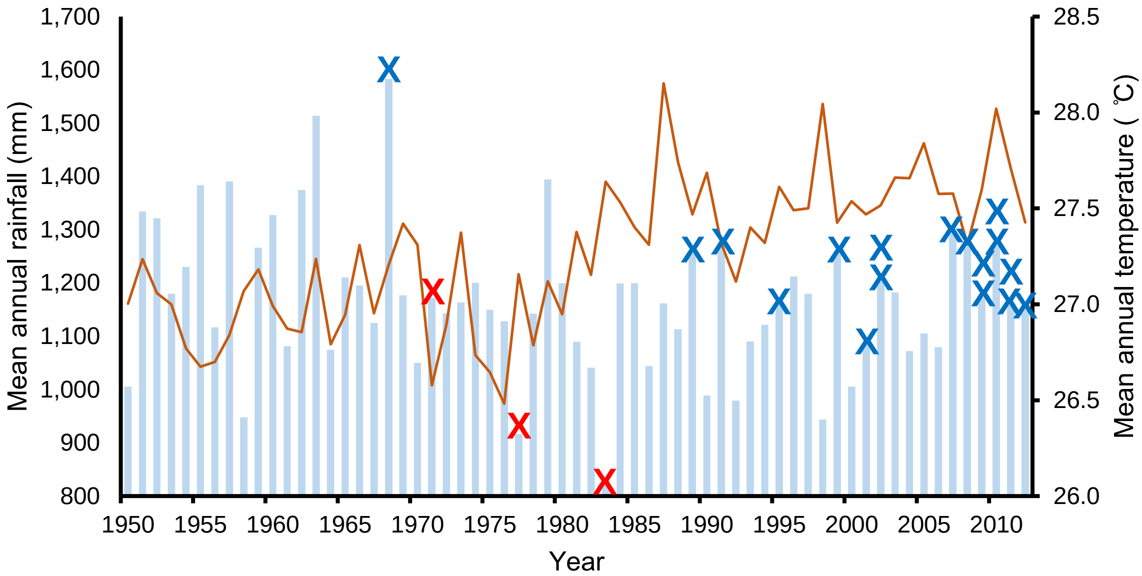

Figure 24. Extreme climate events (droughts and floods) relative to mean annual rainfall (left-hand y-axis; bars) and mean annual temperature (right-hand y-axis; line) in Ghana from 1950 to 2012. Crosses represent specific events.

Table 13. List of climate hazards and their impacts in Ghana between 1968 and 2017[287]. Climate hazards in northern Ghana are in **bold**.

Year	Disaster description	Region/s affected	Total deaths	Total people affected	Total damage (US$)
1968	Flood	Central	--	25,000	74,700,000
1971	**Drought**	**Countrywide**	**--**	**12,000**	**100,000**
1977	**Drought**	**Northern, Upper East, Upper West**	**--**	**--**	**--**
1983	Drought	Countrywide	--	12,500,000	--
1989	**Flood**	**Northern**	**7**	**2,800**	**--**
1991	Flood	Greater Accra	5	2,000,000	--
1995	Flood	Greater Accra	145	700,000	12,500,000
1999	**Flood**	**Northern, Upper East, Upper West**	**52**	**324,602**	**21,000,000**
2001	Flood	Greater Accra	12	144,025	--
2002	Flood	Greater Accra	--	200	--
2002	Flood	Greater Accra	4	2,000	--
2007	**Flood**	**Northern, Upper East, Upper West**	**56**	**332,600**	**--**
2008	**Flood**	**Northern**	**--**	**58,000**	**--**
2009	Flood	Greater Accra, Ashanti, Volta, Western, Central, Eastern	16	19,755	--
2009	**Flood**	**Northern**	**24**	**139,790**	**--**
2010	Flood	Greater Accra, Central, Volta	45	7,500	--

[287] EM-DAT 2016. Disaster List for Ghana. Available at: http://emdat.be/disaster_list/index.html

2010	**Flood**	**Brong Ahafo, Eastern, Western, Upper East, Upper West, Northern**	**18**	**9,674**	**--**
2011	Flood	Eastern	6	12,571	--
2011	Flood	Greater Accra, Eastern, Volta	14	81,473	--
2013	**Flood**	**Northern, Volta**	**5**	**25,000**	**--**
2015	Flood	Greater Accra	25	5,000	12,000,000
2016	Flood	Greater Accra	10	--	--

4.2.3.1 *Floods*

Floods can cause widespread damage to infrastructure and farmland, impacting the livelihoods of many Ghanaians. The increasing concentration of rainfall into the late wet season over the last two decades has increased the frequency and severity of floods in northern Ghana[288]. The extent of the impacts of floods in northern Ghana is exemplified by the severe floods that affected the region in 2007. These floods — which resulted in the GoG declaring the region a disaster zone — claimed 56 lives and displaced ~332,000 people[289,290]. In addition, the floods caused extensive damage to infrastructure — damaging ~500 km of roads, ~34,000 homes, ~10 schools, 51 health facilities and 69 bridges[291,292]. The floods also affected agricultural production in the region — affecting ~70,500 hectares of farmland and causing the loss of ~144,000 metric tonnes of food crops – including maize, sorghum, millet, groundnuts, yam, cassava and rice[293,294]. The loss in production, coupled with the restricted access to markets because of damaged roads and bridges led to negative growth in the agricultural sector for the first time since 1994[295]. Another example of the impacts of flooding in Ghana is the intense floods that occurred in parts of northern Ghana, Accra and the Agona District in 2010 and resulted in the loss of human life, livestock and farmland, as well as extensive damage to infrastructure.

4.2.3.2 *Droughts*

As the wet season in northern Ghana has become shorter, the dry season has increased in length and severity[296]. Furthermore, as the variability in the rainfall pattern has steadily increased in northern Ghana, the occurrence of intermittent droughts has also become more common[297,298] — even during the wet season[299]. Like floods, droughts have severe impacts on the agricultural livelihoods of northern Ghanaians (see Section 5.2.2).

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[288] Bawayelaazaa Nyuor A, Donkor E, Aidoo R, Saaka Buah S, Naab J, Nutsugah S, Bayala J, Zougmoré R. 2016. Economic impacts of climate change on cereal production: implications for sustainable agriculture in Northern Ghana. *Sustainability* 8: 724.
[289] Government of Ghana 2007. Joint assessment report of flood disasters in the three northern regions of Ghana. *Inter-ministerial Disaster Relief Committee and UN Country Team.*
[290] Armah F.A, Yawson D.O, Yengoh G.Y, Odoi J.O, Afrifa E.K.A. 2010. Impact of Floods on Livelihoods and vulnerability of Natural Resource Dependent Communities in Northern Ghana. *Water* **2**(2): 120–139.
[291] Government of Ghana 2007. Joint assessment report of flood disasters in the three northern regions of Ghana. *Inter-ministerial Disaster Relief Committee and UN Country Team.*
[292] Akudugu MA, Alhassan A-R. 2012. The climate change menace, food security, livelihoods and social safety in Northern Ghana. *International Journal of Sustainable Development and World Policy* 1: 80–95..
[293] Government of Ghana 2007. Joint assessment report of flood disasters in the three northern regions of Ghana. *Inter-ministerial Disaster Relief Committee and UN Country Team.*
[294] Armah F.A, Yawson D.O, Yengoh G.Y, Odoi J.O, Afrifa E.K.A. 2010. Impact of Floods on Livelihoods and vulnerability of Natural Resource Dependent Communities in Northern Ghana. *Water* **2**(2): 120–139.
[295]Choudhary V, Christienson G, D'Alessandro S.P, Josserand H.P. 2016. Ghana: Agricultural Sector Risk Assessment. *World Bank Agriculture Global Practice Note.*
[296] Akudugu MA, Alhassan A-R. 2012. The climate change menace, food security, livelihoods and social safety in Northern Ghana. *International Journal of Sustainable Development and World Policy* 1: 80–95.
[297] Ibid.
[298] Sulemana A. 2017. Management and use of non-timber forest products (NTFPs) as climate change adaptation strategy in Lawra District, Ghana. MPhil, University of Ghana, Accra.
[299] Marchetta F (ed). 2011. *On the move livelihood strategies in Northern Ghana*. Centre d'Etudes et de Recherches sur le Développement International (CERDI). Clermont-Ferrand.

4.3 Predicted future climate change

4.3.1 Approach for predicting future climate change

For this feasibility study, a peer-reviewed ensemble of general circulation models[300] (GCMs) was used to overcome the uncertainty of individual models when predicting future changes in rainfall, temperature and additional climatic characteristics. The ensemble spans 10 GCMs downscaled using five regional climate models (RCMs) and the WorldClim baseline dataset under two representative concentration pathways (RCPs) of the IPCC Fifth Assessment Report[301,302]. RCP 4.5 was used to represent an optimistic scenario of future global greenhouse gas (GHG) emissions, whereby emissions peak in 2040 and decline afterwards. Conversely, RCP 8.5 was used to represent a business-as-usual scenario where emissions continue to rise throughout the 21st century. The mean of the ensemble climate projections was used as an indication of the most likely predicted changes in future climate. Medium- (2055) and long-term (2085) climate change predictions were generated across Ghana and compared with a baseline climatology. For each administrative region of the country, mean predicted changes in rainfall, temperature, potential evapotranspiration and the moisture index were extracted for 2055 and 2085 under the two RCP scenarios. It is important to note that most GCMs are limited in their ability to correctly reproduce the main features of the atmospheric circulation patterns over West Africa[303]. This limitation contributes to uncertainty in projections of future rainfall.

Following the analysis of predicted climate change across all of Ghana, climatic changes in northern Ghana specifically were predicted using the CORDEX dataset.

4.3.2 Predicted changes in rainfall characteristics

The ensemble climate projections suggest that mean annual rainfall in Ghana will slightly increase by approximately 3% by 2055 and 2085 periods under RCP 4.5, and ~3% and ~5% by 2055 and 2085, respectively, under RCP 8.5 (Table 14a; Figure 25).

While the overall change in annual rainfall is predicted to be relatively small, rainfall across Ghana is predicted to become more seasonal. Rainfall in the wettest month in Ghana is expected to increase considerably (by ~6% under RCP 4.5 and ~11% under RCP 8.5 by 2085), again with the largest increases expected in the three northern regions (Table 14b). Conversely, rainfall in the driest month is predicted to decrease across Ghana, with the most pronounced decreases generally expected in the southern and central regions (Table 14c). In the three northern regions, the driest months currently receive nearly zero rainfall and, therefore, no decrease in rainfall during the driest month is expected or indeed possible in the future.

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300 General Circulation Models simulate the earth-atmosphere relationship and estimate the impact of greenhouse gas (GHG) levels on climate variables, including rainfall and temperature.
301 Platts PJ, Omeny PA, Marchant R. 2015. AFRICLIM: high-resolution climate projections for ecological applications in Africa. African Journal of Ecology 53, 103-108.
302 Data were downloaded from www.york.ac.uk/environment/research/kite/resources/.
303 USAID. 2011. Ghana climate change vulnerability and adaptation assessment.

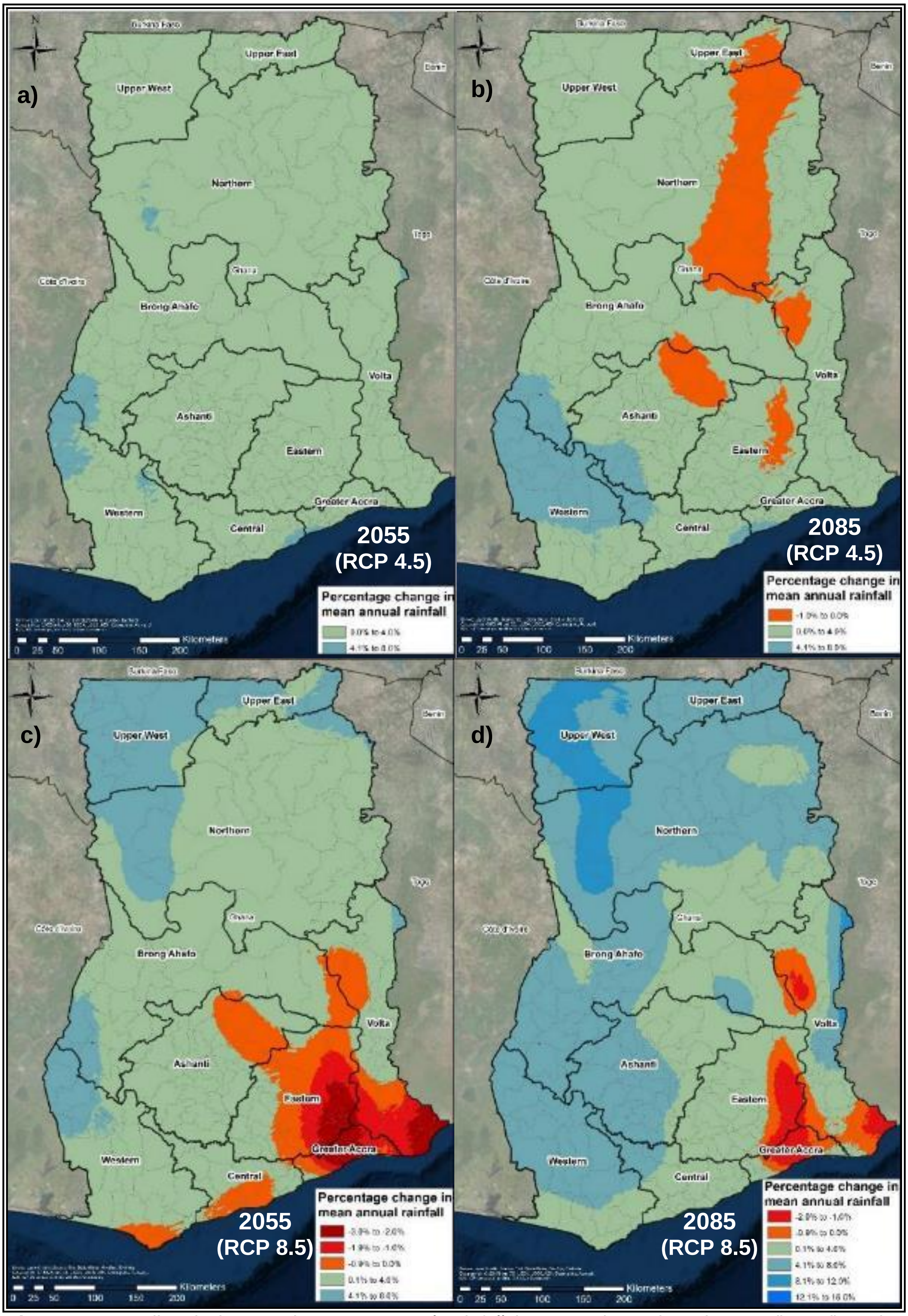


Figure 25. Predicted changes in mean annual rainfall by 2055 (a & c) and 2085 (b & d) under representative concentration pathways (RCPs) 4.5 (a & b) and 8.5 (c & d).

Table 14. Predicted medium- (2055) and long-term (2085) changes in mean rainfall characteristics under representative concentration pathways (RCP) 4.5 and 8.5 of the IPCC AR-5 for the regions of Ghana using the mean from an ensemble of ten general circulation models (GCMs) downscaled using five regional climate models (RCMs). Colour scales relate to the percentage change. The bold border indicates the northern regions.

a) Mean annual rainfall		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (mm)	mm (∆)	mm (∆)	mm (∆)	mm (∆)
Ashanti	1,389	1,426 (3%)	1,431 (3%)	1,426 (3%)	1,458 (5%)
Brong Ahafo	1,230	1,265 (3%)	1,263 (3%)	1,268 (3%)	1,296 (5%)
Central	1,381	1,433 (4%)	1,442 (4%)	1,410 (2%)	1,435 (4%)
Eastern	1,454	1,476 (1%)	1,480 (2%)	1,461 (0%)	1,487 (2%)
Greater Accra	936	962 (3%)	966 (3%)	930 (-1%)	939 (0%)
Northern	1,112	1,145 (3%)	1,131 (2%)	1,156 (4%)	1,177 (6%)
Upper East	970	990 (2%)	986 (2%)	1,021 (5%)	1,036 (7%)
Upper West	1,013	1,049 (4%)	1,048 (3%)	1,081 (7%)	1,103 (9%)
Volta	1,256	1,287 (2%)	1,281 (2%)	1,273 (1%)	1,295 (3%)
Western	1,624	1,692 (4%)	1,707 (5%)	1,683 (4%)	1,725 (6%)
Ghana	1,247	1,283 (3%)	1,281 (3%)	1,286 (3%)	1,312 (5%)

b) Mean rainfall in wettest month		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (mm)	mm (∆)	mm (∆)	mm (∆)	mm (∆)
Ashanti	210	219 (4%)	233 (6%)	218 (4%)	230 (9%)
Brong Ahafo	198	211 (7%)	214 (8%)	211 (6%)	226 (14%)
Central	255	259 (1%)	268 (5%)	257 (1%)	264 (4%)
Eastern	223	225 (1%)	230 (3%)	224 (0%)	231 (3%)
Greater Accra	200	197 (-1%)	201 (1%)	190 (-5%)	190 (-5%)
Northern	226	241 (7%)	242 (7%)	244 (7%)	258 (14%)
Upper East	249	266 (7%)	267 (7%)	268 (7%)	284 (14%)
Upper West	242	259 (7%)	264 (9%)	268 (10%)	276 (14%)
Volta	209	218 (4%)	219 (5%)	218 (4%)	227 (9%)
Western	296	304 (2%)	314 (6%)	305 (3%)	313 (5%)
Ghana	228	239 (5%)	243 (6%)	241 (5%)	252 (11%)

c) Mean rainfall in driest month		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (mm)	mm (∆)	mm (∆)	mm (∆)	mm (∆)
Ashanti	14.7	15.0 (3%)	14.6 (0%)	16.3 (11%)	15.0 (2%)
Brong Ahafo	7.4	7.4 (0%)	7.4 (0%)	8.3 (11%)	7.7 (4%)
Central	28.5	27.1 (-5%)	25.5 (-10%)	25.9 (-9%)	25.2 (-12%)
Eastern	24.6	24.3 (-1%)	23.9 (-3%)	24.4 (-1%)	23.3 (-5%)
Greater Accra	14.0	13.9 (-1%)	12.9 (-8%)	13.5 (-3%)	12.9 (-8%)
Northern	2.1	2.1 (0%)	2.1 (0%)	2.2 (4%)	2.1 (0%)
Upper East	0.7	0.7 (0%)	0.7 (0%)	0.7 (0%)	0.7 (0%)

Upper West	1.0	1.0 (0%)	1.0 (0%)	1.0 (0%)	1.0 (0%)
Volta	13.7	13.5 (-1%)	13.3 (-3%)	13.7 (0%)	13.1 (-4%)
Western	31.3	29.7 (-5%)	28.9 (-8%)	28.3 (-10%)	28.2 (-10%)
Ghana	11.1	10.9 (-2%)	10.6 (-4%)	11.0 (-1%)	10.6 (-5%)

Focussing on only northern Ghana and examining predicted rainfall per month rather than a year, a continued change in rainfall is anticipated. Rainfall will continue to be increasingly concentrated into May and August/September — with decreases noted in the lead-up to, and periods between, and after these months (Figure 26). Projections of monthly rainfall estimate an increase of ~5mm/month in April and July/August, increasing per decade towards the end of the century. Wet season onset and cessation months of March and October have a variable decrease per decade of ~10mm/month, while the mid wet season month of June expresses a decrease in the latter half of the century of ~15mm. These projected changes in monthly rainfall are more extreme under the RCP 8.5 scenario (dashed and arrows). Overall, the models project a further reduction in early wet season rainfall (April to June) and increase in late wet season rainfall (July to September) in the future. This indicates that the shortening of the wet season in northern Ghana as a result of climate change will continue.

The multi-model analysis presents a consensus in monthly model anomaly direction (Figure 27), particularly under the RCP 4.5 scenario. The RCP 4.5 model variation ranges from +20 to -20 in strong direction change months of June and August, the months that are less clear in direction of change – April, May and October – exhibit several models either side of the 0mm/month change mark. The RCP 8.5 precipitation character is similar to the profile of RCP 4.5 – exceptions being increases in May and October – but with an increase in magnitude of variation, particularly positive change.

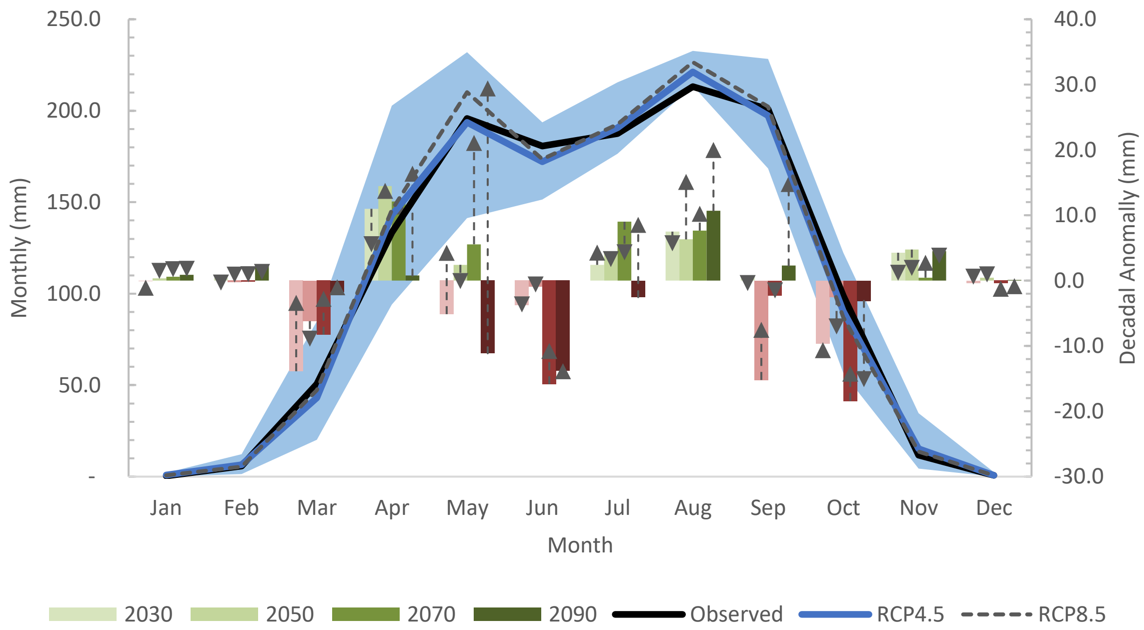


Figure 26. Monthly precipitation profile and monthly precipitation volume changes per decade for RPC 4.5 and RCP 8.5 in northern Ghana.

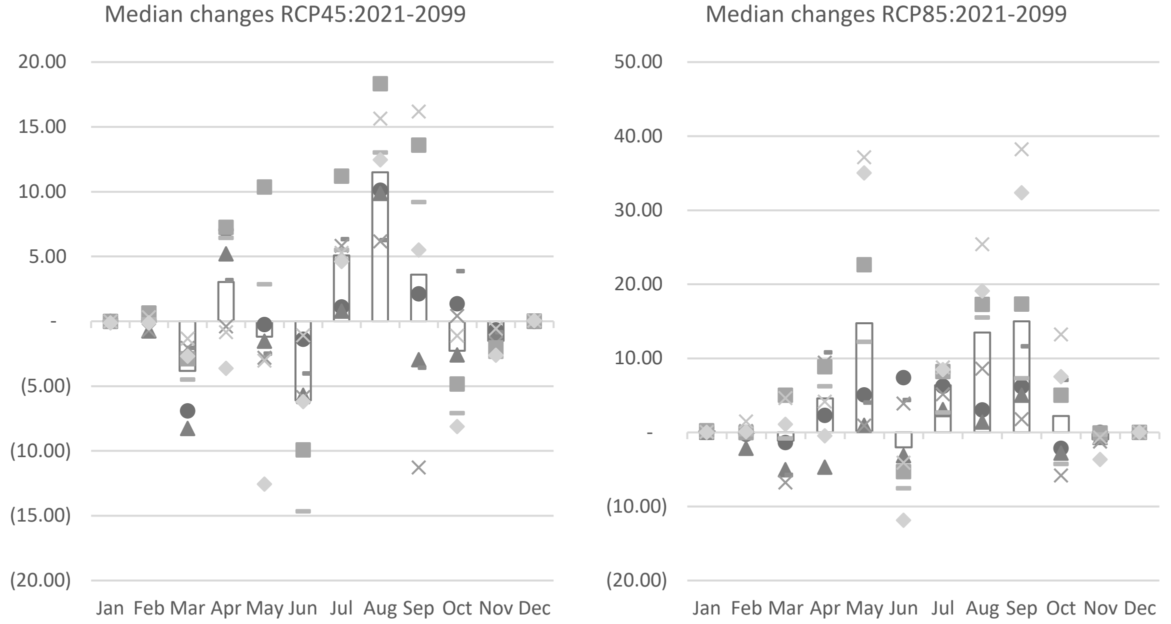


Figure 27. Median precipitation anomalies and model variance for RCP 4.5 (left) and RCP 8.5 (right).

Along with a change in the timing of rainfall, the models also predict a change in the nature of rainfall events. For both RCP 4.5 and RCP 8.5, there will be a reduced occurrence of low-volume rainfall (<11mm) events and an increased occurrence of high-volume rainfall (11 – 21mm) events (Figure 28 and Figure 29).

This result is supported by the predicted increase in rainfall intensity over time (Figure 30) under both the RCP 4.5 (increased rainfall intensity of 0.06mm/hour per decade) and RCP 8.5 scenarios (increased rainfall intensity of 0.14mm/hour per decade).

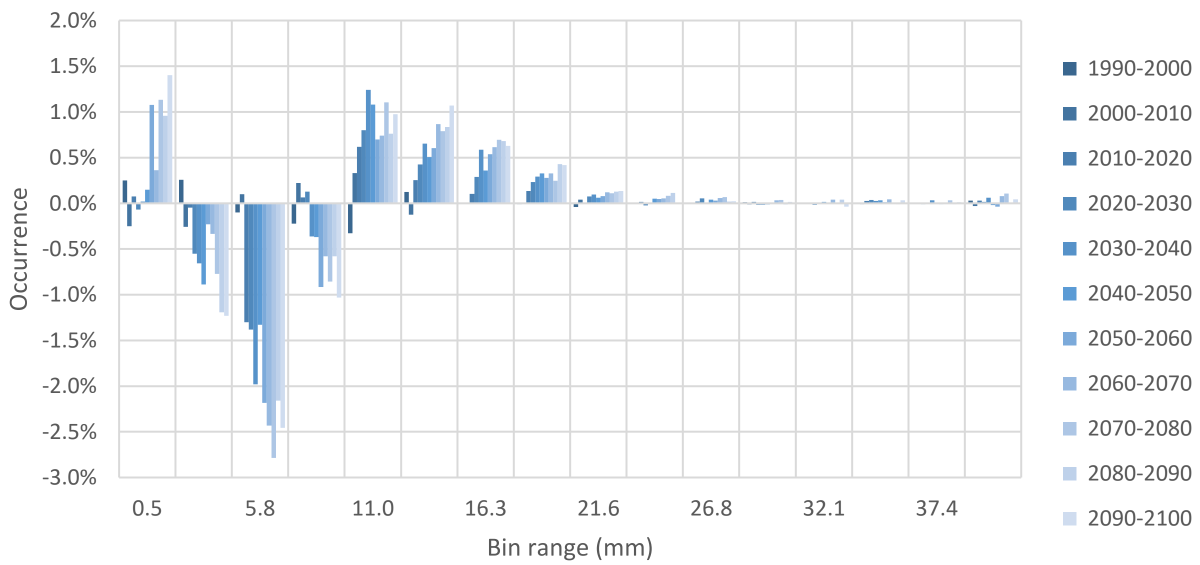


Figure 28. Anomaly precipitation profile for northern Ghana for RCP 4.5.

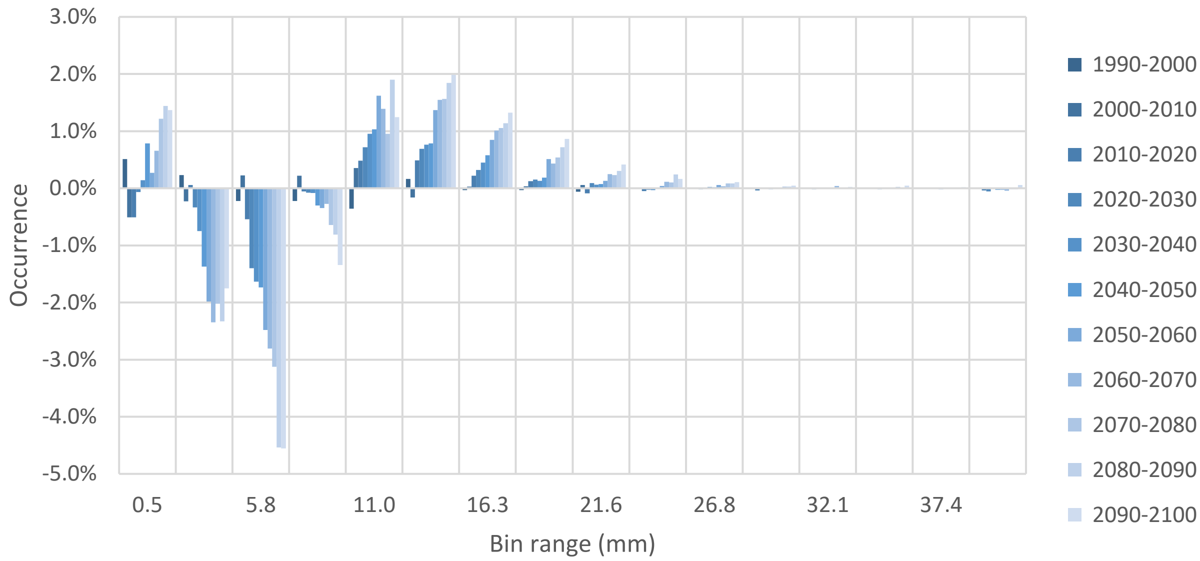


Figure 29. Anomaly precipitation profile for northern Ghana for RCP 8.5.

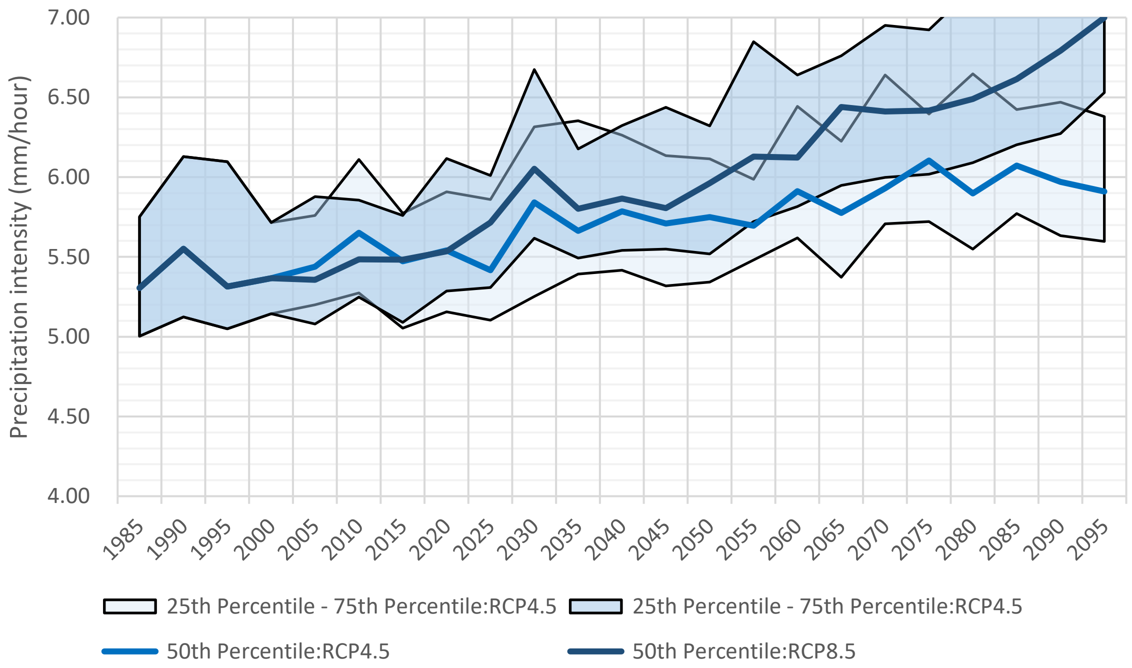


Figure 30. Modelled changes in precipitation intensity (mm/hr) through time for northern Ghana.

The increased occurrence of high-volume rainfall events and increased rainfall intensity, combined with the finding that overall annual rainfall volume is likely to remain fairly constant, indicate that the nature of rainfall in northern Ghana is likely to change. Instead of falling as frequent low volume events, the rain will be more likely to occur as less frequent but more intense higher volume events. The increased occurrence of higher rainfall events is associated with an increase in flood risk, while the overall reduction in the number of rainfall events is associated with more frequent dry spells.

4.3.3 <u>Predicted changes in temperature variables</u>

The ensemble of climate models indicates that annual average temperatures will increase markedly throughout the 21st century across Ghana (Table 15a; Figure 31). Under RCP 8.5, the annual average temperature of Ghana is expected to increase by ~4.5℃ (16.4%) by 2085 (Table 15a). Increases in annual average temperature are predicted to be greatest in the northern regions of Ghana. For example, the annual average temperature of the Upper East Region is predicted to increase from ~28.2℃ to ~33.1℃ (an increase of 4.9℃) by 2085 under RCP 8.5 (Table 15a). Annual minimum and maximum temperatures are also expected to increase in all the regions of Ghana, with the northern regions again expected to experience the largest changes (Table 15b; c). The annual maximum temperature of the Upper East Region is expected to increase from ~34.1℃ to an extreme ~38.8℃ by 2085 under RCP 8.5 (Table 15c).

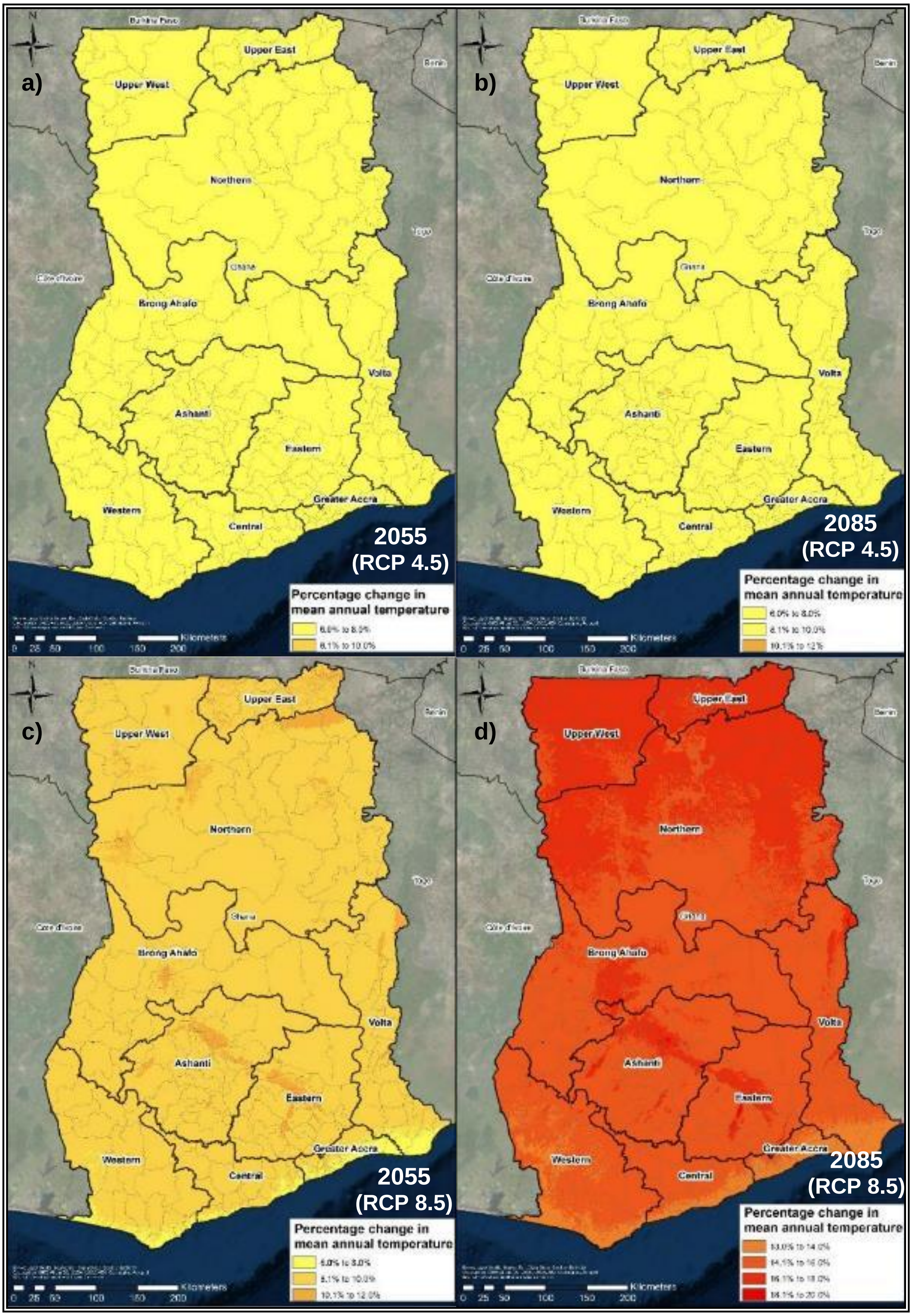


Figure 31. Predicted changes in mean annual average temperature by 2055 (a & c) and 2085 (b & d) under representative concentration pathways (RCPs) 4.5 (a & b) and 8.5 (c & d).

Table 15. Predicted medium- (2055) and long-term (2085) changes in mean temperature characteristics under representative concentration pathways (RCP) 4.5 and 8.5 of the IPCC AR-5 for the regions of Ghana using the mean from an ensemble of ten general circulation models (GCMs) downscaled using five regional climate models (RCMs). Colour scales relate to the percentage change. The bold border indicates the northern regions.

a) Mean annual average temperature		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (℃)	℃ (∆)	℃ (∆)	℃ (∆)	℃ (∆)
Ashanti	25.9	27.9 (7.7%)	28.4 (9.4%)	28.6 (10.3%)	30.2 (16.4%)
Brong Ahafo	26.8	28.9 (7.6%)	29.3 (9.4%)	29.6 (10.2%)	31.2 (16.5%)
Central	26.2	28.1 (7.2%)	28.5 (8.8%)	28.7 (9.5%)	30.3 (15.3%)
Eastern	26.0	28.0 (7.5%)	28.4 (9.2%)	28.6 (10.0%)	30.2 (16.1%)
Greater Accra	26.9	28.7 (6.8%)	29.2 (8.4%)	29.3 (9.0%)	30.8 (14.7%)
Northern	27.7	29.9 (7.8%)	30.4 (9.6%)	30.7 (10.5%)	32.5 (16.9%)
Upper East	28.2	30.5 (8.0%)	31.0 (9.8%)	31.2 (10.7%)	33.1 (17.3%)
Upper West	27.8	30.0 (8.0%)	30.5 (9.8%)	30.8 (10.7%)	32.6 (17.2%)
Volta	27.1	29.1 (7.3%)	29.6 (9.1%)	29.8 (9.8%)	31.4 (15.9%)
Western	26.3	28.2 (7.2%)	28.6 (8.8%)	28.8 (9.5%)	30.3 (15.3%)
Ghana	27.0	29.1 (7.6%)	29.5 (9.4%)	29.8 (10.2%)	31.5 (16.4%)

b) Mean annual minimum temperature		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (℃)	℃ (∆)	℃ (∆)	℃ (∆)	℃ (∆)
Ashanti	21.1	23.2 (10.0%)	23.6 (12.2%)	23.9 (13.5%)	25.6 (21.5%)
Brong Ahafo	21.6	23.7 (9.9%)	24.2 (12.2%)	24.5 (13.4%)	26.2 (21.5%)
Central	22.3	24.4 (9.4%)	24.9 (11.4%)	25.1 (12.5%)	26.8 (19.9%)
Eastern	21.1	23.2 (9.9%)	23.6 (12.1%)	23.9 (13.3%)	25.5 (21.2%)
Greater Accra	22.8	24.9 (8.9%)	25.3 (10.9%)	25.5 (11.8%)	27.2 (18.9%)
Northern	21.9	24.2 (10.2%)	24.7 (12.6%)	25.0 (13.9%)	26.8 (22.4%)
Upper East	22.0	24.3 (10.7%)	24.8 (13.0%)	25.1 (14.4%)	27.1 (23.1%)
Upper West	21.7	24.0 (10.6%)	24.5 (12.9%)	24.8 (14.4%)	26.7 (23.1%)
Volta	21.9	24.0 (9.6%)	24.5 (11.9%)	24.8 (12.9%)	26.5 (20.8%)
Western	22.2	24.2 (9.3%)	24.7 (11.4%)	24.9 (12.5%)	26.6 (20.0%)
Ghana	21.7	23.9 (10.0%)	24.4 (12.2%)	24.7 (13.5%)	26.4 (21.6%)

c) Mean annual maximum temperature		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (℃)	℃ (∆)	℃ (∆)	℃ (∆)	℃ (∆)
Ashanti	30.7	32.6 (6.2%)	33.0 (7.7%)	33.2 (8.2%)	34.8 (13.3%)
Brong Ahafo	31.9	33.8 (6.1%)	34.3 (7.6%)	34.4 (8.1%)	36.1 (13.2%)
Central	30.0	31.8 (5.9%)	32.2 (7.3%)	32.4 (7.9%)	33.9 (12.8%)
Eastern	30.9	32.7 (6.0%)	33.2 (7.5%)	33.4 (8.1%)	34.9 (13.1%)
Greater Accra	30.8	32.5 (5.7%)	32.9 (7.1%)	33.1 (7.6%)	34.6 (12.4%)
Northern	33.3	35.4 (6.1%)	35.9 (7.6%)	36.1 (8.2%)	37.8 (13.5%)
Upper East	34.1	36.3 (6.2%)	36.8 (7.7%)	37.0 (8.3%)	38.8 (13.6%)

Upper West	33.6	35.7 (6.2%)	36.2 (7.7%)	36.4 (8.3%)	38.2 (13.6%)
Volta	32.1	34.0 (5.9%)	34.4 (7.4%)	34.6 (7.9%)	36.2 (12.9%)
Western	30.3	32.1 (5.9%)	32.5 (7.3%)	32.7 (7.8%)	34.2 (12.7%)
Ghana	32.1	34.0 (6.1%)	34.5 (7.6%)	34.7 (8.1%)	36.3 (13.2%)

Focussing on only northern Ghana and examining monthly rather than annual temperatures, it is noted that temperature is predicted to increase fairly uniformly across all months, with the highest increases occurring later in the century (Figure 32).

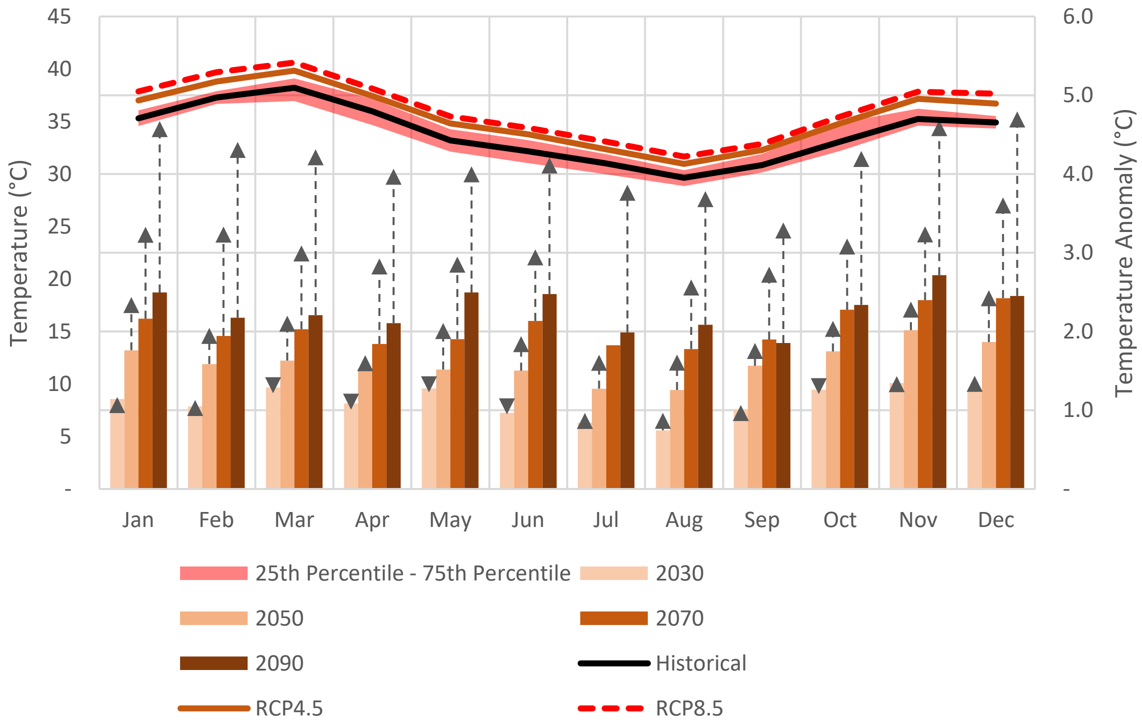


Figure 32. Predicted changes in mean monthly temperature (lines) and magnitude temperature change (bars) for northern Ghana for RCP 4.5 and RCP 8.5.

4.3.4 Predicted changes in potential evapotranspiration and moisture

The mean of the 10 GCMs suggests that potential evapotranspiration (PET)[304] will increase across Ghana throughout the 21st century under both RCPs Table 16a). This increase will be most apparent in the northern regions where PET will increase by ~8.5% by 2085 (Table 16a). The predicted increase in PET will be marginally greater than the predicted minor increase in annual rainfall, resulting in a decrease in the annual moisture index[305] in most regions of the country (Table 16b). The extent to which the moisture index will change depends on the period in question (2055 versus 2085) and the RCP used to generate climate projections (Table 16b).

[304] Defined as the amount of evaporation that would occur if a sufficient water source were available.
[305] Annual moisture index = Mean annual rainfall / Potential evapotranspiration.

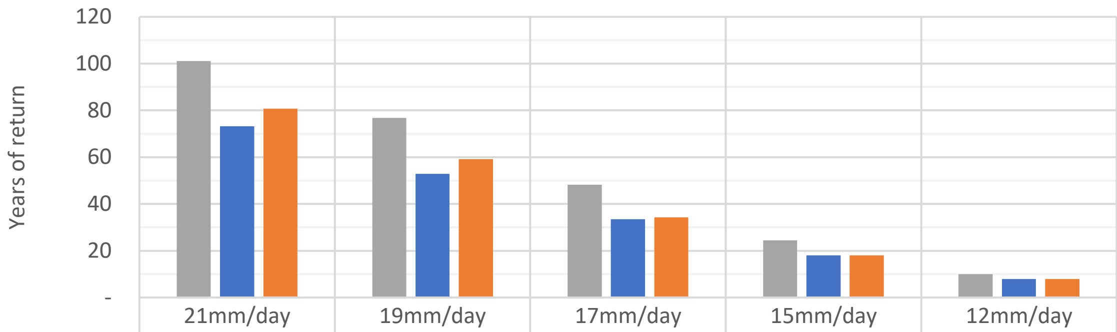
Table 16. Predicted medium- (2055) and long-term (2085) changes in additional climate characteristics under representative concentration pathways (RCP) 4.5 and 8.5 of the IPCC AR-5 for the regions of Ghana using the mean from an ensemble of ten general circulation models (GCMs) downscaled using five regional climate models (RCMs). Colour scales relate to the percentage change. The bold border indicates the northern regions.

a) Mean potential evapotranspiration		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (mm)	mm (Δ)	mm (Δ)	mm (Δ)	mm (Δ)
Ashanti	1,662	1,721 (3.5%)	1,737 (4.5%)	1,738 (4.5%)	1,786 (7.4%)
Brong Ahafo	1,743	1,806 (3.6%)	1,823 (4.6%)	1,824 (4.7%)	1,878 (7.7%)
Central	1,502	1,536 (2.2%)	1,548 (3.0%)	1,546 (2.9%)	1,576 (4.9%)
Eastern	1,681	1,737 (3.4%)	1,754 (4.4%)	1,756 (4.5%)	1,804 (7.3%)
Greater Accra	1,540	1,575 (2.3%)	1,587 (3.1%)	1,588 (3.1%)	1,622 (5.3%)
Northern	1,862	1,934 (3.9%)	1,954 (4.9%)	1,955 (5.0%)	2,016 (8.3%)
Upper East	1,931	2,008 (4.0%)	2,029 (5.1%)	2,028 (5.0%)	2,095 (8.5%)
Upper West	1,893	1,969 (4.0%)	1,989 (5.0%)	1,989 (5.0%)	2,054 (8.5%)
Volta	1,741	1,800 (3.4%)	1,818 (4.4%)	1,820 (4.5%)	1,870 (7.4%)
Western	1,544	1,583 (2.6%)	1,595 (3.3%)	1,594 (3.3%)	1,627 (5.4%)
Ghana	1,750	1,812 (3.5%)	1,829 (4.5%)	1,830 (4.6%)	1,882 (7.6%)

b) Mean moisture index (MI)		RCP 4.5		RCP 8.5	
		2055	2085	2055	2085
Administrative regions	Current (MI)	MI (Δ)	MI (Δ)	MI (Δ)	MI (Δ)
Ashanti	0.82	0.81 (-1.3%)	0.81 (-1.8%)	0.81 (-1.8%)	0.80 (-2.5%)
Brong Ahafo	0.69	0.68 (-1.2%)	0.67 (-2.4%)	0.68 (-1.6%)	0.67 (-2.4%)
Central	0.88	0.89 (1.2%)	0.89 (0.6%)	0.87 (-1.0%)	0.87 (-1.1%)
Eastern	0.86	0.84 (-2.0%)	0.83 (-2.8%)	0.82 (-3.8%)	0.81 (-4.7%)
Greater Accra	0.58	0.58 (0.7%)	0.58 (0.1%)	0.56 (-3.4%)	0.56 (-4.1%)
Northern	0.58	0.57 (-1.4%)	0.56 (-3.5%)	0.57 (-0.9%)	0.56 (-2.1%)
Upper East	0.47	0.46 (-2.2%)	0.46 (-3.6%)	0.47 (-0.1%)	0.47 (-1.2%)
Upper West	0.51	0.51 (-0.9%)	0.50 (-2.3%)	0.52 (1.6%)	0.51 (0.4%)
Volta	0.70	0.69 (-1.1%)	0.68 (-2.5%)	0.68 (-2.8%)	0.67 (-4.0%)
Western	1.01	1.02 (1.0%)	1.02 (0.9%)	1.01 (-0.1%)	1.02 (0.3%)
Ghana	0.70	0.69 (-0.9%)	0.69 (-2.0%)	0.69 (-1.3%)	0.69 (-2.1%)

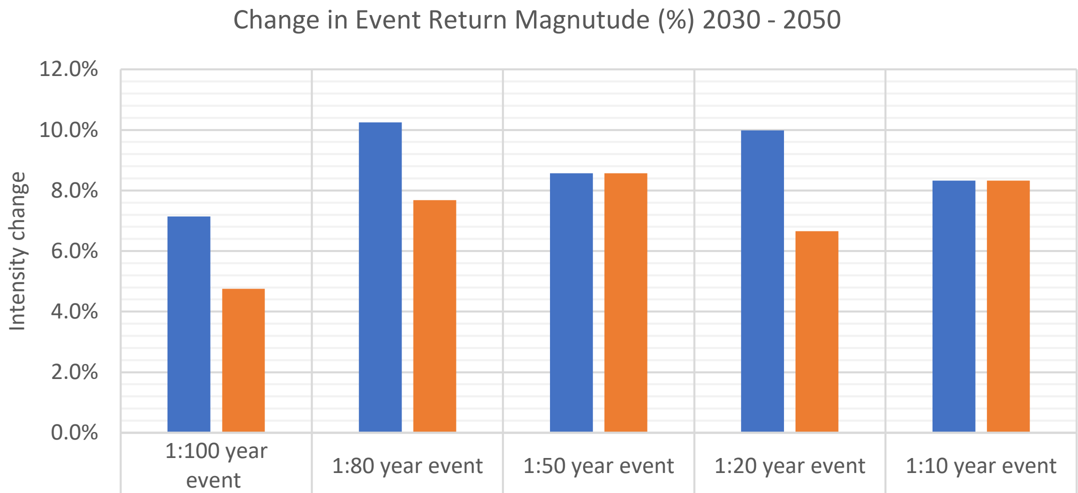
4.3.5 Predicted changes in extreme events

The analyses presented in Section 4.3.2 predict an increased occurrence of higher rainfall events and increased rainfall intensity in northern Ghana over the next 80 years. With these results in mind, the return rate of extreme rainfall events was assessed. The assessment demonstrated that extreme rainfall events are likely to become more common over time, with events that historically occurred 1 in every ~100 years predicted to occur 1 in ~73 years and 1 in every ~80 years under RCP 4.5 and RCP 8.5 scenarios, respectively (Figure 33). Furthermore, extreme rainfall events are predicted to become more intense over time (**Figure 34**), with 1 in 10-year events projected to be ~8.3% more intense (under both RCP 4.5 and RCP 8.5 scenarios).



	21mm/day	19mm/day	17mm/day	15mm/day	12mm/day
Historical	101.13	76.84	48.19	24.50	9.99
RCP4.5	73.18	52.84	33.47	18.02	7.97
RCP8.5	80.73	59.11	34.27	17.97	7.92

Figure 33. Change in extreme event return period for northern Ghana for RCP 4.5 and RCP 8.5.



	1:100 year event	1:80 year event	1:50 year event	1:20 year event	1:10 year event
RCP4.5	7.14%	10.25%	8.56%	9.99%	8.32%
RCP8.5	4.76%	7.69%	8.56%	6.66%	8.32%

Figure 34. Change in extreme event intensity for northern Ghana for RCP 4.5 and RCP 8.5.

As flood events are already occurring regularly in northern Ghana during large rainfall events (Section 4.2.3), an increase in the frequency and intensity of extreme rainfall events will lead to increased flooding. This will endanger lives, reduce agricultural production and cause damage to infrastructure.

While the previous analysis demonstrated that flood risk is likely to increase in northern Ghana, the anticipated narrowing of the wet season (**Figure 26** and **Figure 27**) and the switch from many low rainfall events to less frequent high rainfall events (**Figure 28–Figure 30**) suggest that dry spells are also likely to become more common. This was assessed for northern Ghana by analysing the change in frequency of dry days – days that receive less than 0.5mm or rain – under both the RCP 4.5 and RCP 8.5 scenarios. Overall, the number of dry days per month is predicted to increase above the historical average throughout the year, with the largest increases occurring in the dry season months of November to February (**Figure 35**). Noteworthy is the increased frequency of dry days in the wet season onset and cessation months of March (increasing by 2.8 – 5.6 days per month) and October (increasing by 1.4 – 1.7 days per month).

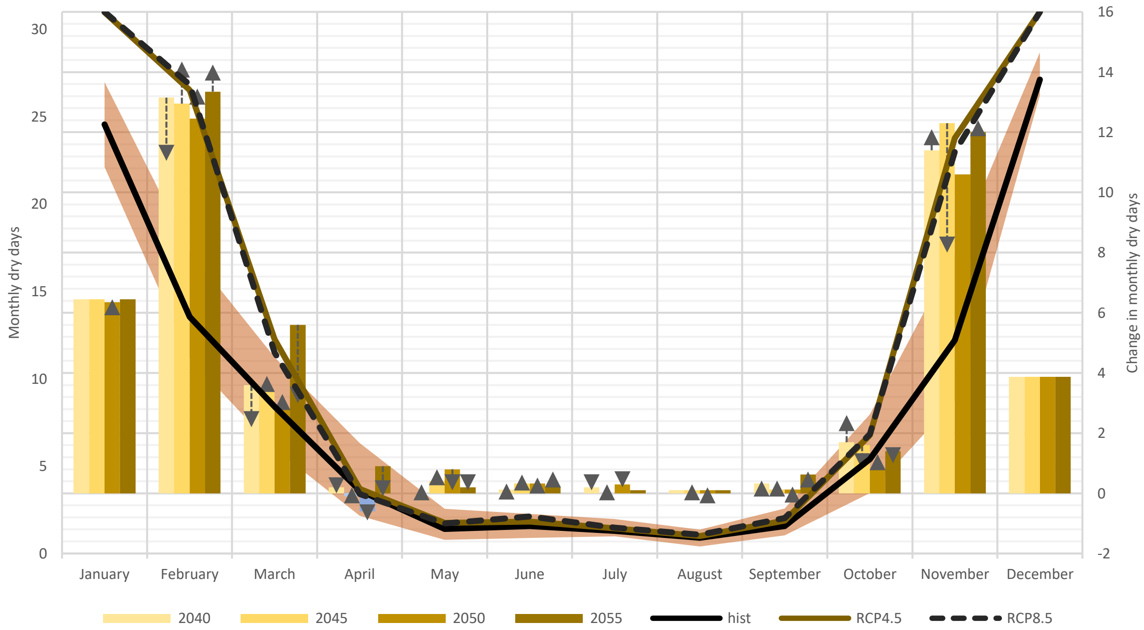


Figure 35. Modelled number of dry days per month (lines) and magnitude change in number of dry days per month (bars) for northern Ghana for RCP 4.5 and RCP 8.5.

An increasing number of dry days per month will increase the risk of droughts occurring in northern Ghana.

The frequency of three-day heat waves is also expected to increase in the future for northern Ghana. In the analysis presented below (**Figure 36**), a heat wave was defined as three consecutive days with temperatures predicted to exceed the hottest average monthly temperature. Under both scenarios, heat waves are predicted to increase in frequency through time, with the most pronounced increase evident for RCP 8.5 (**Figure 36**).

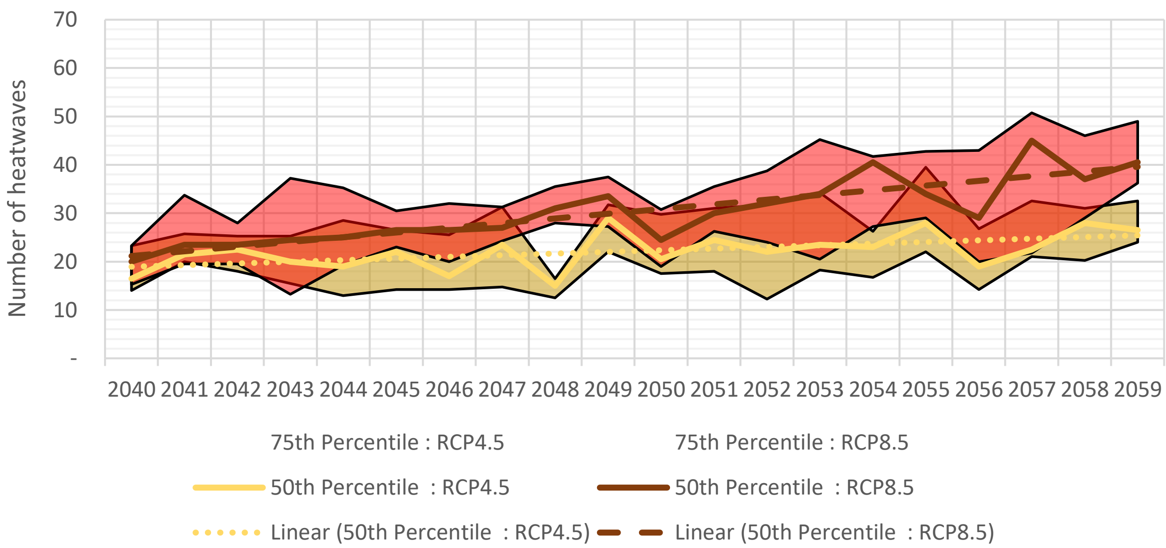


Figure 36. Projected number of three-day heat waves (2040 – 2060) for northern Ghana for RCP 4.5 and RCP 8.5.

5 Climate change impacts and adaptation needs in northern Ghana

5.1 Introduction

This section presents information on the impacts of climate change on smallholder farmers and agroecological systems in northern Ghana. Details are provided on the climate change impact pathways based on the extensive literature on northern Ghana. Finally, the section provides a summary of the adaptation needs in the region derived from the detailed information on climate change impacts and their pathways.

5.2 Climate change impacts

Northern Ghana is expected to be severely affected by climate change in both the short- and long-term. Based on analyses presented in Section 4, the climate of northern Ghana is expected to change in the following ways.

- The length of the wet season will decrease.
- Rainfall intensity will increase.
- The rainfall profile in northern Ghana will change. Instead of falling as frequent low volume events, the rain will be more likely to occur as less frequent but more intense higher volume events.
- Extreme rainfall events will become more frequent.
- The number of dry days per month will increase.
- Maximum and minimum temperature will increase throughout the year.
- Heatwaves will become more frequent.
- Potential evapotranspiration will increase, while the annual moisture index will decrease.

Agroecological systems in northern Ghana, on which the livelihoods of smallholder farmers rely, are already under considerable stress because of *inter alia*: i) unfavourable climate conditions; ii) extensive environmental degradation related to high population growth rates; and ii) outdated and unsustainable farming methods (see Section 3.3). The effects of future climate change are expected to exacerbate the current problems in these systems through the negative impact pathways (**Figure 37**) outlined below.

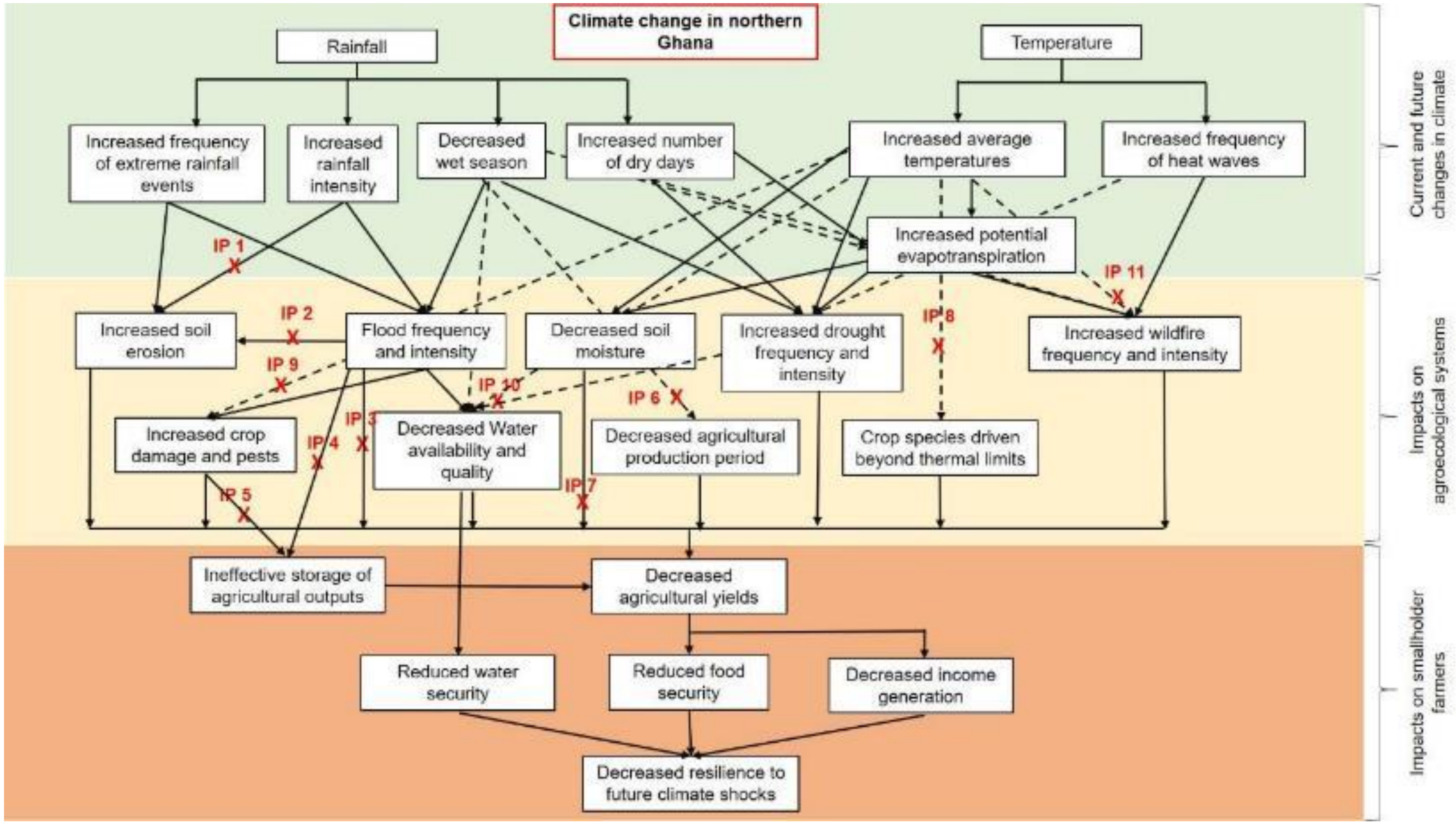


Figure 37. Schematic representation of potential climate change impact pathways (IPs) on smallholder farmers in northern Ghana. The direction of the arrows shows the direction of the causal pathway. Dashed lines show where a pathway intersects a component but does not influence that component. X's suggest points along impact pathways where adaptation interventions could reduce the impacts of climate change on smallholder farmers. The schematic is an elaboration based on Obirih-Opareh and Onumah (2014)[306].

[306] Obirih-Opareh N. & Onumah J.A. 2014. Climate change impact pathways on agricultural productivity in Africa: a review. Journal of Environment and Earth Science 4, 115–121.

5.2.1 Impact on frequency and severity of flooding

Regular and severe flooding limits agricultural productivity in northern Ghana by inundating farms, killing livestock and reducing the area of agricultural land[307,308]. For example, widespread flooding events in 2007 negatively impacted food security and livelihood systems by causing extensive crop and livestock loss[309,310,311]. The flooding was estimated to have caused a loss of cereals and food items amounting to ~257,000 tons and damaged ~40 dams and a host of wells[312]. In addition, the floods caused the relocation of several farming communities[313]. Similarly, floods in 2010 — which preceded a period of drought — damaged farmlands, food crops and livestock, consequently weakening household livelihoods across all three regions in northern Ghana[314]. The floods were caused by excess spillage from the Bagre and Kampianga dams in neighbouring Burkina Faso coupled with heavy rains[315]. Flooding is a significant risk to agriculture in flood-prone areas and close to water bodies in the NR and UER[316]. Examples of areas in northern Ghana vulnerable to flooding include farmland along the Saveligu-Diary stretch of the Tamale–Bolgatanga highway and those along the White Volta River running from Burkina Faso through the UER and NR[317]. These areas have over the years experienced different levels of flooding[318].

The concentration of rainfall in a shortened wet season, an increase in rainfall intensity and an increase in extreme rainfall events will lead to more frequent and severe flooding in northern Ghana[319]. The increased frequency and severity of floods – particularly in areas near rivers – will lead to soil erosion, major crop losses and damage to agricultural infrastructure – including post-harvest storage facilities and irrigation (Impact Pathways 2, 3 and 4 in **Figure 37**). Floods beyond established floodplains are not frequent in northern Ghana, but intense flooding in 2007 and 2009 caused extensive flooding in the region[320]. More severe flooding will increase the frequency of such generalised flooding in northern Ghana. The increased frequency and severity of flooding will also result in on-field waterlogging, which will reduce crop yields by decreasing the oxygen available for roots and reducing the activities of soil

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[307] Nyantakyi-Frimpong H, Bezner-Kerr R. 2015. The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. *Global Environmental Change* 32: 40–56.
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[311] Ngwese NM, Saito O, Sato A, Boafo YA, Jasaw G. 2018. Traditional and local knowledge practices for disaster risk reduction in northern Ghana. *Sustainability* 10: 2-7.
[312] Lewis AJ, Yeboah IA. 2010. Movement under environmental disasters: The case of flooding and bushfires for selected periods in Ghana. Paper presented at the Paper presented at the ESF-UniBi-ZiF research conference on 'Environmental Change and Migration: From Vulnerabilities to Capabilities'. December 5-9, 2010, Bad Salzuflen, Germany.
[313] Ibid.
[314] Ngwese NM, Saito O, Sato A, Boafo YA, Jasaw G. 2018. Traditional and local knowledge practices for disaster risk reduction in northern Ghana. *Sustainability* 10: 2-7.
[315] Lewis AJ, Yeboah IA. 2010. Movement under environmental disasters: The case of flooding and bushfires for selected periods in Ghana. Paper presented at the Paper presented at the ESF-UniBi-ZiF research conference on 'Environmental Change and Migration: From Vulnerabilities to Capabilities'. December 5-9, 2010, Bad Salzuflen, Germany.
[316] Sumani JBB. 2018. Exploring perceptions of the potential of agricultural insurance for crop risks management among smallholder farmers in northern Ghana. DPhil, Antioch University, New England.
[317] Ibid.
[318] Lewis AJ, Yeboah IA. 2010. Movement under environmental disasters: The case of flooding and bushfires for selected periods in Ghana. Paper presented at the Paper presented at the ESF-UniBi-ZiF research conference on 'Environmental Change and Migration: From Vulnerabilities to Capabilities'. December 5-9, 2010, Bad Salzuflen, Germany.
[319] Van de Giesen N, Liebe J, Jung G. 2010. Adapting to climate change in the Volta Basin, West Africa. *Current science* 98: 1033–1037.
[320] Van de Giesen N, Liebe J, Jung G. 2010. Adapting to climate change in the Volta Basin, West Africa. *Current science* 98: 1033–1037.

organisms [321,322,323]. An increase in the intensity and frequency of floods will also cause damage to crops through physical impacts and periods of prolonged inundation.

5.2.2 Impact on frequency and intensity of droughts

Given the population's reliance on rain-fed agriculture, droughts pose one of the greatest threats to the agricultural sector in northern Ghana, with the most immediate consequence being a decrease in crop – especially sorghum, millet, maize and groundnuts – and fodder production. These losses negatively impact the livelihoods of smallholder farmers, particularly in the northern savanna zones[324]. When crops fail, farmers often resort to selling livestock to supplement income. As the food-deficit increases, farmers are forced to sell more valuable livestock, including draught animals such as oxen and donkeys[325], reducing the productive capacity of farms in the long-term. Drought also affects fodder production, leading to weight reduction and deaths among livestock. Overall, these factors reduce the output capacity of the agricultural sector, potentially leading to socio-economic stress, food insecurity and famine. For example, a severe drought in 1983 affected 12.5 million people across the country, resulting in severe famine and the death of hundreds of people, mostly children[326]. The most affected regions of the 1983 drought were the Upper and Northern regions, southern Brong-Ahafo and northern Ashanti, where the decrease in rainfall severely reduced the output of maize and other cereals, including the loss of ~60,000 ha of cocoa trees[327]. The severity of this 1983 drought ranks it as the fourth highest impacting climate disaster in Africa over the past 35 years[328]. The impact of droughts can also be compounded by heat stress. During heat waves, plants open their stomata to allow for cooling by evapotranspiration. However, during a drought, plants are unable to do this, leading to increased leaf temperatures. This can shorten the duration of growth of leaves and grains and thus limit the ability of the plant to accumulate enough carbohydrate necessary for substantial grain growth[329]. The combination of drought and heat stress can, therefore, have detrimental effects on the growth and productivity of crops[330].

Reduced wet season length (i.e. longer dry seasons), more dry days per month, increasing temperatures, more frequent heatwaves and increasing evapotranspiration rates will all contribute to an increase in the frequency and intensity of droughts in northern Ghana. This increase in the frequency and intensity of droughts will severely affect rain-fed agriculture (Impact Pathway 10 in **Figure 37**)[331].

[321] http://soilquality.org.au/factsheets/waterlogging
[322] Other gases detrimental to root growth – including carbon dioxide and ethylene – also accumulate around the roots. Furthermore, waterlogged soils release increased amounts of nitrous oxide (N_2O), a particularly damaging greenhouse gas.
[323] Dumenu WK, Obeng EA. 2016. Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. *Environmental Science & Policy* 55: 208–217.
[324] Choudhary V, Christienson G, D'Alessandro S.P, Josserand H.P. 2016. Ghana: Agricultural Sector Risk Assessment. *World Bank Agriculture Global Practice Note.*
[325] Toulin C. 1986. Drought and the farming Sector: Loss of Farm Animals and Post-drought Rehabilitation. *Alphan- African Livestock Analysis Network* **10**
[326] Agency for International Development 1984. Disaster Case Report: Ghana – Food Shortage. Available at: http://pdf.usaid.gov/pdf_docs/PBAAB318.pdf
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[329] Farrell A. High temperature stress. *University of West Indies.* Available at: http://plantsinaction.science.uq.edu.au/book/export/html/158
[330] Mittler R. 2006. Abiotic stress, the field environment and stress combination. *TRENDS in Plant Science* **11(**1): 1360–1385
[331] The World Bank 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a sustainable land and water management project. Sustainable Development Department, Africa Region.

5.2.3 Impact on the length of the agricultural growing season

The unimodal rainfall regime in northern Ghana — comprising a single short wet season and an extended dry season — severely curtails agricultural production by supporting a single crop cycle per year under rain-fed conditions[332,333]. Smallholder farmers cultivate crops only during the single wet season and yields are often insufficient to meet year-round household food needs — especially during the long dry season[334,335,336]. Smallholder farming households in northern Ghana frequently experience severe food insecurity for about three to six months annually[337]. On average, the NR and UWR experience up to five months with insufficient food supply[338]. The UER is the worst affected, with food shortages for up to six months[339].

A shortened agricultural production period because of a shorter wet season will decrease crop yields and income as the number of achievable cropping cycles within a growing season will be reduced (Impact Pathway 6 in **Figure 37**) [340]. Additionally, the later onset of the wet season may result in on-field operations – including *inter alia* seedbed preparation, planting and harvesting – being performed at the wrong times, which could lead to crop failure and fewer harvests[341]. Shorter wet seasons will also result in reduced harvests of NTFPS by shortening the growing season and reducing the potential of food trees to bear fruit [342].

There are indications from recent crop suitability models that the impacts are site specific and crop specific[343]. Under the without-climate-policy climate change scenario, the suitability of maize for example - which is the dominant staple crop in Ghana with high cultural and economic value - will decrease in the Upper West Region (UWR) under RCP2.6 and RCP8.5, while the UWR will become more suitable for groundnut production under both RCP2.6 and RCP8.5. With few exceptions, cassava production will remain largely unaffected by the changing climate, with interestingly greater losses of suitable areas coming with higher gains in suitability in different areas in the northern region under RCP8.5. Sorghum, which is a more tolerant crop under marginal conditions in Ghana, will remain the most suitable crop for the northern parts and will remain this way under climate change in the medium term (2050s) with only predicted net losses of suitability of 2% under RCP2.6 and around 5% under RCP8.5 scenarios. Except for cassava and groundnut, all suitability combinations of crops are projected to decrease for the areas where both crops currently have the high suitability class. The most common suitability under climate change for the northern regions will be sorghum and groundnuts.

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[332] Aniah P, Kaunza-Nu-Dem M, Ayembilla JA. 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. *Heliyon* 5: 1-25.
[333] Adam I (ed). 2018. *Agricultural finance intervention in Ghana*. Alliance for Financial Inclusion. Accra.
[334] Sulemana A. 2017. Management and use of non-timber forest products (NTFPs) as climate change adaptation strategy in Lawra District, Ghana. MPhil, University of Ghana, Accra.
[335] Adam I (ed). 2018. *Agricultural finance intervention in Ghana*. Alliance for Financial Inclusion. Accra.
[336] Fagariba C, Song S, Baoro SKGS. 2018a. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West District. *Sustainability* 10: 1484.
[337] Sulemana A. 2017. Management and use of non-timber forest products (NTFPs) as climate change adaptation strategy in Lawra District, Ghana. MPhil, University of Ghana, Accra.
[338] Quaye W. 2008. Food security situation in northern Ghana, coping strategies and related constraints. *African Journal of Agricultural Research* 3: 334-342.
[339] Ibid.
[340] Kasei RA, Ampadu B, Yalevu S. 2014. Impacts of climate variability on food security in Northern Ghana. *Journal of Earth Sciences and Geotechnical Engineering* 4: 47-59.
[341] Iizumi T & Ramankutty N. 2015. How do weather and climate influence cropping area and intensity? *Global food security*. 4: 46–50.
[342] The World Bank 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a sustainable land and water management project. Sustainable Development Department, Africa Region.
[343] Lisa Murken, L.; Gornott, C.; Aschenbrenner, P; Chemura, P; Hattermann, F; Hagen, K; Lehmann, J; Liersch, S; Rohrig, F; Schauberger, B; Amsalu W. Yalew. 2019. Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agricultural Sector. Potsdam Institute for Climate Impact Research (PIK); Telegraphenberg A 31. 14473 Potsdam; Germany

Rainfall-based factors are most important in determining crop suitability, varying by crop. One study analysing climate change effects on four crops in Ghana: maize, sorghum, cassava and groundnut found that under projected climate change, optimal suitability will decrease for all crops except for groundnuts under RCP8.5. Under current climatic conditions, 18% of Ghana has optimal suitability for two crops; 2% of land area optimal for three crops and 0$% of land area having optimal suitability for the four crops. Under projected climate change, areas with optimal suitability for two and three crops will decrease by 12% while areas marginally and moderately suitable will increase.. The results are spatially distinct: cassava and groundnut will be more suitable for the South while groundnut and sorghum will be more suitable in the North. Maize, Sorghum, Cassava and groundnuets are important staple crops planted on nearly three million hectares annually, which is 83% of all the cropped area in Ghana[344].

5.2.4 Impact on crop and livestock production

High temperatures in northern Ghana are limiting crop yields by negatively affecting the growth of important crops[345,346]. In addition, the rate of evapotranspiration is increased by high temperatures, causing desiccation of pastures, which limits livestock production as a result of poor feeding, stunted growth and death of livestock[347]. Moreover, heat stress caused by high temperatures is curtailing livestock production in northern Ghana by promoting poor animal health and mortality[348]. As temperatures increase, common northern Ghanaian crop and livestock varieties are likely to be pushed beyond their optimum thermal limits and yields would consequently decrease (Impact Pathway 8 in **Figure 37**). Rising temperatures have already caused scorching and withering of crops in northern Ghana, resulting in reduced yields[349]. Increased early and late wet season temperatures have, for example, reduced net revenue per hectare of sorghum by a ~US$170 and ~US$90, respectively[350]. The reductions in net revenue are substantial given that national per capita income in Ghana is ~US$780[351].

In addition, the reduction in soil water content and the lowering of groundwater levels in northern Ghana as a result of increased temperatures and potential evapotranspiration will decrease crop production as less water will be available for crop growth (Impact Pathway 7 in **Figure 37**)[352]. Furthermore, increased temperatures and longer dry seasons will affect the physiological functioning of crops and soil organisms and lead to premature drying and reduced crop productivity[353,354].

5.2.5 Impact on weeds, pests and post-harvest losses

Agricultural weeds and pests limit agricultural yields in northern Ghana by competing with and feeding directly on crop plants[355]. Weed infestation is a key agricultural challenge in some

[344] Chemura A, Shauberger B, Gornott C (2020) Impacts of climate change on agro-climatic suitability of major food crops in Ghana, PLoS ONE 15 (6):e0229881
[345] Fagariba C, Song S, Baoro SKGS. 2018a. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West District. *Sustainability* 10: 1484.
[346] Dapilah F, Nielsen JØ, Friis C. 2019. The role of social networks in building adaptive capacity and resilience to climate change: a case study from northern Ghana. *Climate and Development*: 1–15.
[347] Fagariba C, Song S, Baoro SKGS. 2018a. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West District. *Sustainability* 10: 1484.
[348] Ibid.
[349] Dapilah F, Nielsen JØ, Friis C. 2019. The role of social networks in building adaptive capacity and resilience to climate change: a case study from northern Ghana. *Climate and Development*: 1–15.
[350] Bawayelaazaa Nyuor A, Donkor E, Aidoo R, Saaka Buah S, Naab J, Nutsugah S, Bayala J, Zougmoré R. 2016. Economic impacts of climate change on cereal production: implications for sustainable agriculture in Northern Ghana. *Sustainability* 8: 724.
[351] Ibid.
[352] Yiran GAB, Stringer LC, Attua EM, Evans AJ, Challinor AJ, Gyasi EA. 2017. Mapping vulnerability to multiple hazards in the savannah ecosystem in Ghana. *Regional Environmental Change* 17: 665-676.
[353] Dumenu WK, Obeng EA. 2016. Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. *Environmental Science & Policy* 55: 208–217.
[354] Ibid.
[355] Sumani JBB. 2018. Exploring perceptions of the potential of agricultural insurance for crop risks management among smallholder farmers in northern Ghana. DPhil, Antioch University, New England.

areas such as the NR[356]. The most common weed in northern Ghana is the parasitic plant Striga (*Striga hermonthica*), which not only makes agricultural lands less fertile by mining soil nutrients but also strangles the roots of some crops — leading to crop plant mortality and reduction in crop yields[357]. Striga – which is a major problem for millet, maize and sorghum – thrives in farmland land that is cropped continuously without adequately replacing lost nutrients (i.e. experiencing declining fertility)[358,359]. Another challenge to crop cultivation in northern Ghana is the occurrence and effects of the fall armyworm (*Spodoptera frugiperda*) [360]. The fall armyworm (FAW) is a worm that feeds directly on leaves, stem and reproductive parts of crop plants resulting in reduced yields and food insecurity[361,362]. During the 2017 farming season, FAW devastated crops, especially maize, throughout Ghana[363].

Increased temperatures will lead to expansion of weed and pest ranges (Impact Pathway 9 in **Figure 37**) — and their negative impacts on smallholder agricultural production — as previously cooler areas warm up[364]. In addition, increased temperatures will cause stored agricultural products to spoil at an enhanced rate as a result of increased fungal growth and insect activity[365] (Impact Pathways 5 and 9 in **Figure 37**). This will be especially common in cases where post-harvest storage facilities are inadequate – particularly those with poor aeration[366]. In general, at warmer temperatures, insect pest lifecycles become shorter and their multiplication rates greater, with the potential to cause more damage[367]. As with insects, fungi also have optimal growth conditions, and increases in temperature are likely to affect the prevalence and species composition of fungi in storage areas. High post-harvest losses (PHLs) are already limiting agricultural production in Ghana by causing the loss of up to ~20% of crop harvests[368]. Post-harvest losses in maize, cassava, yam and rice in Ghana amount to over 35%, 34%, 24% and 7% of yields respectively[369]. Studies estimate that ~50% of perishable food commodities such as fruits, vegetables, roots and tubers in the country are lost every year through PHLs[370].

Other than causing food spoilage, fungal growth can also result in: i) reduced seed viability – especially legumes, for example, groundnuts[371]; ii) discolouration; iii) caking; iv) mouldy smells; and v) the production of mycotoxins[372]. Human and animal exposure to mycotoxins can have effects on health, including central nervous, cardiovascular, pulmonary and gastrointestinal system effects, as well as death[373,374].

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[356] Ibid.
[357] Ibid.
[358] Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
[359] Nyantakyi-Frimpong H, Bezner-Kerr R. 2015. The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. *Global Environmental Change* 32: 40–56.
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[363] Ibid.
[364] http://www.nri.org/images/images/nri-news/2013/rural21-climate-change.pdf
[365] http://www.extension.umn.edu/agriculture/small-grains/harvest/management-of-stored-grain-with-aeration/
[366] http://www.extension.umn.edu/agriculture/small-grains/harvest/management-of-stored-grain-with-aeration/
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[371] http://www.nri.org/images/images/nri-news/2013/rural21-climate-change.pdf
[372] Stathers T, Lamboll R & Mvumi BM. 2013. Postharvest agriculture in changing climates: its importance to African smallholder farmers. *Food Security*. 5: 361–392.
[373] FAO. 2008. Climate change: Implications for food safety. Rome. Available at: http://www.fao.org/ag/agn/agns/files/HLC1_Climate_Change_and_Food_Safety.pdf.
[374] Rising temperatures and increased plant stress are expected to enhance pre- and post-harvest mycotoxin contamination rates and ecological ranges in many countries. Food scarcity may consequently result in people consuming food of a much lower quality.

5.2.6 Impact on intensity and extent of soil erosion

As a result of increasing pressure on farmland and natural resources caused by rapid population increase, soil erosion — which is limiting crop yields by removing fertile topsoil from cultivated land and leaving behind bare ground that is devoid of nutrients — has increased in the last two decades and is now visible on most farmlands in northern Ghana[375]. Soils in northern Ghana are highly susceptible to erosion because of the thin vegetative coverage and torrential nature of the region's unevenly distributed rainfall[376]. Furthermore, the main crops grown in northern Ghana (e.g. millet and guinea corn) do not provide adequate coverage to protect the soil against the forces of rain and runoff while the widespread practice of clean weeding by hoe and the removal of crop residues for fuel leaves the soil bare at the onset of the rains[377]. During heavy downpours of rain, raindrops make direct contact with the soil. Raindrop energy causes clay particles to disperse and, subsequently, block the pores in the soil, which leads to run-off and consequently, erosion. The agricultural lands situated on long slopes are particularly prone to this[378].

