Federal Ministry for Economic Cooperation and Development

Potsdam Institute for Climate Impact Research

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Summary for Policymakers

Climate Risk Analysis for Identifying and Weighing Adaptation Strategies for the Agricultural Sector in Northern Ghana

– A Study at District Level in the Upper West Region –

2021

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This Summary for Policymakers is complemented by the Scientific Report, the Methods Factsheet, the Supplementary Material as well as four short documentary films.

Setting the Scene

Climate change is already affecting the agricultural sector in northern Ghana and its impacts will continue to increase in the future. This puts livelihoods and economic growth at risk and shows the urgent need for effective adaptation strategies. However, decision-makers in northern Ghana have to cope with limited information on climate risks and on suitable adaptation strategies at the district and the regional level.

This summary provides decision-makers and implementers in Ghana's Upper West Region (UWR) and beyond with **localised information on current and future climate risks for the agricultural sector** including information on future crop yields**.** It presents **four suitable adaptation strategies** which enable farmers to cope with these climate risks and stabilise their crop yields. Additionally, this summary makes **suggestions for strengthening an enabling environment** that supports all farmers in taking up adaptation strategies that are most suitable for them.

Key Recommendations

Improved seeds can significantly increase production. To benefit from the use of improved seeds and limit potential negative outcomes, more research in local breeding including farmers' participation needs to be done and access to resources needs to be ensured.

Cashew plantations alley cropped with legumes have a great economic potential under climate change, especially when the whole product chain is utilized. We recommend to incentivize small-scale cashew production to avoid negative outcomes like increased inequality and food insecurity.

Farmer Managed Natural Regeneration (FMNR) is an affordable strategy with low input requirements and positive co-benefits for societies and the environment. We recommend a wide upscaling in the whole region.

Irrigation of high value cash-crops can create jobs and be a valuable source of income in the dry season. We recommend the public development and maintenance of irrigation infrastructure for dry-season irrigation in areas where it is economically useful and environmentally sustainable.

The Study Area

The Climate Risk Analysis at district level was conducted in the Upper West Region (UWR), one of 16 administrative regions in Ghana, located in the north-western part of the country. It focuses on the three districts Lawra, Sissala East and Wa West (Figure 1) to cover a range of biophysical, economic and social conditions. Despite this regional focus, the study approach allows for an upscaling of results to other districts within the UWR and beyond.

The tropical climate of northern Ghana is characterised by a mean annual temperature of 27.5 °C and a single rainy season. The total amount of annual rainfall is about 1 000 mm with most of it falling between mid of April and beginning of October (Figure 2). The amount of rainfall varies greatly from year-to-year.

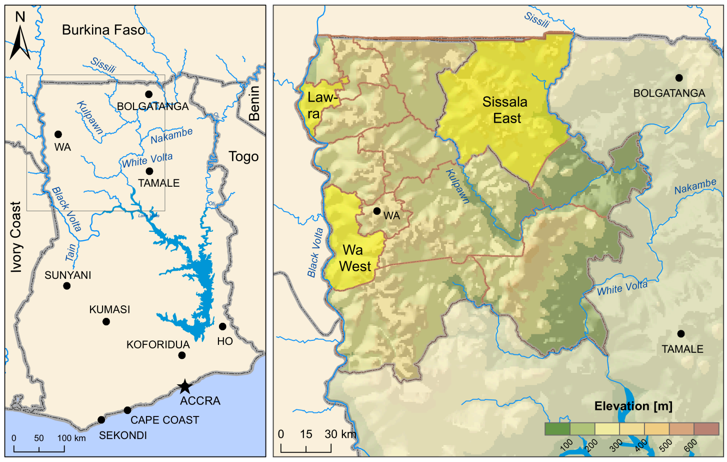

Figure 1: Map of Ghana (left) and the Upper West Region including the three districts Lawra, Sissala East and Wa West (right).

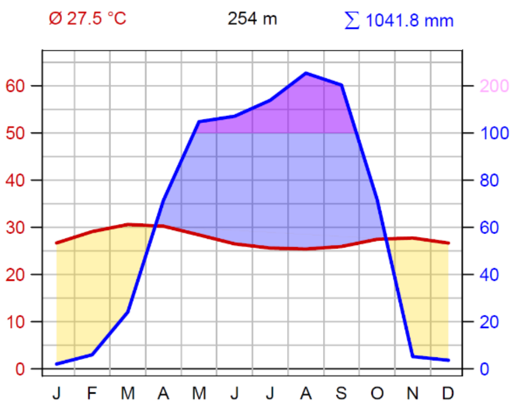

Figure 2: Climate diagram at 12.25 °N and 2.25 °W based on W5E5 data. The red line indicates the mean monthly temperature and the blue line the monthly rainfall sum.

The climate conditions have a hug impact on the livelihoods of the majority of the 850 000 inhabitants in northern Ghana (2020). 84.7 % of the population live in rural areas and 77.0 % of all households rely on agriculture (REACH baseline study, 2020).

