Research article

Mapping the vulnerability of indigenous fruit trees to environmental change in the fragile savannah ecological zone of Northern Ghana

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ABSTRACT

Following the incidence of environmental change globally and its negative consequences on livelihoods of local populations, vulnerability assessment has become central to mitigation and adaptation response in the global south. However, researches on vulnerability to climate change in the African continent have seldom focused on Indigenous Fruit Trees (IFTs) although they are an essential part of the strategic forest resources and livelihood systems of local communities. This paper explores the vulnerability of two IFTs, shea (Vitellaria paradoxa) and dawadawa (Parkia biglobosa) to climatic and other stressors that are not directly linked to climate change in rural Ghana and the implications for planning. The paper analyzed vulnerability from farmer perspectives elicited through a mixed study design involving the use of Participatory Rural Appraisal (PRA) methods and a household survey. The results reveal that IFTs are highly vulnerable to drought, rainstorms, bushfires and charcoal production and less vulnerable to heavy precipitation, flash floods and sand mining. Such vulnerability arising from the combined effects of multiple stressors has led to a decreasing trend in production and yields of IFTs over the past few decades, adversely affecting livelihoods of rural women and households. To reduce vulnerability, it is an imperative to promote Environmental Change Adaptation Planning (ECAP) that prioritizes conservation and propagation of IFTs, and diversification of rural livelihoods.

1. Introduction

The long-standing contribution of forest ecosystems to the livelihood activities of households in the Global South has been recognised in both research in addition to policy debates (Chaudhury, 2017; Sonwa et al., 2012; Ofoegbu et al., 2017). It is estimated that the monetary contribution of forests to economies in the Global South exceed US$250 billion – exceeding the value of total development assistance and global output of minerals such as gold and silver collectively (Agrawal et al., 2013). Forest ecosystems are frequently noted to contribute in no mean way towards poverty reduction interventions of rural smallholders in Africa, and elsewhere in the world (Schreckenberg et al., 2012; Rasmussen et al., 2017; Mawa et al., 2021). Moreover, majority greater proportion of smallholder households within the rural and urban divide in Sub Saharan Africa (SSA) rely on forest resources and related products such as food, fodder, medicine as a means of earning a living (Belcher et al., 2015). Wild fruit tree consumption and marketing forms an important strategy in addressing food insecurity within a setting of climate change and variability for women in Ghana and Nigeria (Dapilah, 2012; Dansi et al., 2012).

However, the capacity of forested ecosystems to provide essential products for households into the future in SSA will be largely dependent on how they respond to global environmental change (Arneth et al., 2019; Sonwa et al., 2012). According to Kupika et al. (2017), 25%–42% of plant species in SSA could be under serious threat with a possibility of extermination attributable to more than 90% disappearance of their preferred habitats by 2085. The region is experiencing increasing climate change (Niang et al., 2014). Current and projected climate change for the region point to rising temperatures and declining rainfall (Niang et al., 2014). It is predicted that the regularity, extent and concentration of droughts and floods are expected to increase in the future (IPCC, 2018; IPCC, 2014). As such, the region has been identified as highly susceptible to climate change (Niang et al., 2014; Serdeczny et al., 2016). In climate change research, vulnerability is referred to as ‘the degree to which a system is susceptible to and unable to cope with adverse effects of climate change variability and extremes’ (Thomas and Warner, 2014).
Indigenous Fruit Trees (IFTs): shea (Vitellaria paradoxa) and dawadawa (Parkia biglobosa) trees in Northern Ghana. The shea and dawadawa are wild trees species that have huge socio-economic and cultural importance and have been viewed as a means for addressing poverty and food insecurity in this part of Ghana (Al-hassan and Abubakari, 2005; Dapilah, 2012). Yet, how these IFTs are responding to increasing environmental change in the North of Ghana and in parts of Africa are not well known. Against this backdrop, this paper aims to close this research gap by deepening our understanding of the exposure and sensitiveness of an ecological system to climate change and non-climate related factors influence the health and yields of shea and dawadawa trees using mixed method approaches. The empirical fieldwork was undertaken in four study sites in the Wa Municipal area of the Upper West Region in Ghana with a focus on measuring the perceptions of survey respondents on climate change. The paper asks whether anthropogenic and climatic factors have any significant influence on the health and yields of shea and dawadawa trees. We then explored why and how these IFTs are vulnerable to environmental change processes and how such an understanding can inform Environmental Change Adaptation Planning (ECAP).