Through soil erosion, nutrients – including nitrogen (N), phosphorous (P) and potassium (K) – and organic matter are lost via sediment removal and leaching[379,380]. Smallholder farming systems in northern Ghana are characterised by low soil nutrient addition (for example, fertiliser and manure) and return of nutrients to the soil is limited by the collection of crop residues for household and other uses[381,382]. Farmers have many uses for crop residues, including as fodder, fencing, thatching material and fuel[383]. Livestock farmers also let their animals graze on the stubble[384]. Animals are restricted from roaming freely on the farming areas during the wet season to prevent them from destroying crops, which reduces manure supply to soils[385,386]. Consequently, organic matter does not trickle down to the soils resulting in increasing depletion of soil nutrients from the crop areas[387,388.] Fertiliser nutrient application rate in Ghana is low (~8kg ha^{-1}) while depletion rates of 40–60 kg ha^{-1} of nitrogen (N), phosphorus (P), and potassium (K) per year are among the highest in Africa[389]. Estimates show negative nutrient balance for all crops in Ghana[390].

Increased rainfall intensity and an increase in extreme rainfall events will increase soil erosion in northern Ghana (Impact Pathway 1 in **Figure 37**). As a result, crop yields will decrease further than current levels and the need for costly agricultural inputs – for example, fertilisers

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375 Salifu E, Agyare WA, Larbi A. 2019. Effect of soil and water conservation methods on maize performance and soil water retention in Northern Region of Ghana. *International Journal of Scientific & Technology Research* 8: 116-120.
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377 Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
378 http://www.fao.org/docrep/t0389e/t0389e02.htm
379 http://crops.extension.iastate.edu/cropnews/2008/06/heavy-rain-soil-erosion-and-nutrient-losses
380 http://www.fao.org/docrep/t0389e/t0389e02.htm
381 Boakye-Danquah J, Antwi EK, Saito O, Abekoe MK, Takeuchi K. 2014. Impact of farm management practices and agricultural land use on soil organic carbon storage potential in the savannah ecological zone of Northern Ghana. *Journal of Disaster Research* 9: 484-499.
382 Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
383 The World Bank 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a sustainable land and water management project. Sustainable Development Department, Africa Region.
384 Ibid.
385 Ibid.
386 Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
387 Ibid.
388 Ibid.
389 Martey E, Kuwornu JKM, Adjebeng-Danquah J. 2019. Estimating the effect of mineral fertilizer use on land productivity and income: Evidence from Ghana. *Land Use Policy* 85: 463-475.
390 Ibid.

– will increase[391]. Even at present, very few smallholder farmers in northern Ghana can afford to apply the recommended amounts of inorganic fertilisers. The current marginal impact of soil erosion on yield loss across Ghana has been estimated at ~14 kg ha^{-1} for maize, ~4 kg ha^{-1} for cowpeas and ~40 kg ha^{-1} for cassava[392].

5.2.7 Impact on water availability

Limited water storage capacity in northern Ghana is restricting agricultural production by preventing smallholder farmers from adequately storing excess rainfall and runoff generated during the wet season for use during the dry season[393]. Availability of water resources in northern Ghana is strongly seasonal with ~90% of the annual rainfall occurring between June and September[394]. However, water-storage capacity in agroecological landscapes across northern Ghana is not at full potential[395,396]. Investment in water-storage infrastructure is insufficient in most areas, with limited construction of dams and dugouts[397,398,399]. In addition, most small reservoirs in northern Ghana are functioning below their potential capacity as a result of poor management and maintenance[400]. As a result, smallholder farmers in northern Ghana have severe challenges with water supply during the dry season[401]. In most districts of the UWR and NR, ~15-50% of households currently travel for more than 30 minutes to get drinking water with a high dependency on unimproved water sources[402].

High temperatures in northern Ghana already contribute to reduced water-retention capacity and frequent drying of water bodies that serve as sources of drinking water for both livestock and households — including wells, dams, and streams[403,404]. In particular, high temperatures increase the evaporation of water bodies, particularly those exposed to direct sunlight[405]. Most of the water bodies in northern Ghana have no trees along their banks, contributing to substantial loss of water through the evaporation process[406].

Decreasing wet season length coupled with rising temperatures will increase the frequency of the drying-up of surface water bodies such as dams and streams resulting in reduced water availability[407,408] (Impact Pathway 10 in **Figure 37**). For example, inflows into the Volta in Ghana

[391] Laube W, Schraven B & Awo M. 2011. Smallholder adaptation to climate change: dynamics and limits in Northern Ghana. *Climatic Change.* 111: 753–774.
[392] Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
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[405] Fagariba C, Song S, Baoro SKGS. 2018a. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West District. *Sustainability* 10: 1484.
[406] Ibid.
[407] Ibid.
[408] Yiran GAB, Stringer LC, Attua EM, Evans AJ, Challinor AJ, Gyasi EA. 2017. Mapping vulnerability to multiple hazards in the savannah ecosystem in Ghana. *Regional Environmental Change* 17: 665-676.

were reduced significantly in 2001, 2007 and 2013-2014 as result of prolonged droughts, resulting in low levels of water in the Akosombo, Kpong and Bui reservoirs[409]. Other rivers that have experienced reduced flows – and are projected to completely dry up in the future – include the Yendi and Tano[410]. It is estimated that changing rainfall patterns in Ghana will lead to a general reduction in annual river flow by 15-20% for the year 2020 and 30-40% for 2050[411]. This will include seasonal drying up of hitherto perennial rivers[412]. An increase in dry season length will also lead to reduced groundwater[413]. For example, it is projected that groundwater in the UER will decrease by 5-22% and 30-40% by 2020 and 2050 because of climate change[414]. As a result of climate change, smallholder farmers in northern Ghana will have even further restricted access to water during the dry season (Impact Pathway 10 in **Figure 37**)[415]. This will reduce their ability to engage in dry season gardening as an alternative livelihood to supplement their food and income[416]. Also, access to potable drinking water for livestock and humans will be reduced during the dry season[417]. The reduced supply of potable surface water will increase the exposure of smallholder farmers to water-borne and other hygiene-related diseases such as diarrhoea, cholera, etc.[418]. The increased disease load among smallholder farmers will reduce labour output and lead to reduced agricultural production[419]. Furthermore, women and children will also have to spend more time travelling longer distances in search of good quality water resulting in reduced time for agricultural activity and reduced productivity[420].

5.2.8 Impact on water quality

Poor farming practices — such as farming along streams, improper application of fertilisers and allowing unsupervised livestock to drink from water bodies — have resulted in increased pollution and eutrophication of water bodies in northern Ghana[421]. The quality of fresh water in rivers and other water bodies in northern Ghana will be further impacted negatively by increased flooding as more eroded material and pollutants will be deposited into water bodies[422,423]. The increased deposition of eroded soil and pollutants such as fertilisers and pesticides into water sources will further reduce water quality (Impact Pathway 10 in **Figure 37**)[424,425,426]. The increased runoff and erosion will also reduce the storage capacity of

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[409] Republic of Ghana. Ghana National Drought Plan. Available at https://knowledge.unccd.int/sites/default/files/inline-files/1%20FINAL_NDP_Ghana.pdf.
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[422] Yiran GAB, Stringer LC, Attua EM, Evans AJ, Challinor AJ, Gyasi EA. 2017. Mapping vulnerability to multiple hazards in the savannah ecosystem in Ghana. *Regional Environmental Change* 17: 665-676.
[423] Kankam-Yeboah K, Amisigo B, Obuobi E. 2011. Climate change impacts on water resources in Ghana. *Ghana and Unesco 2009/2010, 65–69. Accra: Ghana National Commission for UNESCO/Ministry of Education*.
[424] Dapilah F, Nielsen JØ, Friis C. 2019. The role of social networks in building adaptive capacity and resilience to climate change: a case study from northern Ghana. *Climate and Development*: 1–15.
[425] Yiran GAB, Stringer LC, Attua EM, Evans AJ, Challinor AJ, Gyasi EA. 2017. Mapping vulnerability to multiple hazards in the savannah ecosystem in Ghana. *Regional Environmental Change* 17: 665-676.
[426] Kankam-Yeboah K, Amisigo B, Obuobi E. 2011. Climate change impacts on water resources in Ghana. *Ghana and Unesco 2009/2010, 65–69. Accra: Ghana National Commission for UNESCO/Ministry of Education*.

reservoirs through enhanced siltation[427]. The reduction in storage capacity of reservoirs and dams in northern Ghana will — in turn — cause them to collapse more frequently, leading to flooding downstream or to store less water and dry quickly in the dry season. These impacts will increase the vulnerability of smallholder farmers to dry season water scarcity and reduced agricultural production[428].

5.2.9 Impact on the frequency and severity of uncontrolled bushfires

Bush burning in northern Ghana is embedded in the cultural values and traditional farming systems of the people[429]. It is a cultural custom among the Dagomba, Moshie, Mamprusi, Kusasi, Gonja, Gurima, Talensi, Komkomba, Wala and Dagaaba ethnic groups[430]. The bush burning custom — an annual ceremony undertaken in the evening of the ninth day of the month of fire[431] — is considered to bring good fortune to participants[432]. In addition, bush burning is also widely applied as an annual land-management practice in northern Ghana that is used to prepare farming land and improve soil fertility[433]. However, bush burning has begun to have harmful effects on the environment as the socio-cultural norms that regulated it in the past have begun to disintegrate, resulting in increased incidences (i.e. more frequent and widespread than the annual burns used to prepare farming land and improve soil fertility) of uncontrolled bushfires[434,435]. Rapid population growth is also driving the increased occurrence of uncontrolled bushfires in northern Ghana by increasing the demand for farmland and shortening the length of fallow periods[436]. This promotes more widespread and frequent bushfires by limiting tree regrowth and favouring more combustible grasses[437]. As much as 37,000 ± 2,600 km^2 (~46–60%) of land is annually burned in northern Ghana – representing 53–56% of total annual burns across the country[438].

Uncontrolled bushfires in northern Ghana are limiting agricultural production by causing extensive damage to crops and fruit trees[439]. Smallholder farming households in the region annually lose ~US$231 (~50% of average household income) because of uncontrolled bushfires that destroy crops and fruit trees[440]. In addition, frequent and intense bushfires reduce the fertility of farmlands by removing soil organic matter[441,442]. Furthermore, uncontrolled bushfires in northern Ghana are also reducing the capacity of agroecosystems to provide critical ecosystem services such as NTFPs, forage, soil stabilisation and flood

427 Yiran GAB, Stringer LC, Attua EM, Evans AJ, Challinor AJ, Gyasi EA. 2017. Mapping vulnerability to multiple hazards in the savannah ecosystem in Ghana. *Regional Environmental Change* 17: 665-676.
428 Ibid.
429 Kosoe EA, Adjei PO, Oduro W. 2015. The forest fire problem of degrading Tain II Forest Reserve in Ghana: rethinking community participation in fire management and sustainable forestry. *Ghana Journal of Geography* 7: 79-112.
430 Ibid.
431 The ceremonies are based on the lunar calendar, therefore the exact date changes from year to year. However, the event usually falls in the months of August, September, or October.
432 Kosoe EA, Adjei PO, Oduro W. 2015. The forest fire problem of degrading Tain II Forest Reserve in Ghana: rethinking community participation in fire management and sustainable forestry. *Ghana Journal of Geography* 7: 79-112.
433 Republic of Ghana (ed). *Program on affirmative finance action for women in Africa (AFAWA): Financing climate resilience agricultural practices in Ghana*.
434 Ibid.
435 Kosoe EA, Adjei PO, Oduro W. 2015. The forest fire problem of degrading Tain II Forest Reserve in Ghana: rethinking community participation in fire management and sustainable forestry. *Ghana Journal of Geography* 7: 79-112.
436 Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra..
437 Republic of Ghana 2000. Ghana: Northern Savanna Biodiversity Conservation Project. Ministry of Lands and Forestry in collaboration with the Ministry of Health.
438 Kpienbaareh DL. 2016. Assessing the relationship between climate and patterns of wildfires in Ghana. *International Journal of Humanities and Social Sciences* 8: 1-20.
439 Appiah M, Damnyag L, Blay D, Pappinen A. 2010. Forest and agroecosystem fire management in Ghana. *Mitigation and Adaptation Strategies for Global Change* 15: 551-570.
440 Ibid.
441 Ibid.
442 Martey E, Kuwornu JKM, Adjebeng-Danquah J. 2019. Estimating the effect of mineral fertilizer use on land productivity and income: Evidence from Ghana. *Land Use Policy* 85: 463-475.

mitigation by causing vegetation loss in fallowed/grazing lands[443] and woodlands[444,445]. Bushfires reduce the composition and density of vegetation in woodlands leading to reduced NTFP yields[446,447,448]. Bush burning is the primary contributing factor to the shortage of forage for livestock in northern Ghana during the dry season[449]. Uncontrolled bushfires worsen the exposure of grazing lands to soil erosion by further decreasing vegetation and litter cover and exposing more soil to rain splash detachment and erosion[450]. Removal of vegetation and litter cover by uncontrolled bushfires also causes extreme fluctuations in soil temperature and moisture leading to desertification[451]. This, in turn, reduces the productivity of grazing lands, leading to reduced livestock production[452].

The frequency and intensity of uncontrolled bushfires in northern Ghana is increasing. While this increase is largely driven by rapid population growth and the break-down of socio-cultural norms that used to regulate land in northern Ghana, climate change is exacerbating the problem. In particular, the frequency and intensity of bushfires is closely linked to climatic conditions, with dryer conditions and increased temperatures promoting the ignition and spread of bushfires[453].The effects of: i) high temperatures; ii) increased evapotranspiration; iii) more dry days; and iv) dry conditions related to more frequent and intense droughts, will result in bushfires becoming more frequent and severe (Impact Pathway 11 in **Figure 37**). This will have serious repercussions on farming activities, including the destruction of crop fields – particularly of the dry mature crop[454]. Additionally, like floods and pest infestations, bush fires will also damage produce stored in granaries for future use. Lastly, uncontrolled and more frequent bush fires will further reduce the capacity of agroecosystems to provide critical ecosystem services such as NTFPs, forage, soil stabilisation and flood mitigation.

5.2.10 Gendered impacts of climate change

Gender inequalities in Ghana disproportionately affect the adaptive capacity of women to current and future climate change, as opposed to men (See Section 3 in Annex 8: Gender Assessment and Action Plan for a detailed discussion on gender inequality in Ghana). The effects of climate change on households and communities will be exacerbated if the adaptive capacity of both men and women are not strengthened in parallel. Overlooking either gender will affect production and income within a household, having knock-on effects on families, children and the community. Although traditional knowledge has established coping mechanisms within communities to the harsh climatic conditions experienced in northern Ghana, it is unlikely to adapt quickly enough to overcome the effects of future climate change[455].

Women — along with children and the elderly — are among the most vulnerable groups to the effects of climate change. This is largely because women and female-headed

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443 farmland in fallow is used for livestock grazing in northern Ghana
444 Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra..
445 Appiah M, Damnyag L, Blay D, Pappinen A. 2010. Forest and agroecosystem fire management in Ghana. *Mitigation and Adaptation Strategies for Global Change* 15: 551-570.
446 Asante F, Amuakwa-Mensah F. 2015. Climate change and variability in Ghana: Stocktaking. *Climate* 3: 78–99.
447 Ibid.
448 The World Bank 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a sustainable land and water management project. Sustainable Development Department, Africa Region.
449 Republic of Ghana (ed). *Program on affirmative finance action for women in Africa (AFAWA): Financing climate resilience agricultural practices in Ghana*.
450 Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
451 Appiah M, Damnyag L, Blay D, Pappinen A. 2010. Forest and agroecosystem fire management in Ghana. *Mitigation and Adaptation Strategies for Global Change* 15: 551-570.
452 Ibid.
453 Kpienbaareh DL. 2016. Assessing the relationship between climate and patterns of wildfires in Ghana. *International Journal of Humanities and Social Sciences* 8: 1-20.
454 http://www.nri.org/images/images/nri-news/2013/rural21-climate-change.pdf
455 Damptey T.M. & Essel A.K. 2012. Gender perspectives of climate change coping and adaptive strategies in Ghana. UN Women.

households have fewer resources to cope with reductions in food and water security and the effects of extreme weather events such as droughts and floods. This is particularly pertinent in rural communities, where people are often reliant on climate-sensitive natural resources for their livelihoods. Several factors contribute to the vulnerability of women to climate change including, *inter alia*, the effects of: i) migration; ii) water availability; iii) decreased agricultural yields; and iv) reliance on climate-sensitive livelihoods. These are described in more detail below.

- When climatic conditions become less favourable for agricultural practices, men often migrate out of rural areas in search of work in other sectors. Women are left behind to not only continue with their domestic duties but also to continue the agricultural work on their land. Much of this agricultural work comes in the form of subsistence farming, with little or no pay, leaving women without the financial resources to adapt to climate change.
- Women have limited rights to own or control land. Without ownership of the land they are working on, women are unable to make the necessary decisions or access the necessary funds to improve agricultural practices, leading to reduced agricultural productivity and food security. This affects not only the women themselves but also their households and potentially the wider community.
- Water scarcity associated with shifting rainfall patterns and drought can have a substantial impact on women, most of whom are responsible for the collection of water for household uses such as drinking, cooking and cleaning. When water security is threatened, extra effort is required for women to collect water — with women having to travel further to collect water. Similar pressures are observed with regards to the collection of fuelwood which will become scarce as climate conditions worsen. This compounds the additional workload placed on women maintaining both domestic duties and agricultural responsibilities, with little capacity to adapt to growing climatic pressures.
- Many rural Ghanaian women are reliant on natural resource-based livelihoods that are climate-sensitive. As the availability of natural resources becomes threatened by climate change, so do income generation and food security.

5.3 Adaptation needs in northern Ghana

The already vulnerable livelihoods of smallholder farmers in the north of Ghana (see above) will be negatively impacted by climate change. Decreases in agricultural yields as a result of the expected effects of climate change detailed above will result in a reduction in the quantity and quality of food, which will further decrease food security in Ghana's northern regions. This will result in a deterioration of the fragile climate-resilience of northern Ghanaian smallholder farmers and a reduction in their ability to absorb future climate-related shocks. When food production is low, smallholder farmers resort to purchasing food from other producers. However, loss of income generation associated with decreased yields constrains farmers ability to purchase food, leading to farmers selling assets such as livestock to supplement income. With the tightening of household budgets, less money will be invested in human capital – for example, education, health and quality nutrition. Furthermore, households lacking the capital and assets to buy food will have to rely on food aid, which can negatively impact the self-esteem, independence or dignity of farmers who pride themselves on supporting their families[456]. These smallholder farmers will, therefore, be forced to adopt alternative livelihoods, many of which are unsustainable and cause environmental degradation, including firewood harvesting and charcoal production. Smallholder farmers in northern Ghana thus require the implementation of climate change adaption interventions that target the impact pathways described above (see Section 5.2) and contribute to overcoming the baseline problems of poverty and food insecurity.

As climate change affects men and women differently — with cultural practices making women more vulnerable than men — men and women have different adaptation needs.

[456] http://www.nri.org/images/images/nri-news/2013/rural21-climate-change.pdf

Mainstreaming gender into the climate resilient and sustainable livelihoods project design – including conceptualisation, implementation, monitoring and evaluation – is therefore necessary to build the adaptive capacity of households and communities in the Upper West, Upper East and Northern regions. The design of project activities will thus be guided by the results of Annex 8: Gender Assessment and Action Plan, ensuring that women (including divorcees and widows), the youth, elderly and other vulnerable groups are not only included in the project, but that the relationships between the cultural roles of men and women are considered. The proposed project interventions will, therefore, address gender equality through several pathways, including:

- incorporating a gender action plan into the development of the development plans and community climate action plans, based on the specific gaps identified within each community;
- integrating women into the project specific institutional structures and involving them in the project's decision-making process;
- ensuring women's participation in all climate change adaptation training;
- ensuring equal opportunity and access to women farmers for on-the-ground adaptation interventions;
- targeting women for specific adaptation interventions, with a particular focus on climate-resilient additional livelihoods;
- providing women with business and financial training;
- raising awareness of the importance of equal opportunity for all people and the role women play in climate change adaptation across a community;
- establishing long-term monitoring and evaluation programs to assess the effectiveness of interventions for achieving gender equality; and
- sharing lessons learned through project interventions to help create a paradigm shift in the approach to gender equality in climate change adaptation projects.

6 Climate flood risk study

A comprehensive flood risk assessment was commissioned by UNEP to assess flood risk and climate change in the Northern Savannah region, to provide input to the proposed project. Section 6.1 presents the historic flood event in the project districts. Section 6.2 presents flood hazard maps and effects of floods in terms of people, agricultural area, buildings and roads affected for various return periods. Finally, Section 6.3 presents climate projections for the various types of floods.

6.1 Historic flood events

In this section an overview of historical floods is presented. The information is split into Sub-sections per flood mechanism. Sub-section 6.1.1 presents the historical floods in the White Volta due to spilling of the Bagre dam. Next, in Sub-section 6.1.2 and Sub-section 6.1.3 fluvial flooding (river flooding) and pluvial flooding (rainfall flooding) are discussed, respectively. In Sub-section 6.1.4 flooding from dams and reservoirs other than the Bagre dam is discussed. Lastly, in Sub-section 6.1.6 the conclusions regarding historical flooding are presented.

The information used in this chapter is partially based on the field visits of the Northern Savannah zone, conducted in December 2022. Further information sources used in the analysis are: media articles about flood events (collected during the inception phase), discharge measurements in the White Volta, water level measurements in the Bagre reservoir and historic rainfall characteristics from the World Bank Climate Change Portal[457].

6.1.1 Floods on White Volta caused by Bagre dam spilling

Along the main branch of the White Volta, river flooding is mainly due to spilling of the Bagre dam (Figure 38), which is located upstream in the White Volta in Burkina Faso. The project districts affected by the Bagre dam are Binduri, Garu and East Mamprusi. Yunyoo-Nasuan, which is also located in the East, is not affected by Bagre spilling, as it is not connected to the White Volta river but to the Oti river. Figure 39 shows the location of the Bagre dam and (part) of the catchment area, as well as the districts that are located downstream.

[457] World Bank. 2023. Opgehaald van World Bank Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/

Figure 38. Bagre dam spilling[458].

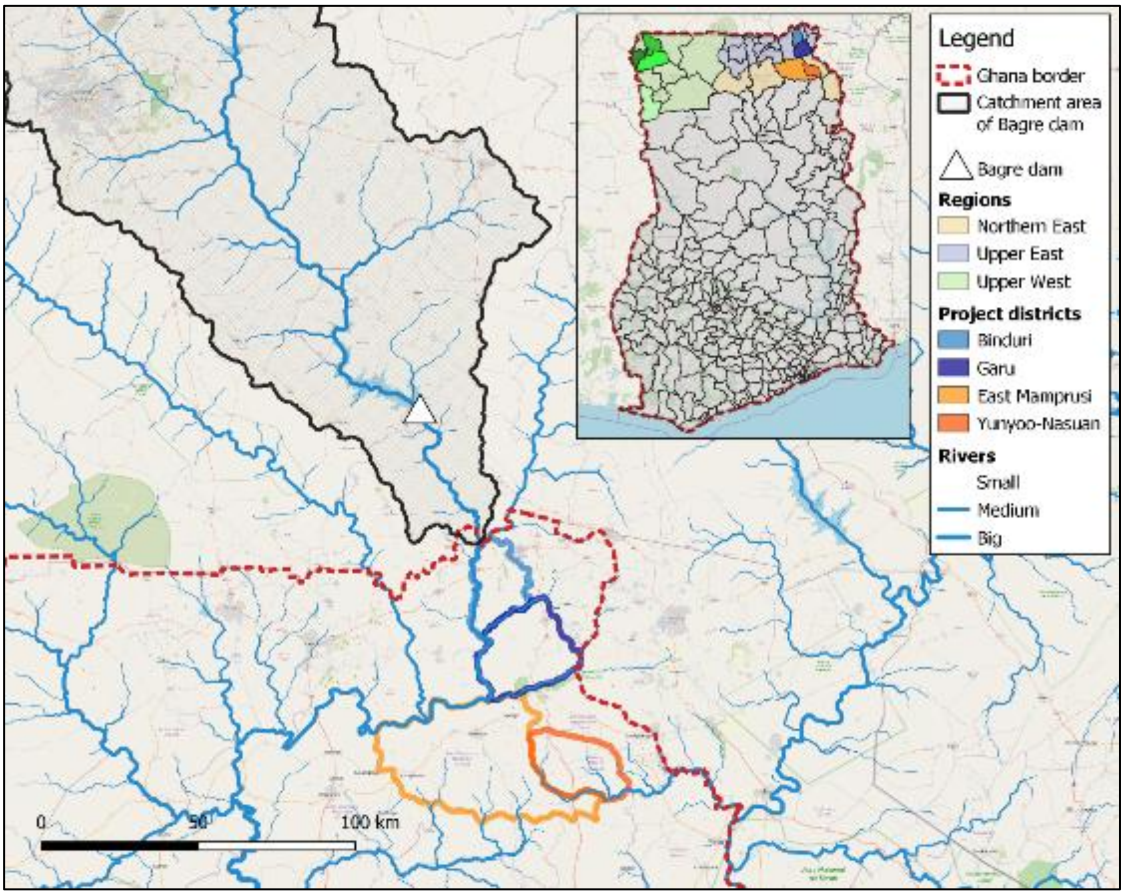

Figure 39. Catchment area and location of the Bagre dam in Burkina Faso with respect to the project districts in the east.

[458] https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Burkina-Faso-warns-Ghana-over-the-spillage-of-Bagre-Dam-1615760?gallery=1

- **Historic trends in spilling**

The Bagre dam in Burkina Faso was constructed in 1993. In 2008 its capacity was increased[459]. The Bagre dam is operated according to a fixed protocol: when the reservoir water level reaches 235 meters, the gates open to release water.

We used various data sources to assess White Volta flooding due to spilling of the Bagre dam:

- Discharge observations at Yarugu Kobori (the first gauging station on the White Volta in Ghana 2 km from the border with Burkina Faso) from 1998-2007 and in 2012. The high discharges at Yarugu Kobori are dominated by Bagre spilling, but there is also some inflow from smaller tributaries between Bagre and the gauging station in Ghana. Based on an estimate of the upstream tributary flows and the trend in Yarugu Kobori discharges we identified spilling events. We estimated that a discharge of over 400 m^3/s was caused by spilling. In addition, we explicitly labelled large spills (indicated with "major"), based on spilling duration, local information, and internet research. It should be noted that for the years based on this data, the findings has some uncertainty, as sometimes the data is incomplete and the identification if a discharge peak is due to Bagre spilling is partially based on expert judgement.
- Bagre reservoir water level data from 2013–2022. When the reservoir water level is higher than 235m a spill occurs. In some cases, maximum spilling rates are available, as indicated. Based on spilling rates, maximum reservoir water level, the duration of the spill and internet news items we estimated the magnitude of the spill.
- We were not able to collect hydrological data for the period between 2008 and 2011. However, news items from the internet provide information whether a spilling occurred or not.

The table below summarizes the results from the approach as outlined above. We conclude that the spilling frequency has not changed much during past decades. However, the maximum spilling rate (outflow from the dam) seems to have increased over the years. This could also be due to an increase of the reservoir capacity by raising the reservoir dikes in 2008. The Agricultural Officer of East Mamprusi also confirmed that the floods due to spilling became more severe in the past decade.

Appendix 2 shows figures of the discharge measurements at Yarugu Kobori and water level measurements in the Bagre dam.

Table 17. Spilling information of the Bagre dam, based on various sources.

Source of information	Max Discharge [m^3/s] Yarugu Kobori or max Bagre water level [m]	Spill & magnitude	Spilling timing	Remark
Discharge 1998	727	Spill, major	August and throughout September and November	Incomplete data
Discharge 1999	548	Spill	Mid July and early August	Incomplete data
Discharge 2000	366	Unclear		
Discharge 2001	445	Spill	Early June	Spilling not certain and incomplete data
Discharge 2002	136	No spill		
Discharge 2003	583	Spill	End of August and September	
Discharge 2004	243	No Spill		

[459] https://reliefweb.int/report/burkina-faso/burkina-faso-ghana-one-countrys-dam-anothers-flood

Discharge 2005	539	Spill	Early September	
Discharge 2006	445	Spill	Mid September	Spilling not certain
Discharge 2007	1268	Spill, major	Multiple spills throughout July, all of August and early September	
2008 Internet	No info	Spill	News item internet	**Dam capacity increased**, spilling based on news item internet
2009 Internet	No info	Unknown	No news found	No news found, likely no spilling
2010 Internet	No info	Spill	News item internet	Spilling based on news item internet
2011 Internet	No info	Unknown	No news found	No news found, likely no spilling
Discharge 2012	1500	Spill, major	At least early July	Incomplete data
Level 2013	233.06	No spill		
Level 2014	235.18	Spill, major	Starting September 4	
Level 2015	235.12	Spill, major	Starting August 16	
Level 2016	235.09	Spill, major	Starting August 23	
Level 2017	233.08	No spill		
Level 2018	235.13	Spill, major	Starting August 30	Spilling rate 700 m3/s
Level 2019	235.02	Spill		
Level 2020	235.17	Spill, major	Starting August 13	
Level 2021	234.49	No spill		
Level 2022	235.08	Spill, major	Starting September 1	Spilling rate more than 1000 m3/s

Figure 40 shows an example of the flood impact in 2020. The road linking Walewale to the Mamprugu Moaduri district, close to the Kpasenkpe community was flooded because of Bagre spilling.

Figure 40. Flooded road linking Walewale to Mamprugu Moaduri district. Location: North East Region, Mamprugu Moaduri District, Kpasenkpe Community (2020)[460].

- **Catchment precipitation trends**

We used the World Bank Climate Change Knowledge Portal[461] to analyze precipitation trends for the Bagre dam catchment area. The portal presents amongst others decadal historical

[460] Shared by Agriculteral officer of East Mamprusi district (2020)
[461] https://climateknowledgeportal.worldbank.org/country/burkina-faso/trends-variability-historical

precipitation information on catchment, country and regional level for the last 70 years. We are interested in the catchment upstream of the Bagre dam, which is the catchment that determines the water level in the reservoir. The following regions capture the Bagre dam subbasin: Northern Center, Center, Plateau Center and South Center. As Bagre dam was constructed in 1993 and available data starts at 1998, we are especially interested in trends during the last two decades (2001–2010 and 2011–2020). The values and graphs show the following:

- There is a slightly increasing trend in annual precipitation over the last 20 years. Before that, the annual precipitation was decreasing over the years (Figure 41–Figure 44). Figure 46 presents the annual average precipitation between 1998 and 2022 and the related spilling as indicated in Table 17.
- For the higher annual precipitation amounts (more than 600 mm), spilling has occurred in all but one year (2000). On the other hand, spilling did occur in years with lower annual rainfall as well. This indicates that even though annual rainfall is a factor in the likelihood of spilling, other factors play a role as well, such as operational management of the dam.
- When looking at monthly data, we focus on the historically wettest months of July–August–September, with August having the highest precipitation. The monthly precipitation data shows us that there is a relatively large monthly increase in precipitation in August during the last decade (2011–2020), while the monthly precipitation during the rainy season and especially in August for 2001–2010 is decreasing (red circle Figure 41–Figure 44).
- The five-day maximum precipitation shows an even stronger increasing trend, which is ongoing during the last 70 years (Figure 45). This is in line with the general trend in the West-African Savannah region, being that the wet season is getting shorter, the total annual precipitation is (on average) reducing, but the intensity of the rain is increasing (during a shorter rainy period). Besides the monthly precipitation, the five-day precipitation is also an important parameter that can trigger Bagre dam spilling, because these events result in large fluvial floods. Figure 45 also shows a strong increase in the five-day maximum precipitation during the rainy season (mostly in August) for the last decade compared to the period between 2001–2010, indicated with the red circle.

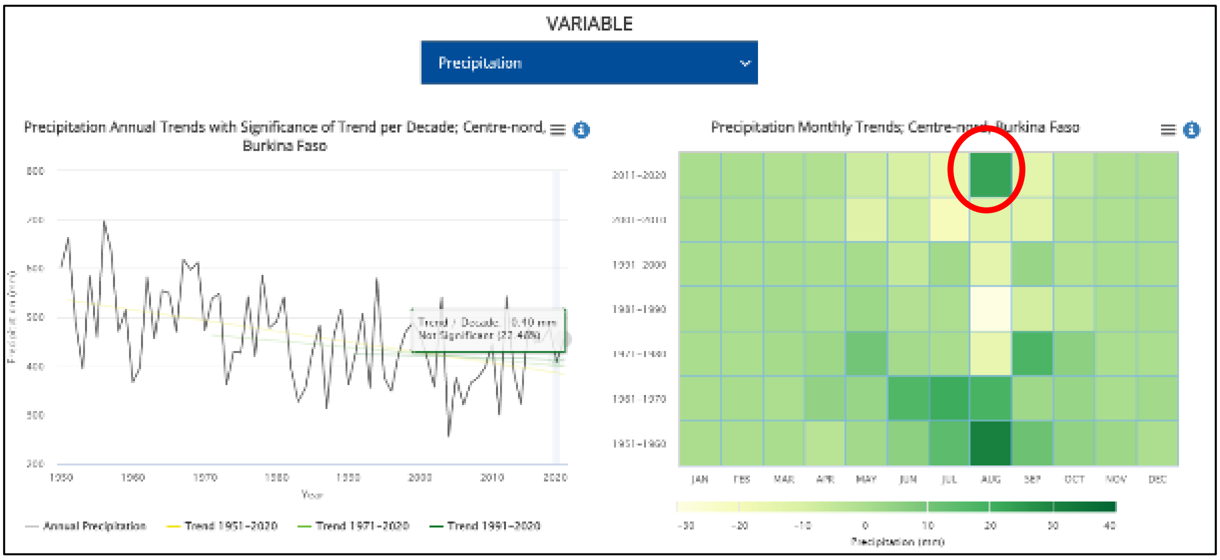

Figure 41. Annual and monthly decadal precipitation trends between 1950-2020 for Centre-Nord, Burkina Faso.

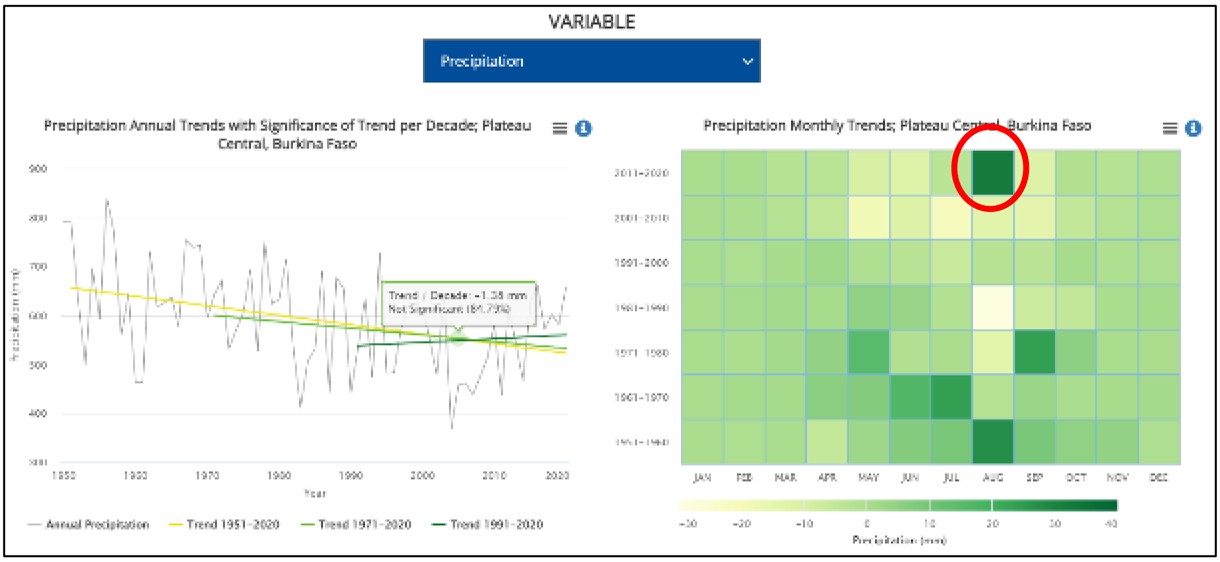

Figure 42. Annual and monthly decadal precipitation trends between 1950-2020 for Plateau Central, Burkina Faso.

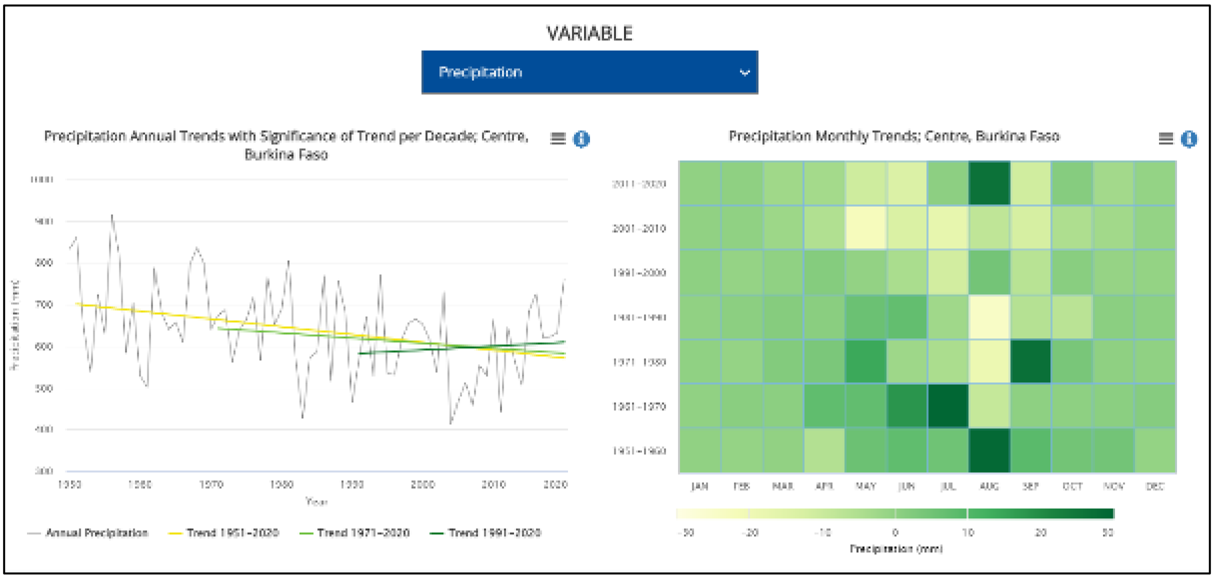

Figure 43. Annual and monthly decadal precipitation trends between 1950-2020 for Centre, Burkina Faso.

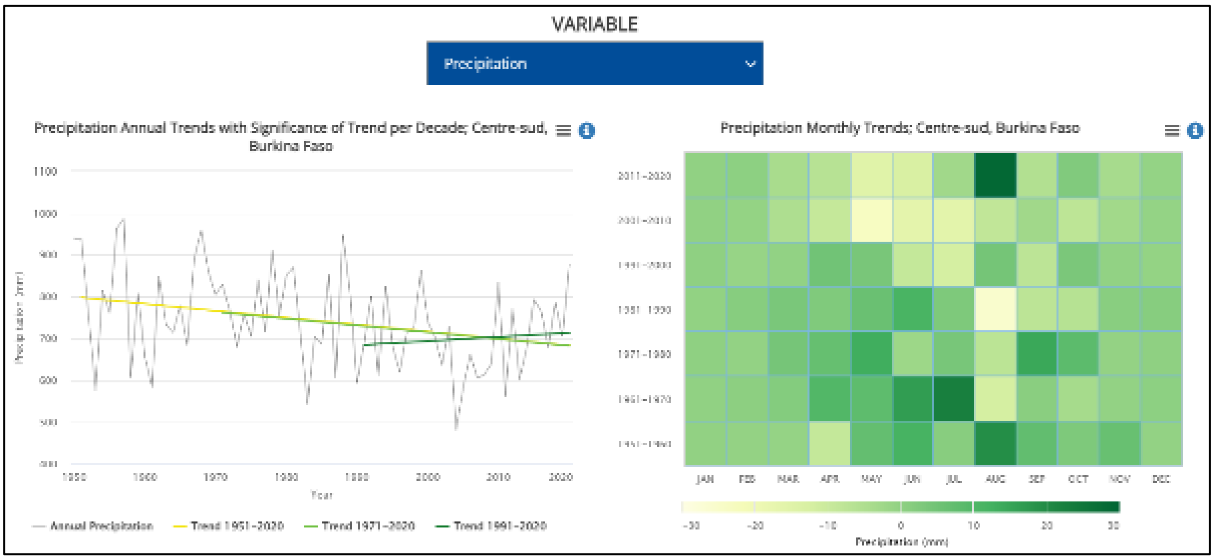

Figure 44. Annual and monthly decadal precipitation trends between 1950-2020 for Centre-South, Burkina Faso.

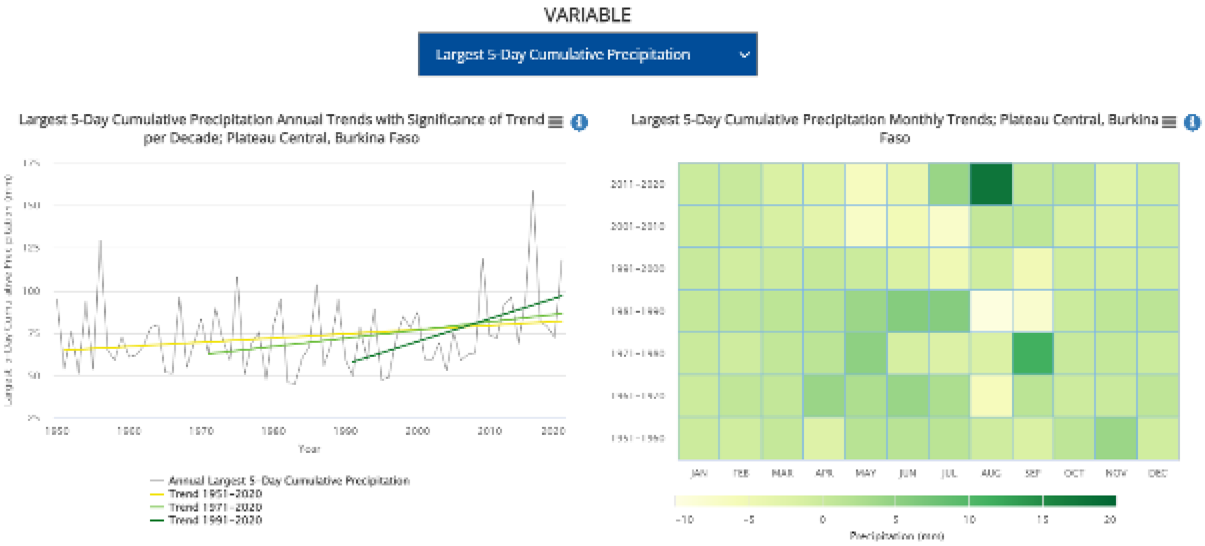

Figure 45. The 5-day cumulative decadal and monthly precipitation trends between 1950-2020 for Plateau Centre, Burkina Faso.

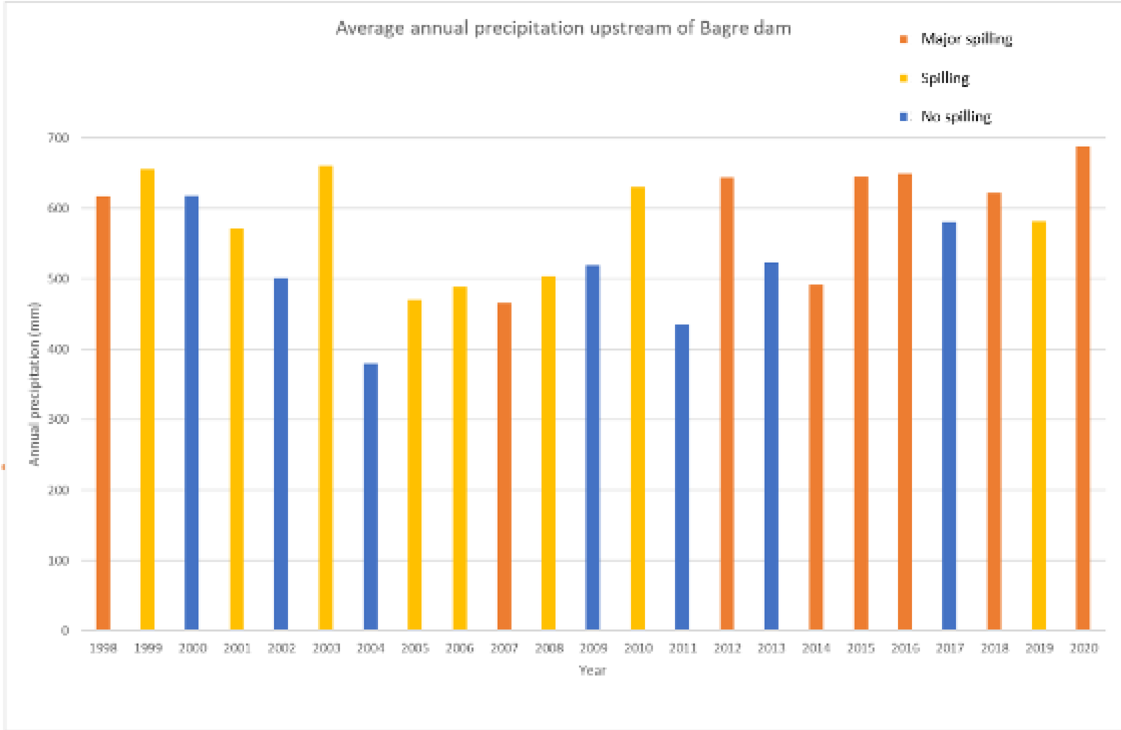

Figure 46. Average annual precipitation upstream of the Bagre dam between 1998-2020, based on average between annual precipitation in Burkina Faso regions: Centre, Centre Sud, Centre Nord, Plateau Central[462].

- **Conclusion**

Historical spilling data shows the spilling frequency (and with that flooding frequency along the upper White Volta districts) has not changed. However, the magnitude of the floods resulting from Bagre dam spilling seem to have changed: during the last decade, floods are longer and more extreme compared to the 10 years before. Local inhabitants confirm this.

One of the largest Bagre spilling induced the floods that occurred in August 2020 when the access road to the bridge over the White Volta was washed away. An incident that had not occurred until then.
The precipitation trends within the Bagre dam sub-catchment (one of the important spilling drivers) support the flood magnitude observations: more precipitation and more intense precipitation is registered during the last decade (2011–2020) compared to the 10 years before that (2001–2010).

Besides hydrological and meteorological data showing similar trends during the last 20 years, we also mention the importance of other potential causes of spilling of the Bagre dam:

- Operational management of the dam.
- Siltation of the reservoir decreases the capacity resulting in more frequent and higher spilling rates.
- Bagre reservoir capacity was increased in 2008 by increasing the reservoir impoundment. This can lead to higher spilling rates (larger stored volumes and higher reservoir water levels).

The effect on White Volta floods of the latter two points is however unclear.

[462] World Bank Climate Change Portal

6.1.2 Fluvial floods

Fluvial flooding, or river flooding, is due to rainwater ending up in the river, causing overbank flow. In the previous section, flooding along the main branch of the White Volta due to spilling of the Bagre dam was discussed. In this section we focus on the fluvial floods that occur in the Black Volta and its tributaries as well as Oti and its tributaries, and parts of the White Volta catchment not affected by the Bagre spilling. Each of the project districts are affected by fluvial floods.

The impact of historic fluvial flood events has been determined from the interviews during the field visits as well as from results collected within the inception phase from media articles and previous projects. This impact and the historical trend of these types of floods are elaborated below.

- **Impacts of historic events**

Yunyoo-Nasuan is only affected by the Oti river, both the Yunyoo-Nasuan district and the Oti river are not affected by the Black or White Volta. The other eastern project districts are affected by the White Volta. The four western project districts are connected to the (tributaries of) the Black Volta. In the western districts, the river flooding is highly dependent on the rainfall pattern in the catchment area of the (tributaries of) the Black Volta, affecting the Black Volta water levels. The river flooding due to rainfall is variable and can take place several times during the wet season.

Fluvial floods were reported by farmers and agricultural officers to affect crops, as well as livestock. Crops and livestock are being washed away, and crops are damaged because of prolonged submergence. Farmers often are farming close to the river because they do not have irrigation systems. In severe cases also roads and houses are flooded and washed away when built in the floodplains. Also, human casualties have been reported due to river flooding. Especially the main roads seem to be vulnerable to fluvial flooding, often resulting from inadequately designed river crossing. When such a road is blocked or damaged, regions are completely cut off. In the Upper West region, fluvial floods mainly affect communities along river tributaries as in this region (districts Lawra, Jirapa, Wa West and Lambussie) there is only little (farming) activity in the main floodplains along the Black Volta.

In Yunyoo-Nasuan it was reported that the worst recent flood happened in 2020 when 4 people died and several properties as well as harvests were ruined. The Agricultural Officer of East Mamprusi district shared pictures of flood impacts in 2020 in the West Gonja district and in the Mamprugu Moaduri district (see Figure 47–Figure 50). These districts are not part of this project, but the pictures are illustrative for the typical agricultural damages caused by fluvial floods.

Figure 47. Location: Savannah Region, West Gonja District, Yangon Community. Date: September 16th, 2020[463].

Figure 48. Location: North East Region, Mamprugu Moaduri District, Yiziesi Community. Date: October 4th, 2020[464].

[463] Shared by Agricultural officer of East Mamprusi district.
[464] Shared by Agricultural officer of East Mamprusi district.

Figure 49. Location: North East Region, Mamprugu Moaduri District, Tantala Community. Date: October 4th, 2020[465].

Figure 50. Location: North East Region, Mamprugu Moaduri District, Tantala Community. Date: October 4th, 2020[466].

[465] Shared by Agricultural officer of East Mamprusi district.
[466] Shared by Agricultural officer of East Mamprusi district.

- **Historic trends**

Historical water level or discharge observations from hydrological gauging stations are not available within the project districts, except for stations on the White Volta as presented in Sub-section 6.1.1: *Historical trends in spilling.* We therefore decided to use precipitation data to assess whether any fluvial flood trends can be determined in the past decades. We use five-day precipitation sums as a proxy for fluvial flooding, since fluvial floods occur after extreme precipitation for a longer period. Precipitation data are available on a regional level from the World Bank Climate Change Knowledge Portal, derived from ERA5 Reanalysis data. The portal provides information for the Upper West, Upper East and Northern Region. The North East Region was created in 2018, but in the portal it is not included as a separate sub-region. The Northern Region is much larger than the North East Region, this should be considered when drawing conclusions from that data.

To consider the developments of fluvial floods in the past 70, 50 and 30 years, we look at the trend in annual maximum five-day precipitation over 1951–2020, 1971–2020 and 1991–2020. Figure 51 to Figure 53 show these for the Upper West, Upper East and Northern region. There is an upward trend in the annual maximum 5-day precipitation for all three regions and all selected time periods, however, these trends are mostly small and not statistically significant. This means that it cannot be concluded that the increase in the annual maximum five-day precipitation is different from random variations between years. Clear recent changes in fluvial floodings were also not reported by the farmers or officers in the districts.

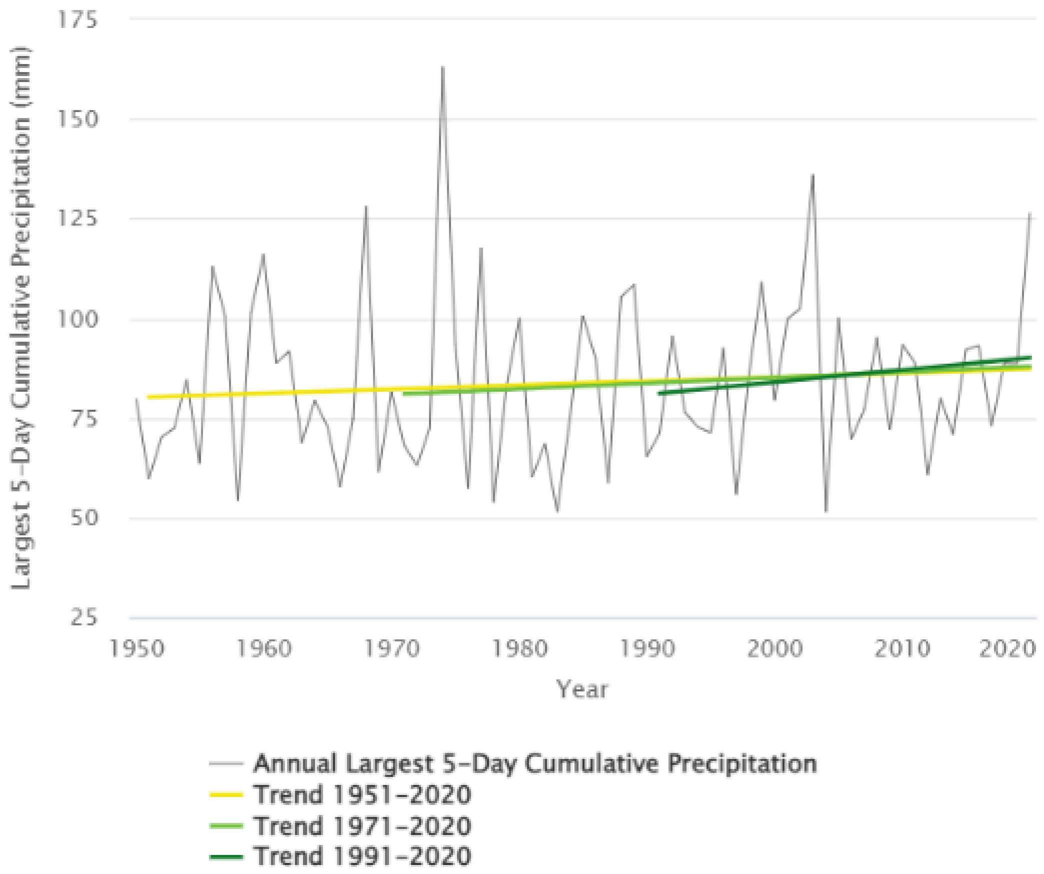

Figure 51. Largest 5-Day Cumulative Precipitation Annual Trends per decade; Upper West Region, Ghana.

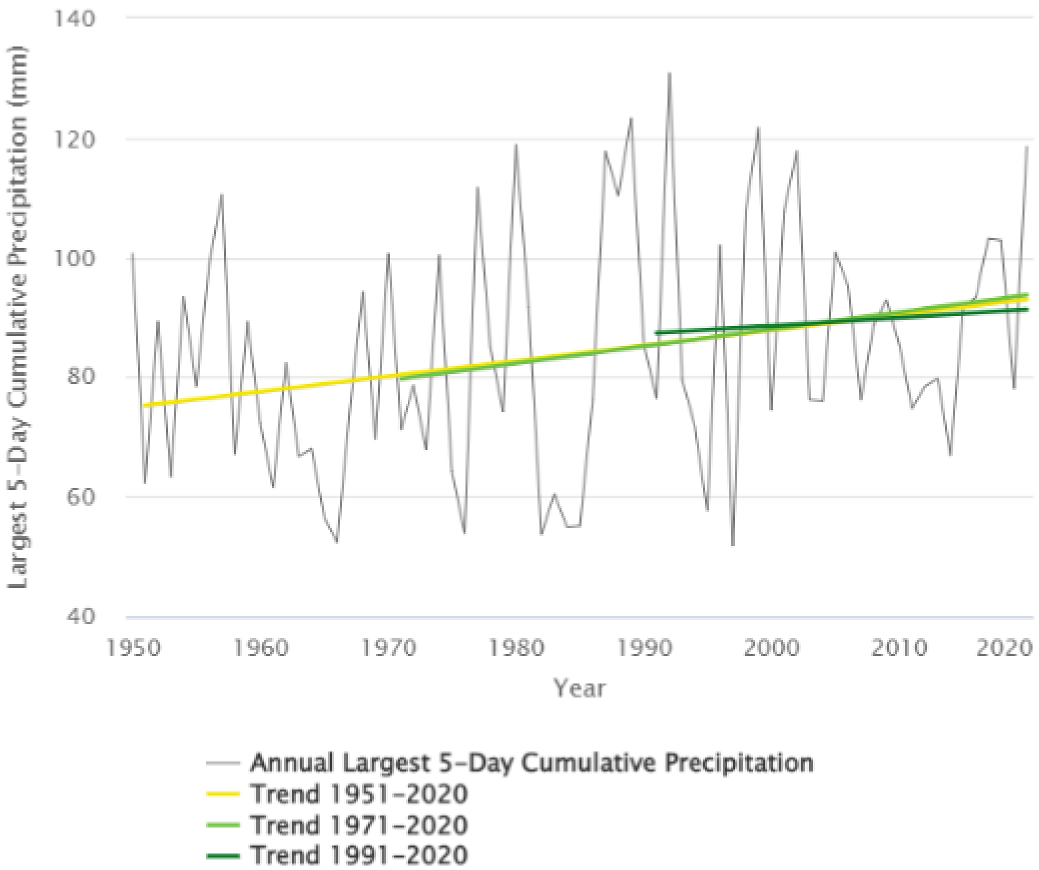

Figure 52. Largest 5-Day Cumulative Precipitation Annual Trends per decade; Upper East Region, Ghana.

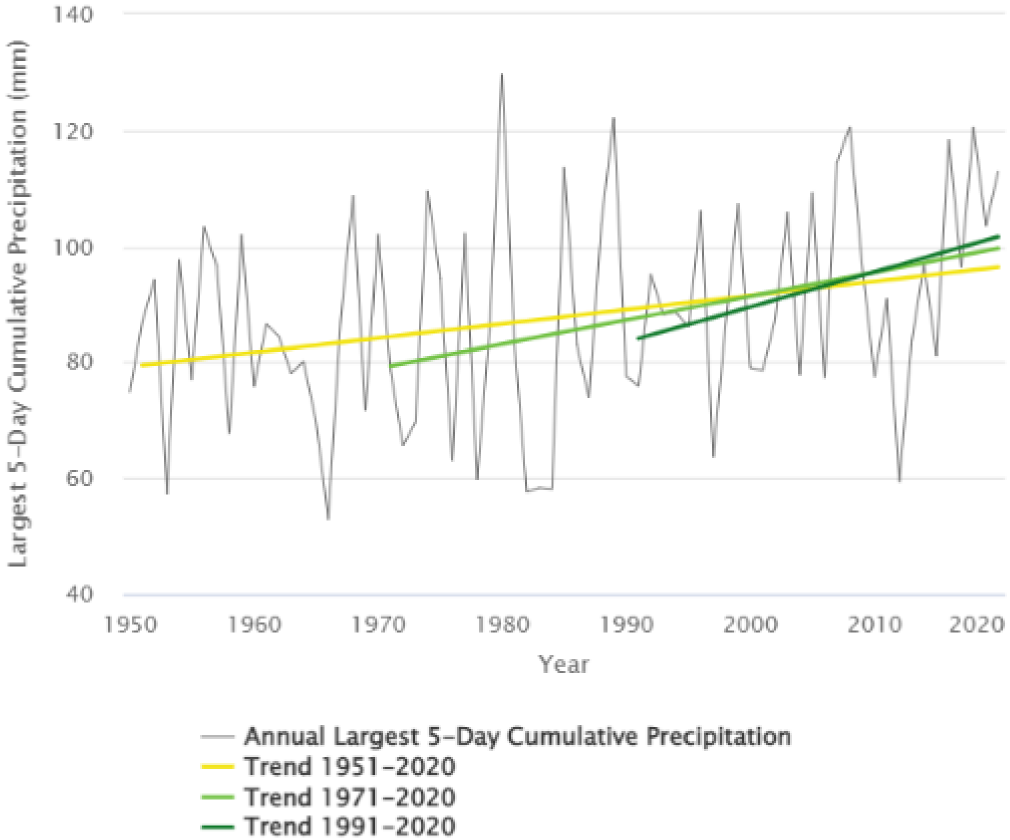

Figure 53. Largest 5-Day Cumulative Precipitation Annual Trends per decade; Northern Region, Ghana.

- **Conclusion**

We conclude that fluvial floods play a role in Oti, White Volta and Black Volta and their tributaries. Farmers farm close to the river due to a lack of irrigation systems. Crops and livestock are therefore exposed to fluvial floods, and also at various instances agricultural damages have been recorded. In severe cases the floods also affect houses and roads or even cause casualties. Fluvial floods may have slightly increased in frequency or severity; however, it cannot be concluded from the data that this trend is different from annual variations. This may be caused by the large annual and decadal variations in this climate.

6.1.3 Pluvial floods

Pluvial floods, also called flash floods, are floods that occur after heavy rainfall, often only in short time periods. They are the result of rainwater not infiltrating into the soil, causing overland flows or water accumulations. Pluvial floods can occur anywhere, not only close to the rivers.

- **Impacts of historic events**

Pluvial floods have caused crops and fertile soil to be washed away. It can also affect livestock, houses, and roads. Besides that, the heavy torrential rain falling on young crops can cause damage. All these impacts were mentioned in the interviews with farmers and Agric and Nadmo district officers as well.

The effects of flash floods, resulting from rainfall can be seen in Figure 54 and Figure 55. The figures show examples of damaged roads and dam breaches in August 2021 in the Upper West Region.

Figure 54. Roads were destroyed by floods in Upper West Region Ghana, August 2021. Photo: Ministry of Roads and Highways Ghana[467].

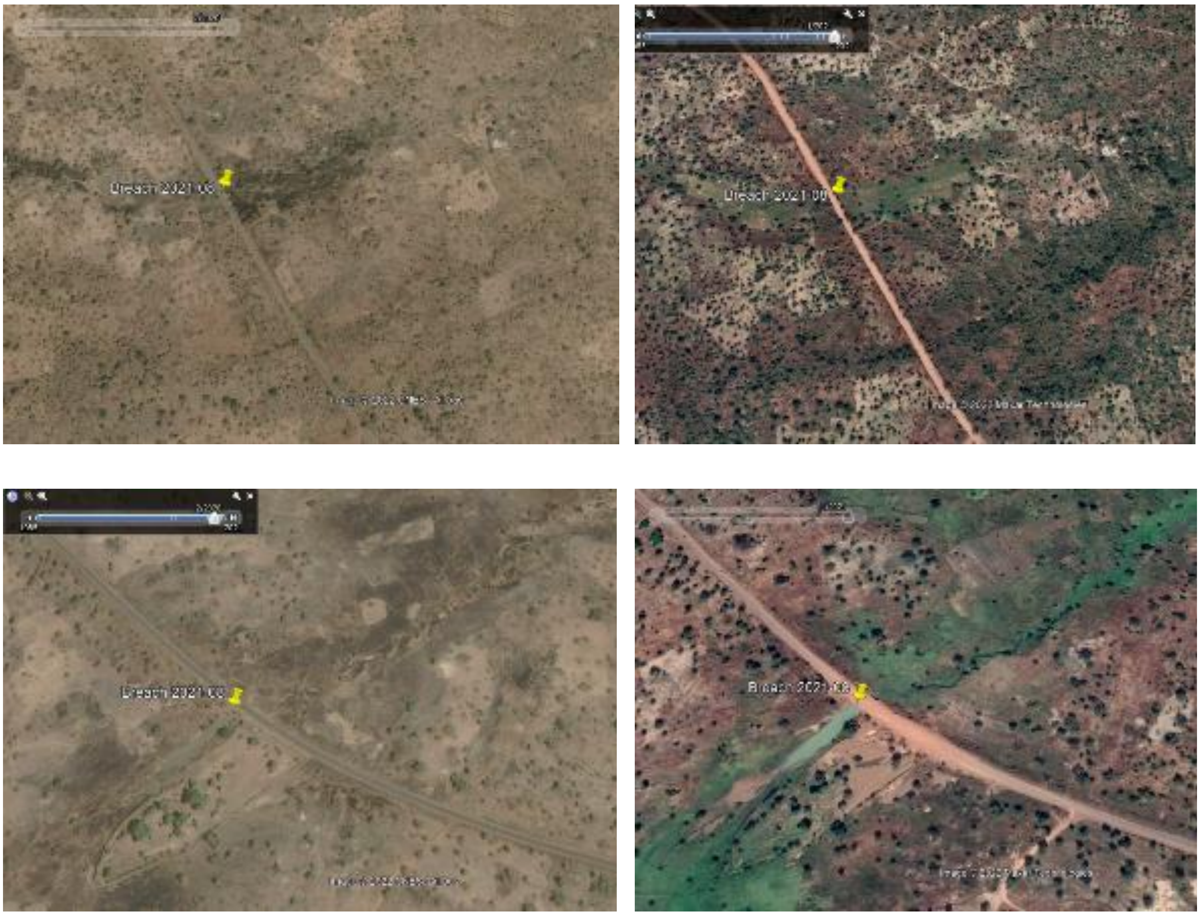

Figure 55. Satellite images from the August 2021 flood obtained from Google Earth Engine. Breach location indicated with the yellow marker.

- **Historic trends**

Pluvial floods are caused by short and intense rainfall events. Some of the district officers mentioned that there has been an increase in rainfall intensities, whereas others mentioned it did not change or less rainfall events occurred. We consider the maximum 1-day precipitation in the World Bank Climate Change Portal as a proxy for pluvial floods. Figure 56 to Figure 58

[467] floodlist.com

show the trends in 1-day precipitation. Note that for the Upper West Region and Upper East Region, the trends are small and not statistically significant. For the Northern Region, the trend is larger, but also not statistically significant. It can therefore not be concluded that the increase in annual maximum 1-day precipitation is different from annual variations.

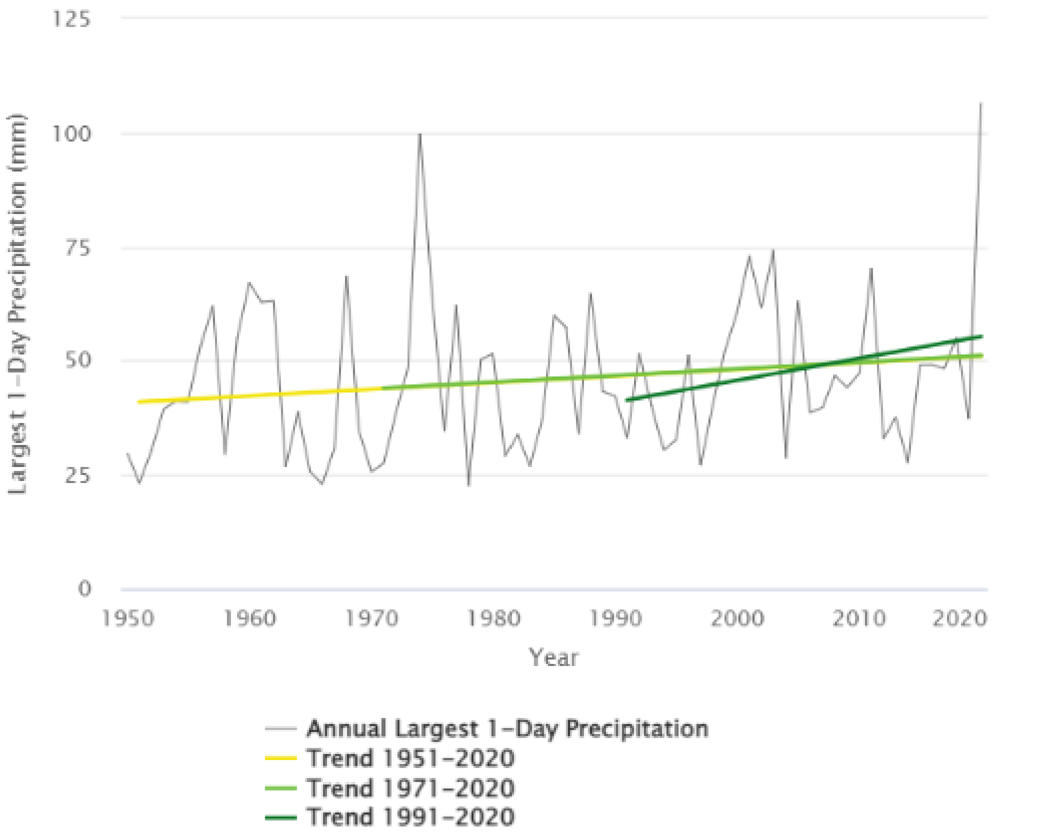

Figure 56. Annual largest 1-day precipitation trends per decade in Upper West Region, Ghana[468].

[468] World Bank Climate Portal

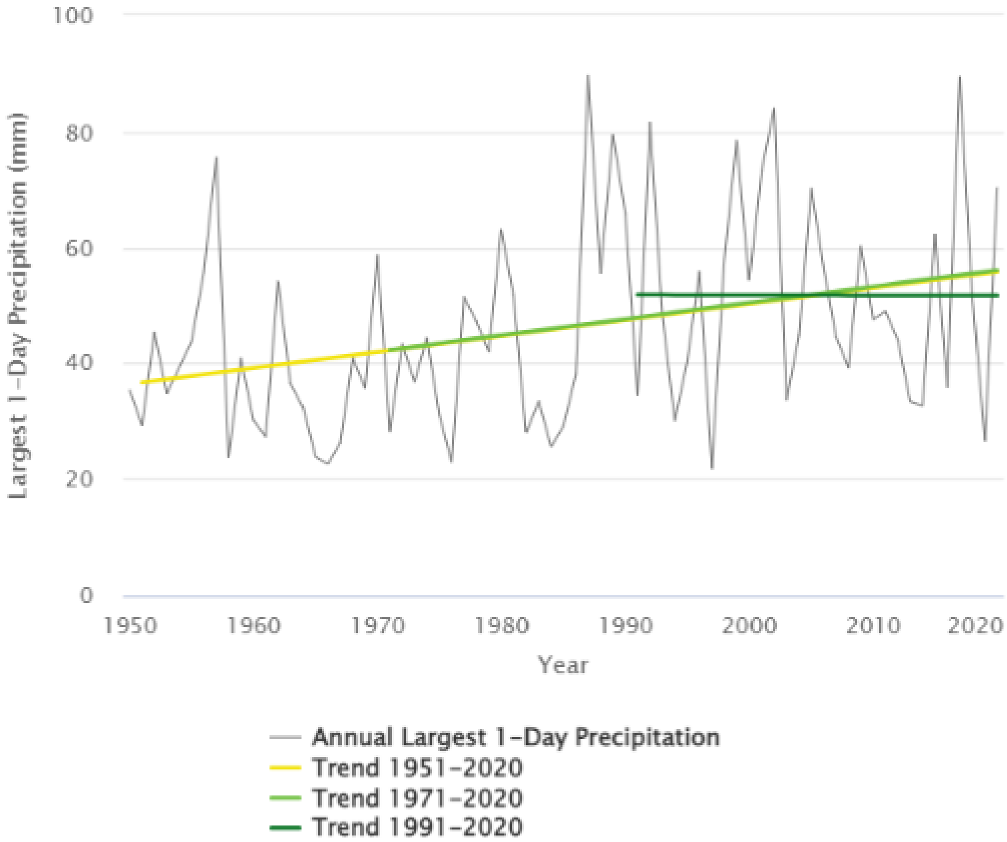

Figure 57. Annual largest 1-day precipitation trends per decade in Upper East Region, Ghana[469].

[469] World Bank Climate Portal

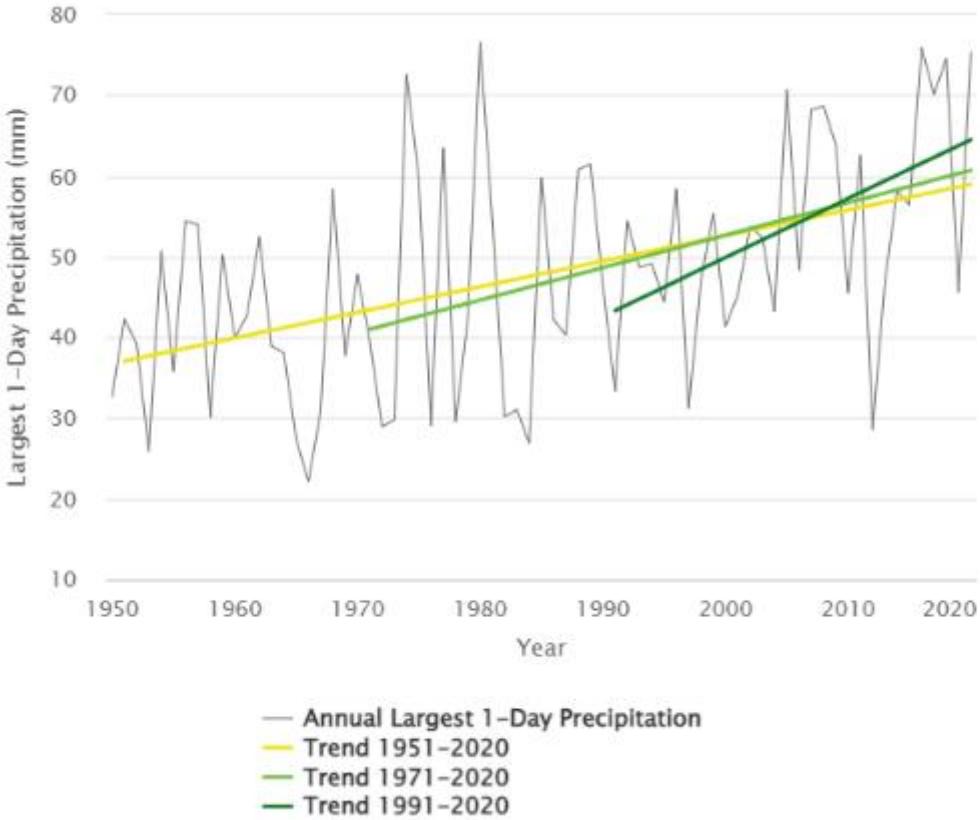

Figure 58. Annual largest 1-day precipitation trends per decade in Upper West Region, Ghana[470].

- **Conclusion**

We conclude that pluvial floods play a role in all districts. Flash floods result in crops and fertile soil being washed away. Besides that, torrential rains cause damage to young crops.
Pluvial floods may have increased in frequency or severity; however, it cannot be concluded from the data that this trend is different from annual variations. This may be caused by the large annual and decadal variations in this climate.

6.1.4 Dams and reservoirs

The spilling of the Bagre dam is discussed in Sub-section 6.1.1. In this Sub-section we discuss flood risk resulting from other dams and reservoirs. During the field visits, the farmers and district officers mentioned two flood causes related to dams and reservoirs. In the Garu district, the uncontrolled spilling of the Tamne reservoir causes agricultural fields to flood. Besides that, in 2021 rainfall caused small reservoir dams to breach. This is elaborated below.

- **Tamne reservoir**

The Tamne reservoir was constructed between 2016 and 2019. In 2021, the first year of full-scale operation, the Tamne reservoir and the Tamne River flooded, causing damages in the Garu district (Upper East region) as well as in the Tenpane and Pusiga districts (outside the areas of focus of this project). Media articles report agricultural fields being damaged and houses being submerged[471,472]. The Garu district officers confirmed the 2021 floods. It should be investigated if better operation can prevent uncontrolled spillage in the future. Figure 59 shows a picture of the dam.

[470] World Bank Climate Portal
[471] https://www.gbcghanaonline.com/general/tamne-floods-farmlands-submerged-residents-rendered-homeless/2021/
[472] https://www.myjoyonline.com/about-40-houses-flooded-in-upper-east-region/

From data analysis of GPM data[473] we can conclude that the rainy season of 2021 had a below-average precipitation when looking at the total amount of rainfall up to the end of August (when the basin flooded), or when looking at the entire rainy season. The rainy season of 2020 was relatively wet, with high total amounts of precipitation, which could have lead to a full reservoir. With proper reservoir management (lowering the reservoir level during the dry season) this should however not have led to floods in 2021.

Figure 59. Picture of the Tamne dam in December 2022, during our field visit. Water level is almost maximum.

- **Small dams and reservoirs**

Large amounts of rainfall can cause dam breaches of local dams and dugouts. These breaches can also cut off roads. Figure 60 and Figure 61 show examples of such dam breaches in 2021 in the Upper West Region. It was confirmed by the Agric and NADMO district officers, and during the interview with WRC, that the small reservoir dams have a risk of breaching and as such are a potential cause of flooding.

In 2019, the Government of Ghana launched the One Village One Dam Initiative, with the aim of constructing a total of ten Small Earth Dams in each constituency in the Northern Regions. The regions identified five hundred and sixty (560) sites for the construction of Small Earth Dams. In all interviews, the initiative was said to have been ineffective. The dams are referred to as dugouts, that are not large enough to act as reservoirs to overcome the dry season. It appears that there was insufficient hydrological assessment before constructing the dugouts. Furthermore, the dugouts have a high risk of breaching, due to poor construction, poor maintenance and misuse of the dams, for example by farmers who let their cattle walk into the pond. In the Task 3 report, small reservoirs as a flood adaptation measure will be further discussed.

[473] Global Precipitation Measurement Mission

Figure 60. Example of a dam breach in the Upper West region, west of Nawdoli. Left: February 2020, Right: November 2021. Obtained from Google Earth.

Figure 61. Example of a dam breach in the Upper West region, north of Moyiri. Left: April 2021, Right: November 2021. Obtained from Google Earth.

- **Conclusion**

Breaches of small reservoir dams cause flood risk in all districts, especially when dams are poorly constructed, maintained or treated. Besides that, uncontrolled spilling of the Tamne reservoir causes flood risk in the Garu district, this is likely due to inadequate operational control. In the Task 3 report potential solutions will be discussed.

6.1.5 Delayed onset of the wet season

In interviews with the farmers and agricultural officers, the change of the rainy season was often mentioned first when we asked them about climate change. They mentioned that the onset of the wet season has shifted from February/March until sometimes as late as June, which is also confirmed by precipitation observations in **Figure 62** showing the cumulative precipitation for the years 1979 (dark blue) –2020 (dark red) for the Upper West Region (left) and Upper East Region (right). **Figure 62** shows that the total amount of rainfall in the wet season has reduced, but also that the wet season starts later. The Bagre spilling and fluvial floods have not changed and generally happen in August and September. Farmers have to wait for the onset of the wet season to sow their seeds, which means the crops have not matured before the rivers flood and the harvest is lost.

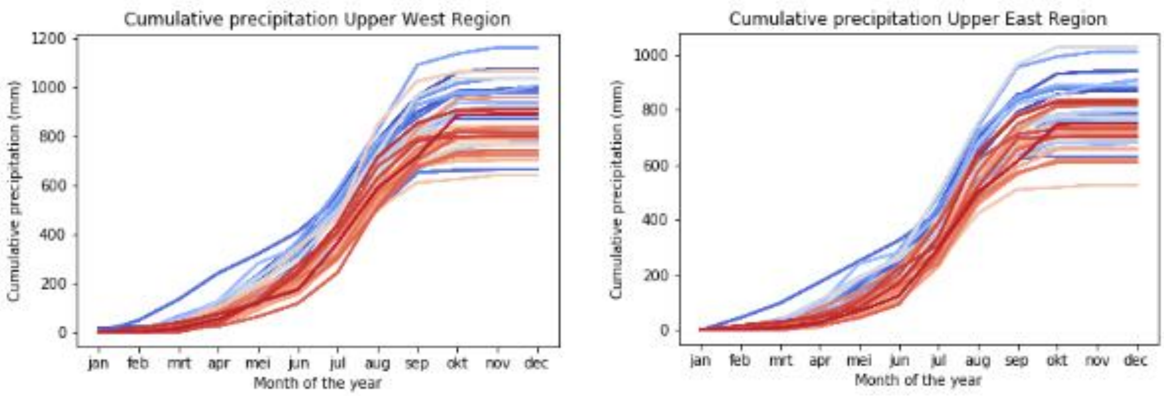

Figure 62. Cumulative precipitation for 1979 (dark blue) – 2020 (dark red) for the Upper West Region (left) and Upper East Region (right)[474].

6.1.6 Conclusions

Among the historic flood events we discerned the following types of floods:

- Floods due to spilling of the Bage dam along the main branches of the White Volta;
- Fluvial floods along the White Volta, Black Volta and Oti and their tributaries;
- Pluvial floods (flash floods due to local intense rainfall);
- Floods due to spillage of the Tamne reservoir;
- Floods due to breaches in small reservoir dams.

Table 18 below summarizes what districts are affected by what types of floods.

Table 18. Summary of types of floods per district.

	Jirapa (Upper West)	Lambussie (Upper West)	Lawra (Upper West)	Wa West (Upper West)	Binduri (Upper East)	Garu (Upper East)	East Mamprusi (North East)	Yunyoo-Nasuan (North East)
Fluvial	Yes, Black Volta	Yes, Black Volta	Yes, Black Volta	Yes, Black Volta	Yes, White Volta	Yes, White Volta	Yes, White Volta	Yes, Oti
Pluvial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bagre	No	No	No	No	Yes	Yes	Yes	No
Tamne	No	No	No	No	Yes	Yes	No	No
Breaches of small reservoir dams	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

For these floods we conclude from historic trends that:

- Fluvial flooding: A climate change trend is detected that is statistically non-significant.
- Pluvial flooding: A climate change trend is detected that is statistically non-significant.
- Bagre flooding: Frequency of spilling from the Bagre dam has not changed, but there are indications that the spilling became more severe in the past decades. This coincides with a slight increase in annual average rainfall in the Bagre catchment, an increase in rainfall in the month August, which is the wet season, and an increase in yearly maximum 5-day

[474] ERA5 Reanalysis extracted from Google Earth Engine.

rainfall amounts in the past decade. While rainfall patterns are not the only factor determining the likelihood of spilling, rainfall becoming more concentrated in the wet season months and intensities increasing does lead to an increased risk of spilling. There are indications of a climate change trend, however other causes such as a change in operational management can also play a role.

- Tamne flooding: We have no data to support climate change analysis on this topic. It is related to (annual) rainfall patterns and pluvial flooding, but also has high uncertainty when relating it to climate change due to its management.
- Breaches of small reservoir dams: We have no data to support climate change analysis on this topic. It is related to (annual) rainfall patterns and pluvial flooding, but also has high uncertainty when relating it to climate change due to its relation to construction related variables such as strength and year of construction.

From media reports and observational data of the White Volta and the Bagre dam it is concluded that floods related to spilling of the Bagre dam have become more severe in the past decade but the frequency did not change. This is also confirmed by monthly precipitation data for the regions in Burkina Faso in which the Bagre catchment is located.

During the field visits, no specific increase in fluvial floods, other than those related to Bagre spilling, or pluvial floods was mentioned. This is supported by analysis of the annual maximum 5-day precipitation and annual maximum 1-day precipitation in the Northern, Upper West and Upper East Region in Ghana from ERA5 Reanalysis data as presented in the World Bank Climate Change Portal. However, there may be a slight upward trend and also the most severe floods both pluvial and fluvial happened in 2020 and 2021.

The flood event in 2021 due to spilling of the Tamne reservoir is presented in this chapter too. Due to the dam being newly constructed, no historic data is available. From media articles and google satellite imagery it was shown that breaching of small dams causes floods as well.
Finally, the delayed onset of the wet season over the past decades was shown. While this is not a cause of floods directly, it results in shorter growing seasons and therefore the crops planted in the flood plains of the river not being mature before the fluvial floods or Bagre spills arrive in August or September.

In Section 6.2, flood hazard maps and flood risks will be presented for all of the districts. In Section 6.3 climate projections for the various flood types will be discussed.

6.2 Flood hazard and risk assessment

6.2.1 Methodology to derive flood maps

Flood risk maps are derived for return periods of 1, 2, 5, 10, 20, 50 and 100 years (referred to as T1 up to and including T100) by making use of different types of information sources. The maps show the estimated flood extents for a given return period.

- **Data sources flood risk maps**

The flood risk maps are based on the following data sources:

- *JRC seasonal water bodies*

Satellite observations can give an indication of water occurrence on land and its variation through time. For the satellite-based maps used in this study we use water occurrence maps based on JRC Yearly Water Classification History data and the JRC Monthly Water History data[475]. The maps are derived from more than 30 years of available Landsat 5,7 and 8 satellite images (1984–2020) and show different facets of surface water dynamics at a 30m resolution. We make use of the Seasonal water occurrence map. The seasonal water occurrence shows the areas that are wet on a yearly basis but are dry for parts of the year. This map is constructed from many observations over the past decades and gives an accurate view of locations that have regularly been flooded. We interpret these extends as flooded areas with a return period of 1 year (or the “minimum yearly flood extent”).

- *Flood extents calculated in the World Bank White Volta project*

Within the World Bank White Volta flood risk assessment[476], flood hazard and flood risk maps have been created for the White Volta river and its main tributaries. These are the only available flood risk maps for this area that are derived from hydrological and hydraulic 1D2D models. These maps are available for return periods of 50 and 100 years.

