Adaptive strategies of smallholder farming systems to changing climate conditions in the vicinity of Kogyae Strict Nature Reserve within the Forest-Savanna Transitional Zone of Ghana

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Abstract

The strong climate linkages to farming systems render them and dependent communities vulnerable to climate change and variability. Knowledge of existing responses to climate change is important for the formulation of policies and adaptive strategies for resilience. The paper examines a fifty-year climatic records from 1961-2011, community perceptions, experiences and knowledge for evidence of climate change and impacts. Climate change-driven farmer adaptive responses were critically examined relative to farming practices; and crop climatic requirements for growth, development, maturity and harvesting. A mixed methodological approach was adopted to address issues of climate change, exposures, sensitivities and adaptive responses. The results showed that the area has experienced a steady rise in temperature, reduced rainfall amounts of 3.0mm per annum, reducing events of rainfall excesses and increasing deficits, narrowing of rainfall period and a shift of the double to a single rainfall maxima regime. Farmers have observed these patterns of changes and experienced the impacts. Consequently, evidence-driven adaptive responses in the transformation of farming practices, timing of cultivation and choice of crops have been developed by farmers. It is recommended that further adaptive strategies be planned to improve farmers' adaptive capacities and reduce sensitivity of crops to climate perturbations.

Key Words: Climate Change; Small-scale farming; Adaptation; Sensitivity; Adaptive capacity, Vulnerability

Introduction

Importance of farming systems

Climate change in many parts of Africa is already apparent (Collins, 2011; Hoffman et al., 2011; Nicholson et al., 2013), with diverse consequences such as compositional and functional changes for farming systems. Intensification and increase in frequency of these events are projected to negatively affect local crop production in Africa, especially in the low land and dry areas (Berg et al., 2013; Sultan et al., 2013). Already, the overall agricultural productivity loss in Africa due to climate change was estimated to range between 17% and 28%, as compared to 3% to 16% for the world as a whole (Cline, 2007). Africa's urgent adaptation needs stem from the continent's foremost sensitivity and vulnerability to climate change, together with its low levels of adaptive capacity (Ludi et al., 2012). Traditional farming systems are dynamic, and their responses to changes in climate would be varied in time. Thus, continuous analysis is required for dynamic adaptation policy formulation. This study examines existing vulnerabilities and adaptation situations of the local farming system as a basis for building an informed resilience system.

For many countries in Africa, agriculture makes substantial contributions to socio-economic development. The smallholder farmer contribution is recognized for their key importance in this regard. About 50% of developing-country rural populations are smallholder farmers (UNCTAD, 2010). World Bank (2013b) estimates put the number in Sub-Saharan Africa (SSA) at 175 million, with 70% being women. In SSA, the smallholder farms (those with farmlands 2 hectares or less) represented 80% of all farms and contributed up to 90% of production (Wiggins, 2009).

Non-climatic and climatic vulnerabilities

The small-scale farming is plagued with many challenges and stressors. The farmers are largely poor, have low income and literacy rate. Deteriorating socio-economic farming situations in rural areas have created pushing conditions that have caused the migration of young men to urban centers, leaving aged farmers and females to support farming. Characteristically, farm sizes are small and marginal in quality (Jirström et al., 2011; Harris & Orr, 2014). Yields are relatively poor (Chauvin et al., 2012). There is limited use of farm inputs, poor access to effective production technologies and credit facilities, high risks for crop failures, and poor returns in output markets. In 2013, the Agriculture sector received only 1.5 percent of the Annual Budget Funding Amount (ABFA) (GSS, 2014).

Small-scale farming system is climate-driven: specifically rain-fed (FAO, 2006; IFAD, 2011). Germination, growth and maturation processes; harvesting and storage are basically dependent and linked to climate. Hence, decisions on the choice of crops and farming practices are inextricably determined by local climatic factors, making the system and dependent communities exposed and sensitive to climate. High temperatures reduce yields and tend to encourage weed and pest proliferation (Müller et al., 2011). An assessment using the FAO/IIASA Agro-Ecological Zones model (AEZ) in conjunction with IIASA's world food system, as well as climate variables from five different emissions scenarios, showed further impacts on agricultural potential by the 2080s (Fischer et al., 2005).

The small-holder farming systems and adaptive responses

Small-scale farming systems are not static, but dynamic over time (Nyong et al., 2007; Ng'ang'a et al., 2013). They are believed to have emerged in their current forms through a series of gradual transformation as a response to environmental (including climate) and other changes, and the need to reduce inherent risks (Leblois et al., 2014). Whereas these adaptive processes have been successful, and ensured sustained co-evolution of the traditional farming system with the biophysical supporting system, there is no guarantee that existing coping strategies can effectively sustain production and livelihoods in the face of current rapid and long-term environmental changes.