In section part, we highlight the theoretical basis of the paper, focusing on how forest ecosystems such as IFTs are vulnerable to climatic and human-induced environmental change processes. We then proceed with a description of the study context and methodological approach in the third part. Part four covers the results including the social and economic status of our respondents, perceptions of vulnerability of IFTs to climate and human-induced stressors and the impact of these stressors on yields of IFTs. Part five discusses the results and their implications for planning adaptation of resource-dependent livelihoods in a changing environmental landscape in SSA. Our conclusions follow in part six.

2. Vulnerability of shea and dawadawa trees to environmental change

This paper takes inspiration from the vulnerability to environmental change literature to explore the susceptibility of shea and dawadawa trees to the impact of the changing environment in Northern Ghana. Vulnerability is often viewed in relation to the nature, extent, intensity and regularity of climate related change that an ecological system suffers an exposure, how sensitive it is, and its ability to undergo adaptation (IPCC, 2014; Adger et al., 2006; Derbile et al., 2021). The IPCC (2014) placed a spotlight on three domains of vulnerability, which includes the degree of exposure, sensitivity and the ability to adapt. The degree to which an ecology is exposed has been defined as the extent and intensity of variation of a climate stimulus (Adger et al., 2006; Fellman, 2006). It includes the elements at risk of a change in the climate of the ecology and how they are in contact with the phenomenon of climate change. The sensitivity of an ecological system to climate change underscores the nature of the adverse effects or beneficial effects on it as a result of climate change and variability (IPCC, 2014). These effects can be direct (e.g., flood, severe drought) or indirect (e.g., food insecurity due to a reduction in crop yields). Thus, sensitivity of the ecological system relates to how it entirely reacts to climatic extreme events and the extent to which form and function is changed as a result. The extent of exposure and sensitivity of an ecological system collectively define ultimate/likely impact of a climate stimulus on it. However, there is a general consensus that although an ecological system may seem to have a semblance of significant exposure and sensitivity to climatic stress, it cannot be conclusive that it is indeed susceptible to climate change (Adger et al., 2006). For the reason is that the ecological system's ability to adapt and even build resilience has nothing to do with its exposure and sentiveness (Thomas and Warner, 2019). In socio-ecological systems, the ability to adapt and bounce back after undergoing stress is examined in respect of the sturdiness of its internal structure in response to change (Berkes et al., 2005).

The shea and dawadawa trees are highly vulnerable to variable climatic circumstances, in addition to over-exploitation, and unfavourable land use activities that inhibit their generative capacity to growth maturity (Dapilah et al., 2018; Allakonon et al., 2021). Climatic factors have been observed to affect the availability of IFTs. The IPCC (2014) reported that a significant population of native species are under an imminent threat of extinction based on climate change. In Nigeria, Allakonon et al. (2021) observed an alteration in the shea tree density and their survival rate as part of evidence of dire impacts of ecological change attributed to climate change. Dimobe et al. (2020) projected that suitable habitats of shea trees in Burkina Faso are likely to lose their current value by about 13% by the year 2070 if estimated future climate circumstances become reality. Moreover, Thiombiano and Kampmann (2010) and FAO &UNEP (2020) also opine that prominent tree species of great economic value to indigenous communities such as shea and dawadawa have been subjected to degradation and are over-exploited. In northern Ghana, Dapilah et al. (2018) identified urban expansion exhibited in land use conversion into residential use, sand and stone mining as the main driver of shea tree depletion. Seasonal bush burning which is a common practice in Northern Ghana is also considered to be deleterious to savanna ecosystems including IFTs such as shea and dawadawa tree species. Therefore, mapping the vulnerability of IFTs to environmental change in places such as Northern Ghana is urgently needed towards promoting sustainability in the utilization of environmental resources and their protection against future climate change stressors.