- *JRC global flood model*

For (parts of) the districts that are not covered by the White Volta World Bank project and for the unavailable return periods, we use the 10, 20, 50 and 100 year flood extents from the JRC global hydrological model[477]. This global hydrological model is available in the global disaster risk portal hosted by UNEP. The model was selected to be most suitable for this study, as presented in the inception report[478].

- *HAND maps: Height Above Nearest Drainage*

In a HAND-map the relative height of a certain location in a drainage network is shown. Elevation maps are used to determine flow paths of rivers and as such they can be used as in indication of flood extents for a given flood depth. The HAND map shows for each location how high the land is with respect the nearest local low-point in the terrain. The local low-points are typically lakes or river channels. Therefore, for a location near a river, the HAND-value reflects how high that location is with respect to a drainage point in the river. The method to derive a HAND-map is described by Rennó et al (2008)[479]. The flood depth is related to the flood extent by assuming all locations with Height Above Nearest Drainage value below the flood depth are flooded.

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[475] Pekel J.-F, Cottam A, Gorelick N, Belward A. 2016. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422.
[476] HKV. 2012. Flood hazard assessment White Volta.
[477] Dottori F, Alfieri L, Salamon P, Bianchi A, Feyen L, Hirpa, F. 2016. Flood hazard map of the World. Joint Research Centre (JRC).
[478] HKV. 2022. GCF Climate change and flood risk assessment Northern Savannah zone in Ghana - Inception Report.
[479] Rennó C, Nobre A, Cuartas L, Soares J, Hodnett M, Tomasella J, Waterloo, M. 2008. HAND, a new terrain descriptor using SRTM-DEM: Mapping terra-firme rainforest environments in Amazonia. Remote Sensing of Environment, 3469-3481.

Water level measurements are very rare in this area in Ghana. Instead, we use flood extents from the JRC global flood model, the JRC seasonal water bodies and the World Bank White Volta project to determine the corresponding threshold for the HAND-value for a given return period. Doing so, the existing inundation maps have been extrapolated to other areas. HAND-thresholds for return periods for which no flood extents were available are interpolated from those for which flood extents were available. The results are presented in Table 19.

Table 19. HAND levels for the different return periods of the flood risk maps.

Return period	HAND level	HAND level determined with
T1	1.25 m	Seasonal water bodies JRC
T2	1.50 m	Interpolation
T5	2.00 m	Interpolation
T10	2.50 m	Interpolation and JRC global flood model T10
T20	3.00 m	Interpolation and JRC global flood model T20
T50	4.00 m	White Volta project and JRC global flood model T50
T100	5.00 m	White Volta project and JRC global flood model T100

The various sources are combined to derive inundation maps for the various return levels, as presented in Table 20.

Table 20. Data used to determine flood extent for the different return periods.

Return period	
T1	HAND < 1.25m & Seasonal water bodies JRC
T2	HAND < 1.50m & Seasonal water bodies JRC
T5	HAND < 2.00m & Seasonal water bodies JRC
T10	HAND < 2.50m & Seasonal water bodies JRC
T20	HAND < 3.00m & Seasonal water bodies JRC
T50	HAND < 4.00m & Seasonal water bodies JRC & White Volta project T50
T100	HAND < 5.00m & Seasonal water bodies JRC & White Volta project T100

6.2.2 Flood maps

The flood extent maps of the eight project districts are presented in Figure 63. Light yellow, mostly at the center of the flood extents, represents the yearly flood plains (T1 return period).

Dark purple, at the edges of the flood extents, represents the T100 return period. Colors for other return periods are presented in the legend. The impacts are shown in the next section. By combining these flood extents with e.g. population data, they can be interpreted.

It should be noted that the T1-extents are dominated by the seasonal water bodies by JRC, which are based on observational data. The White Volta project T50 and T100 are results from hydrological flood models calibrated with observational data as well. However, the flood extents following from the HAND-analyses are derived from elevation maps and are the result of interpolation. The maps give an indication of flood extents, but these have not been validated with observational data, as these were not available for that area.

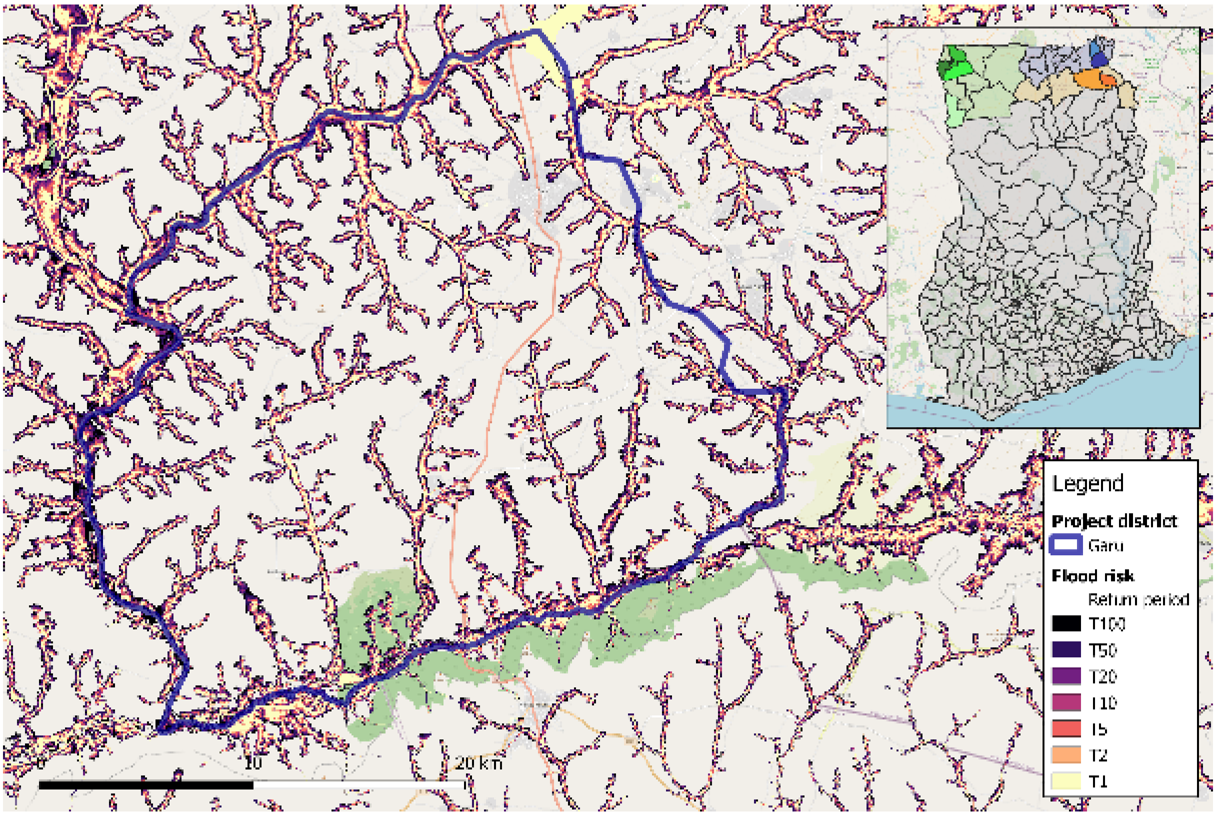

Figure 63. Flood risk map, example for the Garu district.

6.2.3 Effects of floods

By combining the flood extents for the various return periods with population density maps, land use maps, building footprints and road locations, the impact of the floods is determined.

- **People affected**

The number of affected people per district is presented in Table 21 as well as in Figure 64. These numbers are an indication of the potentially affected number of people per flood return period (and associated flood extent). Also shown is the yearly expected damage, for which the damages per return period have been weighted according to probability of occurrence.

The yearly average gives the yearly effect of a flood, as average over a very long time span. Some years the effect will be (way) less, other (exceptional) years the effect will be much higher.

The indications of affected population are found by intersecting the flood extent for each return period with the Global Human Settlement Layer (GHSL) of the European Commission (population map)[480,481]. An example of this combination of the flood extent map and the population density is shown in Figure 65.

The GHSL is based on data from satellite images. Therefore the total population in the districts is different from the numbers presented by the 2021 population and housing census data. The map does provide insight in the spatial distribution of population within the districts however, which is not (yet) available from the 2021 census. Therefore, we use the GHSL maps, with

[480] Schiavina M, Freire S, MacManus K. 2022. GHS-POP R2022A - GHS population grid multitemporal (1975-2030). European Commission, Joint Research Centre (JRC).
[481] Freire S, MacManus K, Pesaresi M, Doxsey-Whitfield E, Mills J. 2016. Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE).

the population number corrected to match the 2021 population and housing census data for each district[482].

From **Table 21** it can be concluded that East Mamprusi and Yunyoo-Nasuan have the most people affected by floods. This is also the case when looking at the percentage of the total population that is affected by floods. In all districts this percentage (yearly average divided by total population) is around 1% (between 0.9% and 1.5%), whereas in East Mamprusi and Yunyoo-Nasuan these percentages are 2.13% and 4.41% respectively. Besides this, in East Mamprusi the total population is a lot higher than in the other districts. This makes the total number of people affected higher as well. In Yunyoo-Nasuan, the flood extends are remarkably wide, this causes a high number of affected people, despite the limited total population.

Table 21. Indication of number of people affected by flood with indicated return period. The numbers of affected people are rounded to hundreds. Also, the total number of inhabitants of the district is given, as well as the yearly average number of people affected.

	Total population	T1	T2	T5	T10	T20	T50	T100	Yearly average
Binduri	76679	300	700	1100	1700	2500	4800	7900	757
East Mamprusi	188006	2100	4000	5900	8300	11000	17700	24400	4006
Garu	71774	300	600	900	1300	1900	3500	5600	633
Jirapa	91279	400	800	1300	1900	2700	5000	8300	879
Lambussie	51118	300	700	1200	1600	2300	4100	6800	738
Lawra	58433	400	800	1300	2000	2700	5200	8200	885
Wa West	91457	400	800	1300	1900	2700	4700	7900	872
Yunyoo-Nasuan	56879	1100	2500	4000	5700	7700	12400	17000	2510

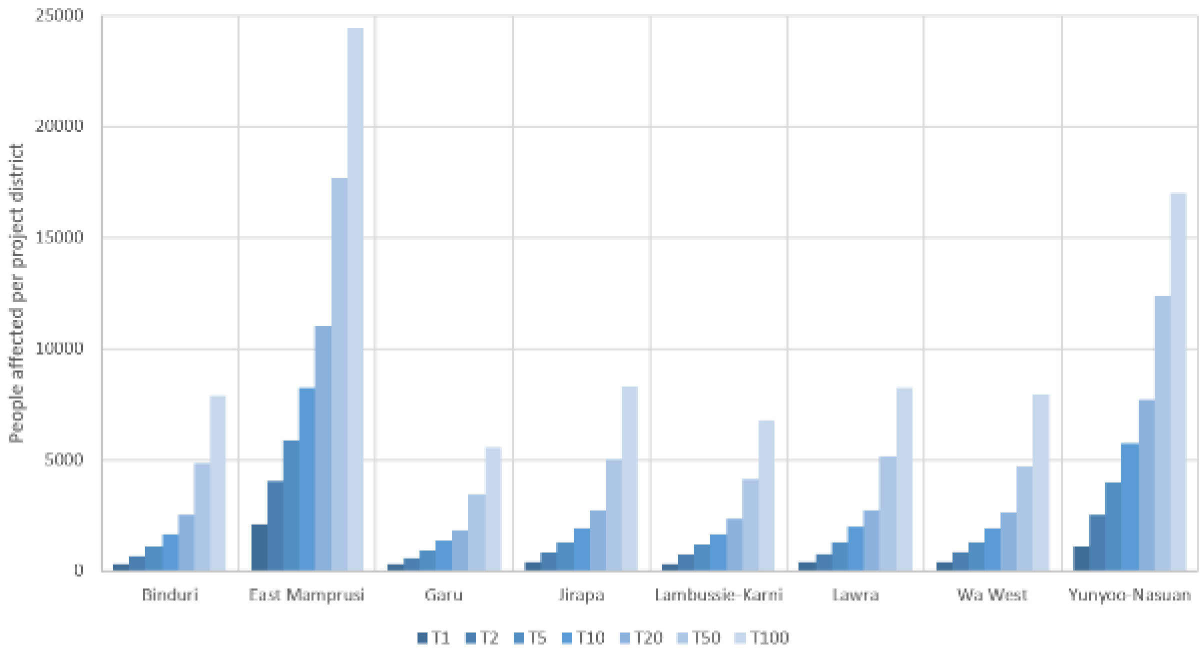

Figure 64. Affected number of people per district for the different return periods of floods. The height of the bar indicates the total number of people affected for the given return period.

[482] Ghana Statistical Service. 2022. Ghana 2021 population and housing census - General Report Volume 3. Ghana Statistical Service.

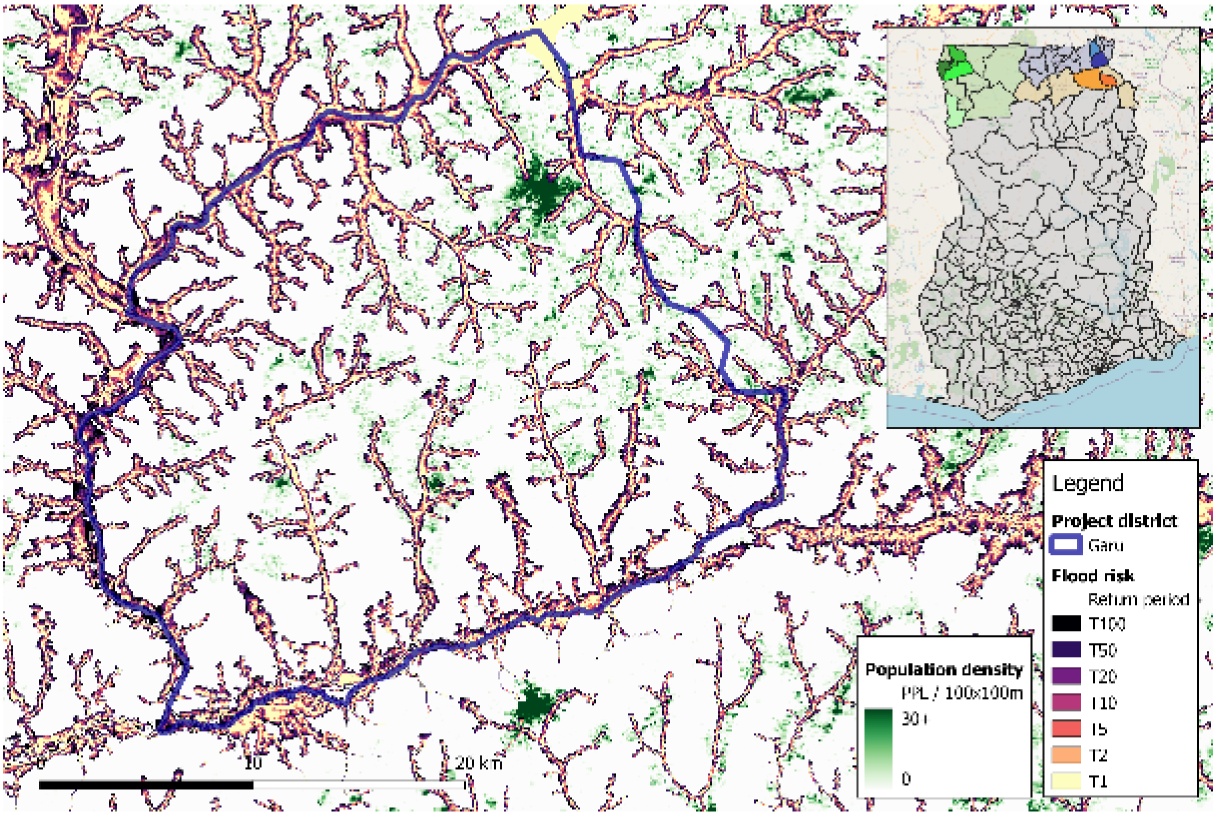

Figure 65. Example of the combination of flood risk and population density. In this case the Garu district is shown.

- **Agricultural area affected**

The impact of floods on land use is measured by the amount of cropland affected. These numbers are found by masking the area marked as cropland in the 2019 epoch of the Copernicus Global Land Service (CGLS) map[483] the flood extents. The results are presented in Table 22 and Figure 66. The table presents the total area of the entire district and the affected km^2 of cropland per district. Also shown is the yearly expected damage, for which the damages per return period have been weighted according to probability of occurrence. The yearly average gives the yearly effect of a flood, as average over a very long time span. Some years the effect will be (way) less, other (exceptional) years the effect will be much higher.

The table and figure show that in East Mamprusi, the total area of affected cropland is highest. This is also the largest district in terms of total area, cropland area, and number of inhabitants. This district is followed by Binduri, Garu and Yunyoo-Nasuan.

Table 22. Indication of area of cropland affected by floods in km^2 with indicated return period, per district. The "Total area" column indicates the total area of the entire district. The yearly average indicates the area of cropland affected in an average year (over 100 years).

	Total area (km2)	T1	T2	T5	T10	T20	T50	T100	Yearly average
Binduri	392	25	31	41	51	60	74	89	32
East Mamprusi	1708	59	72	100	126	151	191	233	76
Garu	676	26	31	41	50	59	72	89	32
Jirapa	1188	12	15	20	26	32	42	54	16
Lambussie	811	5	7	9	11	14	18	23	7
Lawra	527	7	8	11	15	18	24	31	9
Wa West	1492	5	6	9	11	14	19	26	7
Yunyoo-Nasuan	488	23	29	41	52	63	79	96	31

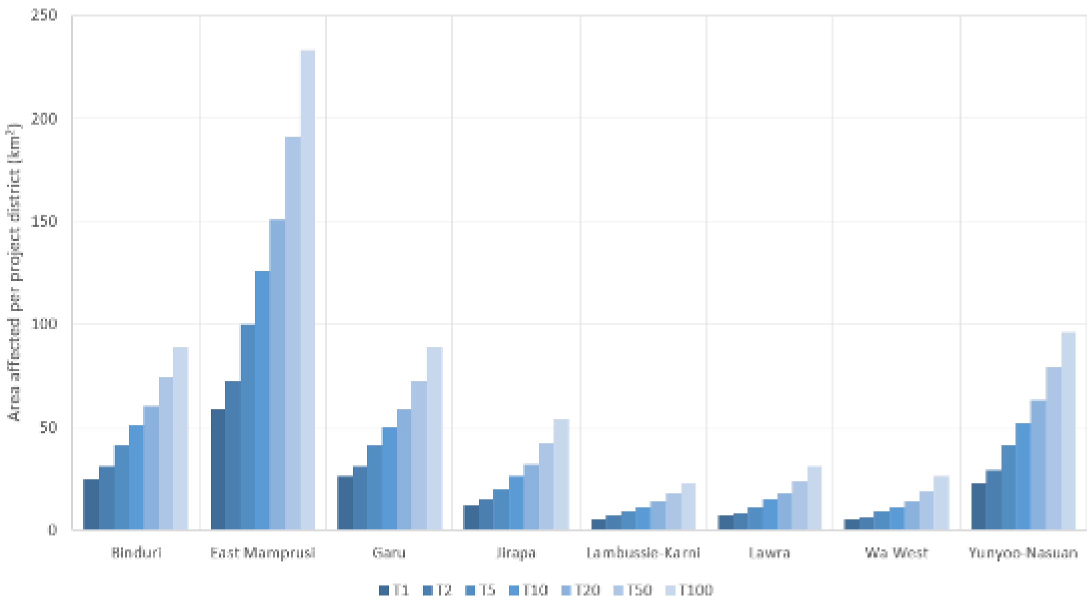

Figure 66. Affected area of cropland affected by floods per district for the different return periods of floods. The height of the bar indicates the total affected area for the given return period.

- **Buildings affected**

[483] Buchhorn M, Smets B, Bertels L, Lesiv M, Tsendbazar N.-E, Masiliunas D, et al. 2020. Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch 2019: Globe (Version V3.0.1).

The number of affected buildings in each district is found by combining the flood extents with the building footprints as available from the Google Open Buildings dataset[484] (Sirko, et al., 2021). An indication of the affected number of buildings is given in
Table 23 and Figure 67. Also shown is the yearly expected damage, for which the damages per return period have been weighted according to probability of occurrence. The yearly average gives the yearly effect of a flood, as average over a very long time span. Some years the effect will be (way) less, other (exceptional) years the effect will be much higher.

The highest number of affected buildings is found in East Mamprusi, which is also the largest district in terms of area and inhabitants. Other districts with high numbers of affected buildings are Yunyoo-Nasuan and Lawra. Still, it should be noted that the number of affected buildings does not say all about actual damage. Buildings will probably be flooded, but whether they will be severely damaged by a flood as well, depends also on other factors such as building technique, flow velocity and duration of the flood.

Table 23. Indication of number of buildings affected by floods, with indicated return period, per district. Also given is the yearly average of buildings affected by floods (over 100 years).

	T1	T2	T5	T10	T20	T50	T100	Yearly average
Binduri	84	113	225	422	845	2099	3910	205
East Mamprusi	780	1042	1598	2354	3236	5604	7875	1212
Garu	257	323	502	734	1024	1943	3061	393
Jirapa	182	249	438	696	1087	2381	4165	342
Lambussie	183	253	576	952	1447	2681	4257	385
Lawra	236	312	516	832	1211	2965	4895	420
Wa West	160	214	416	625	890	1945	3493	298
Yunyoo-Nasuan	348	471	761	1180	1650	2827	3966	568

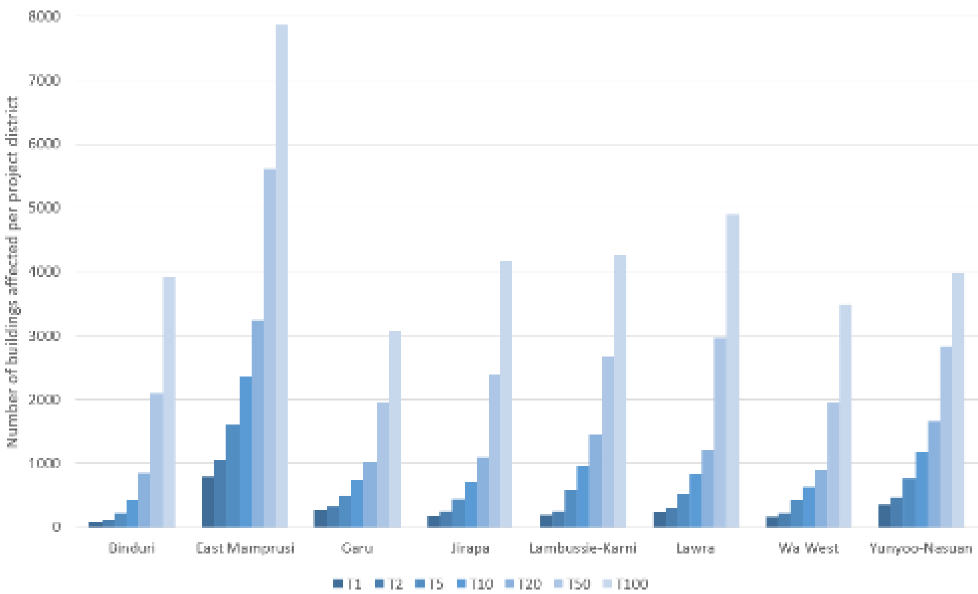

Figure 67. Indication of number of buildings affected by floods, with indicated return period, per district.

- **Roads affected**

484 The Google Open Buildings dataset is available via: https://sites.research.google/open-buildings/#explore.

The effect of floods on roads is measured in km's of road flooded. This is calculated by combining the flood extents with the Open Street Map open data road information. Based on the OSM labels of each road, each 100m road segment is classified as Main road, Secondary road, or Local road. Bridges are considered separately in this assessment. Footways, paths, trails, and residential roads (small roads within cities and towns) are not a part of one of the considered categories.

The affected kilometres of road and affected number of bridges are presented in
Table 24. Also presented in
Table 24 is the yearly expected damage, for which the damages per return period have been weighted according to probability of occurrence. The yearly average gives the yearly effect of a flood, as average over a very long time span. Some years the effect will be (way) less, other (exceptional) years the effect will be much higher.

At first glance, all districts seem comparable when looking at the affected kilometres road, but when looking a bit more closely some things are worth mentioning. First of all, Wa West has the most kilometres of affected road (33km), whereas East Mamprusi is the largest district (30km road affected). Lawra has a high number of affected road kilometres (19km) and the highest number of affected bridges (9 bridges, same as East Mamprusi), for a relatively small district. Especially when the affected roads are connection roads between towns and districts, this can have a big impact on the (local) economy, livelihoods and the daily life. For example, if transportation routes of goods are being cut off, local farmers will lose their income as their products cannot reach the fresh markets in the nearby town or city. Also, many (young) people from the villages work in the city during the week. Roads being cut off might limit their commute and the income of their families.

Table 24. Kilometres of road affected by floods and number of bridges affected by floods, including the total km's of roads per category and district. Also given: the average number of km's road affected per year (over 100 years).

		Total	T1	T2	T5	T10	T20	T50	T100	Yearly average
Binduri	Main roads	14	1	1	1	1	2	3	3	1
	Secondary roads	7	0	0	0	1	1	1	1	0
	Local roads	183	4	5	8	11	13	19	23	6
	Bridges	4	3	3	3	3	3	4	4	3
East Mamprusi	Main roads	61	3	4	5	6	7	8	10	4
	Secondary roads	68	3	4	6	8	10	15	34	4
	Local roads	364	16	20	30	39	48	68	86	22
	Bridges	13	8	10	10	12	12	12	13	9
Garu	Main roads	32	1	1	1	1	1	2	3	1
	Secondary roads	17	0	0	0	0	1	1	1	0
	Local roads	196	8	10	13	15	20	26	32	10
	Bridges	2	1	1	1	1	1	2	2	1
Jirapa	Main roads	57	2	2	4	5	7	9	13	3
	Secondary roads	90	4	5	7	8	10	15	19	5
	Local roads	206	8	9	13	18	22	32	41	10
	Bridges	9	6	6	7	7	8	9	9	6
Lambussie	Main roads	15	1	1	2	2	3	4	5	1
	Secondary roads	83	3	4	7	9	10	13	18	4
	Local roads	142	7	8	10	14	16	24	32	9
	Bridges	7	5	5	5	6	6	7	7	5
Lawra	Main roads	49	2	3	4	6	7	11	13	3
	Secondary roads	30	2	2	3	4	5	7	9	2

	Local roads	181	11	14	17	21	26	38	48	14
	Bridges	12	8	9	12	12	12	12	12	9
Wa West	Main roads	61	3	3	4	5	6	9	12	3
	Secondary roads	88	5	5	8	10	12	17	23	6
	Local roads	395	18	23	30	37	46	66	85	24
	Bridges	5	4	4	4	4	4	4	4	4
Yunyoo-Nasuan	Main roads	24	1	2	3	3	4	5	7	2
	Secondary roads	28	1	1	2	3	3	5	6	1
	Local roads	106	9	12	17	20	24	32	40	12
	Bridges	1	1	1	1	1	1	1	1	1

- **Conclusions**

From the flood effects assessment, focus districts can be defined. **Table 25** below summarizes this. East Mamprusi and Yunyoo-Nasuan have the most people affected by floods, when looking at absolute numbers, as well as when looking at the percentage of the total population that is affected by floods. When looking at agricultural area affected by floods, East Mamprusi is affected most, followed by Binduri, Garu and Yunyoo-Nasuan.

The highest number of affected buildings is found in East Mamprusi. Other districts with high numbers of affected buildings are Yunyoo-Nasuan and Lawra. Wa West has the most kilometres of affected road, followed by East Mamprusi. Lawra has a high number of affected road kilometres, but more striking for the size the district has, are the number of affected bridges, which is the same as East Mamprusi, which is a larger district. Overall, it can be concluded that East Mamprusi is affected most by floods. For a large part this is because of the size of the district.

Table 25. Summary of effects of floods.

	Total population	Total area (km2)	Population affected yearly average	Percentage of population affected yearly average	Cropland affected (km^2) yearly average	Buildings affected yearly average	Roads affected (total kms) yearly average	Bridges affected yearly average
Binduri	76679	392	757	0.99%	32	205	7	3
East Mamprusi	188006	1708	4006	2.13%	76	1212	30	9
Garu	71774	676	633	0.88%	32	393	11	1
Jirapa	91279	1188	879	0.96%	16	342	18	6
Lambussie	51118	811	738	1.44%	7	385	14	5
Lawra	58433	527	885	1.51%	9	420	19	9
Wa West	91457	1492	872	0.95%	7	298	33	4
Yunyoo-Nasuan	56879	488	2510	4.41%	31	568	15	1

6.3 Climate change analysis

In Section 6.1, historic flood events with various causes were discussed. The historic trends in annual total precipitation, annual maximum 1-day and 5-day precipitation from World Bank Climate Change Portal were used to look at trends in these events, together with information from the field visits and media searches. It was concluded that flood events along the White Volta from the Bagre spilling has become more severe over the past years. The other flood types, fluvial floods along other parts of the White Volta as well as the Black Volta and the Oti and pluvial floods have increased, but this increase is not or not yet large enough to conclude that this is significantly different from annual variations.

In this section we consider projections of these events, specifically the project of RCP4.5 for the year 2050 and RCP4.5 and RCP8.5 for the year 2100. The RCP4.5 is a stabilization scenario where forcing is stabilized before 2100 by employing technologies and strategies to reduce greenhouse gas emissions. The RCP8.5 is a business-as-usual scenario and characterized by increasing greenhouse gas emissions and high greenhouse gas concentration levels.

We use the same proxies for pluvial and fluvial floods as in Section 6.1; annual maximum 1-day and 5-day precipitation respectively. We look at the CMIP6 multi-model ensemble. Both the World Bank Climate Change Portal and the IPCC Interactive Atlas[485] have been used to extract climate projections.

6.3.1 Bagre spilling

In Section 6.1 it has been shown that floods due to spilling of the Bagre dam have become more severe in the past decade. We look at the climate projections for total precipitation in four regions in Burkina Faso; Centre, Centre Sud, Centre Nord, Plateau Central. We present the scenarios SSP2–4.5 and SSP5–8.5 for the years 2040–2059 and 2080–2099 for percent change in annual rainfall in Table 26. In all scenarios and for both periods of projection the annual rainfall increases. This means that without adjustments of the capacity and operations of the Bagre dam, floods due to spilling will become more frequent in a future climate with these scenarios.

Table 26. Increase in annual rainfall (%) for the Centre Sud, Centre, Plateau Central and Centre Nord regions in Burkina Faso, for scenarios SSP2-4.5 and SSP5-8.5 and years 2040-2059 and 2080-2099 relative to reference period 1995-2014.

	SSP2-4.5 2040-2059	SSP5-8.5 2040-2059	SSP2-4.5 2080-2099	SSP5-8.5 2080-2099
Centre Sud	27.3%	30.3%	18.1%	46.8%
Centre	25.8%	22.0%	11.2%	59.8%
Plateau Central	28.0%	28.8%	14.2%	61.3%
Centre Nord	23.1%	32.8%	19.7%	54.4%

[485] IPCC. 2023. IPCC WGI Interactive Atlas. Opgehaald van https://interactive-atlas.ipcc.ch/

6.3.2 Fluvial floods

The annual largest 5-day precipitation for the Upper West, Upper East and the Northern regions in Ghana are presented in Figure 68. All regions show an increase in largest 5-day precipitation in the months July–October between 2020 and 2100 for both scenarios SSP2–4.5 and SSP5–8.5. Note that the color scale is different for the SSP5-8.5 scenario on the right than for the SSP2–4.5 scenario on the left.

Scenario: SSP2–4.5 Scenario: SSP5–8.5

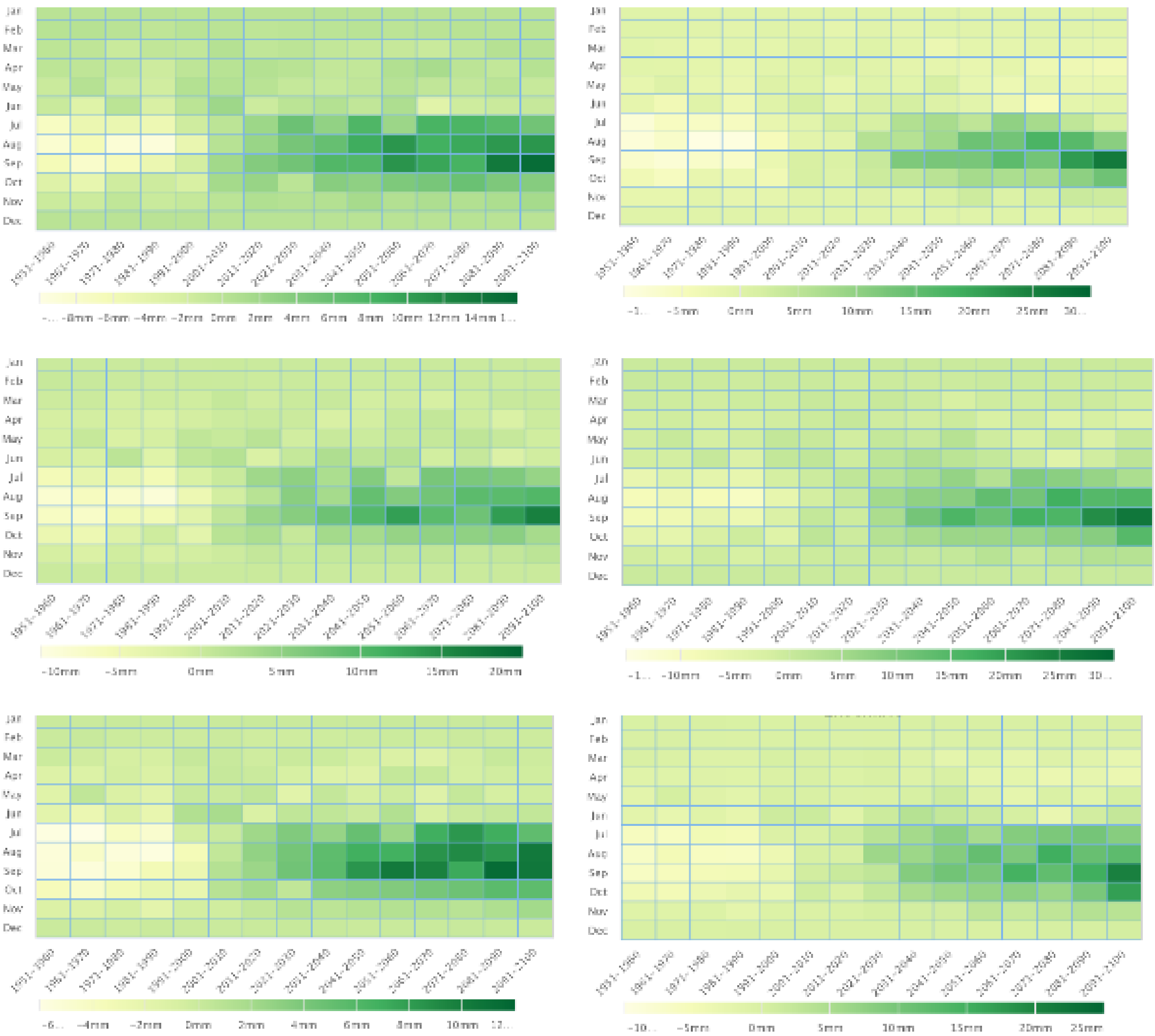

Figure 68. Projected Average Largest 5-Day Precipitation Anomaly in the Upper West (upper panes), Upper East (middle panes) and the Northern Region (bottom panes), Ghana. Reference period: 1995-2014[486].

The increase in maximum 5-day precipitation is confirmed by the IPCC Interactive Atlas, which provides changes in annual maximum 5-day precipitation in % for the SSP2–4.5 and the SSP5–8.5 scenario for the West Africa Region (**Table 27**). The quantiles, P25–P75, P10–P90, P5–P95, provide information on the spread of the CMIP6 model ensemble. The numbers in the column P25|P75 provide the range between which the middle 50% of the model projections fall, e.g. for the Near-Term period the SSP2–4.5 scenario, 50% of the ensemble members suggest a relative change between 1.2% and 7.5%. Simultaneously, 80% of the

[486] World Bank Climate Change Knowledge Portal

models suggest a relative change between 0.7% and 11.3%. Negative numbers indicate a reduction in annual maximum 5-day precipitation.

Table 27. CMIP6 Annual maximum 5-day precipitation change relative to 1995-2014 (%). Scenario: SSP2-4.5 and SSP5-8.5. Region: Western Africa[487].

Period	Scenario	Median	P25| P75	P10 | P90	P5 | P95
Near Term (2021-2040)	SSP2-4.5	5.1	1.2 | 7.5	0.7 | 11.3	-1.6 | 12.3
	SSP5-8.5	7.2	3.8 | 10.9	0.4 | 12.9	-0.5 | 14.3
Medium Term (2041-2060)	SSP2-4.5	7.7	2.8 | 12.8	0.3 | 14.8	-1.1 | 15.9
	SSP5-8.5	11.4	6.6 | 17.1	2.1 | 18.8	-0.1 | 23.8
Long Term (2081-2100)	SSP2-4.5	10.7	5.7 | 16.9	1.1 | 20.9	-1.7 | 21.7
	SSP5-8.5	21.0	10.8 | 29.7	3.5 | 40.0	-1.1 | 50.4

6.3.3 Pluvial floods

The annual largest 1-day precipitation for the Upper West, Upper East and the Northern regions in Ghana are presented in Figure 69. All regions show an increase in largest 1-day precipitation in the months July–October between 2020 and 2100 for the scenarios SSP2–4.5 and SSP5–8.5. Note that the colour scale in the left images (SSP2–4.5 scenario) differs from the colour scale in the right images (SSP5–8.5 scenario).

[487] IPCC Interactive Atlas

Scenario: SSP2–4.5 Scenario: SSP5–8.5

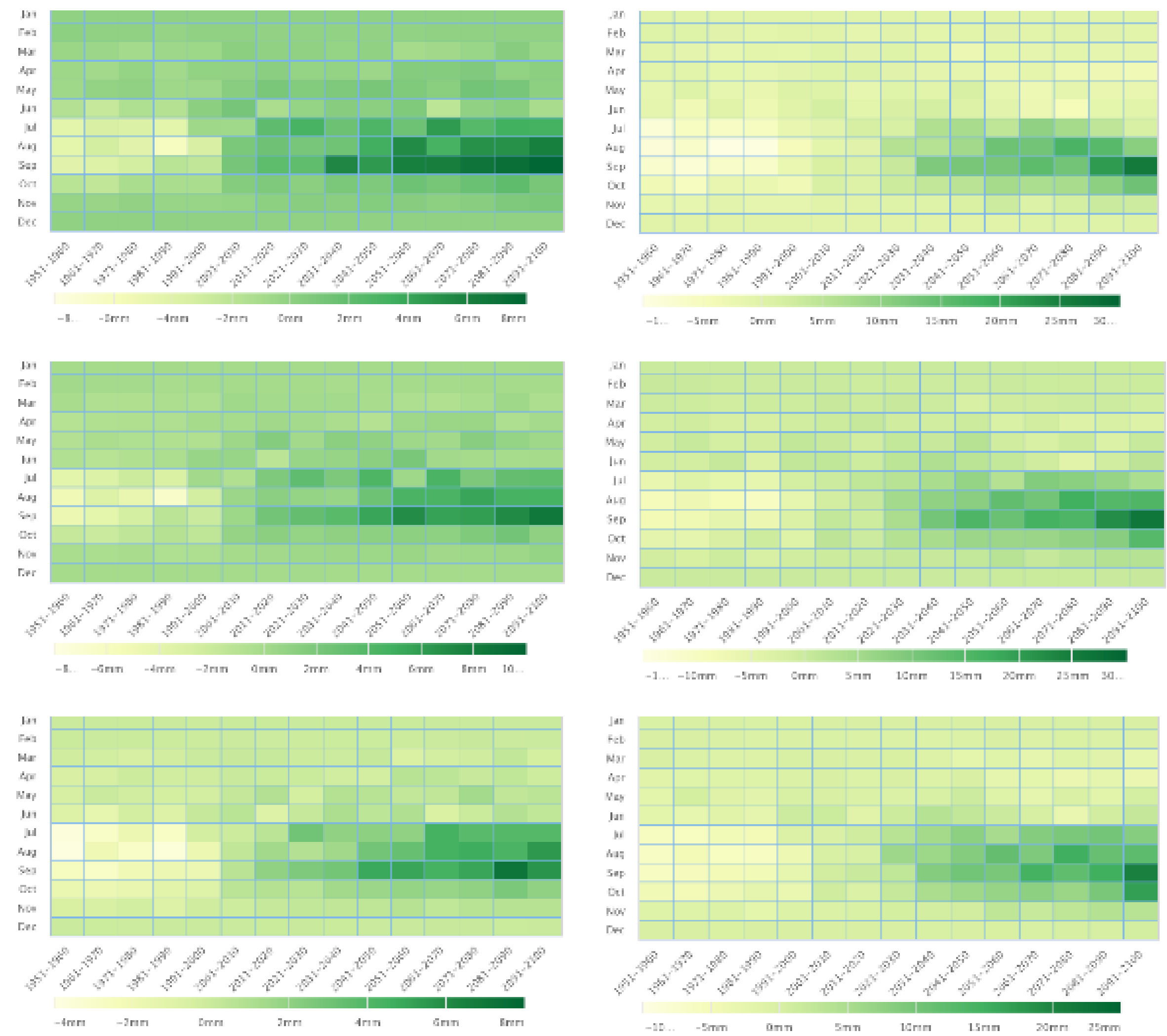

Figure 69. Projected Average Largest 1-Day Precipitation Anomaly in the Upper West (upper panes), Upper East (middle panes) and the Northern Region (bottom panes), Ghana. Reference period: 1995-2014[488].

The increase in maximum 1-day precipitation is confirmed by the IPCC Interactive Atlas, which provides changes in annual maximum 1-day precipitation in % for the SSP2–4.5 and the SSP5–8.5 scenario for the West Africa Region (**Table 28**). The quantiles, P25–P75, P10–P90, P5–P95, provide information on the spread of the CMIP6 model ensemble. For clarification of the meaning of these quantiles, we refer to the explanation above.

Table 28. CMIP6 Annual maximum 1-day precipitation change relative to 1995–2014 (%). Scenario: SSP2–4.5 and SSP5–8.5. Region: Western Africa[489].

Period	Scenario	Median	P25| P75	P10 | P90	P5 | P95
Near Term (2021-2040)	SSP2-4.5	7.6 %	3.9| 10.9 %	0.9 | 13.4 %	0.2 |14.8 %
	SSP5-8.5	10.3 %	6.1 | 14.5	2.7 | 16.7 %	0.8 | 18.0 %
Medium Term (2041-2060)	SSP2-4.5	12.3 %	6.4 |16.6 %	3 |18.7 %	1.9 |20.4 %
	SSP5-8.5	18.0 %	9.3 | 24.6	6.4 | 31.0 %	1.5 | 36.7 %
Long Term (2081-2100)	SSP2-4.5	15.3 %	8.4 |21.3 %	5.2 |27.5 %	3.1 | 29.9 %
	SSP5-8.5	35.5 %	19.4 | 44.4	8.4 | 63.9 %	2.0 | 95.5 %

488 World Bank Climate Change Knowledge Portal
489 IPCC Interactive Atlas

- **Conclusions**

From the climate change analysis, we conclude that all three types of floods will become more severe by 2050 and 2100, according to the SSP2–4.5 and the SSP5–8.5 scenarios.

Annual maximum 1-day precipitation is expected to increase between 2% and 20% by 2050 with 90% confidence and between 3 and 30% by 2090 in the SSP2–4.5 scenario, assuming emissions are stabilized. In the SSP5-8.5 scenario, assuming business as usual this increase is between 2% and 37% by 2050 and between 2 and 96% by 2090. This will increase the severity of the flash floods.

Annual maximum 5-day precipitation is expected to change between -1% and 16% by 2050 with 90% confidence and between -2 and 22% by 2090 in the SSP2-4.5 scenario, assuming emissions are stabilized. In the SSP5-8.5 scenario, assuming business as usual this increase is between 0% and 24% by 2050 and between -1% and 50% by 2090. This will increase the severity of the fluvial floods in future climate.

It is shown that the total annual precipitation in the Bagre catchment is increasing with approximately 25% (stabilization of emissions) to 30% (business-as-usual) by 2050 and 15% (stabilization of emissions) to 55% (business-as-usual) by 2090. If the Bagre dam capacity and operations are not changed accordingly, this will increase flood hazards in future climate drastically.

6.4 Conclusions

The following types and/or causes of floods have been identified for the project districts:
- Floods due to spilling of the Bagre dam along the main branches of the White Volta;
- Fluvial floods along the White Volta, Black Volta and Oti and their tributaries;
- Pluvial floods due to severe and heavy rainfall.

All flood types affect farmers and communities in the following ways; crops and livestock are being washed away, roads and houses are being damaged and sometimes people are being washed away or drown. In case of intense precipitation, crops are damaged by the impact of the rain. Finally, agricultural fields close to the river are inundated when water levels increase and result in lost harvest.

6.4.1 Impacts

From the flood effects assessment, focus districts are defined. Overall, East Mamprusi is affected most by floods. For a large part this is because of the size of the district. The number of affected people is highest in East Mamprusi and Yunyoo-Nasuan. Both in terms of absolute numbers, as well as the percentage of the total population that is affected by floods. When looking at agricultural area affected by floods, East Mamprusi is affected most, followed by Binduri, Garu and Yunyoo-Nasuan. The highest number of affected buildings is found in East Mamprusi. Other districts with high numbers of affected buildings are Yunyoo-Nasuan and Lawra. Still, the actual damage depends also on other factors such as building technique, flow velocity and duration of the flood. Lastly, the most km's of affected road are found in Wa West, followed by East Mamprusi. Lawra has a high number of affected road km's as well, but more striking for the size the district has, are the number of affected bridges, which is the same as East Mamprusi (which is way larger).

- **Floods due to spilling of the Bagre dam**

From media reports and observational data of the White Volta and the Bagre dam it is concluded that floods related to spilling of the Bagre are detected to have become more severe in the past decade, even though frequency did not change. This is also confirmed by monthly precipitation in the regions in Burkina Faso in which the Bagre catchment is located: Centre, Centre Sud, Centre Nord and Plateau Central for the past decades.
Climate projections show that the total annual precipitation in the Bagre catchment is increasing with approximately 25% (stabilization of emissions) to 30% (business-as-usual) by 2050 and 15% (stabilization of emissions) to 55% (business-as-usual) by 2090. If the Bagre dam capacity and operations are not changed accordingly, this will increase hazards due to spilling of the Bagre dam in future climate significantly.

- **Fluvial floods**

Communities along tributaries of the White Volta not affected by Bagre spilling also experience fluvial floods, as well as those along the Oti, the Black Volta and their tributaries.
During the field visits, no change in the number or severity of fluvial floods was mentioned by the officers or the farmers. Since fluvial floods are the result of longer durations of heavy rainfall, the annual maximum 5-day precipitation is used as an indicator of fluvial flood.

The annual maximum 5-day precipitation for the Northern, Upper West and Upper East Region in Ghana is presented by the World Bank Climate Change Portal. Due to large annual variations, the detected small trends in this parameter is not statistically significant.
Annual maximum 5-day precipitation is expected to change between -1% and 16% by 2050 with 90% confidence and between -2 and 22% by 2090 in the SSP2–4.5 scenario, assuming emissions are stabilized. In the SSP5–8.5 scenario, assuming business as usual this increase is between 0% and 24% by 2050 and between -1% and 50% by 2090. This will most likely result in an increase in the severity of the fluvial floods in future climate.

- **Pluvial floods**

Pluvial floods, or flash floods, can happen across the districts. The most severe case of pluvial flood referred to by officers were the floods of August 2021, in which main roads were damaged leaving districts inaccessible from the rest of the country. This event aside, no increase in the frequency or intensity of pluvial floods was mentioned by the officers or farmers. This is confirmed by analysis of the annual maximum 1-day precipitation in the Northern, Upper West and Upper East Region in Ghana as presented in the World Bank Climate Change Portal. Due to large annual variations, the detected small trends in these parameters are not statistically significant.

Annual maximum 1-day precipitation is expected to increase between 2% and 20% by 2050 with 90% confidence and between 3 and 30% by 2090 in the SSP2–4.5 scenario, assuming emissions are stabilized. In the SSP5–8.5 scenario, assuming business as usual this increase is between 2% and 37% by 2050 and between 2 and 96% by 2090. This indicates an expected increase the severity of the flash floods in future climate.

- **Floods due to inadequate dam design, operations, or maintenance**

In 2021 the newly constructed Tamne reservoir spilled resulting in a large flood. Better dam operations could likely have prevented this spilling, since no controlled releases were used to maintain some capacity for flood mitigation in the dam.

Besides the large Tamne reservoir, there are various small scale reservoirs or dugouts in the area used for irrigation. These are often poorly constructed, not well maintained, and in some cases damaged by cattle walking on the edges or over the dam to drink water. This results in breaching of those dams, causing floods.

- **Delayed onset of the rain season**

In all districts, the delayed onset of the wet season was mentioned as one of the principal issues. The start of the rain season has shifted from February/March to May/June over the last 40 years. This was confirmed by ERA5 Reanalysis data for the Upper West and Upper East Regions. This delayed onset of the rain season is not a direct cause of floods. However, it results in a shortening of the growing season for rainfed agriculture, which concerns most farmers. This means that the crops, mostly cultivated in floodplains of the rivers, have not fully matured like before when the water levels in the river rise and the fields flood. This results in harvest losses.

7 Barriers to implementing climate change adaptation in northern Ghana

Despite climate change being the focus of several of Ghana's development policies and strategies, barriers still exist that prevent the wide-spread adoption of climate change adaptation technologies and practices in the country. These barriers have constrained the potential, of past and ongoing development initiatives, to elicit a transformational change of the agro-based rural economy of northern Ghana. Therefore, to build the climate-resilience of vulnerable communities sustainably these barriers, and ways to overcome them should be explicitly considered during project design. The most significant barriers to enhancing the climate-resilience of smallholder farmers in northern Ghana are described below.

7.1 Limited institutional and technical capacity for implementing and monitoring climate change adaptation interventions.

Government institutions play an important role in enhancing the adaptive capacity of local communities to climate change by providing mechanisms which shape interactions and coordination among stakeholders[490] and bridging the knowledge gap for the implementation of interventions. Although climate change adaptation features prominently in Ghana's development policies, there is limited institutional capacity within the GoG to strengthen climate-resilience on the ground. This is particularly pertinent at the regional and district levels, where limited coordination and collaboration between sectors of government prevents the effective management of adaptation interventions. While the existence of Regional and District Environmental Management Committees provide the basic structure for regional governance, these committees have limited resources and technical capacity to coordinate adaptation interventions. The basis of this limitation is that government staff are not adequately trained to integrate climate change adaptation into local development planning and to coordinate the implementation of interventions. Furthermore, district extension officers – who serve as the link between institutions and farming communities – lack the technical capacity to facilitate and monitor the implementation of on-the-ground interventions.

In Ghana, climate change adaptation has been integrated into specific policies and strategies (see Section 8) and various development initiatives (see Section 9), at both national and local levels. Such integration is, however, limited at the local level. Because of the limited technical capacity among local-level government staff (described above), district and community development plans frequently do not consider climate change impacts and therefore do not include provisions for the implementation of climate change adaptation. Consequently, districts and communities do not receive support for the design and implementation of locally appropriate climate change adaptation interventions.

The eight District budget plans 2019-2022, 2020-2023; 2021-2024 were reviewed for information relating to income and expenditures and development priorities. The quality of reporting varies between Districts but common to all budget plans were the following:

- All budget plans for the eight District report on problems of under-staffing, lack of transport and office space;
- All District achieve low delivery rates of income received and low ambition;
- Annual achievements are low in number and coverage;
- All report delays in central government fiscal transfers;
- All have a weak analysis of challenges and risks to development planning;
- All aim to reduce impacts of disasters but there is no mainstreaming across sub-programme.

[490] Agrawal A. & Perrin N. 2009. Climate adaptation, local institutions and rural livelihoods. In: Adger W.N., Lorenzoni I. & O'Brien, K.L. (eds.). Adapting to Climate Change: Thresholds, values, Governance. Cambridge University Press: 350–367.

- The quality of how well disaster risk reduction was addressed varies. Four of the eight had a reasonably proactive approach to DRM, three of the eight reflected a very limited plan on DRM and one of the eight recognised the linkages between ecosystem management and disasters.
- Only 1 District reported on CCA and DRM activities in their latest year of achievements.

7.2 Limited geographic extent and population coverage of climate change adaptation projects.

Climate change adaptation projects in northern Ghana have generally been focused within a limited geographic area and target a limited number of target communities. This leads to only a small proportion of smallholder farmers benefitting from project interventions. The geographic extent and upscaling potential of baseline investments is generally restricted because: i) there is limited institutional and technical capacity to implement interventions on a wide scale; ii) infrastructure and resources are largely degraded, limiting district extension officers' access to remote areas; iii) projects have inadequate access to additional funding to expand initiatives, relying mostly on donor funding with limited local investment; iv) interventions are projectised, incorporating limited scope for upscaling; and v) the cost of implementation of initiatives is high. The limited geographic extent and population coverage of these projects restrict the spread of adaptation technologies across the north of Ghana and therefore inhibits transformational change.

7.3 Limited coordination and communication between projects, government and academic institutions.

Climate change adaptation initiatives in Ghana are generally carried out in isolation, with limited coordination between stakeholders to maximise the extent of their impact and share lessons learned. This negatively affects the efficiency and sustainability of project interventions. At the national level, institutions are ill-equipped to facilitate the coordination between adaptation initiatives and encourage collaboration to catalyse the upscaling of interventions. Without such communication and coordination between stakeholders, climate change adaptation initiatives in Ghana will likely continue to operate in isolation, not benefiting from the collective knowledge of those that are ongoing or completed.

7.4 Inadequate knowledge of climate-resilient agricultural practices and EbA interventions by local communities and extension officers.

Smallholder farming communities in northern Ghana are generally unaware of current and future climate change-related risks and are therefore unable to adapt appropriately. The adoption of climate change adaptation technologies has been identified as one of four main agricultural adaptation pathways[491] to building climate resilience and is, therefore, necessary to ensure the climate-resilience of rural smallholder farmers in northern Ghana. Such technologies can include *inter alia*: i) new climate-resilient crop varieties; ii) early warning systems; iii) climate-resilient irrigation systems; iv) agricultural inputs – including fertilisers and pesticides; and v) a variety of other EbA and CRA interventions. However, many smallholder farmers in northern Ghana are unaware of the suite of climate change adaptation technologies available to them.

District extension officers – who serve as the link between institutions and farming communities – lack the technical capacity to facilitate and monitor the implementation of on-the-ground interventions. There are often too few extension officers to adequately cover a district, limiting their ability to effectively interact with and transfer information to the

[491] Smit B & Skinner MW. 2002. Adaptation options in agriculture to climate change: a typology. Mitigation and Adaptation Strategies for Global Change. 7(1): 85–114.

communities they serve. Consequently, the transfer of knowledge and training on project interventions that should be facilitated by district agricultural extension officers does not reach all vulnerable populations.

7.5 Limited access to financial resources (including access to loan finance) to finance adaption interventions.

Poverty is limiting agricultural production in northern Ghana by hindering farmers from adopting more efficient but costly farming technologies and practices such as irrigation, mechanised tilling, fertiliser application, use of resistant varieties, as well as proper planting and harvesting times. These practices are needed to increase agricultural yields and improve food security[492]. Smallholder farmers in northern Ghana use low technology equipment such as hoes, and more rarely, bullock ploughs because they cannot afford more expensive machinery such as tractors[493,494]. High costs of agricultural inputs accentuate the negative effect of poverty on the ability of smallholder farmers to adopt modern technologies and practices[495]. Agro-input marketing in northern Ghana is rudimentary, and farmer-based organisations are weak and therefore unable to acquire fertiliser and other inputs in bulk to reduce cost.

Smallholder farmers in northern Ghana have insufficient access to credit for financing adoption and application of modern agricultural technologies[496,497]. Commercial banks, private partners and micro-finance institutions are often not ready to provide loans because smallholder farmers in northern Ghana: i) generally have limited financial knowledge; ii) have limited credit history; iii) lack collateral[498]; and iv) rely on unpredictable rain-fed agriculture for their income, which means that loans are deemed high-risk [499,500]. Furthermore, many smallholder farmers in northern Ghana are unable to contract loans because they have defaulted on the repayment of loans contracted from banks in the past[501]. Studies have shown that smallholder farmers in northern Ghana can increase their income by ~17% by taking out credit for financing land preparation and the purchase of planting materials as well as other farm inputs at the start of the farming season[502,503].

Insufficient access to agricultural insurance limits agricultural production in northern Ghana by causing smallholder farmers to continuously sell productive assets such as livestock, poultry and land to overcome shortfalls related to extreme events such as floods[504,505]. Most smallholder farmers sell these assets to buy food — primarily grains and cereals[506,507]. However, ~80% of smallholder farmers in northern Ghana fail to restock the key productive

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[492] Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
[493] Schraven B. 2010. Irrigate or migrate? Local livelihood adaptation in Northern Ghana in response to ecological changes and economic challenges. *Unpublished PhD thesis, ZEF: University of Bonn*.
[494] Ibid.
[495] Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
[496] Darko E, Atazona L (eds). 2013. *Literature review of the impact of climate change on economic development in northern Ghana. Opportunities and activities*. Overseas Development Institute.
[497] Wossen T, Berger T. 2015. Climate variability, food security and poverty: Agent-based assessment of policy options for farm households in Northern Ghana. *Environmental Science & Policy* 47: 95–107.
[498] Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
[499] Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
[500] Antwi-Agyei P. 2012. Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability. DPhil, University of Leeds, Leeds.
[501] Ibid.
[502] Ibid.
[503] Wossen T, Berger T. 2015. Climate variability, food security and poverty: Agent-based assessment of policy options for farm households in Northern Ghana. *Environmental Science & Policy* 47: 95–107.
[504] Aniah P, Kaunza-Nu-Dem M, Ayembilla JA. 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. *Heliyon* 5: 1-25.
[505] Ibid.
[506] Ibid.
[507] Ibid.

assets they have sold after the extreme event is over[508]. In these situations, continuously selling off productive assets results in a dwindling of tangible productive assets, endangering future food production and availability[509].

[508] Ibid.
[509] Ibid.

8 Project Strategy

Problem statement

Climate change will have substantial impacts on the livelihoods of smallholder farmers in northern Ghana (Section 5). Decreased wet season length, increased rainfall intensity, increased temperatures and increased frequency of floods and droughts, among other effects, are expected to reduce already suboptimal crop yields, subsequently decreasing the food security and income generation of the country's most vulnerable people. These negative impacts will be compounded by – and further enhance – severe environmental degradation resulting from *inter alia* rapid population growth, a dependence on natural resources and the use of unsustainable agricultural techniques. Without effective adaptation action, it is likely that northern smallholder farmers will remain vulnerable to the current and future effects of climate change, with serious repercussions for the northern Ghanaian economy.

Adaptation response

An effective adaptation response needs to overcome the current barriers (Section 6) to implementing climate change adaptation interventions in northern Ghana. This will be achieved in the following ways.

- Barrier 1 will be addressed by strengthening the technical and institutional capacity of regional and district government structures in northern Ghana to plan, budget, implement and monitor climate change adaptation interventions. The policy work will take place in year 4-5 of the project, once results can be harvested and used for planning purposes. The EPA will execute this output, based on experience gathered in the execution of the country's National Adaptation Planning process, due to be completed in 2025. The activities to be funded to address barriers related to institutional and technical capacity This will include i) training for extension officers on climate-resilient agriculture and EbA to strengthen their capacity to facilitate the implementation of climate change adaptation interventions; and ii) equipping relevant regional and district structures with the means to monitor climate change adaptation interventions. In addition, the project will facilitate the integration of climate change adaptation into regional and district development plans, thereby providing government with the institutional frameworks to continue implementing climate change adaptation interventions beyond the lifespan of the project.
- Training on climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods will be provided to extension officers and local communities thereby addressing Barrier 2. Secondly, extension officers and local communities will implement these climate change adaptation interventions, allowing them to gain practical knowledge of these practices. Thirdly, training materials and knowledge products capturing best practice and lessons learned including those related to use of fire by communities from other initiatives such as the SLWMP, AF and IFAD projects whose terminal evaluation were due in the first half of 2021 and through the project will be disseminated, allowing knowledge of climate change adaptation to be shared with institutions and individuals who were not directly involved in project implementation. Finally, the project will conduct community-level knowledge-sharing and awareness-raising events for both beneficiary and non-beneficiary communities in northern Ghana. By increasing the knowledge of climate change adaptation in non-beneficiary communities, these events will promote the autonomous upscaling of climate change interventions promoted by the project.

  Barrier 2, will be addressed by convening of knowledge-sharing conferences (Activity 1.4) annually with participants from: i) district-level government staff[510]; ii) regional-level

[510] E.g. extension officers, representatives from District Assemblies and DEMCs.

government staff[511]; iii) national-level government staff[512]; iv) climate change adaptation project and programme managers; v) representatives of academic and research institutions; vi) NGO staff; vii) representatives of multilateral development agencies; and viii) project beneficiaries. These conferences will promote information sharing and encourage coordination between current and future climate change adaptation projects/programmes. A robust monitoring and evaluation strategy will be put into place. The PPFA will further develop the activity plan related to economic valuation of ecosystems and how that can be pulled into decision at the regional administration and District Assembly planning and budgeting processes.

- The project will contribute to overcoming barrier 3 by increasing the capacity of the most vulnerable smallholder farmers to form FBOs, strengthening financial management capacity, links to value chains being developed in parallel thereby facilitating linkages to manage finances, and thereafter access agricultural credit and insurance. In addition, through the implementation of climate-resilient agricultural practices, smallholder farmers will generate more consistent income, allowing them to finance adaptation interventions once the project has finished.

Together, the above-mentioned interventions overcome the barriers to climate change adaptation in northern Ghana, thereby contributing to a paradigm shift within the agricultural sector towards climate-resilient sustainable development.

In addition to overcoming the barriers to implementation, the climate change adaptation interventions proposed in this project need to: i) target the impact pathways described above (Section 5.2); and ii) contribute to overcoming the baseline causes (Section 3) of poverty and environmental degradation.

Based on a review of past and ongoing projects in Ghana (Section 9), best practice and lessons learned have been extracted (Section 10) and a set of recommendations for the design and implementation of climate change adaptation projects has been generated (Section 10). These recommended approaches to adapting to climate change are detailed in Table 29, along with the specific climate change impact pathways that they overcome.

[511] E.g. staff from regional EPA offices, Regional Department of Agriculture office and REMCs.
[512] E.g. staff from the MESTI, MoFA, EPA, Ministry of Local Government, MoF and the NDA.

Table 29. Description of recommended climate change adaptation interventions and the climate change impact pathways that they disrupt

Climate change adaptation Intervention	Climate change impacts addressed	Description	Impact pathway/s disrupted
Ecosystem-based adaptation interventions			
Agroforestry	• Increased frequency and severity of floods • Reduced crop and livestock production • Reduced length of the agricultural growing season • Increased soil erosion	• Trees used in agroforestry reduce the impact of intense rainfall, increasing infiltration and reducing soil erosion. This will lessen the impacts of flooding on crops. • Leaf litter from trees provides natural mulching functions, increasing soil moisture and nutrient content. This will improve crop yields. • Increased soil moisture content, combined with microclimate regulation, from agroforestry will allow farmers to grow crops over a longer period. • Tree roots secure the soil, further restricting erosion.	IPs 1, 2, 4, 8 & 9.
Small-scale communal fodder banks	• Reduced length of the agricultural growing season • Reduced crop and livestock production • Increased drought frequency and intensity • Increased soil erosion	• The reduced length of the agricultural growing season, combined with more frequent and intense drought, will reduce fodder availability for livestock during the dry season. Fodder banks supplement the diet of livestock during the dry season, resulting in reduced losses. • Nutrient-rich plants used in fodder bank reduce the impact of intense rainfall, increasing infiltration and reducing soil erosion. Plant roots also secure the soil, further restricting erosion.	IPs 1, 2, 6 & 9
Riverbank restoration	• Increased frequency and severity of floods • Reduced crop and livestock production • Increased soil erosion	• Restoring riparian vegetation will reduce the effect of intense rainfall and flooding on the riverbanks and surrounding fields. • Increased flood protection will reduce crop losses, while the restored vegetation will provide fodder for livestock. • Restoring riparian vegetation with indigenous species will bind soil and reduce erosion.	IPs 1, 2, 3 & 4
Fire management	• Increased frequency and severity of bushfires	• High wet season rainfall would result in the enhanced build-up of biomass in agro-ecological systems which will persist into the dry season. The effects of: i) high temperatures; ii) evapotranspiration; and iii) dry conditions, along with this abundant fuel load, will result in bush fires becoming more frequent and severe. These fires pose a threat to the livelihoods of smallholder farmers who rely on natural resources for their livelihood. Effective fire management is therefore necessary to control the effects of these fires and limit damage to crops and property.	IP 11
Climate-resilient agriculture interventions			
Crop rotation and intercropping	• Reduced crop and livestock production • Increased soil erosion	• Increased temperatures – that may push certain crops beyond their thermal limits – combined with more frequent extreme events will reduce agricultural yields. By growing a variety of crops with different temperature	IPs 1, 4, 5, 6, 8, 9 & 10

	• Increased weeds, pests and post-harvest losses	and inundation limits, farmers can reduce the risk of losing their entire harvest during an extreme event. • The effects of climate change – including more intense rainfall over a shorter period – will compound the problem of soil erosion in northern Ghana, leading to reduced soil moisture and the leaching of nutrients from the soil. This will lead to a decrease in crop yields and an increase in the need for agricultural inputs – for example, fertilisers. Crop rotation and intercropping will reduce runoff and improve infiltration, thereby reducing the impact of climate change on soil erosion. • By diversifying crops and staggering harvest times, crop rotation and intercropping can reduce the need for long-term post-harvest storage and reduce the impact of crop-specific pests and diseases. Furthermore, crop rotations can break the pest/disease cycle over time.	
Slash and mulching	• Increased drought frequency and intensity • Increased soil erosion	• A reduction in soil water content and the lowering of groundwater levels in northern Ghana – as a result of increased potential evapotranspiration and more frequent droughts – will decrease crop production as less water will be available for crop growth. Slash and mulching will increase water infiltration and reduce evaporation, thereby improving soil moisture, disrupting this climate change impact pathway. • Slash and mulching dissipates the energy of rainfall, improving infiltration and reducing runoff. Consequently, soil moisture and nutrient availability will be increased, thereby reducing the impact of climate change on soil erosion.	IPs 1 & 7
Contour bunding	• Increased drought frequency and intensity • Reduced length of the agricultural growing season • Increased soil erosion	• By increasing infiltration, contour bunds improve soil moisture, thereby countering the climate change impacts of increasing temperatures and potential evapotranspiration. Increased soil moisture content also allows for smallholder farmers to grow crops for a longer period. • Contour bunding reduces on- and near-field runoff velocity, thereby: i) decreasing soil and nutrient loss; ii) increasing the drainage of water into the soil; and iii) decreasing the formation of damaging geomorphic features such as rills and gullies. This disrupts the climate change impact of increased soil erosion.	IPs 1 & 7
Vegetative barriers	• Increased drought frequency and intensity • Increased soil erosion	• By increasing infiltration, vegetative barriers improve soil moisture, thereby countering the climate change impacts of increasing temperatures and potential evapotranspiration. • Vegetative barriers reduce runoff velocity, improve infiltration and decrease the formation of damaging geomorphic features such as rills and gullies, disrupting the climate change impact of increased soil erosion.	IPs 1 & 7

Ridging	• Increased drought frequency and intensity • Increased soil erosion	• Tied ridging is effective in retaining on-field water and increasing soil water content during dry conditions, reducing the impact of extended dry periods resulting from climate change. • Ridging allows for the controlled drainage of excess water, reducing the effect of water-logging and erosion associated with heavy rainfall events.	IPs 1 & 7
Organic composting and zai pits	• Reduced crop and livestock production • Increased drought frequency and intensity • Increased soil erosion	• Zai pits reduce surface runoff, thereby improving water retention and infiltration. This, combined with increased soil nutrients, will increase agricultural yields, even during dry periods. • Organic composting increases soil nutrients, countering the effect of nutrient loss from increased soil erosion.	IPs 1 & 7
Cover cropping	• Reduced crop and livestock production • Increased soil erosion • Increased weeds, pests and post-harvest losses	• Cover cropping shades the soil surface, reducing soil temperatures and helping retain soil moisture. Improved infiltration also increases soil moisture, countering the climate change impacts of increased temperatures and evapotranspiration. • Cover cropping creates a protective barrier over exposed soils, dissipating the energy during intense rainfall events, consequently reducing soil erosion and increasing infiltration. Furthermore, residues from cover crops maintain soil quality by replacing nutrients in soils which have been leached by surface runoff and erosion. • A dense mat of cover competes strongly with weeds that grow as a result of increased rainfall. The consequent reduction in weeds improves crop yields.	IPs 1, 5, 7 & 9
Climate-resilient seed varieties	• Increased flood frequency and severity • Increased drought frequency and intensity • Reduced length of the agricultural growing season • Reduced crop and livestock production	• Flood-resilient seed varieties are adapted to flood pressures resulting from intensified rainfall events. • Drought-resilient seed varieties are adapted to cope with prolonged dry seasons resulting from climate change. • Seed varieties with shorter growing cycles will allow farmers to complete the harvest despite a reduction in the length of the agricultural growing season. • Heat stress-resilient seed varieties are adapted to higher temperatures, allowing for increased productivity and reduced crop losses during heat waves.	IPs 3, 6, 7, 8, & 10
Dry season gardening	• Reduced length of the agricultural growing season	• A shortened agricultural production period because of a shorter wet season will decrease crop yields and incomes as the number of achievable cropping cycles within a growing season will be reduced. Dry season gardening allows for additional production to supplement food and income supply during the prolonged dry season.	IPs 5, 6 and 9
Climate-resilient post-harvest management			

Post-harvest storage devices	• Increased flood frequency and severity • Increased weeds, pests and post-harvest losses	• Improved post-harvest storage methods will reduce the impact of and damage caused by intense rainfall and flooding on post-harvest storage facilities and infrastructure. • Increased humidity, moisture migration and condensation caused by flooding leads to rotting of harvested crops. Improved post-harvest storage devices will reduce the likelihood of flood-induced fungal growth and spoilage during storage and drying. • Post-harvest storage devices reduce loss of grain caused by increasing temperatures which result in increased insect activity, fungal growth and rodent pest infestation.	IPs 3, 4, 5 & 9
Alternative climate-resilient livelihoods			
Shea butter production	• Reduced crop and livestock production • Increased soil erosion	• Shea butter production will provide alternative livelihoods and additional sources of income during periods where climate change impacts, such as floods and droughts, affects supply and production of other crops. • Trees used for shea butter production reduce the impact of intense rainfall, increasing infiltration and reducing soil erosion.	IPs 3, 4, 5, 6, 7 & 8
Small ruminant rearing	• Reduced crop and livestock production • Increased drought frequency and intensity	• Small ruminant rearing will provide alternative livelihoods and additional sources of income to farmers, reducing the negative impact of climate change-induced crop failure on their food and income security. • Small ruminants are well adapted to the arid conditions and are more tolerant to drought conditions than other livestock, therefore can reduce the negative impacts of dry seasons on livestock farming.	IPs 5, 6, 7 & 8
Climate-resilient water infrastructure investments			
Boreholes and check dams	• Reduced crop and livestock production • Reduced length of the agricultural growing season • Reduced water availability • Reduced water quality	• A shortened agricultural production period because of a shorter wet season and insufficient water supply will decrease crop yields and incomes. Boreholes and check dams allow smallholder farmers to irrigate their crops, thereby allowing production to continue during the prolonged dry season to provide farmers with food and income security throughout the year. • Boreholes and weirs can support livelihood activities such as dry-season gardening and small ruminant rearing to counter the impacts of prolonged climate change-induced dry periods. • Decreasing wet season length coupled with rising temperatures will increase the frequency of the drying-up of surface water bodies such as dams and streams resulting in reduced water availability. Furthermore, increased flooding and erosion will reduce the quality of the water that is available. Boreholes and check dams will provide communities with improved access to quality water.	IPS 6, 7 & 10

Overall. The climate change adaptation interventions focus on introducing:

- EbA interventions that maintain and enhance the supply of ecosystems goods and services to beneficiary communities;
- climate-resilient agricultural practices to maintain or enhance agricultural production under changing climatic conditions;
- climate-resilient post-harvest management to reduce losses from climate change impacts;
- alternative climate-resilient livelihoods that enhance and diversify income generation – targeted particularly at women; and
- climate-resilient water infrastructure that enhances water security and agricultural production under changing climatic conditions.

To reduce the vulnerability of smallholder farmers in northern Ghana to climate change, the project should implement a range of interventions drawn from the table above in selected beneficiary communities in northern Ghana (see Section 10: Recommendations for details on the selection of communities). Beneficiary communities should select interventions from this menu of interventions that: i) address the most urgent climate change impacts in their community; ii) are appropriate to their unique geographic and ecological contexts (for instance proximity to a river and/or availability of surface water resources).

9 National policies and strategies

9.1 Introduction

National policies and strategies provide an important platform for the management and regulation of development in a country. Ghana recognises the potential impact of climate change on multiple sectors of its economy and has therefore implemented several policies and strategies dealing directly with climate change and adaptation. Moreover, several other policies are in place which direct the country's approach to environmental challenges and should be considered in the implementation of climate change adaptation interventions. These policies and strategies are detailed below.

9.2 Ghana National Climate Change Policy (NCCP, 2015–2020)[513]

The National Climate Change Policy (NCCP) is Ghana's primary climate change policy. This policy has been prepared and designed within the context of national sustainable development priorities. It provides a clearly defined pathway for dealing with the challenges of climate change within the current socio-economic context of Ghana and looks ahead to the opportunities and benefits of a green economy.

The NCCP's response to climate change comprises three phases.

i) Phase one involves the presentation of the policy, analyses of the current situation and the broad policy vision and objectives.
ii) Phase two presents in greater detail the initiatives and programmes identified in the NCCP in the form of an Action Programme for implementation.
iii) Phase three details how climate change programmes and actions identified in phase two can be integrated, in a time-bound and budgeted manner, into annual work plans of implementing units.

GoG recognises that climate change must be included in policies and sectoral activities to achieve sustainable growth. As such, the vision outlined in the NCCP is: "To ensure a climate-resilient and -compatible economy while achieving sustainable development through equitable low-carbon economic growth for Ghana". This vision conforms with existing national policies and statutes.

The objectives of the NCCP are: i) low carbon growth; ii) social development; and iii) effective adaptation to climate change. To achieve these objectives, seven pillars have been included in the policy: i) governance and coordination; ii) capacity building; iii) science, technology and innovation; iv) finance; v) international cooperation; vi) information, communication and education; and vii) monitoring and reporting. Moreover, four thematic areas have been identified to address adaptation challenges. These include: i) energy and infrastructure; ii) natural resources management; iii) agriculture and food security; and iv) disaster preparedness and response.

NCCP is implemented by the Ministry of Environment, Science, Technology and Innovation (MESTI), which is also responsible for the national environment portfolio. MESTI operates through several agencies to research and promote awareness regarding climate change. Broad action areas have been identified to guide the implementation of the policy at the sectoral and decentralised levels. The action areas for the agriculture and food security sector include:

- strengthening of institutional capacity for research and development;

[513] Ministry of Environment, Science and Technology (MEST), Republic of Ghana. 2014. Ghana National Climate Change Policy. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/NEWS/2015/07/22//Ghana+Climate+Change+Policy.pdf

- developing and promoting climate-resilient cropping systems;
- adapting livestock production systems;
- supporting climate adaptation in fisheries and aquaculture;
- supporting water conservation and irrigation systems;
- transferring risk, and alternative livelihood systems;
- improving post-harvest management; and
- improving marketing systems.

Five main policy sectors have been prioritised by the NCCP: i) Agriculture and Food security; ii) Disaster Preparedness and Response; iii) Natural Resource Management; iv) Equitable Social Development; and v) Energy, Industrial and Infrastructural Development. These policy areas have been subdivided into ten programme areas that address the critical issues of climate change in Ghana. The ten programme areas will include *inter alia*:

- developing climate-resilient agriculture and food security systems;
- building climate-resilient infrastructure;
- increasing the resilience of vulnerable communities to climate-related risks;
- improving management and resilience of ecosystems;
- minimising impacts of climate change on access to water; and
- addressing gender issues in climate change.

Overall, the abovementioned programme areas will: i) improve food security; ii) increase the resilience of infrastructure and communities to climate change; iii) improve environmental and ecosystem management practices to increase biodiversity and carbon sequestration; iv) optimise important socioeconomic factors; and v) contribute to the formation of more efficient systems for improved economic growth. Programmes with relevance to the proposed project are outlined in **Table 30** below.

Table 30. Climate change programmes with relevance to the proposed project.

Programme Area	Focus Area	Principles	Objectives
Agriculture and Food Security	• Develop climate-resilient agriculture and food systems.	• The understanding that sustainability of natural resources — including land, forests, water and genetic biodiversity — is significantly influenced by agricultural practices. • The need for sustainable agricultural systems as a fundamental basis for achieving national food security and poverty reduction.	• Develop climate-resilient agriculture and food systems for all agro-ecological zones. • Develop human resource capacity for climate-resilient agriculture.
Disaster Preparedness and Response	• Build climate-resilient infrastructure.	• The development of infrastructure and associated facilities has a direct influence on sustainable	• Improve the understanding of how appropriate infrastructure can reduce vulnerability to climate-related events.

	Increase resilience of vulnerable communities to climate-related risks.	development in Ghana. • Incorporating climate-resilient standards into the construction of basic infrastructure will significantly reduce the vulnerability of Ghana to climate change hazards. • The access of an individual or community to physical or social assets and resources gives a fair representation of their vulnerability to climate change. • The vulnerability of groups to climate change is not uniform throughout the country because of varying physical, socioeconomic and technical characteristics. Consequently, resilience measures differ accordingly.	• Establish various measures to protect livelihoods and assets of vulnerable communities from climate-related hazards. • Build local capacities to reduce risk and vulnerability.
Natural Resource Management	• Improve management and resilience of terrestrial and aquatic ecosystems.	• The recognition that climate change will intensify poverty and environmental degradation. • The need to maintain integrity of terrestrial, aquatic and marine ecosystems, recognising their value in the provision of ecosystem services.	• Ensure effective management and conservation of terrestrial and aquatic ecosystems by appropriate agencies. This will improve the resilience of these ecosystems to climate change.

9.3 Ghana National Climate Change Adaptation Strategy (NCCAS, 2012)[514]

Ghana's NCCAS promotes a consistent, comprehensive and targeted approach to increasing climate resilience and decreasing the vulnerability of local communities. The goal of the strategy is to enhance Ghana's current and future development by strengthening its adaptive capacity and building the resilience of communities and ecosystems to the impacts of climate change.

Adaptation objectives are outlined for nine development sectors, including: i) livelihoods; ii) energy; iii) agriculture; iv) health; v) early warning; vi) fisheries management; vii) land use; and viii) water. A cross-sectoral approach was then applied to arrive at a selection of ten national priority adaptation programmes that can be applied across the various climate-vulnerable sectors. These priority adaptation programmes are:

- Increasing resilience to climate change impacts — identifying and enhancing early warning systems.
- Alternative livelihoods — minimising impacts of climate change on the poor and vulnerable.
- Enhance national capacity to adapt to climate change through improved land-use management.
- Adapting to climate change through enhanced research and awareness-raising.
- Development and implementation of environmental sanitation strategies to adapt to climate change.
- Managing water resources as an approach to climate change adaptation, to enhance productivity and livelihoods.
- Minimising climate change impacts on socio-economic development through agricultural diversification.
- Minimising climate change impacts on human health through improved access to healthcare.
- Demand- and supply-side measures for adapting the national energy system to impacts of climate change.
- Adaptation to climate change — sustaining livelihoods through enhanced fisheries resource management.

The implementation of the NCCAS will form part of the decentralised planning and implementation system. Ministries, Departments and Agencies (MDAs) at the national level are responsible for policy, planning, monitoring and evaluation of development programmes, with MESTI being the supervisory agency. The execution of adaptation programmes is undertaken at the sub-national level, specifically by government agencies and district assemblies.

9.4 Ghana's Nationally Determined Contributions (INDC, 2020-2030)[515]

Ghana's NDCs put forward action plans for both climate change mitigation and adaptation to align with the country's medium-term development agenda. Through the INDCs, Ghana commits to 11 adaptation programmes of action in seven priority economic sectors listed below.

- Sustainable land use including food security;
- Climate-proof infrastructure;
- Equitable social development;

[514] UN Environment and UNDP. 2012. National Climate Change Adaptation Strategy. CC DARE. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/PUBLICATIONS/2016/04/16/Ghana_national_climate_change_adaptation_strategy_nccas.pdf
[515] Government of Ghana. 2015. Ghana's intended nationally determined contribution (INDC) and accompanying explanatory note. UNFCCC. Available at: http://www4.unfccc.int/ndcregistry/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf

- Sustainable mass transportation;
- Sustainable energy security;
- Sustainable forest management; and
- Alternative urban waste management.

These programmes of action will be the strategic focus of a "10-year post-2020 enhanced climate action plan" currently under development. The long-term adaptation goal set out in the INDC is to increase climate resilience and decrease vulnerability for enhanced sustainable development. **Table 31** outlines the priority adaptation plans that will be implemented to achieve this goal.

Table 31. Priority adaptation policy actions to be implemented to achieve Ghana's INDC adaptation goal.

Sector	Strategic Area	INDC Policy Actions	Number of Programmes of Action
Agriculture and food security	Sustainable land use	Agriculture resilience building in climate vulnerable landscapes	3
Sustainable forest resource management		Value addition-based utilisation of forest resources	2
Resilient infrastructure in built environment	Climate resilient strategic infrastructure	City-wide resilient infrastructure planning	1
		Early warning and disaster prevention	1
Climate change and health	Equitable social development	Managing climate-induced health risk	2
Water resources		Integrated water resources management	1
Gender and the vulnerable		Resilience for Gender and the Vulnerable	1

The 2018 NDC agriculture chapter is centred around three main agricultural priorities: conservation agriculture, climate smart technologies to increase fisheries and livestock productivity; post-harvest management and food processing. Complementary actions on water conservation and irrigation development, agroforestry are highlighted as needing government attention.

9.5 National Climate-resilient Agriculture and Food Security Action Plan (2016-2020)[516]

This Action Plan provides the implementation framework for the effective development of climate-resilient agriculture (CRA) and food production strategies for all agro-ecological zones in Ghana. Moreover, the framework formulates specific strategies for building the human resource capacity required for effective promotion and implementation of CRA. The objective of the Action Plan is to facilitate the NCCP in effectively integrating climate change considerations into the development policies and programmes of the food and agricultural sectors. The specific aims of the Action Plan are to:

- develop climate-resilient agriculture and food systems for all agro-ecological zones;
- develop human resource capacity for climate-resilient agriculture; and
- elaborate on the implementation framework and the specific climate-resilient agriculture activities to be carried out at the respective levels of governance.

[516] Essebey G.O, Nutsukpo D, Karbo N, and Zougmore R. 2015. National Climate-resilient Agriculture and Food Security Action Plan of Ghana (2016-2020). Working Paper 139. Copenhagen, Denmark: CGAIR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: www.ccafs.cgair.org

The Ministry of Food and Agriculture (MOFA) is responsible for the implementation of the Action Plan, with the Environment and Climate Change Unit (ECCU) having direct responsibility for the dissemination, capacity building and coordination of the implementation. The ECCU will work in collaboration with the Ministerial Climate Change Task Force to ensure that relevant activities are integrated into the annual work-plans and budgets for all national Directorates of MoFA. At a decentralised level, the Departments of Agriculture of the Metropolitan, Municipal and District Assemblies will be responsible for the implementation of on-the-ground activities. At the community level, farmers and farmer groups will be responsible for the implementation of activities on their management units.

9.6 The National Environment Policy (NEP, 2014)[517]

The National Environment Policy (NEP) seeks to redirect development towards more environmentally sustainable practices. The primary objective of the NEP is to improve the environment, living conditions and quality of life for all of Ghana's citizens. To achieve this, the NEP aims to reconcile economic development with conservation and promote the sustainable use and maintenance of Ghana's natural resources. In addition, the policy aims to maintain ecosystem function, preserve biodiversity and integrate environmental considerations into socio-economic planning at the national, regional, district and community levels. The NEP, therefore, commits the government to take account of national environmental priorities with sufficient attention to long-term sustainability. GoG also bears accountability for policy formulation, project implementation, monitoring compliance, capacity building, education and environmental enforcement.

Implementation of the NEP is primarily the responsibility of the EPA under the MESTI, with responsibilities assigned to separate institutions for environmental and natural resource development and management activities. The NEP highlights Ghana's vulnerability to climate change and supports a comprehensive approach to environmentally sustainable management.

9.7 Ghana Shared Growth and Development Agenda II (2014–2017)[518]

Ghana Shared Growth and Development Agenda (GSGDA) II explicitly states the centrality of climate change in development planning. It articulates the development agenda revolving around the climate change issues concerning, among other things, agriculture and food security.

