Research Article

Climate Change Adaptation: An Ecosystem-Based Approach for Livelihood Improvement of Fringe Communities around Worobong South Forest Reserve in Ghana

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Anthropogenic and climate-induced change can potentially impact negatively on direct dependents of forest ecosystem services. To help build resilient societies, we examined the vulnerability of ecosystem-dependent communities in the Worobong South Forest Reserve (WSFR). We also examined climate variability impacts on forests and further suggested ecosystem-based adaptation (EbA) strategies for livelihood improvements in the study area. The reserve can be found in the Eastern region of Ghana. We administered 250 questionnaires as well as studied time series data for temperature and rainfall with satellite images using the mixed method approach. The types of questionnaires used were open-ended and closed-ended semistructured questionnaires. The study also involved a focus group discussion and the development of trend analysis of relationships between the two data sets in 2016. Our results show that respondents perceived variation in average annual temperature and rainfall over the past few decades as the main reasons for the decline in the supply of bush meat, freshwater, tree barks, and leaves in the study area. The results of the questionnaire corroborated those of the data for the time series obtained from the Ghana Meteorological Agency (GMeT) which is correlated with changes in the structure of (WSFR). To build resilient livelihoods and ecosystems, residents suggested strategies such as intensification of agroforestry systems with gain sharing arrangements, forest regulation enforcement, and bushfire control as ways to sustain the forests in the WSFR. We conclude that any measure to develop any climate change resilient mechanism in the WSFR should include those suggestions from residents.

1. Introduction

Climate change and the issues arising out of it is a defining challenge of our time [1, 2] and a threat to ecosystem services and goods supply in the long term. However, climate change may also provide other opportunities for a better accounting system for our natural resources globally [3]. According to TEEB [4] and Dasgupta, [5], the ecosystem goods and services are categorized into provisioning, regulating, cultural, and supporting services. Although key to the West African economy, agriculture, hunting, and other forest goods and services besides timber are livelihood activities that are responsive to climate change [6]. For instance, it has been reported that agriculture is a major livelihood activity that provides sources of income for approximately 75% of the population of West Africa, contributing about 30–50% of the gross domestic product (GDP) in that respect [7]. However, it is estimated that after 2040, climate change impacts will likely affect ecosystems and service-dependent economies by reducing their GDP's by an estimated 3.4% as a result of a predicted global rise in temperature of between 1.5°C and 2.2°C by 2060. Also, an estimated rise of 4.1°C in temperature will likely cost African countries a loss of 10 percent GDP [8] from the loss of livelihoods that are mainly dependent on ecosystem services. This is crucial

considering that Africa is among the regions at risk because of records of some of the worst impacts of climate change in the past [9, 10].

The impact of temperature and rainfall changes plays critical roles in ecosystems. For instance, there are reports of a sturdy decline in rainfall and the number of rainy days per each season over the past 30 years at the Nyerere International Airport in Tanzania [11]. Also, it has been reported in some studies in Ghana that salt and some major crop production has declined because of an erratic pattern of rainfall and temperature for more than twenty years [12, 13].

Comparing data from meteorological services and indigenous knowledge on climate change in the past has led to an increased accuracy in measuring the climate change impact on ecosystem services [14]. Such data comparison has been used to draw strong relationships between maize yields and mean seasonal precipitation in Tanzania [15]. According to Descheemaeker et al. [16] and Dinar et al. [17], a rise in temperature of 2.5°C is likely to reduce revenue from agriculture by 46% in Burkina Faso, but in a worst-case scenario, a 5°C rise may lead to a 93% to 100% reduction. Natural ecosystem provisions such as soil, water, air quality, pest control, carbon sequestration, seed dispersal, biodiversity conservation, and pollination are all affected by changes in the environment or climate within an area [18, 19]. Subsistence farmers are particularly exposed to climate change effects because their activities rely on weather conditions, mostly rainfall and temperature across the world [18].