3. Study area and methodology

3.1. The study area

The study sites were in the Wa Municipal area, which is within the Upper West Region, Ghana. The municipality lies between latitude 1.40° N to 2° 45’ N and longitude 9° 32’ W to 10° 20’ W and shares administrative boundaries with five other districts (Figure 1). It lies in the fragile Guinean Savannah agro-ecological zone. The shea and dawadawa tree is well-adapted to the climatic conditions of the savannah ecological zone and thrives favorably under a precipitation of 600–1400 mm annually while 3–7 dry months are usually experienced (less than 50 mm). A mean temperature 10–30 degree Celsius is also experienced in the area with alluvial soils which are very common (Orwa et al., 2009). Shea and dawadawa are agro-managed crops which mostly survive in the wild in the savannah regions (Lamien et al., 2006; Dienda et al., 2009). The shea tree in particular grows to attain an average height of 7.5 m but also has the potential to achieve a height of 12 m or more under very favourable conditions (Dimobe et al., 2019). It is resistent to fire by the help of a coarse thick trunk (Garba and Muhammad-Lawal, 2020). The dawadawa tree species have the capacity...
to grow under average precipitation of 500 mm annually in the Sahel and increasing to 4500 mm in the Guinea-Sudan ecological zone (Houndonougbo et al., 2020). It survives under a mean temperature of 26°C in regions where the dry season ranges between 4 to 8 months, the dawadawa tree is prominent. The tree is able to resist drought due to its long taproot which extends deeper into the soil to draw water and relevant soil nutrients. The fruit, although green when it is still growing is about 40 cm long and becomes brown on maturity. Several seeds are usually found in a single pod covered by a yellowish soft lining, which is sweet and edible. The shea and dawadawa trees have huge socio-economic and cultural importance for majority of households due to diminishing agricultural yields in Northern Ghana (Jasaw et al., 2015). The various parts of the shea and dawadawa tree species have diverse purposes. The fruits of the trees are eaten and the leaves are very palatable for livestock and (Lovett, 2004). The actual seeds are black and are processed into a natural spice, which is a delicacy many natives. The bark of the dawadawa pod is processed by boiling it in water while the residue of water after kneading the shea butter are used as a strengthener for plastering mud buildings in northern Ghanaian communities. They are also used for producing intricate designs in such buildings. Besides the dawadawa, shea butter (obtained from shea kernel) and used for cooking. Shea butter is also used for a variety of cosmetic, medicinal as well as ritual purpose in Northern Ghana (Laube et al., 2017). Moreover, the shea and dawadawa trees help to regulate the microclimate of the areas where they are growing and serve as wind breaks, contribute to erosion control and provide a good dwelling environment various micro and macro organisms (Jasaw et al., 2015).

3.2. Research methods and participants

The sampling procedure for this study was deliberately planned to ensure the participation of a fair sample of villages in the Municipality. The first step in selecting the sample involved a proportional stratification. The stratification distinguished villages of the Municipality principally on the basis of location (North, South, West and East). Four study sites were purposively selected across each stratum for data collection (Table 1). Following the sampling of the study sites, qualitative data were obtained using a multiplicity of research methods such as semi-structured questionnaire administration, in-depth interviews, focus group discussions and participatory workshops.

Table 1. Distribution of sample.

| Community | Population | Sample Share (%) |
|-----------|------------|------------------|
| Kpongou   | 2,266      | 80 (40)          |
| Nakore    | 1,772      | 60 (30)          |
| Guli      | 709        | 20 (10)          |
| Sing      | 1184       | 40 (20)          |
| Total     | 200        | 100              |

* Based on Ghana Statistical Service (2012).

We conducted interviews with key informants (a) on the basis of their roles in policy formulation or policy implementation or as persons involved in environmental planning and management in the municipality; and (b) individuals who depend on forest-based livelihoods. We identified key informants via a consultative discussion with actors during a workshop in Wa in February, 2019. We sought the inclusion of both males and females. A total of 71 key informants were also sampled including actors at the community and institutional level. At the community level, 28 in-depth interviews were carried out with actors such as chiefs, earth priests, assembly members, shea and dawadawa processors and traders as well as ordinary residents of the study sites. At the municipal level, a total of 12 key informants were sampled, including the Development Planning Officer, Field Officer at the National Disaster Management Organization (NADMO), Agricultural Extension Officer, Officer at the Ministry of Food and Agriculture (MoFA) and the Department of Community Development. Interviews were conducted face-to-face between March–June, 2019 with the aid of an interview guide.

3.3. Semi-structured questionnaire

The questionnaire we administered to participants contained a mix of open-ended and close-ended questions on factors that drive vulnerability of shea and dawadawa trees, environmental change processes taking place in the communities, the trends and patterns of environmental change across temporal and spatial scales and the extent of exposure and or susceptibility to environmental hazards and the adaptive capacity of shea and dawadawa trees to ecosystem change.
processes. To ensure that this data collection instrument was free from errors, we vetted it, and the challenges and matters that arose were discussed and resolved subsequently. Interviewees from diverse peri-urban communities in the Wa Municipality were chosen for pre-testing the tool. This provided us with information on the effectiveness, accuracy and average duration of the interviews. This was done prior to the data collection.