Emergent adaptive strategies are due to the complex interactions of multiple socio-economic and environmental factors (Dessai et al., 2007). Hence, it is critical to isolate actual climate change-driven impacts and adaptive strategies, and the particular dimensions of climate change that are being adapted to. It has also been argued that traditional farming communities adapt to environmental changes, but according to how the changes impact on local needs and livelihood strategies (Ayers, 2011; Ribot, 2010). Among other factors, it has been noted that adaptive strategies may be ecological zone-specific (World Bank, 2010). Even within the same geographical space, it has been found that different groups adopt multiple and different adaptive strategies in

Africa (Westerhoff and Smith 2009; Onyeneke and Madukwe, 2010). Hence, studies must be carried out across the entire spectrum of ecological zones and communities with a diversity of environmental and socio-economic vulnerabilities in order to identify the spatio-temporal dynamics of local climate change impacts and strategies. This will avoid the formulation of generalized adaptive interventions and policies for different local situations.

In Ghana, studies have been carried out on household perceptions of climate change and local adaptation strategies, with the majority adopting anthropological and sociological approaches (Fosu-Mensah et al, 2012; Laube et al 2012; Mapfumo et al., 2013; Codjoe& Owusu, 2011). However, many of the studies do not address the complex linkages of the adaptations to empirical climatic information and their implications for the requirements of crop growth, development, harvesting and storage processes. The projections of future climate change and the impacts on the suitability of farmlands to support faming systems are rarely investigated. This limits the scope and utility of recommendations for developing effective policy responses and planned adaptive strategy. Above all, many of the studies are carried out in the northern savanna zones since it has a long history of being subjected to climatic and non-climatic stressors (Antwi-Agyei et al. 2012). Only a few have been conducted in other ecological zones where the dominant livelihood is climate-dependent small scale farming.

The Forest-Savanna Transitional Zone (FSTZ) in Ghana is prone to rapid biophysical and socio-economic transformations, given its ecological status as a transitional ecotome. The presence of both dry semi-deciduous forest and woodland savanna conditions encourage the adoption of a variety of small-scale farming systems found in both dry forest and savanna zones. The area is considered naturally vulnerable to environmental perturbations, with indications of the occurrence of climate change and variability. In their predictive analysis of all the ecological zones in Ghana, Stanturf et al. (2011), obtained the highest decline of -2.94% of wet season rainfall by the year 2080. The area has received limited attention regarding local contextualized studies on climate change and responsive adaptive strategies. This limits the capacity for theorizing and formulating contextually targeted planned anticipatory adaptations that inform climate-resilient small-scale farming systems. The paper, therefore, explores local trends in climate change and the impacts on smallholder farming systems; the nature and mechanisms in farmer responses adaptive strategies to climate change and variability.

Materials and methods

Study area

The area is delimited by the latitudes 1° 25" 0' W and 1°0".0' E and the longitudes 8°.0".0'N and 9°.25".0'N (Figure 1). It contains a number of water sub-catchments and ecosystems impacted to different extent by anthropogenic management. The area has a bimodal rainfall regime, with the major rainy season occurring between March and July, and the minor rainy season occurring between September and November. The mean annual rainfall is around 1364 mm. From the months of December to March, the area experiences a dry season which is marked by high temperatures. Temperatures are usually high throughout the year, with a mean temperature of about 27°C. Humidity is high during the rainy season, with the drier months, especially, December to February recording very low humidity.

The area stretches across the northern forest-savannah transitional zone, with vegetation that has been described variously as Guinea Savannah (Taylor, 1960) and Derived Savannah (Rose-Innes, 1977). It consists of mosaics of forest and savannah formations. It is seen as a “scar tissue", a product of a long history of stressful events and transformation (Hawthorne, 1996). The Kogyae Strict Nature Reserve (KSNR), which was gazetted in 1971, is an important vegetation formation in the area. The soils in the savannah mosaics are fragile and liable to alternate flooding and drying as a result of the flat-bedded sandstone rocks near the surface. The soils of the forest mosaics are loamy and liable to dry out because of excellent drainage.

Settlements in the area are located within and outside the nature reserve. Inhabitants of these settlements are largely immigrants, mostly from the northern parts of Ghana (Ayivor and Ntiamoa-Baidu, 2015).The main land use within and the vicinity of the KSNR food crop cultivation. These include yam, cassava, plantain and groundnuts. The main land use within and the vicinity of the KSNR is the cultivation of food crops. These include yam, cassava, plantain and groundnuts. In recent years, some farmers have started cultivating other crops, including rice. Hunting, charcoal burning and other minor livelihoods also prevail (Oduro-Ofori, 2015)

Climatological Analysis and Perceptions of Climate Change

Records of rainfall and temperature from the Ghana Meteorological Agency (GMet) were procured in 2013 for the 1961-2011 period. This period was adopted to enable analysis from a decadal perspective. These records were from the closest available meteorological station in Ejura, in the Ashanti Region. Analyses were done for trends, variability, distribution and anomaly of rainfall and temperature to determine evidence of climate change. Projections were made to determine the implications for cropping systems. These were done using chart tools in Microsoft Excel.