Climate adaptation is a driver of sustainable development edge at the local setting with potential benefits in social equality improvement, economic savings, and environmental quality [20]. Adaptation is a climate action widely accepted as an intervention for vulnerable areas of the world. Several adaptation models have evolved around people and natural resources [21, 22]. Ecosystem-based adaptation (EbA), one of such models, is fashioned around ecosystems and natural resource-dependent communities such as recommended by UNEP [23] report. The goal of (EbA) is to dispense the natural system to buffer itself against the worst effects of climate change and other drivers of ecosystem deprivation. Also, ecosystem-based adaptation maintains the ecosystem resilience required to provide services that supports people and species adaption to climate change [23, 24]. Ecosystem services available within the forest for use by forest-dependent households are wild fruits, firewood, timber, and charcoal [25], and they play significant roles in an EbA strategy. In Uganda, integrated tree crops (barrier crop) and agriculture used as strategy led to the improvement of soil fertility and increased yields [4]. As part of the strategies to bolster the forest ecosystem and livelihoods of dependents, communities are encouraged to increase agroforestry practices, cultivate exotic and indigenous early maturity timber species, combat illegal chainsaws, establish greenbelts, fight against bushfires, improve irrigation, and stagger crop cultivation [26, 27]. The most important consideration in designing adaptation strategies is to consider the local conditions because there are different risks associated with ecosystems and affected livelihood groups [28, 29]. Considering local conditions could address the pitfalls in adopting any aspect of the approaches.

There has been a drastic reduction in forest cover from 8.2 million hectares in the 1980s to less than 1.2 million hectares in recent times through degradation and deforestation [30, 31]. According to the Ministry of Lands and Natural Resources [32], there were 188 natural areas under reservation, comprising 6 Ramsar sites, 125 forest reserves, and 16 protected areas. As a result of hunting, agriculture, illegal logging, other livelihood activities, and forest fires, many forest reserves such as the WSFR have experienced severe degradation [33]. The myriad of human activities and climate change impacts associated with WSFR underscore the search for the most effective, cost-efficient, and sustainable approach to resolving the conflicts between human livelihood and sustainability of natural resources and their associated ecosystem services. As a result, we sought to examine the vulnerability of fringe communities in accessing ecosystem services from the WSFR because of human activities and the effect of climate change or variability and propose appropriate EbA strategies to improve livelihoods and enhance forest management.

2. Materials and Methods

2.1. Study Area. One of the initial pristine forests created in the Fanteakwa District is the Worobong South Forest Reserve. The reserve is located in Begoro South, in the Eastern region of Ghana. The total size of the WSFR is 109.35 km^2. The reserve lies between latitude 4°30′N and 6°24′N and longitude 0° 35′W and 0°21′W in the semideciduous forest zone. The mean annual rainfall of the semideciduous forest zone is between 1200 mm and 1500 mm [19]. The area is made up of fringe communities that are natural resource dependent, leading to logging, frequent fires, and expansion of farmlands into forest areas. We chose this study site because of the high level of species diversity and their high dependency on natural resources, especially within the forest [33].

3. Methods

3.1. Study Design. We conducted this research using the mixed method approach for data collection [34]. The types of questionnaires used were open-ended and closed-ended semistructured questionnaires to solicit information about ecosystem services that WSFR provides, climate change (rainfall and temperature), or variability, and how they impact the respondent's livelihood. Before data collection, we conducted a pilot test within a section of the local population to validate the questionnaires we had prepared where we sought the respondent's understanding of our questions and used the feedback to design our questionnaires. We held a single focus group discussion with 12 residents from the five selected communities to set the climate and livelihood context within the chosen communities and recommend interventions for livelihoods and ecosystem improvements. We also held interviews with

some key informants such as the directors of the Forestry Commission of Ghana and the Ministry of Food and Agriculture (MOFA) of within the district (where WSFR is located) and the Feyiase chief all within the same district on their understanding on how the local residents adapt to climate change or variability. Ethical clearance was sought from the committee of ethics at the University of Ghana.