A total of eight focus group discussions were held for males and females (four male groups and four female groups) in the study sites. The average size of the groups was eight. Participants in the focus group discussions were purposively selected to reflect the socio-economic segments of the community (e.g., age and occupation) and in-depth local knowledge of community environment and change processes. Participants discussed emerging issues raised in the semi-structured interviews. The aim was to understand groups’ perspectives and experiences of environmental change in their communities and in particular the exposure, sensitiveness and adaptation ability of the two IFTs studied. The interviews and discussions were conducted in the presence of two research assistants with the aim of reducing interpretation bias and for clarification of discrepancies, and to enable validation of responses from interviewees. The interviews were conducted either in the local language (Walail) or English language with each lasting between 45 min and 1h 15 min. All the interviews were audio recorded after permission of the respondents was granted.

The survey was used to supplement data collected from semi-structured interviews and focus group discussions. A total of 200 questionnaires were administered to household heads in the study sites. The questionnaire was pre-coded with a few open-ended questions. The procedure adopted in sampling was meant to ensure a fair number of households in the study sites. Issues covered in the survey included the socio-economic profile of households; perceptions of environmental change process across temporal scales including climate change and impacts on shea and dawadawa trees. The use of the survey allowed a thorough analysis and appreciation of salient practices and forms of activity relative to environmental change and IFTs.

The data generated from the field were analyzed using qualitative and quantitative methods. Content analysis which involves searching transcripts and documents was used to analyze data derived from semi-structured interviews and focus group discussion. In this case, the text in the transcripts were coded based on the following categories: perception of climate change, climate stressors, vulnerability of shea and dawadawa trees to climate stressors, human-induced process and impacts on shea and dawadawa trees. This allowed us to grasp the varying opinions of our respondents and to have deep insights that enabled us to address the research question. Transcript data were presented in quotes and discussed in relation to, and contrasted with the experiences or opinions of other informants.

### 3.4. Data analysis

The survey data were coded and inputted into Statistical Package for Social Sciences (SPSS version 24). We cross-tabulated, analysed the variables and interpreted the frequencies before processing the results into tables, graphs and percentages. We used Chi-square ($\chi^2$) analysis to determine how respondents’ perspectives on climatic and anthropogenic stressors impact the health and production of shea and dawadawa trees in the study site. Statistical significance where $P$ values were less than 0.05 ($p < 0.05$).

**Hypothesis:**

1. Anthropogenic factors (bushfires, sand winning and charcoal production) have no significant influence on the health and production of shea and dawadawa fruit trees.
2. Climatic factors (drought, heavy rainfall, rain storms and flash floods) have no significant influence on the health and production of shea and dawadawa fruit trees.

The Chi-square model used was as follows:

$$\sum_{i=1}^{k} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where: $E_{ij}$ is the anticipated frequency of the cell in row $i$ and column $j$ and $n$ is the sampled population. $E_{ij} = \frac{(row \; total \; x \; column \; total)}{n}$

The degree of freedom (df) = $c * (r - 1) + (c - 1)$ but from the table, $c = 3$ and $r = 4$

$df = (3-1) (4-1) = 2 * 3 = 6$ for climatic stressors and for anthropogenic stressors, $df = (3-1) (3-1) = 2^2 = 4$. The confidence level was $0.95$, $\alpha$ was $0.05$ while $\chi^2$ was critical at 12.6.

**Ethical approval**

The methodology used in this paper followed the ethics policy of the Simon Diedong Dombo University of Business and Integrated Development Studies and was duly approved by the Research Ethics Committee.

### 4. Results

#### 4.1. Socio-demographic profile of respondents

Out of the 200 household heads or spouses who participated in the survey, 64% of them were males whereas 36% were females. Over one-third (67%) of the respondents were within the age cohort of 41–50 while the least (4%) were in the age bracket of 21–30 (4%) and 60+(4%). More than half of the respondents (64%) had no formal education with about 29% and 4% of them having attained primary and tertiary education respectively. A predominant majority of respondents (86%) were married. As described previously, the primary data analyzed here was collected from four communities, Kpong, Nakore, Gul and Sing through Participatory Rural Appraisal (PRA) Methods and a household survey. A total of eight (8) focus group discussions were held for males and females, seven (7) in-depth interviews amongst key informants and two hundred (200) questionnaires were administered to household respondents.