In the medium-term, the focus of GSGDA II interventions will be prioritised in favour of the following focus areas: i) natural resource management and minerals extraction; ii) biodiversity management; iii) protected areas management; iv) land management and restoration of degraded forest; v) integrated marine and coastal management; vi) wetlands and water resources management; vii) waste management, pollution and noise reduction; viii) community participation in natural resource management; ix) climate variability and change; and x) natural disasters, risks and vulnerability.

The focus of agriculture development strategy under GSGDA I (2010-2013) was to accelerate the modernisation of agriculture. This would contribute significantly to the structural transformation of the economy through an effective linkage between agriculture and industry, which would result in: i) increased job creation; ii) higher export earnings; iii) strengthened food security; and iv) a constant supply of raw materials. A major objective of the agriculture

[517] CGIAR Research Program on Climate Change, Agriculture and Food Secuirty (CCAFS). 2016. National Climate-resilient Agriculture and Food Security Action Plan of Ghana (2016–2020). Available at: https://ccafs.cgiar.org/publications/national-climate-resilient-agriculture-and-food-security-action-plan-ghana-2016-2020#.WOdIndKGOM8
[518] National Development Planning Commission (NDPC). 2014. Ghana Shared Growth and Development Agenda (GSGDA) II, 2014–2017. Available at: https://s3.amazonaws.com/ndpc-static/pubication/GSGDA+II+2014-2017.pdf

modernisation strategy under GSGDA I was to reduce the risks associated with agricultural production through improved access to farming technologies, inputs and extension services, increased area under irrigation, increased access to credit, and a significant reduction in post-harvest losses.

To strengthen the Ghanaian agricultural sector, GSGDA II will promote the integration of research and technology into all aspects of agriculture. The specific interventions to be implemented include: i) strengthening Research- Extension-Farmer Linkages (RELCs); ii) integrating the concept of extension services into the agricultural research system to increase the participation of end-users in technology development; and iii) strengthening coordination and collaboration between research institutions, locally and abroad to improve cost-effectiveness of research. The GoG will increase funding for agricultural research by creating incentives for the private sector to participate in such research, as well as in the dissemination of its outcomes. In the medium term, CSGDA initiatives will minimise post-harvest losses as well as establish the appropriate sub-structures and links for the accelerated take-off of agro-industrialisation.

GSGDA II will ensure the development of private sector-led extension services, while also supporting the private sector delivery of agricultural services to enhance productivity and quality control. Strategies aimed at promoting seed development for improved yields will include: i) developing and introducing climate-resilient and high-yielding crop varieties; ii) supporting the production of certified seeds; and iii) supplying improved planting equipment.

Building the capacity of smallholder farmers is critical for improving agricultural productivity. The conventional way of achieving this — through the provision of extension services — has not been effective because of resource and capacity constraints. In the medium term, policies to be implemented by GSGDA will have the objective of expanding the nucleus scheme, where small farmers are attached to a nucleus farm, and/or an agricultural estate. The nucleus farms will identify and test seed varieties, develop growing techniques and provide extension, mechanisation and marketing services to the smallholder farmers. Moreover, smallholder farmers will access inputs and credit from the nucleus farms. The nucleus farmers will ensure that good agricultural practices (GAPs) are adopted and standards enforced. This is expected to lead to an increase in output and product quality for the smallholder farmers.

9.8 National Action Programme to Combat Drought and Desertification[519]

The NAP-CCD was formulated to combat drought and desertification in areas of Ghana prone to these climate impacts — including the Upper East, Upper West, Northern, certain parts of Brong Ahafo, Ashanti, Central, Greater-Accra and Volta Regions. NAP-CCD's objective is to emphasise local development programmes for drought-prone, semi-arid and arid areas that are environmentally sound and sustainably integrated. This is based on participatory mechanisms and integration of strategies for poverty alleviation and other sector programmes — including forestry, agriculture, health, industry and water supply — into efforts to combat the effects of drought.

Implemented by the EPA, a major challenge of the programme is promoting CRA by eliminating all practices which contribute to deforestation and desertification, especially bush burning. NAP-CCD provides an important framework for addressing this challenge. The agroecological focus of the document — mainly the Savanna regions of the Northern regions and the Accra plains as well as the transitional zones of the mid-belt — also underscores the importance of NAP-CCD as a policy document for promoting CRA.

[519] Environmental Protection Agency. 2002. National Action Programme to Combat Drought and Desertification. Available at: http://www.unccd.int/ActionProgrammes/ghana-eng2002.pdf

9.9 Ghana Food and Agriculture Sector Development Policy (FASDEP II, 2007)[520]

FASDEP II guides development and interventions to modernise the agricultural sector culminating in a structurally transformed economy in Ghana. The objectives of FASDEP II are: i) food security and emergency preparedness; ii) improved growth in incomes; iii) increased competitiveness and enhanced integration into domestic and international markets; iv) sustainable management of land and environment; v) applied science and technology in food and agriculture development; and vi) improved institutional coordination.

The MoFA has the primary responsibility for implementation of FASDEP II within the context of a coordinated government program. A Medium-Term Agriculture Sector Investment Plan (METASIP) was adopted in 2010 as the strategic tool for implementing FASDEP II over five years (2011–2015). However, all government agencies have important roles to play in its implementation to ensure its success. Additionally, the roles of the private sector, civil society organisations, development partners and other MDAs in implementation are outlined in the policy document. At the district level, a framework for the coordination of activities of MDAs is outlined in district plans, overseen by the MoFA. The emphasis of FASDEP II on environmental sustainability provides a connection with the NCCP to ensure a logical and coordinated approach to adaptation.

9.10 The Ghana Strategic Investment Framework for Sustainable Land Management (GSIF 2011–2025)[521]

GSIF is a programmatic approach to address land-degradation issues and promote sustainable land management. The goal of GSIF is to support country priorities in improving natural resource-based livelihoods by decreasing land degradation. The objectives of GSIF are to: i) mainstream and upscale sustainable land-management decisions; ii) secure ecosystem services; and iii) improve rural livelihoods in Ghana. Activities under the auspices of GSIF will be designed to reverse land degradation to sustain high agricultural production and ensure food security, whilst at the same time maintaining ecosystem integrity.

GSIF is implemented by MESTI, while administration is overseen by the National SLM Secretariat based at the EPA. Individual programmes are implemented by Environmental Management Committees at the regional (REMCs), municipal (MEMCs), district (DEMCs) and community levels (CEMCs).

9.11 The Ghana Irrigation Policy (2011)[522]

The Ghana Irrigation Policy plans to achieve sustainable growth and enhanced performance of irrigation while contributing fully to the objectives of the Ghanaian agriculture sector. The policy has four objectives, namely: i) accelerating the performance and growth in Ghana's agricultural land under irrigation; ii) removing current constraints on land and water resources to promote balanced socio-economic engagement in the water sector; iii) raising the environmental performance of all types of irrigation and related agricultural practices; and iv) enhancing services which extend cost-effective, demand-driven irrigation services to public and private irrigators through a series of clear economic incentives for farmer participation. The targets of the policy are to: i) improve national food security; ii) intensify and diversify production of agricultural commodities; iii) increase livelihood options; iv) optimise natural

[520] Ministry of Food and Agriculture. 2007. Food and Agriculture Sector Development Policy (FASDEP II). Available at: http://mofa.gov.gh/site/?page_id=598
[521] Environmental Protection Agency 2011: Ghana Strategic Investment Framework (GSIF) for Sustainable Land Management (SLM). Republic of Ghana, Ministry of Environment, Science and Technology.
[522] Ministry of Food and Agriculture. 2011. National Irrigation Policy, Strategies and Regulatory Measures. Available at: http://mofa.gov.gh/site/wp-content/uploads/2011/07/GHANA-IRRIGATION-DEVELOPMENT-POLICY1.pdf

resource usage; v) reduce negative environmental impacts; and vi) expand investment space for irrigated production.

The implementing units are the Ghana Irrigation Development Authority under the MoFA, the District Assemblies and the Water Resources Commission, working together with the Department of Cooperatives, the private sector, non-governmental organisations (NGOs) and farmer associations. To ensure effective implementation, the policy commits to decentralising irrigation services and encouraging private sector participation from individual farmers and commercial operators. This is important for climate change adaptation as it allows for effective engagement with farmers to ensure the translation of policy activities at the respective local levels.

9.12 The Tree Crops Policy (TCP)[523]

The Tree Crops Policy (TCP) provides guidance on the strategic actions necessary for the development of the tree crops sub-sector. Tree crops in Ghana include coconut, cashew, cocoa, rubber, kola and shea nut. The TCP is intrinsically linked to the FASDEP II and focused on six main objectives in promoting sustainability and growth in the tree crop sub-sector, namely: i) supporting increased production and productivity of tree crops; ii) promoting investment in the tree crop sub-sector and increasing processing capacities; iii) improving marketing through value chain development; iv) promoting sustainable practices for environmental protection; v) supporting research and development in the tree crop sub-sector; and vi) improving coordination and management of the policy. These objectives of TCP are consistent with climate change adaptation practices, including CRA.

The TCP is implemented by a number of MDAs with the MoFA and its directorates acting as the coordinating authority. Other ministerial involvement includes the Ministry of Trade and Industry, and the Ministry of Finance and Economic Planning. Additionally, the Savanna Accelerated Development Authority and several research institutes and universities will be involved in implementation.

9.13 Ghana Forest and Wildlife Policy[524]

The policy covers the laws, institutions, systems, organisations and individuals that are related to the conservation and sustainable development of forest and wildlife resources. This includes the conservation of flora and fauna as well as the maintained provision of forest ecosystem services. The policy also recognises the Ghana Shared Growth and Development Agenda and international conventions that Ghana has ratified. These include the UN Non-Legally Binding Instrument on All Types of Forests[525] and the ECOWAS Forest Policy framework[526]. The policy is implemented by Ministry of Lands and Natural Resources.

Objectives of the Ghana Forest and Wildlife Policy include:

- managing and enhancing the ecological integrity of Ghana's forest, savanna, wetlands and other ecosystems. This is necessary for the preservation of soil and water resources, conservation of biological diversity, and enhancing carbon stocks for sustainable agricultural production.
- Promoting the rehabilitation and restoration of degraded landscapes through: i) forest plantation development; ii) enrichment planting; and iii) community forestry. These

[523] Ministry of Food and Agriculture. Tree Crops Policy. Available at: http://mofa.gov.gh/site/?page_id=10246
[524] Ministry of Lands and Natural Resources. 2012. Ghana Forest and Wildlife Policy. Available at: https://www.clientearth.org/external-resources/ghana/forests-and-wildlife/2012-Forest-and-wildlife-policy-GHANA.pdf
[525] UN. 2011. United Nations Forum on Forests (UNFF) Fact Sheet. Available at: http://www.un.org/esa/forests/wp-content/uploads/bsk-pdf-manager/81_FACT_SHEET_UNFF.PDF
[526] http://agris.fao.org/agris-search/search.do?recordID=XF2009437559

initiatives are informed by appropriate land-use practices, to enhance environmental quality and sustain the supply of raw materials for domestic and industrial consumption.
- Promoting the development of viable forest and wildlife-based industries and livelihoods. For example, the processing of forest and wildlife resources that are in demand both locally and internationally.
- Promoting and developing mechanisms for transparent governance, equity-sharing and community participation in forest and wildlife resource management.
- Promoting training, research and technology development that supports sustainable forest management. Additionally, the policy plans to increase the amount and quality of information available to forestry institutions and the general public.

9.14 Regional and international policies and strategies

Ghana is committed to the Comprehensive Africa Agriculture Development Programme (CAADP)[527], which all African Union members have committed to. The focus of the CAADP is to stimulate agriculture-led development that eliminates hunger and reduces poverty and food insecurity. Specifically, CAADP supports country-driven agricultural development strategies and programmes that contribute to the attainment of an average annual agricultural growth rate of 6%. Moreover, NEPAD's overarching vision for Africa held that, by 2015, Africa should:
- achieve food security;
- improve agricultural productivity to attain a 6 percent annual growth rate;
- develop dynamic regional and sub-regional agricultural markets;
- integrate farmers into a market economy; and
- achieve a more equitable distribution of wealth.

Apart from CAADP, there is also the Regional Agricultural Policy for West Africa (ECOWAP)[528], which elaborates on the strategies for agricultural development across the countries of the West African region. ECOWAP sets out a vision of "a modern and sustainable agriculture based on effective and efficient family farms and promotion of agricultural enterprises through the involvement of the private sector". The stated objectives aligned with the vision affirm the principle of regional food sovereignty. In this regard, the concept and implementation of CRA are very crucial in the overall implementation of ECOWAP.

Beyond Africa, Ghana is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC). Apart from participating in the international deliberations on how to address climate change through mitigation and adaptation, Ghana has benefited from the programmes and projects initiated within the framework of the UNFCCC. The relevant ministries — including MESTI and MOFA — have provided some of the linkages in these projects. There are also bilateral collaborations involving several countries including Denmark, Norway, the Netherlands, Germany and the United Kingdom. The formulation of the action plan takes account of the opportunities that come with these multi- and bilateral relationships with Ghana and provision is made to take advantage of the opportunities in the action plan.

[527] http://www.nepad.org/cop/comprehensive-africa-agriculture-development-programme-caadp
[528] ECOWAS. 2008. Regional Agricultural Policy for West Africa: ECOWAP. Available at: http://www.diplomatie.gouv.fr/IMG/pdf/01_ANG-ComCEDEAO.pdf

10 Past and ongoing projects

10.1 Introduction

The Government of Ghana is aware of the difficulties facing people living in the country's northern regions and the potential future threats on climate change on these vulnerable communities. Several past and ongoing projects have attempted to improve agricultural and land management practices to reduce environmental degradation, increase crop yields and enhance biodiversity. However, few of these projects have explicitly considered the potential impacts of climate change on the agro-based rural economy. This is an important omission given the vulnerability of the agricultural sector to climate threats and the important role that the sector can play in the Ghanaian economy. This section provides details about past and ongoing projects in northern Ghana. **Table 32** provides a comparison between GCF-funded Activities and the proposed project.

10.2 Ghana Environmental Management Project (2009–2016, CIDA~US$6,633,000)[529,530]

GEMP was funded by the Canadian International Development Agency. The Ministry of Finance (MoF) is responsible for the distribution of GEMP funds, while the project is implemented by the MESTI through the EPA. Regional Environmental Management Committees (REMCs) are responsible for the governance and implementation of the GEMP, collaborating with district and community environmental management committees (DEMCs and CEMCs respectively) to manage environmental issue and implement GEMP activities at the community level. The roles of CEMCs include planning, budgeting, implementation, supervision, monitoring and evaluation of GEMP initiatives.

GEMP had two main objectives. The first objective was to support the EPA to coordinate anti-desertification initiatives in Ghana. The second objective was to support the implementation of the National Action Programme (NAP) to combat desertification. The project provided support for specific priority initiatives identified by the NAP, with focus on the three northern regions of Ghana. GEMP supported community-based subprojects working to reduce land degradation from desertification by promoting vegetative cover and environmentally friendly alternative livelihoods. Specific activities within these two objectives included: i) enhanced development and implementation by Ghanaian institutions of effective policies and practices; ii) improved land and water management by districts and rural communities of the three northern regions; iii) enhanced institutional capacity of EPA in the three northern regions to deliver on its mandate in a gender sensitive manner; iv) increased leadership by GOG to plan, manage and coordinate initiatives to combat desertification; and v) increased gender sensitive awareness on desertification and capacity of northern districts and their communities to address priority desertification and drought projects of the NAP.

10.3 Sustainable Land and Water Management Project (2011−2020, GEF, US$44,000,000)

The Sustainable Land and Water Management[531] Project (SLMWP) was initially funded from 2011–2016 through a GEF grant (US$8,150,000) and in-kind co-financing from the Government of Ghana (GoG) (US$7,800,000)[532]. In 2014, an additional funding grant from the

[529] Ministry of Environment, Science, Technology and Innovation (MESTI) and Environmental Protection Agency (EPA). 2015. Ghana Environmental Management Project: 2014 Annual and Project completion report.
[530] Boudreau B. 2013. Mid-term project evaluation of the Ghana Environmental Management Project (GEMP): Final Report.
[531] SLWMP uses TerrAfrica's definition of SLWM: the adoption of land use systems that, through appropriate management practices, enables land users to maximise the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources.
[532] The World Bank. 2010. Project appraisal document on a proposed grant from the Global Environment Facility Trust Fund in the amount of US$8.15 million to the Republic of Ghana for a Sustainable Land and Water Management Project. Available at: http://projects.worldbank.org/P132100?lang=en.

GEF was approved (US$8,750,000; US$4,500,000 in-kind co-financing from GoG), and the project closing date was extended to 2018[533]. A third funding grant from GEF was approved (US$12,770,000; US$2,000,000 in-kind co-financing from GoG) in 2016, and the project duration was extended by a further two years[534]. The project is implemented by the MESTI in collaboration with the Ministry of Food and Agriculture (MoFA), EPA, the Forest Services and Wildlife Divisions of the Forestry Commission and the Savanna Accelerated Development Authority (SADA). SLWMP is being implemented in 12 districts in the Northern, Upper East and Upper West regions of Ghana, namely: i) Mamprugu Moaduri; ii) Sawla-Tuna-Kalba; iii) West Gonja; iv) West Mamprusi; v) Bawku West; vi) Builsa South; vii) Kassena-Nankana West; viii) Talensi; ix) Daffiama-Bussie-Issa; x) Sissala East; xi) Sissala West; and xii) Wa East. Each region encompasses 4 districts where implementation is taking place.

The objectives of the SLMWP were to: i) demonstrate improved sustainable land and water management practices aimed at reducing land degradation, and enhancing maintenance of biodiversity in selected micro-watersheds; and ii) strengthen spatial planning for identification of linking watershed investments in the Northern Savanna region of Ghana. Two innovative methods were used to plan, promote and implement project interventions: i) a dynamic menu of SLWM technologies and support packages designed specifically for the unique socioeconomic, and environmental context of northern Ghana; and ii) a subproject facility that enables communities and farmer groups to propose needs-based, community-level projects using the SLWM menu. The majority of project funding is allocated directly to water and land management activities, including: i) strengthening the capacities of districts and rural communities to plan the sustainable use of micro-watersheds; ii) enhancing the capacity of local extension staff to promote SLWM technologies, and develop subproject agreements with local farmers; iii) implementing SLWM in micro-watersheds through the financing of subproject inputs and the operational costs of district extension agencies; iii) supporting natural habitat and wildlife management activities to maintain, and enhance the ecosystem services provided by watersheds; and iv) monitoring of SLWM interventions and environmental services.

10.4 Acumen Resilient Agriculture Fund, (2018-2030, Green Climate Fund, USD25M):

The project will be focused on Ghana, Nigeria and Uganda and executed by Acumen Ltd. The project will invest in 18-20 portfolio companies with an investment range of USD300,000 to 3M per company. These companies must demonstrate how they will help low income farmers adapt to climate change. Market solutions can be in three areas: i) inputs for climate resilient agriculture ii) extension services to improve resilience and increase yields and iii) formal off-take markets for better prices. Technical assistance will be provided to investees to build sustainable scalable businesses. Capital may be provided for value chain diversification, diversity income streams or invest in extension services. Up to 50% of funds will be directed to Aggregator models, up to 30% for innovative financial mechanisms and up to 30% for digital platforms.

10.5 Program on Affirmative Finance Action for Women in Africa: Financing Climate Resilience Agricultural Practices in Ghana (2019–2024, Green Climate FUnd, US$8,293,972)

The objective of the AFAWA programme is to empower vulnerable women groups in Ghana to participate in low-emission climate-resilient agricultural practices by providing them with

[533] The World Bank. 2014. Project paper on a proposed additional grant in the amount of US$8.75 million from the Global Environment Facility Trust Fund to the Republic of Ghana for a Sustainable Land and Water Management Project. Available at: http://projects.worldbank.org/P132100?lang=en.
[534] The World Bank. 2016. Project paper on a proposed additional grant in the amount of US$12,768,832 from the Global Environment Facility Trust Fund to the Republic of Ghana for a Sustainable Land and Water Management Project. Available at: http://projects.worldbank.org/P132100?lang=en.

lines of credit and technical assistance. The focus of the programme will be women led micro, small, medium-sized enterprises (MSMEs)[535] and FBOs[536] in the 43 most vulnerable districts of Ghana to climate change. Most of these districts will be in northern Ghana where vulnerability to climate change is very severe. The programme will provide, in Component 1, affordable loans to women led MSMEs[537] and FBOs[538] to enable them to adopt climate-resilient agricultural practices. Under component 2, the programme will provide training to MSMEs, FBOs and selected local financial institutions (LFIs) to improve their technical and business skills. This will include conducting capacity building workshops to: i) raise awareness among target beneficiaries on the use of climate-resilient agricultural practices; ii) train beneficiaries on value addition and productivity measures in the agriculture value chain such as food crop processing and packaging; iii) train beneficiaries on the uptake of social protection mechanisms such as weather index-based crop insurance facilities; iv) train selected beneficiaries as 'Training of Trainers' (ToT) on climate-resilient agricultural practices; and v) use the TOT to support the implementation of other programme sub-components.

The AFAWA programme is funded by the GCF while the African Development Bank (AfDB) is the Accredited Entity. The AfDB has received US$18.5 million in loans and US$1.5 million in grants from the GCF to partner LFIs in providing loans to selected MSMEs and FBAs. The LFIs selected by the AfDB will each provide US$ 5 million loans. The programme is expected to benefit 400 women led MSMEs and FBOs and 373,720 total beneficiaries across the country.

The project will be located in 18 Districts in the Northern Savanah zone, implemented by UNDP and executed by the Forestry Commission. The project seeks to restore forest carbon stocks across the landscape by restoring 200,000 hectares of off-reserve savannah woodland and placing it under community self-financing management, restoring 100 ha of shea degraded parklands, creating 25,000 hectares of modified Taungya system/forest plantation in severely degraded forest areas, and completing an integrated monitoring system and completing the REDD+ architecture for safeguards, forest monitoring and reporting.

Revenues from sustainable woodfuel production and NTPS will enable the establishment of a fund to continue the community-based management of restored areas. Women's cooperatives will be trained in shea kernel aggregation and direct marketing with support from NGOs and the private sector through performance-based contracts to undertake activities across the value chain.

10.7 Increased Resilience to Climate Change in northern Ghana through the Management of Water Resources and Diversification of Livelihoods (2015–2020, Adaptation Fund US$8,293,972)

This project is being implemented through UNDP's National Implementation Modality (NIM), with MESTI acting as the national executing agency. The Adaptation Fund provided US$8,293,972 in funding to the project[539].

The main objective is to enhance the resilience and adaptive capacity of rural livelihoods to climate change impacts, and threats to water resources in the northern regions of Ghana. The

[535] with more than 51% of the firm's assets holding or shares being owned by a woman
[536] at least 60% of the members being women
[537] Enterprises that employ from 1 to 100 employees and have financial needs up to USD$ 1 million. This includes farm-based associations such as producers' associations and cooperative societies.
[538] Association of farmers who come together to pursue a common goal to foster improvement in their areas of operations.
[539] Adaptation Fund. 2015. Project Summary for The Increased Resilience to Climate Change in Northern Ghana through the Management Water Resources and Diversification of Livelihoods. Available at: https://www.adaptation-fund.org/project/increased-resilience-to-climate-change-in-northern-ghana-through-the-management-water-resources-and-diversification-of-livelihoods/

project is implementing interventions in 10 districts[540], across the Upper East, Upper West and Northern regions of Ghana. To meet objectives the project will focus on three approaches, namely: i) improving water access in these regions; ii) increasing the institutional capacity for climate resilient management of surface and groundwater; and iii) diversifying livelihoods of rural communities[541].

10.8 Adaptation of Agro-Ecosystems to Climate Change (AAESCC; 2012−2017, US$3,900,000)

AAESCC is funded by the German Federal Ministry for Economic Cooperation and Development (GIZ) and is implemented by MoFA. AAESCC is being implemented in 16 communities in eight districts of the Brong-Ahafo and Northern regions of Ghana. The objective of AAESCC is to reduce climate-related crop losses in the savanna and transitional regions of Ghana through pilot measures. The results of these pilot measures will then be used to define agricultural sector policy and national support measures for the adaptation of land use systems to climate change. To realise the project objectives, the following approaches are being used: i) developing climate-resilient farming systems; ii) delivering climate-resilient extension services; and iii) adopting climate-resilient policies. An example of an activity implemented by the project is the planting of drought-resistant maize varieties in demonstration plots in the 16 pilot communities, which is being done in conjunction with the Savanna Agricultural Research Institute (SARI). Furthermore, project activities have resulted in *inter alia*: i) 600 farmers – 300 in each region – being sent weather forecasts by mobile phone, which has improved their ability to management and plan agricultural activities; and ii) the Ghana Meteorological Agency (GMA) being equipped with automatic weather stations in the eight project districts, which has improved weather forecasting for the region.

10.9 Africa Adaptation Programme (AAP; 2010−2013; Government of Japan US$2,709,000 and US$57,000 UNDP)

The AAP was provided with US$2,709,000 from the Government of Japan and an additional US$57,000 from the UNDP Ghana country-office (CO)[542]. The project ran for a duration of three years - from 2010-2013 - and was implemented by the AAP project management unit (PMU), while the UNDP CO acted as the executing entity[543]. Objectives for the AAP were to enhance the understanding of the links between climate change adaptation (CCA) and disaster risk reduction (DRR), and integrate these into national, district, and sector-level development plans[544]. Stakeholder training on mainstreaming CCA and DRR was conducted in 170 districts[545], while the implementation of CCA projects were conducted in five pilot districts, including: Aowin Suaman, Keta, Fanteakwa, West Mamprusi and Sissala East[546]. Approaches and activities focused on developing capacity and financing options for mainstreaming CCA, as well as developing early warning systems. In the five pilot districts, CCA was integrated into district level government planning and budgeting, while flood and drought mapping as well as research on indigenous knowledge of climate change was conducted. At a national level the AAP organised policy dialogues with senior decision makers

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[540] Builsa, Bongo, Bawku West, Bawku, Sissala East, Lawra, Nadowli, Bole, Zabzugu-Tatale and Savelugu.
[541] UNDP 2015. The Increased Resilience to Climate Change in Northern Ghana through the Management Water Resources and Diversification of Livelihoods project proposal. Adaptation Fund. Washington DC. USA. Available at: https://www.adaptation-fund.org/wp-content/uploads/2015/09/RESUBMISSION_Ghana-AF_proposal_-29-January-2015.pdf
[542] UNDP. 2017. UNDP in Ghana: Africa Adaptation Programme (AAP). Available at: http://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/project_sample.html,
[543] UNDP. 2013. Africa Adaptation Programme on Climate Change Ghana: Final Project Review Report. Available at: http://www.gh.undp.org/content/dam/ghana/docs/Doc/Susdev/UNDP_GH_SUSDEV_AFRICA%20ADAPTATION%20PROGRAMME%20ON%20CLIMATE%20CHANGE%20GHANA.pdf.
[544] UNDP. 2017. UNDP in Ghana: Africa Adaptation Programme (AAP). Available at: http://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/project_sample.html
[545] UNDP Ghana. 2013. Africa Adaptation Programme in Ghana. Available at: http://www.gh.undp.org/content/dam/ghana/docs/Doc/Susdev/UNDP_GH_Susdev_AAP_Sum%20of%20Achievements.pdf.pdf.
[546] UNDP. 2017. UNDP in Ghana: Africa Adaptation Programme (AAP). Available at: http://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/project_sample.html

and mobilised finance for the development of the National Climate Change Policy (NCCCP). In addition, AAP assisted in improving the frequency, volume and quality of weather data provided by the Ghana Meteorological Agency (GMet) by installing eight automated weather stations, and a high-speed computer[547].

10.10 CARE Adaptation Learning Programme (ALP; 2010−2014, US$7,930,000)[548]

CARE ALP was co-funded by: i) UKAid via the United Kingdom's Department for International Development (DFID); ii) the Danish International Development Agency (DANIDA); iii) the Finnish Ministry of Foreign Affairs; and iv) the Austrian Development Agency. The programme was implemented by DFID in eight communities in the districts of East Mamprusi and Garu-Tempane, which are located in the Northern and Upper East Regions of Ghana. By working directly with the eight target communities, CARE ALP sought to identify successful approaches to Community-Based Adaptation (CBA). The programme also supported the incorporation of these approaches into development policies and programmes to increase the adaptive capacity of vulnerable households in these communities to climate variability and change. Towards the implementation of the aforementioned, CARE ALP planned to: i) develop and apply innovative approaches to CBA to generate best practice models; ii) empower local communities and civil society organisations to have a voice in decision-making and adaptation; iii) promote best practice models for CBA among adaptation practitioners; and iv) influence national, regional and international adaptation policies and plans[549].

10.11 Climate Change Adaptation in northern Ghana Enhanced (CHANGE; 2013−2015, US$3,000,000)[550]

CHANGE was funded by the Government of Canada through the Department of Foreign Affairs, Trade and Development (DFATD). The project ran from January 2013 to September 2014 and was then extended for a third year, which was funded by Canadian "Feed The Children" and concluded in December 2015. CHANGE was implemented by: i) Regional Advisory and Information Network Systems (RAINS); ii) Trade Aid Integrated (TAI); and iii) Tumu Deanery Regional Integrated Development Programme (TUDRIDEP). Implementation took place in 17 communities in the following districts: i) Savelugu-Nanton; ii) Bolgatanga; and iii) Sissala East, which are located in the Northern, Upper East and Upper West regions of Ghana respectively. The project's primary objective was to assist smallholder farmers in improving their adaptive capacity and in building their resilience to the impacts of climate change on agriculture, food security and livelihoods. The primary objective was comprised of three goals: i) to improve access to climate change information and to strengthen the capacity of smallholder farmers to implement adaptive actions; ii) to use a participatory stepped-down training approach to train agricultural extension agents, farmers and farmer-based organisation (FBO) leaders to implement climate change-adaptive agriculture practices that build community resilience; and iii) to increase the participation of women in sustainable agriculture and alternative livelihoods. To achieve these goals, the project's technical partners – for example, SARI and MoFA – delivered four training modules on: i) productive and environmentally-sustainable agronomic practices; ii) the use of agricultural calendars; iii) seasonal weather forecast information; iv) weather forecasting techniques; and v) other climate-resilient agriculture (CRA) techniques. Over the course of the project, participants received follow-up training on *inter alia*: i) CRA agricultural practices and conservation

[547] UNDP. 2013. Africa Adaptation Programme on Climate Change Ghana: Final Project Review Report. Available at: http://www.gh.undp.org/content/dam/ghana/docs/Doc/Susdev/UNDP_GH_SUSDEV_AFRICA%20ADAPTATION%20PROGRAMME%20ON%20CLIMATE%20CHANGE%20GHANA.pdf.
[548] Nottawasaga Institute. 2015. Adaptation Learning Program (ALP) Final Evaluation Report. Available at: http://iati.dfid.gov.uk/iati_documents/5258664.pdf.
[549] CARE. 2015. ALP Contact Card. Available at: http://careclimatechange.org/wp-content/uploads/2016/04/ALP-Contact-Card-2015.pdf.
[550] Canadian Feed the Children. 2015. Change project stakeholder learning forum: Project Wrap-Up Summary. Available at: http://www.canadianfeedthechildren.ca/downloads-projects/CHANGE-Project-Summary-of-Results.pdf.

agriculture; ii) sustainable soil and water management practices; iii) the effective use of agriculture data; iv) harvesting; and v) storage and prevention of post-harvest losses.

An end-of-project evaluation found that: i) 100% of FBO leaders reported an increased understanding of climate change, its effects and adaptation measures; ii) 95% of farmers attended at least one training module and considered it an important source of information on climate change and adaptation; iii) 93% – 66% female – of farmers tested one or more CRA method, far exceeding the target of 75%; and iv) 95% – 66% female – of farmers who implemented CRA strategies reported an increased agricultural productivity[551].

10.12 Economics of Adaptation to Climate Change (EACC, 2008–2010, World Bank)

The Economics of Adaptation to Climate Change was a study conducted by the World Bank in partnership with the governments of Bangladesh, Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam to estimate the costs of adapting to climate change. It was funded by the governments of the Netherlands, Switzerland and the United Kingdom. The objectives of the study were to: i) develop a global estimate of adaptation costs for informing the international community's efforts in climate negotiations; and ii) to help decision-makers in developing countries assess the risks posed by climate change and design national strategies for adapting to climate change. The study was conducted on two parallel tracks: i) a global track where national databases were used to generate aggregate estimates at a global scale; and ii) a series of country level studies. Country level studies were conducted to help in understanding adaptation from a bottom-up perspective[552,553].

10.13 Ghana Agricultural Sector Investment Programme (GASIP; 2015−2020 – first two cycles of three years each, more are planned in the long-term, US$113 million)[554]

GASIP funding includes: i) an approved International Fund for Agricultural Development (IFAD) loan of US$71.6 million; ii) an Adaptation for Smallholder Agriculture Programme (ASAP) grant of US$10 million; iii) co-financing from participating financial institutions of US$17.5 million; iv) US$7.6 million from the Government of Ghana; v) US$1.7 million from district governments; and vi) US$4.6 million from beneficiaries. MoFA is responsible for the implementation of the programme. GASIP will be implemented in every region of Ghana. During the first two years of implementation, agribusinesses and individuals in 50 districts in northern Ghana will have access to programme benefits based on their eligibility for support coupled with opportunities for viable value chain development. The programme will implement its work using a geographical expansion plan.

GASIP intends to contribute to sustainable poverty reduction in rural Ghana. The Programme Development Objective (PDO) is: "agribusiness including smallholders, have enhanced their profitability and climate change resilience". The impact indicators of the PDO will measure: i) outreach to smallholders - including women and the youth; ii) profitability of interventions at all stages of the value chain; and iii) adoption of climate change adaptation measures. GASIP was designed as a longterm- programme that will be implemented in three year cycles. The initial design covers two cycles. Prior to the end of each cycle, an Intercycle Review Mission (IRM) will be organised to assess progress and prepare for the next cycle. Each IRM will consider the effectiveness of the approach to reduce rural poverty and the readiness of qualified investment proposals from each component for the next phase. GASIP includes three

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[551] Canadian Feed the Children. 2015. Change project stakeholder learning forum: Project Wrap-Up Summary. Available at: http://www.canadianfeedthechildren.ca/downloads-projects/CHANGE-Project-Summary-of-Results.pdf.
[552] The World Bank Group. 2010. The Economics of Adaptation to Climate Change – A synthesis report: Final consultation draft, August 2010. Available at: https://siteresources.worldbank.org/EXTCC/Resources/EACC_FinalSynthesisReport0803_2010.pdf
[553] The World Bank Group. 2010. Economics of Adaptation to Climate Change: Ghana. Available at: http://www.worldbank.org/en/news/feature/2011/06/06/economics-adaptation-climate-change
[554] IFAD. 2015. GASIP Fact Sheet. Available at: https://www.ifad.org/topic/resource/factsheet.

components, which are comprised of several subcomponents: i) value chain development; ii) rural value chain infrastructure; iii) knowledge management, harmonisation and policy support[555].

10.14 Innovative Insurance Products for the Adaptation to Climate Change (IIPACC, 2009−2014, €3,832,000 GIZ)

The IIPACC project was provided with €3,832,000 in funding from the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU) and ran from 2009−2014[556]. The German Development Cooperation (GIZ) acted as the executing agency, while the project was jointly implemented by the National Commission of Ghana and the German Technical Cooperation (GTZ)[557]. The IIPACC objectives were to support the development of a sustainable agricultural insurance system by introducing innovative and demand-orientated crop insurance products to protect against financial risks caused by extreme weather events, and other forms of climate change[558]. The project interventions were implemented in seven of Ghana's ten regions, including the Northern, Upper East and Upper West regions[559,560]. IIPACC approaches and activities focused on creating institutional preconditions and a knowledge basis for the introduction of risk insurance schemes for the agricultural sector in Ghana and supported the establishment of the Ghana Agricultural Insurance Programme (GAIP). Through GAIP the project introduced a drought index insurance product for maize, soya and sorghum farmers. In addition, an area-yield-index product was introduced in three pilot districts for smallholder farmers, while a multiple-peril crop insurance product was introduced for commercial farmers[561,562]. To strengthen national capacity, workshops were held for the Ghanaian insurance sector on product development, business planning, financial projections, marketing, distribution and claims management[563]. Additionally, automated weather stations were installed in various districts, and Ghana Meteorological (GMet) staff were provided with training and new equipment to enhance efficiency and accuracy in weather forecasting[564].

10.15 IUCN Towards Pro-poor REDD+ Project (Phase 1: 2009−2012 with US$4,610,960, Phase 2: 2013−2016 with US$4,610,960, DANIDA)[565]

The funding for each phase is shared between the five forested countries involved in the project, namely: Ghana, Cameroon, Uganda, Indonesia and Guatemala. Funding is provided

[555] Programme Management Department. 2014. Ghana Agricultural Sector Investment Programme (GASIP) Design Report.
[556] Gille S. 2013. The case of Ghana – Innovative insurance products for the adaptation to climate change. MCII-GIZ Workshop, Bonn. Available at: http://www.climate-insurance.org/fileadmin/mcii/documents/20130411__MCII-GIZ_Workshop_SGille.pdf
[557] Stutley C. 2010. Innovative Insurance Products for the Adaptation to Climate Change Project Ghana (IIPACC): Crop Insurance Feasibility Study 2010. Available at: http://seguros.riesgoycambioclimatico.org/DocInteres/eng/Ghana-Crop-Insurance.pdf.
[558] Gille S. 2013. The case of Ghana – Innovative insurance products for the adaptation to climate change. MCII-GIZ Workshop, Bonn. Available at: http://www.climate-insurance.org/fileadmin/mcii/documents/20130411__MCII-GIZ_Workshop_SGille.pdf
[559] German Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety. 2016. Innovative Insurance Products for Climate Change Adaptation. Available at: https://www.international-climate-initiative.com/en/projects/projects/details/innovative-insurance-products-for-climate-change-adaptation-187/?printview=printProjectAsPdf
[560] Graphic Online. 11th September 2011. Agriculture insurance is key to increasing productivity. Available at: https://www.modernghana.com/news/350027/1/agriculture-insurance-is-key-to-increasing-product.html
[561] German Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety. 2016. Innovative Insurance Products for Climate Change Adaptation. Available at: https://www.international-climate-initiative.com/en/projects/projects/details/innovative-insurance-products-for-climate-change-adaptation-187/?printview=printProjectAsPdf
[562] Warner K, Yuzva K, Zissener M, Gille S, Voss J & Wanczeck S. 2013. Innovative Insurance Solutions for Climate Change: How to integrate climate risk insurance into a comprehensive climate risk management approach. Report No. 12. Bonne: United Nations University Institute for Environment and Human Security (UNU-EHS).
[563] GIZ. 2013. IIPACC. Available at: *https://unfccc.int/files/adaptation/cancun_adaptation_framework/loss.../giz_2.pdf.*
[564] GIZ. 2013. IIPACC. Available at: *https://unfccc.int/files/adaptation/cancun_adaptation_framework/loss.../giz_2.pdf.*
[565] The REDD desk. 2017. IUCN towards pro-poor REDD+ project. Available at: http://theredddesk.org/countries/initiatives/iucn-towards-pro-poor-redd-project.

by the Danish International Development Agency (DANIDA)[566]. The IUCN acts as the executing entity, while on the ground interventions are conducted by partner organisations. In Ghana, implementation has been conducted by A Rocha in communities surrounding Mole National Park, while Codesult Network have led interventions in the Wassa Amenfi forests[567]. Project objectives include, *inter alia:* i) to demonstrate the value of human rights-based approaches and pro-poor principles in REDD+ and economic development strategies through landscape-level results; ii) enhance national capacities to mainstream human rights-based approaches and pro-poor principles into climate, REDD+ and green growth strategies; and iii) integrate human rights-based approaches and pro-poor principles into global frameworks and standards beyond project countries[568]. Project approaches included, *inter alia:* i) piloting and assessing pro-poor benefit sharing mechanisms for performance-based REDD+ proxy actions that are consistent with national REDD+ strategies; ii) identifying and promoting policy and institutional arrangements required to equitably and efficiently deliver performance-based payments for REDD+ activities; and iii) generating and promoting lessons about the design and implementation of pro-poor REDD+ benefit-sharing mechanisms[569].

10.16 Promoting a value chain approach to climate change adaptation in agriculture in Ghana (2012−2017, GEF SCCF Grant US$2.5 million, IFAD loan US$8.5 million, Government of Ghana US$0.3 million and US$0.2 million beneficiaries' contribution)[570]

This project was funded by the Special Climate Change Fund (SCCF) and implemented by the IFAD. The executing agency was MOFA, specifically the Roots and Tubers Improvement and Marketing Programme (IFAD Project)[571]. The project objectives included, *inter alia:* i) to reduce climate-induced risks to the cassava value chain; ii) achieve food security; and iii) generate income for pilot rural communities in Ghana[572]. Implementation activities were carried out in the Ashanti, Brong-Ahafo, Northern and Volta regions of Ghana[573]. The project approach targeted individuals and groups of women, men and youth living in remote rural areas who are involved in cassava processing, production, and marketing activities. Activities for the project focused on the following three areas: i) awareness raising on climate change and capacity building to address its impacts along the cassava chain; ii) supporting adaptation to climate change in cassava production; and iii) promoting innovative adaptation solutions along agricultural value chains[574].

10.17 Resilient Landscapes for Sustainable Livelihoods (RLSL; 2013−2016, US$3,360,000)[575]

UNDP was the implementing agency for the RLSL project. MoFA was the executing agency, while FAO and WFP were executing partners. RLSL was implemented across 10 communities in the three northern regions of Ghana – Northern, Upper East and Eastern.

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566 The REDD desk. 2017. IUCN towards pro-poor REDD+ project. Available at: http://theredddesk.org/countries/initiatives/iucn-towards-pro-poor-redd-project
567 IUCN. July 2016. IUCN "Towards pro-poor REDD" Phase II: Mid-term review Final Report. Available at: https://www.iucn.org/sites/dev/files/midterm_review_of_toward_pro-poor_redd_phase_ii_project_-_final_report.pdf.
568 The REDD desk. 2017. IUCN towards pro-poor REDD+ project. Available at: http://theredddesk.org/countries/initiatives/iucn-towards-pro-poor-redd-project.
569 IUCN. 2015. The REDD+ benefit-sharing project: Facilitating countries and communities in designing pro-poor REDD+ benefit-sharing schemes. Available at: http://theforestsdialogue.org/sites/default/files/2_george_akwah.pdf.
570 IFAD. 2015. Ghana: Promoting a value chain approach to climate change adaptation in agriculture in Ghana. Available at: https://www.ifad.org/documents/10180/b0c49e3d-5d00-454d-9d40-c78f79f5150b.
571 GEF. 2016. Promoting value chain approach to adaptation in agriculture. Available at: https://www.thegef.org/project/promoting-value-chain-approach-adaptation-agriculture.
572 IFAD. 2015. Ghana: Promoting a value chain approach to climate change adaptation in agriculture in Ghana. Available at: https://www.ifad.org/documents/10180/b0c49e3d-5d00-454d-9d40-c78f79f5150b.
573 IFAD. 2015. Ghana: Promoting a value chain approach to climate change adaptation in agriculture in Ghana. Available at: https://www.ifad.org/documents/10180/b0c49e3d-5d00-454d-9d40-c78f79f5150b.
574 IFAD. 2015. Ghana: Promoting a value chain approach to climate change adaptation in agriculture in Ghana. Available at: https://www.ifad.org/documents/10180/b0c49e3d-5d00-454d-9d40-c78f79f5150b.
575 Ministry of Food and Agriculture. 2012. Resilient Landscapes for Sustainable Livelihoods Project Proposal.

The objectives of the RLSL were to: i) develop the capacity of national and local institutions; and ii) strengthen the resilience of districts and communities in northern Ghana to climate change and disaster risks through the development, and implementation of sustainable land management approaches. The objectives were achieved through three components. Firstly, the social component of the programme involved the development of community cooperatives and other community-based organisations, to enhance the benefits provided by programme activities. Secondly, the technical component focused primarily on agricultural practices and interventions including: i) the development of demonstration plots; ii) the establishment of community-based seed production units to supply rural farmers with farming inputs; and iii) the training of rural farmers on Sustainable Land and Water Management (SLWM) interventions. Lastly, the financial component involved the establishment of revolving funds to assist with the provision of farming inputs and diversification into additional livelihood activities[576].

10.18 Support Transition Towards Climate Smart Agriculture Food Systems (2015–2016, Government of Norway, US$1,159,634)

This project was implemented by FAO, with MOFA as the executing agency, with US$1,159,634 in funding provided by the Government of Norway. The project objectives were to ensure food security by improving smallholder farmers' resilience to climate change-induced hazards. The project aimed to achieve this objective by facilitating the scaling up of climate smart agriculture (CRA) in Ghana. Project activities included, *inter alia*: i) assisting Ghana in creating the required policy and financial environment for CRA; ii) providing smallholder farmers with access to resources and knowledge to implement CRA; and iii) engaging with stakeholders to encourage the uptake of CRA practices[577].

10.19 Water, Climate and Development Project (WACDEP; 2011−2016, US$17.8 million)[578]

WACDEP was funded by: i) the Austrian Development Cooperation; ii) the Danish International Development Agency (DANIDA); iii) United Kingdom; and iv) other Global Water Partnership (GWP) financing partners. The funding was distributed amongst eight African beneficiary countries, one of which was Ghana. The project was implemented in West Gonja district - Northern Region – and in the Bakwu and Binduri districts – Upper East Region – by the African Ministers Council on Water (AMCOW), the Ghana Water Partnership and the Volta Basin Authority (VBA)[579].

WACDEP promoted water as a key part of sustainable regional and national development and contributed to climate change adaptation for economic growth and human security. The objectives of the programme were to support countries like Ghana in: i) the integration of water security and climate resilience in development planning processes; ii) the development of partnerships and capacity of institutions and stakeholders to build climate change resilience through better water management; and iii) the development of "no regret" financing and investment strategies for water security and climate change adaptation. The project was structured around four components including: i) investments in regional and national development; ii) innovative green solutions; iii) knowledge and capacity development; and iv) partnership and sustainability[580].

Projects that never received funding

[576] Mission notes. Meeting with the FAO. 2016.
[577] FAO. 2016. FAO Project list. Available at: http://www.fao.org/ghana/programmes-and-projects/project-list/en/
[578] Global Water Partnership. 2011. WACDEP Flyer. Available at: http://www.gwp.org/WACDEP.
[579] Global Water Partnership. 2011. WACDEP Flyer. Available at: http://www.gwp.org/WACDEP.
[580] WACDEP. 2012. Technical Background Document. African Ministers Council on Water (AMCOW). Available at: http://www.gwp.org/WACDEP.

10.20 Ghana Rural Resilience and Innovations Project[581] (GRRIP)

This project was proposed and numerous interventions were drawn up but it never received funding. The proposal aimed to receive US$7 million in grant funding from the GEF, and US$40 million in co-financing from the Ghanaian Ministry of Finance and Economic Planning (MoFEP). GRRIP would have been implemented over a three-year period by the Ghanaian Environmental Protection Agency (EPA). It was designed to follow on from a previous project "Ghana Environmental Management Project (GEMP)" that aimed to reverse land degradation and desertification trends in northern Ghana. The GRRIP project aimed to: i) reduce poverty through strategic economic growth; ii) improve land management techniques to ensure food security; iii) increase the resilience of communities to extreme weather events; iv) promote rural micro-enterprise development; and v) empower women. Interventions were planned for 22 districts in northern Ghana, including the Upper East, Upper West and Northern region. The project aimed to achieve this by introducing eco-innovative technologies that would improve crop productivity and survival, teach communities how to convert agricultural waste into cooking fuel, introduce alternative livelihood strategies, and assist in gaining private sector investments in raw-material production.

[581] EPA. April 2015. Project proposal – Ghana Rural Resilience and Innovations Project (GRRIP). Prepared by the NAP Secretariat.

Table 32. Comparison between GCF-funded activities in Ghana

Project feature	Acumen Resilient Agriculture Fund	AfDB Program on Affirmative Finance Action for Women in Africa (AFAWA): Financing Climate Resilient Agricultural Practices in Ghana	UNDP Shea Landscapes Emission Reduction	UNEP Climate Resilient Landscapes for sustainable livelihoods
Geographical Location	Ghana, Nigeria, Uganda	43 Districts	Northern Savanna Zone (NSZ)	Northern Ghana (Northern, Upper East and Upper West Regions)
Ghana Regions and Districts	Country -wide	Not detailed in the proposal.	5 Regions (Upper East, Upper West, North East, Savannah, Northern) and 18 Districts including: Lambussie, Sissala West, Sisssala East, Daffiama Bussie Issa, Wa Municipal, Wa East, Bole, West Gonja, Central Gonja, Bawku West, Bongo, Kassena Nankana, Bolgatanga, Talensi, East Mamprusi, Gushiegu, Karaga, Nanumba North	3 Regions (North East, Upper East, Upper West) and 9 Districts including: Bunkpurugu Nyakpadun, Yunyoo-Nasuan, Garu, Tempane, Binduri, Lawra, Lambussie, Jirapa and Wa West)
Result Areas	Adaptation	Cross-cutting programme on: (1) reduced emissions from energy access and power generation, and forest and land use; (2) increase resilience of most vulnerable people and communities, health and wellbeing and food and water security, and ecosystem and ecosystem services	Cross cutting project - Mitigation with focus on forestry and land use (65%) and adaptation with focus on ecosystem and ecosystem services (35%)	Adaptation project focusing on most vulnerable people, communities, and regions (70%) and ecosystem and ecosystem services (30%)
Expected Mitigation Impact	N/A	1,939,426 tCO_2e in 15 years of the Line of Credit (LoC) tenor and 3,232,377 tCO_2e in 25 years. These estimates exclude the avoided emissions from the use of biomass-based energy such	6.139 million tCO_2e in emission reductions and removals over the first 7 years of the project lifetime and 25.24 million tCO_2e over 20 years	1.2 million tCO_2e over the 7 years of the project

		wood fuel and charcoal as the result of the switch to renewable energy.		
Expected Adaptation Impact	Across the three countries: 2.1M direct beneficiaries 7.9M indirect beneficiaries	Over 373,720 direct beneficiaries (females: 224,280; males: 149,420 and firm beneficiaries: 20)	100,200 direct beneficiaries and 540,000 indirect beneficiaries – 15% of population in the NSZ The project will provide adaptation co-benefits for target populations by restoring ecosystems services, reducing the risks of environmental shocks, and increasing incomes and options for livelihoods on 471,500 hectares of land in the NSZ	691,125 direct beneficiaries and 1,416,953 indirect beneficiaries – 36.2% of the population of northern Ghana
GCF investment	23M equity investment + 3M grant over 12 year: 2018 – 2030.	US$20,000,000 over 55 years: 2019-2024 Including senior loan for line of credit (LoC): US$18.5M and Technical Assistance (TA) grant: US$1.5M	US$30,100,000 grant over 7 years: 2021 - 2028	US$23M grant over 7 years: estimated 2024 - 2031
Executing Entity	Acumen Resilient Agriculture Fund Ltd	African Development Bank and Local Financial Institutions (LFIs) in Ghana	Forestry Commission of Ghana (Climate Change Directorate)	Ghana Environmental Protection Agency and UN Capital Development Fund
Project approach	The project will invest in 18-20 portfolio companies with an investment range of USD300,000 to 3M per company. These companies must demonstrate how they will help low income farmers adapt to climate change. Market solutions can be in three areas: i) inputs for climate resilient agriculture ii) extension services to improve resilience and increase yields	Empower vulnerable women groups in Ghana through Line Credit (LoC) and through Technical Assistance (TA) to participate in low-emission climate resilient agricultural practices. The programme will provide, in Component 1, affordable loans to micro, small, medium-sized enterprises	The project seeks to restore forest carbon stocks across the landscape by restoring 200,000 hectares of off-reserve savannah woodland and placing it under community self-financing management, restoring 100 ha of shea degraded parklands, creating 25,000 hectares of modified Taungya system/forest plantation in severely degraded forest areas, and completing an integrated monitoring system and completing the REDD+	The key results from the project will be an improved capacity at the District Assembly level for adaptation planning and investment, consistent with evidence of climate change risks in the Districts. This will be complemented by field level work with communities to develop Community Adaptation Action Plan and to work with subsistence farmers to implement climate resilient methods of

	and iii) formal off-take markets for better prices. Technical assistance will be provided to investees to build sustainable scalable businesses. Capital may be provided for value chain diversification, diversity income streams or invest in extension services. Up to 50% of funds will be directed to Aggregator models, up to 30% for innovative financial mechanisms and up to 30% for digital platforms.	(MSMEs) and farmer based associations (FBAs) led by women who will adopt low-emissions and climate resilient agricultural practices and, in component 2, technical assistance for adoption of low-emission and climate resilient practices for MSMEs and a local bank, enhancement of regulatory framework, and knowledge dissemination. The AFAWA programme is implementing climate-resilient measures such as the use of drought resistant seeds to address the high vulnerability of agriculture in the Savannah agro-ecological zones to climate risks. It is also replacing technologies such as diesel-based tractors and the use of firewood and charcoal for agro-processing with low carbon technologies such as off-grid solar and biogas. It will also improve value addition, diversification, productivity and profitability for economic growth and development by funding the acquisition of for example, storage and processing facilities.	architecture for safeguards, forest monitoring and reporting. Revenues from sustainable woodfuel production and NTPS will enable the establishment of a fund to continue the community-based management of restored areas. Women's cooperatives will be trained in shea kernel aggregation and direct marketing with support from NGOs and the private sector through performance-based contracts to undertake activities across the value chain. .	agricultural production. Farmer-based organizations will be supported to develop financial literacy and savings groups and to connect with value chains being developed in parallel to this project. This financial strengthening will enable the farmer groups to connect to the local banking sector thereby promoting higher returns that can be reinvested. The District Assembly development investments should support this livelihood strengthening as well as investing in climate risk reduction by investing in ecosystem services for drought and flood management and disaster risk reduction. Knowledge, learning and upscaling of adaptation investments across the District Assemblies as well as in the larger Regional Administration will be promoted through a robust monitoring and evaluation system fitted to the adaptation interventions as well as a robust publication and awareness strategy. These outputs and Outcomes should deliver three of the four Fund impact level results on numbers of beneficiaries, numbers of hectares under climate resilient management and value of assets protected from

		The AFAWA programme is expected to reach local financial institutions and some 400 women-led FBAs and agribusiness MSMEs practicing climate resilient agricultural activities. The total direct and indirect beneficiaries are 373,720 people.		disasters. The project strategy addresses barriers to adaptation around low technical and institutional capacity and awareness of adaptation and low access of the largely subsistence farming population to improved methods and finance.
Paradigm shift rationale	This will be the world's first climate change fund focused on agri-business. This will enable Acumen to develop a strong track record in climate resilient agriculture and will enable Acumen to raise larger, future funds to invest in companies that are aligned to climate goals. By investing in for-profit companies, ARAF will be creating financial sustainable companies that are able to grow and attract other investment capital. It is anticipated that ARAF success in the sector will catalyse investor confidence in the sector and attract higher leverage ratios for GCF investment in future.	The AFAWA programme is built as a pilot initiative and precursor for similar programmes to be replicated in the future in Ghana and elsewhere in Africa. These future investments are expected to be supported from the AfDB huge climate change adaptation and mitigation costs estimated to be over US$1.5 billion. It will contribute to climate resilient development pathways through unlocking and unleashing the productive potentials of women to participate in low carbon growth and climate resilient agricultural practices. The shift will be achieved and sustained through the provision of innovative financing to LFIs to lend to women-owned agribusiness enterprises on Climate Resilient Agriculture (CRA) activities in Ghana. It will contribute to low-emission	The project will shift paradigm by enabling communities to generate revenue from sustainable forest management from the CREMA model which has not been done in the past at scale and in a robust manner. Furthermore, the involvement of the Global Shea Alliance (GSA) will help build experience that can later be scaled up and used in the development of a regional shea landscape programme. There is a paradigm shift in demonstrating that restoration (tree planting) can be achieved at scale for shea, especially in the large savannah landscape currently prone to desertification and land degradation. By restoring shea landscapes, communities will be generating emission reductions which will be eligible for future payments. In the meantime, community investment funds can be created or strengthened supplied by revenue from community forest management and shea	The model can be replicated in 43 Districts in the Northern Savannah zone and the experience can inform fiscal decentralization processes and mechanism from central government to the District Assemblies, supported by National Adaptation Planning processes. The technical capacity and understanding of regional and district institutions to plan for and implement climate change adaptation will be strengthened. The project will create an enabling environment for the Government of Ghana to replicate and maintain project activities after the initial investment period, through the integration of climate change adaptation into regional and district medium-term development plans. The project will also help to address market failure regarding access to finance for smallholder farmers by investing in Farmer-based Organisations and their financial management capacity,

		sustainable development pathways through (1) use of clean and renewable energy along the entire agricultural value chain and agribusiness ventures; (2) use of sustainable agricultural intensification strategies to reduce GHG emission from agriculture. The benefits of the programme will be amplified by the Ghana Incentive Based Risks Sharing Facility for Agricultural Finance (GIRSAL) which is expected to underwrite some of the projects financed on either a pro rata or first loss basis. If successful, this may also change attitude of banks and investors in Ghana towards agriculture and revolutionize financing for agriculture in the country.	collection, processing and sale that will be available for further development for community needs, which will continue into the future.	and by linking to value chains and the Ghanaian financial sector for loans and insurance. The implementation of climate-resilient agricultural practices (Activity 2.3) is expected to generate consistently higher incomes for smallholder farmers, allowing them to finance adaptation interventions once the project has finished. Links to the on-going AFAWA GCF investment will be explored during the PPFA.

11 Best practices and lessons learned

Climate change is threatening the livelihoods of vulnerable communities in northern Ghana. To build their resilience and elicit transformational change in the Ghanaian agricultural sector, rural communities need to adapt to the threats that have been identified above (Section 5) in a manner that is locally appropriate and effective. The best way to ensure that adaptation interventions are suitable for Ghana is to draw from the best practices and lessons learned from previous projects. The practices detailed below have been drawn from a range of local and international development projects (Section 9) and studies to guide the best practices for future projects. Additionally, stakeholder consultations with representatives from regional- and district-level government departments — as well as communities from the three northern regions and target districts — have provided insights on the local appropriateness of international best practices. By upscaling the successes of past and ongoing initiatives, the sustainability of future interventions can be ensured and the climate change-resilience of rural communities in northern Ghana effectively enhanced. The best practices and lessons learned are discussed in the sections below.

11.1 Foundational Support Initiative – promoting community engagement

The SLWMP provided a foundational support initiative, which ensured that project activities were needs-based, locally appropriate and supported by rural communities. Through this initiative, the training undertaken during and knowledge drawn from the implementation of SLWM intervention options served as a foundation on which upscaling and the design of further innovative interventions were encouraged. The success of such an initiative is reliant on environmental management committees for its promotion (see below), as well as intervention options that are locally applicable, encouraging the development of a needs-based project. This practice encourages community buy-in, effectively includes and uses traditional knowledge, and contributes to the long-term sustainability of project interventions.

11.2 Regional, District and Community Environmental Management Committees

Past and ongoing projects in northern Ghana have benefitted greatly from the formation of regional, district and community environmental management committees. The benefits of such committees include *inter alia*: i) improved stakeholder engagement, which includes the facilitation of meetings and social interactions to promote knowledge dissemination and training[582]; ii) a collaborative multi-stakeholder approach to implementation, which enables coordination, efficiency and the effectiveness of efforts across regions towards a common goal[583]; iii) the implementation and monitoring of environmental management plans[584]; iv) the integration of long-term climate change adaptation into regional and district development plans[585]; and v) the enforcement of environmental bylaws and regulations regarding natural resources.

11.3 EbA as a framework to integrate sustainable land management and climate change adaptation interventions.

Smallholder farmers around the world, including those in northern Ghana, are disproportionately vulnerable to climate change. Changes in temperature, rainfall and the frequency or intensity of extreme weather events directly affect crop and livestock productivity,

[582] UNDP. 2017. UNDP in Ghana: Africa Adaptation programme (AAP). Available at: http://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/project_sample.html
[583] Canadian Feed the Children. 2015. Project Results Summary: CHANGE.
[584] Canadian Feed the Children. 2015. Project Results Summary: CHANGE.
[585] Canadian Feed the Children. 2015. Project Results Summary: CHANGE.

which negatively influences food security, income and wellbeing of smallholder farmers[586]. In light of the observed and expected impacts of climate change, many governments, NGO's and multilateral organisations are actively promoting initiatives to help smallholder farmers become climate-resilient[587]. One of these initiatives is the implementation of EbA practices which can: i) increase the climate-resilience of smallholder farmers; and ii) strengthen the capacity of agro-ecosystems to provide goods and services.

EbA in agricultural systems involves the implementation of agricultural management practices that use or take advantage of biodiversity, ecosystem services or ecological processes to increase the capacity of crops or livestock to adapt to climate change[588]. Although many smallholder farmers around the world are already implementing EbA practices, there is still a tendency for many development initiatives to promote technologies that simplify smallholder farming systems, making them more vulnerable to climate change and/or market stresses[589]. The promotion of practices that are ecosystem-based can reverse this trend by encouraging farming systems that are not only resilient to climate change but also more ecologically and socially sustainable.

EbA practices have been proven to build the resilience of crops and livestock to climate change. These practices can be implemented from plot to landscape level. For example, on-farm management of genetic biodiversity — including the diversification of crop varieties or the inclusion of wild relatives — can ensure a broader source of crop resilience to the uncertain occurrence and effects of extreme weather events[590]. To be considered EbA practices, activities need to meet the criteria outlined in **Table 33** below.

Smallholders can benefit from EbA interventions in multiple ways beyond helping them adapt to climate change. Central to this is the provision of valuable ecosystem goods and services — including water, food, nutrient regulation, pest control and pollination — on which farming depends. Additional benefits of EbA practices include the diversification of agricultural production systems and generation of income. For example, the use of agroforestry in coffee, cocoa or cattle production systems can diversify revenue by providing timber, fruits, fuelwood and building materials[591]. Smallholder farmers can use these products to generate further income, especially in years when agricultural production is reduced as a result of climate change. These additional products reduce farmer vulnerability to market changes as well as their dependence on outside products, thereby improving food security.

[586] Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C & Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems and Environment.* 211: 126-132.
[587] FAO. 2013. Submission by the Food and Agriculture Organisation of the United Nations (FAO) on the Support to Least Developed and Developing Countries in the National Adaptation Plan Process Regarding the Integration of Agriculture, Fisheries and Forestry Perspectives. Available at: http://unfccc.int/resource/docs/2014/smsn/igo/150.pdf
[588] Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C & Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems and Environment.* 211: 126-132.
[589] Eakin H. 2005. Institutional change, climate risk, and rural vulnerability: cases from central Mexico. *World Development.* 33: 1923–1938.
[590] Ratnadass A, Fernandes P, Avelino J & Habib R. 2012. Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for Sustainable Development.* 32: 273–303.
[591] Rice RA. 2008. Agricultural intensification within agroforestry: the case of coffee and wood products. *Agriculture, Ecosystems and Environment.* 128: 212–218.

Table 33. Summary of three main dimensions and underlying criteria that agricultural practices need to satisfy to be considered EbA practices that are appropriate for smallholder farmers. Practices that fulfil at least one criterion in the 'ecosystem-based' and 'adaptation benefits' dimensions can be considered EbA practices. Practices that also fulfil at least one criterion in the third dimension are EbA practices appropriate for smallholder farmers[592].

Dimension 1: ecosystem-based	Dimension 2: adaptation benefits	Dimension 3: livelihood security
• Is based on the conservation, restoration and sustainable management of biodiversity. • Is based on the conservation, restoration and sustainable management of ecosystem services and processes.	• Maintains or improves crop, livestock or farm productivity in face of climate change. • Reduces the biophysical impacts of extreme weather events on crops, animals or farming system. • Reduces crop pest and disease hazards as a result of climate change.	• Strengthens food security of smallholder households. • Increases or diversifies income generation of smallholder households. • incorporates traditional or local knowledge of smallholder farmers. • Uses local, available and renewable inputs. • Requires implementation costs and labour affordable to smallholder farmers.

Past and ongoing projects in northern Ghana have been disjointed in that many interventions have not been linked. By grouping interventions under EbA, the resulting benefits will be aligned with both development and climate-resilience objectives. For EbA to be scaled up in northern Ghana, it is important to promote the adoption of EbA practices in the appropriate farming systems and contexts. This will encourage the continued use of these practices in areas where farmers are already using EbA approaches and also reduce the ongoing loss of biodiversity and ecological integrity within farming systems. The use of EbA practices by smallholder farmers in northern Ghana can be promoted and upscaled through a multi-sectoral approach which includes those listed below.

- The improvement of understanding and scientific evidence for the long-term effectiveness of different EbA practices in enhancing the resilience of crops, livestock and farming systems under climate change conditions[593].
- The identification of EbA options that are most appropriate for smallholder farmers living in different socioeconomic and agroecological contexts, as the relative merits and drawbacks of individual practices are often context-dependent[594].
- The restructuring of current, and the development of new, agricultural and climate change policies. These policies should be clearly defined and must promote actions that, while achieving production targets, also maintain the capacity of agro-ecosystems to provide services and help improve farmer livelihoods.
- The promotion of EbA by the GoG and development organisations through a combination of policies, incentives, training, capacity-building and technical support. Smallholder farmers will then have both the necessary resources and the required knowledge to make informed decisions about how to adopt and effectively use EbA practices.
- The GoG investing more in strengthening and providing support to extension programmes, farmer field schools, agricultural technical programs and universities. Initiatives should ensure that the curricula and outreach activities of these programmes include EbA practices. Many countries have dismantled or significantly reduced their extension

[592] Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C & Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems and Environment.* 211: 126-132.
[593] FAO. 2013. Submission by the Food and Agriculture Organisation of the United Nations (FAO) on the Support to Least Developed and Developing Countries in the National Adaptation Plan Process Regarding the Integration of Agriculture, Fisheries and Forestry Perspectives. Available at: http://unfccc.int/resource/docs/2014/smsn/igo/150.pdf
[594] Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C & Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems and Environment.* 211: 126-132.

programs[595], yet the need for such support — especially for smallholder farmers facing the impacts of climate change — is greater than ever[596].

- Greater investment in extension services is needed to ensure that smallholder farmers have access to best available information on EbA strategies and can make informed decisions about their farming systems. This will increase the uptake rates of EbA practices.
- The establishment of innovative multi-sectoral alliances — for example, among farmers, NGOs, government departments, scientists, universities and the private sector — can play a valuable role in supporting extension services and helping to promote effective EbA practices[597].

11.4 Importance of integrating gender considerations into project interventions

It is generally recognised that the ability of women to adapt to climate change is dependent on their: i) involvement in policy development and decision-making; ii) integration into local committees that are focused on climate change adaptation — including EbA; and iii) capacity to implement adaptation practices[598]. Moreover, the actions that women can take depend on the strength of their networks, particularly gender-focused climate change organisations. The empowerment of women in all aspects of climate change adaptation — including access to relevant information, skills and adequate resources — is essential to them becoming climate-resilient. Shifts in gender roles and increases in women's contributions to household incomes have been shown to lead to greater respect and recognition for women in Ghana[599].

The *CARE Adaptation Learning Program* identified that in most cases, a dynamic approach to gender is needed to effect sustainable change. This requires an analysis of gender dynamics across communities to explore how gender power relations give rise to discrimination, subordination and exclusion of people in society[600]. Gender analysis ensures that gender is understood as an important factor influencing climate vulnerability and adaptive capacity and contributes to a deeper understanding of context-specific challenges to adaptation. Initiatives should therefore not address women as a single homogenous group but should instead challenge assumptions about women and consider them as individuals who are able to contribute considerably to adaptation practices. This is best done using a participatory approach that guides the understanding of individual and institutional aspects governing control over, access to, and use of resources in their communities. Vulnerable groups are thus enabled – including women – to take practical action to adapt to climate change. Central to this is working with men as well as women to address the structural inequalities and power dynamics in the agricultural sector, taking into account the opinions and influence of women. Moreover, initiatives should anticipate and avoid negative consequences of challenging gender roles, such as increased domestic violence, social stigmatisation or marginalisation. This can be achieved by working with those in power to seek long-term systemic change and improved governance to advocate that they address inequality and strengthen the adaptive capacity of vulnerable groups[601].

[595] Chang HJ. 2009. Rethinking public policy in agriculture: lessons from history, distant and recent. *Journal of Peasant Studies.* 36: 477–515.
[596] Porter JR, Xie L, Challinor A, Cochrane K, Howden SM, *et al*. 2014. Chapter 7: Food security and food production systems. In: Aggarwal P & Hakala K (eds). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, New York.
[597] Munang R, Andrews J, Alverson K & Mebratu D. 2013. Using ecosystem-based adaptation to address the social dimensions of climate change. *Environment*. 56: 18–24.
[598] Gaye I. 2009. Gender and climate change: Women matter. UN Economic Commission for Africa.
[599] Webb J. 2015. Gender dynamics in a changing climate: how gender and adaptive capacity affect resilience. *Care Climate Change.*
[600] Otzelberger A, and Ward, N. 2016. Understanding gender in community-based adaptation: Practitioner brief 3. *Care Climate Change.*
[601] Webb J. 2015. Gender dynamics in a changing climate: how gender and adaptive capacity affect resilience. *Care Climate Change.*

Village Savings and Loans Associations (VSLA) are another useful tool for economically empowering women and raising their social and political status. These microfinance programs are based on the practice of group savings, where members of a community pool their savings and this pool then becomes available for loans within the community. The interest generated through these loans grows the initial capital and increases the capacity of the VSLA to provide additional loans. By providing money when needed most, VSLAs can have a major impact on health, education, GDP growth and employment within a community, ultimately improving livelihoods and building the adaptive capacity of vulnerable groups[602]. In Ghana, VSLAs have enabled women to access credit, empowering them to increase their agricultural productivity. This has caused a positive shift in respect for women, with empowered women beginning to be seen as a benefit to their households and communities[603], ultimately leading to greater access to land for women. Additionally, access to loans through VSLAs increases opportunities for women to start businesses and improves the profitability of such businesses[604], thereby improving livelihoods and increasing adaptive capacity.

Gender considerations should also be accounted for in the post-harvest processing of agricultural produce during the project planning phase. Post-harvest processing systems can be diverse, depending both on the type of the products being processed and on the culture of the local community. The implementation of climate-resilient post-harvest processing techniques leads to increased agricultural outputs and higher quality products which can then be sold at premium prices at local markets[605]. However, training and equipment are required to make these techniques accessible to communities. The *Post-Harvest Handling and Storage*[606] project in Rwanda demonstrated that the inclusion of at least 50% of women in training programs significantly reduced post-harvest losses. This is because the majority of post-harvest activities are already performed by women.

11.5 The promotion of autonomous upscaling of project interventions through knowledge sharing between beneficiary and neighbouring communities

Past and ongoing climate change adaptation projects in northern Ghana have demonstrated that the autonomous upscaling of project interventions was prevalent at the intra-village/community level, but not at the inter-village/community level. Reasons for this may include: i) interventions being implemented in isolated villages and communities; and ii) limited methods and opportunities for knowledge sharing.

The strategic selection of project intervention sites in areas of northern Ghana — where communities/villages are located close enough to one another to ensure contact between community members — is imperative for autonomous upscaling. Meetings to promote knowledge-sharing between beneficiary and neighbouring communities can then be facilitated. These meetings can include: i) the viewing of films which highlight EbA intervention benefits and share the testimonies of beneficiary community members; ii) the direct sharing of knowledge gained and consequent discussions on interventions; and iii) training sessions facilitated by beneficiary community members. Moreover, farmers from neighbouring communities will also have opportunities for discussion when selling their produce at local markets.

Autonomous upscaling of agricultural EbA interventions can also be promoted through the establishment of demonstration plots in both beneficiary and neighbouring communities. The

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[602] Care 2016. Briefing Paper to the United Nations High Level Panel on Women's Economic Empowerment Working Group on Financial, Digital Inclusion and Property Available at:
http://www.care.org/sites/default/files/documents/care_briefing_paper_to_the_un_hlp_working_group.pdf
[603] Webb J. 2015. Gender dynamics in a changing climate: how gender and adaptive capacity affect resilience. *Care Climate Change.*
[604] http://www.care.org/work/economic-development/microfinance
[605] Van Dusen A, and Beyard K. 2013. Post-Harvest Handling and Storage (PHHS) Project. *USAID Rwanda*.
[606] Van Dusen A, and Beyard K. 2013. Post-Harvest Handling and Storage (PHHS) Project. *USAID Rwanda*.

use of demonstration plots to highlight the advantages of climate change-resilient seed varieties was both popular and successful in several of the past and ongoing projects in northern Ghana. Funding does, however, should be allocated for implementation and monitoring of plots. If implemented correctly and upscaled autonomously, there can be major advances in the strengthening of rural food security. Demonstration plots can also be used to research drought-resistant seeds and crop varieties, such as the Climate Seed Knowledge (CSK) initiative implemented as part of the CHANGE project[607].

[607] Canadian Feed the Children. 2015. Project Results Summary: CHANGE.

12 Recommended adaptation interventions

12.1 Introduction

This Feasibility Study has shown that local communities in the northern regions of Ghana are vulnerable to numerous threats associated with climate change. Shifting rainfall patterns and rising temperatures will lead to a longer dry season and a shorter and more intense wet season. In northern Ghana, these changes in climate are likely to have an array of negative effects on the livelihoods of local communities. The agricultural sector, particularly with regards to smallholder farmers, will be the most impacted. Changes in rainfall and temperature regimes are expected to further reduce already suboptimal crop yields and consequently threaten food security and income generation of the country's most vulnerable people. Without effective adaptation action, it is likely that northern smallholder farmers will remain vulnerable to the current and future effects of climate change, with serious repercussions for the northern and Ghanaian economy. A recommended approach to climate change adaptation for northern Ghana is described below, detailing appropriate interventions strategies.

12.2 Recommended overall approach

12.2.1 <u>An integrated approach to climate change adaptation in northern Ghana through Ecosystem-based Adaptation</u>

The effects of future climate change are expected to exacerbate the current problems in these systems through, *inter alia*:

- increased frequency and severity of floods – particularly in areas near rivers – that will lead to soil erosion, major crop losses and damage to agricultural infrastructure, including post-harvest storage and irrigation facilities;
- increased frequency and intensity of droughts leading to, among other things: i) increased frequency in the drying-up of surface water bodies such as dams and streams; and ii) a decline in agricultural productivity as the ability of small-scale farmers to engage in dry season gardening is reduced;
- shortened agricultural production period resulting in decreased crop yields and income as the number of achievable wet season cropping cycles and harvests of non-timber forest products (NTFPs) from agroecosystems are reduced;
- pushing common northern Ghanaian crop and livestock varieties beyond their optimum thermal limits and expanding the range ranges of weeds and pests as previously cooler areas warm-up;
- elevated soil erosion and loss of soil nutrients leading to decreased crop yields and increased pollution and eutrophication of water bodies; and
- more frequent and severe uncontrolled bushfires resulting in the destruction of crop fields – particularly of the dry mature crop – and reduced capacity of agroecosystems to provide critical ecosystem services such as NTFPs, forage, soil stabilisation and flood mitigation.

Ecosystem-based Adaptation (EbA) is defined as adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach[608]. EbA provides a cost-effective and low-risk approach for: i) increasing the climate-resilience of smallholder farmers; ii) conserving the capacity of agro-ecosystems to provide goods and services; and iii) implementing interventions that build climate resilience even when climate impacts are uncertain. Given the dependence of smallholder farmers on ecosystem goods and services, as well as uncertainty regarding future changes in climate, it is recommended that an EbA approach be implemented to enhance the climate resilience of northern Ghanaian farmers to drought and flood risks and to reduce the risk of disasters. For a detailed description of EbA, see Section 10.3.

[608] Vignola R., Locatelli B., Martinez C., Imbach P. 2009. Ecosystem-based adaptation to climate change: what role for policymakers, society and scientists? Global Change 14:691–696.

12.2.2 Community-level action plans, community engagement and a menu of climate change adaptation interventions.

Community engagement is important to ensure that adaptation interventions are locally appropriate and supported by the beneficiary communities. In order to build local support for project initiatives it is necessary to develop community-level climate change action plans. Defining a climate change action plan at the community level reduces the potential for conflict or disagreements within communities over new approaches being adopted. The community-level action plan validates the most relevant and appropriate adaptation interventions, for a particular community, from a menu of appropriate climate change adaptation interventions that align with the mandate of the plan.

A community engagement initiative (see Section 10.1) encourages farmers and Farmer Groups to implement, upscale and modify a range of needs-based and locally appropriate EbA interventions in northern Ghana. This approach contributes to the long-term sustainability of project interventions by: i) encouraging community buy-in and ownership of interventions; ii) effectively including and using traditional knowledge; and iii) accounting for local variations in climatic conditions among beneficiary communities.

An extensive and dynamic menu of interventions should detail all available climate change adaptation interventions supported by the project (see Section 11.4). Communities will then be able to identify and validate specific interventions suited to their individual needs and use the skills and training derived from their implementation as a foundation to support future upscaling and the innovative design of further locally appropriate interventions. Additional support including training, demonstrations, supervision and agricultural inputs should be provided by environmental management committees (see Section 10.2). This support will ensure the informed, effective and sustainable implementation of interventions. The continuation of this support will be dependent on the meeting of criteria outlined in an agreement signed by the farmer and environmental management committee. The continued support may include training, guidance and agricultural inputs (depending on the capacity and resources of environmental management committees) needed to: i) implement later stages of the intervention; ii) expand the area under the intervention; and iii) support additional climate-resilient livelihoods linked to the intervention.

12.2.3 Strengthening institutional structures to promote coordination and collaboration in development planning.

Inter-disciplinary and multi-sectoral coordination and collaboration during the planning and implementation phases of climate change initiatives are essential for upscaling, transformational change and sustainability. Municipal and District Assembly planning processes should be strengthened to create awareness of the impacts and risks of climate change on development sub-programmes and to develop capacities to analyse and identify preferred adaptation strategies as well as to develop investment plans and track implementation progress. That way full and effective use can be made of inter-governmental transfers for local development planning.

Regional, District and Community Environmental Management Committees (REMCs, DEMCs and CEMCs, respectively) – established during the GEMP – provide a solid platform around which to build institutional understanding and action for climate change adaptation. These committees fall under the EPA and are responsible for governance and implementation of environmental management programmes at their respective levels. At the highest level, the REMCs report to the EPA regional offices and provide support for the governance of NAP programmes at the district and community levels. DEMCs form part of the District Assembly (DA) and are responsible for environmental issues related to the NAP, providing guidance and support to environmental management programmes at the community level. CEMCs are then responsible for on-the-ground implementation of environmental programmes of the DA, including planning, budgeting, supervision, monitoring and evaluation.

Each of northern Ghana's three regions has a single REMC, with numerous DEMCs and CEMCs falling under them. In the Northern Region, a total of 20 DEMCs and 135 CEMCs have been established, while in the Upper West Region, 10 DEMCs and 43 CEMCs are in place. The Upper East region has the smallest number of CEMCS at 32, with 13 DEMCs.

12.2.4 Access to finance

The project should increase the capacity of the most vulnerable smallholder farmers to aggregate through farmer-based organisations (FBOs) and to strengthen financial management capacity, as well as to connect to value chains which would facilitating linkages to agricultural credit and insurance. The implementation of climate-resilient agricultural practices will generate consistently higher incomes, allowing them to finance climate resilient agriculture beyond the project grant. Strengthening the aggregation and bankability of smallholder farmers will facilitate engagement between FBOs and local financial institutions to improve access of beneficiary communities to credit and insurance products. Several LFIs in Ghana, including Agricultural Development Bank and EcoBank[609], run outreach programmes that assist farmers in accessing credit. These programmes: i) help farmers to establish organisations/cooperatives; ii) provide financial management training; and iii) take farmers through the loan application process. However, these programmes tend to focus on central and southern Ghana where agricultural production is higher and there are more commercial farming operations. The project should work with relevant LFIs to extend these services to beneficiary communities in northern Ghana. Connecting smallholder farmers to the national banking system will enable the possibility of connecting to international capital from impact funds.

Potential agribusiness companies for value chain development include:

- Ghana Nuts Ltd (https://www.ghananuts.org/) which is one of the leading agro processors in Ghana, and manufactures and export a huge range of edible oils in the shea and soya value chains as well as animal feed meals;
- Esoko (https://esoko.com/) which provides smallholders with access to inputs and finance through a virtual marketplace, while driving business for input dealers and financial service providers. Esoko seeks to increase farm level productivity; access to climate-smart agricultural information to aid in farm level decision making and climate resilience; digital transactional records that ensure digital and financial inclusion to farmers;
- Agriaccess Ghana Ldt (https://www.agriaccessgh.com/) working to bring about change in the agricultural sector through input support to smallholder farmers, job creation, commodity trading and post-harvest management with focus on maize, soya, sorghum and peanut value chains;
- Faranaya Agribusiness Ldt (https://www.agdevco.com/our-investments/by-investment/Faranaya-Agribusiness-Centre-Ltd) – This is a top-quality sorghum company and the supply to the leading brewery, Guinness Ghana Breweries Ldt. This company is flexible and prepare to change and seeks to bring about changes in the agricultural landscape through smallholder input support, commodity trading and post-harvest management;
- Bunge Loders Crokhaan Industries Ldt - (https://www.dnb.com/business-directory/company-

[609] Based on interviews with representatives from ADB and EcoBank.

profiles.bunge_loders_croklaan_industries_limited.73768213d5f41305f8eee3861f93345d.html) – this company is part of the wholesale sector industry and dwells in nuts and nut by-products, cocoa butter, essential cooking oils and cooking oils, except corn; and

- Savannah Fruit Company Ldt (https://www.savannahfruits.com) - focuses on the sustainable production and export of high quality, community processed natural products to the international edible and cosmetic markets. SFC practices a socially and environmentally responsible business and ensures value addition at source is maximized. The source organic shea nuts in conservation areas while ensuring biodiversity conservation.

12.2.5 Autonomous upscaling

Considering financial limitations on adaptation projects, direct interventions are generally restricted to specific beneficiary communities. Therefore, for adaptation to be effective on a regional scale across northern Ghana, it is necessary for interventions to be upscaled beyond the initial scope of the project. This is best achieved through the promotion of autonomous upscaling. This is where the structures put in place for the implementation of interventions in a specific community and the knowledge made available to those communities are designed so that they can be easily taken up by neighbouring communities without the need of project support. For this to be achieved, several factors need to be considered in project design.

Firstly, the beneficiary communities need to be interconnected with surrounding communities. If project interventions are applied in remote communities, there is limited scope for information and extension services to be extended beyond the target community. However, if the selected communities are adequately connected with surrounding communities (through shared markets and organised meetings), the services made available and the lessons learned from interventions can easily be shared between communities.

Secondly, interventions need to show noticeable benefits that will generate interest with surrounding farmers. For example, if an intervention is seen to noticeably improve the productivity of agricultural land, surrounding farmers will be more inclined to implement similar interventions on their own land. This again links to the interconnectivity of beneficiary communities, as interventions need to be accessible for them to be noticeable to non-beneficiary farmers.

Thirdly, the cost of interventions should be minimised to make implementation feasible outside of grant-financed projects. If interventions are too costly, farmers may be unable to finance their implementation. This problem can also be overcome by the establishment of micro-loan institutions to finance such projects.

Finally, an enabling environment needs to be created in the form of regional policies and institutions that promote the adoption of EbA interventions. The establishment of cross-sectoral institutional frameworks at all levels of governance – national, regional, district and community levels – will enable the sharing of knowledge and technical capacity extension services for the implementation of EbA. Such regional institutional frameworks are also important for the fair distribution of knowledge between farmers, as individual farmers may withhold lessons learned to prevent competition from other farmers who may benefit from similar interventions.

12.2.6 Knowledge management and long-term monitoring.

Effective knowledge management – including the generation, collection, handling and dissemination of information – is an important aspect of climate change adaptation initiatives. Access to current and detailed information on climate trends and adaptation interventions is essential for stakeholders at all levels of a project, including: i) government institutions; ii) district extension officers; and iii) farming communities. The first component to address is the generation and collection of relevant information. Long-term M&E of ongoing projects provides a means of assessing the effectiveness of adaptation initiatives, helping ensure the long-term sustainability of interventions. Furthermore, the information gathered, and lessons learned from M&E can improve awareness and the development of best practices for future initiatives. Academic and research institutions should be involved in the M&E process to provide a stable and long-term knowledge generation programme that is beneficial to all parties involved. Government institutions should play a role in the coordination of information-gathering activities and ensure the proper management of data, allowing for its effective dissemination. Additionally, government institutions can convene knowledge-sharing conferences on climate change, allowing stakeholders to actively engage one another, share information and establish working relationships. This will lead to improved M&E and greater coordination in the generation and sharing of information.