The main crops cultivated are maize, groundnuts, sorghum, rice, yams, cow peas, Bambara beans and soybeans (Ghana Statistical Service (GSS), 2013; Ghana Statistical Services, 2019). Farmers in northern Ghana largely depend on rainfall to water their crops as irrigation infrastructure is poorly developed. This limits most agricultural activities to the six-month rainy season. Additionally, the high year-to-year variability in rainfall amounts and onset of the rainy season as well as dry spells and heavy rainfall events represent an unreliable risk, especially to smallholder farmers.

These challenging climate conditions, practices of deforestation, bush burning, and soil degradation paired with governmental interventions and agricultural policies that have disadvantaged the northern part of Ghana since colonial times led to a north-south divide of Ghana. This can to a large extend explain the high vulnerability of the UWR. The region is the poorest one in the country, with a rate of 71.0 % of the population having income levels below the poverty line (Ghana Statistical Service, 2018).

Climate change is likely to further increase the vulnerability of smallholder farmers which calls for robust adaptation planning to increase the resilience of farmers in the UWR.

The Study Approach

To provide localised information on current and future climate risks as well as recommendations on suitable adaptation strategies for the agricultural sector, an impact-action-uncertainty chain was followed (Figure 3). As a first step, the current and future changing climate conditions were analysed. To account for uncertainties in future emissions one high emissions scenario and one low emissions scenario were used. Thereby, the high emissions scenario is built upon the assumption of continuously high future emissions while the low emissions scenario assumes high mitigation efforts and thus a future that is in line with the Paris Agreement and global warming that is likely well below 2°C. Secondly, the resulting future impacts of climate change on crop production were modelled. Additionally, the influence of socio-demographic variables like gender, age, and migration status on the vulnerability to climate change was analysed to obtain information on the distinct needs of different groups in facing climate risks. Then, the results were fed into an action dimension to assess different adaptation strategies with regard to their risk reduction potential, their cost-effectiveness, and other socio-economic evaluation criteria, such as potential maladaptive outcomes and development co-benefits. Finally, the uncertainty attached to the results was critically discussed and recommendations targeting decision-makers were given.

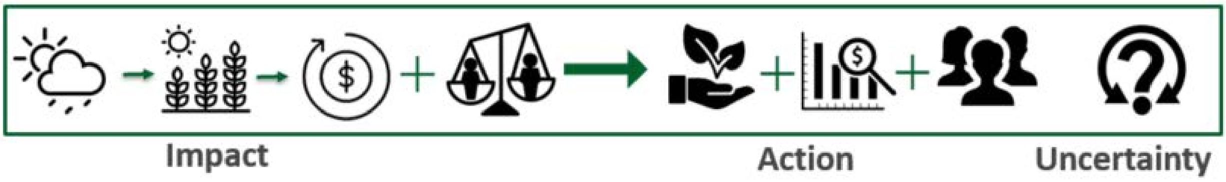

Figure 3: Study approach showing the impact-action-uncertainty chain applied.

The analysis utilised data from global climate models, a crop model and a farm level cost-benefit analysis. Information from expert interviews and literature complemented the findings.

Relevant stakeholders from Ghanaian local and national governmental institutions, civil society, academia, the private sector, practitioners and development partners were engaged throughout the study process to ensure that the study results are suitable for the UWR and can best support local decision-makers in adaptation planning and implementation. In three workshops and eleven expert interviews the key stakeholders at the regional and national level contributed with conceptual inputs, technical expertise as well as local insights which shaped and validated the study design and results (Figure 4). At the beginning of the study process, the local stakeholders actively steered the foci of the climate risk analysis, by specifying, contextualising and prioritising the adaptation strategies to be analysed in the study.

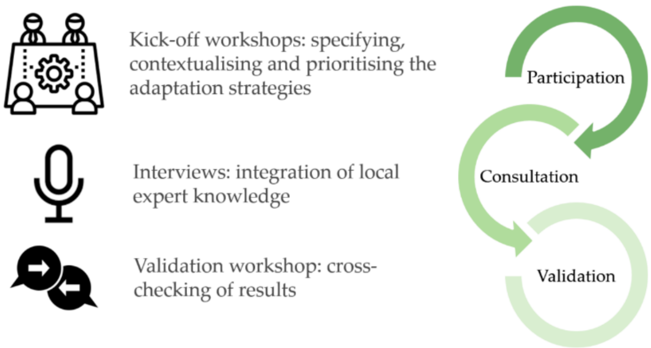

Figure 4: Stakeholder engagement followed throughout the study process.

To further ensure the suitability of the study results for the local context, the study was co-created with researchers from the University for Development Studies (UDS). The collaboration with the implementing Resilience Against Climate Change (REACH) project created synergies and ensured the usability and uptake of the study results.

Past and Projected Future Climate Changes

Temperature has increased in the last decades in the UWR with an average **rate of +0.15 °C** per decade since 1980 (Figure 5). In line with this also the number of very hot days (maximum temperature above 35 °C) has increased.