The study adopted a cross-sectional assessment of different communities and small scale farming systems in the area. The methods included questionnaire administration, focus group discussions, key informant interviews and on-site observations. One hundred (100)

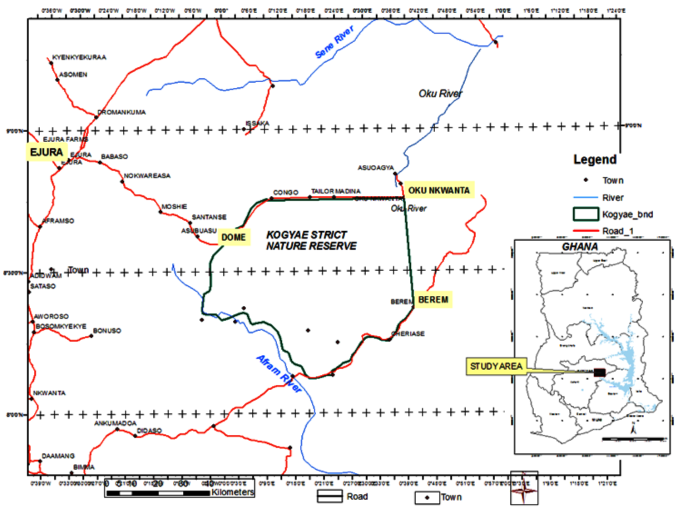

Fig. 1 Study Area

questionnaires were administered through purposive sampling among the farming population in the selected communities. The choice of the technique was occasioned by the fact that only farmers who have lived in the area for at least 10 years were targeted. The study focused on nine (9) fringe communities of the Kogyae Strict Nature Reserve as central points, but extended a few kilometers away from the communities to cover farmlands and other land use types. The communities included Domi, Oku Nkwanta, Berem, Congo Nkwanta, Congo No.3, Njaya, Kyeasi and Kyekyebon (Fig. 2). In addition to questionnaire administration, one (1) focus group discussion was conducted in each of the communities, totaling nine (9) discussions in all. It was ensured that community groups of gender, tribe, age and farmers of different cropping systems were adequately represented. Local assemblymen and agents of traditional chiefs facilitated the selection of participants. A total of 102 individual participants, made of 52% males and 48% females were engaged in the focus group discussions. Each group was made up of between nine (9) and 15 adult participants aged 18 to 72 years. The discussions were held in March, 2014 when they were preparing their farms for the major cropping season.

The discussions explored existing farming systems, non-climatic induced stressors, vulnerabilities, farmer knowledge, experiences and perceptions of climate change and impacts. Rainfall and temperature change and variability were operationally defined variously as change in annual rainfall amount, unpredictability of onset of rainfall seasons, unreliability of predicting rainfall intensity, variable distributions patterns and extremes of drought events. Farmer knowledge and experiences of changes in these climatic elements, as well as the dynamics occasioned in farming systems were examined. Responses from the questionnaire were entered into Microsoft Excel spreadsheet and analyzed for percentage responses. Relevant themes were identified from responses received during focus group discussions. Key narratives were critically analyzed and interpreted.

Cropping exposure and sensitivity to climate

Farming systems may differ in their sensitivity to climate change, resulting in different levels of impact. Factors which contribute to sensitivity and vulnerabilities include existing stressors, farmer situation, challenges and level of dependencies. Farming and cropping systems were analyzed for exposure and sensitivity to climate change in terms of rainfall variables, that is, onset, distribution, amount, excess and deficit and variability. For the analysis of climate change-exposure, the degree of associations between rainfall and yearly productivity was examined from the farmer perspective. The timing of seasonal farming in relation to the on-set and distribution rainfall was also examined. Sensitivity analysis considered existing stressors; alternative water sources to farming aside rainfall; agro-climatic suitability for crops with change in rainfall; and alternative forms of livelihoods to farming.

Farmer adaptive strategies and needs for a sustainable livelihood

The dynamics of the repertoire and the configurations in the choice of cultivated crops by farmers were identified. Farmer decisions on the timing of farm operations such as land preparation, cultivation of crops, agronomic practices, timing of harvesting and storage were examined. Others such as crop water requirements, drought tolerance capacities, water use management, harvesting and post-harvest activities were noted.

Farmer strategies were investigated in relation to their knowledge and experiences of climate change and related challenges to crop growth, development, productivity, harvesting and storage. These included the timing of cropping, selection of land types, crop choice and diversification, technological adoptions and investments, among others. Others were recent modifications in farming practices that are responsive to climate change and crop-drought tolerance capacities. Based on the nature and quantum of the level of exposure and sensitivities, farmer experiences, knowledge, perceptions and expressed opinions on potential solutions to their challenges, capacity needs for enhanced capacity options and resilient farming livelihoods were determined.