Once data is collected, systems should be improved for the handling and management of information on a national level. Information on climate trends, national policy and adaptation options should be made available in a centralised location that is easily accessible to all stakeholders. An online platform, such as Ghana's Climate Change Data Hub, provides an ideal system for the management of data in the country. The institutions responsible for the handling of climate information should be adequately trained (see Section 11.2.6) to deposit the information onto the data hub and keep all information relevant and up-to-date. Furthermore, the content of the hub should be restructured and extended to include details of: i) past and ongoing climate change adaptation interventions; and ii) practical adaptation interventions. This will make the relevant information more accessible to end-users.

Finally, the dissemination and sharing of information should be addressed. While the online data hub provides a solid platform for the dissemination of knowledge, not all end-users have adequate access to online resources. Alternative methods for raising awareness and sharing information should therefore be introduced to make this information accessible to rural communities (see Section 11.2.6).

12.2.7 Training on the integration and implementation of EbA interventions.

For climate change adaptation to be effectively integrated into development initiatives in northern Ghana, training from the national- to the community-level is necessary. National, regional and district level staff from the relevant institutions, including the EPA and Department of Agriculture (DoA), should receive training on *inter alia*: i) the effects of climate change; ii) benefits of climate change adaptation – including EbA to improving the climate-resilience of rural communities; iii) integrating climate change into development plans and implementing climate change adaptation initiatives; and iv) M&E of interventions. This training will not only enable staff to effectively implement adaptation interventions but will also support the integration of climate change adaptation into national and regional development plans. Such training can be carried out via in-house workshops, courses and demonstrations presented by experts from these departments and academics from local universities.

Once trained and equipped to integrate climate change adaptation into the planning and implementation of local development initiatives, EPA and DoA staff will then have the capacity to transfer the knowledge and skills gained to staff and members of DAs, REMCs, DEMCs and CEMCs. DA staff that would receive training include environmental, coordinating, budgeting and planning officers. This training will increase the capacity of the DAs to include climate change considerations into future medium-term district development plans. Similarly, REMCs will be strengthened in their capacities to oversee and coordinate regional activities related to climate change adaptation initiatives. DEMCs and CEMCs will also be equipped to handle the planning, implementation and monitoring of climate change projects and programmes at the district- and community-levels respectively. Such training should be carried out in the relevant regions, districts and communities through workshops, training courses, demonstrations and meetings.

To ensure that the district extension officers are prepared to facilitate the implementation of climate change adaptation and EbA interventions at the community level, extension officers within the targeted districts should receive training on: i) climate change adaptation and EbA; ii) development of community climate change action plans; iii) the implementation of a menu of climate change adaptation interventions; and iv) how to train smallholder farmers to implement the menu of climate change adaptation interventions.

Training programmes should be designed and conducted by appropriate national departments within the GoG, particularly the EPA, Department of Agriculture and Extension Services Division. The training should build on existing extension service manuals and guidelines.

Once trained and equipped, extension officers will be equipped to lead workshops, training meetings and demonstrations in target communities. Demonstrations will equip farmers technically and practically and will highlight the advantages of climate change adaptation interventions over some of the traditional farming techniques. Such demonstrations and training will ensure that smallholder farming communities are fully aware of: i) relevant climate change impact pathways ii) the objectives of the climate change adaptation interventions; iii) their responsibilities within the interventions; and iv) the implementation and function of all of the interventions provided in the menu of climate change adaptation interventions with regards to enhancing climate-resilience. Extension officers should also identify special interest groups within the communities and provide them with targeted training on specific adaptation technologies from the menu of climate change adaptation interventions.

Apart from training communities on the benefits and implementation of climate change adaptation interventions, it is recommended that training on basic business and financial management is also provided. This will allow them to optimally manage income generated from increased yields, along with post-harvest storage and processing. Furthermore, training on the establishment and advantages of village savings and loans associations (VSLAs) will provide beneficiary communities with financial services that were previously unavailable to them. These financial services will help improve the long-term sustainability and upscaling potential of initiatives.

12.2.8 Enhancing climate change adaptation knowledge and awareness of rural communities.

Non-beneficiary communities should also be exposed to the climate change adaptation interventions being implemented in other parts of northern Ghana to generate awareness and initiate transformation change of smallholder farming in the region. This can be done through the organisation of knowledge-sharing and awareness-raising events. For example, field visits by non-beneficiary farmers and extension officers from non-target districts to farms where climate change adaptation interventions have been implemented will expose them to the practical benefits of climate change adaptation interventions and EbA. Such visits could include demonstrations and the sharing of testimonies by beneficiary farmers. Furthermore, attendees should be provided with basic theoretical and practical training on the implementation of adaptation interventions through both physical demonstrations and the provision of practical implementation guides which include simple “how to implement” instructions on all of the available interventions. Such events will enhance interest in the benefits of climate change adaptation in non-target communities, which will promote the autonomous upscaling of interventions.

Awareness in northern Ghana can also be enhanced via the broadcasting of information through phone-in radio and video-documentaries. These shows would: i) disseminate knowledge on the threats of climate change; ii) provide information on climate change adaptation methods; and iii) serve as a platform for extension officers and farmers to share success stories and give advice. Furthermore, such broadcasts have the potential to reach communities that are participating in other development initiatives that aren't specifically aimed at improving climate-resilience, allowing them to incorporate climate change adaptation techniques into their interventions. Consequently, the upscaling and replication of project interventions will be promoted in areas not directly targeted by initiatives.

12.3 Recommended geographies for intervention

12.3.1 <u>Selecting regions and districts for intervention</u>

Based on the CCV assessment (Section 2), it is recommended that adaptation interventions be directed to smallholder farming communities in the three northern regions of Ghana (**Figure 70**). As the most vulnerable region in the country to climate change, the Upper West Region should be given priority for adaptation support. It is suggested that the final selection of target districts should be based on comprehensive and transparent consultations with a variety of stakeholders at the national, regional and district levels. The selection process should consider which districts are currently receiving climate change adaptation support from other projects. Districts receiving support from the SLWMP and the Adaptation Fund project[610] – two relatively large climate change adaptation projects in northern Ghana (Section 9) – should receive less priority during the selection process than districts without support (**Figure 71**). It is suggested that those districts that are without support and have high relative CCV scores should be targeted for future adaptation intervention (**Figure 70**).

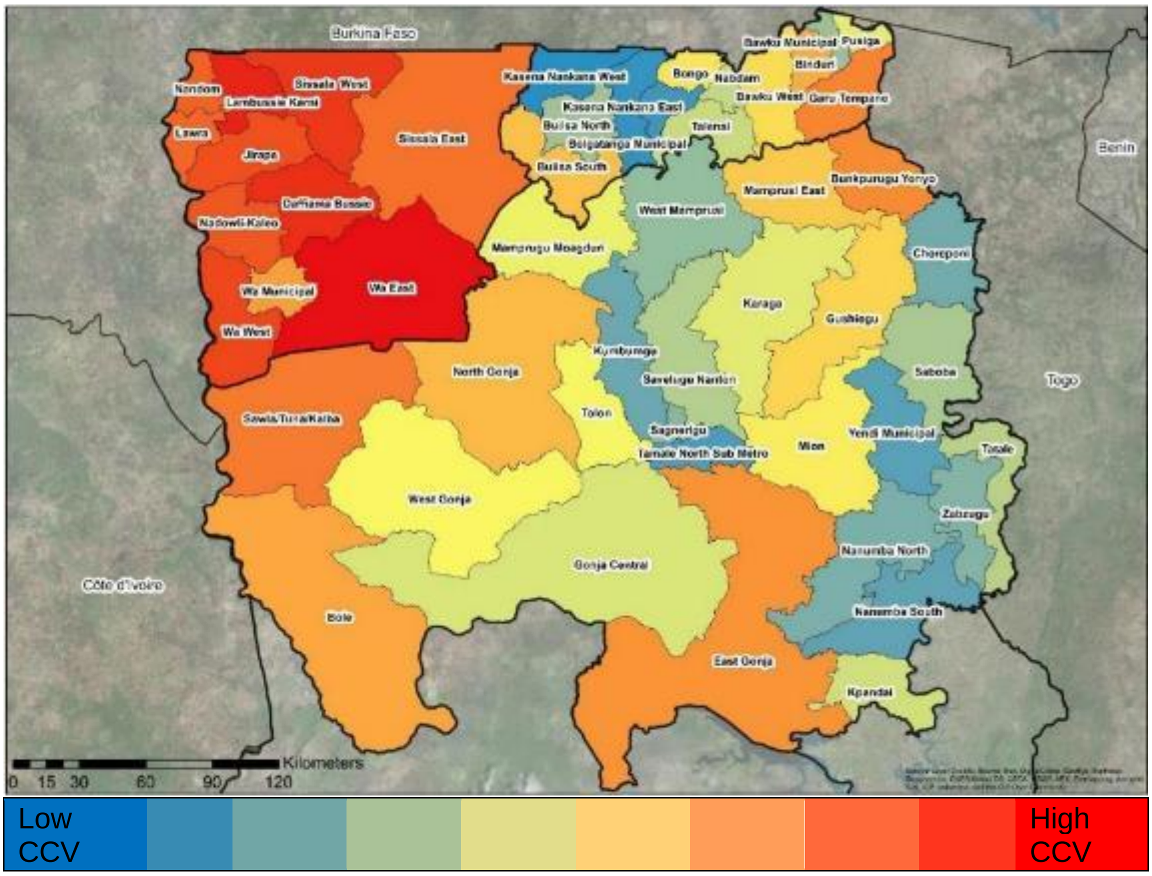

Figure 70. Map indicating the relative climate change vulnerability (CCV) of districts in northern Ghana.

[610] Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods.

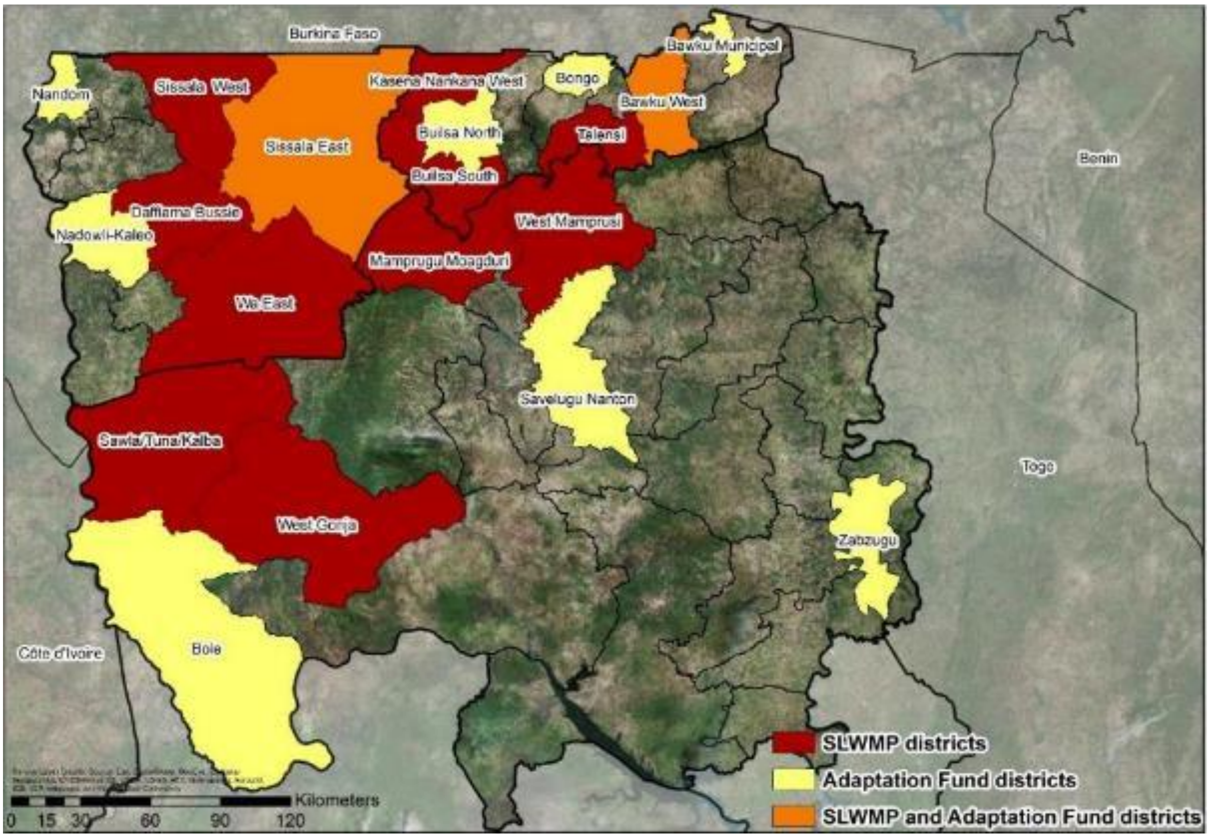

Figure 71. Districts in northern Ghana receiving support from the Sustainable Land and Water Management Project (SLWMP) and/or the Adaptation Fund project "Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods."

12.3.2 Selecting beneficiary communities

Beneficiary communities within target districts should be selected following a rigorous and nationally driven consultation process involving national, regional, district and community representatives.

During the selection process, priority should be given to communities that:

- are highly vulnerable to climate change. This should include high exposure to climate impacts (for example, located on the banks of a flood-prone river; located on sloped land prone to soil erosion and degradation), high sensitivity to a changing climate (for example, a large percentage of community members are farmers) and low adaptive capacity (for example, the community is poor with limited access to additional livelihood options). Priority should be given to those communities that can demonstrate recent negative impacts of climate change on the community;
- have a relatively high population (**Figure 72** shows the distribution of communities);
- are within 5 km of at least five other vulnerable communities with relatively high populations that could benefit from autonomous upscaling of adaptation interventions;
- have favourable land tenure arrangements; and
- express a willingness to participate.

Additionally, it is recommended that beneficiary communities be selected in a manner that ensures a representative geographic coverage across each target district.

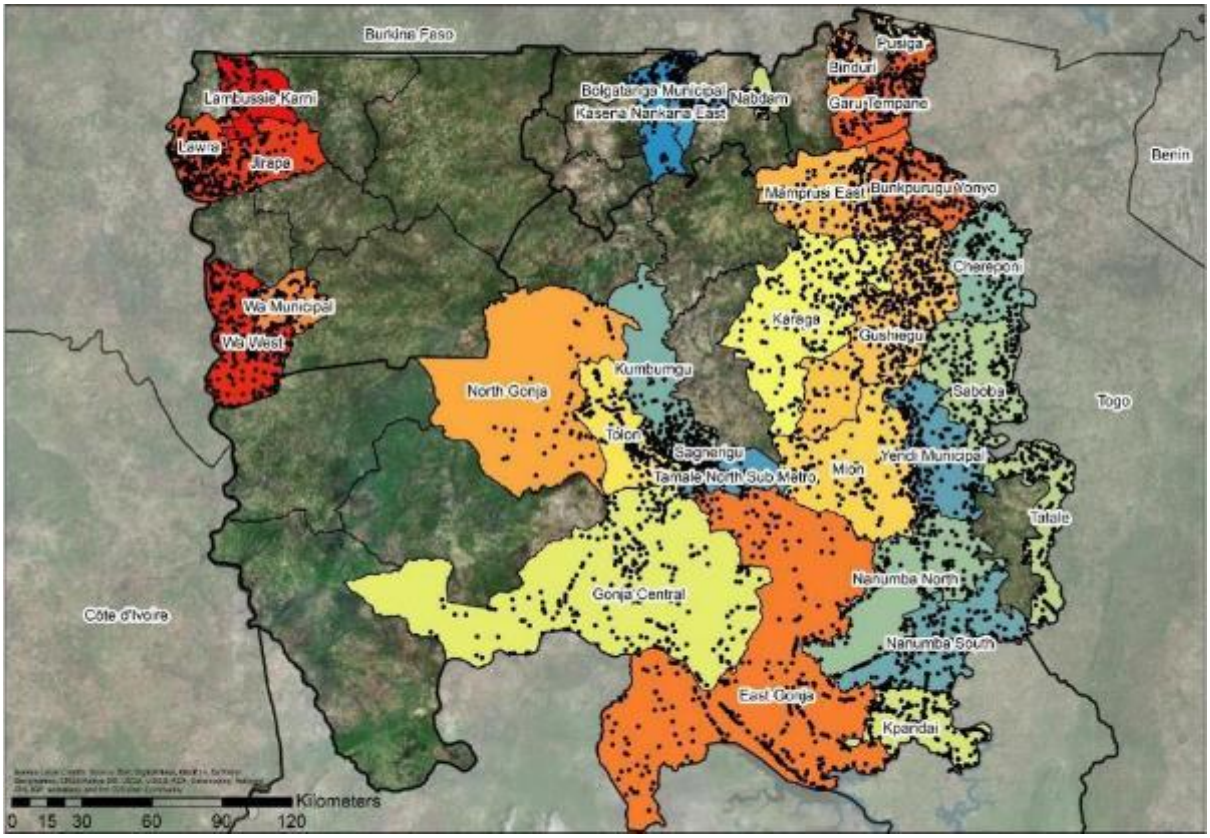

Figure 72. Community distribution[611] in the districts of northern Ghana that are not receiving supporting from SLWMP or the Adaptation Fund project[612].

12.4 The suite of recommended climate change adaptation interventions

12.4.1 Climate-resilient Agriculture

Climate-resilient Agriculture (CRA) is an integrative approach that assists with the reorientation and transformation of agricultural systems to ensure food security and environmental sustainability in a changing climate[613]. In general, the agricultural interventions and technologies that contribute to CRA are not new and mostly reflect popular sustainable agriculture and intensification approaches. Under CRA, however, these interventions and technologies are evaluated for their capacity to achieve the above-mentioned outcomes given the observed and expected impacts of climate change. By promoting the sustainable use of ecosystems and their services to build the climate resilience of agricultural practices, CRA ties in well with the EbA approach to climate change adaptation.

Conservation Agriculture (CA) is one component of a CRA approach and is based on the integrated management of soil, water and biological resources, as well as external inputs. The approach aims to reduce soil erosion, sustain soil fertility, improve water-use efficiency and increase crop yields using three overarching farming principles, including: i) minimum soil disturbance; ii) organic soil cover; and iii) diversified crop rotations. These three principles of CA can be applied in a wide range of conditions and situations and align well with the principal of EbA. In the dry and degraded northern regions of Ghana, CA can be used to *inter alia*: i) maintain and/or enhance soil fertility and physical properties; ii) enhance the water-holding capacity of soils; and iii) keep soil temperatures constant. The CA component of CRA can

[611] Community distribution data were supplied by the Ghana Statistical Service.
[612] Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods.
[613] Definition from the Food and Agriculture Organisation of the United Nations.

increase the resilience of smallholder farmers in northern Ghana to the observed and predicted impacts of climate change by: i) reducing soil erosion and soil fertility loss during heavy rainfall events and floods; ii) enhancing soil moisture retention during elongated dry seasons and periods of drought; and iii) maintaining soil temperature conditions suitable for crop production during periods of elevated atmospheric temperature. By achieving the above, CA has the potential to enhance agricultural outputs and reduce commercial inputs of smallholder farmers in northern Ghana, even under considerable changes in climate. This will lead to increased agricultural profits and food security and reduce the unsustainable expansion of agricultural activities into natural areas.

Numerous CA interventions exist for assisting farmers to adapt to climate change. To build climate-resilience, CA interventions should target crops that contribute considerably to food security and income generation. In northern Ghana, these crops include: i) sorghum; ii) millet; iii) maize; iv) yams; v) cowpeas; vi) soybeans; vii) cassava; and viii) groundnuts. According to past and ongoing projects in Ghana and West Africa, the CA interventions described in the below section are the most appropriate for increasing the climate-resilience of smallholder farmers in the northern regions.

It is important to note that CA interventions seldom function optimally in isolation and, therefore, an integrated approach to implementation is recommended. Additionally, although the outcomes of CA are generally positive, several environmental and social issues may arise that constrain implementation or produce adverse results. For example, social and cultural attachment to bush burning as a method of land preparation may impede the uptake of a no-burning approach (see below) and the increase of crop pest and diseases as a result of on-field residue may deter slashing and mulching (see below).

12.4.1.1 Crop rotation and intercropping

Crop rotation involves rotating the type of crop that is planted in a specific field following a defined order. The rotation schedule can vary from one growing season to several years. Using this intervention, consecutive crops should belong to different families. For example, a field should first be planted with a cereal (e.g. maize, sorghum or millet), then with a legume (e.g. soybeans or cowpea), then with a root crop (e.g. cassava or yam), and finally again with a cereal. In some cases, vegetables such as tomato and eggplant may be included in the rotation. Crop rotations can: i) increase soil nitrogen levels through fixation of atmospheric nitrogen; ii) reduce pests and diseases in the cropping system by breaking pest/disease cycles; iii) control weeds by including smothering crop species; iv) improve soil quality by distributing nutrients evenly in the soil profile (i.e. deep-rooted crops transfer nutrients from deep to shallow soil profiles) and increasing biological activity; v) better distribute temporal labour requirements by staggering planting and harvest times; and vi) decrease food insecurity and income risks as poor growing seasons – or periods within growing seasons – may affect some crops but not others. Crop rotation can, therefore, overcome many of the shortcomings of monocultures, such as: i) increased crop-specific pests and diseases over time; ii) reduction in soil fertility in specific soil root zones; and iii) decreased root development and crop yields. It is important to note that rotations are generally not sufficient to maintain crop productivity and extracted nutrients must be replaced by inorganic and/or organic fertilisers. Crop rotation is particularly useful on flat land. The increase in yield of cereal crops farmed in rotation with legumes can be substantial. For example, the yield of sorghum following a groundnut rotation can average 30–40% higher than the yield of a sorghum monoculture in northern Ghana[614,615].

[614] Buah S. S. J. – 2004 – SARI Annual Report 2004. Savanna Agricultural Research Institute annual report – Upper West farming systems research group.

[615] Schmidt G. & Frey E. – 1992 – Cropping systems research at the Nyankpala Agricultural Experiment Station. In: Improving farming systems in the interior savanna zone of Ghana. Acquaye and NAES Ieds.) pp. 14–35.

Likewise, a maize-cowpea rotation can result in significantly higher maize yields compared with a maize monoculture[616].

Crop rotations can be combined with intercropping – the cultivation of two or more crops simultaneously on the same field – to optimise the enhancement of climate-resilience. The purpose of intercropping is to produce greater yields on a given piece of land by making use of resources (e.g. nutrients in different soil horizons) or ecological processes (e.g. mutualism) that would otherwise not be used by a single crop. Additionally, intercropping can reduce pest burdens as different crops are unlikely to share the same insect pests. Careful planning is required to ensure that intercropped species do not compete for physical space, nutrients, water or sunlight. Rather, intercropped species should benefit each other, thereby increasing the overall crop fitness which results in higher yields. For example, intercropping with a species that enhances soil moisture will be beneficial to other nearby crops. Different intercropping methods are appropriate in northern Ghana, including: i) multiple cropping – a form of polyculture whereby two or more crops are grown on the same piece of land in a single growing season; ii) relay intercropping – the growing of two or more crops on the same field with the planting of the second crop taking place after the first has completed its development; and iii) strip cropping – the growing of different crops on the same field but in alternate strips. Strip cropping is particularly effective on sloped land.

Intercropping has the potential to considerably reduce soil and nutrient loss through soil erosion compared with monocultures (**Table 34**). For example, where a field with a maize monoculture may lose ~10.93 Mg of soil and ~0.74 kg and phosphorus per hectare per year, a field with a maize-soybean intercrop only loses ~2.81 Mg of soil and ~0.14 kg of phosphorus per hectare per year (**Table 34**). Strip cropping is also an effective intercropping method for reducing soil and nutrient loss through soil erosion (**Table 34**). By constraining soil and nutrient loss, intercropping can markedly lessen yield losses and therefore loss of income. In a millet-sorghum strip cropping system, a farmer may only lose ~14.8 kg of millet and sorghum per hectare per year[617]. In a hand tillage[618] system – the traditional use of hoes and spades to prepare fields – also farming millet and sorghum, a farmer may lose ~39.2 kg per hectare per year[619]. Relative to a hand tillage system, strip cropping can save approximately 62% of crop productivity that would have otherwise been lost because of soil and nutrient loss[620]. This productivity saving can result in a ~62% income saving for farmers[621].

By reducing the amount of soil and nutrients removed from a field through soil erosion, intercropping can lower considerably the cost of fertilisers needed to replenish on-field nutrients (**Table 35**). For example, under a groundnut monoculture, a farmer would have to spend ~GH₵235.60 on Sulphate of Ammonia, ~GH₵10.50 on Triple Superphosphate and ~GH₵28.00 on Muriate of Potash every year to replenish lost soil nutrients (**Table 35**). Using a maize-groundnut intercrop, the same farmer only has to spend ~GH₵141.55, ~GH₵7.50 and ~GH₵19.80 on Sulphate of Ammonia, Triple Superphosphate and Muriate of Potash respectively per year (**Table 35**). This represents an approximate total reduction in potential fertiliser costs of 40% per year. Strip cropping can also substantially lessen yearly fertiliser costs compared with a monoculture (**Table 35**).

Crop rotations and intercropping can build the climate-resilience of smallholder farmers by increasing crop productivity during favourable climatic conditions and increase/maintain

[616] Horst W.J. & Hardter R. – 1994 – Rotation of maize with cowpea improves yield and nutrient use of maize compared to maize monocropping in an alfisol in the northern Guinea savanna of Ghana. Plant and Soil 160: 171–183.
[617] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[618] The use of hoes and spades to prepare fields. This is the
[619] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[620] Ibid.
[621] Ibid.

productivity during adverse climatic periods. This can lead to enhanced food security and income generation for smallholder farmers.

This intervention would contribute to disrupting potential impact pathways 1, 4, 5, 6, 8, 9 and 10 in **Figure 37**.

Table 34. The difference in soil loss and nutrient loss through erosion between bare soil, monoculture and intercropping systems[622]. Note: no bunding.

Cropping system	Soil loss (Mg ha^{-1} year^{-1})	Nitrogen (kg ha^{-1} y^{-1})	Phosphorus (kg ha^{-1} y^{-1})	Potassium (kg ha^{-1} y^{-1})	Calcium (kg ha^{-1} y^{-1})	P_2O_5 (kg ha^{-1} y^{-1})	K_2O (kg ha^{-1} y^{-1})
Bare soil	19.51	65.24	0.74	8.92	310.67	9.41	17.99
Monoculture							
Maize	10.93	31.30	0.35	4.28	149.05	4.45	8.63
Groundnut	8.59	26.08	0.29	3.57	127.19	3.69	7.20
Cowpea	5.46	20.87	0.24	2.85	99.38	3.05	5.75
Soybean	3.90	20.87	0.24	2.85	99.38	3.05	5.75
Intercropping							
Maize-Groundnut	5.46	15.65	0.18	2.14	74.52	2.29	4.32
Maize-Cowpea	6.09	12.54	0.14	1.70	59.71	1.78	3.43
Maize-Soybean	2.81	12.54	0.14	1.70	59.71	1.78	3.43
Strip cropping[623]	3.52	11.77	0.13	1.61	65.39	0.65	3.25

Table 35. The difference in cost of common fertilisers required for replenishing nutrients lost through soil erosion between bare soil, monoculture and intercropping systems[624]. Note: no bunding.

Cropping system	Sulphate of Ammonia (GH₵ ha^{-1} y^{-1})	Triple Superphosphate (GH₵ ha^{-1} y^{-1})	Muriate of Potash (GH₵ ha^{-1} y^{-1})	Total cost (GH₵ ha^{-1} y^{-1})
Bare soil	589.95	28.20	72.00	690.15
Monoculture				
Maize	283.10	13.50	34.00	330.60
Groundnut	235.60	10.50	28.00	274.10
Cowpea	189.05	9.00	24.00	222.05
Soybean	189.05	9.00	24.00	222.05
Intercropping				
Maize-Groundnut	141.55	7.50	19.80	168.85
Maize-Cowpea	113.05	6.00	14.00	133.05
Maize-Soybean	113.05	3.00	14.00	130.05
Strip cropping[625]	137.00	1.37	6.00	144.37

[622] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[623] Under a sorghum-millet intercrop.
[624] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[625] Under a sorghum-millet intercrop.

12.4.1.2 Slash and mulching

Slash and mulching is intended to replace the traditional practice of slash-and-burn agriculture. Instead of preparing fields by slashing on-field vegetation and burning it, slash and mulching involves slashing vegetation and leaving it on the field to dry and form mulch. The mulching process can: i) enhance biological activity in the soil; ii) increase rainwater infiltration which results in reduced surface runoff and enhances soil moisture; and iii) increase soil organic matter as the mulch material decomposes (**Figure 73**). To further enhance the positive effects of the approach, slash and mulching should be integrated with a minimum/zero tillage and direct-planting method. After a field has been slashed and the mulch left to decompose, a glyphosphate-based herbicide (e.g. Round-Up, Chemosate or Helostate) should be applied[626] to suppress weed growth and reduce the weed seed bank. Thereafter, the farmer should wait 7–10 days before planting directly through the mulch using a dibbler or planting stick[627].

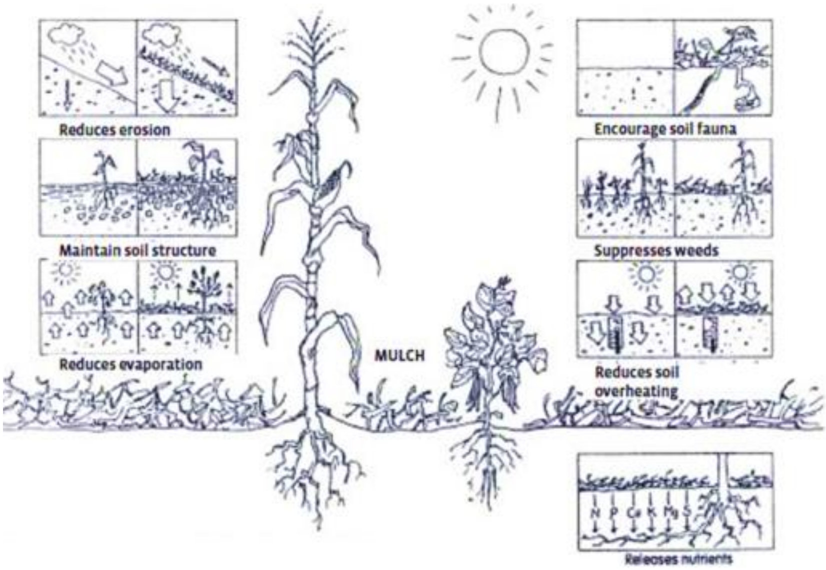

Figure 73. Diagram of the effects of mulching on soil[628].

By having the above effects on soil, slash and mulching has the potential to considerably reduce soil and nutrient loss through erosion compared with bare soil and traditional hand tillage. Where bare soil and a field prepared via hand tillage can lose approximately 19.51 and 9.36 Mg $ha^{-1}y^{-1}$ of soil respectively, a field farmed following the slash and mulching approach can lose ~0.82 Mg $ha^{-1}y^{-1}$ [629]. Likewise, total nutrient losses through soil erosion is ~90% lower on slash and mulching fields (3.14 kg $ha^{-1}y^{-1}$) than on hand tillage fields (35.93 kg $ha^{-1}y^{-1}$)[630]. By reducing soil and nutrient loss, slash and mulching can reduce crop productivity failures and income loss resulting from soil erosion. For example, in a millet-sorghum intercrop managed by traditional hand tillage methods, a farmer can lose a total of approximately 39.2 kg $ha^{-1}y^{-1}$ [631]. For the same intercrop but managed using slash and mulching, a farmer can expect to lose only ~3.5 kg $ha^{-1}y^{-1}$ [632]. This represents both a ~91% productivity and income saving relative to hand tilled system.

[626] Herbicide should be applied using the following rates: i) 450ml for every 15L of water for perennial weeds; ii) 300ml for every 15L of water for annual weeds; and iii) 15L for every 100m^2 of land.
[627] Boahen P., Dartey B.A., Dogbe G.D., Boadi E.A., Triomphe B., Daamgard-Larsen S. & Ashburner J. – 2007 – Conservation agriculture as practised in Ghana.
[628] Image from: Mueller-Saemann K.M. & Kotschi J. 1994. Sustaining growth: Soil fertility management in tropical smallholdings.
[629] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[630] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[631] Ibid.
[632] Ibid.

Through a reduction of soil and nutrients losses, the slash and mulching approach can considerably decrease the costs associated with replenishing soil nutrients using fertilisers. While a hand tillage approach can require ~GH₵318 ha^{-1} y^{-1} of fertiliser (the same fertilisers as above) to replenish nutrients lost through soil erosion, a slash and mulching system only requires ~ GH₵27 ha^{-1} y^{-1} [633]. The potential fertiliser costs for a field prepared and maintained using the slash and mulching method is, therefore, only ~9% of the hand tillage cost.

This intervention would contribute to disrupting potential impact pathways 1 and 7 in **Figure 37**.

12.4.1.3 Contour bunding

Contour bunding is a CA technique that involves building earthen or stone bunds on moderately to steeply sloped agricultural land (**Figure 74**). The approach can reduce on- and near-field runoff velocity, thereby: i) decreasing soil and nutrient loss; ii) increasing the drainage of water into the soil; and iii) decreasing the formation of damaging geomorphic features such as rills and gullies. The use of either earth or stones to build bunds depends largely on the accessibility of the required materials, the availability of labour and the purpose of the bunds. For example, the construction of stone bunds is generally more labour intensive than earthen bunds and stone bunds are more effective than earthen bunds in areas of high runoff or when the aim is to halt and reverse gully development.

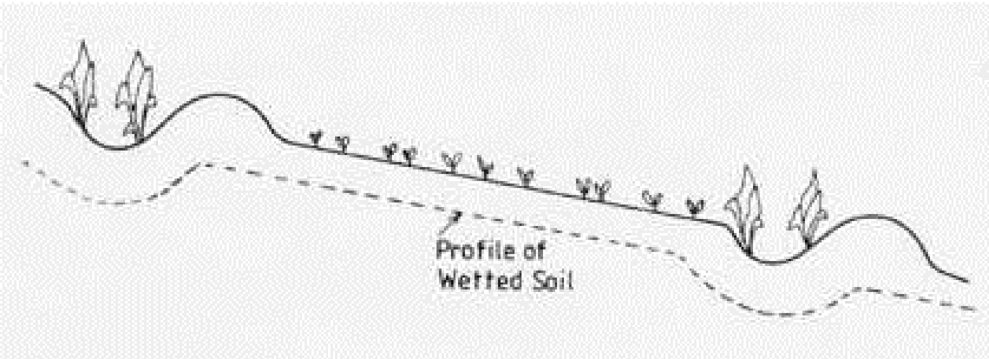

Figure 74. Diagram of a contour bunding system[634].

By constructing contour bunds, farmers can reduce soil and nutrient loss through soil erosion and supplement their additional efforts (e.g. intercropping; see above). Where a field with a monoculture of soybeans can lose ~3.90 Mg $ha^{-1}y^{-1}$ of soil when bunding is absent, the field could lose ~87% less if bunding were present; approximately 0.49 Mg $ha^{-1}y^{-1}$ (**Table 36**; **Table 37**). Likewise, a maize field with no bunding can lose 31.30, 0.35 and 4.28 kg ha^{-1} y^{-1} of nitrogen, phosphorus and calcium respectively (**Table 36**). Conversely, a field with bunding could lose 2.61, 0.03 and 0.36 kg ha^{-1} y^{-1} of the same nutrients (**Table 36**), representing a substantial reduction in nutrient loses. Contour bunds can further diminish crop productivity failures and income loses. For example, a ~93% reduction in crop yield loses and income loses is achievable when bunds are constructed to reduce soil erosion on a maize monoculture[635].

Like intercropping (described above), contour bunding can extensively lower the costs of fertiliser required to replenish soil nutrients lost through erosion. The total cost of fertiliser needed to return soil nutrients to an optimal level on a maize-groundnut intercrop with bunding

[633] Ibid.
[634] Image from: http://www.fao.org/docrep/T0321E/t0321e-11.htm.
[635] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.

can be ~GH₵13.95 ha^{-1} y^{-1} (**Table 36**). For the same intercrop without bunding, this cost can be ~GH₵168.85 ha^{-1} y^{-1} (**Table 36**). Across a variety of monocultures and intercrops, bunding is effective in decreasing substantially the costs of replacing lost soil nutrients (**Table 36**; **Table 37**).

It must be noted that contour bunding can have negative effects on crop yields in certain scenarios[636]. For example, in Burkina Faso, Ethiopia and Eritrea, long-term studies found that farmers who constructed contour bunds had lower crop yields in high rainfall years[637,638]. Even though soil and nutrient loss was reduced when using these structures, decreased runoff and heavy rainfall resulted in the waterlogging of fields. It is, therefore, important to supplement contour bunding with additional interventions that increase water infiltration. Additionally, bunds should be designed, adapted and tested in conjunction with local farmers to ensure that the structures account for local conditions[639,640].

This intervention would contribute to disrupting potential impact pathways 1 and 7 in **Figure 37**.

Table 36. The difference in soil loss and nutrient loss through erosion between bare soil, monoculture and intercropping systems with bunding[641].

Cropping system	Soil loss (Mg ha^{-1} year^{-1})	Nitrogen (kg ha^{-1} y^{-1})	Phosphorus (kg ha^{-1} y^{-1})	Potassium (kg ha^{-1} y^{-1})	Calcium (kg ha^{-1} y^{-1})	P_2O_5 (kg ha^{-1} y^{-1})	K_2O (kg ha^{-1} y^{-1})
Bare soil[642]	19.51	65.24	0.74	8.92	310.67	9.41	17.99
Monoculture							
Maize	0.74	2.61	0.03	0.36	12.43	0.38	0.73
Groundnut	1.07	2.61	0.03	0.36	12.43	0.38	0.73
Cowpea	0.68	1.97	0.02	0.27	9.38	0.25	0.54
Soybean	0.49	1.64	0.02	0.22	7.81	0.25	0.44
Intercropping							
Maize-Groundnut	0.68	1.04	0.01	0.14	4.95	0.13	0.28
Maize-Cowpea	0.76	0.77	0.009	0.11	3.67	0.11	0.22
Maize-Soybean	0.19	0.67	0.008	0.09	3.19	1.15	0.18

Table 37. The difference in cost of common fertilisers required for replenishing nutrients lost through soil erosion between bare soil, monoculture and intercropping systems with bunding[643].

Cropping system	Sulphate of Ammonia (GH₵ ha^{-1} y^{-1})	Triple Superphosphate (GH₵ ha^{-1} y^{-1})	Muriate of Potash (GH₵ ha^{-1} y^{-1})	Total cost (GH₵ ha^{-1} y^{-1})
Bare soil[644]	589.95	28.20	72.00	690.15
Monoculture				
Maize	23.75	1.20	3.00	27.95

636 Showers K.B. 2005. Imperial gullies: soil erosion and conservation in Lesotho. Athens, Ohio: Ohio University Press.
637 Dutilly C., Sadoulet E. & de Janvry A. 2003. How improved natural resource management in agriculture promotes the livestock economy in the Sahel. Journal of African Economics 12: 343–370.
638 Herwig K. & Ludi E. – 1999 – The performance of selected soil and water conservation measures – case studies from Ethiopia and Eritrea. CATENA 36: 99–114.
639 Showers K.B. – 2005 – Imperial gullies: soil erosion and conservation in Lesotho. Athens, Ohio: Ohio University Press.
640 Hincliffe F., Guijt I., Pretty J.N. & Shah P. New horizons: The economic, social and environmental impacts of participatory watershed development. Gatekeeper series no. 50. International Institute for Environment and Development.
641 Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
642 No bunding.
643 Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
644 No bunding.

Groundnut	23.75	1.20	3.00	27.95
Cowpea	18.05	0.75	2.20	21.00
Soybean	15.20	0.75	1.80	17.75
Intercropping				
Maize-Groundnut	9.50	0.45	4.00	13.95
Maize-Cowpea	6.65	0.30	0.80	7.75
Maize-Soybean	5.70	0.30	0.80	6.80

12.4.1.4 Vegetative barriers

Vegetative barriers serve the same purposes as contour bunding, namely: i) decreasing soil and nutrient loss; ii) increasing the drainage of water into the soil; and iii) decreasing the formation of damaging geomorphic features such as rills and gullies. Barriers made from vegetation generally perform as well as earthen and stone bunds in: i) reducing soil and nutrient loss; ii) decreasing crop failures and income loss; and iii) lessening the costs of replenishing soil nutrients using fertilisers[645] (**Table 36** and **Table 37**). The use of vegetative barriers, however, presents several advantages over contour bunding. For example, planting and maintaining vegetative barriers requires considerably less physical labour than constructing a stone bund. Additionally, by using species like Vetiver – a drought- and flood-resistant, multi-use perennial grass – to establish barriers, smallholder farmers can benefit from the multiple uses of the vegetation. In the case of a *Vetiver spp.* barrier, the vegetation could be used as fodder for livestock and to produce household utilities and crafts like baskets and mats.

This intervention would contribute to disrupting potential impact pathways 1 and 7 in **Figure 37**.

12.4.1.5 Ridging

Ridging is a CA method used to increase the retention of rainwater on croplands and decrease soil and nutrient loss resulting from soil erosion. Ridging is particularly suitable for row crops (e.g. maize and soybean) and crops that are sensitive to inundation (e.g. tomatoes and sweet potatoes). Depending on whether the aim of the intervention is to increase soil water storage or to increase drainage, either ridges or tied-ridges can be established on a field. Ridges (**Figure 75**) are constructed by digging furrows into the soil using an animal- or hand-drawn ridger, and the end of each furrow is left open to allow for the free drainage of excess water. It is important to construct ridges with spacing that allows for the optimal wetting pattern (**Figure 75**). Tied-ridges are prepared in a similar manner to ridges, however, where furrows are left open in a ridging system, furrows are dammed at regular intervals in a tied-ridging system (**Figure 76**). This decreases water run-off and increases the in-field retention of water. Ridging is an effective method for allowing excess water to drain off a field during periods of heavy rainfall, thereby avoiding the issue of waterlogging. Conversely, tied-ridging is effective in retaining on-field water and increasing soil water content in dry conditions. Such an intervention would be appropriate when attempting to extend the growing period into the dry season. On sloping or undulating land, ridges should always be constructed along the contour of the field to prevent down-slope soil and nutrients loss.

[645] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.

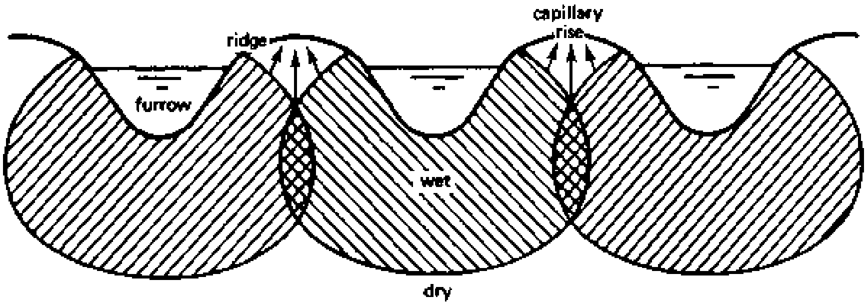

Figure 75. Cross-sectional diagram of a ridge-furrow system[646].

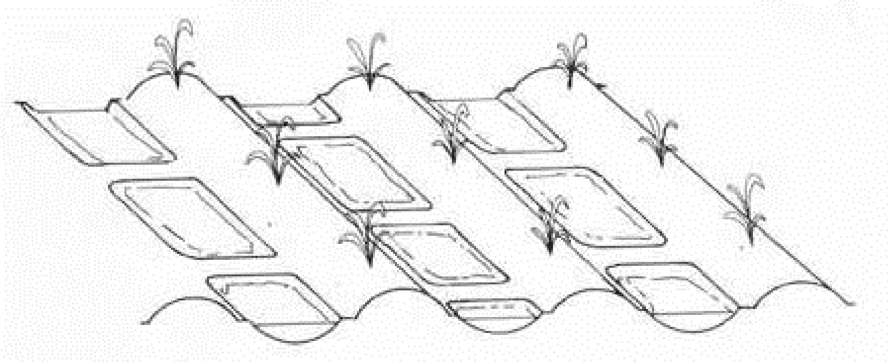

Figure 76. Diagram of a tied-ridge system[647].

Ridging is an effective approach for reducing the loss of soil and nutrients through erosion. Subsequently, it can reduce costs associated with replenishing soil nutrients, decrease crop yield losses and increase financial gains. For example, where bare soil and soil prepared using hand tillage can lose ~19.54 and ~9.38 Mg $ha^{-1}y^{-1}$ of soil, a system prepared with ridges may lose ~1.99 Mg $ha^{-1}y^{-1}$ of soil[648]. Ridging also reduces total nutrient losses through soil erosion from ~35.93 (hand tillage) to ~12.08 kg ha^{-1} y^{-1} [649]. In doing so, ridging lowers the total costs of replacing soil nutrients from ~GH₵318.68 ha^{-1} y^{-1} in a hand-tilled system to ~GH₵67.84 ha^{-1} y^{-1} [650]. Ridging can decrease millet and sorghum yield loses resulting from soil erosion from 39.24 kg ha^{-1} y^{-1} in a hand-tilled system to 8.4 kg ha^{-1} y^{-1}, thereby reducing income losses of farmers by ~81%[651].

This intervention would contribute to disrupting potential impact pathways 1 and 7 in **Figure 37.**

12.4.1.6 Organic composting and planting pits (zai)

Organic composting is an effective and low-cost method for enhancing soil fertility. While inorganic fertilisers may be unaffordable for many smallholder farmers, most of the inputs required to produce organic compost are readily available in rural households. After a compost pit is built, residue from vegetative cuttings, livestock manure, rumen content from slaughtered livestock and household waste can be added to the pit and left to decompose **Figure 77**). The

[646] Image from: http://www.fao.org/docrep/s8684e/s8684e04.htm.
[647] Image from: http://www.fao.org/docrep/T0321E/t0321e-11.htm.
[648] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.
[649] Ibid.
[650] Ibid.
[651] Nimoh F., Adjei-Gyapong T., Amegashie B. & Quansah C. 2015. Feasibility of sustaining SLWM activities through PES market mechanism – Final Technical Report.

method requires minimal maintenance; the pit must be kept moist by watering and the materials should be turned occasionally to allow for the circulation of air.

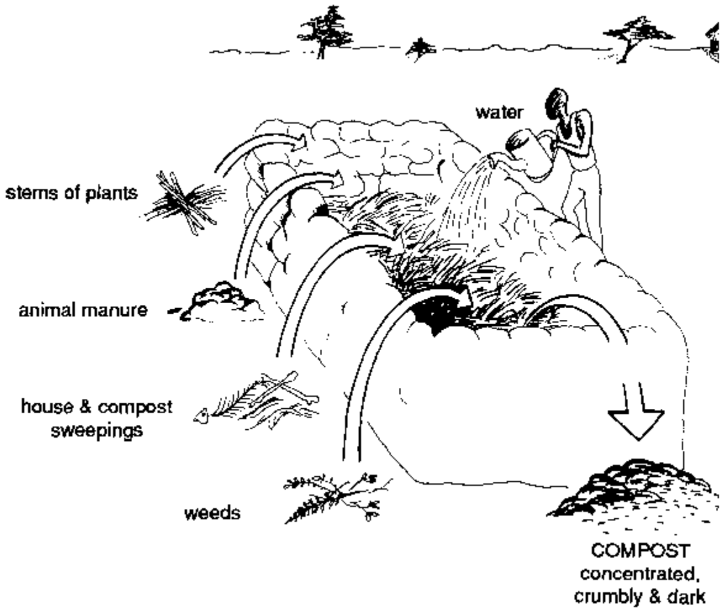

Figure 77. A compost pit indicating required inputs[652].

A traditional planting pit or zai (**Figure 78**), increases the concentration of nutrients as well as facilitating water infiltration and retention. Traditional techniques can be improved by increasing the depth and diameter of the pits and by adding organic matter. The implementation of this technique will result in improved yields (depending on rainfall), especially on lands that were formerly degraded and unproductive[653].

This intervention would contribute to enhancing soil fertility, thereby reducing the effect of potential impact pathway 1 and 7 in **Figure 37**.

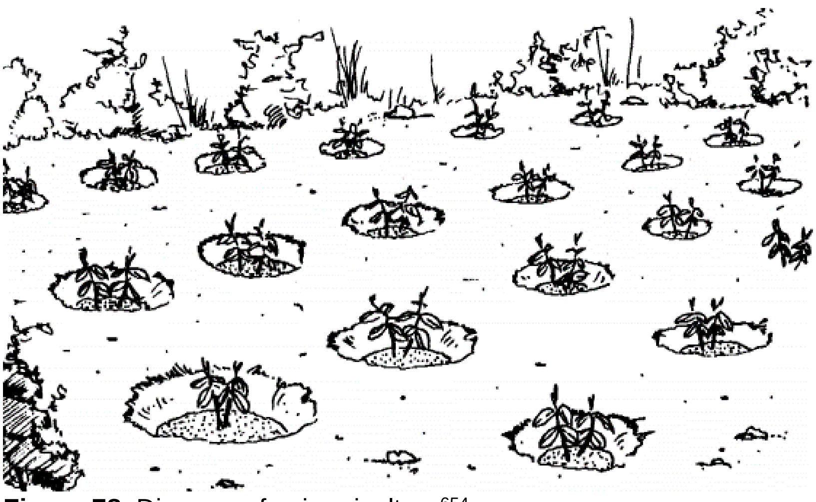

Figure 78. Diagram of zai agriculture[654].

12.4.1.7 Cover cropping

[652] Image from: http://www.fao.org/docrep/x5301e/x5301e0a.htm.
[653] FAO. 2010. "Climate-resilient" Agriculture: Policies, practices and financing for food security, adaptation and mitigation. Available at: http://www.fao.org/docrep/013/i1881e/i1881e00.pdf
[654] Image from: Lee M.D. & Visscher J.T. 1990. Water harvesting in Five African Countries. IRC Occasional Paper No. 14.

Cover cropping is a technique of growing low-lying crops, including *inter alia* sweet potato, melon, pumpkin, beans and pea. Planting different crops together – multiple cropping – is a valuable form of cover cropping as this has multiple functions (**Figure 79**). Non-food leguminous crops can also be planted as cover crops and later used as green manure/compost to improve soil fertility. Cover crops can serve many purposes on a farm, including nutrient conservation, soil erosion control, improved water infiltration and quality, reduced weed and pest pressure and increased biodiversity. Furthermore, they maintain a mulch or carbon-rich organic matter covering, which maintains soil quality by adding to its nutrient content. Cover crops such as trailing vines and leaves shade the soil's surface and protect it from the impacts of rain, wind and trampling by humans and animals. Additionally, a dense mat of cover competes strongly with any weed seed. Cover crops can also be planted between taller cash crops where soil would normally be bare (**Figure 80**) or integrated into cash crops through relay planting or intercropping[655]. Such methods of cover cropping extend the area available for food production and make maximum use of all available land, which increases agricultural output and strengthens food security.

This intervention would contribute to disrupting potential impact pathways 1, 5, 7 and 9 in **Figure 37**.

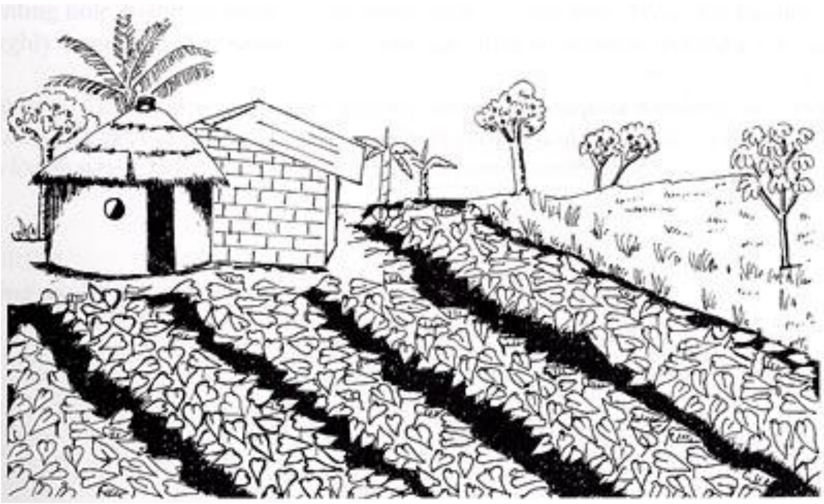

Figure 79. Illustration of cover cropping using food crops[656].

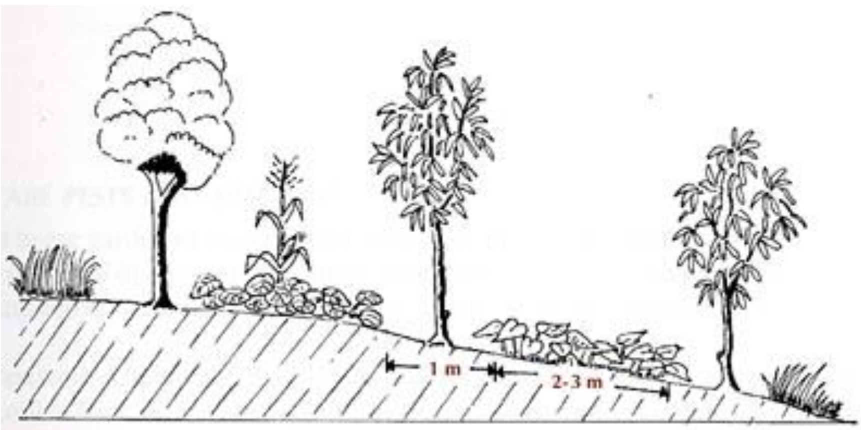

Figure 80. Cover cropping between tree crops[657].

[655] http://CRAnr.wsu.edu/cover-cropping/
[656] Image from: http://www.fao.org/docrep/003/X3996E/x3996e33.htm
[657] Image from: http://www.fao.org/docrep/003/X3996E/x3996e33.htm

12.4.1.8 Climate-resilient seed varieties

Seeds are a core resource for crop production systems and carry the genetic potential necessary for crop adaptation to a changing climate. The development of new climate-resilient seed varieties – including drought, flood and heat stress-resilient varieties – is ongoing but needs to move forward at a pace that meets changing demands and requirements. Urgent action is, therefore, necessary to ensure that a local genetic resource base (including wild relatives), adequate capacities and effective collaboration among policy makers, scientists and end users – smallholder farmers – are available to meet increasing needs. This will include intensifying the conservation of plant genetic resources (PGR) both *in situ* and *ex situ*. For example, the survival of wild crop relatives – an important source of genetic diversity – could be threatened by climate change. Experiments which involved the simulation of climate change effects on wild relatives of groundnut (*Arachis spp.*), potato (*Solanum spp.*) and cowpea (*Vigna spp.*) in Latin America, adversely affected all taxa. Approximately 16 to 22% of these species are expected to become extinct, with most of them losing over 50% of their range. While increased habitat conservation will be important for the survival of most species, those that are predicted to undergo major reductions in range size should be a priority of collection and storage in seed and gene banks[658].

Climate-resilient seed varieties that have outstanding adaptation attributes including yield stability and high nutrient content should be promoted. To ensure that the supply of the selected varieties meets the demand and consequently guarantees sustainability in the system, the crop and product preferences of smallholder farmers should be taken into account. This demand-driven adaptation to climate change is not only a means of safeguarding food security but also of maintaining and improving plant genetic diversity.

Once the appropriate climate-resilient seed varieties have been selected, locally relevant seed delivery systems need to be developed and implemented to ensure that seeds are freely available. Currently, most smallholder farmers access seed from what is known as an informal or farmer seed system, with few having access to commercial seed systems. Both commercial and farmer seed systems are necessary for the distribution of climate-resilient seed varieties. The promotion of small-scale seed enterprises that can form the necessary link between research and local communities to bring genetic progress from the laboratories to the farmer's field is considered as a priority activity by the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture[659]. In northern Cameroon for example, local varieties of sorghum, millet and maize were not adapted to lower wet season rainfall and an increase in the frequency of droughts. To improve yields, earlier maturing varieties of these crops were developed and farmer seed enterprises were organised to produce certified seed which could be sold to farmers from the surrounding villages. The new varieties resulted in increased yields despite unfavourable agro-ecological conditions related to climate change. As a result, there was an autonomous upscaling of this initiative and a high demand for seed. This led to the implementation of 68 community seed enterprises with over 1,000 members – both men and women – producing over 200 tonnes of seed per year[660].

The promotion of climate-resilient seed varieties in northern Ghana will ensure stable crop yields under future climate change scenarios. This will strengthen food security and safeguard the livelihoods of local smallholder farmers.

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[658] Jarvis A, Lane A & Hijmans RJ. 2008. The effect of climate change on crop wild relatives. *Agriculture, Ecosystem & Environment*. 126: 13–23.
[659] Allara M, Kugbei S, Dusunceli F & Gbehounou. 2012. Coping with changes in cropping systems: plant pests and seeds. Proceedings of a Joint FAO/OECD Workshop: Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Available at: http://www.fao.org/docrep/017/i3084e/i3084e.pdf
[660] Guei RG, Barra A & Silue D. 2010. Promoting smallholder seed enterprises (SSE): Quality seed production of rice, maize, sorghum and millet in northern Cameroon. The International Journal for Agricultural Sustainability.

This intervention would contribute to disrupting potential impact pathways 3, 6, 7, 8 and 10 in **Figure 37**.

12.4.1.9 Dry season gardening

As a result of the strong seasonality of rainfall in northern Ghana – with a short wet and a long dry season – rainfed agriculture is limited to at most half of the year. While some smallholder farmers take up alternative livelihoods or seek temporary employment elsewhere during the dry season, others may choose to continue growing food through dry season gardening.

Dry season garden is typically implemented on a smaller scale than wet season farming, hence the name "gardening" rather than "farming". This is because it can only be practised in areas with a nearby water source, where water is available even during the driest months of the year. As it is done on a small scale, dry season gardening is used to predominantly grow vegetables and leafy greens rather than the common wet season crops such as cereals or roots and tubers. Typical crops grown during the dry season include onions, tomatoes, peppers, bitter leaf and other green herbs[661].

Crops are irrigated by hand, with the farmer collecting water from local water sources and applying it with a hose, watering can or bucket (Figure 81). In some instances, farmers can irrigate their dry season crops by digging channels from the water source to the vegetable beds. Where the water table is high, farmers can dig shallow wells to supply the water – Shallow Groundwater Irrigation (SGI). Other water sources include micro-dams, wells and boreholes (see Section 10.6). For those farmers who can afford it, a pump run by a generator is used to pump water to their vegetable beds. An alternative to this is the use of a treadle and hand pump, which just as effective and energy free[662].

Figure 81. A woman practising dry season gardening in Ghana[663].

Dry season gardening, when practised in an agroecological manner together with agroforestry (see Section 11.4.2.1), can contribute to: i) environmental restoration; ii) sustainable livelihoods; iii) strengthened food security; iv) and improved nutrition. Furthermore, any excess produce may be sold to generate additional income during the dry season.

This intervention would contribute to disrupting potential impact pathways 5, 6 and 9 in **Figure 37**.

[661] https://traxghana.com/2017/03/31/the-value-of-dry-season-gardening/
[662] https://traxghana.com/2017/03/31/the-value-of-dry-season-gardening/
[663] Image from: https://twitter.com/grow_ghana

12.4.2 Ecosystem–based adaptation interventions

In a changing climate, the threats of land degradation are becoming more severe and the need for sustainable land management is becoming increasingly obvious. Factors such as desertification, rising temperatures, more frequent droughts and intensified rainfall events will have a negative effect on ecosystems, leading to extensive land degradation, erosion and loss of soil nutrients, resulting in a loss of productivity of agro-ecosystems. This will in turn impact on the livelihoods of farming communities, intensifying the need for further expansion of farmlands and exploitation of natural resources, creating a negative cycle. Ecosystem–based adaptation, however, has the potential to reduce the impacts of human activity on ecosystems, restoring them to a more productive state and promoting their sustainable use. This will create a virtuous cycle in which lands become more productive, promoting further restoration and restricting further degradation. Within this, it is imperative to create conditions that allow communities to be innovative in dealing with their ecosystem management challenges, building on traditional knowledge where appropriate, but also being open to modifications and new institutional solutions. Sustainable, climate-resilient ecosystem management practices are, therefore, vital to ensure the long-term productivity of agro-ecosystems and food security in northern Ghana.

12.4.2.1 Agroforestry

Agroforestry is a sustainable ecosystem–based land use management system in which trees or shrubs are grown around or among crops and/or pastureland. Similar to intercropping, agroforestry uses the interactions of multiple plants, combining the protective attributes of forestry with the productivity of both agriculture and forestry to create a more diverse, productive and sustainable land-use system. Through agroforestry, the system becomes more resilient to environmental change – including climate change – and promotes sustainable agriculture and forest product harvesting. This provides multiple socio-economic, environmental and ecological benefits, including *inter alia*: i) soil erosion control and reduced land degradation; ii) enhanced soil fertility; iii) improved drainage; iv) the production of fodder, timber and fuelwood; v) the provision of specialty crops; vi) the provision of derived products such as gums, resins latex and oil; vii) carbon sequestration; viii) reduced greenhouse gas emissions; ix) enhancement of wildlife habitats; and x) the provision of medicinal plants. Additionally, the benefits of agroforestry can extend into the dry season through the provision of additional livelihoods and incomes to farming communities. Agroforestry, therefore, strengthens the resilience of farming communities to the effects of climate change, especially when using climate-resilient tree species that are drought tolerant, have high thermal limits and are able to withstand extreme climate events. For example, when crops fail because of drought, farmers will be able to fall back on the alternative climate-resilient livelihoods offered by agroforestry, such as the selling of fuelwood and timber or processing of shea butter (see Section 11.5.1). Furthermore, the symbiotic relationships between species used in agroforestry will increase overall agricultural productivity under conditions of climate change. Examples of the benefits of agroforestry for productivity are detailed below.

- Agroforestry will reduce erosion by binding the soil in tree roots. In addition, agroforestry improves infiltration and thereby reduces runoff. This is important under climate change conditions, as rainfall events in Ghana are becoming more intense, increasing the threat of erosion of agricultural land. Trees can also create a buffer zone along rivers, preventing riverbank erosion and protecting nearby agricultural lands against floods.
- Trees will improve soil fertility by increasing organic matter and fixing nitrogen. Additionally, trees with deep reaching roots help to recycle nutrients into the topsoil (**Figure 82**). Leaf litter can also provide natural mulching function, retaining soil moisture and increasing the organic matter content of soils.

- Canopy cover from trees used in agroforestry influence the microclimate of agricultural systems, modifying the flow of heat, retaining moisture and reducing the potential damage caused by wind and rain. Shade from trees offers protection from solar radiation during the day and insulates against long wave radiation loss at night[664], reducing thermal shock and minimising evaporation. Furthermore, trees can also protect crops from exposure to wind, rain and hail which can damage crops. The manipulation of microclimates through agroforestry will, therefore, reduce the impact of climate change on agricultural systems in northern Ghana.

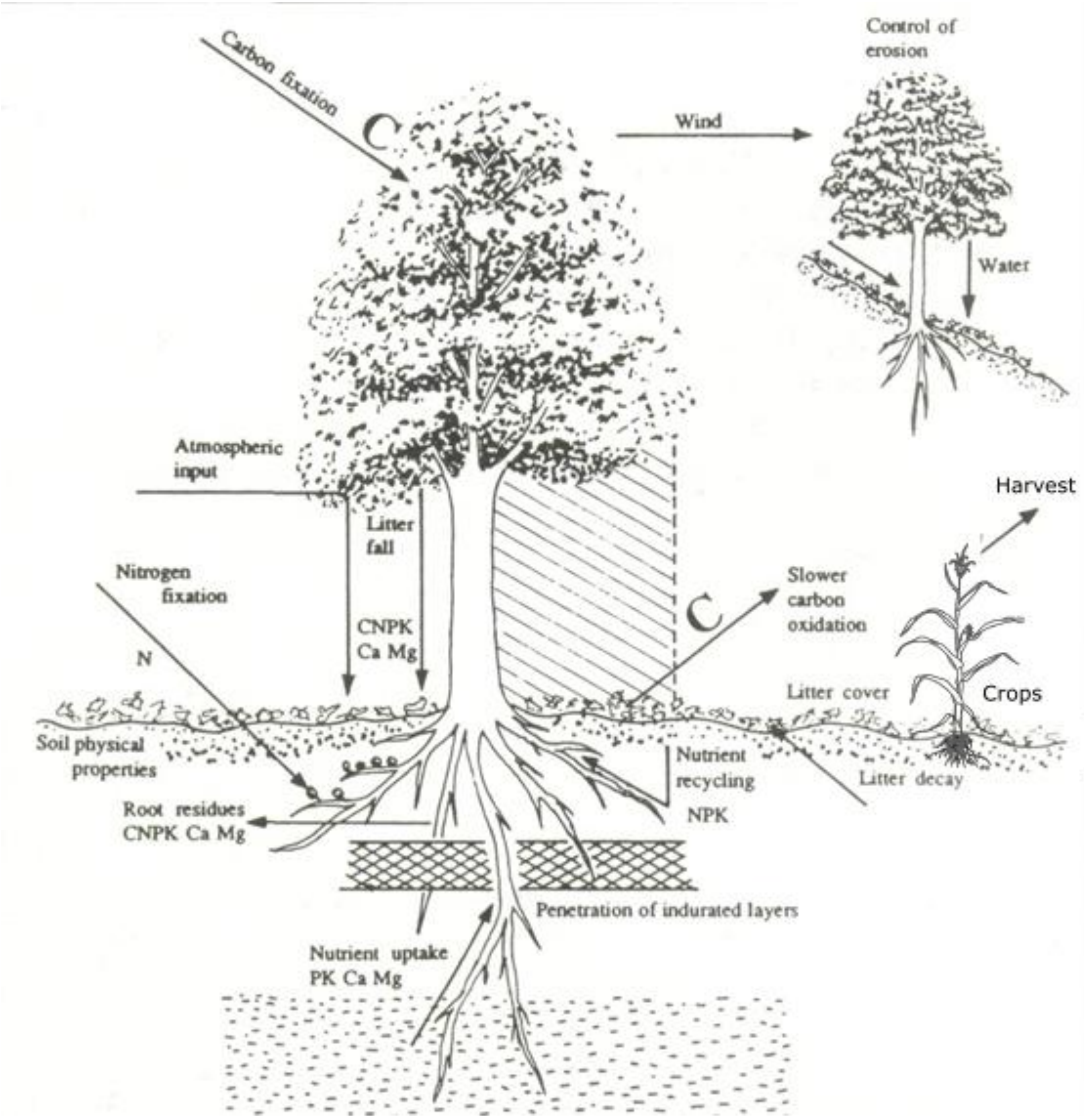

Figure 82. Nitrogen cycle under agroforestry showing major stores and flows[665].

Several agroforestry practices – including woodlots, woody fallows, intercropping, live fences and alley cropping – have been found to be economically viable and profitable investments for farmers in other countries[666]. For example, mango plantations intercropped with soybean produce a positive net economic return within three years, with substantially higher returns than for monoculture maize plantations over the long-term (**Figure 83**). In Ghana, agroforestry has been successfully incorporated into several land management programs – including

[664] Stigter K, Ofori E, Kyei-Baffour N, and Walker S. 2011. Microclimate management and manipulation aspects of applied agroforestry. *The Overstory* 240.
[665] Adapted from Young A. 1989. Agroforestry for Soil Conservation.*CAB International*.
[666] World Bank. 2010. Sustainable Land and Water Management Project. Republic of Ghana.

SLWMP and GSIF – to improve the economic viability of the agricultural sector. For example, woody fallows in the savannas of northern Ghana have achieved a benefit to cost ratio of 2.07 and an economic rate of return of ~34%, making it an economically viable practice. The payback period for most agroforestry practices is between one and six years, except when the end-product is timber, which has a benefit timeframe of 10-30 years (see **Table 38**). However, the returns on agroforestry investments are sensitive to fluctuating tree and agricultural product prices. The viability of agroforestry is also increased by incentivising carbon sequestration. For example, a mango-soya intercrop system has the potential to sequester 2,020 Mg CO_2 per hectare over a 30-year period. At an estimated price for carbon sequestration of ~US$5.80/Mg CO_2[667], this would return ~US$11,700 additional income over 30 years.

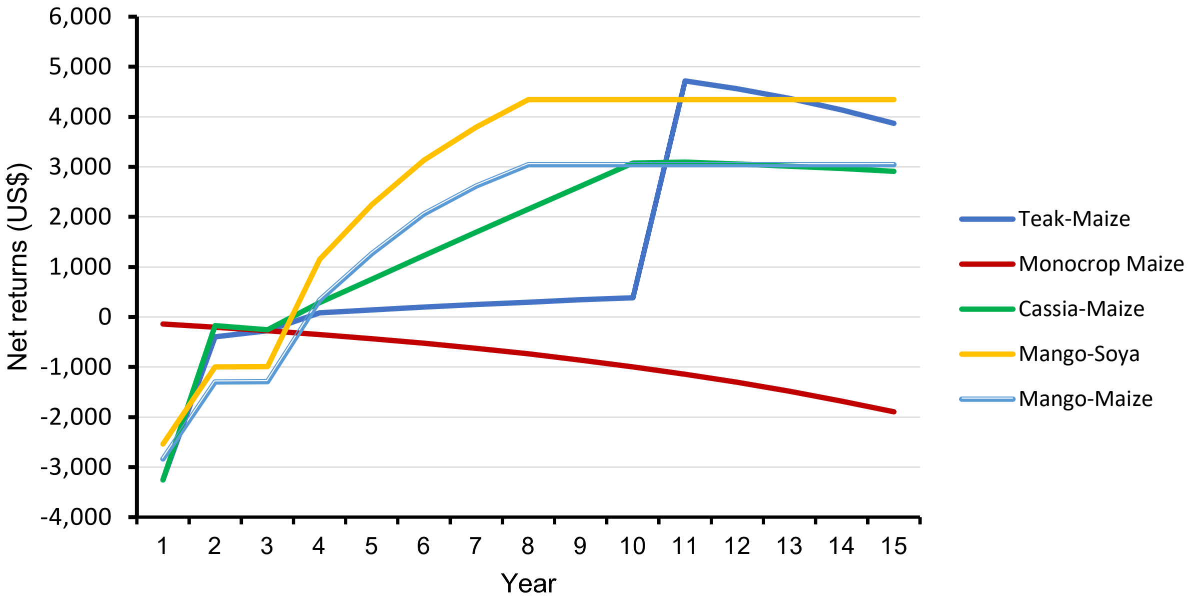

Figure 83. Comparison of net returns of existing and improved land use practices in the long-term[668].

Smallholder farmers will be presented with several agroforestry practices to choose from (**Table 38**), depending on the specific needs for each farm. For each practice, a list of products and services provided by the practice, together with a list of suitable species, has been collated. The selection of tree species takes into account current and future climate change conditions to ensure the long-term sustainability of interventions. Preference is given to climate-resilient species with a high tolerance for drought and greater thermal limits. A detailed list of tree species and their characteristics is given in Section 11.3 Appendix 3.

This intervention would contribute to disrupting potential impact pathways 1, 2, 3 and 4, 8 in **Figure 37**.

Table 38. Agroforestry practices available for northern Ghana[669].

Practice	Main Products/services	Species	Specifications

[667] Hamrick and Goldstein 2015. Ahead of the Curve – State of the Voluntary Carbon Markets". *Forest Trends' Ecosystem Marketplace*. Washington DC. Available at: www.forest-trends.org
[668] Nimoh F, Adjei-Gyapong T, Amegashie B, Quansah C. 2015. Feasibility of Sustaining SLWM Activities Through PES Market Mechanism. Ministry of Environment, Science, Technology and Innovation, Ghana.
[669] Adapted from: Nimoh F, Adjei-Gyapong T, Amegashie B, Quansah C. 2015. Feasibility of Sustaining SLWM Activities Through PES Market Mechanism. Ministry of Environment, Science, Technology and Innovation, Ghana.

Multipurpose tree species on farmlands	• Timber; • poles; • fuelwood; • fruits; and • fodder.	• *Senna siamea;* • *Albizia lebbeck;* • *Grevillea robusta;* • *Albizia chinensis;* and • *Tectona grandis.*	*Sites:* Scattered on the farm and along farm boundaries and roads and around homes. *Planting:* Seedlings to be raised using quality seed during dry season and planted in wet season (April–June) *Benefits timeframe:* After four years and continue for several years.
Woodlots	• Poles; and • Fuelwood.	• *Senna siamea;* • *Tectona grandis;* • *Azadirachta indica*; • *Albizia lebbeck;* • *Eucalyptus camaldulensis;* • *Eucalyptus tereticornis*; and • other locally preferred species.	*Sites:* Unproductive sites on the farm *Planting:* Seedlings to be raised by farmer groups in the dry season and planted during early rains (April–June). *Spacing:* Firewood- 2 m x 2 m Pole: 2.5 m x 2.5 m to 3 m x 3 m *Benefits timeframe:* First harvest after 3–4 years every two years thereafter.
Woody fallows	• Soil fertility improvement	• *Calliandra calothyrsus;* • *Gliricidia sepium;* • *Sesbania sesban'* • *Albizia lebbeck;* and • *Cajanus cajan.*	*Sites:* Degraded lands that need fallow *Planting:* Seedlings to be raised by farmer groups initially but later sawn directly when they become plentiful *Spacing:* 1.5 m x 1.5 m or seed broadcast directly in the field *Benefits timeframe:* Wood obtained after 1–2 years and soil improvement realised after 2 years and continues for ~3 years.
Fodder banks	• Supplementary fodder for goats and sheep	• *Gliricidia sepium;* • *Calliandra calothysus;* • *Cajanus cajan;* • *Albizia lebbeck;* and • *Sesbania sesban*	*Site:* Near home and should be fenced to protect from livestock; use live fencing or wire. Also to be planted on soil conservation structures. *Planting:* Direct seeding in well-prepared land and plant in a block for ease of fencing. *Benefits timeframe:* Within 1–2 years.
Live fences	• Protection and environmental services	Live Fence Posts: • *Gliricidia sepium;* • *Erythrina abyssinica*;	*Live fence posts* Widely spaced, single lines of woody plants, regularly

		• *Albizia lebbeck;* • *Casuarina equisetifolia*; and • *Jatropha curcus.* Barriers or Hedges: • *Euphobia tirucalli;* • *Calliandra calothyrsus; and* • *Jatropha cursus*	pillared for supporting barbed wire. *Barriers or hedges* More densely spaced fences and can have different species, reinforced with barbed wire or reeds at early stages. *Benefits timeframe:* From 1–2 years.
High-value trees	• Mango (fruits), cashew nut, locust bean and shea nut production.	• *Mangifera indica* ○ Varieties: Kent, Keitt, Van Dyke, Ngowe, Apple mango, Sensation, Alphonso and Tommy Atkins. • *Vitellaria paradoxa;* • *Parklia biglabosa; and* • *Anacardium occidentale.*	*Site:* Sandy soil with good drainage *Spacing:* 7 m x 10 m to 10.5 m x 10.5 m *Benefits timeframe:* From 3 years, increase at 4-5 years and reach economically viable levels thereafter.

12.4.2.2 Fodder banks and rangelands

Livestock owned by smallholder farmers and pastoralists in northern Ghana are restricted to forage on available vegetation within herding distance of their central base. As a result, grazing is limited mainly to grasses, which are only nutritionally adequate for a few months of the year[670]. Additional food is then supplied largely through crop residue, which contributes significantly to the dry-season diet of many animals. However, the crop residues are also only available for a limited time during the year and have low nutritional value. It is therefore generally accepted that better pasture is required to supplement these nutritional shortfalls. Studies have shown that two to four hours of grazing in nutrient-rich fodder banks significantly reduced weight loss in cattle[671].

Fodder banks provide a viable solution to the nutritional shortfall faced by many West African ruminants. A fodder bank is a fenced pasture of ~4 ha, sown with nutrient-rich plants that can be used to supplement the diet of livestock during the dry-season. Seeds are sown at the onset of the wet season and allowed time to grow. During the growth period, livestock is excluded from the area. Grazing is then deferred until the dry season when other food sources are limited. Fodder banks should be established close to the pastoralists homestead so that access can be monitored and livestock can be prevented from entering during the growing season. The size of the fodder bank required can be determined using the number of livestock requiring fodder – particularly pregnant and lactating cows which will benefit most from the additional nutrients – set against their nutritional requirements and the potential nutritional yield of the fodder per hectare. The calculation of plot size is influenced by the species of plant grown. Species that are high in protein, such as Stylo, *Stylosanthes hamata,* are preferable for use in fodder banks. Stylo fodder banks in Nigeria have been observed to remain

[670] FAO. Fodder Banks: for Pastoralists or Farmers. Available at: http://www.fao.org/wairdocs/ilri/x5488e/x5488e0t.htm
[671] Bayer W. 1984. Fodder utilization. ILCA/NAPRI symposium on livestock Production in the subhumid zone of Nigeria, Lugard Hall, Kaduna, Nigeria.

productive for several years, with the amount of stylo seed in the soil increasing over time, allowing the fodder banks to regenerate naturally under proper management[672].

In circumstances where larger scale pastoral lands are required, rangelands are a sustainable option when managed correctly. Sustainable management of rangelands involves the optimisation of ecosystem goods and services through the protection and enhancement of soils, riparian vegetation, watersheds and vegetation complexes[673]. Much of this revolves around manipulation of grazing activities by livestock across the rangeland, rotating between different areas of the rangeland. This helps avoid overgrazing of a single location, allowing vegetation adequate time to regenerate between grazing intervals. The herding of animals also helps distribute livestock impacts across the entire rangeland area, ensuring that organic matter is laid onto and into the soil in an even manner[674].

This intervention would contribute to disrupting potential impact pathway 1, 2, 6 and 9 in **Figure 37**.

12.4.2.3 Riverbank protection

The protection of riverbanks from erosion is best accomplished by strengthening the banks themselves. Several methods are appropriate for this, including the use of *inter alia*: i) vegetation; ii) windrows and trenches; iii) sacks and blocks; iv) gabions and mattresses; v) articulated concrete mattresses; vi) soil-cement combinations; and vii) retaining walls.

Using an EbA approach, riverbank protection can be achieved by planting vegetation either as a standalone intervention or together with hard infrastructure – such as gabions or mattresses. Vegetation used to protect/stabilise riverbanks may include a combination of trees (a further application of agroforestry – see Section 11.4.2.1), shrubs and grasses, or each of these planted on their own. Apart from the planting of vegetation, riverbanks may be protected through the use of structure made from vegetation, for example, fascines. A fascine is a bundle of vegetation which is tied together, it is then placed in a shallow trench that runs parallel to the riverbank and partially buried and staked in place. This creates a log-like structure that will root quickly, grow and cover the surface of the bank. As a result, the soil is bound and the riverbank is protected from erosion.

Additional to the abovementioned is the use of live staking to protect and restore riverbanks. This practice reintroduces plant life onto stream and riverbanks. Although being labour intensive it is a low-cost practice that requires minimal training and equipment. Stem cuttings are taken from trees and are inserted directly into stream and riverbanks. These cuttings are referred to as “live stakes” and will eventually grow into new trees and are an effective way to establish a root network and prevent further soil loss[675].

This intervention would contribute to disrupting potential impact pathways 1, 2, 6 and 9 in **Figure 37**.

12.4.3 <u>Fire management</u>

Bushfires are a regular occurrence in northern Ghana, threatening the economic potential of forestry and agriculture[676], and causing the loss of thousands of lives and millions of dollars

[672] FAO. Fodder Banks: for Pastoralists or Farmers. Available at: http://www.fao.org/wairdocs/ilri/x5488e/x5488e0t.htm
[673] Wikipedia. Rangeland Management. Available at: https://en.wikipedia.org/wiki/Rangeland_management
[674] Drynet 2015. Development of sustainable rangeland management practices in the communal lands of Namibia. Available at: http://dry-net.org/initiatives/development-of-sustainable-rangeland-management-practises-in-the-communal-lands-of-namibia/
[675] Fetter JR & Kyler K. 2017. Live staking. The Pennsylvania State University. Available at: http://extension.psu.edu/natural-resources/water/watershed-education/watershed-publications/live-staking/pdf_factsheet.
[676] Appiah M, Damnyag L, Blay D, and Pappinen A. 2010. Forest and agroecosystem fire management in Ghana. *Mitigation and Adaptation Strategies for Global Change* 16(6):551-570.

every year[677]. Estimates show that up to 90% of the total area of the dry northern savanna zone of Ghana is prone to annual bushfires[678]. The vulnerability of northern Ghana to fire is due to the long dry season which causes the vegetative biomass carried over from the wet season to dry out. The resulting fuel load facilitates the spread of bushfires. This problem is exacerbated by the effects of climate change, including rising temperatures, a prolonged dry season and more frequent droughts, which increase the threat of bushfires. Effective fire management is, therefore, important to control the use of fire in farming practices and reduce the environmental damage caused by bushfires in northern Ghana.

To effectively manage the incidence of and damage caused by bushfires, it is important to consider the role fire plays in livelihood activities, particularly with regards to traditional farming practices. Traditional farming systems such as slash-and-burn agriculture have a significant impact as a source of bushfires which often burn out of control[679]. For example, farmers burn land to increase the area available for the cultivation of crops or to clear competing weeds and pests from agricultural land. Furthermore, at the beginning of the dry season, herders often start fires to stimulate the growth of young shoots which are considered more palatable and nutrient rich. Although being profitable in the short-term, these practices can negatively impact the diversity of indigenous plant communities as well as damaging the soil and reducing the long-term productivity of agricultural land. Such practices, however, form an integral part of indigenous knowledge and therefore active support and commitment from local communities are essential for effective fire management.

Several fire management practices are suited to northern Ghana and have been shown to effectively reduce the threat of bushfires in the region. Such practices should be community-based and multi-sectoral, applying both international best practices and indigenous knowledge. This approach is aligned with Ghana's National Wildfire Management Policy[680]. The effective management of fire can have considerable benefits for local communities, including: i) reducing damage to farmland and property; ii) increasing agricultural production; iii) maintaining soil quality; iv) increasing the availability of NTFPs; and v) increasing the economic potential of smallholder farms.

Fire management practices

<u>Reducing human-caused ignitions</u>: While bushfires are a natural part of savanna ecology, human-caused ignitions significantly increase the prevalence of fires. To reduce the effect of human-caused ignitions, their primary causes need to be addressed. Fire plays a central role in many agriculture and rangeland management practices in northern Ghana, as well as being used for hunting and cultural practices[681]. However, through the implementation of sustainable land-use practices and improved CRA techniques, the productivity of agricultural and pastoral land will increase. Consequently, the need to use fire-based practices such as slash-and-burn agriculture will be reduced.

In cases where burning is still required, this should be overseen by a dedicated community fire marshal, using controlled burns and firebreaks (see below) to manage the spread of the fire. Community by-laws should be used to enforce responsible fire practices, whereby farmers wishing to use fire to clear an area are required to apply for permits from the designated authorities and make adequate arrangements to control the spread of the burn.

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[677] Addai E.K, Tulashie S.K, Annan J, and Yeboah I. 2016. Trend of fire outbreaks in Ghana and ways to prevent these incidents. *Safety and Health at Work* 7(4): 284-292.
[678] GoG. 2006. National Wildfire Management Policy. Available at: http://www.rspo-in-ghana.org/sitescene/custom/userfiles/file/NATIONAL_WILDLIFE_MANAGEMENT_POLICY.pdf
[679] Nsiah-Gyabaah K. 1996. Bushfires in Ghana. *IFFN* 15**:** 24-29
[680] GoG. 2006. National Wildfire Management Policy. Available at: http://www.rspo-in-ghana.org/sitescene/custom/userfiles/file/NATIONAL_WILDLIFE_MANAGEMENT_POLICY.pdf
[681] GoG. 2006. National Wildfire Management Policy. Available at: http://www.rspo-in-ghana.org/sitescene/custom/userfiles/file/NATIONAL_WILDLIFE_MANAGEMENT_POLICY.pdf

Firebreaks: The creation of firebreaks can prevent the spread of fire between areas. Firebreaks should also be maintained around any property or infrastructure that is at risk of being damaged by fire. A firebreak is a gap in vegetation that provides a barrier to slow or stop the progress of a bushfire. The primary goal of creating a firebreak is to remove the deadwood and undergrowth down to the base soil, thereby removing potential fuel for the spread of a fire. Once created, the firebreak should be constantly maintained, particularly during the dry season when the threat of fire is highest.

Controlled Burning: In cases where burning of bush is needed, early and controlled burning under the supervision of the Ghana National Fire Service, local fire marshals and community members reduces the negative impacts of bushfires[682]. Wildland fire use is another technique closely linked to controlled burns, where naturally ignited fires are monitored and allowed to burn in a controlled manner. Such controlled burns help promote the germination of some desirable plants, reduce the build-up of fuel and decrease the likelihood of hotter, uncontrollable fires.

Volunteer fire suppression teams: Fire suppression refers to a range of firefighting tactics used to suppress bushfires and is an important part of bushfire management, whether used to deal with controlled burns, natural fires or human-caused ignitions. The technique, equipment and training used for fire suppression is dependent on what is available in the area in which the fire occurs. In developing countries, fire suppression tactics often involve the throwing of sand or the beating of fires with paddles or palm fronds. These techniques, however, are labour intensive and therefore require logistical support and coordination within communities to be effective. Volunteer fire suppression teams, under the guidance of a community fire marshal, should be established within communities to coordinate fire suppression activities. Such teams must undergo training both in terms of safety and technique for firefighting activities. Fire awareness campaigns in farming communities should include a focus on the negative impacts of fire on agriculture and on the mutual benefits of joining volunteer fire suppression teams to reduce these impacts.