3.2. Data Collection. We selected five communities with a population of 3,205, namely, Feyiase, Mianya, Kumfere, Akwansrem, and Miaso, from sixteen (16) communities for the survey. We selected these five communities because of their high species diversity and people's high dependency on natural resources and ecosystem services [33]. These selected areas have populations of 1,129, 225, 634, 599, and 618, respectively. Furthermore, we systematically solicited 250 responses, representing about 8% of the study population. We selected the sample size for this study based on reports from previous studies that hundred (100) responses are a good representation for a survey of a population which is not more than 5000 as is the case with our study if the error margin we are looking at is 10% or less [35, 36]. We also administered survey instruments to the five selected communities using the population size of each correspondent community by assigning a percentage to get the correspondent respondents accordingly. We solicited 88 responses from Feyiase and 17 in Mianya. In addition, we sought fifty responses from Miaso, 47 and 48 from Komfere, and Akwansrem, respectively, by selecting household heads or their representatives for each quota. Our sample criteria were based on persons whose sources of income are mainly generated from forest resources with livelihood dependency on ecosystem services. The sampling was conducted systematically to enable us to design a sample frame and also select respondents alongside. Our focus group discussion was made up of a team of twelve (12) members including a local chief, farmers, and hunters involving both sexes. Moreso, we explored other secondary sources of data including online journals for published papers and reports. We also obtained the annual minimum and maximum temperature and rainfall between 1985 and 2015 from the Ghana Meteorological Agency (GMeT). We further examined trends in harvesting of timber for commercial reasons in WSFR to corroborate the results of the questionnaires. We obtained satellite images of the WSFR from the Centre for Remote Sensing and Geographic Information System (CERGIS) [37] which depicts a gradual change in the structure of the forest over a decade.

3.3. Data Analysis. We analyzed the data with descriptive statistics to determine the socioeconomic characteristics of the respondents. Cross-tabulation analysis was performed by linking the various ecosystem services to the respondent's livelihoods and also matching each type of socioeconomic behaviour with the respondents to determine any associations between revenue derived from ecosystem services and perceived climate change using a chi-squared test. Temperature and rainfall over the period of 1985–2015 from

GMeT were analyzed to establish historical trends. In addition, CERGIS satellite images of the WSFR were obtained for the temporal analysis of the status of the WSFR between 2000 and 2015 and explained the relationships between climate data and the satellite images of the WSFR. We use NVIVO software for the qualitative analysis of assessment of the interviewees. We matched the size of each household with the years of engagement in each livelihood activity for each respondent through Pearson's correlation coefficient to show if there was any relationship. This was to assess whether the size of respondents' households explained the extent of use of the forest ecosystem services and for that matter the likely impact on the resources.

4. Results

4.1. Socio-Demographic Respondents. Results from the study show that a little above 86% of the respondents were engaged in farming, and a few about 0.4% engaged in palm wine tapping. A little over forty-one (41.6%) of the respondents were females, while 58.4% were males. We recorded the highest number of female responses at Mianya with 58.8% with 41.2% being males of the total 17 questionnaires administered. We identified three major social groups of income within the five communities, namely, the high, middle, and low-income groups. The results further showed that a little over 63% of the respondents were classified within the low-income bracket with an annual income of less than 100 dollars, 17.2% within the high-income earners with an annual income of more than 200 dollars, and the rest in the middle-income bracket earning between 100 and 200 dollars per annum. In general, 33.6% of respondents had attained a junior high or a middle school level of education, while 27.6% had no formal education. The 35–44 year age group constituted about 30% of respondents, while the 45–55 age bracket constituted 24.8%. The rest of the age brackets were 27.6% for the15–34 age group and 16.8% for those above 55 years.