#### 4.2. Perception of climate change and impacts on shea and dawadawa trees

The results reveal perceptions of the incidence of climate change and climate variability. Respondents mentioned that changing climate is accompanied by an erratic rainfall pattern, short rainy season, increasing regularity of extreme climatic events including floods, rising temperatures and windstorms. The view of a middle-aged respondent Guli gives a general impression of the erratic nature of rainfall as expressed by our respondents. ‘In some years, the rains will start very early whiles in some other years, rains will stop very early’. Likewise, a 30-year-old female farmer during an interview had this to say about the changing rainfall pattern in Nakore: ‘when I was a child, we had more rains than presently. The rains were consistent and made it possible for our parents to know when it will start and when it will end’. The results from the interviews and discussions were not different from our survey results. Majority of respondents (98%) believed that their communities have witnessed climate change and variability over the last thirty years. About 89% of respondents perceived that annual rainfall amounts had declined accompanied by short duration of the wet season (87%), an intensification of lateness in the beginning of the season (94%) and early stoppage of the rains (98%). Moreover, the respondents perceived that climate extreme events including prolonged drought (92%), heavy rainfall (84%), flash floods (75%) and increasing temperatures (95%) as well as increasing regularity of windstorms (88%) have increased over the last two to three decades.

#### 4.2.1. Climate change impact on shea and dawadawa trees

The assessment revealed four climatic stressors, namely, drought, heavy rainfall, rain storms and flash floods. The essence of the assessment
was to determine respondents’ perceptions on the impact of these stressors on the health and production of shea and dawadawa trees. The results revealed observed significant impacts of rainstorms and droughts on the health and production of these indigenous trees. The analysis revealed that droughts and rainstorms had the greatest negative impact on both shea and dawadawa trees while heavy rainfall and flash floods had the least impact. First, from the analysis of the survey data, majority of respondents (about 67%) ranked the negative impact of drought on shea health and production as high. Similarly, for dawadawa trees, the majority of respondents (68%) ranked the impact of drought as high (Table 2). From interviews and FGDs, respondents/discussants agreed that drought does affect the health and production of the shea and dawadawa trees negatively. In particular, prolonged drought was identified to affect the flowering and size of the fruits of the IFTs. High temperatures associated with drought thwarted the flowering of trees leading to poor fruiting, a point that was generally agreed on by respondents. Drought caused the fruits and nuts produced by the IFTs to be malnourished, smaller and ultimately of reduced quality. As mentioned, drought caused the fruits and nuts produced by the IFTs to be malnourished, smaller and ultimately of reduced quality. As mentioned, drought caused the fruits and nuts produced by the IFTs to be malnourished, smaller and ultimately of reduced quality. As mentioned, drought caused the fruits and nuts produced by the IFTs to be malnourished, smaller and ultimately of reduced quality.

Secondly, majority of respondents (50%) and (34%) indicated that rainstorm had high impact on shea and dawadawa health and production, respectively. This assertion was corroborated by the qualitative data. Respondents in interviews and discussions mentioned that rainstorms were frequent between April and June, a period that coincides with the flowering, pollination and fruiting of the two IFTs studied. Hence, the intensity and frequency of rainstorm in this period do cause the shedding of pollens of the shea and dawadawa trees leading to low yields and production. However, in comparative terms, rainstorm was identified by respondents as having a higher negative impact on shea than dawadawa trees, something attributed to the phenotypical differences between the two. Our respondents believed that the pollens of shea were fragile and highly susceptible to winds. As narrated by one respondent in Kpongo: ‘winds that accompany rains at the beginning of the seasons are very destructive and cause a lot of havoc to shea trees. For instance, these strong winds can destroy the shea tree pollens and cause even unripe fruits to fall prematurely’. When strong winds occur shear fruit usually responds to gravity when it is matured and ripe. This is not the case with dawadawa fruits which hardly fall due to strong winds. The assessment revealed an inverse relationship between wind/rainstorms and the yield of shea nuts. In years of strong winds, particularly, during the fruiting of shea trees, the yield of shea nuts was often low and vice-versa.

As the results show, heavy rainfall and flashfloods have the least negative impact on shea and dawadawa health and production. The analysis reveals that majority of respondents (53%) ranked heavy rainfall as having a low impact on shea and dawadawa health and production while 68% of respondents hold a similar view in respect of flash floods. It was for example argued that although flash floods caused soil erosion, exposing the roots of IFTs to the vagaries of the weather, they did not cause severe harm. Likewise, heavy rainfall did not occur frequently during the flowering and pollination stages of the IFTs, hence, had low impacts on their health and productivity.