This intervention would contribute to disrupting potential impact pathway 11 in **Figure 37**.

12.4.4 Climate-resilient post-harvest management techniques

12.4.4.1 Post-harvest storage

Early processing and storage of agricultural produce can reduce post-harvest losses and preserve the quality, quantity and nutritional value of the product. Furthermore, adequate post-harvest storage allows surplus food to be stored for use during dry season and low production years or for a staggered sale.

Traditional on-farm storage methods are unreliable in capacities to meet the above-mentioned storage ideals. Such traditional storage methods typically include mud and thatch stores or simple gunny sacks[683]. Grain stored these methods is particularly prone to losses caused by insect and rodent pests. Consequently, insecticides are commonly used, which are costly and can cause health problems if not used properly. Hermetic storage technology and Zero Energy Cooling Chambers (ZECC) are alternative storage solutions to these traditional techniques. These types of storage are proven technologies for reducing on- and off-farm storage losses,

[682] Gariba C.A. 2011. Bush fires in Northern Ghana. *Ghana Web.* Available at: http://www.ghanaweb.com/GhanaHomePage/NewsArchive/Bush-Fires-in-Northern-Ghana-224358
[683] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf

but the uptake of such technologies in Africa has been limited[684]. Reasons for this limited uptake are both social and technical. Firstly, farmers often tolerate post-harvest losses because systemic incentives to address the problem are lacking. Until output markets consistently reward farmers for products of a greater quality, they will be reluctant to invest in new storage technologies. Secondly, the system-wide uptake of improved technologies will depend on contextual factors including *inter alia*: i) cost/benefit; ii) market knowledge; iii) socioeconomic preferences; iv) enterprise-level capacity; v) rural infrastructure and logistics; vi) financial services; vii) distribution and transport services; and viii) the wider institutional environment[685]. Consequently, a market system perspective is necessary to facilitate the commercialisation of proven technologies to reduce post-harvest losses. The hermetic storage technology mentioned above is a pesticide-free method that eliminates insects and moulds creating an anaerobic environment and producing carbon dioxide. This technology uses natural respiration together with the impermeability of plastic and metal to alter the ambient environment where pests would otherwise thrive[686]. Examples hermetic storage methods include metal silos[687], plastic drums[688] and high-density polyethylene bags[689]. For example, the use of metallic silos in northern Afghanistan reduced the post-harvest storage loss of grain from 15–20% to less than 1–2%. Furthermore, the quality of the stored grains was retained as they were protected from insects, rodents and mould. These grains could, therefore, be stored for longer periods[690].

Effective grain storage involves stores against moisture, rodents, birds and thieves, and ensuring that storage conditions within stores are sub-optimal or lethal for pests such as fungi, insects and mites. The most important of these storage conditions are: i) temperature; ii) moisture; and iii) gas composition[691]. Cool temperatures are essential for the effective storage of grain, which should be allowed to cool after drying before loading it into a store. Temperature can then be controlled during storage by shading or by keeping storage containers indoors where it is cooler. Drying and then storing grain at or below 13% moisture content prevents all fungal development and grain below 10% moisture content is protected against weevil (*Sitophilus spp.*) infestation[692]. Furthermore, external changes in humidity would not affect the grain once stored in airtight containers. In terms of controlling gas composition, this can be achieved by using hermetic storage containers, which have been discussed above. If these containers are kept sealed for at least the first six weeks of storage, prevents bio-deterioration[693].

The importance of post-harvest storage in strengthening food security is detailed in **Table 39** below.

[684] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[685] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[686] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[687] Tefera T, Kanampiu F, De Groote H, Hellin J, *et al*. 2010. The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*. 30: 240–245.
[688] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[689] Baoua IB, Amadou L, Ousmane B, Baributsa D & Murdock LL. 2014. PICS bags for post-harvest storage of maize grain in West Africa. *Journal of Stored Products Research*. http://dx.doi.org/10.1016/j.jspr.2014.03.001
[690] FAO. 2010. "Climate-resilient" Agriculture: Policies, practices and financing for food security, adaptation and mitigation. Available at: http://www.fao.org/docrep/013/i1881e/i1881e00.pdf
[691] Stathers T, Lamboll R & Mvumi BM. 2013. Postharvest agriculture in changing climates: its importance to African smallholder farmers. *Food Security*. 5: 361–392.
[692] Birch LC. 1945. A contribution to the ecology of *Calandra oryzae* L. and *Rhyzopertha dominica* Fab. (Coleoptera) in stored wheat. *Transactions of the Royal Society of South Australia*. 69(1): 140–151.
[693] Stathers T, Lamboll R & Mvumi BM. 2013. Postharvest agriculture in changing climates: its importance to African smallholder farmers. *Food Security*. 5: 361–392.

Table 39. The importance of post-harvest storage in food security[694].

Dimension of food security	Description	Effects of post-harvest storage
Availability	The overall ability of the agricultural system to meet food demand.	• Seed storage determines the quality and quantity of food produced in the subsequent season. • Food is available to households throughout the year.
Stability	Relates to individuals who are at high risk of temporarily or permanently losing access to the resources needed to consume adequate food, either because these individuals cannot ensure *ex-ante* against income shocks or they lack the reserves to maintain consumption *ex-post* or both.	• Maximal food reserves are ensured, which can maintain or increase in value and can be sold to cover other income shocks or emergency needs.
Access	Covers access of individuals to adequate resources (entitlements[695]) to acquire the food necessary for a nutritious diet.	• Maintains the nutritional value of food by preventing deterioration caused by fungi, insects, birds or rodents. • The prices of grain and other crops increase during the year – as availability decreases. Food stocks, therefore, act as investments which increase in value if their quality can be maintained and so can help household purchasing power keep up with market costs.
Utilisation	Encompasses all food safety and quality aspects of nutrition. Its subdimensions are therefore related to health, including the sanitary conditions across the entire food chain.	• Maintains the nutritional value and quality of stored food which has positive health implications.

Examples of post-harvest storage solutions

<u>Metal silos</u>

The metal silo is a post-harvest technology that has the potential to play an important role in ensuring food security. It is a cylindrical structure, constructed from a galvanised iron sheet and airtight, creating an anaerobic environment which kills any insect pest that may have entered during filling (**Figure 84**). Furthermore, pests including rodents, insects and birds are unable to access the grain stored inside the silo. A recent study of maize storage in metal silos found that almost all losses from insects had been eliminated, saving an average of 150 to 200 kg of grain, an increase of 1.8 to 2.4 months of storage duration and a complete reduction in insecticide costs[696].These silos can be fabricated in different sizes, with storage capacities of 100–3000 kg, costing between US$35 and US$375[697].

[694] Adapted from: Stathers T, Lamboll R & Mvumi BM. 2013. Postharvest agriculture in changing climates: its importance to African smallholder farmers. *Food Security*. 5: 361–392.
[695] Entitlements are defined as the set of all those commodity bundles over which a person can establish command given the legal, political, economic, and social arrangements of the community of which he or she is a member.
[696] Gitonga ZM, De Groote H, Kassie M & Tefera T. 2013. Impact of metal silos on households' maize storage, storage losses and food security: An application of a propensity score matching. *Food Policy*. 43: 44–55.
[697] Tefera T, Kanampiu F, De Groote H, Hellin J, *et al*. 2010. The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*. 30: 240–245.

Figure 84. A metal silo[698].

For effective storage of grain in a metal silo, the product should be dried to a moisture content of less than 14% in the case of cereals and less than 10% for pulses and oilseeds[699,700]. Once the dried grain has been placed in the silo, storage efficiency depends on storage length, losses during storage – including quality deterioration – and storage volume[701]. When used correctly, metal silos offer several advantages, including: i) maintaining the quality of the stored product; ii) creating an anaerobic environment which provides non-residual fumigation; iii) reducing the use of insecticides; iv) requiring minimal space allowing them to be placed within or near a home; v) reducing post-harvest losses to almost 0%; vi) enabling smallholder farmers to take advantage of fluctuating grain prices; vii) preventing access by pests and pathogens that can damage grain and harm human health; and viii) can be built on-site with local labour and easily available materials[702]. Additionally, the metal silo can have socio-economic economic and environmental impacts as described below.

- It is an important food security element in the grain storage and distribution chain. Smallholder farmers with metal silos are able to feed their families throughout the year and are able to sell any surplus at local markets. Grains, particularly maize and beans, can be stored for up to three years in a metal silo[703]. Consequently, smallholder farmers are able to set aside reserves needed under climate change conditions and crop failure[704].
- Secure post-harvest storage empowers smallholder farmers. Metal silos facilitate an increase of incomes, as farmers are able to store grains which can be sold at premium prices late in the post-harvest season when demand is greater than supply[705]. Increased incomes can be used to improve the standard of living in smallholder

[698] Image from: http://paepard.blogspot.co.za/2015/08/
[699] Tefera T, Kanampiu F, De Groote H, Hellin J, *et al*. 2010. The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*. 30: 240–245.
[700] A simple method for checking the moisture content includes: i) placing a few grains in a dry glass bottle together with two to three table spoons of salt; ii) the content is then mixed thoroughly and left to stand for 15 to 20 minutes; iii) if salts particles adhere to the glass, it shows that they have absorbed some moisture from the grains and the grains are not yet dry; iv) if the grains do not adhere to the glass, then the grain is ready for storage.
[701] Thamaga-Chitja JM, Hendriks SL, Ortmann GF & Green M. 2004. Impact of maize storage on rural household food security in northern Kwazulu-Natal. *Tydskrif vir Gesinsekologie en Verbruikerswetenskappe*. 32: 8–15.
[702] FAO. 2008. Agricultural and Food Engineering Technologies Service. Household Metal Silo: Key Allies in FAO's Fight Against Hunger. Rome, Italy. Available at: http://www.fao.org/fileadmin/user_upload/ags/publications/silos_E_light.pdf
[703] SDC. 2008. Latin America Section: Fighting Poverty with Metal Silo and Job Creation. Berne, Switzerland. Available at: https://www.shareweb.ch/site/Agriculture-and-Food-Security/focusareas/Documents/phm_sdc_latin_brief_silos_central_america_e.pdf
[704] FAO. 2008. Agricultural and Food Engineering Technologies Service. Household Metal Silo: Key Allies in FAO's Fight Against Hunger. Rome, Italy. Available at: http://www.fao.org/fileadmin/user_upload/ags/publications/silos_E_light.pdf
[705] Florkowski J & Xi-Ling W. 1990. Simulating the impact of pecans storage technology on farm price and grower's income. *Southern Journal of Agricultural Economics*. 22: 217–222.

households and allows farmers to invest in their farms, which can further improve incomes.

- Engaging in metal silo fabrication and marketing can stimulate job creation and rural enterprise development[706]. For example, tinsmiths involved in metal silo production in South America earn an additional ~US$470 per year[707].
- By reducing post-harvest food losses, metal silos contribute to safeguarding agro-ecosystems. Reducing the loss of already scarce food supplies is more sustainable than increasing production to compensate for post-harvest losses. To increase production, more intensive farming or an expansion of the area under cultivation is required. Both of these interventions have negative effects on the environment, especially in the case of rural smallholder farms, which tend to be located in fragile ecosystems or on marginal land[708]. Furthermore, the use of metal silos minimises the use of pesticides, which can have negative impacts on the environment and lead to the secondary poisoning of non-target species – including birds – as well as potentially harming human health[709].

<u>Purdue Improved Crop Storage (PICS) bag</u>

The PICS[710] bag (**Figure 85**) is one of several hermetic storage bag products – others include, the GrainPro SuperGrain bag, the IRRI Superbag and the AgroZ® Bag. Each of these bags applies the same hermetic principles but differs in design[711].

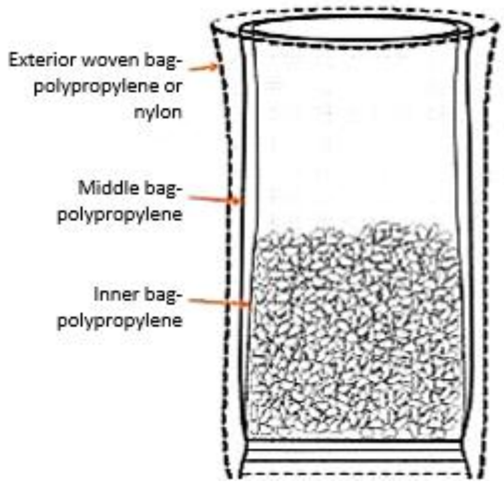

Figure 85. Makeup of a PICS bag[712].

The PICS bag technology uses a triple layer bag system where two airtight polyethylene bags are placed inside a protective sack. This bag – 50 or 100 kg capacity – was initially developed for the storage of cowpea in West Africa, but its use has since expanded to the storage of maize, coffee, millet and sorghum[713]. The PICS bag is an alternative hermetic storage method

[706] Tefera T, Kanampiu F, De Groote H, Hellin J, *et al*. 2010. The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*. 30: 240–245.
[707] SDC. 2008. Latin America Section: Fighting Poverty with Metal Silo and Job Creation. Berne, Switzerland. Available at: https://www.shareweb.ch/site/Agriculture-and-Food-Security/focusareas/Documents/phm_sdc_latin_brief_silos_central_america_e.pdf
[708] Calderon M. 1981. The ecosystem approaches for apprehending the extent of post-harvest grain losses. *Phytoparasitica*. 9: 157–167.
[709] Konstantinou IK, Hela DG & Albanis TA. 2006. The status of pesticide pollution in surface waters (rivers and lakes) of Greece. Part I. Review on Occurrence and Levels. *Environmental Pollution*. 141: 555–570.
[710] Baoua IB, Amadou L, Ousmane B, Baributsa D & Murdock LL. 2014. PICS bags for post-harvest storage of maize grain in West Africa. *Journal of Stored Products Research*. http://dx.doi.org/10.1016/j.jspr.2014.03.001
[711] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[712] Image from: https://www.rockefellerfoundation.org/blog/awareness-key-reducing-post-harvest/
[713] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf

to metal silos (see above), which have been promoted in sub-Saharan Africa[714]. Smallholder farmers' use of metal silos, however, by the high initial investment required and the limited availability of this technology[715]. The PICS technology has an advantage over the metal silo, in that while performing the same function, it is much cheaper to purchase – costing US$10–13 per tonne per year[716], compared with the metal silo which costs US$316[717]. Furthermore, it has an established local distribution network in West Africa, as well as being simple, lightweight and durable. PICS bags are also produced locally in six African countries, with more than 2.5 million being produced and sold to date[718].

Additional socioeconomic factors suggest that hermetic bags are preferred to silos at the smallholder level. Firstly, in areas where natural disasters (for example, floods and droughts) are common, or where conflict is prevalent, PICS bags provide the added benefit of mobility whereas silos are sedentary. Secondly, where theft is a problem, it is easier to hide bags. Finally, the culture of reciprocity often places social pressure on farmers to give away their surplus grain to family and/or community members who have grain deficits during the dry season. As a result, many farmers prefer to conceal their surplus grain to avoid this and to save grain for future consumption or sale[719].

<u>Zero Energy Cooling Chambers (ZECC)</u>

ZECCs have been developed based on the principle of direct evaporative cooling[720]. These chambers remain 10–15°C cooler than the atmospheric temperature and maintain ~90% relative humidity (**Figure 86**). This prevents the spoilage of fruits and vegetables in environments affected by high temperatures (**Table 40**) and will be considerably effective under future climate change conditions in Ghana where temperatures are already high and are expected to increase.

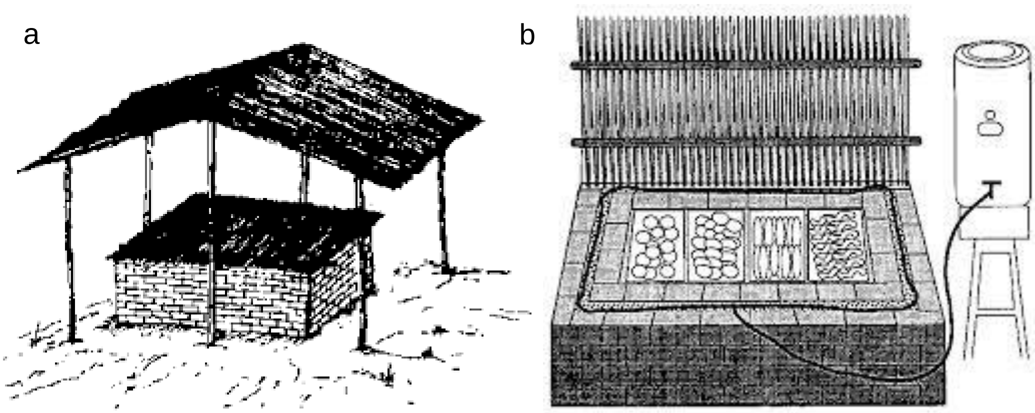

Figure 86. Examples of Zero Energy Cooling Chambers (ZECC)[721,722].

[714] Tefera T, Kanampiu F, De Groote H, Hellin J, *et al*. 2010. The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*. 30: 240–245.
[715] Tefera T, Kanampiu F, De Groote H, Hellin J, *et al*. 2010. The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*. 30: 240–245.
[716] http://postharvest.nri.org/loss-reduction/choosing-the-right-grain-store/storage-search/89-pics-triple-bags
[717] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[718] Baoua IB, Amadou L, Ousmane B, Baributsa D & Murdock LL. 2014. PICS bags for post-harvest storage of maize grain in West Africa. *Journal of Stored Products Research*. http://dx.doi.org/10.1016/j.jspr.2014.03.001
[719] Fintrac. 2016. Smallholder Grain Storage in Sub-Saharan Africa: A case study on Hermetic Storage Technology Commercialisation in Kenya. Available at: https://www.fintrac.com/sites/default/files/Smallholder_GrainStorage.pdf
[720] Occurs when air, which is not already saturated with water, passes over a wet surface. The water evaporates into this air, raising its moisture content and decreasing its temperature. The efficiency of evaporative cooling depends on the moisture content of the surrounding air. Very dry air can absorb a considerable amount of moisture and cooling is consequently greater.
[721] Image from: http://collections.infocollections.org/ukedu/uk/d/Jii01ee/4.4.html
[722] Image from: https://www.researchgate.net/publication/233612639_Pre-cooling_systems_for_small-scale_producers

The use of ZECCs has been found to considerably increase the shelf life of fruit and vegetables when compared with storage at room temperature (**Table 40**). Furthermore, the physiological loss in weight of stored products was also found to be less[723]. If ZECCs are taken up widely by smallholder farmers, the availability of fruit and vegetables will increase and consumers will pay less. The farmers will also not be forced to make distress sales and will, as a result, see greater financial returns.

Table 40. The shelf life of various fruits and vegetables inside a ZECC[724].

Produce	Time of storage	Normal shelf life	Shelf life inside ZECC
Leafy vegetables	Summer	<1	~3
	Winter	3	8–10
Other vegetables	Summer	1–2	5–6
	Winter	4–5	10–12
Potato	Spring/Summer	40	97
Mango	Summer	4	8
Orange	Winter	8–10	50–60

Advantages of ZECCs include the following[725].

- They can be constructed by unskilled individuals.
- No mechanical or electrical energy is required for their construction or operation.
- They allow farmers to store fresh produce for a few days and thus avoid the need for early sales at lower prices.
- They are ideal for the small-scale household storage of fruit and vegetables.
- The consequent reduction in losses means that the money spent on materials is easily made up again.
- These chambers are also useful for temporary storage of curd, milk and cooked food.
- They can also be used for mushroom cultivation, raising silkworms and for the storage of biofertilisers.

The disadvantages of ZECCs are outlined below[726].

- Capital is required to purchase the materials necessary for construction.
- Their operation relies on a dependable source of water throughout the year.

This intervention would contribute to disrupting potential impact pathways 3, 4, 5 and 9 in **Figure 37**.

12.4.5 Alternative climate-resilient livelihoods

12.4.5.1 Shea butter production

Local communities in northern Ghana will potentially be able to benefit from the climate-resilient land management practice of agroforestry (Section 11.4.2.1) through the production of shea butter. The African shea tree (*Vitellaria paradoxa*) is indigenous to the dry savanna belt of West Africa and is a valuable source of NTFPs. Although shea trees do not reach maturity until ~25 years, they begin to bear fruit after ~15 years and can continue to produce fruit for up to 200 years after maturity[727]. The fruit of the tree, known as shea nuts, are rich in a mixture of oils and triglycerides which can be processed into shea butter for use in food preparation, cosmetics and moisturisers. Traditionally, most of the shea butter produced is used for home consumption and to meet local market demand[728]. However, there is growing

[723] http://ucce.ucdavis.edu/files/datastore/234-2143.pdf
[724] http://collections.infocollections.org/ukedu/uk/d/Jii01ee/4.4.html
[725] http://ucce.ucdavis.edu/files/datastore/234-2143.pdf
[726] http://ucce.ucdavis.edu/files/datastore/234-2143.pdf
[727] Hatskevich, A., Jenicek, V. and Darkwah, S.A., 2011. Shea industry–a means of poverty reduction in Northern Ghana. *Agricultura Tropica et Subtropica*, *44*(4), pp.223-228.
[728] Masters E.T, Yidana J.A, and Lovett P.N. Reinforcing sound management through trade: shea tree products in Africa. FAO. Available at: http://www.fao.org/docrep/008/y5918e/y5918e11.htm

demand for the export of shea nuts and shea butter to the international market, with a rise in the export value of shea nuts and shea butter from ~US$830,000 in 2000 to ~US$27,600,000 in 2011[729]. The majority of exported shea nuts are industrially processed into shea butter and subsequently separated into a vegetable fat fraction (stearin) – formulated into cocoa butter equivalents/improvers (CBEs/CBIs) – and an oil fraction, used as a low-value base for margarine and animal feeds. A by-product of the CBE/CBI production process is a bioactive, unsaponifiable substance, which can be used in skin products, including cosmetics and moisturisers. The therapeutic uses of these compounds are significantly stimulating international interest in shea butter, which may benefit producers.

After initial production and collection, shea products can follow one of two value chains (**Figure 87**), involving either in-country or off-shore processing of shea nuts. For the latter, shea nuts are exported in their raw form to global markets, where they are then industrially processed. However, this value chain limits the income potential for Ghanaian communities as the nuts are being sold in their least valuable state, where the purchaser is responsible for costs of post-harvest processing. Additionally, transport costs of shea raw nuts are relatively high compared with processed shea products (**Table 41**), further limiting the potential income for producers. In-country processing is, therefore, necessary to add value to the production of shea nuts. The resulting product, shea butter, can then be sold for a higher price which would increase profits. While much of this processing can be done through large-scale mechanical extraction[730] which increases the export value of the products, the primary producers are still selling the shea nuts in their least valuable form, restricting their income and profitability.

[729] World Agroforestry Centre. 2013. Shea trees booming in Ghana. Available at: http://www.worldagroforestry.org/news/shea-trees-booming-ghana
[730] The current/potential capacity for mechanical shea processing in Ghana is 200,000 tonnes of shea nuts per year; Lovett P.N. 2013. The shea industry's economic impact in Africa. *Global Shea Alliance*. Available at: www.globalshea.com

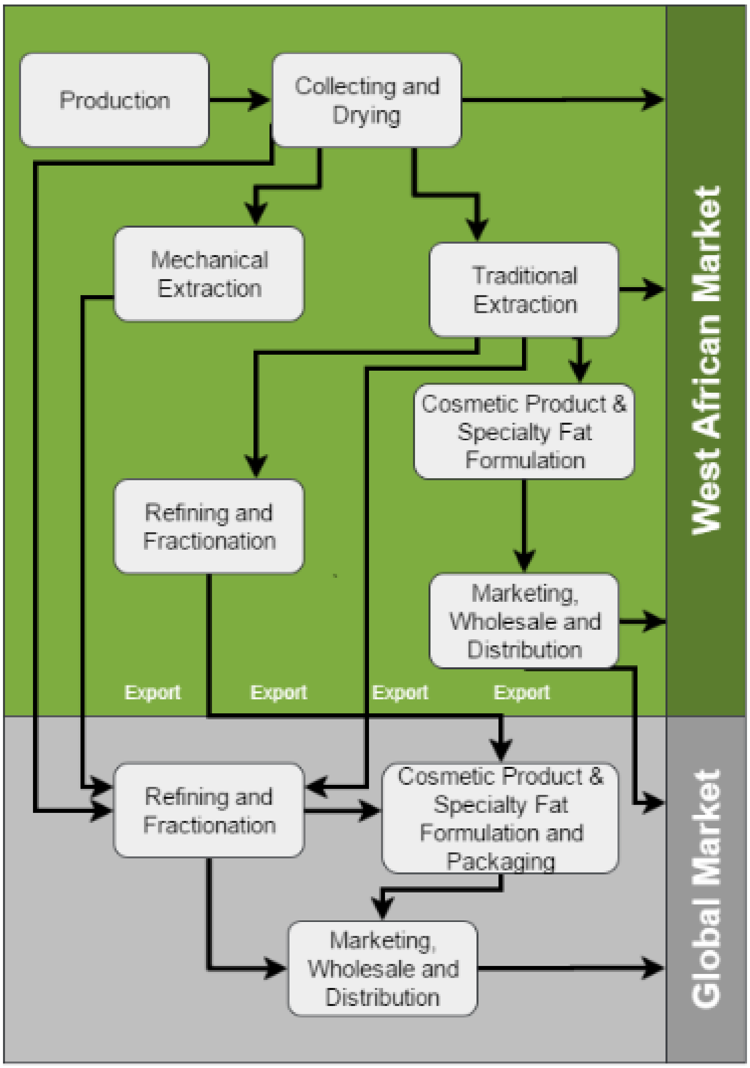

Figure 87. Value chain for Shea nuts in West Africa[731].

Table 41. Estimated costs of shea nuts exported from Ghana[732].

Description	Details
Farm-gate price per tonne of shea nuts	~US$150
Available stearin per tonne shea nuts	~230kg
Transport costs to nearest port per tonne shea nuts	~US$20
Tonnes of shea nuts required per tonne of stearin	4.40
Equivalent cost per tonne of stearin (at port entrance)	~US$740

To increase the value of shea nuts to rural communities in northern Ghana, community-based processing is required. Although traditional extraction does occur in villages on a small-scale, to provide for export markets the production of reasonable quantities of high-quality shea butter and the improvement of post-harvest extraction techniques is required. For example, traditional extraction using kneading methods only yield ~30-35% butter by dry weight, while expeller methods that include the use of solvents yield up to 45%. Similarly, reducing the processing costs and time requirements for producing shea butter would improve efficiency – and thus profitability – of production[733]. Furthermore, improving the product quality of shea butter will help fetch a higher price and improve shelf-life. Studies have shown that shea butter

[731] Lovett P.N. 2013. The shea industry's economic impact in Africa. *Global Shea Alliance*. Available at: www.globalshea.com
[732] Masters E.T, Yidana J.A, and Lovett P.N. Reinforcing sound management through trade: shea tree products in Africa. FAO. Available at: http://www.fao.org/docrep/008/y5918e/y5918e11.htm
[733] Masters E.T, Yidana J.A, and Lovett P.N. Reinforcing sound management through trade: shea tree products in Africa. FAO. Available at: http://www.fao.org/docrep/008/y5918e/y5918e11.htm

processing using modern methods is a viable enterprise in northern Ghana, with benefits outweighing costs. In terms of market value, processors using traditional extraction methods usually sell on open markets where prices are low (~US$0.15 per kg), whereas those using improved methods are able to sell to exporting agencies at much higher prices (~US$0.26 per kg) [734].

Several processing techniques are available to improve the production of shea butter in rural communities. Much of this revolves around the use of mechanical extraction equipment such as crushers, mills, and hydraulic presses. The most financially viable of these is the bridge press. This method has a net present value of ~470 per tonne of shea nuts processed and a cost-benefit ratio of 1.5, as opposed to the traditional method, which has values of ~24 and 1.02, respectively. The bridge press method also remains viable following a 10% cost overrun, whereas the traditional method does not [735]. The Bridge Press method uses a manually operated hydraulic press to mechanically extract shea butter from shea nuts. Dried kernels are pounded, as per the traditional method, but then do not need to be roasted before milling, saving time, fuel and labour. Additionally, after milling, there is no need for the kneading or rinsing stages, again saving time and effort. The drawback of the bridge press method is that because of increased operational and capital costs, the total income per batch of shea nuts is reduced. However, the return per woman-hour is substantially increased[736], as women are able to process a greater number of batches per week. The processing of shea butter, therefore, provides opportunities for economic empowerment of women in both rural and urban areas.

This intervention would allow beneficiaries to optimise financial returns from agroforestry activities implemented to disrupt impact pathway 3, 4, 5, 6, 7 and 8 in **Figure 37**.

12.4.5.2 Small ruminant rearing

As in many other West African states, food security is the primary objective of smallholder farmers in Ghana. Currently, more than 50% of the predominantly rural population of northern Ghana face food shortages between harvests, as a result of erratic rainfall and declining soil fertility[737]. This is expected to be exacerbated by future climate change conditions, including a longer dry season (refer to Section 11.4.2.2). Consequently, smallholder farmers in the north of the country may have to start looking to alternative climate-resilient livelihoods, such as small ruminant rearing, to maintain income generation and food security.

Small ruminants – i.e. sheep and goats – are kept by more than 80% of smallholder crop farmers in northern Ghana. These animals are predominantly used as liquid assets for when crops fail or food reserves are depleted[738]. The major small ruminant breeds in northern Ghana are the indigenous West African Dwarf goat and West African Dwarf sheep (Djallonke breed)[739]. Approximately 49% of northern Ghanaian farmers raise sheep and goats together, while ~38% and ~13% rear goats and sheep alone, respectively[740]. Goats are favoured as

[734] Issahaku H, Sarpong D.B, and Al-hassan R. 2012. Evaluating the Viability of Shea Butter Production: A Comparative Analysis. *Research Journal of Finance and Accounting* **3**(8): 47-52.
[735] Issahaku H, Sarpong D.B, and Al-hassan R. 2012. Evaluating the Viability of Shea Butter Production: A Comparative Analysis. *Research Journal of Finance and Accounting* **3**(8): 47-52.
[736] Teca 2006. Introducing a mechanical press for making shea butter in northern Ghana. FAO. Available at: http://teca.fao.org/technology/introducing-mechanical-press-making-shea-butter-northernghana
[737] Amankwah K. 2013. Enhancing food security in Northern Ghana through smallholder small ruminant production and marketing. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/282342
[738] Amankwah K. 2013. Enhancing food security in Northern Ghana through smallholder small ruminant production and marketing. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/282342
[739] Oppong-Anane K. 2006. Country pasture/forage resource profile: Ghana. Publishing Policy and Support Branch, Office of Knowledge Exchange, Research and Extensions, FAO, Rome, Italy. Available at: www.fao.org/ag/agp/agpc/doc/counprof/PDF%20files/Ghana-English.pdf
[740] Adams F. 2015. Socio-economic analysis of small ruminant livestock production in northern Ghana. PHd. Thesis. Kwame Nkrumah University of Science and Technology, Kumasi. Available at: http://ir.knust.edu.gh/bitstream/123456789/9264/1/Faizal%20Adams.pdf

they are well adapted to the arid conditions and are more tolerant to drought than other livestock[741,742].

Smallholder farmers in northern Ghana who do own livestock employ one of two management systems dependent on the season. During the wet season, animals are usually tethered to prevent them from feeding on crops. Tethering, however, often results in decreases in body condition and mortality because of restricted movement and browsing as well as exposure to the weather[743]. During dry months, free range management is generally used. Free ranging takes place after harvesting and often results in inadequate supplementary feeding during the late dry season when pastures are routinely burnt. Furthermore, free range animals are prone to high rates of livestock theft. Both these management strategies are also affected by the limited capacity of local veterinary services to render care to animals.

The responsibilities of above-mentioned management types are distributed evenly between male and female spouses in the household. Women are involved in less physical activities such as cleaning barns/kraals/pens and occasionally herding/tethering, feeding, provision of water, caring for weak animals and fodder harvesting. Men, in contrast, are involved in the more physically laborious activities including: i) constructing of barns/kraals/pens; ii) marketing of animals; and iii) caring for sick animals. Despite this share of responsibility between men and women in the family, men are the sole decision makers with regards to small ruminant management activities[744].

Socio-economic value of small ruminant production

Annual costs of sheep and goat rearing

For sheep production – given an average herd size of 12 animals – smallholder households in northern Ghana spend ~US$20 (~US$1.6 per sheep) on the purchase of external inputs – including *inter alia* veterinary services, medicines, fencing/housing, dipping and supplementary feed. Goat rearing is marginally cheaper at ~US$17 (~US$1.5 per goat). Furthermore, the non-cash (stock theft and mortality) costs for the rearing of sheep and goats are ~US$123 (~US$10 per sheep) and ~US$78 (~US$7 per goat) respectively[745]. These costs suggest that an improvement in basic animal health care and nutrition will lead to an increase in meat production in traditional small ruminant rearing. However, despite the higher costs for raising sheep, the gross value per sheep is significantly higher than that for goats (**Table 42**).

Table 42. The gross value of small ruminants (sheep and goats) per household in northern Ghana[746].

	Sheep	Goats
Average flock size	12	12
Non-marketed products	**~US$91**	**~US$54**
Meat consumed at home	~US$66	~US$38
Manure	~US$0	~US$0
Hide	~US$4	-
In-kind	~US$21	~US$16
Marketed products	**~US$99**	**~US$20**

741 Lebbie SHB. 2004. Goats under household conditions. *Small Ruminant Research.* 51(2): 131–136.
742 Peacock C. 2005. Goats: A pathway out of poverty. *Small Ruminant Research*. 60(1): 179–186.
743 Amankwah K. 2013. Enhancing food security in Northern Ghana through smallholder small ruminant production and marketing. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/282342
744 Adams F. 2015. Socio-economic analysis of small ruminant livestock production in northern Ghana. PHd. Thesis. Kwame Nkrumah University of Science and Technology, Kumasi. Available at: http://ir.knust.edu.gh/bitstream/123456789/9264/1/Faizal%20Adams.pdf
745 Adams F. 2015. Socio-economic analysis of small ruminant livestock production in northern Ghana. PHd. Thesis. Kwame Nkrumah University of Science and Technology, Kumasi. Available at: http://ir.knust.edu.gh/bitstream/123456789/9264/1/Faizal%20Adams.pdf
746 Adams F. 2015. Socio-economic analysis of small ruminant livestock production in northern Ghana. PHd. Thesis. Kwame Nkrumah University of Science and Technology, Kumasi. Available at: http://ir.knust.edu.gh/bitstream/123456789/9264/1/Faizal%20Adams.pdf

Meat	~US$242	~US$115
Less cash cost	~US$20	~US$17
Less non-cash cost	~US$123	~US$78
Gross value	**~US$190**	**~US$74**

Other benefits of small ruminant rearing

Over 60% of northern Ghanaian households facing food shortages use the income generated from the sale of livestock to purchase food[747,748]. Although manure does not contribute to the gross value of small ruminants in northern Ghana, it can result in increased crop yields. Smallholder houses commonly use cattle manure, for example, as an alternative to inorganic fertiliser. The use of sheep and goat manure is also an appropriate alternative to inorganic fertiliser for promoting early growth in crops such as millet and sorghum[749]. Thus, strategies to improve small ruminant manure harvesting are desirable to increase crop production. This will reduce the amount of money spent on inorganic fertilisers to improve soil fertility in the degraded agro-ecological areas of northern Ghana, thereby increasing the profitability of agriculture.

Apart from the benefits of manure, most case studies from West Africa (including Ghana) found that livestock is a source of liquid assets – used for *inter alia* financing crop farming and for the payment of school fees – and insurance for resource-poor smallholder farmers[750]. Small ruminants also feed on crop residues after harvesting, which decreases wastage and prevents the influx of pests – particularly rodents. Therefore, livestock can make an important contribution to household food security and sustainable rural development[751,752,753].

Potential as an alternative livelihood in northern Ghana

The rapid increase in demand for livestock products in developing countries – such as Ghana – and their integration into global markets provides new opportunities for small-scale livestock producers[754]. There is a substantial local demand for livestock products. Ghana currently produces only ~30% of its national demand for meat, of which northern Ghana supplies ~70%[755]. The primary reason for the north's domination of the country's livestock product market is the good grazing available in the grassland areas of the Guinea Savanna Agro-ecological Zone, which is highly conducive to livestock farming. After slaughter, the marketing of livestock products is ensured by traders who connect the smallholder livestock farmers from the north of Ghana to the consumer markets in the central and southern areas of the country[756,757]. However, smallholder livestock farmers in northern Ghana have not yet taken

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[747] International Centre for Development Oriented Research in Agriculture (ICRA) & Nyankpala Agricultural Experimental Station Ghana (NAES). 1993. Coping with uncertainty: Challenges for agricultural development in the Guinea Savanna Zone of the Upper West Region of Ghana. *Working Document Series 28.* Wageningen, The Netherlands.

[748] Quaye W. 2008. Food security situation in northern Ghana, coping strategies and related constraints. *African Journal of Agricultural Research*. 3(5): 334–342.

[749] Karbo N, Bruce J & Otchere EO. 1999. The role of livestock in sustaining soil fertility in northern Ghana. *ILEIA News Letter.* Available at: http://www.old.iita.org/cms/details/crop-livestock /arti16.pdf.

[750] Amankwah K. 2013. Enhancing food security in Northern Ghana through smallholder small ruminant production and marketing. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/282342

[751] De Vries J. 2008. Goats for the poor: Some keys to successful promotion of goat production among the poor. *Small Ruminant Research.* 77(2-3): 221–224.

[752] Bosman HG. 1995. Productivity assessments in small ruminant improvement programmes. A case study of the west African dwarf goat. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/206542

[753] FAO. 2012. Livestock sector development for poverty reduction: an economic and policy perspective – Livestock's many virtues. Rome. Available at: http://www.fao.org/docrep/015/i2744e/i2744e00.pdf

[754] FAO. 2012. Livestock sector development for poverty reduction: an economic and policy perspective – Livestock's many virtues. Rome. Available at: http://www.fao.org/docrep/015/i2744e/i2744e00.pdf

[755] Amankwah K. 2013. Enhancing food security in Northern Ghana through smallholder small ruminant production and marketing. PHd. Thesis. Wageningen University. Available at: http://edepot.wur.nl/282342

[756] ICRA & NAES. 1993. Coping with uncertainty: Challenges for agricultural development in the Guinea Savanna Zone of the Upper West Region of Ghana. *Working Document Series 28.* Wageningen, The Netherlands.

[757] APD, VSD, LPIU, SRID & GTZ-MoAP. 2009. Review of MoFA's activities in support of livestock development in Ghana in support of livestock development in Ghana', in Animal Production Directorate
(APD), V. S. D. V., Livestock Planning and Information Unit (LPIU), Statistical Research and Information Directorate (SRID) and Market Oriented Agricultural Programme (GTZ-MoAP) (ed), pp. 84. Accra, Ministry of Food and Agriculture (MoFA).

advantage of the above-mentioned income generating opportunities. This is because of a combination of technical and institutional constraints that have persisted over recent decades[758,759,760]. These constraints include: i) inadequate structure and delivery of local veterinary services; ii) the principle of optimum investment in staple food crop production, but comparatively minimal investment in small ruminant rearing; iii) the lack of supplementary feeding during the dry season; iv) the traditional practice of bush burning; v) stock theft; vi) limited implementation of sustainable grazing management strategies; and vii) an unequal distribution of incomes along the livestock supply chain[761,762].

Policies or recommendations that outline the appropriate measures to mitigate the above-mentioned constraints and thereby improve the traditional small ruminant livestock production system in northern Ghana deserve much attention. Currently, there is limited support in this form and the majority of smallholder farmers engaged in small ruminant rearing do not have the capacity to make these improvements themselves. Most of the income from small ruminant rearing in northern Ghana is used to cover household expenses and to purchase food during the dry season. As a result, the small ruminant production system, which lacks investment, is vulnerable to risks including mortality and theft. These issues make a convincing case for livestock policies that recognise the total benefits of small ruminant rearing, including non-market products in smallholder households. The marketing of small ruminant products will increase if policies are devised to provide cost-effective and economic alternatives – such as loans for the purchasing of food during the dry season – that will substitute the non-market role of sheep and goats in smallholder livelihoods. Unless there are less expensive and attractive options, the current status quo of small ruminant rearing will remain a permanent feature in the northern Ghanaian agricultural system since the non-market functions of the animals are deeply rooted in rural livelihoods.

One practical, but long-term alternative that will lessen the non-market (socio-economic products) roles of sheep and goats is to actively incorporate smallholder farmers into formal financial and insurance markets. This will entice farmers to become market-oriented producers. Furthermore, it will help reduce the losses of small ruminants, resulting from the practice of holding onto mature animals to serve non-market functions, which exposes them to diseases, vehicular accidents and theft. Along with this, by increasing the capacity of extension services (particularly veterinary), the survival rate of animals will increase as well as the interest of smallholder farmers in the ownership of small ruminants. Consequently, large herd sizes will allow for excess animals to be sold at markets, particularly during religious festivals when the demand for meat is high and the market prices are strong. Income generated from this alternative livelihood will supplement that obtained from crop farming. This extra income can then be used to purchase food during food shortages, as well as to pay for veterinary services and other agricultural inputs necessary to increase both crop and livestock production. Furthermore, fodder production through agroforestry and other climate-resilient land management interventions will lead to less pressure on local grazing sources and allow for animals to be fed during the dry season. This will further strengthen the resilience of smallholder farmers in northern Ghana under conditions of climate change. Manual piston pumps can be used

[758] Animal Research Institute. 1999. Livestock systems diagnostic survey: Lawra District, Upper West Region, Ghana. *Technical Report*.
[759] ICRA & NAES. 1993. Coping with uncertainty: Challenges for agricultural development in the Guinea Savanna Zone of the Upper West Region of Ghana. *Working Document Series 28.* Wageningen, The Netherlands.
[760] Quaye W. 2008. Food security situation in northern Ghana, coping strategies and related constraints. *African Journal of Agricultural Research*. 3(5): 334–342.
[761] Addah W, Baah J, Tia S & Okine E. 2009. Knowledge and practices of smallholder farmers and herdsmen in the use of acaricides and gastrointestinal anthelminthes in Ghana. *Livestock Research for Rural Development*. 21(198): http://www.lrrd.org/lrrd21/11/adda21198.htm
[762] Animal Research Institute. 1999. Livestock systems diagnostic survey: Lawra District, Upper West Region, Ghana. *Technical Report*.

This intervention would allow beneficiaries to optimise financial returns from land management activities implemented to disrupt impact pathway 5, 6, 7 and 8 in **Figure 37**.

12.4.6 Climate-resilient infrastructural investments

12.4.6.1 Boreholes

Obtaining water from underground sources can help build climate resilience of rural communities by providing water during the dry season, supporting livelihoods such as dry season gardening and small ruminant rearing. Boreholes are similar to traditional wells, except the hole is sunk with a much smaller diameter drill. The hole is drilled using special machines and lined with PVC or metal tubing. Because of the small diameter, a pump is required to access the water. Hand pumps with a bucket piston system (**Figure 88**) can be used for water sources near the surface (less than 6 m), however when the water is being drawn from deeper, electric pumps may be required. A single borehole in Ghana is estimated to be able to supply water to up to 300 people for a period of 30–40 years[763].

This intervention would contribute to disrupting potential impact pathways 6, 7 and 10 in **Figure 37**.

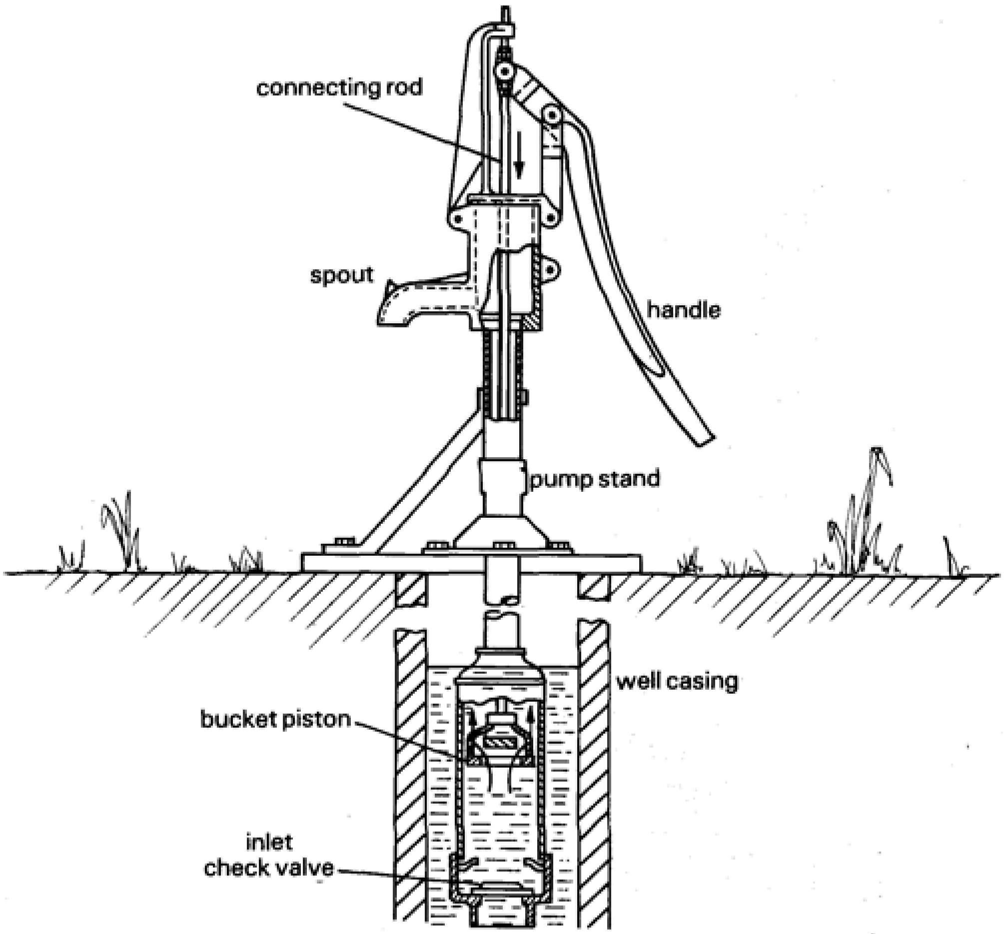

Figure 88. Hand pump with single-acting bucket piston[764].

[763] USAID 2009. Ghana Wash Project – Boreholes and Hand-dug Wells. Available at: http://ghanawashproject.org/water/boreholes-wells/
[764] Fraenkel P.L. 1986. Water Lifting Devices. *FAO Natural Resources Management and Environment Department.* Available at: http://www.fao.org/docrep/010/ah810e/AH810E06.htm

12.4.6.2 Check Dams

A check dam is a small, temporary or permanent dam constructed across a drainage ditch, stream or river to lower the speed of water flow. By reducing flow rates, check dams suppress erosion and allow sediment to settle. Furthermore, check dams can improve groundwater recharge[765], increasing water availability during the dry season. The physical structures can be built using logs, stone, gravel-filled sandbags or bricks and cement[766], or in the case of living check dams, bamboo (or other locally available timber) supported by the roots of trees planted on the banks as well as other plants growing in and around the check dam.

Living check dams are inexpensive and easy to install when compared with those constructed from concrete and stone or brick. The materials used for the construction of living check dams can be gathered from surrounding forests or grown specifically for the purpose. For example, bamboo lots can be planted as part of agroforestry operations and used for the construction and maintenance of check dams. Agroforestry alongside water ways can also be used to strengthen check dams, where the roots from trees to trees entwine with the check dam structures, providing physical support and prolonging the lifespan of the dams. This interaction serves a double purpose, as the roots of the trees help stabilise the riverbanks and further prevent erosion. Living check have the added benefit of being more aesthetically pleasing in natural environments. Consequently, local communities are generally more accepting of them.

This intervention would contribute to disrupting potential impact pathways 6, 7 and 10 in **Figure 37**.

13 Detailed Project Description

Based on the feasibility analysis described in previous sections, the proposed project will undertake the following intervention.

13.1 Geographies of intervention and target beneficiaries:

The proposed project will be implemented in the Savannah, Northern, North East, Upper East and Upper West Regions of northern Ghana. As described above, the five northern regions are especially exposed to negative climate change impacts. Additionally, the northern populace is extremely sensitive to climate variability and change and has limited capacity to adapt to any changes in climate[767]. It is for these reasons of excessive exposure, elevated sensitivity and limited adaptive capacity that the northern regions of Ghana are considered the most vulnerable regions of the country to climate change[768]. See Section 3 of Annex 2 — Feasibility Study,[769] for a detailed analysis that identifies the three northern regions as the most vulnerable to climate change impacts.

Within the northern regions of Ghana, implementation of the proposed project will be focused on eight of the 42 districts that comprise northern Ghana (Figure 3), namely:

- Jirapa , Lambussie, Lawra and Wa West in the Upper West Region;
- Binduri and Garu in the Upper East Region; and
- East Mamprusi and Yunyoo-Nasuan in the North East Region.

[765] Ruffino L. 2009. Rainwater harvesting and artificial recharge to groundwater. Brussels: SAI Platform. Available at: http://www.saiplatform.org/uploads/Library/Technical%20Brief%202%20%20Rainwater%20harvesting%20%20artificial%20recharge%20to%20groundwater.pdf.
[766] Ruffino L. 2009. Rainwater harvesting and artificial recharge to groundwater. Brussels: SAI Platform. Available at: http://www.saiplatform.org/uploads/Library/Technical%20Brief%202%20%20Rainwater%20harvesting%20%20artificial%20recharge%20to%20groundwater.pdf.
[767] See 'Climate rationale and context' above for more information on sensitivity and adaptive capacity.
[768] Please see Annex 2 'Feasibility Study': Section 3 for a full description of how climate change vulnerability was calculated.
[769] Section 3: Climate change vulnerability of the districts and regions of Ghana.

These districts were selected for project implementation using a comprehensive, quantitative assessment of district-specific vulnerability to climate change — incorporating exposure, sensitivity and adaptive capacity of communities — and a rigorous stakeholder engagement process (see Section 3 of Annex 2: Feasibility Study, and Annex 7h: Stakeholders Engagement Plan). The project will scale up best practices from other ongoing projects, thereby increasing the geographic and population coverage of support in the three northern regions.

The districts are partly in the Sudan Savanna Zone, located in the north-eastern corner of Ghana, with the majority of the zone located in Burkina Faso and Mali. It is characterised by fire-swept short grasses interspersed with low-density woodland. Grass cover is low, and some areas of land are bare and severely eroded. The Sudan Savanna Zone receives the least rainfall of Ghana's agro-ecological zones (~940 mm per annum) and only one rainfall season. Other Districts are in the Guinea Savanna Zone (or Interior Savanna Zone), located north of the Transitional Zone. This is the largest agro-ecological zone in Ghana, covering the northern half of the country. The zone is characterised by wooded grassland, consisting of a ground cover of grasses of variable height, interspersed with fire-resistant, deciduous, broad-leaved trees. In general, tree cover and height decrease from south to north along a gradient of decreasing rainfall. The Guinea Savanna Zone receives ~1,100 mm of rainfall per year, mostly during one rainfall season.

From those districts not currently receiving support, and taking climate change vulnerability scores into account, the final project districts were selected by national, regional and district level stakeholders from: i) the National Designated Authority (NDA) of Ghana within the Ministry of Finance (MoF); ii) members of the inter-ministerial Technical Advisory Committee (TAC) to the NDA; iii) staff of the Directorate of Crop Services from the Ministry of Food and Agriculture (MoFA); iv) representatives of the Environmental Protection Agency (EPA) from the Ministry of Environment, Science, Technology and Innovation (MESTI); v) Ministry of Local Government, Decentralization and Rural Development (MLGDRD) and vi) members of civil society organisations.

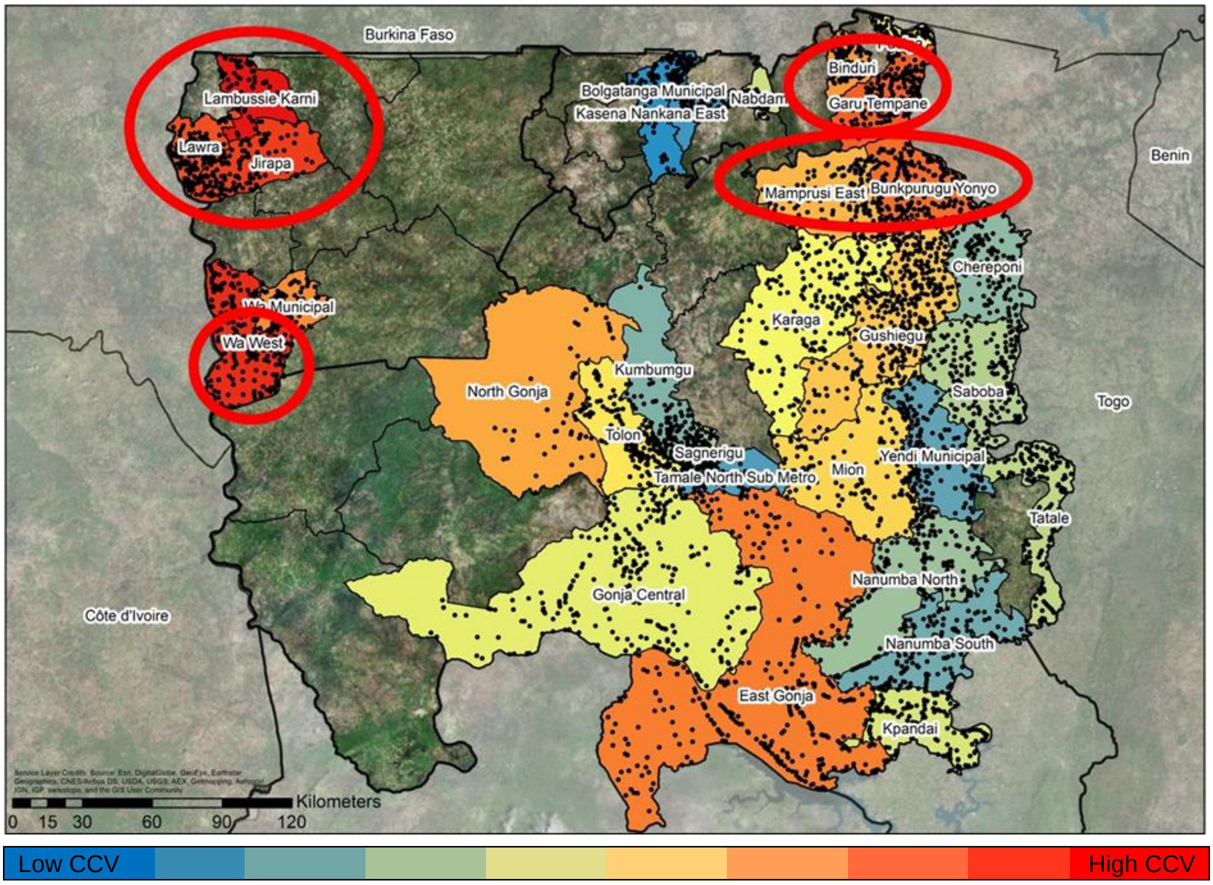

Figure 89. Target districts of the project within the three northern regions. Districts that are not depicted in this map are receiving support from the SLWMP and Adaptation Fund projects and thus were not considered eligible for selection.

Within each district, 15 communities will receive direct support from the project. Each community will receive support for three consecutive years (Table 43). Across the eight districts, the project will, therefore, support 120 communities over seven years. The direct beneficiary communities will be selected based on a rigorous set of selection criteria and comprehensive consultations at the national, regional, district and community levels (see Financing Proposal Annex 7h: Stakeholder Engagement Plan). The selection criteria include *inter alia*: i) high vulnerability to climate change[770]; ii) proximity[771] to at least five other vulnerable communities to promote knowledge and technology transfer to these vulnerable communities; iii) a willingness to participate; and iv) favourable land availability and access. Beneficiary communities will also be selected to ensure a representative geographic coverage across each district. The selection process has and will continue to involve consultations with: i) representatives from MESTI, MoFA and the NDA at the national level; ii) EPA and Department of Agriculture staff from the Northern, Upper East and Upper West regional offices; iii) zonal EPA officers within target districts; iv) District Assemblies (DA)[772] from the eight target districts; v) leaders from potential beneficiary communities (including chiefs and chief mothers); and vi) beneficiary community members.

Table 43. Timeframe for community support for a single district. A total of 15 communities will be supported in each district.

	Year

[770] i.e. high exposure and sensitivity and low adaptive capacity.
[771] <5km
[772] Consultations with District Assemblies focused on district extension officers, planning officers, disaster risk officers and fire services.

Community	1	2	3	4	5	6	7
Community 1 – 3							
Community 4 – 6							
Communities 7 – 9							
Communities 10 – 12							
Communities 13 – 15							

At the time of writing, four communities within each district have been selected based on the criteria described above. These communities were selected following detailed community consultations (see Annex 7h: Stakeholder Engagement Plan and Section E.5.3) that took place during the development of this Funding Proposal. Three of the four communities already identified will be selected to receive support during the first year of project implementation. The remaining community, as well as the additional communities that will also be identified through the selection process described above, will receive support from the second year of project implementation onwards.

Project objective:
The proposed project objective is to enhance the climate resilience of vulnerable smallholder farming communities in northern Ghana by improving food security and enhancing the agro-based rural economy.

The project is approach will be implemented in eight districts in northern Ghana that have been specifically chosen because: i) of their high vulnerability to climate change impacts (see Annex 2: Feasibility Study, Section 3); and ii) they are currently not receiving support from other ongoing initiatives.

The project's objective will be achieved by the successful implementation of project activities to achieve five outputs as outlined in the Theory of Change and detailed below.

13.2 Output 1: Improved climate data and early warnings made available to facilitate proactive drought and flood management.

There is a national need in Ghana for a paradigm shift in the current reactive approach to agricultural planning and management related to climate change. Output 2 will catalyse this much needed paradigm shift to a proactive planning and management approach to climate hazards by providing solutions for the key institutional and technological limitations and barriers to building resilience identified in Ghana. Building on the institutional and technical capacity support under Output 1, activities under this Output are designed to provide impact-based forecasts and early warnings of drought and flood hazards to the most vulnerable communities. This will enable farmers to take proactive measures to minimise crop losses and make the most of environmental conditions to increase food security and agricultural productivity. GMet will have ownership as well as O&M responsibility of the equipment procured under Output 2.2. Prior to the arrival of the equipment and handover, there will be a legal agreement between EPA and GMET governing the role and responsibilities for the equipment.

<u>Activity 1.1: Implement a new early warning data information and management system to provide access to improved data sources and new datasets on floods and droughts</u>

An analysis of current drought and flood early warning services in Ghana indicates that the majority have incomplete coverage and limited channels for information transfer and dissemination. Several studies — including a gap analysis of drought and flood risk management and early warnings in Ghana[773], a capacity needs assessment of the Ghana Meteorological Agency (GMet)[774], a Gender Assessment and Action Plan (See Funding Proposal Annex 8), and the assessments under the UNEP CLIMWARN project[775] — have also revealed several technological barriers to building the resilience in the agricultural sector to the impacts of climate change, namely relating to information access. Stakeholder consultations (see Funding Proposal Annex 7h: Stakeholder Engagement Plan) revealed that if women were provided improved technologies and financial services, they would likely invest in the land, leading to increased production — and potential increased income — which benefits not only themselves, but their families and communities too. Further to this, drought and flood information management and early warning systems have been identified as gaps by stakeholder consultations during the project development process (See Funding Proposal Annex 7h).

This activity has been designed based on lessons learned and recommendations on drought and flood early warning systems as identified by the GCF Readiness Programme, which was initiated in 2015. A summary of these recommendations is detailed below.

- Availability of hydrometeorological data is one of the key constraints for drought and flood management in Ghana. This limitation can be managed by upgrading the existing hydrometeorological network and combining training on applying satellite-based data within drought and flood management.
- Web-based solutions should be the focus because they enable easier dissemination of information and provide access to new users. This is further supported by the rapid growth of mobile data infrastructure in Ghana. Feedback on the use of a web-based platform was positive among stakeholders. Community members also expressed interest in increased access to climate information during the 2024 mission.
- Access to near real-time satellite-based data and indices provides great value to communities. There is a need for further capacitating local knowledge of satellite data, including additional validation and ground-proofing for its use in drought and flood management in Ghana.
- Dissemination of drought and flood information from the national to the local level is a key requirement that the current CTCN and GCF activities have not completely achieved. Focus on the linkage between national-level planning and local-level implementation with assistance from agricultural agents should be prioritised.
- Active engagement and involvement of key national agencies is very important in implementing early warning systems.
- Capacity building and training, particularly for women, is vital for successful implementation and long-term sustainability of early warning systems.

This intervention will focus on transforming the technical capacity of hydrometeorological service delivery systems to provide the information required to elicit a shift to proactive drought and flood management in Ghana, including a new data information and management system providing easy access to new and improved quality data for planning, early warning and response to drought and flood hazards. The web-based service delivery platform will be a multidisciplinary, multipurpose decision support system (DSS) enabling the dissemination of information and relevant technical tools related to climate change adaptation within the agriculture and water sector in Ghana.

[773] Tindan, P.D., Appiah, D.O. & Segbefia, A.Y. Attentiveness to Early Warning Drought Information: Implications for Policy Support and Climate Risk Reduction in Ghana. *Int J Disaster Risk Sci* 13, 25–37 (2022). https://doi.org/10.1007/s13753-021-00390-2
[774] CTCN assistance in Ghana: Needs assessment report. (2017). Available at: https://www.ctc-n.org/system/files/dossier/3b/activity_2_2_ctcn_ghana_-_needs_assessment_report.pdf
[775] More information on this project can be found here: https://www.unep.org/news-and-stories/video/un-environment-climwarn-project

Activity 1.2: Enhancing hydrometeorological and groundwater monitoring observation networks

The new data and information management system, combined with an enhanced service delivery platform for hydrometeorological services, will facilitate the cross-sectoral integration of up-to-date climate information and drought and flood early warnings to enable proactive instead of reactive management. Easier access to improved data sources and new datasets facilitated by the improved early warning system will address the barriers highlighted by stakeholders. This data information system will introduce innovative modelling approaches, based on remote sensing data, Artificial Intelligence and service delivery platforms. Additionally, with improved access to quality climate data information, farmers will be more actively involved in planning processes pertaining to drought and flood management. Proactive measures that farmers will be supported to undertake via this intervention include, *inter alia*: i) timing crop planting for optimum yields; ii) shifting to drought- and flood-resistant crops; and iii) relocation of agricultural efforts to more suitable sites that will minimise crop losses.

Activities and sub-activities are detailed below.

Sub-Activity 1.1.1. Implement a new data information and management system as a web-based data portal, providing easy access to enhanced existing data sources and new datasets through:

- Producing recommendations for improved use of existing Hydromet information and for use of new innovative and cost-efficient data sources (such as satellite-based information);
- Enabling easy access to relevant and automatically updated satellite-based near-real-time information through implementing a new data information and management system as a web-based data portal;
- Implementation of methods for merging the existing hydrometeorological information with satellite-based data sources for improved data accuracy and data made available through the new data information and management system;
- Implementing methods for downscaling and correcting the existing climate forecast products to produce a new seasonal forecast with Ghana with data available through the new data information and management system.

Sub-Activity 1.1.2. Develop and implement decision-support services (DSS) for climate-related hazard management, focused on improved drought and flood planning:

- Development and implementation of a web-based service delivery and decision-support (DSS) platform, including a crop growth model;
- Upgrading and implementation of national water resource allocation model(s);
- Implementation of risk knowledge services within the DSS platform, including mapping of existing hazards;
- Implementation of hazard monitoring and early warning services within the DSS platform;
- Validation and ground truthing of the DSS platform services within the eight target districts and sectors in vulnerable communities (includes technical testing activities and stakeholder feedback in selected districts/regions/applications, before complete finalisation of the products).

Activity 1.2: Enhancing hydrometeorological and groundwater monitoring observation networks

To improve the accuracy and coverage of climate data, this activity focuses on enhancing hydrometeorological and groundwater observation networks in the country, particularly Northern Ghana. Monitoring wells were established as part of the Hydrological Assessment of

Northern Ghana Project (HAP) for the monitoring of groundwater levels for informed decision-making; however, the network coverage needs to be expanded to capture a wider range. More comprehensive and detailed data will be captured by strategically expanding and upgrading these networks, thereby enabling better-informed decision-making at all levels. Women's involvement in the design, operation, and use of enhanced hydrometeorological and groundwater monitoring networks will be promoted to ensure gender-sensitive data collection and equitable access to climate and water information. Moreover, women will be trained as hydrometeorological and groundwater monitoring officers, technicians, and data users, ensuring their active participation in network operations and decision-making processes. In addition to expanded coverage, improving the network will include groundwater data loggers and receivers. This improved data will enhance the understanding of the impact of micro-climate change.

Activities and sub-activities are detailed below.

Sub-Activity 1.2.1. Improvement of the hydrometeorological observation network coverage and technology

- Assessment of the current gaps and installation requirements to meet hydrometeorological data needs
- Installation of monitoring wells for middle and southern Ghana to fill network coverage gaps
- Installation of solar energy technology systems to guarantee the continuous functioning of hydro-meteorological equipment and communication systems in remote areas

Sub-Activity 1.2.2. Development of a sustainability plan for the enhanced hydrometeorological and groundwater monitoring network

- Identification of operation and maintenance requirements of the improved network, including long-term costing
- Mapping of institutional responsibilities for the relevant stakeholders for ensuring sustainability of the hydrometeorological and groundwater monitoring network

<u>Activity 1.3: Capacitate key technical staff at national, regional and district levels, including GMet, HYDRO and WRC, for drought and flood services delivery</u>

This activity addresses the vital need for robust drought and flood management services by strengthening key entities, including Ghana Meteorological Agency (GMet), Ghana Hydrological Authority (HYDRO), and Water Resources Commission (WRC) at the national, regional, and district levels. The primary goal is to fortify their capabilities in delivering accurate and timely drought and flood-related information and support services. Specialized training programs will be initiated (with at least 30% of participants from GMet, HYDRO and WRC being women), tailored to equip personnel with advanced skills in drought and flood monitoring, assessment, and response, incorporating the latest technologies and best practices. Training programmes will integrate gender-sensitive content, focusing on how drought and flood services affect women and men differently, and ensuring that gender is mainstreamed in the delivery of these services. Additionally, a mentorship programme will also be developed to facilitate career advancement and leadership opportunities for women in technical roles at GMet, HYDRO, and WRC. Specifically designed programs for the agricultural sector aim to enhance local communities' understanding of drought and flood hazards, ensuring effective utilization of delivered data. Adopting a user-engaged co-production approach will boost farming communities' response capability to climate change, drought and flood through new Decision Support System (DSS) tools and services.

Activities and sub-activities are detailed below.

Sub-Activity 1.3.1. Capacitate key technical staff to use the DSS platform and outreach to potential regional and local users through:

- Production of documentation, technical user guides and training materials for the developed services;
- Training workshops on the use of the developed platform with key government organisations at national and local levels for both technical staff and management level staff;
- Disseminate outreach products to other potential regional and local users.
- This component will also build on the CLIMWARN project's needs analysis for early warning systems among communities in Ghana[776] to facilitate the dissemination and uptake of early warnings at the community level (see Component 3).

<u>Activity 1.4: Establishing a robust national framework for disseminating DSS and climate-related hazard management to communities.</u>

Creating a responsive communication framework is essential for effective early warnings. This activity involves establishing national and community-based Early Warning System communication mechanisms to capacitate local communities in the use of DSS information and flood and drought planning established under Activities 2.1 and 2.2. These mechanisms will ensure the seamless dissemination of critical climate information, enabling swift responses to potential hazards and fostering a proactive approach to climate resilience.

Climate data and drought and flood management information generated under Activity 2.1 will be translated into actionable recommendations and disseminated to national and local stakeholders via a decision support service (DSS) platform and outreach for potential regional and local users. A critical component of the DSS platform will be the drought and flood early warning and forecasting portal, which will provide timely and actional information to support farmers in adopting proactive drought and flood management measures. This web portal and the underlying DSS will be based on the pilot system developed and tested as part of the preceding CTCN/GCF Readiness project and will be focused on upscaling the pilot system to a national scale.

The technical design of these elements will incorporate the feedback from the national workshops and the stakeholder consultations undertaken to date, as well as lessons learned and recommendations from the GCF Readiness activities, as described under Activity 2.1 above. Notably, the national DSS platform established by this Activity will be web-based to ease its dissemination across the country and allow relevant stakeholders to access it without the installation of any software. In addition, a one-day workshop will be carried out to involve women in the development of the national framework by consulting them during the design phase to ensure that the dissemination methods reflect their needs and preferences for receiving climate hazard information.

The proposed DSS and associated tools will enable decision-makers and stakeholders to use the transferred knowledge, practices and technologies actively for the dry and heavy rainfall season planning. This intervention focuses on improving the adaptation to upcoming drought and flood events by supporting elements within the risk reduction aspect of the drought and flood management process. To achieve this objective, the DSS will incorporate the following functionalities:

- Issues and root causes analysis allowing stakeholders to identify, map and discuss the underlying causes behind drought and flood events in Ghana

[776] UN Environment 2017. CLIMWARN Project. Available at: https://www.unenvironment.org/news-and-stories/video/un-environment-climwarn-project

- Data and information to avail near real-time satellite products related to drought and floods, and provide the required data input for the drought and flood warning and forecasting system
- Drought and flood early warning and forecasting portal providing access near real-time information related to droughts and floods, and enable stakeholders to view, analyse and disseminate the information
- Risk management components supporting the risk-based approach for drought and flood management through drought and flood hazard and vulnerability identification for increased adaptation and preparedness to upcoming drought and flood events
- Dissemination relating to how the technical information is conveyed from the web-based system to the end-users in form of automated bulletins, messages, warnings and other communication channels identified as being accessible to women such as local women's groups, community meetings, and radio programmes in local languages.
- Linkage to mobile based app targeting the local farming communities in Ghana

As part of this activity, the project will also implement a mobile-based application for drought and flood early warning within the nationally established DSS. This application will create a link between the national DSS and locally implemented actions by transforming how smallholder farmers are managing their crops. Via this application, these farmers — as well as extension officers participating in outreach activities — will be equipped with forecasts of water demand and predicted yield. The overall objectives with the mobile-based crowdsourcing app are to enable farmers and extension officers to: i) receive reliable and updated information regarding weather-induced risks that impact on food production; and ii) provide feedback from the local level to regional and national levels for drought and flood impact and food production estimates. The focus will be on enabling local institutions and farmers to shift from the current paradigm of reactive planning (disaster response) to proactive planning practices with the help of available early warning information and decision support tools for climate hazards, droughts and floods.

This activity will enhance drought and flood management service quality by facilitating feedback mechanisms. Collecting feedback on the services received will serve to identify areas for improvement, refine training protocols, and optimize forecasting accuracy. This information will be used to produce best practices and undertake awareness-raising campaigns in the communities. Moreover, the initiative will create opportunities for scaling capacity-building efforts to other regions of Ghana, allowing for the enhancement of forecasting services based on lessons learned and successful practices. Through this dynamic feedback loop, monitoring and evaluation of drought and flood forecast activity will contribute to a more responsive, adaptable, and effective forecasting system, ultimately improving the overall resilience of communities and stakeholders relying on accurate drought and flood predictions.

Activities and sub-activities are detailed below.

Sub-Activity 1.4.1. Adapt and supplement existing training materials on climate-related hazard management to target capacity building in local communities

- Training of extension officers and staff on climate-related hazard management in farming practices;
- Training of farmers on climate-resilient farming practices and drought and flood resistant crops.
- Integrate traditional knowledge on drought and flood management and adaptation measures in training activities

Sub-Activity 1.4.2. Increase response capability of farming communities to climate change and drought and flood hazards through using new DSS tools and services, through:

- Training local community members and farmers on the use of the available DSS tools and services;
- Implementation of a mobile-based crowd sourcing application for early warning within national DSS.

Sub-Activity 1.4.3. Collect lessons learned and user feedback from local stakeholders and government institutions through:

- Undertaking awareness-raising campaigns for other vulnerable communities.

Activity1.5: Implement national action plan for coordinating drought and flood hazard management in the agricultural sector

The existing National Drought Management Plan, delineating roles and responsibilities for key institutions, is set to be put into action. This implementation will activate the national coordination mechanism designed for managing flood and drought-related hazards. The plan provides a structured framework for coordinating efforts across various entities, streamlining responsibilities to enhance the efficiency of drought management. Gender experts, relevant policy makers and women's groups will be consulted on how to incorporate actionable gender activities into the national action plan during its development. The development process will involve equal participation of male and female policymakers and staff to foster inclusive decision-making. In coordination with the Ministry of Gender, Children, and Social Protection (MoGCSP) and women's organisations, such as the Alliance for African Women Initiative (AFAWI), the project will identify specific training needs and ensure equal representation and active participation across genders. Additionally, an operations manual outlining gender-responsive procedures will be developed to guide policymakers and staff, promoting open dialogue and inclusive discussions throughout the development of the national action plan and coordination mechanism. By executing this plan, the nation aims to foster collaboration among key institutions, ensuring a unified and organized approach to addressing the challenges posed by drought. The implementation of the National Drought Management Plan signifies a proactive step towards a comprehensive and well-coordinated strategy, emphasizing the importance of synchronized actions in managing and mitigating the impacts of drought-related hazards. To ensure a gender-responsive approach, actionable gender activities will be identified and incorporated into the national action plan, which will include a clear implementation mechanism.

These activities will build the capacity of national institutions, government representatives and relevant regional branches to work together to understand, plan and respond to drought hazards in a coordinated manner. Specific focus will be on promoting a proactive approach to disaster risk reduction and management within NADMO and the Water Resources Commission (WRC). Key outputs, activities and sub-activities under this component are outlined below.

Activities and sub-activities are detailed below.

Sub-Activity 1.5.1: Develop a national flood management strategy to be integrated into national planning mechanisms

- Conduct an assessment of flood impacts across the country
- Consultations with stakeholders for input into the national flood management strategy, including recommendations for strengthening the existing strategic framework for climate-related hazard management;
- Developing a national coordination mechanism for managing climate-related hazards in the agricultural sector, together with national and regional institutions.

Sub-Activity 1.5.2. Implement the national action plan for coordinating flood and drought hazard management in agricultural sector through following sub-activities:

- Production of an action plan for integration of climate information into policy and decision-making processes at national, regional and local level;
- Implementation of the action plan to co-ordinate drought and flood management and clearly define roles and responsibilities

Sub-Activity 1.5.3. Develop and implement a training programme on drought and flood hazards in the agricultural sector through:

- Undertake gender analysis for strengthening project implementation at all levels and mainstreaming of gender considerations in training and rollout activities;
- Providing training on drought hazard management to key national ministries and organisations;
- Providing training on drought hazard management to regional branches within the agricultural sector.

13.3 Output 2: Climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods implemented in beneficiary communities.

As a result of an unfavourable and variable climate — characterised by a long dry season, frequent dry spells and droughts — rainfed smallholder agriculture in northern Ghana's is precarious[777]. In many cases, agricultural production does not cover the food demand of many smallholder households, even in good years[778]. As a result, smallholder farmers in northern Ghana have adopted an array of coping strategies[779] to deal with the unfavourable conditions. These strategies have included: i) early planting; ii) use of drought-tolerant crops; iii) depending on wells and dugouts for cultivating vegetables (and also for animals to drink): iv) harvesting immature food crops; v) decreasing food consumption; vi) altering diets; and vii) clearing new agricultural fields to improve yields[780,781]. In addition, smallholder farmers in northern Ghana have increased their reliance on natural ecosystems and their services — such as fruits, wild meat, nuts, firewood and charcoal — as a coping measure to unfavourable climatic conditions[782]. However, the medium to long-term impacts of climate change are unprecedented and surpass the effectiveness of many of the coping mechanisms adopted by the farmers[783,784]. There is, therefore, a need for smallholder farmers in northern Ghana to adopt modern adaptation[785] technologies and practices such as climate-resilient agriculture

[777] Laube W. 2011. Double exposure: the promises and perils of local adaptation to global environmental change and globalization in northern Ghana. Paper presented at the ICARUS II Conference, School of Natural Resources and Environment, University of Michigan, Ann Arbor.
[778] Ibid.
[779] Coping measures refer to short-term strategies employed by smallholder farmers to lessen the negative repercussions of climate and ecological change on their well-being and livelihood over short period of time normally less than one calendar year. Smallholder farmers discard these reactive measures when the threat is over.
[780] Fagariba C, Song S, Baoro SKGS. 2018. Climate change adaptation strategies and constraints in northern Ghana: Evidence of farmers in Sissala West District. *Sustainability* 10: 1484.
[781] Aniah P, Kaunza-Nu-Dem M, Ayembilla JA. 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. *Heliyon* 5: 1-25.
[782] Ibid.
[783] Etwire PM, Al-Hassan RM, Kuwornu JK, Osei-Owusu Y. 2013. Smallholder farmers adoption of technologies for adaptation to climate change in Northern Ghana. *Journal of Agricultural Extension and Rural Development* 5: 121–129.
[784] Alhassan SI, Shaibu MT, Kuwornu JKM, Damba OT. 2018. Factors influencing farmers' awareness and choice of indigenous practices in adapting to climate change and variability in northern Ghana. *West African Journal of Applied Ecology* 26: 1-13.
[785] Adaptation refers to how smallholder farmers are either modifying their practices or putting in place mechanisms to withstand the adverse effects and impacts of climate change and variability. Adaptation usually comprises medium to long-term adjustments in social ecological systems .

(CRA) and EbA to increase their resilience to climate change[786]. However, many smallholder farmers in the region are unaware of these adaptation technologies and practices and continue to rely on inadequate coping strategies[787,788].

Through Output 3, the proposed project will implement climate-resilient agriculture, landscape restoration for drought and flood management and alternative climate-resilient livelihoods in beneficiary communities. The rationale for selecting these specific interventions and their implementation modality is further described below.

The development of this proposal included, amongst others, the following steps.

1) A detailed vulnerability assessment was undertaken to identify: i) the most vulnerable regions in Ghana; ii) the most vulnerable districts within those regions; and iii) the specific climate change impacts, risks and adaptation needs in northern Ghana (see Annex 2 — Feasibility Study, Sections 2, 3, 4 and 5).
2) An analysis of past and ongoing adaptation projects in Ghana was undertaken to identify best practices and lessons learned and provide recommendations for the implementation of adaptation interventions in this project (see Annex 2 — Feasibility Study, Sections 9, 10 and 11).
3) National, regional, district and community consultations were conducted to validate the findings of the vulnerability assessment and identify locally-relevant adaptation responses to the identified climate change impacts (see Annex 7h: Stakeholder Engagement Plan).

Based on the results of the steps described above, a menu of climate change adaptation interventions has been developed for northern Ghana (see Table 44 and Annex 2: Feasibility Study, Section 11.4). The climate change adaptation interventions identified within this menu have been specifically chosen to circumvent and/or disrupt climate change impact pathways threatening agricultural production of smallholder farmers at the plot, farm and landscape levels (see **Error! Reference source not found.** and Annex 2: Feasibility Study, Section 5).

Table 44. Description of recommended climate change adaptation interventions. See Section B1 for a description of the climate change impacts.

Climate change adaptation Intervention	Climate change impacts addressed	Description
Ecosystem-based adaptation interventions		
Agroforestry	• Increased frequency and severity of floods • Reduced crop and livestock production • Reduced length of the agricultural growing season • Increased soil erosion	• Trees used in agroforestry reduce the impact of intense rainfall, increasing infiltration and reducing soil erosion. This will lessen the impacts of flooding on crops. • Leaf litter from trees provides natural mulching functions, increasing soil moisture and nutrient content. This will improve crop yields. • Increased soil moisture content, combined with microclimate regulation, from agroforestry will allow farmers to grow crops over a longer period. • Tree roots secure the soil, further restricting erosion.
Small-scale communal fodder banks	• Reduced length of the agricultural growing season • Reduced crop and livestock production	• The reduced length of the agricultural growing season, combined with more frequent and intense drought, will reduce fodder availability for livestock during the dry season. Fodder banks supplement the diet of livestock during the dry season, resulting in reduced losses.

786 Etwire PM, Al-Hassan RM, Kuwornu JK, Osei-Owusu Y. 2013. Smallholder farmers adoption of technologies for adaptation to climate change in Northern Ghana. *Journal of Agricultural Extension and Rural Development* 5: 121–129.
787 Kuwornu JK, Al-Hassan RM, Etwire PM, Osei-Owusu Y. 2013. Adaptation strategies of smallholder farmers to climate change and variability: Evidence from Northern Ghana. *Information Management and Business Review* 5: 233.
788 Antwi-Agyei P. 2012. Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability. DPhil, University of Leeds, Leeds.

	• Increased drought frequency and intensity • Increased soil erosion	• Nutrient-rich plants used in fodder bank reduce the impact of intense rainfall, increasing infiltration and reducing soil erosion. Plant roots also secure the soil, further restricting erosion.
Riverbank restoration	• Increased frequency and severity of floods • Reduced crop and livestock production • Increased soil erosion	• Restoring riparian vegetation will reduce the effect of intense rainfall and flooding on the riverbanks and surrounding fields. • Increased flood protection will reduce crop losses, while the restored vegetation will provide fodder for livestock. • Restoring riparian vegetation with indigenous species will bind the soil and reduce erosion.
Flood risk reduction	• Increased frequency and severity of floods	• Ecosystem restoration in degraded flood risk hotspots. • Levees, bunds, and weirs to prevent rivers characterised by floods from bursting their banks.
Fire management	• Increased frequency and severity of bushfires	• High wet season rainfall would result in the enhanced build-up of biomass in agroecological systems which will persist into the dry season. The effects of: i) high temperatures; ii) evapotranspiration; and iii) dry conditions, along with this abundant fuel load, will result in bushfires becoming more frequent and severe. These fires pose a threat to the livelihoods of smallholder farmers who rely on natural resources for their livelihood. Effective fire management is, therefore, necessary to control the effects of these fires and limit damage to crops and property.
Climate-resilient agriculture interventions		
Crop rotation and intercropping	• Reduced crop and livestock production • Increased soil erosion • Increased weeds, pests and post-harvest losses	• Increased temperatures – that may push certain crops beyond their thermal limits – combined with more frequent extreme events will reduce agricultural yields. By growing a variety of crops with different temperature and inundation limits, farmers can reduce the risk of losing their entire harvest during an extreme event. • The effects of climate change – including more intense rainfall over a shorter period – will compound the problem of soil erosion in northern Ghana, leading to reduced soil moisture and the leaching of nutrients from the soil. This will lead to a decrease in crop yields and an increase in the need for agricultural inputs – for example, fertilisers. Crop rotation and intercropping will reduce runoff and improve infiltration, thereby reducing the impact of climate change on soil erosion. • By diversifying crops and staggering harvest times, crop rotation and intercropping can reduce the need for long-term post-harvest storage and reduce the impact of crop-specific pests and diseases. Furthermore, crop rotations can break the pest/disease cycle over time.
Slash and mulching	• Increased drought frequency and intensity • Increased soil erosion	• A reduction in soil water content and the lowering of groundwater levels in northern Ghana – as a result of increased potential evapotranspiration and more frequent droughts – will decrease crop production as less water will be available for crop growth. Slash and mulching will increase water infiltration and reduce evaporation, thereby improving soil moisture, disrupting this climate change impact pathway. • Slash and mulching dissipate the energy of rainfall, improving infiltration and reducing runoff. Consequently, soil moisture and nutrient availability will be increased, thereby reducing the impact of climate change on soil erosion.
Conservation tillage	• Increased drought frequency and intensity • Increased soil erosion	• Soil conservation tillage, also known as reduced tillage or no-till farming, is an agricultural practice that promotes the long-term health and sustainability of soil. It involves minimizing disturbance to the soil structure and organic matter.
Contour ploughing	• Flood management	• Where smaller tractors are used that can work around trees without damaging them. Also, tractor implements that are less damaging to soils can be used. Harrowing may substitute the prevailing practice of disc-ploughing
Contour bunding	• Increased drought frequency and intensity • Reduced length of the agricultural growing season • Increased soil erosion	• By increasing infiltration, contour bunds improve soil moisture, thereby countering the climate change impacts of increasing temperatures and potential evapotranspiration. Increased soil moisture content also allows smallholder farmers to grow crops for a longer period.