4.2. Vulnerability Assessment of WSFR Fringe Communities. Some socio-demographic factors of respondents were analyzed through a cross-tabulation analysis to reveal vulnerability indicators in 127 individuals or 87% of the male respondents and 86 people or close to 83% of the female respondents. These respondents ranked income reduction ahead of wildlife resource depletion and a rise in infectious diseases, etc. Based on livelihood activities of respondents, about 190 respondents or 87% of farmers in total used the decline of their income level as an indicator of their vulnerability to changes in conditions of farming in the area with 182 of the 190 farmers indicating that they have experienced various reductions in crop yields. We also documented about 175 individuals or 70% of the total respondents indicating that there is a decline in forest resources in their communities, while 156 people, constituting 62.4% of the total respondents, used a rise in soil depletion as an indicator of vulnerability. Furthermore, 134 individuals or close to 54% of the respondents also attributed to the

increase in wildlife resource depletion to climate variability or change in the study area. The least rated among the indicators was infectious disease spread with 31 out of 250 respondents attributing it as an indicator of vulnerability.

In comparing communities by analysing their degrees of vulnerability, 89% ($n = 88$) of respondents in Feyiase rated decline in income higher than any other vulnerability (the only community that did), while 88% ($n = 50$) and 85% ($n = 48$) rated reduction in crop yields in Miaso and Akwansrem, respectively. In general, most of the respondents numbering 133 and 84.2% of low-income earning respondents ($n = 158$) rated income reduction as the highest vulnerability indicator in their lives. According to 196 of the 250 respondents, rainfall patterns and temperature have changed over the past 20–30 years increasing both human and natural system vulnerability to climate change. They also showed a situation that had changed their livelihoods. The correlation between the number of years in undertaking a livelihood activity ($M = 3.19$, SD = 1.17) and household size ($M = 6.73$, SD = 2.98) was positive ($r = 0.54$, $n = 250$, $P < 0.01$).

4.3. Rainfall and Temperature Trends. Within the period under consideration, 1986 recorded the highest average annual rainfall of 3204.80 mm with 2002 recording the least with 776 mm (Figure 1). Between the years 1980 and 2015, the standard deviation and mean annual rainfall records were 748.54 mm and 1644.39 mm, respectively. This means that there was high variability in rainfall during that period. The decade spanning 2002 to 2012 recorded a reduced rainfall record in later years with short rain durations, especially during the major seasons. Over a 35-year period between 1980 and 2015, and in some cases, 27 years (1980–2007), temperature analysis at WSFR shows two maximum and minimum output levels. Based on Figure 2, there was a gradual increase in yearly average temperatures between 1980 and 2006 in the study area. There was a 1.1°C increase over the period with a maximum of 27.7°C in 2006 and 20.1 °C as minimum in 1986. Recorded temperatures between 1980 and 2006 showed standard deviation and mean values of 2.1°C and 24.51°C, respectively. The coefficient of the correlation value of 0.69 for the period 1980–2006 was statistically significant ($P < 0.01$).

4.4. Perception on Climate Change or Variability. There was a significant association between respondents' community of association ($\square^2 = 40.3$, $p < 0.001$), income levels ($x2 = 61.7$, $p < 0.005$), and the perception of change in the forest cover. There was a significant association between perceived impacts on ecosystem services such as land clearing ($p < 0.001$), cultivation ($p < 0.001$), and fertilizer use ($p < 0.023$) as human activities which have affected the study area ($x2 = 27.7$, $p < 0.005$). Satellite images taken at WSFR between 2000 and 2015 in two temporal units with the first indicating a relatively bigger area for closed forest (deep green) and the second shown as orange spots indicating a reduction in forest cover with bushfire incidences (Figure 2). The satellite image also displays areas of land degradation (grey colour),

and some small number of settlements (deep brown) within the reserve. Analysis of the satellite image shows that a large portion of the reserve has been degraded by bushfires with an increase in settlement and a reduction in forest cover. The perception of climate change responses from the respondents was statistically analysed using records of temperature and rainfall in WSFR.