Rainfall in the UWR is slowly recovering after the drought period in the 70's-80's with mean annual values currently **still well below the amounts of the mid-20th century** (Figure 6). Precipitation in the past was dominated by high year-to-year variability.

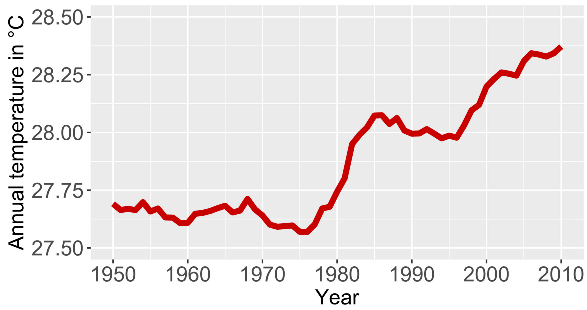

Figure 5: 11-year running mean of mean annual temperature in the Upper West Region.

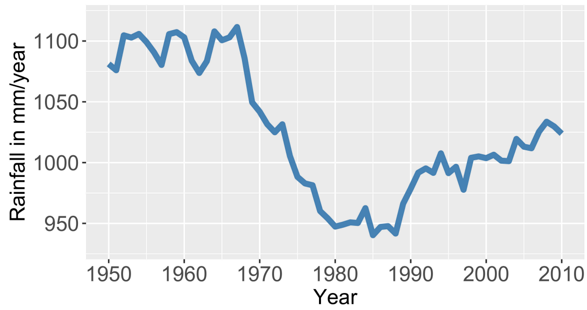

Figure 6: 11-year running mean of mean annual rainfall sum in the Upper West Region.

Future projections of temperature show an overall continuation of the recent increasing trend (Figure 7). **Mean annual temperature is projected to increase by approximately 1.1-1.9 °C until 2050** compared to 2005. Further rises until the end of this century will occur under high future emissions (red line). Also, **extreme temperatures, namely the number of very hot days** (maximum temperature above 35 °C) and **tropical nights** (minimum temperature above 25 °C)**, will increase** with very high certainty. The projections under the two different emissions scenarios span a range of possible future climate conditions that are expected in the Upper West Region.

Future rainfall projections are subject to modelling **uncertainty** (Figure 8-10). In case of low global efforts in climate mitigation (red line), **rainfall amounts** (Figure 8) and **extreme rainfall events** (Figure 9) **might increase until 2050 and beyond**. In the case of strong climate change mitigation and low future emissions (blue line), no major changes in rainfall are expected in this century. The year-to-year variability of rainfall amounts will remain high. A possible change in the future onset of the rainy season is uncertain (Figure 10). The onset, offset as well as length of the rainy season will also in the future be subject to a high year-to-year variability.

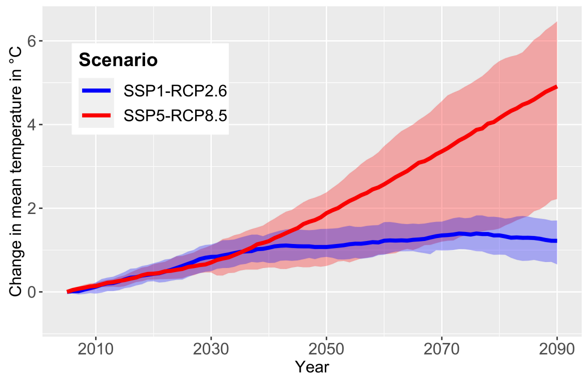

Figure 7: 21-year running mean of change in mean annual temperature in the Upper West Region under the low emissions scenario (blue) and the high emissions scenario (red).

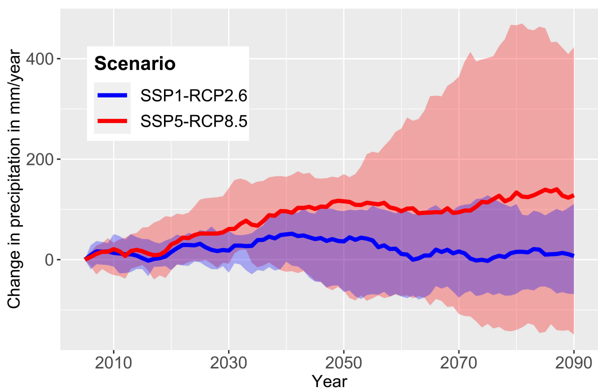

Figure 8: 21-year running mean of change in mean annual rainfall sum in the Upper West Region under the low emissions scenario (blue) and the high emissions scenario (red).