RESULTS

Climate Change

Temperature and Rainfall Trends and anomaly

Analysis of climate data for the area showed that temperature and rainfall have experienced contrasting, yet distinctive trends for the past fifty (50) years (1961-2011). Rainfall has undergone a steady decrease of an average

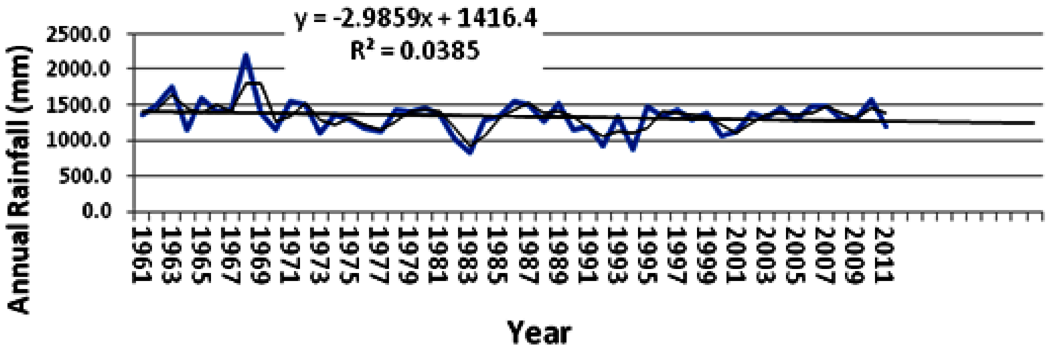

Fig. 2: ANNUAL TOTAL RAINFALL (1961-2011). THERE HAS BEEN A STEADY DECREASE OVER THE YEARS

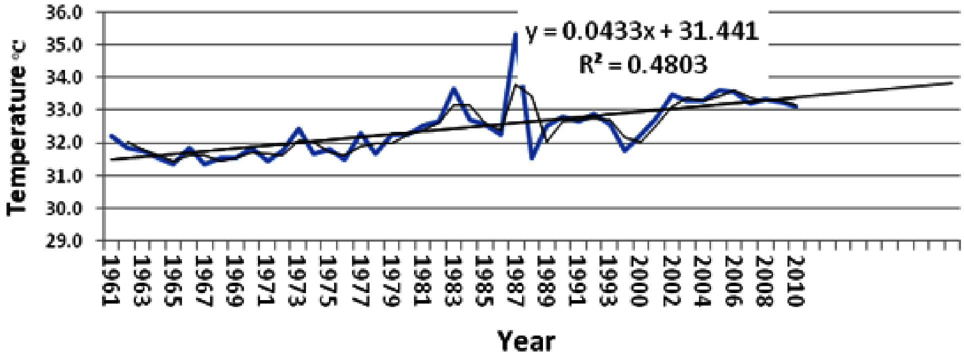

Fig. 3: ANNUAL MAXIMUM TEMPERATURE (1961-2011). THERE HAS BEEN A STEADY DECREASE OVER TIME

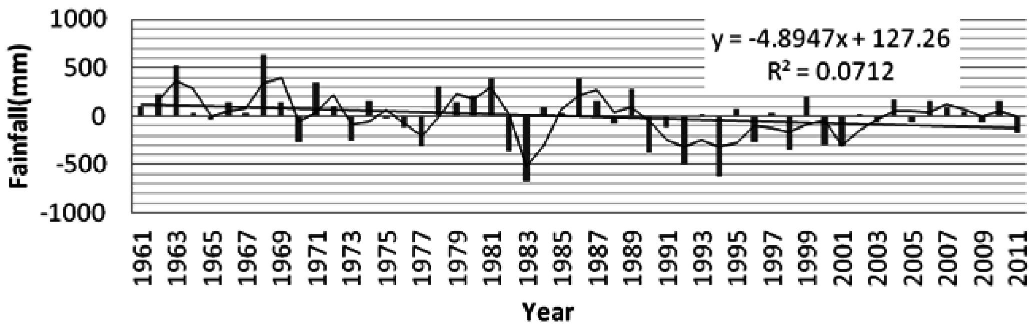

Fig. 4: Rainfall Anomaly (1961-2011). There Is A Trend from Positive Towards Negative Anomaly overtime

of about 3.0 mm per annum (figure 3). This translates into a change of about 150.0mm for the 50-year period. It is apparent that this trend would continue into the future. Notably, the passage of time alone has minimal effect on changes in the modeled rainfall trend: change in time explained just 3.8 percent of the trend in rainfall amount. Conversely, temperature has undergone a steady rise, and is projected to rise in future (figures 3 and 5). The mean quantum in temperature change over the same period is 0.04° C. Change in time explained a higher percentage (48 percent) of the change in temperature, quite higher than the proportion of change explained by time in rainfall change. Rainfall deficits and excesses have characterized the annual rains in the area (figure 4). Generally, rainfall exhibited a definitive trend from annual excess to deficit in the observed anomaly from the early 1960s to the present. From the trendline (Y=4.894x + 127.2) of the anomaly, there has been an annual deficit of 4.89 mm in rain amounts. A clear pattern of equal period (range of 3-5 years) of alternating rainfall deficit and excess characterized the period between the early 1960s and 1990s. Since the 1990s, the pattern of shorter periods of alternating excesses and deficits has changed. From 1990 to 2003, namely a period of 13 years, the area experienced the longest period of rainfall deficit. This was followed by more than a 9-yr period (2003-2011) of rainfall excesses. Whereas the deficits in the 1990s and early