4.5. Proposed Coping Strategies of Respondents. In terms of coping strategies as a result of a decline in resources in WSFR, 63% of the respondents indicated no coping strategies with the situation, with only 9% engaging in off-farm activities such as trading. According to 5% of the respondents, they worked extra hours, while 4% revealed that the expectation of high prices for their stored farm produce was their preferred option. In terms of suggested coping strategies, bushfire control was the most considered intervention accounting for about 28% of the response among the eleven strategies listed by the respondents. Several respondents suggested that agroforestry practices could be another type of intervention to adopt as a coping strategy against climate change. About 8%, 13%, and 6% of the respondents suggested improved incentives, improved law enforcement, and irrigation could adopt as coping strategies, respectively. With the exception of Mianya, all the respondents from the communities indicated their strong endorsement of strict law enforcement as a deterrent to would-be offenders of laws governing natural resources in Ghana (Figure 3).

Lack of knowledge in concepts, trust, and finance were some of the main issues hampering the success of proposed strategies intended for livelihood improvement and ecosystem service enhancement. Irrigation, crop diversification, change of planting time, tree planting, snail and grass-cutter rearing, and handicraft activities were some of the main livelihood activities of respondents. This shows that there is an established relationship between various EbA strategies for adoption and livelihood improvements, this and also enhances forest and ecosystem services.

5. Discussion

5.1. Vulnerability Assessment of WSFR Fringe Communities. Economic activities that depend on forest resources are generally climate sensitive and can potentially have adverse impacts on peoples' livelihoods when there is climate change [9–13]. Most of the respondents fell under the low-income bracket because they generate little from their livelihoods in the study area. This result agrees with the findings of similar research works conducted in other studies elsewhere where people in low income brackets were mostly found to be rural dwellers [38, 39]. Since the majority of the respondents (over 90%) have had some form of formal education and with over 70% of them being adults over 25 years of age, they were in a good position to offer explanations on climate change or variability as they perceive it over the years. They were also more experienced in linking their perceived climate change or variability to losses in the forest ecosystem and its cascading effect on their livelihoods. A closely related study also
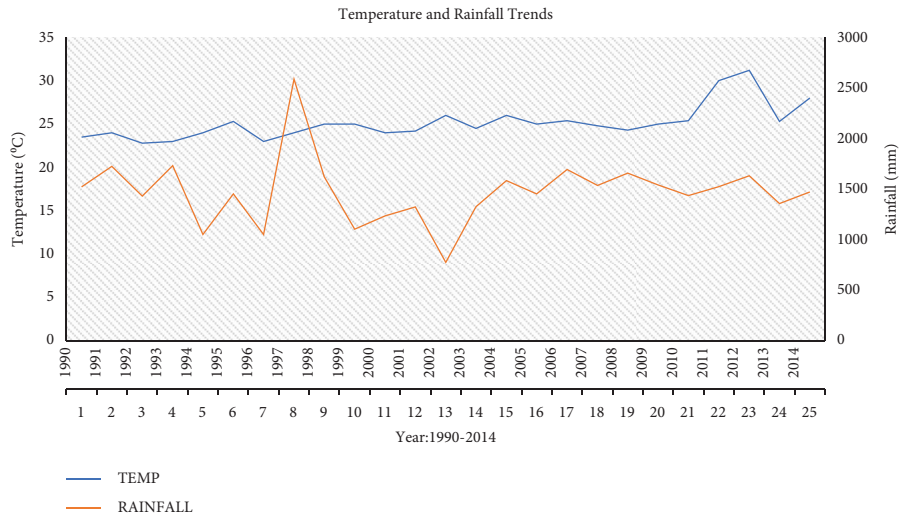
Figure 1: Average annual rainfall and temperature of WSFR. Source: GMeT, 2016.
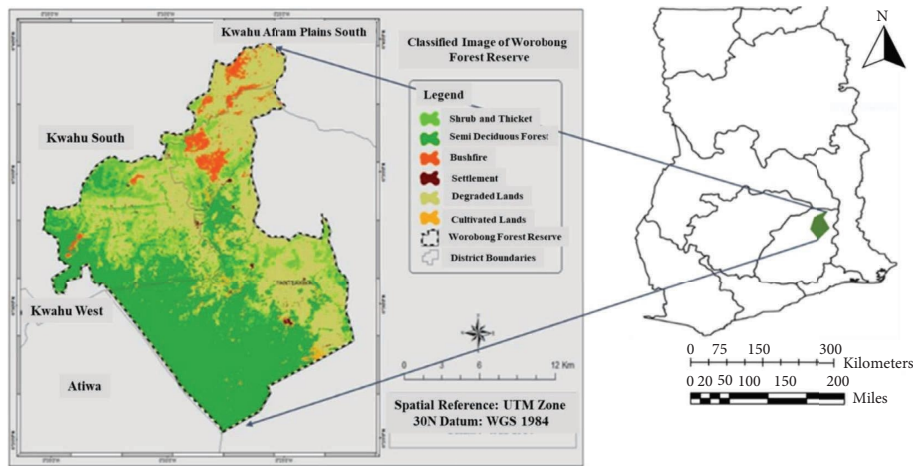