4.2.2. Impact of anthropogenic stressors on Indigenous Fruit Trees

The results also reveal that bush fires, charcoal burning and sand mining were identified as environmental stressors that affect the health and production of shea and dawadawa trees. First, the majority of respondents (69%) ranked bush fires as having the highest impact on shea health and production while 65% asserted similar ranking for the impact of bush fires on dawadawa trees (Table 2). Shea trees are exposed to the risk of bush fires because they grow in the wild with no or less management practices, making them highly vulnerable to perennial bush fires. For example, bush burning is common during the dry season, a period that coincides with the flowering/pollination and fruiting stages of IFTs hence when they are burnt by fires, they are unable fruit well. Moreover, in some instances, fires do kill the shea and dawadawa trees. This makes it highly susceptible to bush fires which destroy trees and or adversely affect their growth and productivity.

Secondly, about 51% of respondents ranked the impact of charcoal burning on the health and production of shea and dawadawa trees high. However, the results further revealed that the impact of charcoal burning on dawadawa health and production was negligible. It was explained by respondents that the production of charcoal has increased over the last decades in response to growing urban demand for charcoal and declining agricultural yields arising from climate change. It was further explained by respondents that charcoal made from the shea tree is of better quality and much preferred by customers compared to that made from dawadawa trees. This makes shea trees susceptible to lumbering for the purposes of charcoal production. Indeed, many respondents mentioned that the shea tree population has been declining over the last decade because

Table 2. Perceived impact of climate change and stressors on IFTs.

| Impacts of climatic stressors on shea health and production | Ranking | Rainstorms | Drought | Heavy rainfall | Flash floods | Total | Value | df | Asymp. Sig. |
|-------------------------------------------------------------|---------|------------|---------|---------------|-------------|-------|-------|----|-----------|
| Low                                                         | 38 (19%)| 15 (7.5%)  | 106 (53%)| 136 (68%)     | 295         |       |       |    |           |
| Moderate                                                   | 62 (31%)| 52 (26%)   | 34 (17%) | 35 (17.5%)    | 183         |       |       |    |           |
| High                                                       | 100 (50%)| 133 (66.5%)| 60 (30%) | 29 (14.5%)    | 322         |       |       |    |           |
| Total                                                      | 200     | 200        | 200     | 200           |             |       |       |    |           |

| Impacts on climatic stressors on dawadawa health and production | Ranking | Rainstorms | Drought | Heavy rainfall | Flash floods | Total | Value | df | Asymp. Sig. |
|-----------------------------------------------------------------|---------|------------|---------|---------------|-------------|-------|-------|----|-----------|
| Low                                                             | 51 (25.5%)| 19 (9.5%) | 118 (59%)| 130 (65%)     | 318         |       |       |    |           |
| Moderate                                                       | 81 (40.5%)| 45 (22.5%)| 34 (17%) | 48 (24%)      | 208         |       |       |    |           |
| High                                                           | 68 (34%) | 136 (68%) | 48 (24%) | 22 (11%)      | 274         |       |       |    |           |
| Total                                                          | 200     | 200        | 200     | 200           |             |       |       |    |           |

| Impacts of anthropogenic stressors on shea and dawadawa health and production | Ranking | Bushfires | Sand mining | Charcoal production | Total | Value | df | Asymp. Sig. |
|-------------------------------------------------------------------------------|---------|-----------|--------------|---------------------|-------|-------|----|-----------|
| Low                                                                           | 26 (13%)| 82 (41%)  | 67 (33.5%)    | 175                 |       |       |    |           |
| Moderate                                                                      | 37 (18.5%)| 52 (26%) | 32 (16%)     | 121                 |       |       |    |           |
| High                                                                          | 137 (68.5%)| 66 (33%) | 101 (50.5%) | 304                 |       |       |    |           |
| Total                                                                         | 200     | 200       | 200           |         |       |     |    |           |

Source: Derived from field survey, 2019
charcoal producers target them for logging for the purpose of charcoal production. The impact of charcoal production on IFTs has been succinctly put forward by a male farmer in Nakore: “all the important trees are now being felled for charcoal. They are now felling the shea tree and the dawadawa trees which are economic trees. Now we do not talk of the shea tree again. All the charcoal you see them carrying are gotten from the shea tree. In the past we used to have big shea trees in the community but now you cannot see even one. Now, if not on your farm, you cannot get shea nuts to pick”.

Finally, majority of respondents (41%) ranked the impact of sand mining on IFTs as low. Thus, only 33% of respondents ranked the impact of sand mining high. Sand mining was mentioned in relation to its negative impacts on the health, development and population of IFTs. The interviewees mentioned that sand mining activities involve the removal of large tracts of vegetation including shea and dawadawa trees. In other instances, it involves the removal of top-soils that support IFTs, hence making them highly susceptible to run-offs from flash floods and windstorms.