		• Contour bunding reduces on- and near-field runoff velocity, thereby: i) decreasing soil and nutrient loss; ii) increasing the drainage of water into the soil; and iii) decreasing the formation of damaging geomorphic features such as rills and gullies. This disrupts the climate change impact of increased soil erosion.
Vegetative barriers	• Increased drought frequency and intensity • Increased soil erosion	• By increasing infiltration, vegetative barriers improve soil moisture, thereby countering the climate change impacts of increasing temperatures and potential evapotranspiration. • Vegetative barriers reduce runoff velocity, improve infiltration and decrease the formation of damaging geomorphic features such as rills and gullies, disrupting the climate change impact of increased soil erosion.
Ridging	• Increased drought frequency and intensity • Increased soil erosion	• Tied ridging is effective in retaining on-field water and increasing soil water content during dry conditions, reducing the impact of extended dry periods resulting from climate change. • Ridging allows for the controlled drainage of excess water, reducing the effect of water-logging and erosion associated with heavy rainfall events.
Organic composting and zai pits	• Reduced crop and livestock production • Increased drought frequency and intensity • Increased soil erosion	• Zai pits reduce surface runoff, thereby improving water retention and infiltration. This, combined with increased soil nutrients, will increase agricultural yields, even during dry periods. • Organic composting increases soil nutrients, countering the effect of nutrient loss from increased soil erosion.
Cover cropping	• Reduced crop and livestock production • Increased soil erosion • Increased weeds, pests and post-harvest losses	• Cover cropping shades the soil surface, reducing soil temperatures and helping retain soil moisture. Improved infiltration also increases soil moisture, countering the climate change impacts of increased temperatures and evapotranspiration. • Cover cropping creates a protective barrier over exposed soils, dissipating the energy during intense rainfall events, consequently reducing soil erosion and increasing infiltration. Furthermore, residues from cover crops maintain soil quality by replacing nutrients in soils which have been leached by surface runoff and erosion. • A dense mat of cover competes strongly with weeds that grow as a result of increased rainfall. The consequent reduction in weeds improves crop yields.
Climate-resilient seed varieties	• Increased flood frequency and severity • Increased drought frequency and intensity • Reduced length of the agricultural growing season • Reduced crop and livestock production	• Flood-resilient seed varieties are adapted to flood pressures resulting from intensified rainfall events. • Drought-resilient seed varieties are adapted to cope with prolonged dry seasons resulting from climate change. • Seed varieties with shorter growing cycles will allow farmers to complete the harvest despite a reduction in the length of the agricultural growing season. • Heat stress-resilient seed varieties are adapted to higher temperatures, allowing for increased productivity and reduced crop losses during heat waves.
Adapted planting calendar	• Reduced length of the agricultural growing season • Increased drought frequency and intensity	• Use of early warning systems and climate data to inform agricultural practices will enable farmers to proactively manage drought impacts and minimize crop losses.
Dry season gardening	• Reduced length of the agricultural growing season	• A shortened agricultural production period because of a shorter wet season will decrease crop yields and incomes as the number of achievable cropping cycles within a growing season will be reduced. Dry season gardening allows for additional production to supplement food and income supply during the prolonged dry season.
Climate-resilient post-harvest storage		
Post-harvest storage devices	• Increased flood frequency and severity • Increased weeds, pests and post-harvest losses	• Improved post-harvest storage methods will reduce the impact of and damage caused by intense rainfall and flooding on post-harvest storage facilities and infrastructure. • Increased humidity, moisture migration and condensation caused by flooding lead to rotting of harvested crops. Improved post-harvest storage devices will reduce the likelihood of flood-induced fungal growth and spoilage during storage and drying.

		• Post-harvest storage devices reduce the loss of grain caused by increasing temperatures which result in increased insect activity, fungal growth and rodent pest infestation.
Alternative climate-resilient livelihoods		
Shea butter production	• Reduced crop and livestock production • Increased soil erosion	• Shea butter production will provide alternative livelihoods and additional sources of income during periods where climate change impacts, such as floods and droughts, affects the supply and production of other crops. • Trees used for shea butter production reduce the impact of intense rainfall, increasing infiltration and reducing soil erosion.
Small ruminant rearing	• Reduced crop and livestock production • Increased drought frequency and intensity	• Small ruminant rearing will provide alternative livelihoods and additional sources of income to farmers, reducing the negative impact of climate change-induced crop failure on their food and income security. • Small ruminants are well adapted to the arid conditions and are more tolerant to drought conditions than other livestock, therefore can reduce the negative impacts of dry seasons on livestock farming.
Other alternative climate-resilient livelihoods, such as beekeeping; bamboo farming; soap making; cane rat/rabbit rearing; chicken /guineafowl farming; juice-making; and aquaculture.	• Reduced crop and livestock production	• Alternative climate-resilient livelihoods provide income during periods where climate change impacts, such as floods and droughts, affects supply and production of other crops. This allows communities to purchase food and other essentials when required. Furthermore, income from alternative climate-resilient livelihoods will allow smallholder farmers to purchase the inputs required to adopt climate-resilient agricultural techniques.
Climate-resilient water infrastructure investments		
Boreholes and check dams	• Reduced crop and livestock production • Reduced length of the agricultural growing season • Reduced water availability • Reduced water quality	• A shortened agricultural production period because of a shorter wet season and insufficient water supply will decrease crop yields and incomes. Boreholes and check dams allow smallholder farmers to irrigate their crops, thereby allowing production to continue during the prolonged dry season to provide farmers with food and income security throughout the year. • Boreholes and weirs can support livelihood activities such as dry-season gardening and small ruminant rearing to counter the impacts of prolonged climate change-induced dry periods. • Decreasing wet season length coupled with rising temperatures will increase the frequency of the drying-up of surface water bodies such as dams and streams resulting in reduced water availability. Furthermore, increased flooding and erosion will reduce the quality of the water that is available. Boreholes and check dams will provide communities with improved access to quality water.

Output 2 of the proposed project will focus on the implementation of appropriate climate change adaptation interventions drawn from this menu in beneficiary communities to reduce their vulnerability to climate change. Each beneficiary community will be trained on climate change interventions and will develop/finalise their own CCAP. The specific adaptation interventions identified within the CCAP – drawn from the menu of climate change adaptation interventions – will then be implemented in each community with the assistance of district extension officers.

<u>Activity 2.2: Train extension officers on climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods.</u>

Various government departments employ extension officers at the district level, including Agriculture, Forest Services, National Disaster Management, Fire Services, Gender and Social Development. These extension officers[789] – who regularly interact with local communities and provide them with training and support relevant to their sector – will be

[789] Particularly those from the Department of Agriculture

responsible for the implementation of the proposed project's on-the-ground activities with local communities.

To ensure that the district extension officers are prepared to facilitate the implementation of climate change adaptation and EbA interventions in target communities, extension officers within the targeted districts will receive training on:

- climate-resilient agriculture, EbA and alternative climate-resilient livelihoods;
- development of Community Climate Action Plans (CCAPs);
- best practices for integrating early warning systems' information into agricultural activities;
- how to use the DSS platform established under Activity 1.2 and deliver outreach on climate data information to target farmers;
- the implementation of a dynamic menu of climate change adaptation interventions[790];
- how to train smallholder farmers to implement the menu of climate change adaptation interventions; and
- all training curriculums and materials will include gender modules, where applicable.

Training workshops that are held in the local communities will be undertaken in the morning during weekdays to ensure that at least 20% of participants are women. The training provided to extension officers will form the foundation of resilience enhancing activities in Output 2. Furthermore, training extension officers to plan and implement climate change adaptation interventions will allow them to extend this knowledge to other communities that are not targeted by this project. This will promote the upscaling of the EbA approach beyond the project intervention sites. The sustainability of this approach is further enhanced by embedding knowledge of EbA within existing government extension structures.

<u>Activity 2.2: Train beneficiary communities in northern Ghana on climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods.</u>

The project will train beneficiary communities in northern Ghana on climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods before any on-the-ground interventions are implemented. In addition, training will capacitate farmers to use the DSS platform — established under Activity 1.1 — and associated tools when implementing climate-resilient agricultural practices. The training will raise the awareness of smallholder farmers in northern Ghana to these adaptation strategies and enhance their capacity to implement them. Awareness is a necessary condition for the adoption of modern agricultural technologies and practices by smallholder farmers in Ghana[791]. Sensitisation workshops will be held in the first year that the project provides support to a community. This will ensure that communities understand the objectives of the project and their responsibilities.

Following this, staff from relevant departments of the GoG[792] and extension officers will train beneficiary communities, including female-headed households (FHHs), women part of the Women in Agriculture Programme (WAP) and women farmers, on climate change and the climate change impact pathways most relevant to them as smallholder farmers. These trainings will take place in local communities during weekdays in the morning to ensure women's participation. Extension officers will then introduce the menu of climate change adaptation interventions (see Annex 2, Section 11.4) to communities, explaining the theoretical and technical elements of each intervention and how they can enhance resilience to climate change. Targeted communities will then be trained to implement climate change

[790] For more information on the climate change adaptation interventions, see Annex 2: Feasibility Study and Annex 22: Examples of Community Climate Action Plans (CCAPs).
[791] Etwire PM, Al-Hassan RM, Kuwornu JK, Osei-Owusu Y. 2013. Smallholder farmers adoption of technologies for adaptation to climate change in Northern Ghana. *Journal of Agricultural Extension and Rural Development* 5: 121–129.
[792] For example, staff within the EPA, specializing in education.

adaptation interventions identified within the menu of interventions. In addition, extension officers will organise farmers into special Common Interest Groups (CIGs)[793] and provide targeted training on specific adaptation technologies from the menu of climate change adaptation interventions. These groups will focus, for example, on interventions such as nursery management to grow seedlings for agroforestry and riverbank protection or post-harvest crop storage.

Finally, demonstration sites will be established by extension officers with willing community members to demonstrate various climate change adaptation interventions that can be implemented at the household level. The demonstration sites will facilitate the training of community members on climate change adaptation interventions.

<u>Activity 2.3: Develop community climate action plans (CCAPs) in collaboration with beneficiary communities.</u>

Extension officers will assist each beneficiary community in finalising a community climate action plan (CCAP) (see Table 2 for examples of preliminary CCAPs). The CCAPs are formal, community-level, medium-term plans that advise DMTDPs. A Gender Officer will support the design of the CCAPs to ensure women's adaptation needs and interests are fully considered. CCAPs will: i) identify the most serious climate threats experienced or likely to be experienced by the community; ii) identify current coping strategies utilised by the community; iii) select and justify potential adaptation interventions from the menu of climate change adaptation interventions that will help build climate resilience; and iv) detail implementation and budgeting requirements to implement potential adaptation interventions. The adaptation interventions detailed in each CCAP will be reviewed against evaluation criteria[794] by DEMCs and REMCs and will then be approved by the PMU and Directorate of Crop Services. Those adaptation interventions that are considered consistent with the evaluation criteria will be implemented in beneficiary communities by the proposed project. CCAPs will be formal medium-term plans for beneficiary communities that will feed into and advise DMTDPs. This will allow other interventions[795] identified within the CCAPs to be implemented by the district authorities. Furthermore, integrating CCAPs into DMTDPs promotes the integration of climate change adaptation into development planning, thereby also enhancing climate resilience and promoting the upscaling of selected climate change adaptation interventions in non-target communities.

<u>Activity 2.4: Implement climate change adaptation interventions, including climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods, identified in the CCAPs in beneficiary communities.</u>

As stated above, a menu of climate change adaptation interventions appropriate for smallholder farming communities in northern Ghana has been developed (Table 2). Each of the interventions included within this menu was explicitly selected to circumvent and/or disrupt climate change impact pathways (**Error! Reference source not found.**) threatening agricultural production of smallholder farmers. Overall, climate change adaptation interventions focus on introducing:

- EbA interventions that maintain and enhance the supply of ecosystems goods and services to beneficiary communities;
- nature-based flood risk reduction interventions;

[793] A group of community members with a common interest in a specific adaptation technique or technology. The groups aid in bringing farmers together for training purposes, discussions and knowledge sharing.
[794] Evaluation criteria will include: i) consistency with budget limits; ii) consistency with EbA interventions from the agreed menu of climate change adaptation interventions; iii) clearly established land ownership/tenure rights; iv) appropriate implementation duration; v) the consistency of the CCAP with environmental and social safeguards; vi) a realistic implementation plan and budget; and vii) the signature of the responsible extension officer.
[795] For example, a community may identify the need to construct a school or health facility within the CCAP.

- fire management practices in agroecological landscapes;
- climate-resilient agricultural practices to maintain or enhance agricultural production under changing climatic condition;
- climate-resilient post-harvest management to reduce losses from climate change impacts;
- use of early warning systems and climate data to enable proactive drought impact management;
- alternative climate-resilient livelihoods that enhance and diversify income generation – targeted particularly at women and the youth; and
- climate-resilient water infrastructure that enhances water security and agricultural production under changing climatic conditions.

Through Activity 2.4, the project will provide technical input[796] support to beneficiary communities to implement the climate change adaptation interventions taken from the menu of interventions and as identified in their CCAPs. The interventions chosen will be appropriate to each communities' unique geographic and ecological contexts (for instance, proximity to a river and/or availability of surface water resources) and responsive to the specific needs of women and the youth as identified in Annex 8: Gender Assessment and Action Plan. This will ensure that both men and women farmers in the WAP are beneficiaries of technical support for the implementation of climate-resilient agricultural practices, EbA and alternative climate-resilient livelihoods interventions. The local communities will be capacitated to implement the interventions with technical support from district extension officers, of which 20% will be women. The community will not receive funding directly, but instead will be provided with the equipment and/or inputs[797] — and training through Activity 2.2 — required to implement each intervention. The details of the extent, implementation needs and budgeting requirements to implement each adaptation intervention will be drawn from the relevant CCAP. Each community will be allocated the same fixed amount to implement its locally appropriate, priority adaptation interventions[798] over three years. Combined, these interventions will result in the restoration of 14,000 ha of forests and 3,000 ha of riparian buffer zones and the introduction of climate-resilient agriculture and agroforestry practices across 4,000 ha and 2,000 ha, respectively.

National and regional staff will also provide technical support to extension officers and beneficiary communities for the implementation and maintenance of climate change adaptation interventions. In addition, specialist consultants will provide technical support for the implementation and maintenance of specialised interventions, such as borehole construction.

<u>Activity 2.5: Develop a monitoring and evaluation strategy for climate advisory services in northern Ghana to improve the accuracy and appropriateness of advisories for smallholder farmers.</u>

Climate advisories are critical for smallholder farmers to adopt farming practices to increasingly erratic climate conditions under which indigenous knowledge systems and traditional coping strategies are no longer reliable[799]

[796] Permissible inputs will include *inter alia*: i) land preparation; ii) simple farming tools; iii) fertiliser sprayers; iv) tree seedlings; v) fencing materials; vi) water storage tanks; vii) climate-resilient seeds; viii) fertilisers; ix) herbicides; and x) pesticides.
[797] Communities will not receive direct access to funds, but instead the executing entity will be responsible for the procurement and delivery of inputs to the beneficiaries.
[798] The interventions implemented will be consistent with the criteria described in Output 3.2.
[799] Naab/ F.Z., Abubakarib. Z, Ahmed. C. 2019. The role of climate services in agricultural productivity in Ghana: The perspectives of farmers and institutions. Climate Services **13**: 24-32

Currently, there are several national institutions tasked with the production and dissemination of climate advisories[800]. However, these advisories are generally not well tailored to the needs of vulnerable smallholder farmers and are not communicated effectively to end-users. Activity 3.4 will, therefore, improve the effectiveness of climate advisories in northern Ghana by facilitating the integration of local knowledge and the experience of end-users into the production and dissemination processes. This process will be centred on the development of a community-based monitoring and evaluation (M&E) system targeting end-users of climate advisories. Output 1 will establish an improved climate information and early warning services, focusing on the institutional framework and technological delivery system for early warning forecasts. Advisories developed based on early warning forecasts and climate data generated by the delivery system will complement the M&E system. In addition, a gender analysis will be conducted to understand how men and women smallholder farmers access and use climate advisory services, focusing on their specific challenges and needs. The analysis will also identify gender-specific barriers such as literacy, access to technology, and traditional roles, as identified in Annex 8: Gender Assessment and Action Plan.

The implementing partner for this output will be the Ministry of Food and Agriculture (MOFA) , which is already indicated in Figure 10. The M&E will serve to ground truth climate advisories and assess their uptake by end-users and local level. Community surveys will be held on an annual basis throughout project implementation to gather primary data from smallholder farmers on their perceptions of climate advisories and to consider links between indigenous knowledge and climate science. Finally, a feedback mechanism will be established within key government institutions — including the Ghana Meteorological Agency (GMet), the Ministry of Food and Agriculture (MoFA), the Ministry of Environment, Science, Technology and Innovation (MESTI), Environmental Protection Agency (EPA), the National Climate Change Committee (NCCC), and the Council for Scientific and Industrial Research (CSIR) — to improve the integration of the M&E data in the production and dissemination of climate advisories.

This Activity will be informed by the best practices and lessons learned generated through UNEP's CLIM-WARN project. The project — which started in 2013 and ended in 2015 — worked with local and international partners in three case study countries (Kenya, Ghana and Burkina Faso) to: i) review the current state of multi-hazard Early Warning Systems (EWS); ii) identify capacity gaps; ii) assess the needs of vulnerable communities; and ii) develop a set of recommendations for decision makers to improve existing EWS.

13.4 Output 3: Restoration of landscape to reduce drought and flood risk.

At the farm level, a variety of nature-based solutions or nature-based infrastructure can be implemented, including reforestation efforts through tree planting to reduce soil erosion and increase infiltration capacity and establishing riparian buffer zones along the riverside to reduce flood impacts. Encouraging the adaptation of flood-based farming measures to store flood water to be used during dry spells and drain the land after rainfall or floods will preserve agricultural production. During the project lifespan, agroforestry and restoration interventions will be implemented in 120 communities. Estimating ~1000 people per community, the direct beneficiaries of these interventions have been calculated by assuming that all 1000 individuals in each of the 120 target communities will benefit. In addition, 2000 hectares in the 8 Districts will restore 2000 hectares of riparian land.

[800] Ghana Meteorological Agency (GMet), the Ministry of Food and Agriculture (MoFA), the Ministry of Environment, Science, Technology and Innovation (MESTI), Environmental Protection Agency (EPA), the National Climate Change Committee (NCCC), and the Council for Scientific and Industrial Research (CSIR)

The proposed project will:

3.1.1. Establish tree nurseries to support reforestation in 120 communities
3.1.2 Undertake community consultations on final location for restoration as per CCAPs and agree on modalities for plantings, maintenance and protection of the sites
3.1.3 Undertaken annual restoration plantings and maintenance in agreed areas as per CCAPs

13.5 Output 4: Increased access of smallholder farmers to financial resources and engagement with the private sector.

In most parts of northern Ghana, NGOs and the MOFA have been encouraging smallholder farmers to diversify from crop production to animal rearing and other non-farm activities because of continuous poor crop yields[801]. However, smallholder farmers, particularly women farmers, in northern Ghana do not have adequate knowledge and financial resources to invest in livelihood diversification successfully. As a result, alternative income-generating activities adopted by the smallholder farmers have remained seasonal, small scale and rudimentary[802]. With the increasing risk of climate change on crop production and the livelihoods of smallholder farmers in northern Ghana, income generated from alternative climate-resilient livelihoods is becoming increasingly important in enhancing food security and strengthening resilience to climate change[803]. There is, therefore, a need to support men and women smallholder farmers in northern Ghana in adopting alternative climate-resilient income-generating activities that can provide a reliable and sustainable flow of income to guarantee food security for households under conditions of changing climate[804]. This need is highlighted by the Presidential Special Initiative on Agriculture and Rural Development[805] which sets a four-year goal for significantly increasing agricultural productivity, as well as ramping up agro-processing and developing new and stable markets for agricultural products. This includes the need for significant investment in de-risking the agriculture and agri-business sector through sustainable agriculture financing and crop insurance schemes.

According to the Bank of Ghana, as of June 2022 the amount of outstanding credit by deposit-taking banks to the agriculture, forestry and fishing sector was GHS 2.2 billion (US$220 million), or only 3.5% of total outstanding credit to the private sector.[806] This is despite agriculture, forestry and fishing representing 22.3% of GDP in 2021.[807] Rural and Community Banks (RCBs) accounted for another GHS 2.2 billion (US$220 million) in outstanding loans as of June 2022, of which an unspecified portion was dedicated to agriculture.[808] Thus even accounting for the RCBs, the agricultural sector remains underweighted in the financial system relative to its contribution to GDP. This situation reflects the high-risk perception of agricultural activities by lenders. As a result, smallholder farmers resort to borrowing from village savings and loans associations (VSLAs) – informal, village-level lending clubs, known as “susu” locally – and borrowing from family and friends. Estimates on the outstanding volume of these two loan sources are difficult to find. Most of such informal lending, which involves very small amounts, usually goes towards essential needs of the family (e.g., school fees), agricultural inputs such as seedlings, emergency expenses (e.g., funerals) or funding of petty trade.

[801] Atuoye K, Antabe R, Sano Y, Luginaah I, Bayne J. 2019. Household income diversification and food insecurity in the Upper West Region of Ghana. *Social Indicators Research*: 1-22.
[802] Ibid.
[803] Wossen T, Berger T, Swamikannu N, Ramilan T. 2014. Climate variability, consumption risk and poverty in semi-arid Northern Ghana: Adaptation options for poor farm households. *Environmental Development* 12: 2–15.
[804] Atuoye K, Antabe R, Sano Y, Luginaah I, Bayne J. 2019. Household income diversification and food insecurity in the Upper West Region of Ghana. *Social Indicators Research*: 1-22.
[805] President of Ghana. Available at http://www.presidency.gov.gh/index.php/initiatives
[806] Bank of Ghana (29 July 2022). *Quarterly Statistical Bulletin, Quarter Two, 2022*. Table 6. Link: https://www.bog.gov.gh/wp-content/uploads/2022/10/Statistical-Bulletin-Quarter-2_2022.pdf
[807] Ibid, based on sector GDP presented in Table 30a.
[808] Ibid, Table 9.

Lack of financial resources is a barrier to the effective implementation of climate adaptation strategies by smallholder farmers in northern Ghana[809] (see Section B.2). Many adaptation interventions — e.g., improved crop varieties — are costly and most smallholder farmers lack the financial resources to adopt them[810,811]. A means through which smallholder farmers in northern Ghana can access financial resources to fund crucial adaptation interventions is agricultural credit. However, local financial institutions (LFIs) in Ghana are generally unwilling to give out loans to individual smallholder farmers for agricultural activities. This is because individual smallholder farmers in northern Ghana generally: i) have limited financial literacy; ii) have limited credit history; iii) lack the collateral to secure loans[812]; and iv) rely on unpredictable rain-fed agriculture for their income, which means that loans are deemed high-risk [813,814].

The IMF further substantiates the lack of access to finance for smallholders. Quoting the World Bank's Findex survey, it notes that access to finance is lagging among the poor, and the five poorest regions (Upper West, Northern, Volta, Upper East, and Brong-Ahafo) — three of which are targeted by this GCF project — remain the least financially included.[815] Further selected financial inclusion data from the Findex survey for the rural and poor segments of the population — rough proxies for the northern Ghana situation show that (i) a considerably lower penetration of accounts at financial institutions and mobile money providers among the poor and rural population compared to the rich and urban, (ii) single-digit percentages of the poor and rural inhabitants borrowing from financial institutions (low-teens when including borrowing via mobile money accounts) and (iii) a high reliance on informal borrowing from family and friends.

To overcome these barriers, emphasis needs to be placed both on the supply side — risk mitigation instruments for lenders to be more confident in lending to smallholders — and the demand side — a way to aggregate individual smallholders to increase project and financial viability.

Output 4 will bridge this gap by increasing the capacity of the most vulnerable smallholder farmers, such as women farmers, to form FBOs and manage finances and thereafter access agricultural credit and insurance. The project will connect the local level demand for credit to international blended finance initiatives which UNEP is brokering. In doing so, this output will contribute to GCF Outcome A7.0 — Strengthened adaptive capacity and reduced exposure to climate risks.

<u>Activity 4.1: Establish farmer-based organisations (FBOs) and Village Savings and Loans Associations (VSLAs) that can access credit and insurance for farming and non-farming livelihood activities.</u>

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809 Antwi-Agyei P. 2012. Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability. DPhil, University of Leeds, Leeds.
810 Antwi-Agyei P, Quinn CH, Adiku SGK, Codjoe SNA, Dougill AJ, Lamboll R, Dovie DBK. 2017. Perceived stressors of climate vulnerability across scales in the Savannah zone of Ghana: a participatory approach. *Regional Environmental Change* 17: 213–227.
811 Antwi-Agyei P. 2012. Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability. DPhil, University of Leeds, Leeds.
812 Bawa A. 2019. Agriculture and food Security in northern Ghana. *Asian Journal of Agricultural Extension, Economics & Sociology* 31: 1-7.
813 Fearon J. 2000. Economic analysis of soil conservation practices in northern Ghana. MPhil, University of Ghana, Accra.
814 Antwi-Agyei P. 2012. Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability. DPhil, University of Leeds, Leeds.
815 International Monetary Fund (December 2019). *Ghana Selected Issues Paper*. IMF Country Report No. 19/368. Link: https://www.imf.org/en/Publications/CR/Issues/2019/12/18/Ghana-Selected-Issues-Paper-48884

The project will establish two FBOs in each of the 120 communities targeted by the project, i.e. a total of 240 FBOs. Eight districts will be targeted by the project, engaging an average of 15 communities per district. The FBOs will meet the minimum requirements for receiving joint liability agricultural loans and insurance identified during a survey of LFIs conducted for the AFAWA programme. The minimum requirements include: i) formal registration with the Ministry of Food and Agriculture (MoFA); ii) an operational bank account; iii) records and bookkeeping; and iv) members with combined agricultural landholdings of between 5 and 15 ha[816].

To ensure the most vulnerable farmers are supported, the project will provide capacity building support to register their organisations with MoFA (Sub-activity 4.1.1). Furthermore, members of the established FBOs will be trained on basic business and financial management techniques, including records and bookkeeping as well as the processes for applying for credit and insurance from LFIs. Extension officers will deliver this training during the first year that each beneficiary community receives support to ensure that the FBOs meet the eligibility criteria set by LFIs for joint liability lending. In addition to improving their access to agricultural credit, basic financial management training will allow beneficiaries to: i) enhance their income from improved climate-resilient agricultural techniques and alternative climate-resilient livelihoods (Output 3); and ii) save money to cope with climate shocks (for example floods or droughts).

The project will train established FBOs to set up Village Savings and Loans Associations (VSLAs, Sub-activity 4.1.2). VSLAs in northern Ghana have been shown to lead to an improvement in financial inclusion for participants — including, substantial increases in savings and receiving a loan[817]. Women-led VSLAs, in particular, have been reported to yield higher annual payouts to local community members. As identified in Annex 8: Gender Assessment and Action Plan, the involvement of existing women-led VSLAs and FBOs[818] as well as women from the WAP will be encouraged. The purpose of establishing VSLAs is twofold. Initially, the VSLAs will provide simple savings and loan facilities to these communities who currently do not have access to formal financial services. Secondly, operating the VSLAs will enable them to maintain up-to-date financial records which will enable the FBOs to meet the eligibility requirements of LFIs for joint liability loans and insurance. The minimum requirements for entering into a VSLA include: i) a commitment to attend regular VSLA meetings; ii) adherence to the rules and regulations set by the VSLA; iii) and a willingness to borrow from the pooled savings and contribute to the repayment of group loans as needed.

The recommended blended finance model (see Activity 4.3) will set up a climate-resilient loan (CRL) program as an exit strategy to finance the continued implementation of EBA/CRA measures after the expiry of the GCF project, both by FBOs that benefited from GCF activities as well as new, future ones.

Specifically, the project will undertake the following sub-activities:

- Sub-activity 4.1.1: Establish FBOs that can access credit and insurance for farming and non-farming livelihood activities, and provide training on basic business and financial management techniques.
- Sub-activity 4.1.2: Establish VSLAs to enable FBOs to develop a sound financial track record that enables them to access credit and insurance products.

[816] Republic of Ghana (ed). *Program on affirmative finance action for women in Africa (AFAWA): Financing climate resilience agricultural practices in Ghana*.
[817] *Karlan, Dean, Beniamino Savonitto, Bram Thuysbaert, and Christopher Udry. 2017. "Impact of savings groups on the lives of the poor." Proceedings of the National Academy of Sciences 114(12): 3079-3084.*
[818] During the 2024 mission, each local community visited had established VSLAs and FBOs, some being women led and some being mixed. Participants indicated that majority of the VSLAs have been started by women in the community.

Activity 4.2: Connect FBOs and local financial institutions to improve access of beneficiary communities to credit and insurance products.

Having established FBOs and VSLAs to improve the capacity of vulnerable communities to access agricultural credit and insurance, the project will provide training and awareness-raising to LFIs in northern Ghana about the benefits of climate-resilient agricultural practices and alternative climate-resilient livelihoods, ensuring the full and equal participation of women and marginalised groups. In addition, separate meetings will be hosted with target communities to capture women's views during the planning process and have representatives of women's groups publicly represent their voices during decision-making processes. LFIs require an awareness of the benefits of these approaches before they can approve agricultural credit to implement them. The AFAWA programme is conducting a similar activity where it will provide selected LFIs throughout Ghana with training on climate-resilient agriculture and value addition in the agricultural value chain. The proposed project will build on these efforts and extend this training to LFIs located near the project intervention sites that are not receiving training through AFAWA. By improving the understanding of LFIs loan officers in northern Ghana of climate-resilient agriculture and alternative livelihoods – and the potential benefits such as enhanced yields, more resilient harvests and improved income — LFIs will be incentivised to extend their services to beneficiary communities.

The project will facilitate engagement between FBOs and local financial institutions to improve access of beneficiary communities to credit and insurance products, see Activity 4.3 on GAIP and GIRSAL, and risk mitigation instruments for agricultural lending. Several LFIs in Ghana, including Agricultural Development Bank and EcoBank[819], run outreach programmes that assist farmers in accessing credit. These programmes: i) help farmers to establish organisations/cooperatives; ii) provide financial management training; and iii) take farmers through the loan application process. However, these programmes tend to focus on central and southern Ghana where agricultural production is higher and there are more commercial farming operations. The project will work with relevant LFIs to extend these services to beneficiary communities in northern Ghana, see Activity 4.3 on partnering with financial institutions.

The US International Development Finance Cooperation (DFC) expressed interest in principle to provide, as exit strategy for the project, a concessional credit line to local financial institutions. As of August 2023, the representative of the DFC engaged by the project team was holding internal discussions to verify if such interest could be formalized in a letter of support by the DFC to be included in the Funding Proposal package. Note that such letter would not constitute co-finance, as the DFC will not be able to produce a firm and quantifiable commitment by the time of the Funding Proposal submission. The Landscape Resilience Fund expressed similar interest in principle to provide a concessional credit line to local financial institutions as exit strategy. As of August 2023, LRF is also holding internal discussions to formalize its interest in a letter of support. LRF has also expressed interest in principle to provide technical assistance to the BACs. See Activity 4.3 below for further details.

Specifically, the project will undertake the following sub-activities:

- Sub-activity 4.2.1: Include representatives from LFIs in the training and awareness-raising events organised through the project.
- Sub-activity 4.2.2: Conduct a road show where representatives from LFIs are taken to beneficiary communities.

[819] Based on interviews with representatives from ADB and EcoBank.

<u>Activity 4.3: Establish a blended finance model to provide credit lines to support climate-resilient agriculture.</u>

Climate-resilient loan (CRL) programs set up by one or more LFIs and funded by concessional IFI credit lines will benefit from four de-risking tools linked to the blended finance model:

i. The **credit score database** compiled with the project's support.
ii. Existing **GIRSAL credit guarantees for agricultural lending**. GIRSAL is a non-banking financial institution 100%-owned by the Ministry of Finance and provides credit risk guarantees to financial institutions that lend to any agribusiness (including FBOs), with no size limit. GIRSAL confirmed its interest in principle in guaranteeing loans issued by local FIs to FBOs, but the actual issuance of such guarantees will be at GIRSAL's discretion based on a credit assessment at the time of the guaranteed request. GIRSAL coverage varies case by case, up to a maximum of 70% of principal (interest and overdrafts are not covered). The underlying loans can have different uses, for instance capex or working capital.
iii. **Off-take agreements with off-takers** identified through the technical assistance provided to FBOs, as well as the use of GCX warehouse receipts as collateral for short-term loans. GCX issues receipts for commodities stored in its warehouses. Receipts specify the amount, grade and market price of the commodity stored (e.g., maize, soybean, sorghum, sesame and cashews). Receipts are valid for 3 months (occasionally 6). Local FIs extend credit to farmers against those receipts. They advance 70% of the receipt value based on the last traded market price and take security on the whole receipt value. Farmers sell the commodities within the receipt duration and repay the loan. Failure to do so results in the local FI's foreclosing on the underlying commodity stored in the GCX warehouse. So far GCX has seen no defaults, with 40% of its warehousing volume now financed.
iv. **Agricultural insurance provided by the new agricultural insurance fund**. The new agricultural insurance fund has been established and will supersede the Ghana Agricultural Insurance Pool (GAIP). The terms of the insurance contracts to be offered by the fund are not yet known. After project end, based on the results of the above actuarial study, the insurance fund will consider tailoring its insurance contracts to EBA/CRA farms (for instance lowering premia in consideration of their lower exposure to climate risks).

To develop the blended finance model, the project will implement the following Sub-activities.

Sub-activity 4.3.1: Provide technical assistance to the staff of the Business Advisory Centers (BACs) using a training-of-trainers approach. This training will enable BACs to coach FBOs and their members on the business and financial aspects of EBA/CRA and on the identification of off-takers and signing of off-take agreements, thereby enhancing FBO bankability for local financial institutions. MOFA/EPA expressed the wish that the government BACs located in each district are the providers of technical assistance to FBOs with regards to business development and access to finance.

Sub-activity 4.3.2: Provide logistical support to BACs through the provision of motorbikes that will allow BAC officers to provide TA to FBOs on-site. Fuel and maintenance of the motorbikes, as well as the allocation of BAC officer time specifically for TA to FBOs under this project will be provided by the EPA.

Sub-activity 4.3.3: Organize annual "climate-resilient agriculture forums" convening FBOs, value chain actors (off-takers, commodity processors and exporters, input providers, GCX), LFIs and NGOs operating in the agricultural sector in the target regions and relevant government entities. These forums will facilitate the establishment of business relationships between FBOs and value chain actors, will allow FBOs to share progress on their path to climate resilience (with focus on enhanced farm profitability) and LFIs to advertise their CRL products, loan application procedures and requirements. Moreover, gender-specific criteria within the blended finance model will be developed to ensure a portion of credit lines are specifically allocated to women farmers and women-owned agricultural businesses.

Sub-activity 4.3.4: Provide technical assistance to LFIs on (i) the on the business and financial aspects of EBA/CRA that make EBA/CRA-adopting FBOs more bankable than conventional ones, (ii) the design of CRL products whose terms reflect the specificities of EBA/CRA and (ii) the identification of and introduction to IFIs that could provide concessional credit lines to fund the local FIs' CRL programs.

This technical assistance will be provided by GIRSAL, with GCF reimbursement of GIRSAL experts' time and logistical costs (rental of training venue and catering). GIRSAL confirmed its interest in partnering for the project. GIRSAL is interested in principle in guaranteeing loans issued by local FIs to FBOs, but the actual issuance of such guarantees will be at GIRSAL's discretion based on a credit assessment at the time of the guarantee request. GIRSAL also agreed to lead the technical assistance to local FIs on the benefits of EBA/CRA for the creditworthiness of farmers. GIRSAL confirmed its experts are fully qualified for the task. In addition, collaboration with AFAWI and local women's groups, such as the WAP, will provide tailored financial literacy training and business support to enhance women's ability to access and manage credit for climate-resilient agriculture.

Sub-activity 4.3.5: Create a credit score database on FBOs and their members that are targeted by the project and have never borrowed before. This function could be performed by an entity such as Financial Access, an NGO with specific expertise in the creation of smallholder farmer credit databases. The database would be made available for free to LFIs to facilitate their lending to target FBOs. The entity will also train LFIs on its scoring methodology and use of the database. As part of the project design consultations, Financial Access expressed its strong interest in creating a credit score database for both farmers and FBOs targeted by the project, to be made available as an online dashboard to LFIs. An entity, such as Financial Access, would also provide technical assistance to LFIs on the Financial Access scoring methodology and use of the dashboard. The selected entity would perform these activities at a cost to the GCF project. Access to the database and technical assistance would be provided at no charge to LFIs.

Sub-activity 4.3.6: Produce actuarial data on the FBOs and their members that adopt EBA/CRA under the project, to be used by the new agricultural insurance fund to fine-tune its agricultural insurance policies for EBA/CRA adopting farms. Data compiled will include recorded annual yields vs. relevant climate data, crop losses in years affected by climate change and any other revenue and cost data that show the increased climate resilience – and hence lower risk profile – of farms adopting EBA/CRA. The data will be included and analysed in a study published at the end of the project by experts engaged by the project. A seminar will be organized with relevant ministries (MOFA, EPA, others) and the agricultural insurance fund to share findings and highlight recommendations pertaining to the design of agricultural insurance products for EBA/CRA.

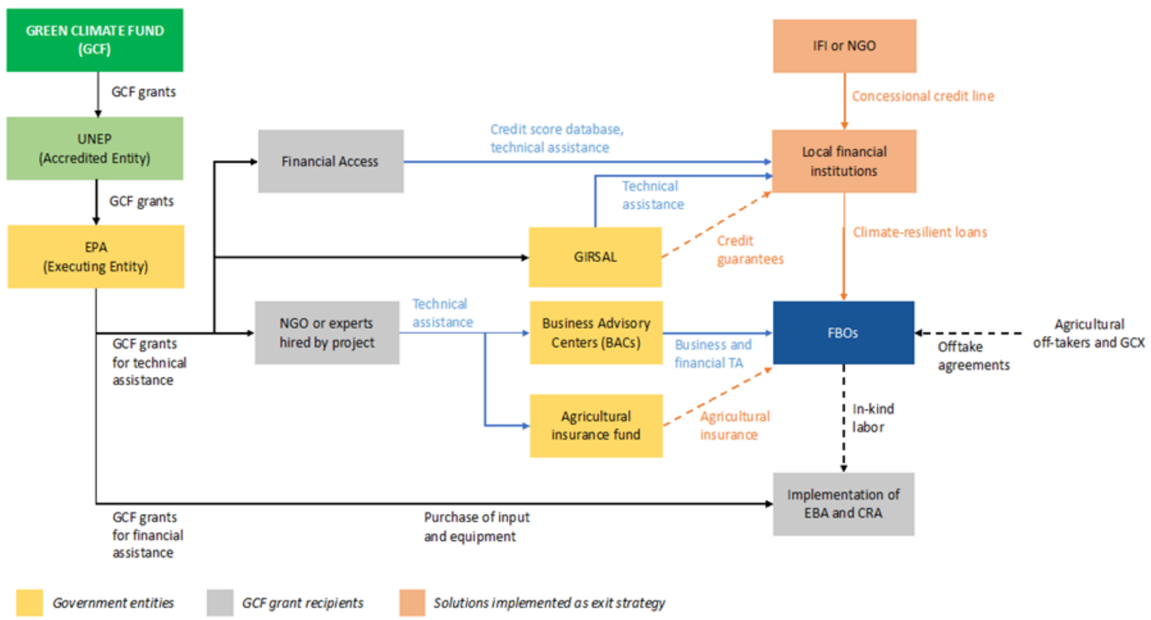


Figure 90. Blended finance model.

During the implementation of the blended finance model, further partnerships with credit providers, technology institutions to set up the credit scoring, off-takers and the new agricultural insurance fund will be developed.

13.6 Output 5: Knowledge and awareness of climate threats to agricultural livelihoods and available adaptation options increased to inform the upscaling of climate change adaptation across northern Ghana.

Smallholder farming communities in northern Ghana are generally unaware of current and future climate change-related risks and are therefore unable to adapt appropriately. Many of the farmers attribute most of the things that happen in their lives — including the impacts of climate change — to divinity[820]. This belief poses a barrier to climate change adaptation because as the smallholder farmers believe that climate change is due to divine will, they are less inclined to implement actions to adapt to it[821]. As a result, there is a need to raise the knowledge and awareness of smallholder farmers in northern Ghana on climate change threats and available adaptation options[822].

To promote the upscaling and replication of project interventions, Output 5 will focus on activities that contribute to knowledge sharing and awareness-raising at national and local levels. By promoting the upscaling and replication of project interventions outside of beneficiary communities, the project will facilitate widespread and sustained behavioural transformation in smallholder farming communities in northern Ghana. The project will specifically integrate findings and experiences of the two approved GCF project. The UNDP-Forestry Commission project does not have a knowledge management output and the AfDB

[820] Antwi-Agyei P. 2012. Vulnerability and adaptation of Ghana's food production systems and rural livelihoods to climate variability. DPhil, University of Leeds, Leeds.
[821] Ibid.
[822] Sova C, Chaudhury AS, Nelson W, Nutsukpo DK, Zougmoré RB. 2014. Climate change adaptation policy in Ghana: Priorities for the agriculture sector.

project has a very small activity on knowledge management (with a grant budget of US$150K). We propose to increase the prominence of this output in its proposal by adding an economic valuation component to measure ecosystem services arising from all three GCF projects, drawing on the methodologies and experiences from our Environmental Economics work.

Activity 5.1: Generate and disseminate knowledge products capturing best practice and lessons learned to inform the upscaling of climate change adaptation across northern Ghana.

A monitoring and economic valuation programme will monitor project progress towards its targets and evaluate the socio-economic impacts of the various climate change adaptation interventions being implemented. The monitoring and economic valuation programme will be designed in collaboration with relevant national research institutions, such as University for Development Studies, Kwame Nkrumah University of Science and Technology, Forest Research Institute of Ghana Soil Research Institute and Ghana Meteorological Agency. A climate change intervention monitor will be placed in each targeted community to collect relevant information stipulated in the monitoring programme. Monitoring and evaluation will focus primarily on *inter alia*: i) the achievement of project targets (see Section E); ii) socio-economic benefits of project interventions; iii) changes in crop productivity under different climate-resilient agriculture and EbA scenarios; iv) socio-economic benefits and uptake of alternative climate-resilient livelihoods; and v) environmental co-benefits of project interventions. The monitoring programme will build an evidence base for the further implementation of climate change adaptation interventions in northern Ghana.

Based on the results of the monitoring and economic valuation programme, various knowledge products detailing best practice and lessons learned through the project will be developed. These knowledge products will include *inter alia*: i) policy briefs, for example a policy brief on guiding the inclusion of CCAP and EbA practices in local government development planning and budgeting, as well as sector focus integration (e.g. agriculture, water, infrastructure) ; ii) climate change adaptation intervention implementation guidelines; iii) training manuals; and iv) reports. These products will include the collection and incorporation of gender-disaggregated data to capture the distinct experiences, challenges, and successes of both women and men in climate adaptation. These knowledge products will then be disseminated to relevant stakeholders, including through the knowledge-sharing and awareness-raising events (Activity 5.2) and the Ghana Climate Change Data Hub. Moreover, capacity-building workshops will be conducted for women's groups and female community leaders on how to use and apply the knowledge captured in these products for local adaptation planning.

Knowledge of best adaptation practice and lessons learned from the implementation of climate change adaptation interventions will support activities under Ghana's NAP Readiness and Preparatory Support programme. In particular, knowledge products generated through the proposed project will inform the development of a national costed adaptation plan.

Activity 5.2: Conduct knowledge-sharing and awareness-raising events.

An awareness-raising campaign will be implemented in both beneficiary and non-beneficiary communities in northern Ghana. The campaign will increase awareness about appropriate climate change adaptation interventions and will promote the upscaling of these interventions outside of the project target sites. The awareness-raising campaign will be developed by a suitably qualified national organisation and will utilise locally appropriate communication and knowledge dissemination mechanisms, such as video documentaries and phone-in radio shows. Additionally, inclusive communication methods such as local languages, visual aids, and interactive sessions will be employed to ensure all community members, including women, are able to understand and contribute to the discussions. All of the awareness-raising activities included in the campaign will be appropriate to local circumstances, taking into account literacy levels and access to different types of media. Women, women's groups and institutions working with women will also be targeted with specific awareness-raising activities.

Knowledge-sharing events will also be organised by district staff and extension officers at each beneficiary community. At each knowledge-sharing event, interested community members from five nearby communities (approximately 100 people, ensuring 50% are women, including those from rural and marginalised communities), along with extension officers from neighbouring districts, will be brought to a beneficiary community to view climate change adaptation demonstration sites and learn from beneficiary community members. Event participants will receive basic theoretical and practical training on climate change adaptation. These events will promote the autonomous upscaling of climate change interventions promoted by the project in non-beneficiary communities.

Annual knowledge-sharing conferences will be convened to promote information sharing and encourage coordination between current and future climate change adaptation projects and programmes in Ghana. Participants will include: i) district-level government staff[823]; ii) regional-level government staff[824]; iii) national-level government staff[825]; iv) project and programme managers; v) representatives of academic and research institutions; vi) NGO staff; vii) representatives of multilateral development agencies; and viii) project beneficiaries. Increased information sharing and coordination between adaptation projects and programmes in Ghana will enhance effectiveness and promote upscaling as best practices and lessons learned are shared between projects. The proposed project will also develop a long-term plan with the GoG to ensure that these conferences continue beyond the lifespan of the project.

Peer learning and experience sharing for both national and subnational institutions will be also supported through participation to national and international forums/events advocating for the international recognition of mechanisms for subnational performance-based grants for adaptation financing, including the LoCAL Global Board as a South-South platform for LDCs and developing countries to share good practises and learning on subnational adaptation.

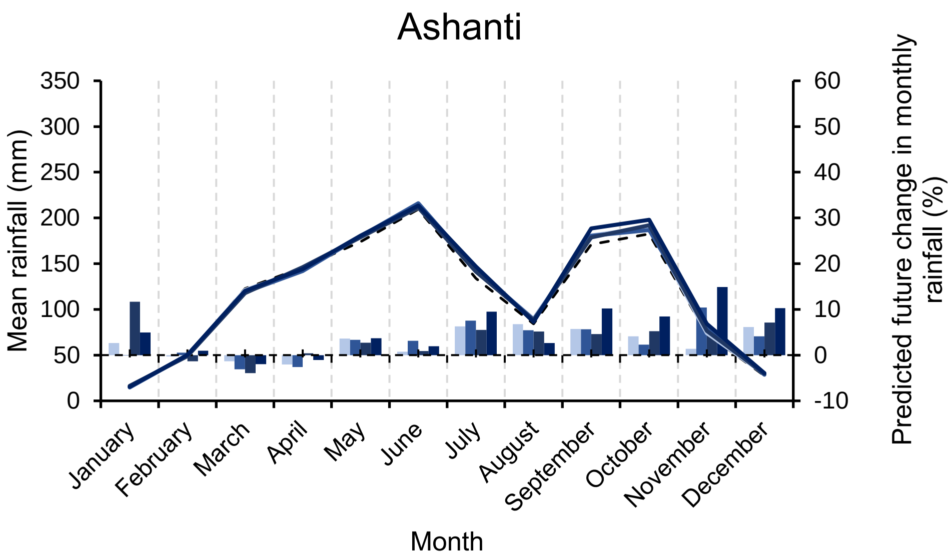
<u>Activity 5.3 Conduct district awareness and training workshops with District Assemblies to integrate CCAPs and EbA in District development plans and District environment plans and budgets</u>

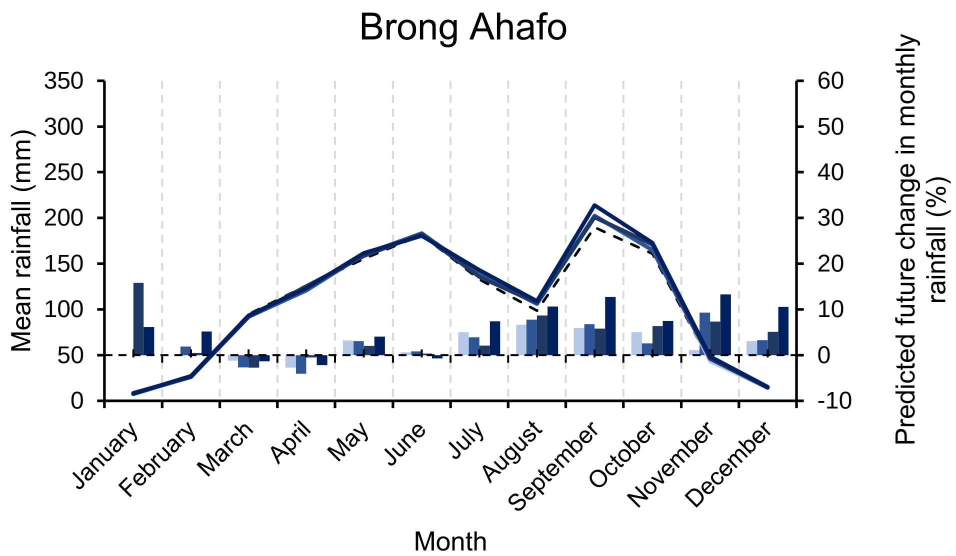
Based on project results, knowledge products produced and economic appraisal of the approach carried out under Output 5, the project will engage with District planning officers to promote dialogue about upscaling the approach through District level budgets. During the training sessions with District Authorities, the project will explore during the implementation phase about the possibilities to connect this project with policy-based grants for greening the public financial management systems based on project's EbA and CCAP experiences.

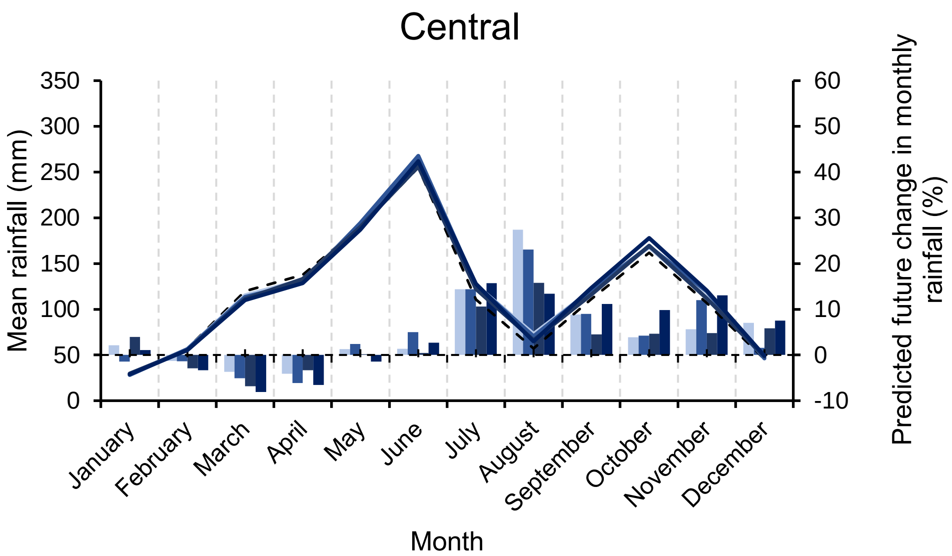
[823] E.g. extension officers, representatives from District Assemblies and DEMCs.
[824] E.g. staff from regional EPA offices, Regional Department of Agriculture office and REMCs.
[825] E.g. staff from the MESTI, MoFA, EPA, Ministry of Local Government, MoF and the NDA.

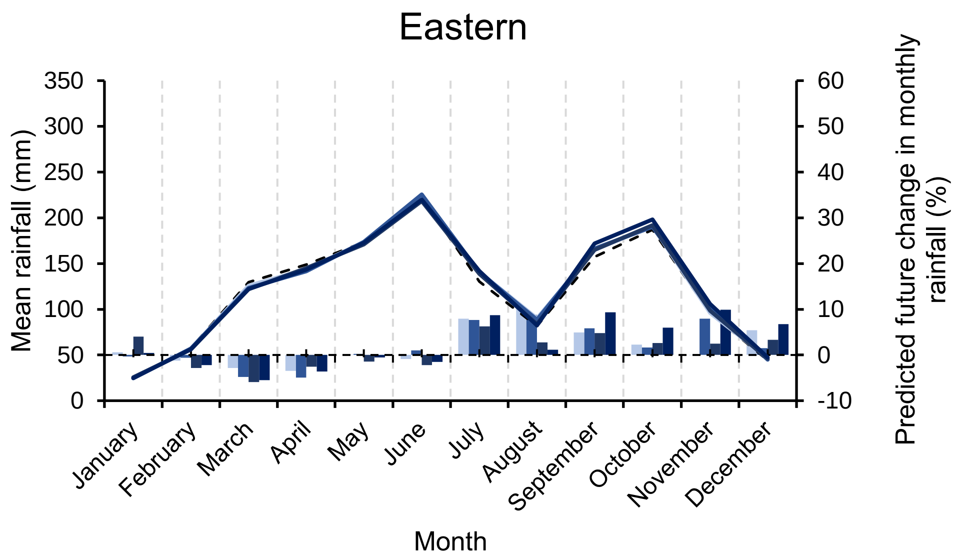
14 Supporting Information

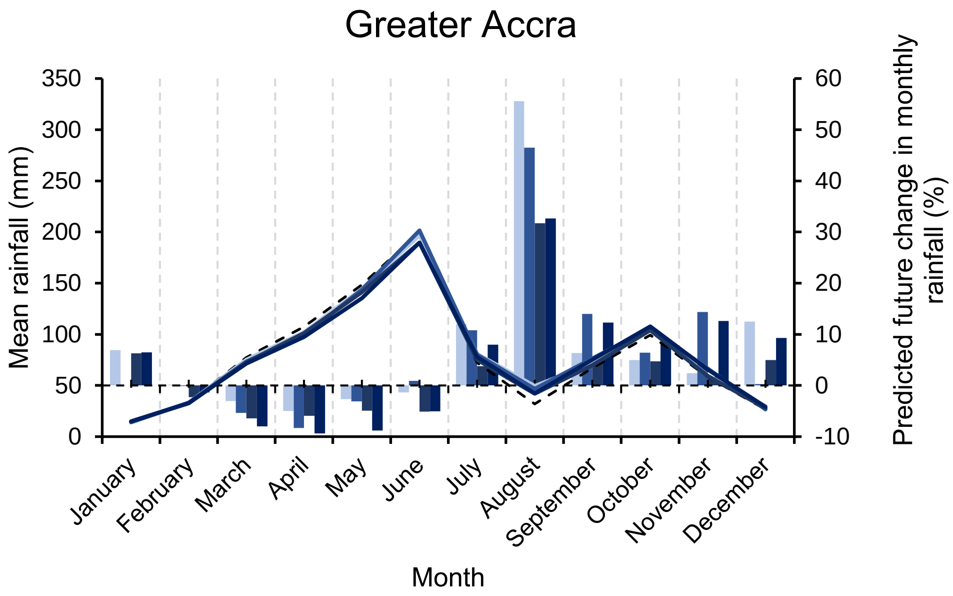
14.1 Appendix 1. Rainfall and temperature profiles for the administrative regions of Ghana by 2055 and 2085 under RCP 4.5 and 8.5.










Greater Accra
Mean rainfall (mm)
Predicted future change in monthly rainfall (%)
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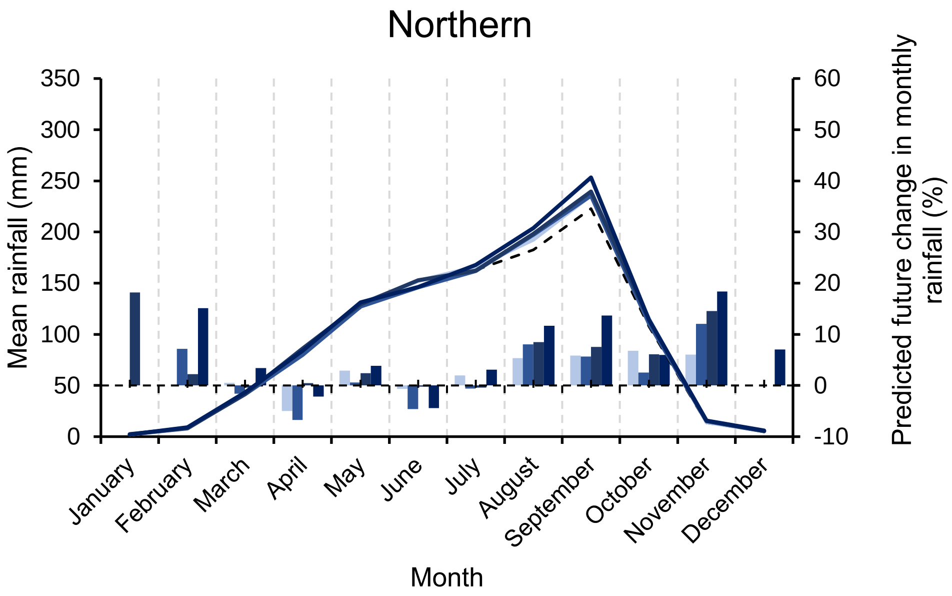
Northern
Mean rainfall (mm)
Predicted future change in monthly rainfall (%)
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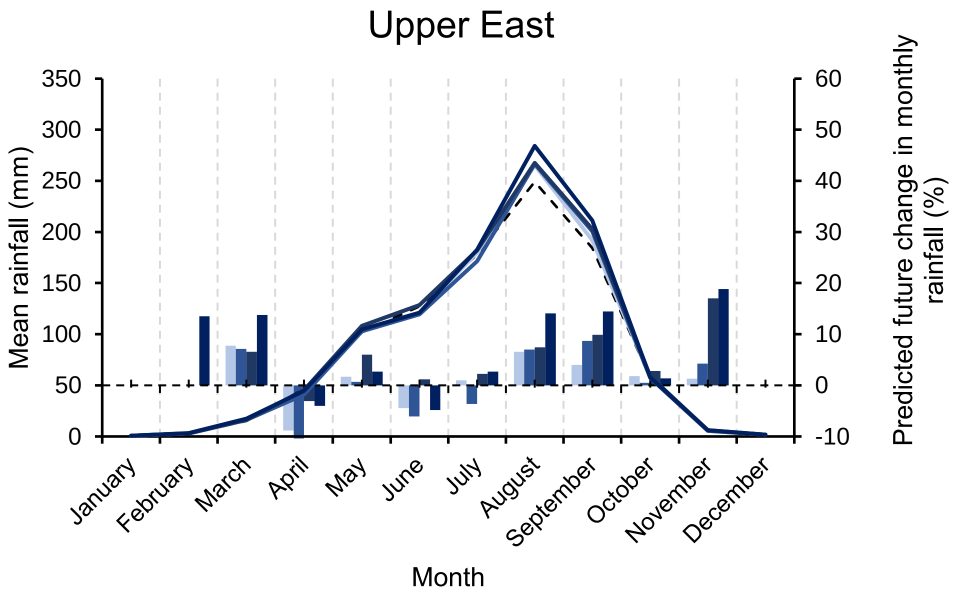
Upper East
Mean rainfall (mm)
Predicted future change in monthly rainfall (%)
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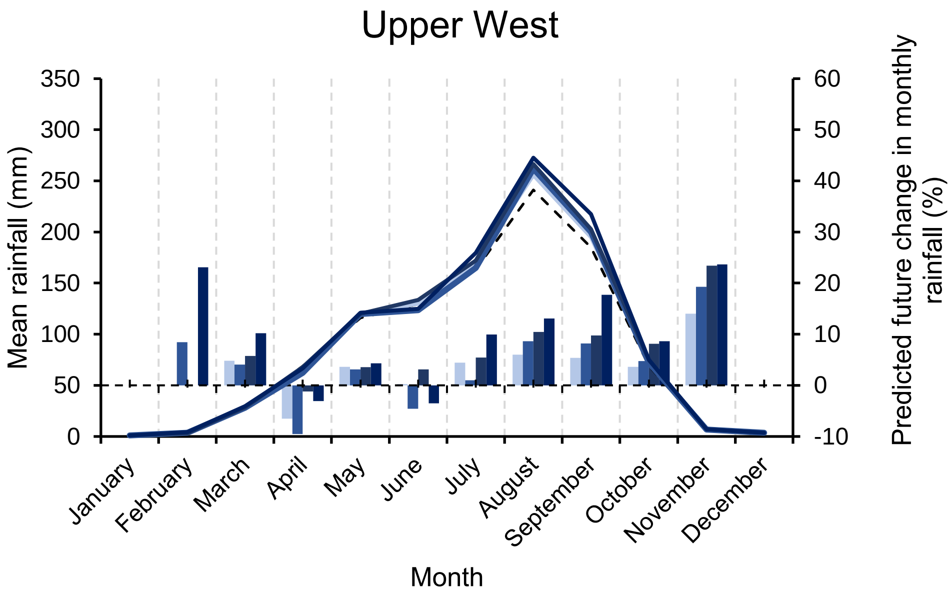
Upper West
Mean rainfall (mm)
Predicted future change in monthly rainfall (%)
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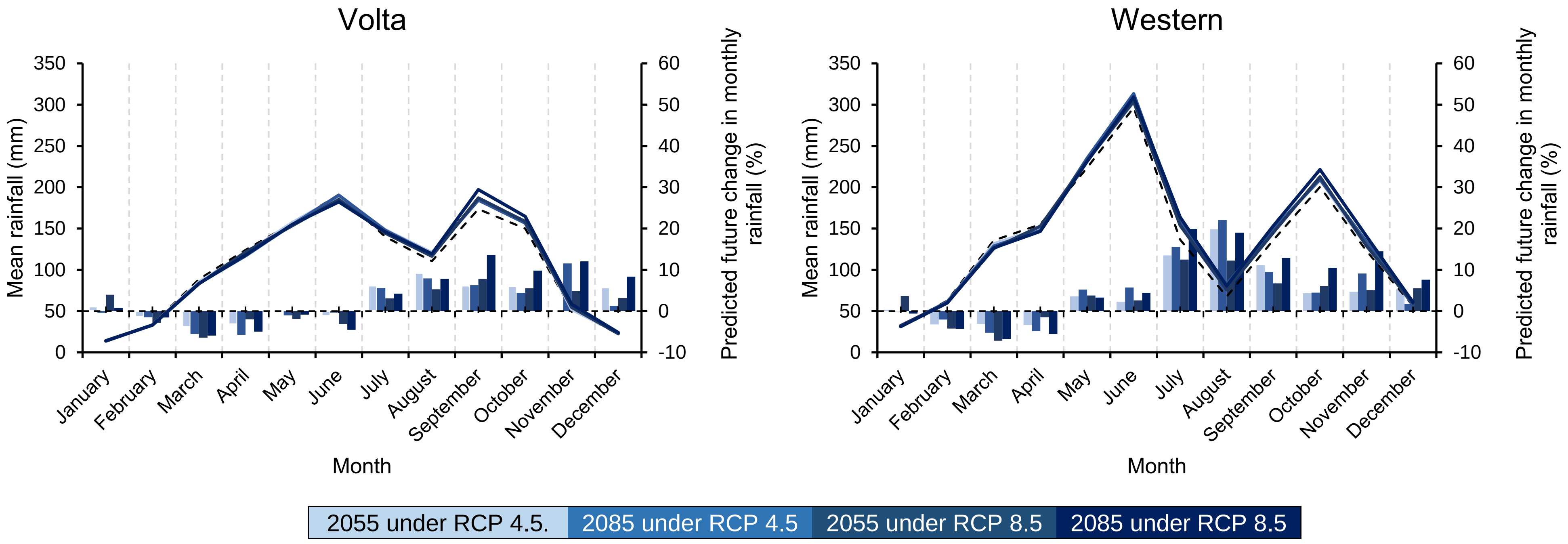
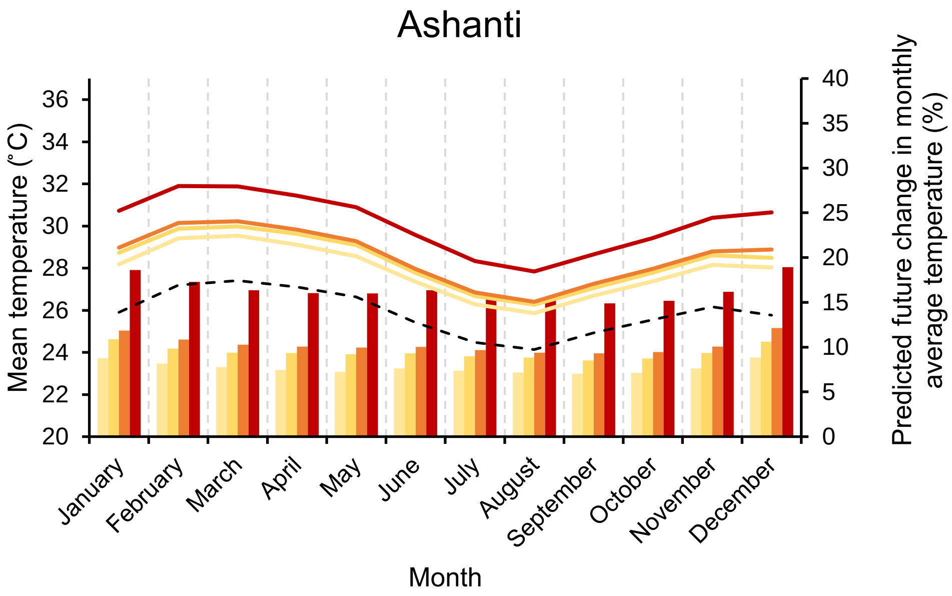


Figure S1. Current and future predicted rainfall profiles of the 10 administrative regions of Ghana. Lines represent mean monthly rainfall (left-hand axis) and bars represent predicted percentage change in mean monthly rainfall (right-hand axis). Colours indicate different climate change scenarios and time periods (legend above). Current (1950–2000) rainfall is represented by the dashed line.


Ashanti
Mean temperature (°C)
Predicted future change in monthly average temperature (%)
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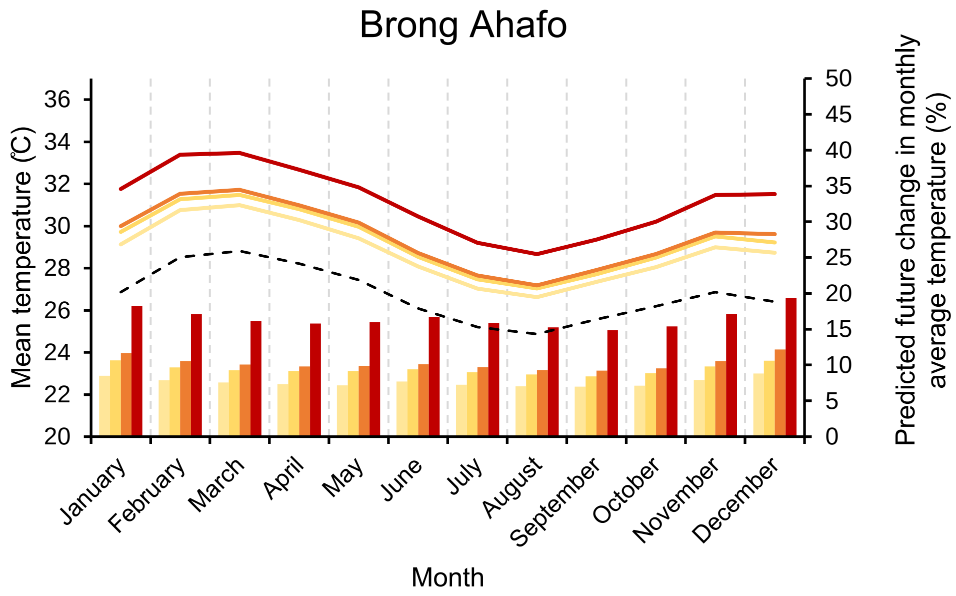
Brong Ahafo
Mean temperature (C)
Predicted future change in monthly average temperature (%)
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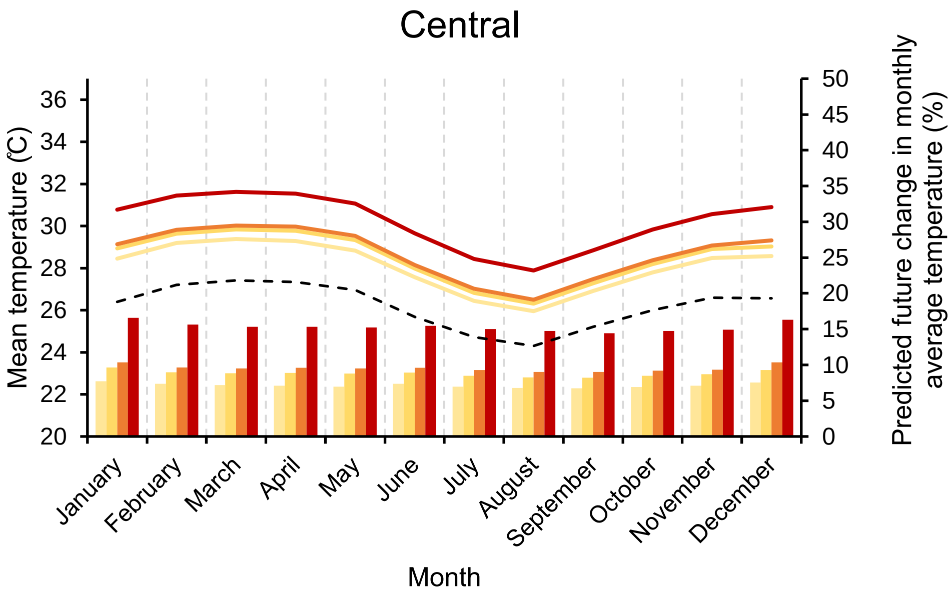
Central
Mean temperature (C)
Predicted future change in monthly average temperature (%)
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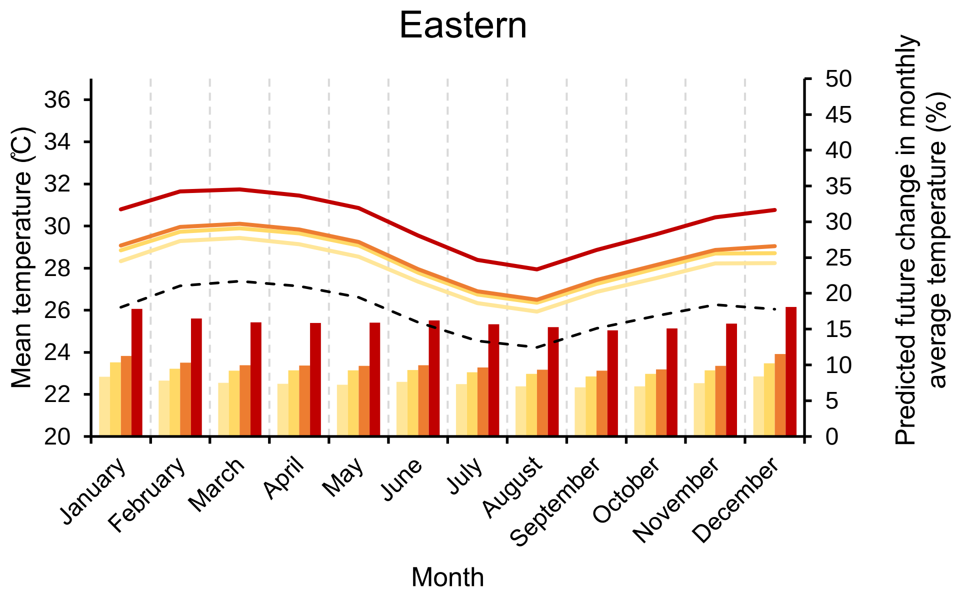
Eastern
Mean temperature (C)
Predicted future change in monthly average temperature (%)
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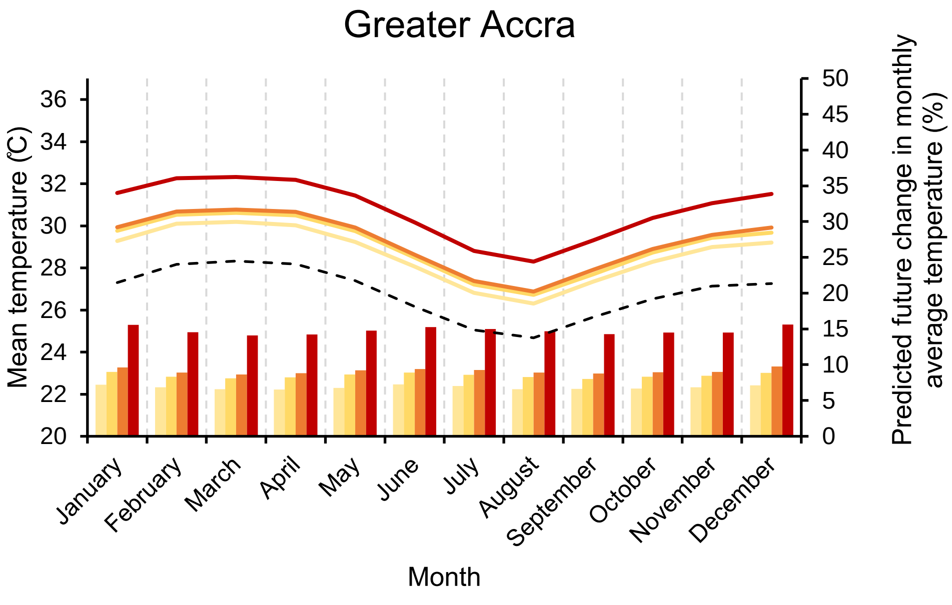
Greater Accra
Mean temperature (°C)
Predicted future change in monthly average temperature (%)
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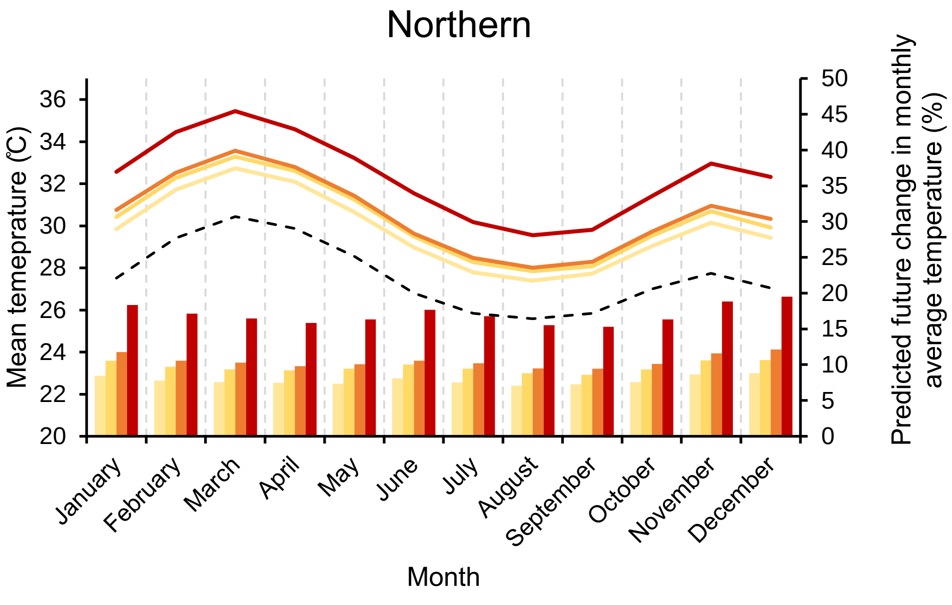
Northern
Mean temeperature (°C)
Predicted future change in monthly average temperature (%)
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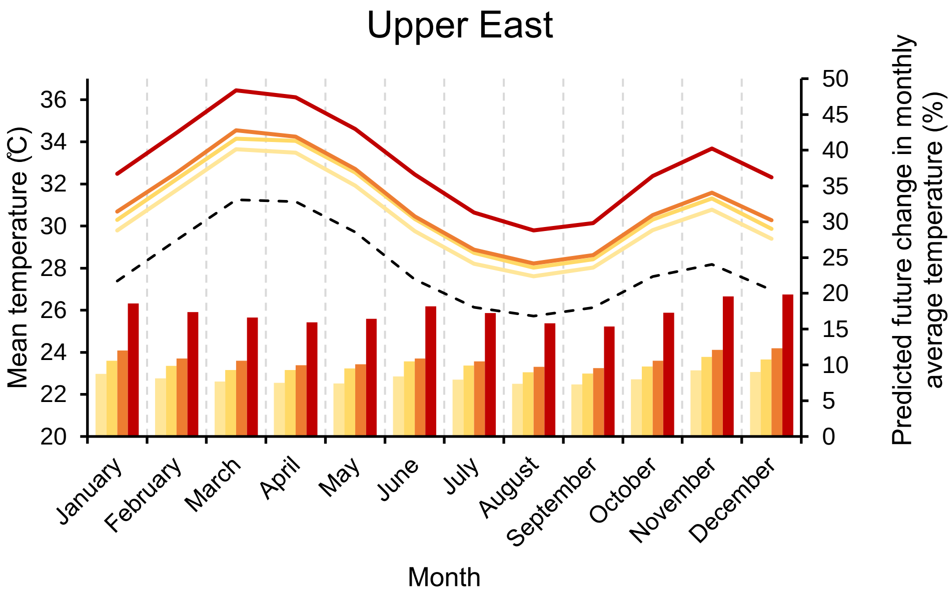
Upper East
Mean temperature (°C)
Predicted future change in monthly average temperature (%)
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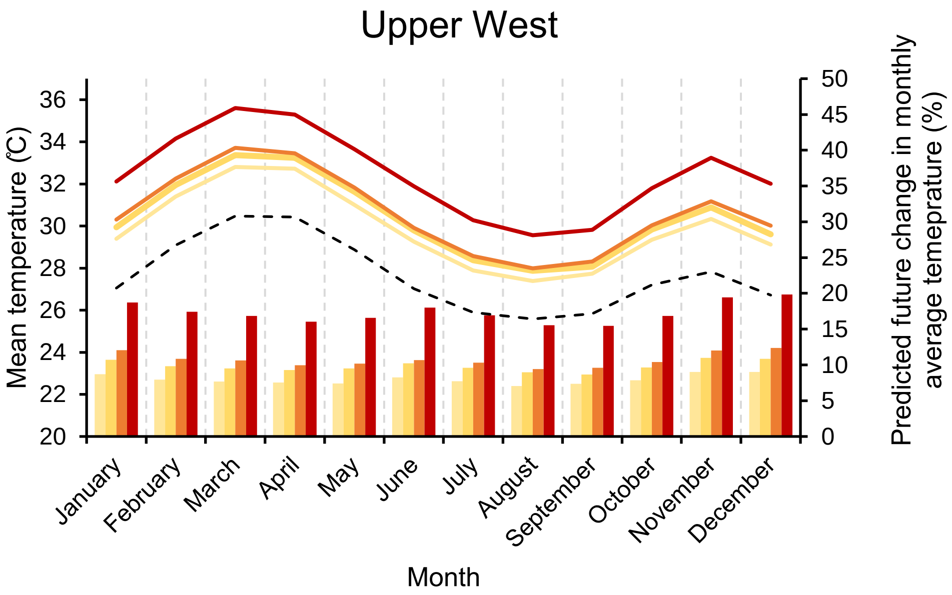
Upper West
Mean temeperature (°C)
Predicted future change in monthly average temperature (%)
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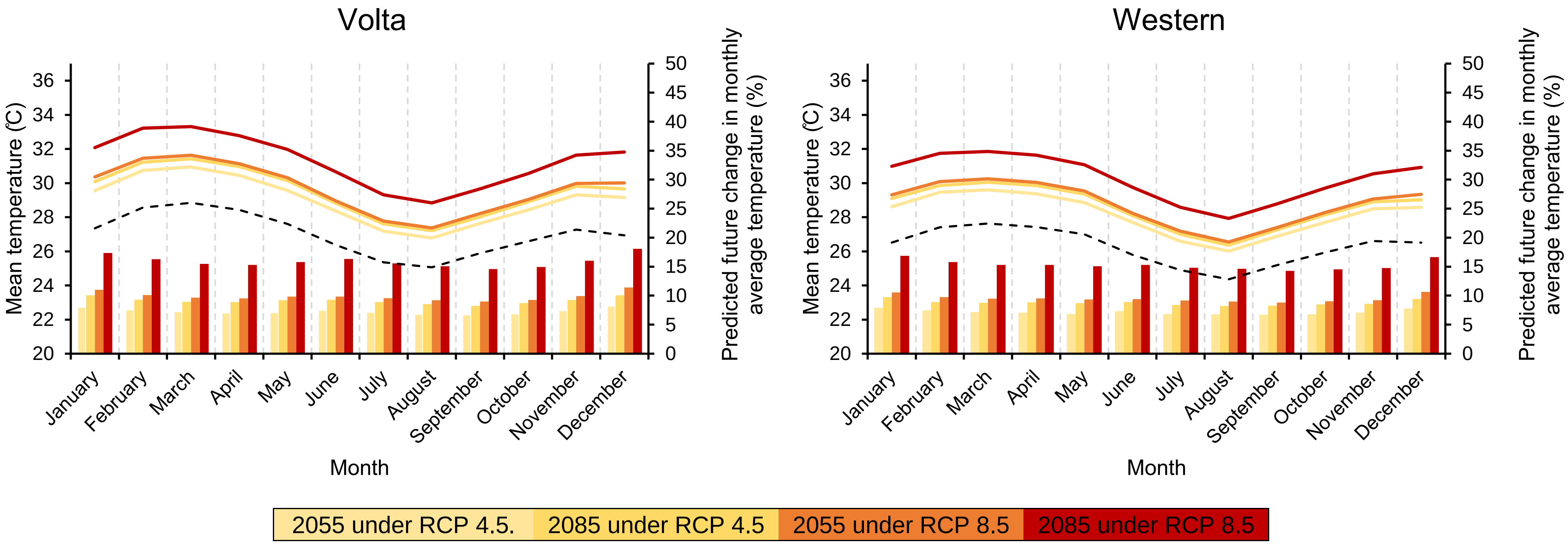

Figure S2. Current and future predicted average temperature profiles of the 10 administrative regions of Ghana. Lines represent mean monthly average temperature (left-hand axis) and bars represent predicted percentage change in mean monthly average temperature (right-hand axis). Colours indicate different climate change scenarios and time periods (legend above). Current (1950–2000) average temperature is represented by the dashed line

14.2 *Appendix 2. Results of the Climate Change Vulnerability assessment.*

Table S1. Exposure, sensitivity, adaptive capacity and Climate Change Vulnerability scores for Ghana's 216 districts. The colour scale relates to the degree of Climate Change Vulnerability.