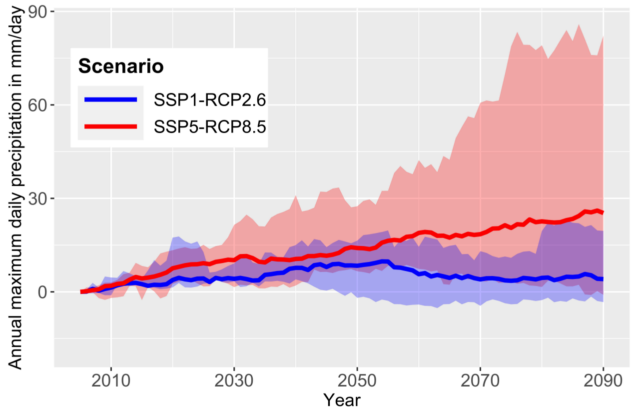

Figure 9: 21-year running mean of change in annual maximum daily rainfall in the Upper West Region under the low emissions scenario (blue) and the high emissions scenario (red).

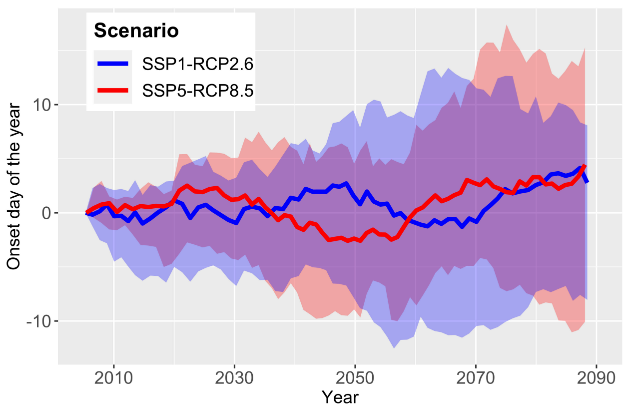

Figure 10: 21-year running mean of change in onset of the rainy season in the Upper West Region under the low emissions scenario (blue) and the high emissions scenario (red). Negative values indicate an earlier onset, positive values a later onset.

Climate Impact		Future Trend[1]	Certainty[2]
	Mean annual temperature	Increasing	Very high
	Number of very hot days & tropical nights	Increasing	Very high
	Heavy rainfall intensity & frequency	High future emissions: Increasing	Low
		Low future emissions: No trend	High
	Mean annual rainfall sums	High future emissions: Increasing	Low
		Low future emissions: No trend	High
	Rainy season onset	No trend	High
	Number of dry spells within the rainy season	No trend	Medium

Table 1: Analysis of future trends of different climate variables.

[1] The trend is determined by a Mann Kendall Test with significance level 0.05 for the years 1979-2016 in the past and the years 2015-2100 under the respective emissions scenario in the future. If at least 40% of the models show a significant trend in the same direction, a trend with a specific uncertainty level (see next foot note) is stated.

[2] The certainty level of future climate projections is determined by the percentage of models agreeing on the trend (with significance level of 0.05) (compare IPCC, 2014). >= 90 %: very high; >= 80 %: high; >= 50 %: medium; <= 50 %: low.

Climate Impacts on Agricultural Production

Using statistical and process-based crop models, the impact of climate change on the following four staple crops was analysed: the **annual grain crops sorghum** and **maize** as well as the **annual legumes groundnuts** and **cow peas**. These four crops were selected based on stakeholder interests, their use within the UWR, data availability and suitability for the crop models.

Cow peas are an annual legume that is adapted to a semi-arid and hot climate and grows on sandy soils. Like most other legumes, cow peas can fix nitrogen in the soil leading to improved soil fertility. The crop takes between 110 and 130 days to mature and is widely used in sub-Saharan Africa, including in West, Central and East Africa. In Northern Ghana, cow peas are an important local food crop as very little of it is sold. At national level, cow peas are the second most common legume crop after groundnuts. In many households, cow peas are planted as an intercrop or on the edges of fields.

Groundnuts are an annual legume that develops peanut pods underground. Like most other legumes, groundnuts can fix nitrogen in the soil leading to improved soil fertility. Groundnuts have a growing period of 90-140 days with sensitivity to rainfall amounts from flowering onwards. They are usually eaten roasted or used for the production of peanut butter and edible oils. In Ghana, groundnuts are consumed as fresh, dry or roasted nut snacks and in soups, with over 90 % of the production taking place in northern Ghana. Groundnuts are grown in monocultures, intercropped, or rotated with cereals due to their nutrient fixing capacity and usability as cover crops.

Maize is a vigorous annual grass and grain crop. The maturing period for maize depends on local conditions and can vary between 70 and 120 days in the UWR. In Ghana, maize is a staple crop that is produced across the country's agroecological regions mostly under rainfed conditions. The highest proportions of maize grain yields are kept by smallholder farmers as staple food or fodder while a part is marketed. Soil fertility and water are the main limiting factors for maize production in Ghana.

Sorghum is an annual grass species cultivated for its grain. The crop takes 90-120 days to mature. Sorghum is adapted to warm days and night temperatures above 22 °C throughout the growing season. Over 90 % of Ghana's sorghum is produced for food and malt in the northern regions (Northern, Upper East and Upper West Region) making it an important staple and cash crop in these areas. Some of the limiting factors to sorghum production in northern Ghana are low soil fertility, a lack of improved varieties, and striga infestation, a parasitic seed plant depriving sorghum of water and nutrients that is also called "witchweed".