4.3. Impact of environmental stressors on yields of IFTs and livelihood

The study further examined the impact of environmental stressors on the yields of IFTs. The analysis of respondent perspectives so far reveals that the combined impacts of climatic and anthropogenic stressors have contributed significantly to a declining trend in the yields of shea and dawadawa fruits. First, analysis of data from the survey show majority (95%) and (91%) of respondents reporting that shea and dawadawa yields respectively were decreasing over the years as a result of the impact of environmental factors (Figure 2). Secondly, results from the Chi-square ($\chi^2$) analysis revealed that environmental factors, especially, climatic factors adversely affect shea and dawadawa health, production and yields.

To further analyse the consequence of climate change on yields of IFTs, we compared rainfall data using the Standard Precipitation Index (SPI) and shea nut yields (Figure 3). While the rainfall data pertains to Wa, the data on shea nut yield reflect country level statistics of Ghana due to the lack of segregated data for the Wa Municipality. However, given that the Wa Municipality is part of the northern savanna area with similar climatic and rainfall patterns, albeit, little variations, and also the major shea producing area of the country, the analysis provides useful proxies for understanding the relationship between rainfall and shea yields. The analysis reveals that shea yields were stable at a range of between 2,000 and 3,000 tons per hectare between 1985 and 2005, a period of relatively normal rainfall ($\text{SPI} = 0$ to $-0.5$ or $+0.5$). The analysis also reveals that between 2006 and 2018, there were more dry years (SPI of $-0.5$ and above) and a drying trend corresponding to a reduction in shea yields (Figure 3). During the period, shea yields dropped from the previous range to between 1000 and 2000 tons per hectare. Although there are many environmental stressors that may impact shea yields, the analysis on rainfall reveals that a drying trend, particularly, droughts adversely affect shea production and lead to a reduction in fruit and nut yields. This corroborates the analysis earlier on that revealed a high impact of drought on shea yields.

Furthermore, respondents and discussants revealed that decreases in yields of shea and dawadawa fruits and nuts have resulted in shortages in supply in the market. This has adversely affected access for women who depend on them as raw materials for various economic activities in the agricultural value chain. The women affected include women who trade in the nuts and seed and or process the raw material into various products, especially shea butter and spices (Figure 4).

The discussants, especially female FGD discussants revealed that women were worried about the declining trend in shea and dawadawa yields because it adversely affected their livelihoods, especially, employment, nutrition and income. First, it has led to shortages in the supply of the nuts and seed, increasing prices, production cuts of shea butter and dawadawa spices, both of which are very important for cooking among rural households. Shea butter (Figure 4a) is the most common and most affordable butter for cooking among rural households and it is known to have very good nutritional and medicinal values. Secondly, cooking spices (kal or kpali) (Figure 4b) made from dawadawa seed is a rich source of plant protein and a good alternative to animal protein, the former being more economically affordable to rural households than the latter.

5. Discussion

This discussion is premised on the conceptual framing of vulnerability as exposure and sensitivity to stress and the lack of and or limited adaptive capacity (Fellmann, 2012; Derbile et al., 2021). The results from the study reveal that IFTs, particularly, shea and dawadawa trees are highly vulnerable to drought, rainstorms, bushfires and charcoal production and less vulnerable to flash floods and sand wining. Hence, exposure to climatic stressors (drought and rainstorm) and non-climatic...
stressors (bushfires and charcoal production) destructively affected the health and production of these IFTs and resulted in a decreasing trend in fruit yields over the past two decades. Our results compare well with some other studies in SSA that show that environmental change, including climate change has negative consequences on forest/tree resources and negative implications on sustainable livelihoods (e.g., Mbow et al., 2014). These studies have highlighted that fruit production of shea trees did not positively correlate with average yearly temperature, temperature and rainfall irrespective of the season and sun shine (Fischer et al., 2016; Bonde et al., 2019). In a similar vein, studies in Burkina Faso and Mali suggest that shea fruit production reduces with rising intensity of temperature and sun shine. Likewise, improved ability to flower and likelihood of lavish flowers have been noted where yearly precipitation is higher while there is a reduction the yearly mean temperatures (Bonde et al., 2019). While these studies highlight vulnerability of IFTs to climate change; our results go beyond such scope, highlighting an integrated and comparative approach to vulnerability assessments and revealing that within the context of environmental change, IFTs are vulnerable to climate and human-induced stressors.