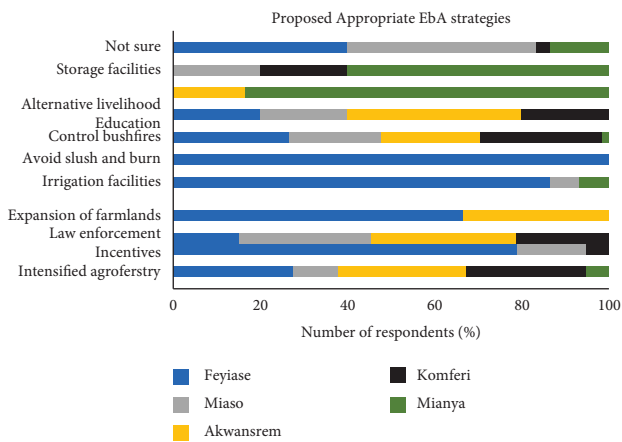Figure 2: Changes in WSFR between 2000 and 2015. Source: CERGIS, 2016 [37].

Figure 3: Adaptation strategies proposed as a measure to minimize climate change impacts.

reported that the quality of lives of people that depends on forest ecosystem services for their livelihoods is affected when there is a change in the forest and the ecosystems it offers [40]. This is because the supply of ecosystem services becomes irregular when the forest ecosystem is impacted negatively leading to degradation emanating from climate variability or change, indiscriminate use of forest and ecosystem resources, and other such factors [11–13, 40].

Reasons why most of the respondents indicated that a reduction in income levels is the biggest vulnerability to a change in the climate is highly correlated with the theory propounded by Dijk [41] and Sulemana et al. [42] that incomes from livelihood activities define the connection for social and economic freedom from exclusion and poverty. Most of the respondents classified under the low-income bracket and mostly dependent on agriculture indicated that the constituted forest resource depletion was one of the bigger threats to their livelihood.