The results project **predominantly negative influences of climate change on crops** in the UWR. Statistical models project that the suitability to grow maize, sorghum or cow peas is slightly declining depending on the amount of future greenhouse gas emissions and the location within the UWR. The suitability to grow groundnuts, on the contrary, might even rise under the high emissions scenario in some regions.

Next to the suitability analysis, projected changes in future yields were determined with a process-based model. While **groundnuts yields** are projected to **remain almost stable** yields for **cow peas, maize and sorghum are projected to decrease** until 2050 (Table 2). The high ranges in yield changes are given due to the dependency on the management practices of the farmer, the region as well as future greenhouse gas emissions. The certainty in the results was analysed according to the number of climate models under which these results are obtained. The certainty ranges between medium and very high. Stronger yield declines were projected for Wa West and Lawra compared to Sissala East, especially visible for maize. The already higher vulnerability of farmers in the latter two districts compared to farmers in Sissala East, due to different microclimates and past economic developments, might thus further diverge in the future.

Crop	District	Yield changes[3]	Certainty[4]
Cow peas	All three districts	-35 % to -10 %	High
Groundnuts	All three districts	-5 % to +3 %	Medium
Maize	Sissala East	-10 % to +2 %	Medium
	Wa West & Lawra	-26 % to -3 %	High
Sorghum	All three districts	-22 % to -2 %	Medium

Table 2: Projected trend in crop yields under climate change until 2050.

Differential Vulnerabilities in the Upper West Region

Based on literature, a crop model analysis as well as interviews, the research revealed that farmers in the Upper West Region are not all equally affected by climate change and also have different capacities to adapt to the new climate conditions. The results show that existing inequalities shape the severity by which climate change is affecting a farmer. **The vulnerability and adaptive capacity of farmers are influenced by inter alia their gender, age, social class** (including factors like economic resources, access to decision making power and education) and **migration status** (differentiating between peasant farmers and nomadic pastoralists). These differential vulnerabilities in the light of climate change are mainly shaped through unequal access to land, resources, information, education, finances, jobs and decision-making power depending on the social characteristics of a farmer.

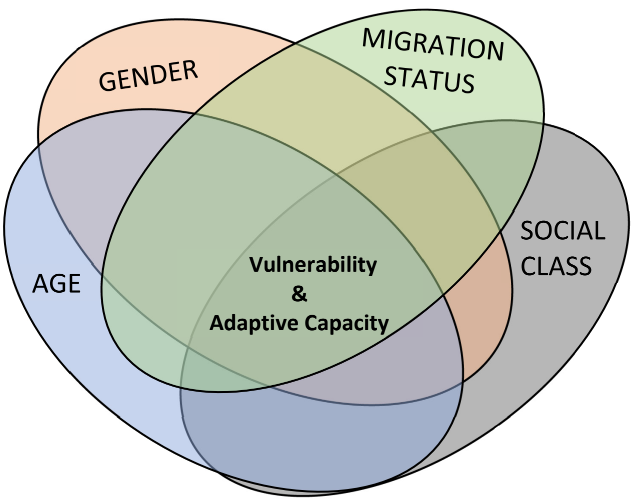

Figure 11: Scheme displaying how the effects of different social characteristics are intersecting and in combination can explain the vulnerability and adaptive capacity of a farmer.

It is important to look at the combination of different social characteristics of a farmer to understand the vulnerability and adaptive capacity, since one social characteristic alone, for instance, gender, fails to give a full explanation (Figure 11). An example from fieldwork from Nyantakyi-Frimpong (2020) shows how the intersection between different social characteristics comes into play: In the case of a drought, a married woman, a widow and a woman married to the chief are differently affected by extreme weather events and have a different capacity to recover from the impacts. While resources are unevenly distributed between men and women, a married woman and especially a woman married to the chief has better access to inputs like drought-resilient seeds and irrigation facilities and thus is less vulnerable in case of a drought.

Ignoring the different social characteristics and the effects of the intersections between them might aggravate rather than diminish existing inequalities and thus will allow mainly the advantaged farmers to adapt to climate change. Adaptation planning has to especially consider

[3] Future yield changes are based on the results of the percentage changes between 2005 and 2050 of the multi-model median. Ranges are given due to differences depending on the district, the management practices of the farmer and the emissions scenario.

[4] The certainty level of future climate projections is determined by the percentage of models agreeing on the direction of trend (compare IPCC, 2014). >= 90 %: very high; >= 80 %: high; >= 50 %: medium; <= 50 %: low

the needs of groups that are disadvantaged in their access to information, resources and decision-making power to mitigate that the greatest vulnerabilities and risks are among people and groups who are already most marginalized.

To decrease differential vulnerabilities in the long term, equal access to land, assets and decision-making power have to be given to disadvantaged groups. Empowering all farmers to participate in political planning processes will ensure the inclusion of all local (traditional) knowledge and skills into adaptation action. Not only the participation of disproportionally affected people and groups will lead to improved outcomes in adaptation, but it is also an important prerequisite for an increase of the adaptive capacity of a whole community.