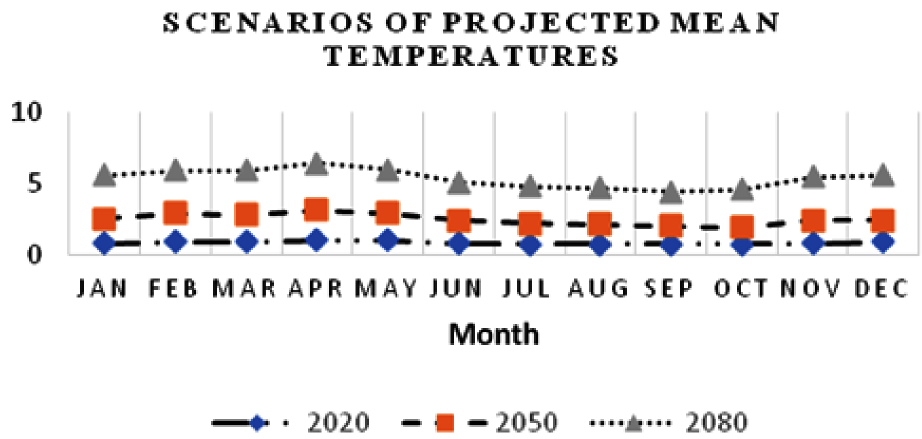

Fig. 5: Projected Change in Average Monthly Temperature

2003s were generally high, the excesses that followed were comparatively low. The trend in the rainfall deficit-excess pattern indicates that the area is becoming drier.

The general pattern of rainfall is expected to change in amount and distributions in time (figures 6, 7 and 8). Existing double maxima of rains in the transition zone is projected to change to a distinct single maxima, with the major rains occurring more exclusively in the second or minor season. It is also obvious that the monthly rainfall amounts, especially in the major season will be reduced significantly. This, however, would not translate into increases during the minor season (figures 7 and 8). Obviously, the onset of heavy rains in the major rainy season will delay. Reduction in the frequencies of heavy rains in the major season, with progressive dominance of evenness in rainfall amounts is indicated by reductions in standard deviations of rainfall amounts: 2020 (74. 13), 2050 (71.81) and 2080 (70.88).

Farmer perception of climate change and impacts

Farmers have observed changes in climate in terms of rainfall and temperature variations. To