The rainfall pattern in the WSFR has been erratic over the past decades with the area consistently recording variable patterns over a period of 35 years (1980–2015). As a result, the adult population (those above 25 years old) has acquired knowledge and experiences to know that there have been changes in the climate that have brought negative impacts on
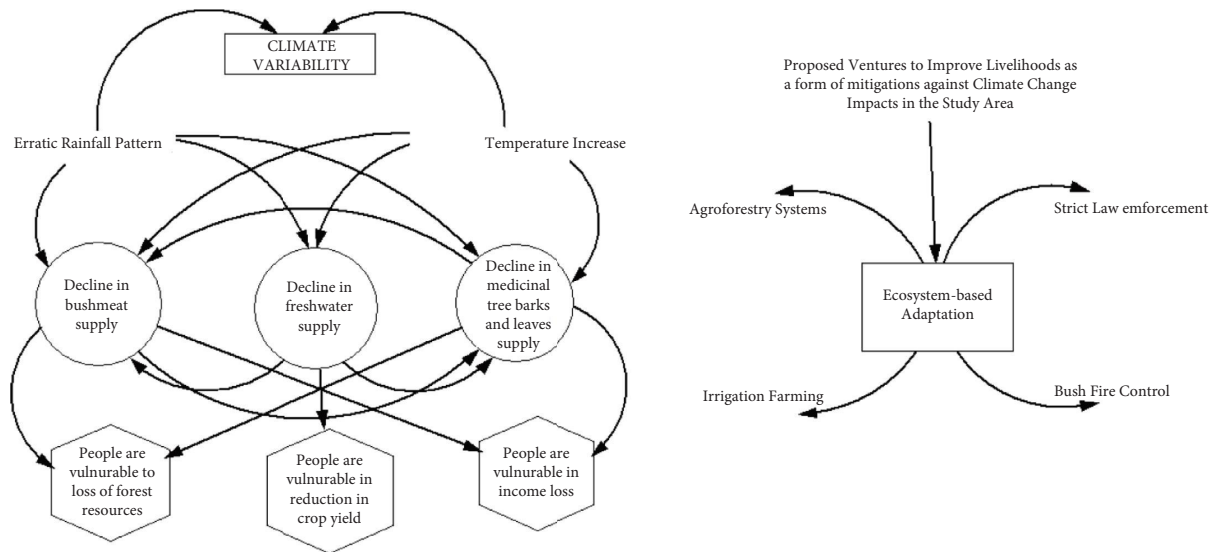
FIGURE 4: A schematic diagram of the research findings showing the impact of climate change or variability on people's livelihoods and the proposed ecosystem-based adaptation ventures to be adopted as mitigating measures.

their livelihoods. Other related studies within the area and other related environments also reported adverse effects of climate variability or change on the livelihood of people, especially on forest natural resources and ecosystem services [12, 13]. The results of people's perception on the effects of climate change on their sustenance were mainly through a reduction in hunting activities, farming practices, fresh water, and pestle and mortar supply because they are no more seeing those ecosystem services as it used to be decades ago.

5.2. Rainfall and Temperature Trends. The observed temperature variation between 20 and 35 years was an indicator that a reasonable level of livelihoods of the respondents could have been affected through impacts on natural resources and ecosystem services. This is because analysis of the trend over the same period shows a change in climate mainly through rising trends in both mean maximum and minimum temperatures and at the same period have a consistent decline in rainfall patterns within the WSFR. This observed trend corroborated the observed trends reported in previous studies [43–45]. The values of the standard deviation and the mean temperatures recorded for this study show strong variability in temperature values, and that was affirmed by a significant coefficient of variation [45]. This implies that temperature changes in the WSFR have been significant with time and are an indicator of gradual warming. Ironically, the area has recorded a weak positive variability in rainfall, although there is a large variability in the amount on a yearly basis. The result of this research confirms or validates the perception that people's lives have been negatively impacted by changes in rainfall and temperature patterns in communities near WSFR. Weather records show that the Eastern region where WSFR is located experiences a bimodal rainfall system between March and July for the main season and August to October for the minor season. Although the reduction in rainfall

pattern is erratic in the study area, the cumulative records are significant to negatively affect local annual and seasonal water balances relevant to the livelihood activities of people within the fringe communities. Previous research within the area reported declines in the production of some major crops due to changes in rainfall and temperature patterns [12].

5.3. Appropriate Ecosystem-Based Adaptation (EbA) Strategies. Most of the respondents indicated that their living standards had reduced. Despite the seemingly deteriorating living standards in the study area, nothing or just a few coping strategies had been implemented in contrast to what farmers would rather do to minimize or spread risks associated with their livelihood activities. Some of these coping strategies are mixed cropping, staggering planting/ sowing, farming sites, and improved crop varieties as happened elsewhere [47]. Few of the respondents decided on extreme, unsustainable, and expensive coping strategies such as the withdrawal of their wards from schools to work as food venders and petty traders. Apart from these coping strategies which were adopted by some of the respondents, there were other introduced strategies such as snail farming, rearing of grass cutters, and livestock production, although they were less preferred in these communities. The results of this study agree with the results of another study by Yeboah and Ameyaw [26], where communities adopted greenbelt establishment, planting food crops and trees, fighting bushfires, and indiscriminate chainsaws as climate change coping strategies.