Adaptation Strategies

Well designed and implemented adaptation strategies cannot only pay off present and future yield losses induced by climate change but also have various positive economic, social and environmental co-benefits and can contribute to combating land degradation.

Based on the projected climate change impacts and stakeholder interests, **four adaptation strategies** were analysed regarding their suitability under changing climate conditions in the Upper West Region:

Improved seeds: This means the use of new seed varieties that produce higher yields, higher quality, provide better resistance to climate stress and/or minimise the pressure on the environment. In the UWR, most farmers use farmer-saved seeds that they obtain from their own production or buy at local markets. These low uptake rates mainly origin in high costs of seeds and inputs as well as bad experiences that have been made, partially due to poor seed quality or mismanagement. The highest uptake rates of improved seeds can be found in the Sissala districts.

Cashew plantation alley cropped with legumes: The cultivation of cashew allows for alley cropping with different kinds of legumes such as groundnuts, soya beans, Bambara beans, and cow peas which can increase the soil fertility, thereby boosting the yield of the cashew crop. Depending on the spacing between the trees, the intercropping can be permanent or only in the first years of tree planting before the canopies are closing. Cashew farming has been popular in the southern part of Ghana but is by now also gradually spreading to the northern parts. The zone along the Black Volta in the UWR is particularly known for falling within the 'cashew belt' - an area with well-drained, light to medium textured, deep soils which are conducive to cashew cultivation.

Farmer Managed Natural Regeneration (FMNR): In FMNR systems, farmers use pruning to encourage the growth of trees and shrubs that regenerate naturally in their fields. The most vital stems are protected from livestock, fire and competing vegetation. The tree growth can be turned into a valuable resource without jeopardising but in fact enhancing crop yields. FMNR is a low-cost land restoration technique that has various benefits for farmers, biodiversity, soil and climate. FMNR is a practice found everywhere in the Sahel and particularly in Niger.

Irrigation: Since rainfall amounts in the UWR are subject to high year-to-year variability and the growing season is limited to the six-month rainy season, irrigated farming can help farmers to secure their income and livelihoods throughout the year. It is mainly practised as an off-season engagement (December – March) and involves rice and vegetable cultivation. The biggest water resources for irrigation are the Black Volta river system in the western part of the UWR as well as groundwater, since the water table is in most parts of the region less than 10 m below the surface. In most cases, irrigation systems are designed in a way that the water from the reservoir is diverted directly to the cropland via open concrete canals or non-concrete farm ditches.

Cost-Benefit Analysis

A **farm-level cost-benefit analysis** was carried out for three different adaptation strategies in the district most suitable for the strategy. Thus, the economic benefit of using improved hybrid and non-hybrid seeds in Sissala East, growing cashews intercropped with legumes in Lawra as well as applying dry-season gardening by irrigating tomato in Wa West could be assessed. Additionally, the Economics of Land Degradation (ELD) Initiative conducted a detailed CBA for FMNR systems in Lawra (Quillérou, 2019), the results of which are displayed here. Due to the slightly different assumptions used, the results should only be compared with caution.

Different economic indicators give detailed insights on the economic potential of the adaptation strategies. In the table below two indicators are displayed: 1) the benefit-cost ratio (BCR) which represents the ratio between discounted benefits and costs of a strategy and is greater than 1 for economically beneficial strategies and 2) the net present value (NPV) which represents the discounted net benefit for a strategy applied on one acre (appr. 4 050 m²). If possible, uncertainties based on future emissions, future economic developments as well as other factors were included in our results. Thereby a range of possible NPVs and BCRs is given for two strategies.

Adaptation strategy	Benefit-cost ratio	Net present value per acre
Improved seeds in Sissala East	1.8 - 2.4	8 400 - 13 300 GH¢
Cashew-groundnuts production in Lawra	2.6	15 300 GH¢
Irrigated tomato in Wa West	1.7 - 2.1	18 200 - 26 700 GH¢
FMNR in Lawra (by ELD)	3.3	NA

Table 3: CBA of four adaptation strategies with values for BCR and NPV. Ranges are given in case different time scales, emissions scenarios and economic development pathways were included in the results.

The indicated values for BCR and NPV display positive economic returns for all strategies independent of the applied time period (current or future), emissions scenario (high or low) or future economic development pathway (negative or positive). Thus, **all four analysed strategies were found to be economically beneficial under the current as well as the projected future climate** compared to business as usual agricultural practices. More specifically, the results indicate that for our case studies, FMNR has the highest ratio between benefits and costs followed by irrigation, cashew intercropped with groundnuts and improved maize seeds.

Policy Recommendations for an Uptake of Adaptation Strategies

Next to their economic potential, the four adaptation strategies were analysed based on further criteria, which are for instance addressing **co-benefits, potential negative outcomes, barriers for implementation, the potential to reduce climate risks as well as existing inequalities**. These results lead to policy recommendations that can support the sustainable uptake of individual adaptation strategies by maximizing potential co-benefits and minimizing negative outcomes.