Furthermore, this study addresses the connection between IFTs and climate extremes in northern Ghana, an area some researchers assert there is little empirical research on (Tom-Dery et al., 2019; Kent, 2018;
Pouydal, 2011). Adding to this body of literature, our results mainly provide insight into the different ways in which climate extreme events including drought, rain/windstorms, heavy rainfall negatively affected flowering processes, fruit production and growth of shea and dawadawa trees. We show in our results that drought and rain/windstorms have the highest negative impact on shea and dawadawa trees. Drought leads to water deficits and stalls the growth of IFTs. However, age and root systems of IFTs are key phenotypical characteristics that determine the resilience of IFTs to drought. For instance, shallow-rooted trees are said to be more susceptible to water deficits than deep-rooted trees (Moore and Allard, 2008). Thus, the shea tree, with its tap and lateral root system, has the ability to cope with drought conditions. Moreover, adult trees are deep-rooted and have the capacity to store water and plant nutrients making them less sensitive to drought compared to young trees. Majority of the shea and dawadawa trees in northern Ghana appear to be young and stunted which increases their susceptibility to drought and water deficits with potential consequences on sustainable livelihoods (Moore and Allard, 2008).

Exploring the susceptibility of forest and tree resources to climate change is urgently needed particularly in Sub-Saharan African region (SSA) where a significant proportion of the population survive on livelihoods that are intricately linked to natural resources (Niang et al., 2014; Dimobe et al., 2020; Rousseau et al., 2017). In Northern Ghana, dawadawa and shea fruits serve as food for many households who suffer from food shortages during the lean season and as such, offer avenues for poverty reduction and economic empowerment of women in particular (Kent 2018; Pouydal, 2011). Women are known to depend on IFTs prominent among which are shea and dawadawa trees for income generation necessary to support their families and for their economic emancipation (Kanlisi et al., 2014; Mawa et al., 2021). Although forests and trees constitute veritable ecological systems that inure benefits for the sustenance and well-being of humanity (FAO, 2010), it is recognized general consensus that climate change and other environmental change stressors, such as bush-burning and tree-logging have devastating effects on the distribution and availability of forests and tree resources (Mbrow et al., 2014; Tom-Dery et al., 2019). Thus, the consequences for rural livelihoods that are largely dependent on the extractive industry in the arid regions of SSA should be a key concern in development.

To reduce livelihood vulnerability, it is imperative to promote Environmental Change Adaptation Planning (ECAP) related to the framework of decentralization and local governance in Ghana, and SSA where similar conditions prevail. Given that IFTs are affected by multiple environmental stressors, akin, to social vulnerability which embodies an amalgamation of socio-cultural, politico-economic and institutional processes (Spielman et al., 2020), an integrated approach is imperative for building the adaptive capacity of IFTs to environmental change. In more specific terms, the following polices and strategies are appropriate within the framework of ECAP: promoting the conservation of IFTs through community participation and behavioral change communication and effective enforcement of legislation at national and local levels; promoting the propagation of IFTs, especially, the establishment of shea plantations among smallholder farmers as a cash crop using shorter maturity duration varieties developed through research; promoting diversification of plant protein sources, particularly, the cultivation of soybeans as an alternative to dawadawa seed for making traditional protein rich spices as businesses and for cooking and nutrition purposes; and finally, promoting livelihood diversification among rural women largely engaged in the agro-industry.

6. Conclusion

This paper sought to deepen understanding of the vulnerability of Indigenous Fruit Trees (IFTs) particularly, shea and dawadawa trees to environmental change in a fragile-savannah ecological zone in Ghana and the implications for development planning. From the results, we conclude that these IFTs were highly vulnerable to environmental change and multiple environmental stressors, including climatic and non-climatic stressors. In the area of climate, IFTs were highly vulnerable to drought and rainstorm but less vulnerable to heavy precipitation and flash floods. For non-climatic factors, IFTs were highly vulnerable to bushfires and charcoal production but less vulnerable to sand mining. We further conclude that consequent to the combined effects of climate related and human-induced stressors, production and yields of IFTs have been on a decline over the past few decades, adversely affecting livelihoods of rural women and households in general. To reduce vulnerability of livelihoods dependent on fragile ecological forest resources such as IFTs, we underscored the strategic importance of Environmental Change Adaptation Planning.

Declarations

Author contribution statement

Emmanuel K. Derbile; Simon Kaba. Kanlisi & Frederick Dapilah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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