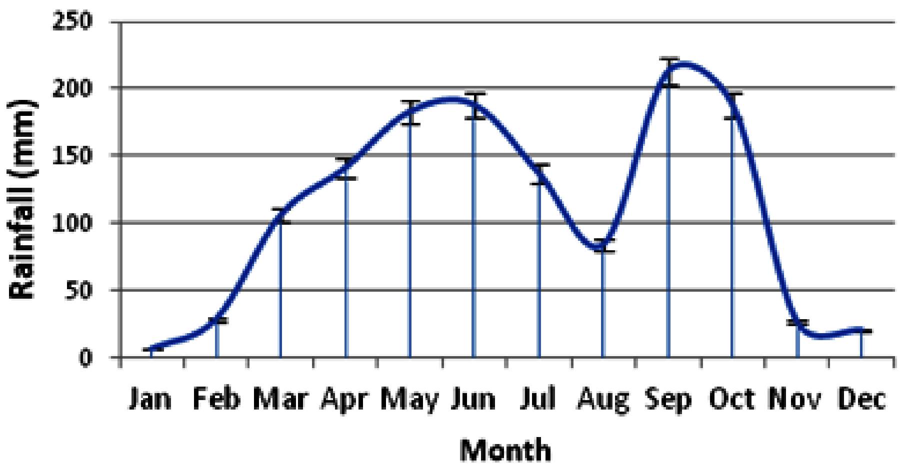

Fig. 6: Projected Annual Rainfall Scenarios

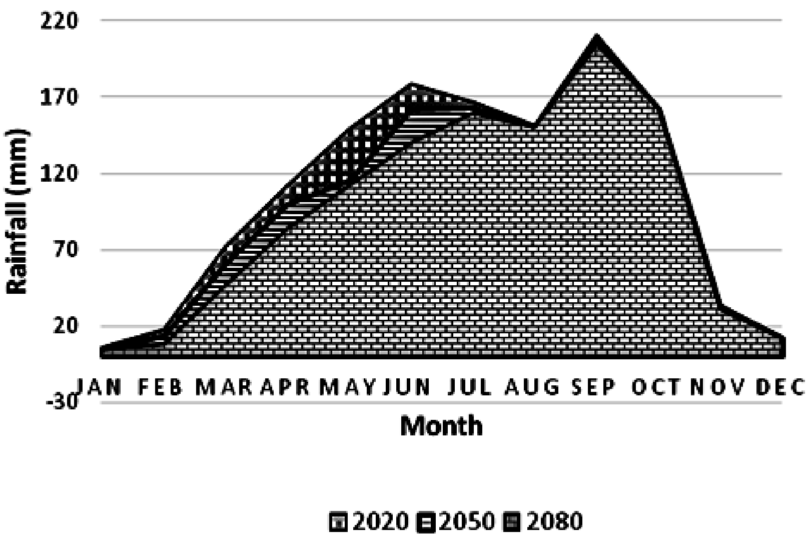

Fig. 7: Current Annual Rainfall

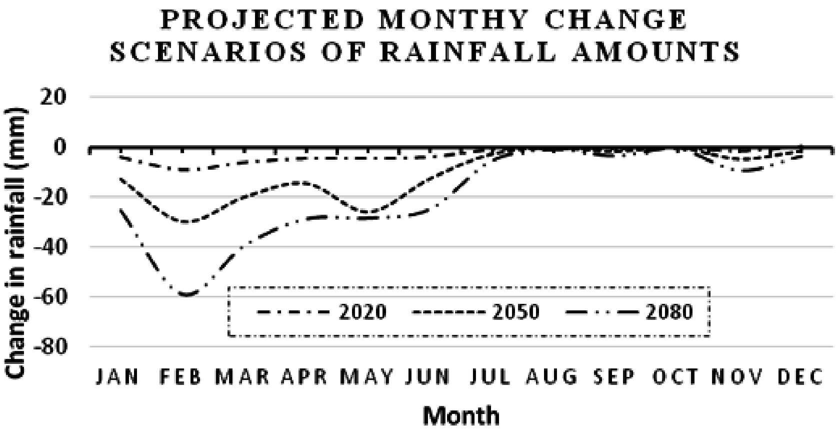

Fig. 8: Projected Changes in Scenarios in Rainfall

many, annual rainfall amount has decreased. Others claimed there has been uncertainty in the onset of rainy season: it may either delay or come quite early. Others indicated that rainfall has become quite erratic and unreliable. This could be in terms of amount, distribution, onset or cessation. Early cessation and poor distribution results in poor or failed cropping. Increased frequencies in bush burning were mentioned as a direct impact of temperature increases and reduced rainfall.

Current non-climatic stressors and vulnerabilities

Communities and farming systems in the area were assessed for conditions such of nature of soil and land tenure system that are not climate related. The poor soil was occasioned by permanent cropping and inability to purchase fertilizer, as well as changing vegetation with the proliferation and dominance of fast growing weeds. Many of the farmers were leasehold tenants and would normally intensify their farming activities to make the best out of their investment. About 74.0% of the farmers depended on others for farmlands: either on lease or shareholding. The farmers have limited financial resources and support to make substantial investments in farming inputs and adopt superior technologies to increase yields. Thus, they are limited in their capacity to expand and intensify their farming operations.

The farming system was totally rain-fed, hence climatically linked and highly exposed to climate dynamics. The percentage of those who employed some form of irrigation was just 2.0%. The farmers relied on the onset of rainy season to prepare their lands for cultivation. Over the years, they have gained experience in the use of weather patterns to predict the onset of rains. After clearing the land, they would wait till the rains begin for some days before seeds were sowed. If rainfall is inadequate or delays, seeds may fail to germinate or seedlings may die.

Farmers were aware that drought condition inhibits flowering, causes abortion of fruits or inhibits grain filling. They showed the research team poorly developed maize cobs (Figure 9) they harvested in the previous seasons when the rainfall was poor. In their ranking of crops according to drought tolerance, the farmers rated the flowering crops as most sensitive to droughty conditions, especially at the flowering and grain filling stage. These

Fig. 9: Negative Effects of Climate on Maize Yield

included maize, rice and cowpea. The ripening stage was not considered highly sensitive to low rainfall. However, a climatically induced challenge at this stage was that if there were heavy continuous rainfall events and limited sunshine at this stage, grains would get rotten. This may also happen when harvested grains are not effectively preserved.

Climatically driven adaptive farming practices

Farmers have been responsive to the observed changes. They have adopted strategies to transform and adapt their farming systems to avoid or minimize the impacts of climate change on their farming systems. They have taken advantage of prevailing climatic dynamics to optimize farming outputs. In principle, the transformations were made with the purpose of avoiding or minimize exposures to adverse climatic conditions, minimize sensitivities and optimize the benefits of favorable periods during the rainy season.

The rain-fed farming system is enhanced by farmers' ability to optimize the use of water, whilst minimizing or avoiding climatically unfavorable conditions. Farmers have, therefore, adopted strategies to minimize exposure of crops to climate change impacts at all the stages of the farming processes and all the phases of entire spectrum of plant growth and development. From accumulated knowledge and experience in recent past, farmers have strategized to avoid or reduce the exposure of maize to climate impacts. Maize has an extended growing period of 125-180 days whereas beans has relatively minimum water demands and short maturation period (75-100 days). Cowpea is cultivated first when the rains delay. After the cowpea is harvested, maize can be cultivated. This strategy is to avoid total loss from cultivating only maize when there is delayed onset of rain. Eighty percent (80.0%) of the farmers indicated that many of these innovations were introduced from about the year 2000.

Optimization of favorable climatic conditions

One stage of the rainy season that has been exploited for effective adaptive strategy development is the period just before and the peak season of the rains. With the observations of a temporal shift of rainfall, with relatively more heavy rains occurring rather at the end major rainy season (March to July) in recent years, farmers make use of stagnant pools of water and flood plains during the minor rainy season for rice cultivation. In the past, (i.e. before the 1990s), farmers claimed this was not the practice. From 1990 onwards, more than 80.0% of the farmers with suitable land conditions cultivated paddy rice with a growing period of 90-150 days.