	Study results & policy recommendations
	Study results Applying **improved seeds can significantly increase agricultural production** by up to 85 % and contribute to stabilising yields under changing climate conditions. However, the outcome of using improved seeds is very **dependent on the varieties**, including its suitability for local soil and weather conditions, cultural acceptance of the product and the input need of the seed. The potential to increase the uptake rates of improved seeds is high in the UWR, especially in regions where the current use is very low, like in Lawra and Wa West. The use is currently hindered by **high costs, lacking trust of farmers** and **unreliable access to inputs, credits and information**. Policy recommendations • **Incentivise the development and use of improved seeds** meeting the requirements of local agro-ecologies under current and future climate. • More research in local breeding including farmers' participation needs to be done. • The wide uptake of improved seeds has to be supported by securing **access to seeds, fertiliser, credits, markets and information**. • To regain farmer's trust in seeds, community-based seed systems shall be established. NGOs can play a major role in facilitating the seed systems.
	Study results The agroforestry measure **cashew plantations alley cropped with legumes** has great economic potential, particularly when the whole product chain is utilised **(i.e. combined with beekeeping, using cashew apple and nut as well as intercropped legume).** Cashew and groundnuts production is projected to remain stable or increase under climate change in the UWR. Despite these promising benefits, the strategy comes with potential negative effects. **Extensive implementation** of cashew production can also lead to **biodiversity loss, food insecurity and increasing inequalities** on a global and local scale. Policy recommendations • **Incentivise small-scale cashew production** that is integrated on the farm and utilises the whole product chain, thus combining cashew **with intercropped legumes, beekeeping and promote the use of the cashew apple**. • The potential negative effects on societies and biodiversity call for a careful design and sensitisation of farmers through e.g. extension services.
	Study results **Farmer Managed Natural Regeneration (FMNR)** systems can **increase yields of staple crops** like maize and sorghum and reduce yield losses due to heavy rainfall events. At the same time, FMNR has various benefits as it is **cost-effective, combats land degradation, contributes to climate mitigation and can easily be applied** by many smallholder farmers, also with limited access to resources. It also highly contributes to the **improvement and diversification of livelihoods and food sources,** while having **no severe potential negative outcomes**. Usually, FMNR is applied as a community engagement, which **strengthens social cohesion**, decreases rural exodus and hinders human-induced bush burning. The low requirements needed to implement FMNR make it especially **beneficial for the most vulnerable groups**. Policy recommendations • **Support the wide upscaling of FMNR** systems on community and household level. The low requirements for input and technical equipment combined with a low risk of negative outcomes put no restrictions on the upscaling of FMNR in the context of smallholder farming communities. • The promotion of FMNR **should target smallholder farmers without heavy machinery** since the high density of trees limits the use of machinery.

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Study results
Irrigation can mitigate climate risks in the UWR by 1) supplying the water needed during the rainy season and therefore mitigating the impact of dry spells on staple crops, 2) compensating crop failures in the rainy season by cultivating irrigated high-value cash crops during the dry season. Both forms require high investments, maintenance costs and technical knowledge. Especially supplying water on staple crops is cost-intensive due to the vast land used. Thus, dry-season irrigation is of higher use in the region. No major change in water availability for irrigation can be expected due to climate. Dry-season irrigation has the potential to strengthen the livelihoods of farmers, especially female farmers, by creating opportunities in the dry season. In return, opportunities to use irrigation facilities can reduce rural to urban migration.

Policy recommendations
• Facilitate the development and maintenance of dams, rivers and boreholes for dry-season irrigation in areas where it is economically useful and where there is no risk of overexploitation of water resources.
• To allow farmers to benefit from irrigation, governmental institutions need to steer high investments in equipment and maintenance and strengthen access to markets for selling cash crops.
• Upscale dry-season irrigation in areas where easy access to water makes it a profitable strategy.
• The potential of dams close to the Black Volta and boreholes in areas where the water table is close to the ground could be further exploited.
• Promoting water-saving agricultural practices and efficient irrigation techniques should be combined with installing irrigation facilities to minimize overexploitation.
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All four adaptation strategies show a high potential to improve the livelihoods of farmers under current and projected future climate conditions in the UWR. Applying heat-tolerant improved seeds, FMNR and cashew plantations might bring even higher benefits in the future than under current climate conditions. Many other adaptation strategies are known and applied in the UWR and can bring additional benefits in combination with the suggested strategies.

To set up an **enabling environment** that is needed for the implementation of a wide range of adaptation strategies, the **following policy recommendations** were identified based on expert knowledge and literature.