The findings of this study are similar to another study where respondents indicated a number of obstacles that hinder their ability to adapt to coping strategies such as lack of finance and access to credit facilities, little knowledge of adaptation strategies, high cost or lack of labour, no access to land, and poor irrigation capabilities [48]. According to Yeboah and Ameyaw [26], the

promised future income or derived benefits from an adaptation strategy were the main motivators for adoption by fringe communities. Some of these derived benefits were the constant supply of farm inputs such as fertilizers and cutlasses, a share of planted trees of up to 40%, and the ability to manage an agroforestry area. Depending on the strategy, EbA mostly targets the most pressing adaptation needs, beginning from the most vulnerable and poor and those likely to be extremely affected by a change in climate the most [49, 50].

Intensification of agroforestry was the main solution offered by most of the respondents as a strategy for the restoration of forest degradation within the reserve, although they expected to be incentivized as stated above to care for their basic needs [26]. There were other proposed strategies such as avoidance of slash and burn farming methods, farmland expansion into the reserve, educating locals on natural resources and environmental protection, and storage of food, but only a few respondents would want to adapt them. All respondents from four communities, namely, Komferi, Akwansrem, Mianya, and Miaso did not find the strategy to avoid slush and burn farming useful. The fundamental underpinning of ecosystems and biodiversity improvement and the impact on livelihood improvement increases the need to focus on the EbA concept to continue educating the communities on the long-term effects of slush and burn on their livelihoods and ecosystem. [46]

6. Conclusions

The study has provided the fringe communities around WSFR with a good structure to adopt a number of proposed strategies by the EbA as a cushion against climate variability, change, and vulnerability. The study also determined the effects of climate variability or change on WSFR over 35 years that lead to a reduction in ecosystem services in the study area due to adverse impacts by human activities. To improve livelihoods in the face of climate change, our study proposed EbA strategies to improve forest ecosystems. Also, the results clearly showed that the farming activity was the common most important livelihood activity embarked on by all communities selected for the study. It has been established that societies build resilience against climate change through well-designed EbA strategies for sustainability. The overexploitation of forest resources and ecosystem services has negatively impacted WSFR, although extreme weather events such as severe drought and flooding have rendered the people within the fringe communities vulnerable to climate change impacts. Respondents who indicated preferences for law enforcement, agroforestry and irrigation, and bushfire control as resilient strategies are willing to adopt in pursuit of resilient strategies to improve their livelihoods in the face of climate change, also indicating that lack of finance, knowledge, permanent lands, and trust were the setbacks encountered by forest-dependent communities. As follow-up to this study, there is the need to evaluate the EbA strategies to determine the real benefits to people and the forest ecosystem in WSFR.

Most importantly, our study sought to prove the validity of the already existing theory that poverty is the main driver of high dependency on natural resources and ecosystem services, especially for rural dwellers [51, 52], and it also shows that these rural dwellers are aware of climate variability or change and the adverse impacts it has on their livelihoods and ecosystem services and further show that any intervention meant to improve their livelihoods to cushion them against climate change impacts should involve them from the onset to ensure its eventual success because they are already aware of a number of interventions that could improve their lives against climate change impacts. However, there was a theory that climate change impacts on a natural resource and ecosystem-dependent communities could lead to the withdrawal of pupils from schools by their parents to help in income-generating activities, thereby neutralizing the efforts made towards achieving the sustainable development goals of 2015 in Ghana and millennium development goal number 4. Figure 4 depicts the findings from the research and the proposed ventures that can be used as mitigation measures against the impact of climate change on livelihoods in the WSFR.

Data Availability

Data for the research was added to the manuscript and published in the paper.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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