Between May and June when the seasonal rains has long started, and planting of traditional crops was long over, marshy areas with high amount of soil moisture are prepared and cultivated with rice, since a high amount of moisture is required for the establishment of the seedlings. Three months after planting, in September, vegetative and fruiting coincide with the time of rains when the marsh lands get flooded. The farmers claimed that this critical stage of rice development requires high amount of water for fruiting or grain filling, or else there would be crop failure.

Reduction of crop sensitivity

The small-scale farming has evolved strategies to minimize sensitivity to climate change and variability impacts. One approach is the broadening of both within and between varieties of species. Some of the crop varieties introduced are capable of surviving on minimal water availability. Others were selected based on properties that enhance their capacities for drought resistance and avoidance. Some crops could be cultivated at different times of the year during the rainy season. For instance, different varieties of rice were cultivated, with each having different maturing periods and water requirements. If the seasonal rains are poor, the varieties with short maturation and minimal water requirements provide the insurance for food and household economic security, and prevent total loss of investments. According to the farmers, different crops have unique properties that ensure food security under different rainfall intensity and distribution. For instance, they claimed cassava could survive for a longer period of drought in the soil. Cowpea has a shorter growing period and less water demand, hence could be cultivated twice in a year, thus ensuring food security and improving household income. Consequently, cowpea has gained special attention and preference in recent years. Farmers have also adopted different drought resistant varieties crops developed by the Crop Research Institute (CRI) of the Council for Scientific and Industrial Research of Ghana (CSIR) located in Ejura within the forest savanna transition zone.

Discussion

Climate change

Evidence from this study suggest that the Northern Forest-Savanna Transition has been experiencing climate change since the 1960s (figures 2-7). The change is in the dimensions of monthly mean temperature, rainfall anomaly, rainfall distribution, shift in rainfall seasonality and annual rainfall amounts. Similar trends in climate change have been reported by other investigations in Ghana (Owusu & Waylen, 2009). Collins (2011) has statistically established a significant warming of between 0.5-0.8 degrees between 1970 and 2010 over West Africa using remotely sensed data with a greater magnitude of change in the latter 20 years of the period compared to the former. Obviously, the long term trend in climate change could continue based on the forecast made.

Shorter-interval alternating deficit and excess rainfall events that characterized annual rainfall dynamics from the 1960s is giving way to extended alternating deficits and excesses since the early 1990s (figure 4). Earlier research has made references to this trend, especially in relation to rains in the Sahel savanna (Mouhamed et al, 2013). Notably, the current phase of excess rain in the study is not as substantial in amounts compared to the preceding phase of deficits or dryness. Again, it is less in quantum than previous excesses. In the long-term, there is a general decline in rains: with an increasing trend in the short time scale. Hence, there is the need for caution in making definitive judgments on rainfall trends; rather, references must be made to the time scale of such analysis. The current phase of wet period appear to be part of short-term cyclic pattern inherent in the rainfall system. Clearly, the propensity in the anomaly is towards a deficit or general relative dryness in the area, and this would have both short and long term-implications for the farming systems without other sources of water (Figure 4). Prolonged and intense drought stress on both human and natural systems could be obvious corollary of these predicted climate change patterns. Prolonged deficits in rains could over-stretch existing coping strategies.

The rainfall regime of the area is shifting from the double to single rainfall maxima (figures 7 and 8). Heavy rains are expected to diminish in frequency during the major rainy season (May to August).This is expected to result in significant temporal decrease in rainfall amount and distribution, especially in the major rainy season. It is obvious that there will be a shift in the peak of rains from the major to minor season, with the new peak occurring in September to November. This is typical of the climatic pattern of the Guinea savanna. Thus, a more savanna type climatic conditions should be expected to prevail in future in the area. This may result in the change of cultivated crops, in favor of crops that are tolerant of savanna conditions. Existing farming systems may be subjected to extreme drought stress- resulting in high crop water demands, limited yields, food insecurity, low household incomes and poverty as prevailing in current savanna zones (Antwi-Agyei et al. 2012).

Exposure and sensitivity to climate change

The farming system in the area is strongly linked to climatic patterns, an indication of a significant exposure of the farming system to climate change. According to the study, all the stages of the farming activities, land preparation, sewing of crops, crop growth, development and maturity are strongly tied to rainfall events. As widely reported, the small-scale farming system is highly exposed to climate change since it is exclusively rain-fed (FAO, 2006; IFAD, 2011). There is alternative to the use of rain water for farming in the area, which implies a high degree of vulnerability to climate change.

Over-dependence of farmers on rain-fed agriculture with serious vulnerabilities render them highly sensitive climate change (Babel and Wahid 2011; Brouwer et al., 2007; Hertel et al. 2010; Johnson and Hutton, 2012). It has been demonstrated in this study that as climate change intensifies further, agro-climatic suitability for crops in the transitional zone will reduce (figures 10-12). Areas that are currently supporting different cultivated crops may no longer do so. Whereas indications confirm variability within crop and regional responses to climate change, general trends have been established.