Enabling Environment for Adaptation in the Upper West Region

	Study results & policy recommendations
Barriers for implementation	**Study results** Three main barriers are hindering the general uptake of adaptation strategies: (1) **Land tenure insecurities** discourage or even inhibit investments in adaptation strategies. (2) **Access to finances for establishing new adaptation strategies, easily accessible markets for selling products and inputs like seeds and fertilizer** is unreliable and not given for all farmers. Especially remote areas are cut off during the rainy season. (3) Farmers have **insufficient information** on the benefits and implementation of individual adaptation strategies. **Policy recommendations** A farm-level decision for adaptation strategies will be effective only if supported by institutions: (1) Governmental institutions shall **guide a participatory tenure reform** that can support tenure security, especially for female and young farmers. (2) Access to **credits, markets and inputs has to be scaled up** to cover all areas in the UWR all year around. (3) **Demonstration sites** to showcase suitable adaptation strategies should be established to gain farmer's trust in the measures. **Strengthening extension services in all districts** is recommended to support the information flow to farmers.
Differential vulnerability	**Study results** A wide range of **intersecting social identities like gender, age, economic situation, and migrant status** shape how climate risks are experienced by different groups as well as their opportunities to adapt to the changing climate. Disadvantaged groups currently face a disproportionally higher climate risk. **Policy recommendations** **Equal access to decision making power, assets, and land** has to be ensured to increase the adaptive capacity of the most vulnerable groups as well as whole communities. Ensuring the participation of disproportionately affected people and groups in political planning processes not only mitigates the reinforcement of existing inequalities but also contributes to the effective adaptation of whole communities to the impacts of climate change.
Land degradation	**Study results** Land degradation is severely **affecting the yields of farmers** in the UWR. The negative effects of climate change and land degradation can reinforce each other. **Policy recommendations** Governmental structures and farmer communities have to set combating land degradation as a top priority to mitigate the aggravation of impacts of climate change due to degraded lands.
Uncertain climate conditions	**Study results** **Uncertainties** surround future rainfall projections. Additionally, continuously high **year-to-year variability in rainfall amounts** is projected for this century. Temperatures, on the contrary, will rise for certain. **Policy recommendations** Adaptation strategies should be beneficial under a wide **range of possible future rainfall** amounts in the UWR and ideally increase the resilience against dry conditions as well as heavy rainfall events (e.g. agroforestry measures). Adaptation strategies that address **resilience to heat** (e.g. heat-tolerant varieties) are recommended since temperatures will certainly rise.

	Study results & policy recommendations
Choosing adaptation strategies	Study results There is no "one fits all" adaptation strategy as the **most suitable adaptation strategies vary with farmer and location** due to different environmental, social and economic prerequisites. Many different adaptation strategies hold the potential to mitigate climate risks. A **combination of different adaptation strategies** can increase positive outcomes, but in some cases, one strategy can limit the positive effects of others. Policy recommendations **Investigate the benefits and negative outcomes of the full range of available adaptation strategies** to select the most suitable ones for the conditions and preferences of the community of farming households. **Combinations of adaptation strategies need to be carefully explored** to tap into the merit of more than one strategy without limiting the benefits of the strategies.
Readiness for Integration	Study results **Many solutions** to stabilise and increase agricultural production in the UWR **are known**. Research about specific adaptation strategies and their effectiveness is improving but is **not yet sufficiently integrated into agricultural practices**. Policy Recommendations Research findings on possible adaptation strategies **need to be communicated fittingly to local decision-makers and farmers**. Governmental institutions are in the position to close the communication gap between science and implementation by, for example, integrating research knowledge into extension services.
Regional upscaling	Study results While the suitability of four adaptation strategies was analysed for the three districts Lawra, Wa West, and Sissala East, these adaptation strategies could also be suitable in other parts of northern Ghana. **Implementation capacities for individual adaptation strategies vary from household to household** and are not generally district specific. Policy Recommendations It is recommended **to explore the potential** of the four analysed adaptation strategies not only within the three districts but in **other parts of northern Ghana**. While some adaptation strategies (e.g. FMNR) can be recommended on a broad scale, other more complex strategies (e.g. cashew plantations) need a careful assessment on community or household level.

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The Summary for Policymakers is based on the Scientific Report "Climate Risk Analysis for Identifying and Weighing Adaptation Strategies for the Agricultural Sector in Northern Ghana - A Study at District Level in the Upper West Region" prepared by the Potsdam Institute for Climate Impact Research (PIK) for the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The study was developed in cooperation with the Ghanaian Ministry of Food and Agriculture (MoFA), the Department of Planning and Land Management at the University for Development Studies (UDS) in Wa, the Resilience Against Climate Change (REACH) project, the HFFA Research GmbH and other Ghanaian stakeholders from local and national governmental institutions, academia, civil society the private sector, development partners as well as farmers' associations.

The Scientific Report at district level builds upon the climate risk study for Ghana's agricultural sector at national level and both studies aim at contributing to Ghana's NDC implementation and the objectives of the NDC Partnership.

For more information and further study results, please visit www.agrica.de. Any questions can be addressed to Christoph Gornott (gornott@pik-potsdam.de) or Paula Aschenbrenner (aschenbr@pik-potsdam.de).