Region	District	Exposure	Sensitivity	Adaptive capacity	Climate Change Vulnerability
Ashanti	Adansi North	0.46	0.08	0.66	-0.62
	Adansi South	0.41	0.08	0.54	-0.51
	Afigya Kwabre	0.63	0.08	0.84	-0.78
	Afigya Sekyere	0.68	0.08	0.63	-0.58
	Ahafo Ano North	0.50	0.08	0.33	-0.29
	Ahafo Ano South	0.63	0.08	0.67	-0.62
	Amansie Central	0.49	0.08	0.64	-0.60
	Amansie West	0.50	0.08	0.82	-0.77
	Asante Akim Central Municipal	0.44	0.08	0.79	-0.75
	Asante Akim North	0.52	0.08	0.59	-0.54
	Asante Akim South	0.43	0.08	0.57	-0.53
	Asokore Mampong Municipal	0.46	0.08	0.84	-0.80
	Atwima Kwanwoma	0.46	0.08	0.93	-0.90
	Atwima Mponua	0.57	0.08	0.71	-0.66
	Atwima Nwabiagya	0.55	0.08	0.81	-0.77
	Bekwai Municipal	0.48	0.08	0.56	-0.52
	Bosome Freho	0.48	0.08	0.44	-0.40
	Bosomtwe /Atwima / Kwanwoma	0.43	0.08	0.92	-0.88
	Ejisu Juaben	0.50	0.08	0.67	-0.63
	Ejura Sekye Dumase	0.58	0.08	0.39	-0.34
	Kma	0.47	0.08	0.71	-0.67
	Kwabre	0.57	0.08	0.90	-0.86
	Mampong Municipal	0.63	0.08	0.54	-0.48
	Obuasi Municipal	0.54	0.08	0.85	-0.80
	Offinso Municipal	0.66	0.08	0.52	-0.46
	Offinso North	0.65	0.08	0.62	-0.57
	Sekyere Afram Plains	0.65	0.08	0.55	-0.50
	Sekyere Afram Plains North	0.52	0.08	0.24	-0.20
	Sekyere Central	0.56	0.08	0.54	-0.50
	Sekyere East	0.59	0.08	0.72	-0.68
Brong Ahafo	Asunafo North	0.49	0.74	0.67	-0.30
	Asunafo South	0.52	0.74	0.58	-0.19
	Asutifi North	0.48	0.74	0.47	-0.12
	Asutifi South	0.47	0.74	0.59	-0.24
	Atebubu Amantin	0.54	0.74	0.26	0.14
	Banda	0.59	0.74	0.25	0.19
	Berekum	0.59	0.74	0.52	-0.08
	Dormaa East	0.53	0.74	0.35	0.05
	Dormaa Municipal	0.50	0.74	0.68	-0.31
	Dormaa West	0.47	0.74	0.58	-0.23

Region	District	Exposure	Sensitivity	Adaptive capacity	Climate Change Vulnerability
	Jaman North	0.64	0.74	0.51	-0.03
	Jaman South	0.57	0.74	0.58	-0.16
	Kintampo North	0.53	0.74	0.36	0.03
	Kintampo South	0.71	0.74	0.24	0.28
	Nkoranza North	0.66	0.74	0.41	0.08
	Nkoranza South	0.63	0.74	0.44	0.03
	Pru	0.51	0.74	0.25	0.14
	Sene East	0.50	0.74	0.32	0.05
	Sene West	0.54	0.74	0.35	0.05
	Sunyani Municipal	0.56	0.74	0.60	-0.18
	Sunyani West	0.61	0.74	0.45	0.00
	Tain	0.60	0.74	0.26	0.19
	Tano North	0.55	0.74	0.61	-0.20
	Tano South	0.60	0.74	0.44	0.01
	Techiman Municipal	0.68	0.74	0.69	-0.18
	Techiman North	0.70	0.74	0.62	-0.10
	Wenchi	0.65	0.74	0.33	0.15
Central	Abura / Asebu / Kwamankese	0.27	0.23	0.48	-0.42
	Agona East	0.27	0.23	0.54	-0.48
	Agona West	0.27	0.23	0.76	-0.70
	Ajumako-Enyan-Esiam	0.27	0.23	0.72	-0.65
	Asikuma / Odoben / Brakwa	0.32	0.23	0.54	-0.47
	Assin North	0.42	0.23	0.46	-0.37
	Assin South	0.35	0.23	0.45	-0.37
	Awutu Senya	0.27	0.23	0.52	-0.45
	Awutu Senya East Municipal	0.26	0.23	0.65	-0.59
	Cape Coast Metro	0.27	0.23	0.80	-0.74
	Effutu	0.26	0.23	0.73	-0.67
	Ekumfi	0.23	0.23	0.32	-0.26
	Gomoa East	0.24	0.23	0.59	-0.53
	Gomoa West	0.23	0.23	0.46	-0.41
	Komenda Edna Eguafo / Abirem	0.28	0.23	0.62	-0.55
	Mfantsiman	0.28	0.23	0.47	-0.41
	Twifo Ati-Morkwa	0.46	0.23	0.71	-0.60
	Twifo Lower Denkyira	0.35	0.23	0.55	-0.47
	Upper Denkyira East	0.54	0.23	0.51	-0.39
	Upper Denkyira West	0.47	0.23	0.82	-0.71
Eastern	Akwapem North	0.45	0.33	0.64	-0.50
	Akwapem South	0.38	0.33	0.78	-0.65
	Akyem Mansa	0.35	0.33	0.28	-0.16
	Asuogyaman	0.36	0.33	0.70	-0.58
	Atiwa	0.55	0.33	0.56	-0.38
	Ayensuano	0.36	0.33	0.48	-0.36
	Birim Municipal	0.40	0.33	0.54	-0.42

Region	District	Exposure	Sensitivity	Adaptive capacity	Climate Change Vulnerability
	Birim North	0.41	0.33	0.75	-0.61
	Birim South	0.40	0.33	0.44	-0.31
	Denkyembour	0.45	0.33	0.88	-0.73
	East Akim	0.54	0.33	0.79	-0.61
	Fanteakwa	0.62	0.33	0.62	-0.42
	Kwaebibirem	0.47	0.33	0.66	-0.51
	Kwahu Afram Plains North	0.41	0.33	0.31	-0.17
	Kwahu Afram Plains South	0.45	0.33	0.16	-0.01
	Kwahu East	0.59	0.33	0.34	-0.14
	Kwahu South	0.64	0.33	0.36	-0.15
	Kwahu West	0.51	0.33	0.73	-0.57
	Lower Manya	0.37	0.33	0.78	-0.66
	New Juaben Municipal	0.46	0.33	0.86	-0.71
	Nsawam Adoagyiri	0.26	0.33	0.90	-0.81
	Suhum Municipal	0.43	0.33	0.84	-0.70
	Upper Manya	0.45	0.33	0.37	-0.22
	Upper West Akim	0.29	0.33	0.55	-0.45
	West Akim	0.45	0.33	0.71	-0.56
	Yilo Krobo	0.50	0.33	0.71	-0.55
Greater Accra	Accra Metropolis	0.26	0.00	0.81	-0.80
	Ada East	0.21	0.00	0.81	-0.81
	Ada West	0.22	0.00	0.70	-0.70
	Adenta	0.29	0.00	0.74	-0.74
	Ashaiman	0.27	0.00	0.93	-0.93
	Ga Central Municipal	0.31	0.00	0.84	-0.83
	Ga East	0.32	0.00	0.84	-0.84
	Ga South	0.26	0.00	0.57	-0.57
	Ga West	0.27	0.00	0.81	-0.81
	Kpone Katamanso	0.29	0.00	0.90	-0.90
	La Dade Kotopon	0.26	0.00	0.95	-0.95
	La Nkwantanang Madina	0.31	0.00	0.94	-0.94
	Ledzokuku / Krowor	0.26	0.00	0.86	-0.85
	Ningo Prampram	0.24	0.00	0.56	-0.55
	Shai Osu Doku	0.32	0.00	0.37	-0.37
	Tema Metropolis	0.25	0.00	0.81	-0.81
Northern	Bole	0.62	0.87	0.20	0.35
	Bunkpurugu Yonyo	0.75	0.87	0.27	0.39
	Chereponi	0.71	0.87	0.47	0.15
	East Gonja	0.57	0.87	0.13	0.37
	East Mamprusi	0.75	0.87	0.33	0.32
	Gonja Central	0.62	0.87	0.27	0.26
	Gushiegu	0.70	0.87	0.29	0.32
	Karaga	0.69	0.87	0.33	0.27
	Kpandai	0.54	0.87	0.21	0.26

Region	District	Exposure	Sensitivity	Adaptive capacity	Climate Change Vulnerability
	Kumbumgu	0.65	0.87	0.42	0.15
	Mamprugu Moagduri	0.63	0.87	0.26	0.29
	Mion	0.64	0.87	0.25	0.31
	Nanumba North	0.63	0.87	0.40	0.15
	Nanumba South	0.60	0.87	0.38	0.14
	North Gonja	0.75	0.87	0.32	0.33
	Saboba	0.62	0.87	0.34	0.20
	Sagnerigu	0.67	0.87	0.44	0.15
	Savelugu Nanton	0.68	0.87	0.39	0.20
	Sawla/Tuna/Kalba	0.79	0.87	0.26	0.43
	Tamale North Sub Metro	0.66	0.87	0.55	0.03
	Tatale	0.62	0.87	0.29	0.25
	Tolon	0.66	0.87	0.28	0.29
	West Gonja	0.73	0.87	0.33	0.30
	West Mamprusi	0.68	0.87	0.42	0.17
	Yendi Municipal	0.61	0.87	0.43	0.10
	Zabzugu	0.60	0.87	0.37	0.15
Upper East	Bawku Municipal	0.79	0.68	0.34	0.20
	Bawku West	0.74	0.68	0.19	0.32
	Binduri	0.77	0.68	0.18	0.34
	Bolgatanga Municipal	0.70	0.68	0.45	0.03
	Bongo	0.76	0.68	0.21	0.31
	Builsa North	0.64	0.68	0.24	0.20
	Builsa South	0.62	0.68	0.09	0.33
	Garu Tempane	0.78	0.68	0.14	0.39
	Kasena Nankana East	0.68	0.68	0.44	0.02
	Kasena Nankana West	0.74	0.68	0.60	-0.10
	Nabdam	0.73	0.68	0.24	0.26
	Pusiga	0.81	0.68	0.27	0.28
	Talensi	0.69	0.68	0.21	0.26
Upper West	Daffiama Bussie	0.76	1.00	0.13	0.64
	Jirapa	0.75	1.00	0.14	0.61
	Lambussie	0.76	1.00	0.10	0.66
	Lawra	0.72	1.00	0.20	0.52
	Nadowli-Kaleo	0.74	1.00	0.17	0.58
	Nandom	0.74	1.00	0.20	0.54
	Sissala West	0.76	1.00	0.13	0.63
	Sissala East	0.74	1.00	0.29	0.45
	Wa East	0.75	1.00	0.07	0.68
	Wa Municipal	0.76	1.00	0.40	0.36
	Wa West	0.72	1.00	0.11	0.61
Volta	Adaklu	0.31	0.56	0.27	-0.10
	Afadzato South	0.61	0.56	0.25	0.09
	Agotime Ziope	0.32	0.56	0.33	-0.15

Region	District	Exposure	Sensitivity	Adaptive capacity	Climate Change Vulnerability
	Akatsi North	0.26	0.56	0.51	-0.36
	Akatsi South	0.26	0.56	0.67	-0.52
	Biakoye	0.59	0.56	0.36	-0.03
	Central Tongu	0.26	0.56	0.44	-0.29
	Ho Municipal	0.50	0.56	0.52	-0.24
	Ho West	0.43	0.56	0.28	-0.04
	Hohoe Municipal	0.70	0.56	0.35	0.05
	Jasikan	0.68	0.56	0.35	0.03
	Kadjebi	0.69	0.56	0.23	0.16
	Keta Municipal	0.24	0.56	0.64	-0.51
	Ketu North	0.28	0.56	0.57	-0.41
	Ketu South	0.27	0.56	0.64	-0.49
	Kpando Municipal	0.57	0.56	0.50	-0.18
	Krachi East	0.48	0.56	0.14	0.13
	Krachi Nchumuru	0.48	0.56	0.14	0.13
	Krachi West	0.43	0.56	0.34	-0.10
	Nkwanta North	0.54	0.56	0.20	0.10
	Nkwanta South	0.67	0.56	0.25	0.12
	North Dayi	0.47	0.56	0.36	-0.10
	North Tongu	0.28	0.56	0.20	-0.05
	South Dayi	0.40	0.56	0.50	-0.28
	South Tongu	0.23	0.56	0.53	-0.40
Western	Ahanta West	0.30	0.45	0.65	-0.51
	Aowin	0.41	0.45	0.60	-0.42
	Bia East	0.48	0.45	0.47	-0.26
	Bia West	0.51	0.45	0.64	-0.41
	Bodi	0.43	0.45	0.31	-0.11
	Ellembelle	0.30	0.45	0.70	-0.57
	Jomoro	0.26	0.45	0.41	-0.29
	Juabeso	0.50	0.45	0.70	-0.47
	Mpohor	0.38	0.45	0.59	-0.42
	Nzema East	0.34	0.45	0.43	-0.28
	Prestea / Huni Valley	0.44	0.45	0.61	-0.41
	Sefwi-Wiawso	0.43	0.45	0.59	-0.39
	Sefwi Akontombra	0.44	0.45	0.59	-0.40
	Sefwi Bibiani-Anhwiaso Bekwai	0.49	0.45	0.80	-0.57
	Sekondi Takoradi	0.36	0.45	0.56	-0.40
	Shama	0.34	0.45	0.72	-0.57
	Suaman	0.42	0.45	0.64	-0.45
	Tarkwa Nsuaem	0.40	0.45	0.76	-0.57
	Wassa Amenfi Central	0.49	0.45	0.30	-0.08
	Wassa Amenfi East	0.52	0.45	0.63	-0.40
	Wassa Amenfi West	0.45	0.45	0.77	-0.57
	Wassa East	0.39	0.45	0.56	-0.39

Table S2. The northern districts of Ghana ranked according to Climate Change Vulnerability. Regions are colour coded.

CCV Rank	District	Region	Sensitivity	Exposure	Adaptive capacity	Climate Change Vulnerability	SLWMP[826] districts	Adaptation Fund[827] districts
1	Wa East	Upper West	1.00	0.75	0.07	0.68	*	
2	Lambussie	Upper West	1.00	0.76	0.10	0.66		
3	Daffiama Bussie	Upper West	1.00	0.76	0.13	0.64	*	
4	Sissala West	Upper West	1.00	0.76	0.13	0.63	*	
5	Wa West	Upper West	1.00	0.72	0.11	0.61		
6	Jirapa	Upper West	1.00	0.75	0.14	0.61		
7	Nadowli-Kaleo	Upper West	1.00	0.74	0.17	0.58		*
8	Nandom	Upper West	1.00	0.74	0.20	0.54		*
9	Lawra	Upper West	1.00	0.72	0.20	0.52		
10	Sissala East	Upper West	1.00	0.74	0.29	0.45	*	*
11	Sawla/Tuna/Kalba	Northern	0.87	0.79	0.26	0.43	*	
12	Garu Tempane	Upper East	0.68	0.78	0.14	0.39		
13	Bunkpurugu Yonyo	Northern	0.87	0.75	0.27	0.39		
14	East Gonja	Northern	0.87	0.57	0.13	0.37		
15	Wa Municipal	Upper West	1.00	0.76	0.40	0.36		
16	Bole	Northern	0.87	0.62	0.20	0.35		*
17	Binduri	Upper East	0.68	0.77	0.18	0.34		
18	North Gonja	Northern	0.87	0.75	0.32	0.33		
19	Builsa South	Upper East	0.68	0.62	0.09	0.33	*	
20	East Mamprusi	Northern	0.87	0.75	0.33	0.32		
21	Gushiegu	Northern	0.87	0.70	0.29	0.32		
22	Bawku West	Upper East	0.68	0.74	0.19	0.32	*	*
23	Bongo	Upper East	0.68	0.76	0.21	0.31		*
24	Mion	Northern	0.87	0.64	0.25	0.31		
25	West Gonja	Northern	0.87	0.73	0.33	0.30	*	
26	Tolon	Northern	0.87	0.66	0.28	0.29		
27	Mamprugu Moagduri	Northern	0.87	0.63	0.26	0.29	*	

[826] Sustainable Land and Water Management Project
[827] Increased resilience to climate change in northern Ghana through the management of water resources and diversification of livelihoods.

CCV Rank	District	Region	Sensitivity	Exposure	Adaptive capacity	Climate Change Vulnerability	SLWMP[826] districts	Adaptation Fund[827] districts
28	Pusiga	Upper East	0.68	0.81	0.27	0.28		
29	Karaga	Northern	0.87	0.69	0.33	0.27		
30	Gonja Central	Northern	0.87	0.62	0.27	0.26		
31	Kpandai	Northern	0.87	0.54	0.21	0.26		
32	Talensi	Upper East	0.68	0.69	0.21	0.26	*	
33	Nabdam	Upper East	0.68	0.73	0.24	0.26		
34	Tatale	Northern	0.87	0.62	0.29	0.25		
35	Savelugu Nanton	Northern	0.87	0.68	0.39	0.20		*
36	Saboba	Northern	0.87	0.62	0.34	0.20		
37	Builsa North	Upper East	0.68	0.64	0.24	0.20		*
38	Bawku Municipal	Upper East	0.68	0.79	0.34	0.20		*
39	West Mamprusi	Northern	0.87	0.68	0.42	0.17	*	
40	Sagnerigu	Northern	0.87	0.67	0.44	0.15		
41	Zabzugu	Northern	0.87	0.60	0.37	0.15		*
42	Nanumba North	Northern	0.87	0.63	0.40	0.15		
43	Chereponi	Northern	0.87	0.71	0.47	0.15		
44	Kumbumgu	Northern	0.87	0.65	0.42	0.15		
45	Nanumba South	Northern	0.87	0.60	0.38	0.14		
46	Yendi Municipal	Northern	0.87	0.61	0.43	0.10		
47	Tamale North Sub Metro	Northern	0.87	0.66	0.55	0.03		
48	Bolgatanga Municipal	Upper East	0.68	0.70	0.45	0.03		
49	Kasena Nankana East	Upper East	0.68	0.68	0.44	0.02		
50	Kasena Nankana West	Upper East	0.68	0.74	0.60	-0.10	*	

14.3 Appendix 3. Additional details for agroforestry practices.

Table S3. Tree and shrub species with agroforestry potential for northern Ghana[828].

Species description	Requirements and propagation	Tree Management	Uses/benefits
Senna siamea • An evergreen tree growing up to 18 m tall • Naturalised in tropics and performing well Ghana • Fast growth even in infertile soils • Drought tolerant	• Altitude: 0–1,000 m • Temperature range: 20–35⁰C • Rainfall: 400–2,800 mm • Soil: most soil with good drainage. • pH: 5.5–7.5 • Propagate by seed • Established by direct sowing • Seed available in northern Ghana	• Weed in first two years • Apply moisture conservation measures (trenching, micro-catchments) in semi-arid conditions. • For fuelwood plant at 2 x 2 m or 2 x 3 m. • For hedges (alley cropping) use 1.5 m x 5 m. • Wood mean annual increment is 20-35 m^3/ha. • Regenerate by pollarding (1.5m) or coppicing (0.3m) - leaving 2-3 shoots/stump.	• Firewood (1 year) and charcoal (2 years) • Erosion control when used as a hedgerow; effectively increases topsoil infiltration, reducing runoff and combating soil erosion. • Windbreak and shelterbelt when densely planted • Reclamation of degraded land • Soil improvement through litter fall used as green manure and mulch • Used in alley cropping due to its coppicing ability and high biomass production
Albizia lebbeck • 15–20 m tall and up to 50 cm diameter • Widely cultivated and now naturalised in dry parts of Africa including Ghana • Tolerates drought	• Altitude: 0–1,800 m • Temperature range: 19–35⁰C • Rainfall: 500–2,500 mm • Slightly acidic soils • Tolerates infertile but not water-logged and alkaline soils • Easily propagated by direct sowing and seedlings • Seed pre-treated by immersing in hot water or soaking in cold water • Seeds can germinate without pre-treatment	• Weed in first two years • Spacing; 3 x 3 m fuelwood and 5 x 5 m for to limit shade on associated crops • For fodder production, spacing should be dense: 0.75 x 0.75 m to 1 x 1 m • Also, plant on soil conservation structures — cut at 50 cm from the ground • Coppice every 6 months — cut at 50 cm	• Fodder for goats and sheep (leaves contain 17–26% crude protein) • Supports beekeeping-profuse flowering lasting throughout the year • Provides good firewood — yields 15–40 t/ha of wood in just one year after planting • Erosion control — used to rehabilitate degraded areas • Soil improvement — N-fixing, high leaf biomass production-green manure • Boundary or barrier planting

[828] Adapted from: Nimoh F, Adjei-Gyapong T, Amegashie B, Quansah C. 2015. Feasibility of Sustaining SLWM Activities Through PES Market Mechanism. Ministry of Environment, Science, Technology and Innovation, Ghana.

Species description	Requirements and propagation	Tree Management	Uses/benefits
Grevillea robusta • Medium-sized tree, 12–25 m tall • Drought resistant — can stand up to six months of drought • Used extensively in dryland agroforestry • Moderate to fast growing	• Altitude: 0–2,300 m • Temperature range: 14–31^{0}C • Rainfall: 600–1,700 mm • Soil: Loam and alluvial soils free of waterlogging and mildly acidic to neutral. • Also on clay and sand soil • Propagate by seed raised in pots • No seed pre-treatment is required • Seed can be acquired from research/seed centres	• Plant at 3 x 3–4 m • Weed in 1–2 years • Volume increments; 5–15 m^3/ha/yr • Height increment 2–3m/yr • Susceptible to termites in early years (use reagent 3G) • Diameter increment -2 cm, in early years • Prune and pollard to yield wood and regulate shading of associated crops • Use rotations of 7–15 years for fuelwood production	• Provides firewood, charcoal and poles (calorific value 4,800–4950 kcal/kg) • Yields medium-weight timber with economic potential • Windbreak • Reclamation of disturbed sites • Soil improvement by providing abundant quantities of leaf mulch • Good for intercropping because of a deep rooting system which causes little interference with shallow-rooted crops
Gliricidia sepium • 2–15 m tall, and may be single or multi-stemmed • Naturalised in many tropical countries — including West Africa • Establishes well on sloping sites • Can grow on disturbed sites such as riverbanks and floodplains • Drought-resistant	• Altitude: 0–1,200 m • Temperature range: 15–30 0C • Rainfall: 600–3,500 mm • Soil: From sandy to deep alluvial deposits • pH: 4.5–6.2 • Propagate by seed • Seed pre-treatment often not necessary • Also propagated by cuttings, though not good in poor soils • Good land preparation needed for direct sowing • Inoculate seed with rhizobia for new sites	• Plant 2.5–3 x 2.5–3 m • Regular weeding • Fast growing, easy to propagate, N-fixing and has light canopy • Pruning and pollarding are the main management activities • Pollarding at 2 m or above for optimal wood biomass production • Coppicing to be used where the primary objective is fuelwood production • Tolerate lopping and browsing	• For fodder: leaves rich in protein and highly digestible • Improved milk and meat (supplementary feed) • Important species for honey production • Firewood and charcoal production (calorific value of 4,550 kcal/kg) • Can be used as a rodenticide and general pesticide • Erosion control when used in hedgerows in alley cropping • Reclamation of degraded land • Improves soil fertility: N-fixing and green manure • Boundary/barrier/support — for example, suitable for live fencing

Species description	Requirements and propagation	Tree Management	Uses/benefits
Calliandra calothyrsus • Often multi-stemmed shrub- 5–6 m tall • Easy to regenerate and fast growing — matures in about six months • Can be used in tree fallows	• Altitude: 250–1,800 m • Temperature range: 22–28 ^{0}C • Rainfall: 700–4,000 mm • Soil: grows in a wide range of soil types but prefers light textured, slightly acidic soils • Tolerates infertile but not water-logged and alkaline soils. • Easily propagated by direct sowing and seedlings • Seed pre-treated by immersing in hot water or soaking in cold water • Seeds can germinate without pretreatment	• Fast growing, easy to regenerate by coppicing. Weeding required in the first year • To be pruned for four to six months in alley-cropping systems to limit shade on associated crops • For fodder production, spacing should be dense: 0.75 x 0.75 m to 1 x 1 m • Also, plant on soil conservation structures — cut at 50 cm from the ground, • Coppice every six months — cut at 50 cm	• Fodder: leaves and pods rich in protein (22% protein) • Annual fodder yield (dry matter) : 7–10 t/ha • Can supply 40–60% of ruminant fodder needs • Supports beekeeping- profuse flowering lasting throughout the year • Provides good firewood: yields 15–40 t/ha of wood in just one year after planting • Erosion control: used to rehabilitate degraded areas • Soil improvement: N-fixing, high leaf biomass production-green manure • Boundary or barrier planting
Euphorbia tirucalli • Shrub or small tree 4–12 m high with brittle succulent branchlets • Widely planted hedge plant used in agroforestry systems in dryland Africa • Highly drought resistant	• Altitude: up to 2,000 m • Soil: Almost any soil type • Easily propagated by branch cuttings • Cuttings obtained from older branches and left under the sun for 1–2 days before planting • Available in northern Ghana	• To form a hedge/live fence, plant at very close spacing (0.5m) • Can be cut after one year and coppices well at 20–30 cm height. • Re-growth is excellent under semi-arid conditions	• Erosion control: protects bare soil in dry areas from wind and water erosion. • Fences can act as erosion breaks • Reclamation of degraded lands • Pruned into hedge and used as a live fence around food crops
Eucalyptus camaldulensis • Grows to 20 m tall • Grown to a less extent in northern Ghana	• Altitude: 0–1,500 m • Temperature range: 21–40 ^{0}C • Rainfall: 250–2,500 mm • Soil: deep, silty or loamy soils with a clay base and accessible water table • Tolerates water-logging and periodic flooding • Tolerant to acidic soils • Propagated by seeds raised in nursery • No seed pre-treatment	• Spacing depends on the end products required (2–3 x 2–3 m) • Poor competition ability with weeds; weed two to three times a year • Slashing instead of clear weeding used when canopy closes at three to five years • For poles and posts, thin to <700 stems/ha • Coppicing is applicable	• Firewood and charcoal: makes good-quality charcoal • Timber: great strength and good durability — wood density is 900–980 kg/cm^3 • Timber rotation is about 10 years
Casuarina equisetifolia • An evergreen tree 6– 35 m tall • Has a finely branched crown • Tolerance to strong winds and drought	• Altitude: 0–1,400 m • Temperature range: 10–35 ^{0}C • Rainfall: 200–3,500 mm • Soil: well-drained and rather coarse textured, principally sands and sand loams • Tolerates slightly alkaline soils but	• Use 2.5 x 2.5 m spacing • Trees are self-pruning • Not fire-resistant, therefore needs protection • Coppices only to a limited extent when cutting young • Growth rates are about 2 m/year in height	• Good fuelwood-calorific value >5,000 kcal/kg • Erosion control: used to control erosion along riverbanks and waterways • Windbreak: tolerance to strong winds • Used to rehabilitate barren, polluted sites • N-fixing: has active root nodules

Species description	Requirements and propagation	Tree Management	Uses/benefits
	intolerant to prolonged waterlogging • Propagation is mainly by seed raised in pots	• Diameter of 5–7 cm achieved in four years • Rotation period: 4–5 years for fuelwood and 10–15 years for poles	• Good for boundary: light shade
Azadirachta indica • A small to medium-sized tree, usually evergreen, up to 15 m tall • Grows almost anywhere in the lowland tropics • Naturalised in Ghana • Drought resistant	• Altitude: 0–1,500 m • Temperature range: up to 40 ^{0}C • Rainfall: 400–1,200 mm • Soil: grows on a wide variety of neutral to alkaline soils pH: 6.2–7 • Easily propagated in the nursery by seed • Direct sowing of fresh seeds possible • No seed pre-treatment • Also propagated by root and shoot cuttings	• Spacing at least 6 x 6 m • Weeding is essential • Sensitive to competition • Responds well to chemical and organic fertilisers • Coppices freely, and early growth from coppice is faster than growth from seedlings. • Withstands pollarding well	• Firewood and charcoal are of excellent quality • Seeds produce oil burned in lamps in parts of Ghana • Erosion control • Nutrient recycling because of well-developed root system for extracting nutrients from the lower soil levels • Good shade for humans and animals in semi-arid lands • Leaves and small twigs are good for mulching and green manure
Mangiferra indica • Naturalised in tropical lowlands • Promoted in northern Ghana • Can tolerate six to eight months of drought	• Altitude: 0–915 m • Temperature range: up to 35^{0}C • Rainfall: 750–2,500 mm • Soil: Sandy soil with good drainage and suited to irrigated fields • Raised by seed of local mongo and scions of desired variety (grafted)	• Apply NPK or manures in planting holes and for 2–3 years after planting • No pruning up to fourth year • Top at four years to improve form and facilitate spraying and harvesting	• Fruit after 2–3 years • Fruit yield at peak productivity can be 3,000–1,500 fruits • Good exposure of fruits to the sun in semi-arid areas results in good colour and relatively free of disease
Parkia biglobosa • Indigenous to West Africa	• Altitude: 0-300 m • Temperature range: 24–28 ^{0}C • Rainfall: 400–700 mm • Soil: Well-drained, thick clay soils preferable, but also suited to shallow sandy soils • Seeds can be treated with concentrated sulphuric acid then immersed in water for 24 hours to break their dormancy period.	• Initial sowing into seed beds, seedlings can be transplanted into pots at three days. • Planted into the field after 20 weeks	• Fruit after 5-10 years • Contribute to soil fertility improvement
Vitellaria paradoxa • Indigenous to West Africa	• Altitude: 0-1,300 m • Temperature range: 24–38 ^{0}C • Rainfall: 300–1,400 mm • Soil: sandy clay, sand, stony soil and laterites. • pH: 6–7 • Direct sowing of fresh seeds possible.	• Spacing: 10 x 10 m • Grafting of saplings can reduce long maturation time. • Mulching essential at nursery stage.	• Fruit after 10–15 years • Full production at 20–30 years. • Used in production of shea butter • Husks of seeds can be used as mulch or fertiliser • Combines well with many cereal crops.

14.1 Appendix 4. Brief market review.

This overview assesses the economic potential and commercial viability of selected alternative livelihoods and cash crops in Ghana (Table A4.1). Livelihood activities that should be promoted in northern Ghana given their importance both for home consumption and sale include: i) collection and processing of non-timber forest products (NTFPs) — in particular shea nuts; and ii) cultivation and sale of food and cash crops — in particular maize, sorghum, cassava, cowpea and soybean. The market analyses presented here, and summarised in Table A4.45 below, are based on information gathered through a desktop review.

Table A4.45. *Economic indicators for shea nut as well as main food and cash crops in northern Ghana.*

Product	National production per year	Current average yield	Production cost (US$)	Sale price (US$ per ton)
Shea nuts	~94,000 tons[829]	15–20 kg fresh fruit/tree/year[830]	Mostly collected from wild growing trees	150-450[831,832]
Maize	~2 million tons[833]	1.9 tons/ha[834]	324-521per ha[835]	384[836]
Sorghum	~280,000 tons[837]	~11 tons/ha[838]	125 per ton[839]	330 - 539[840,841]
Cassava	~21 million tons[842]	~200 tons/ha[843]	440-469 per ha[844]	253[845]
Cowpea	~215,000 tons[846]	~0.4 tons /ha[847]	236 per ha	700[848]
Soybean	~152,000 tons[849]	~1.2 ton/ha[850]	87-120 per ha[851]	380[852]

14.1.1 Shea nuts

Shea nut trees (*Vitellaria paradoxa* C.F.Gaertn.) occur over two-thirds (~159,000 km^2) of Ghana. While these trees are common in northern Ghana, they are sparsely distributed in the Brong Ahafo, Ashanti, Eastern and Volta regions in the south of the country. The majority of shea nut trees in Ghana — approximately 9.4 million — grow wild. The potential yield of these wild-growing trees is ~100,000 tons of dried shea nut per year, with an estimated value of ~US$100 million. Shea nut

[829] TechnoServe (ed). 2018. *Natural resource product analysis - Shea roadmap*. USAID, Winrock International & Feed the Future. Accra.
[830] Kodua TT, Ankamah J, Addaem M. 2018. Assessing the profitability of small scale local shea butter processing: Empirical evidence from Kaleo in the Upper West region of Ghana. *Cogent Food & Agriculture* 4: 1-11.
[831] Masters ET, Yidana JA, Lovett P. Reinforcing sound management through trade: shea tree products in Africa. Available at http://www.fao.org/3/y5918e/y5918e11.htm. [accessed 26 February 2020]
[832] TechnoServe (ed). 2018. *Natural resource product analysis - Shea roadmap*. USAID, Winrock International & Feed the Future. Accra.
[833] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agriculture database (FAOSTAT). [Online]. Available: http://www.fao.org/faostat/en/#data/QC. Accessed 25 February 2020.
[834] AgricInGhana Media 2019. Grains – Maize.
[835] Scheiterle L, Birner R. 2018. Assessment of Ghana's comparative advantage in maize production and the role of fertilizers. *Sustainability* 10: 2-3.
[836] AgricInGhana Media 2019. Grains – Maize.
[837] IndexMundi. 2019. Country statistics. [Online]. Available https://www.indexmundi.com. Accessed 25 February 2020.
[838] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agriculture database (FAOSTAT).
[839] Trading economics. 2020. Ghana - Producer Price For Sorghum (per Tonne, Current LCU).
[840] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.
[841] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agriculture database (FAOSTAT).
[842] Ibid.
[843] Ibid.
[844] Kleih U, Phillips D, Wordey MT, Komlaga G (eds). 2013. *Cassava market and value chain analysis: Ghana case study*. Natural Resources Institute, University of Greenwich & Food Research Institute, Ghana. Accra.
[845] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agriculture database (FAOSTAT).
[846] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agriculture database (FAOSTAT).
[847] Alidu MS. 2019. Evaluation of planting dates on growth and yield of three cowpea [*Vigna unguiculata* (L) Walp.] genotypes in northern Ghana. *Advances in Research* 18: 1-14.
[848]Esoko.2019 Food prices in Ghana – March 2019. [Online]. Available:https://esoko.com/food-prices-ghana-march-2019/.
[849] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agfriculture database (FAOSTAT).
[850] Martey E. 2019. Soil fertility management and economics of soybean in Ghana. DPhil, University of Illinois at Urbana-Champaign, Illinois.
[851] Dogbe W, Etwire PM, Martey E, Etwire JC, Baba IIY, Siise A. 2013. Economics of soybean production: Evidence from Saboba and Chereponi districts of Northern Region of Ghana. *Journal of Agricultural Science* 5: p38.
[852] Martey E. 2019. Soil fertility management and economics of soybean in Ghana. DPhil, University of Illinois at Urbana-Champaign, Illinois.

collection is a primary livelihood activity of many rural communities and employs men as well as women. At the national level, the shea industry benefits approximately two million low-income people — of whom ~95% belong to smallholder farming households — through business ventures that earn ~US$30 million annually in foreign exchange[853]. At the global level, Ghana has the potential to produce ~90% of the world's shea nuts[854]. Ghana's shea industry also has significant potential for growth, particularly given that shea butter is gradually becoming a substitute for cocoa butter in many products. As a result, growth on the shea industry is projected to compare favourably with the cocoa industry[855]. Further details on shea nut value chains and cost estimates are provided in Section 11.4.5.1.

Shea butter processing is one of the most important traditional enterprises and the primary source of income for most rural women in northern Ghana — thereby making shea manufacturing of significant socio-economic importance to local communities. More than 900,000 women in northern Ghana collect over 130,000 tons of dry nuts annually. A further 600,000 women in the region depend on incomes from the sales of shea butter and other shea-related products for their livelihoods. Shea butter is produced by women and women's groups throughout the year in almost every community in the northern regions of Ghana. Income from selling shea nuts and butter is typically controlled by women to spend as needed, for example, to purchase household goods or pay school fees. Profits from selling shea butter have also been found to account for at least 12% of smallholder household income, particularly at challenging times between the end of yearly food stores and before a new harvest.

Despite its importance in providing income to vulnerable women and rural households, the shea industry in its current form is not significantly contributing to sustainable poverty reduction, as picking of shea nuts has limited profitability potential. On average, shea nut pickers in Ghana are currently only able to pick ~2.5 bags per season, with a total value of ~GH¢112 (~US$22)[856]. Some other challenges to the shea industry include: i) uncontrolled pricing at both local and international levels; ii) inadequate information on the ecology and agronomy of the tree as a result of limited research; iii) bush burning; and iv) loss of shea trees through the cutting of the trees for charcoal. There is a need to improve knowledge on the ecology and agronomy of shea trees and control the negative effects of bush burning and shea tree cutting in order to improve the income-generating capacity of the industry for rural women and households.

To fully utilise the potential of shea butter processing as a means of poverty alleviation for rural women in Ghana, it is necessary to introduce technological inputs such as grinding mills, oil filters, toasters, dryers as well as specialised storage facilities. Various improved technologies have been developed and introduced into the shea butter processing industry. Among these are the development and introduction of simple machines such as crushers, kneaders (with boiling drums attached) and hydraulics for efficient extraction of shea butter. The government and non-governmental organisations have also embarked on extensive education campaigns to sensitise women in Ghana on the importance of the shea industry to the national economy. Despite the introduction of the improved technologies into the shea industry and large-scale sensitisation campaigns that have taken place, the level of adoption of the new technologies is still low[857]. This has been because although the improved technologies are locally produced, they are not affordable for women who do not have adequate financial support to purchase them[858]. There is, therefore, a need to avail the women with

[853] Sualihu A. 2019. The effects of sheabutter processing and marketing on incomes of rural women in the northern region of Ghana. MPhil Thesis, University For Development Studies, Accra.
[854] Alena H, Karel S, Joseph EE. 2014. Shea butter processing as an engine of poverty reduction in Northern Ghana: Case study of four communities in the Bolgatanga Municipality. *African Journal of Agricultural Research* 9: 3185-3190.
[855] Sualihu A. 2019. The effects of sheabutter processing and marketing on incomes of rural women in the northern region of Ghana. MPhil Thesis, University For Development Studies, Accra.
[856] Ibid.
[857] Ibid.
[858] Alena H, Karel S, Joseph EE. 2014. Shea butter processing as an engine of poverty reduction in Northern Ghana: Case study of four communities in the Bolgatanga Municipality. *African Journal of Agricultural Research* 9: 3185-3190.

financial support and increased access to credit and insurance. More details on interventions that could optimise financial returns from shea butter processing are provided in Section 11.4.5.1.

14.1.2 Maize

Maize is Ghana's most widely cultivated grain crop (accounting for ~55% of total grain production) and is the primary staple food in the country[859]. It is widely consumed throughout the country and is grown by most rural households. Furthermore, more than 20% of smallholder households (~1 million households) in Ghana gain their primary income from the production and sale of maize[860]. While the crop is grown in all regions of Ghana, there are scattered production hotspots — mostly in the southern regions of the country (Figure A4.1). In northern Ghana, ~81% of smallholder households grow maize for self-consumption, while ~29% regularly produce a surplus for sale in the market [861]. The average annual value of maize consumed per household in the region is ~GH₵360 (~US$67) while sales bring in ~GH₵437 (~US$81) per household[862].

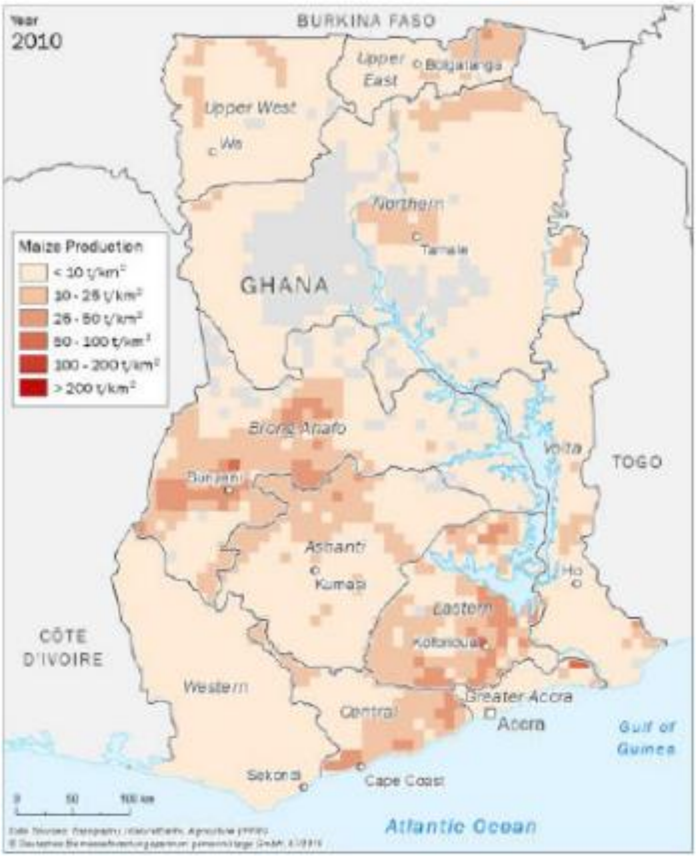

Figure A4,91. Maize production areas in Ghana[863].

Despite the importance of maize for national food security and smallholder farmer's livelihoods, maize yields in Ghana are low, making the production of the crop insufficient for meeting national demand[864].

[859] Awunyo-Vitor D, Wongnaa CA, Aidoo R. 2016. Resource use efficiency among maize farmers in Ghana. *Agriculture & Food Security* 5: 28.
[860] Dery S, Omari R, Ampadu RA, Akinbamijo Y, Abiodun FO, Baumuller H, von Braun J, Debarry A, Gallant K, Getahun TD*, et al.* (eds). 2015. *Potentials and possibilities for German collaboration in agriculture*. Forum for Agricultural Research in Africa (FARA), Ghana Council for Scientific and Industrial Research & Center for Development Research. Accra.
[861] Bellon MR, Kotu BH, Azzarri C, Caracciolo F. 2020. To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development* 125: 104682.
[862] Ibid.
[863] *Kalcher J, Kornatz P, Pohl M, Krause T, Bellot F-F, Lenhart M (eds). 2019. Machbarkeitsstudie Biogas in Togo/Ghana (Phase 1). Deutshes Biomasseforschungszentrum (DBFZ).*
[864] Awunyo-Vitor D, Wongnaa CA, Aidoo R. 2016. Resource use efficiency among maize farmers in Ghana. *Agriculture & Food Security* 5: 28.

The average maize yield for smallholder farmers (1.12 tons ha^{-1})[865] is relatively lower than the estimated potential yield of 6.0 t/ha for Ghana[866]. A recent study has shown that smallholder farmers in Ghana can increase the scale of their maize production and output by ~3% on average by increasing the use of production inputs such as fertilizer, herbicide and pesticide[867]. Limited access to capital and credit precludes farmers from acquiring adequate quantities of inputs such as fertilizer, labour, pesticides and herbicides. Moreover, poor provision of extension services prevents maize farmers in Ghana from using the production inputs efficiently. This is further compounded by the low number of farmers that are organised in farmer-based organisations (FBOs) which are typically used to disseminate information on good agricultural practices.

Incentives and strategies aimed at encouraging smallholder farmers to use more fertilizer, herbicides, pesticides, labour and manure are recommended for increasing the yields for maize in Ghana[868,869]. Such incentives and strategies could take the form of better management by the government of the current fertilizer subsidy programme and efficient input distribution through FBOs to ensure easy access by farmers. In addition, extension officers should encourage maize farmers to join established FBOs by presenting to the farmers the benefits of joining such organizations. In places where there are no established FBOs, extension officers should assist maize farmers to collaborate and form these organizations. This is because information on agricultural technologies and the correct usage of maize production inputs (i.e. fertilizer, herbicides, pesticides, etc) is normally disseminated through farmer organisations, and therefore, farmers who belong to these organisations will more likely have knowledge of suggested technologies and appropriate usage of production inputs than those who are not members of farmer organisations[870]. Financial institutions such as the Agricultural Development Bank should also promote and facilitate the easier acquisition of loans by farmers. Acquired loans will be used to purchase the required production inputs. Farmers, especially those in FBOs, are also encouraged to form their own informal credit schemes with which they can help one another.

Data from recent research show that only 20% of farmers in northern Ghana use improved seeds[871]. Five seed varieties are used in the region, including: i) Obaatanpa — a local open-pollinated variety (OPV) seed that is most commonly used by farmers in the region; ii) Adikanfo — a foreign hybrid variety; iii) Sika-Aburo — another foreign hybrid variety; iv) Mamaba — a local hybrid variety; and v) Sanzal-sima — a local OPV used less commonly than Obaatanpa The Obaatanpa seed variety yields an average of ~3.2 tons/ha[872]. A recent study has shown that the two foreign hybrids, Adikanfo and Sika-Aburo, have higher yields than Obaatanpa. Adikanfo had the highest mean yields (2.5 tons per hectare), which were 57% higher than Obaatanpa's, and 27% higher than Sika-Aburo's[873]. A profitability analysis has shown that despite their higher cost, on average the foreign hybrids Adikanfo and Sika Aburo are more profitable per hectare than other varieties[874]. Adikanfo had the highest mean profits, which were 16% higher than Sika Aburo's and 37% higher than Obaatanpa's. The mean profits from using Obaatanpa exceeded both those of Mamaba and Sanzal-sima[875]. These results suggest that the adoption of improved seeds has the potential to markedly increase maize yields and profits in Ghana.

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865 Martey E. 2019. Soil fertility management and economics of soybean in Ghana. DPhil, University of Illinois at Urbana-Champaign, Illinois.
866 Awunyo-Vitor D, Wongnaa CA, Aidoo R. 2016. Resource use efficiency among maize farmers in Ghana. *Agriculture & Food Security* 5: 28.
867 Ibid.
868 This recommendation pertains to the responsible use of environmentally friendly herbicides and pesticides not harmful ones.
869 Awunyo-Vitor D, Wongnaa CA, Aidoo R. 2016. Resource use efficiency among maize farmers in Ghana. *Agriculture & Food Security* 5: 28.
870 Awunyo-Vitor D, Wongnaa CA, Aidoo R. 2016. Resource use efficiency among maize farmers in Ghana. *Agriculture & Food Security* 5: 28.
871 Seeds that have been deliberately selected and developed for their beneficial properties — such as fast maturity, high yield, resistance to pests and diseases, etc.
872 Innovations for Poverty Action (IPA). 2020. Testing agricultural technologies for maize production in Ghana.
873 Ibid.
874 Innovations for Poverty Action (IPA). 2020. Testing agricultural technologies for maize production in Ghana.
875 Ibid.

Future climate change is projected to have an adverse impact on maize production in Ghana[876]. Current maize growing areas in the northern and central parts of the country are expected to experience decreasing suitability in the future as a result of shortened agricultural production periods due to shorter wet seasons (Figure A4.2). In terms of yield projections, climate change models predict a clear negative yield trend for maize under both RCP2.6 and RCP6.0[877]. As a best estimate, compared to the year 2000, yields for maize in Ghana are projected to decline by ~9 % by 2080 under RCP6.0, and by ~4% under RCP2.6[878]. Adaptation strategies such as irrigation or improved crop varieties are therefore needed in areas that are predicted to become marginal, as the changes in suitability are indicators of climate impacts[879].

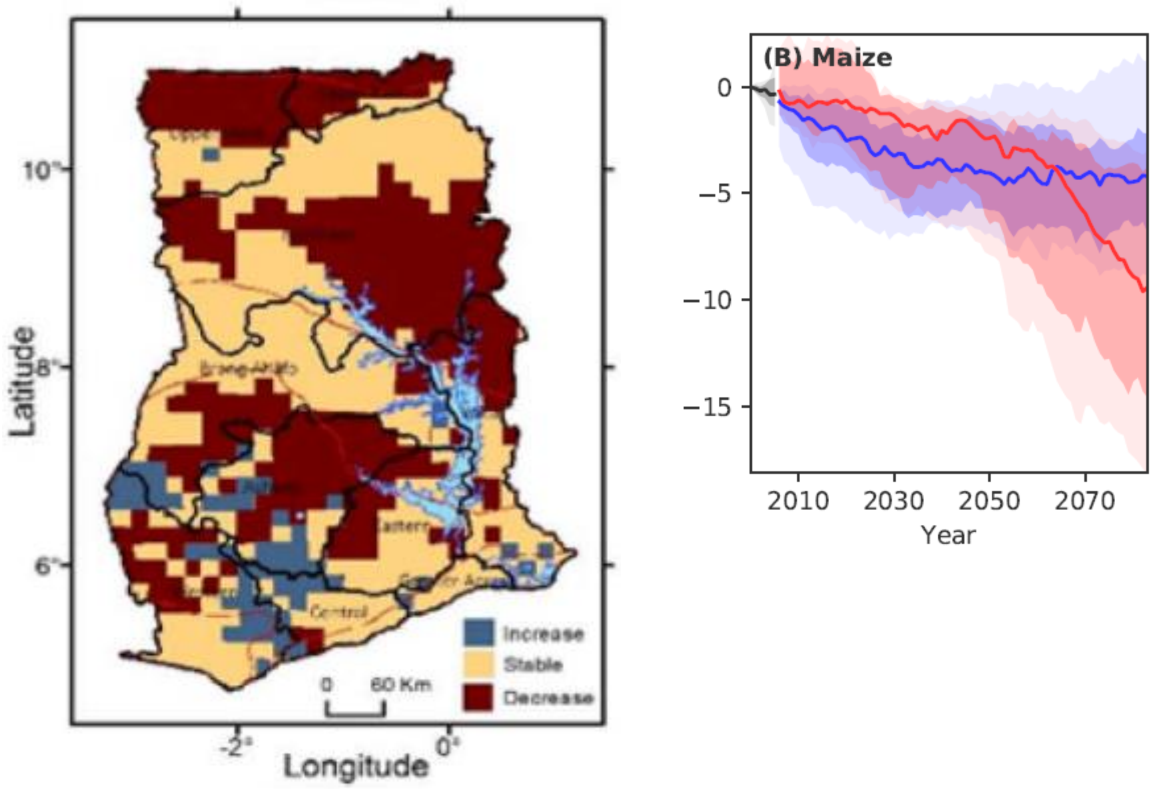

Figure A4.92. Projected change in maize crop suitability under RCP 8.5 (without-climate-policy) by 2050 as compared to current suitability and yields for different GHG emissions scenarios (RCP2.6 (blue) and RCP6.0 (red)) assuming constant land use and agricultural management relative to the year 2000[880,881].

14.1.3 Sorghum

Sorghum is a commodity with high market demand in Ghana, a result of its many uses as a food and beverage[882]. Smallholder farmers in Ghana mainly use sorghum for food — consuming it raw or frying it before eating. Other uses for sorghum include the brewing of alcoholic products, such as a traditional beer called 'pito', non-alcoholic beverages and in the making of dumplings, couscous,

[876] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[877] Ibid.
[878] Ibid.
[879] *Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020a. Climate risk analysis for identifying and weighing adaptation strategies in Ghana's agricultural sector - Executive Summary. Federal Ministry for Economic Cooperation and Development & Ghanaian Ministry of Food and Agriculture (MoFA) Accra.*
[880] *Ibid.*
[881] *Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. Climate risk profile: Ghana. Federal Ministry for Economic Cooperation and Development.*
[882] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.

bread, pancakes, porridges and gruels. Sorghum is mainly grown in the northern parts of Ghana as the southern regions are largely unsuitable for its cultivation[883].

Farmers in Ghana grow a number of sorghum varieties that include[884]:

- **Sweet sorghum** (*Saccharatun*): This variety of sorghum is tall and leafy with a richness of sweet juice in its pith. The stem is often chewed as sugarcane because of this and it can be used as a source of syrup. It has also been used as silage for stock.
- **Broom sorghum** (*Techaicum*): These sorghum plants have a very dry stem and have long and open inflorescence, which are used as brooms.
- **Fodder sorghum**: These are usually grown for forage or for silage, for feeding farm animals.
- **Grain sorghum**: Grain sorghum differs from sweet sorghum because it tends to be stocky and have dried piths which may be slightly juicy. Grain sorghum is mainly used for preparing food (tuo zaafi, koko and masa)[885,886].

Typically, smallholder farmers in Ghana store a percentage of their sorghum harvest for home or family consumption and sell the remainder in the market for extra income. In northern Ghana, ~10% of smallholder farming households cultivate sorghum while ~3.1% regularly produce a surplus for sale in the market[887]. In some regions of northern Ghana such as Navrongo, up to 70% of sorghum growing farmers produce a surplus for sale in the market[888]. The average annual value of sorghum consumed per household in the region is ~GH₵135 (~US$25) while sales bring in an average of ~GH₵324 (~US$60) per household[889]. Smallholder farmers in northern Ghana sell their sorghum produce at an average of GH₵156 (~US$29) per 100 kg[890]. However, the price of sorghum is positively skewed — meaning the price of a bag could be as high as GH₵600 (~US$111) depending on the year, type of market and the level of demand[891].

The potential yield of sorghum in Ghana is reported to be as high as 15 t/ha[892]. However, realised sorghum crop yields across the country are under 1.5 t/ha[893]. The low yields are a result of the use of traditional, outdated farming and management activities that are characterised by low or no farm inputs and the absence of improved planting varieties. The cultivation of indigenous varieties with inherent low yield potential as well as scarce fertilizer use and the low plant densities in the traditional mixed cropping systems has negatively affected yields — especially in northern Ghana[894]. Yields in northern Ghana vary from 0.5-0.9 t/ha in the Northern Region, and 0.7-1 t/ha in the Upper East and Upper West regions[895]. As a result of the low yields, most smallholder farmers in northern Ghana are unable to generate surplus sorghum for sale in markets[896]. There is, therefore, scope for improving sorghum yields in northern Ghana by introducing improved sorghum varieties and promoting good farming practices.

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[883] *Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020a. Climate risk analysis for identifying and weighing adaptation strategies in Ghana's agricultural sector - Executive Summary. Federal Ministry for Economic Cooperation and Development & Ghanaian Ministry of Food and Agriculture (MoFA) Accra.*
[884] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.
[885] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.
[886] Angelucci F (ed). 2013 *Analysis of incentives and disincentives for sorghum in Ghana*. MAFAP& FAO. Rome.
[887] Bellon MR, Kotu BH, Azzarri C, Caracciolo F. 2020. To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development* 125: 104682.
[888] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.
[889] Bellon MR, Kotu BH, Azzarri C, Caracciolo F. 2020. To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development* 125: 104682.
[890] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.
[891] Ibid.
[892] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.
[893] Ibid.
[894] Angelucci F (ed). 2013 *Analysis of incentives and disincentives for sorghum in Ghana*. MAFAP& FAO. Rome.
[895] Ibid.
[896] Oppong-Sekyere D, Asumboya G, Yintii B. 2018. Sorghum production practices: A case study of four districts in Navrongo, Ghana. *Journal of Basic and Applied Scientific Research* 8: 1-15.

Climate change is not expected to affect the yields and production of sorghum in northern Ghana in the medium term (Figure A4.3). Some areas in the south, however, are projected to become less suitable for growing sorghum. The crop, therefore, has a high potential for further cultivation in northern Ghana, even under climate change[897].

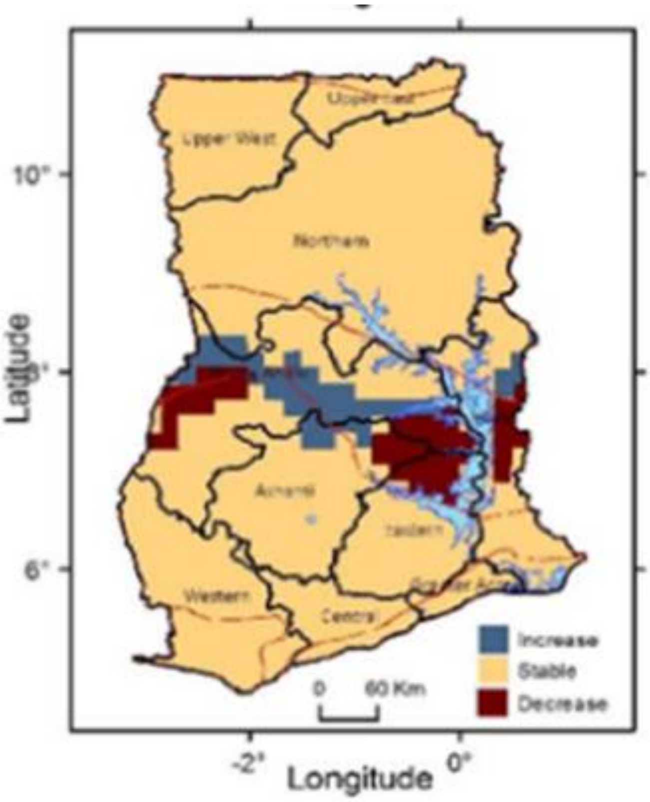

Figure A4.93*. Projected change in sorghum crop suitability under RCP8.5 (without-climate-policy) by 2050 as compared to current suitability[898].*

14.1.4 Cassava

Cassava is one of Ghana's main staple crops and constitutes ~22% of agricultural Gross Domestic Product[899], making it the most important root and tuber produced in the country[900]. In terms of area harvested, cassava is the second-most extensively cultivated food crop in Ghana, after maize[901] — with approximately 1 million ha of cassava being harvested in 2018[902]. Cassava production is primarily concentrated in the southern parts of Ghana — especially the Eastern, Ashanti and Brong Ahafo regions (Figure A4.4). Production hot spots additionally occur in the Volta and Central regions as well as in the north-eastern parts of the Northern Region (Figure A4.4).

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[897] *Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020a. Climate risk analysis for identifying and weighing adaptation strategies in Ghana's agricultural sector - Executive Summary. Federal Ministry for Economic Cooperation and Development & Ghanaian Ministry of Food and Agriculture (MoFA) Accra.*
[898] *Ibid.*
[899] Dery S, Omari R, Ampadu RA, Akinbamijo Y, Abiodun FO, Baumuller H, von Braun J, Debarry A, Gallant K, Getahun TD, *et al.* (eds). 2015. *Potentials and possibilities for German collaboration in agriculture*. Forum for Agricultural Research in Africa (FARA), Ghana Council for Scientific and Industrial Research & Center for Development Research. Accra.
[900] Sahel Capital Partners and Advisory LTD (ed). 2014. *Yam improvement for processing (YIP) Ghana*. Bill & Melinda Gates Foundation. Accra.
[901] Dery S, Omari R, Ampadu RA, Akinbamijo Y, Abiodun FO, Baumuller H, von Braun J, Debarry A, Gallant K, Getahun TD, *et al.* (eds). 2015. *Potentials and possibilities for German collaboration in agriculture*. Forum for Agricultural Research in Africa (FARA), Ghana Council for Scientific and Industrial Research & Center for Development Research. Accra.
[902] Food and Agriculture Organisation of the United Nations (FAO). 2019. Food and Agfriculture database (FAOSTAT). [Online]. Available: http://www.fao.org/faostat/en/#data/QC. Accessed 25 February 2020.

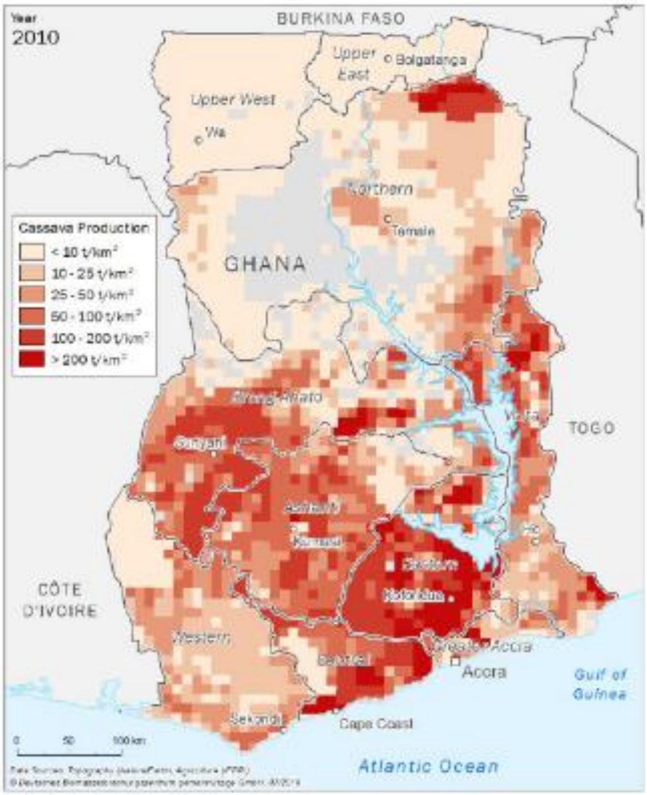

Figure A4.94**.** Cassava production areas in Ghana[903].

In general, smallholder farmers in Ghana store a percentage of their cassava harvest for home or family consumption and sell the surplus in the market for extra income. In northern Ghana, ~2.5% of smallholder households cultivate cassava while ~1.3% regularly produce a surplus for sale in the market[904]. The average annual value of cassava consumed per household in the region is ~GH₵315 (~US$58) while sales bring in ~GH₵303 (~US$56) on average per household[905]. Although the cassava value chain in Ghana is still in its infancy, emerging growth opportunities exist for the production and sale of cassava-derived products[906]. The most common cassava-derived products in Ghana include: i) gari; ii) starch; iii) dried chips for export; and iv) cassava flour for the preparation of local food, such as kokonte or bread.

Cassava yields in Ghana are low (17 t/ha) and well below attainable levels (29t/ha)[907]. This yield gap highlights the potential for smallholders farmers to increase cassava yields by adopting better farming practices[908] — for example, by switching to improved, high-yielding varieties[909]. Ten improved cassava varieties have been released and disseminated by the Council for Scientific and Industrial Research's Crops Research Institute (CSIR-CRI) since 1993[910]. The key attributes of these varieties are their resistance and tolerance to the Cassava Mosaic Disease, with their most suitable ecologies

[903] *Kalcher J, Kornatz P, Pohl M, Krause T, Bellot F-F, Lenhart M (eds). 2019. Machbarkeitsstudie Biogas in Togo/Ghana (Phase 1). Deutshes Biomasseforschungszentrum (DBFZ).*
[904] Bellon MR, Kotu BH, Azzarri C, Caracciolo F. 2020. To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development* 125: 104682.
[905] Ibid.
[906] Dery S, Omari R, Ampadu RA, Akinbamijo Y, Abiodun FO, Baumuller H, von Braun J, Debarry A, Gallant K, Getahun TD*, et al.* (eds). 2015. *Potentials and possibilities for German collaboration in agriculture*. Forum for Agricultural Research in Africa (FARA), Ghana Council for Scientific and Industrial Research & Center for Development Research. Accra.
[907] Aidoo R, Agbenorhevi JK, Wireko-Manu FD, Wangel A (eds). 2019. *Root and tuber crops in Ghana: Overview and selected research papers* Accra: KNUST Printing Press.
[908] Ibid.
[909] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[910] Dery S, Omari R, Ampadu RA, Akinbamijo Y, Abiodun FO, Baumuller H, von Braun J, Debarry A, Gallant K, Getahun TD*, et al.* (eds). 2015. *Potentials and possibilities for German collaboration in agriculture*. Forum for Agricultural Research in Africa (FARA), Ghana Council for Scientific and Industrial Research & Center for Development Research. Accra.

being Forest, Forest Savannah and Coastal Savannah ecological zones. The adoption of improved cassava varieties should, however, be carefully weighed against potential adverse outcomes, such as the resulting decline of agro-biodiversity and loss of local crop types[911].

Another major problem with cassava is its poor storability after harvest[912]. Once the cassava root is unearthed, it has an approximate shelf life of two days without treatment. Ghana has the highest post-harvest losses in the world for cassava of ~21%, attributable to low-value addition at the farm gate, as most harvested cassava tubers reach consumers in their raw state[913]. Furthermore, insufficient access to regional, national and international markets — which results in the limited markets available to the farmers becoming oversaturated resulting in supply outweighing demand — lead to localised low prices of cassava and its derived products[914]. A 50–300% increase in income for cassava farmers may be realised when their products are integrated by new market channels to regional, national and international markets[915]. Additionally, expansion of market channel access may also lead to yield improvement through the increased use of agro-inputs, as well as reducing post-harvest losses.

Future cassava production in Ghana is predicted to be largely unaffected by climate change, except for a few areas (Figure A4.5). In fact, cassava yields are projected to increase significantly in the future as a result of climate change — for example, cassava yield in 2080 is expected to have increased by ~33% relative to that of 2000, under RCP6.0[916], being caused in part by the effects of carbon dioxide fertilisation[917,918]. Cassava is a C3 plant[919], which means that it is able to physiologically benefit from carbon dioxide fertilisation under higher concentration pathways[920]. In addition, cassava is also tolerant of both low and high rainfall extremes[921].

[911] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[912] Aidoo R, Agbenorhevi JK, Wireko-Manu FD, Wangel A (eds). 2019. *Root and tuber crops in Ghana: Overview and selected research papers* Accra: KNUST Printing Press.
[913] Ibid.
[914] Aidoo R, Agbenorhevi JK, Wireko-Manu FD, Wangel A (eds). 2019. *Root and tuber crops in Ghana: Overview and selected research papers* Accra: KNUST Printing Press.
[915] Ibid.
[916] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[917] The carbon dioxide fertilization t effect is the increased rate of photosynthesis in plants that results from increased levels of carbon dioxide (in the atmosphere. The effect varies depending on the plant species, the temperature, and the availability of water and nutrients.
[918] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[919] C3 carbon fixation is the most common of three metabolic pathways for carbon fixation in photosynthesis, along with C4 and CAM. This process converts carbon dioxide and ribulose bisphosphate (RuBP, a 5-carbon sugar) into two molecules of 3-phosphoglycerate. Plants that survive solely on C3 fixation (C3 plants) tend to thrive in areas where sunlight intensity is moderate, temperatures are moderate, carbon dioxide concentrations are around 200 ppm or higher, and groundwater is plentiful. The C3 plants, originating during Mesozoic and Palaeozoic eras, predate the C4 plants and still represent ~95% of Earth's plant biomass, including important food crops such as rice, wheat, soybeans and barley.
[920] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[921] Ibid.

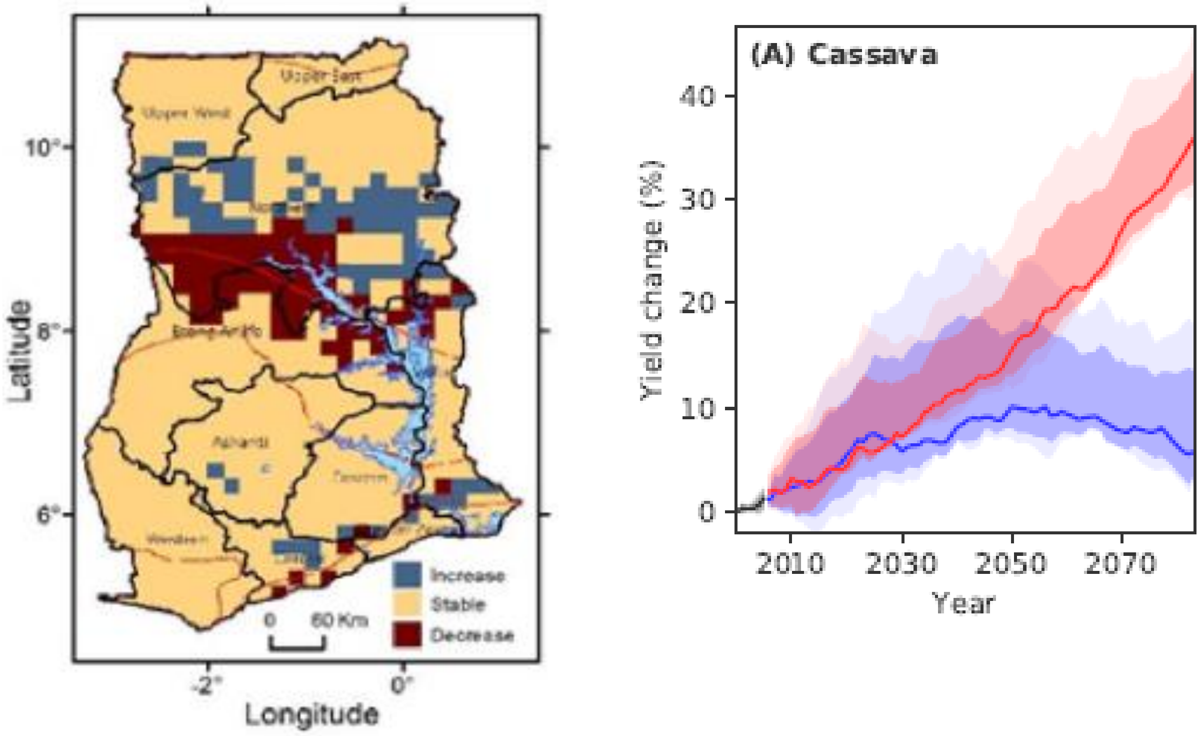

***Figure A4.95**. Projected change in cassava crop suitability under RCP8.5 (without-climate-policy) by 2050, as compared to current suitability and yields for different GHG emissions scenarios (RCP2.6 (blue) and RCP6.0 (red)), assuming constant land use and agricultural management relative to the year 2000[922,923].*

14.1.5 Cowpea

Cowpea (*Vigna unguiculata* L. Walp) is an important cash crop for smallholder farmers in Ghana and a vital source of income[924]. The crop is one of the few in the country that can be profitably produced by smallholder farmers under arid conditions and resource constraints[925,926]. Cowpea is widely consumed in Ghana with an estimated 9 kg consumed per person per year[927]. Mostly cowpea is produced by smallholder farmers, often as an intercrop with maize or millet[928] and is grown across Ghana — however, the areas of greatest production are in the northern regions[929].

Smallholder farmers in Ghana typically store a percentage of their cowpea produce after harvest for home or family consumption and sell the remainder in the market. In northern Ghana, ~4% of smallholder households grow cowpea while ~2.5% of households regularly produce a surplus for sale in the market[930]. The average annual value of cowpea consumed per household in the region is ~GH₵9 (US$2) and sales bring in an average of ~GH₵1,231 (US$228) per household[931]. The

[922] *Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020a. Climate risk analysis for identifying and weighing adaptation strategies in Ghana's agricultural sector - Executive Summary. Federal Ministry for Economic Cooperation and Development & Ghanaian Ministry of Food and Agriculture (MoFA) Accra.*
[923] *Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. Climate risk profile: Ghana. Federal Ministry for Economic Cooperation and Development.*
[924] Ira AH, Zhenyu J, Francis K. 2019. Market preferences for cowpea (*Vigna unguiculata* [L.] Walp) dry grain in Ghana. *African Journal of Agricultural Research* 14: 928-934.
[925] Khalid AM, Ayamga M, Dans-Abbeam G. 2019. Assessing the productive efficiency among smallholder cowpea farmers in northern Ghana. *UDS International Journal of Development* 6: 44-61.
[926] Mensah TA, Tagoe SMA, Asare AT, Agyirifo DS. 2018. Screening of cowpea (*Vigna unguiculata* L. Walp) genotypes for rust (*Uromyces phaseoli* var. *vignae*) resistance in Ghana. *Plant* 6: 67-74.
[927] Ibid.
[928] Ira AH, Zhenyu J, Francis K. 2019. Market preferences for cowpea (*Vigna unguiculata* [L.] Walp) dry grain in Ghana. *African Journal of Agricultural Research* 14: 928-934.
[929] Ibid.
[930] Bellon MR, Kotu BH, Azzarri C, Caracciolo F. 2020. To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development* 125: 104682.
[931] Ibid.

production of marketable surplus is geographically concentrated in northern Ghana and accounts for ~90% of the total production[932]. The demand for cowpea is higher than the supply in Ghana[933]. To date, Ghana remains a net consumer and importer of cowpea[934].

Cowpea yields in Ghana are among the lowest in the world — ranging between ~0.4 and 1.3 t/ha against a potential of 2.6 t/ha[935,936,937]. The low yields of cowpea in Ghana are caused mostly by field pests and weeds[938]. The black cowpea aphid (*Aphis craccivora*), the cowpea flower thrips (*Megalurothrips sjostedti*), the legume pod borer (*Maruca vitrata*) and a variety of pod- and seed-sucking bugs, including *Anaplocnemis curvipes*, are among the most yield-limiting field insect pest species that infest cowpea in northern Ghana[939]. These pests limit cowpea productivity by attacking the plant — including injecting toxins that stunt growth or actively kill cowpea plants, feeding on flower buds and flowers, and sucking on and boring into pods. These attacks cause considerable damage to crops, resulting in low yield and reduced economic losses. Low yields in cowpea are also caused by pathogenic diseases, predominantly rust disease — with infections caused by *Uromyces phaseoli* var. *vignae* being the most severe and damaging[940]. Another cause of low cowpea yields in Ghana is the parasitic plant Striga (*Striga hermonthica*), which not only makes agricultural lands less fertile, by mining soil nutrients but also strangles the roots of cowpea plants — leading to crop mortality and reduction in yields[941].

Smallholder farmers in Ghana use a variety of commercial and traditional methods to control cowpea pests, many of which have limited overall value because of constraints surrounding cost, labour and potential toxicity[942]. For instance, insecticides can be used to control cowpea weevils, but the majority of farmers and traders lack the necessary capital to purchase insecticides or the technical capacity to apply them correctly, which can result in health and environmental issues. A recent study, however, has shown that yield loss because of insect pest infestations can be reduced by 20 and 15% through the use of spring onion extract concentrations of 20 and 15% weight per volume, respectively[943]. Spring onion extracts, therefore, could provide affordable and effective substitutes for synthetic cowpea insecticides — with the additional option of integration with synthetic insecticide application programmes[944]. For cowpea rust disease specifically, the use of rust-resistant cultivars is the most effective method of control, and, of subsequently increasing yields. Additionally, it also serves as an environmentally safe and cost-effective disease management technique[945].

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[932] Mensah TA, Tagoe SMA, Asare AT, Agyirifo DS. 2018. Screening of cowpea (*Vigna unguiculata* L. Walp) genotypes for rust (*Uromyces phaseoli* var. *vignae*) resistance in Ghana. *Plant* 6: 67-74.
[933] Ibid.
[934] Ibid.
[935] Khalid AM, Ayamga M, Dans-Abbeam G. 2019. Assessing the productive efficiency among smallholder cowpea farmers in northern Ghana. *UDS International Journal of Development* 6: 44-61.
[936] Mensah TA, Tagoe SMA, Asare AT, Agyirifo DS. 2018. Screening of cowpea (*Vigna unguiculata* L. Walp) genotypes for rust (*Uromyces phaseoli* var. *vignae*) resistance in Ghana. *Plant* 6: 67-74.
[937] Alidu MS. 2019. Evaluation of planting dates on growth and yield of three cowpea [*Vigna unguiculata* (L) Walp.] genotypes in northern Ghana. *Advances in Research* 18: 1-14.
[938] Salifu B, Atongi AA, Yeboah S. 2019. Efficacy of spring onion (*Allium fistulosum*) leaf extract for controlling major field insect pests of cowpea (*Vigna unguiculata* L.) in the Guinea savannah agroecological zone of Ghana. *Journal of Entomology and Zoology Studies* 7: 730-733.
[939] Ibid.
[940] Mensah TA, Tagoe SMA, Asare AT, Agyirifo DS. 2018. Screening of cowpea (*Vigna unguiculata* L. Walp) genotypes for rust (*Uromyces phaseoli* var. *vignae*) resistance in Ghana. *Plant* 6: 67-74.
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[943] Salifu B, Atongi AA, Yeboah S. 2019. Efficacy of spring onion (*Allium fistulosum*) leaf extract for controlling major field insect pests of cowpea (*Vigna unguiculata* L.) in the Guinea savannah agroecological zone of Ghana. *Journal of Entomology and Zoology Studies* 7: 730-733.
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[945] Mensah TA, Tagoe SMA, Asare AT, Agyirifo DS. 2018. Screening of cowpea (*Vigna unguiculata* L. Walp) genotypes for rust (*Uromyces phaseoli* var. *vignae*) resistance in Ghana. *Plant* 6: 67-74.

Another major cowpea pest is the weevil *Callosobruchus maculates*, a post-harvest pest that infests stored grains and bores holes in the seeds[946]. Damage from *C. maculatus* can cause 100% grain loss under poor storage conditions[947]. Fungal diseases growing on or in stored cowpea also cause a variety of issues, which include poor germination, discolouration, mustiness and a change in taste[948]. A large number of smallholder farmers in Ghana do not have access to adequate storage methods for their cowpea harvests which may result in high levels of infestation and lower-quality seeds. Additionally, consumers prefer cowpea seeds with lower levels of damage and expect discounted prices for damaged seeds, reducing the farmer's sale price. This problem is often exacerbated because without proper storage, as soon as they are harvested, the damage to cowpea seeds increases with time.[949] Smallholder farmers are therefore forced to sell their cowpea at low, harvest-time prices rather than risk losses caused by weevil infestation and fungal infection during storage. There is, therefore, a need for the introduction and promotion of effective and efficient cowpea storage practices that are affordable and environmentally friendly.[950]

A potential solution to the problem of inadequate cowpea post-harvest storage is the recently developed Purdue Improved Cowpea Storage (PICS) technology. The PICS technology involves the storage of seeds in a triple bag consisting of an exterior woven bag with two inner airtight hermetic bags. The airtight condition created by the two inner hermetic bags suppresses the growth and development of weevils. It has been shown to be a very cost-effective and safe method of storage, with 100% seed recovery and the absence of chemicals harmful to human health.[951]

Additionally, the use of cowpea cultivars with more valuable characteristics by smallholder farmers could lead to an increase in yield and income. Three advanced cowpea breeding lines have been developed by the cowpea improvement programme of the Savanna Agricultural Research Institute (SARI):

- **Songotra,** meaning "no striga" in Kasim, is resistant to Striga and exhibits early maturation and is suitable for intercropping. Its yield potential is 2 t/ha and is broadly adopted in Ghana — though it is particularly recommended for the Sudan savanna zone.
- **Padi-tuya** is a large plant with white seeds. It is medium-maturing (65–70 days) and takes a shorter time to cook. It has a yield potential of 2.4 t/ha and is widely cultivated in the whole of northern Ghana
- The **Striga/aphids cross (T2T4)** is still under development and it is at the F7 generation stage and earmarked for release.

A recent study has demonstrated that, of the three cultivars, the Padi-tuya cultivar has the highest mean grain yield, followed by T2T4 and Songotra. The advantage of the Padi-tuya cultivar arises from its ability to recover quickly from drought during the growing season and, as a result, produce higher yields.[952]

Climate change is expected to positively affect cowpea production in Ghana with yields for field peas (including cowpea) projected to increase considerably in the future. For example, field pea yield in 2080 is expected to have increased by ~14% relative to that of 2000, under RCP6.0 (Figure A4.6). As is expected with cassava, the increase in cowpea yield will be caused in part by the effects of

[946] Ira AH, Zhenyu J, Francis K. 2019. Market preferences for cowpea (*Vigna unguiculata* [L.] Walp) dry grain in Ghana. *African Journal of Agricultural Research* 14: 928-934.
[947] Abudulai M, Etwire PM, Wiredu AN, Baributsa D, Lowenberg-DeBoer J. 2017. Cowpea storage practices and factors that influence choice in Ghana. *African Journal of Crop Science* 5: 1-9.
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[949] Ira AH, Zhenyu J, Francis K. 2019. Market preferences for cowpea (*Vigna unguiculata* [L.] Walp) dry grain in Ghana. *African Journal of Agricultural Research* 14: 928-934.
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[952] Ira AH, Zhenyu J, Francis K. 2019. Market preferences for cowpea (*Vigna unguiculata* [L.] Walp) dry grain in Ghana. *African Journal of Agricultural Research* 14: 928-934.

carbon dioxide fertilisation[953,954]. Cowpea, like cassava, is a C3 plant[955] and, resultantly, is able to physiologically benefit from increased carbon dioxide fertilisation under higher concentration pathways[956].

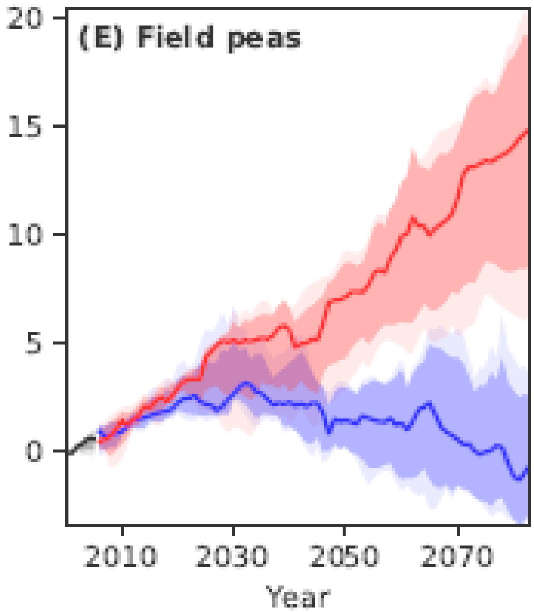

Figure A4.96. *Field pea* (including cowpea) *yields for different GHG emissions scenarios (RCP2.6 (blue) and RCP6.0 (red)) assuming constant land use and agricultural management, relative to the year 2000*[957].

14.1.6 Soybean

Soybean is a relatively new crop in Ghana (introduced in 1910) that is cultivated mostly by smallholder farmers with less than 0.8 ha, under rain-fed conditions[958,959]. Soybean is considered a priority cash crop in Ghana and has been included as a focus crop in the national strategy 'Planting for Food and Jobs' [960,961]. As well as being a cash crop, it has important implications for vulnerable and marginalised groups, as women dominate its cultivation and commercialisation[962]. In northern Ghana, ~12% of smallholder households grow soybean — both for self-consumption and sale[963] — with cultivation

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[953] The carbon dioxide fertilization t effect is the increased rate of photosynthesis in plants that results from increased levels of carbon dioxide (in the atmosphere. The effect varies depending on the plant species, the temperature, and the availability of water and nutrients.
[954] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
[955] C3 carbon fixation is the most common of three metabolic pathways for carbon fixation in photosynthesis, along with C4 and CAM. This process converts carbon dioxide and ribulose bisphosphate (RuBP, a 5-carbon sugar) into two molecules of 3-phosphoglycerate. Plants that survive solely on C3 fixation (C3 plants) tend to thrive in areas where sunlight intensity is moderate, temperatures are moderate, carbon dioxide concentrations are around 200 ppm or higher, and groundwater is plentiful. The C3 plants, originating during Mesozoic and Palaeozoic eras, predate the C4 plants and still represent ~95% of Earth's plant biomass, including important food crops such as rice, wheat, soybeans and barley.
[956] Potsdam Institute for Climate Impact Research, Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ) (eds). 2020b. *Climate risk profile: Ghana*. Federal Ministry for Economic Cooperation and Development.
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[958] Martey E. 2019. Soil fertility management and economics of soybean in Ghana. DPhil, University of Illinois at Urbana-Champaign, Illinois.
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[960] Martey E. 2019. Soil fertility management and economics of soybean in Ghana. DPhil, University of Illinois at Urbana-Champaign, Illinois.
[961] University of Greenwich Natural Resources Institute (ed). 2020. *SAIRLA Story of Change: CABI GALA Ghana – How closing information gaps in the soybean value chain has informed investment and policy decisions in farmers, the private sector and government*. UKAID. London.
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most commonly for market sale. The average annual value of soybean consumed per household in the region is ~GH₵28 (~US$5) while sales bring in an average ~GH₵448 (~US$83) per household[964].

Three broad categories of traders characterise the soybean market in northern Ghana — wholesalers, processors and retailers. Wholesalers are mostly individuals or organisations who buy large quantities of soybean from different sources to either resell to processing firms or regional markets. Processors are individuals or private firms who buy soybean from wholesalers or directly from farmers. Retailers are traders (largely women) who engage in a smaller volume of soybean trade and sell directly to end-users. These retailers are local residents in farming communities who buy soybean at the farm gate and engage in smaller volumes of trade in the local markets. The market prices of quality soybean vary between ~GH₵170–230 (US$34-43) per 100 kg bag, depending on the variety. For example, the market price for the 'Jenguma' variety is ~GH₵170 (~US$32), ~GH₵200 (~US$37) for the 'Selintua I' variety and ~GH₵230 for the 'Salintua II' variety, per bag. On average the expected market price for quality soybean is ~GH₵200 (US$37) per bag, with the poultry industry being a major market for their sale.[965]

Soybean has been demonstrated to grow at yields of up to 4.5 t/ha under the best commercial agricultural practices in Ghana[966]. However, the realised yields and productivity of soybean in Ghana is low[967], with the average yield being ~1.2 t/ha[968]. Soybean yields for smallholder farmers under rainfed conditions average ~0.8 t/ha across the country[969], and average yields under rainfed conditions, drop to ~0.5 t/ha in the more arid areas of northern Ghana[970]. As a result of these low yields, imports are required to meet domestic demand for soybean in Ghana[971].

Low soybean yields and productivity in Ghana is linked to: i) inefficient agricultural practices of farmers; ii) low soil fertility; and iii) inadequate use of production inputs such as certified seeds, rhizobium inoculant and phosphorus fertiliser[972]. Smallholder farmers' limited use of inputs is partly because of a lack of access through agro-dealerships — farmers are not able to find the inputs they need and agro-dealers are not stocking inputs because of a lack of information regarding demand[973]. Very few smallholder farmers use rhizobia inoculants to promote nitrogen fixation, and other improved agricultural technologies like fertilisers, pesticides and good management practices (such as row planting, appropriate seed and row spacing and plant population)[974]. Recent studies have shown that yields in northern Ghana, of commercial soybean varieties, double when using improved agricultural management strategies and inputs (i.e. a high-input/high-output production scenario)[975]. For

[964] Ibid.
[965] Martey E. 2019. Soil fertility management and economics of soybean in Ghana. DPhil, University of Illinois at Urbana-Champaign, Illinois.
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[975] Ibid.

example, crop rotation of inoculated soya with other crops, such as maize, has been shown to considerably improve fertility on fields with multiple crops per year[976].

The adoption of no-tillage has also been shown to significantly increase soybean yields and production in northern Ghana. The increase in soybean yield with no-tillage is mostly due to the improved weed control and water conservation compared with conventional tillage. Significant soil water is lost as a result of ploughing during tillage and smallholder farmers in northern Ghana weed only once when practising no-tillage compared to twice with conventional tillage. Labour is scarce and costly during major weeding times in northern Ghana, which results in late and inadequate weed control. Furthermore, the adoption of no-tillage for soybean production is also more cost-effective than the application of conventional tillage. The input cost of conventional soybean tillage system in northern Ghana is — on average — US$58-73 more than for the no-tillage system. In order to enhance the benefits of no-tillage, there is a need for widespread adoption of better soil management practices — such as the use of cover crops to sustain soil cover — by smallholder farmers. To this end, extension officers should conduct and effectively use demonstrations to inform farmers of the benefits of integrated soil management practices[977].

In addition to the adoption of no-tillage, increased fertilizer application has also been shown to increase soybean yields — regardless of tillage system — in northern Ghana. Averaging over tillage systems, fertilizer application has been shown to result in increases in soybean yield of between 60-66%[978]. However, smallholder farmers should be cautious with fertilizer input, as the marginal rate of return is not always positive even when yields are increased[979]. This is particularly important during drier years. In order to reduce the risk associated with fertilizer use under erratic rainfall conditions, options such as no-tillage and integrated use of organic and mineral sources of plant nutrients in response to soil moisture conditions may be beneficial.

Information on the impact of climate change on future soybean yields and production in Ghana is not readily available. However, crop models have predicted that soybean yields and production in Sub-Saharan Africa will decrease by ~20 kg/ha/year and ~0.02 million tons/year as a result of climate change[980]. Soybean yields are however projected to increase gradually with temperature before sharply decreasing as temperatures rise above 30^{o}C[981]. As with the case for maize, there is a need to adopt adaptation strategies such as irrigation or improved crop varieties in order to increase the resilience of soybean cultivation in Ghana to future climate change impacts[982].

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[978] Ibid.

[979] Ibid.

[980] Ray DK, West PC, Clark M, Gerber JS, Prishchepov AV, Chatterjee S. 2019. Climate change has likely already affected global food production. *PLoS ONE* 14: 1-18.

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