An assessment based on the FAO/IIASA Agro-Ecological Zones model (AEZ) in conjunction with IIASA's world food system or Basic

Linked System (BLS), as well as climate variables from five different GCMs under four SRES emissions scenarios indicated a projected significant decrease in suitable rain-fed land extent and production potential for cereals as estimated under climate change by 2080 (Fischer et al., 2005). In spite of the possible changes predicted, it is also possible that the ultimate impacts would depend on the adaptive options the system adopts to minimize sensitivity and vulnerabilities.

Farmer adaptive responses

Empirical works on farmer adaptation to climate dynamics provides substantiated evidence to this claim (Vincent et al., 2011b; Yaro, 2010; Laube et al., 2012), and this is duly corroborated in this study. As indicated in the results, farmers have observed changes in rainfall and temperature, especially, as they influence their livelihoods and ultimately affect household economy and food security. Small-scale farming systems are known to be modified continuously to adapt to climate change for sustainability through adopting the use of a mix of innovative technologies (Ng'ang'a et al., 2013, Ofori et al., 2015).

Already, some small-scale farmers are adapting to climate change and variability through the use of crop varieties (including varieties from agriculture institutions) and modification of traditional farming practices (PAR, 2010). In this study, the strategies involve changes in land preparation, adjusting the timing of crop cultivation to converge with the periods of rainfall. These coping strategies have been identified by other investigators (Abou-Hadid, 2006; Vincent et al., 2011b). The shifts in seasonality, narrowing of annual rainfall distribution and an emerging pattern towards a single rainfall maxima may have also informed these adjustments.

The selection of a diversity of crops, use of drought resistant and tolerant crops have also been recommended as a means of reducing exposure and sensitivity to climate (Yaro, 2010; Laube et al., 2012). Diversity of crops, breeds and diversification of management strategies are the basis for developing desirable properties such as resilience and sustainability. Traditionally diversity is used as an insurance against risks, including climate related ones (Ayivor et al., 2015).

It has been suggested that African food production systems could effectively build adaptive strategies to curtail climate change risks (Funk et al., 2008). However, it is anticipated that managing intensified climate change risks which is projected to occur by mid-century will be an enormous task, with the highest likelihood of diminishing yield (Berg et al., 2013; Sultan et al., 2013). Based on regional scale, cereals are generally projected to be negatively affected in different localities (including West Africa) (Sultan et al., 2013) with cowpea having a mixed responses to different response under a variety of projected climate change and variability scenarios (Tingem & Rivington, 2009; Lobell et al, 2011). The projected outcome of this study largely supports these claims. Mostly, the crops that were preferred choices for building resilience in the farming system were projected to be negatively affected by climate change intensification from the 2050s onwards (figures 10-12). Maize which is the dominant crop in the area has been considered as one of the most vulnerable to climate change (Zinyengere et al., 2014). This long-term foreknowledge, obviously available to scientist, should inform evidence-based planned and anticipated adaptation and policy options that is more robust and built on current options.

Conclusion and the Way Forward

Climate has changed in the forest savanna transitional zone since the 1960s: it is expected to continue as forecasts indicate. From both the climatological analysis and farmers' perspective, there is demonstrable evidence of reduction in the distribution and amount of rain, increase in uncertainty of onset and cessation of rains, and a general increase in the deficits of rains. There is an emerging trend from a double towards a single rainfall maxima. Anticipated climate change intensification will aggravate climatic stressors on the small-scale farming systems. The existing and anticipated risks imposed by these changes have already set the stage for adaptive changes to minimize threats to the dependent farming system.

The mechanism of farmer response strategies adopted are not random but are systematically targeted and largely thought out to ensure optimal use of available rains to enable successful crop germination, growth and maturity by making changes in timing of cropping and introduction of crops with a variety of water demands.

Though agricultural institutions have contributed only minimally to farming systems adaptation, many of their strategies have gained widespread adoption through farmer experimentation, experience and transfer among neighbors.

It is recommended that any intervention for improved production sustainability must target building on current farmer adaptive capacities by exploiting existing current farmer knowledge and skills. For instance, it should be possible to improve the capacity of farmers in forecasting onset of rainfall to minimize crop failure and investment loss (Ingram et al., 2002; Luseno et al., 2003).

Further adaptive strategies must consider developing complementary strategies that minimize farmer sensitivities, vulnerabilities and non-climatic stresses: this should drive identifying future options of adaptation and policies. Developing alternative sources of water for farming, including irrigation (You et al., 2011; Burney and Naylor, 2012), and improving farmer rain water-capturing and storage capacities must be potential options (Passioura, 2006; Biazin et al., 2012).

Some interventions must also focus on developing new skills of alternative livelihood systems, purposely to curtail farmer climate change exposures, vulnerabilities and sensitivities as community over-dependence on climate-driven livelihoods is lessened. Developing options for adaptation and policy for improved resilience of the small-scale farming systems for sustainability must be informed by the above evidence.

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