

Article

Local Perceptions and Scientific Knowledge of Climate Change: Perspectives of Informal Dwellers and Institutions in Accra, Ghana

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Abstract: The extant literature in urban climate studies suggests that the urban poor are the most vulnerable to climate change. Local perceptions and knowledge of climate change are also generally viewed as crucial for sustainable adaptation planning in developing countries. Yet the extent to which perceptions of climate change are influenced by the context of informal urbanisation in the Global South remains unexamined. This paper aimed to examine the extent to which the context of residents of informal settlements influences their perceptions and the congruence of these perceptions with scientific knowledge of climate change in an African city. Using Accra, Ghana as a case, 582 household surveys, 25 institutional key informant interviews and 14 focus group discussions were conducted and analysed. Results show two main findings: (1) respondents mainly perceived changes in climate change related-phenomena which were in synergy with scientific sources but their claims of increases in flooding were not supported by scientific data; and (2) while the literacy levels of the respondents were unrelated to their perception about climate change, their perceptions were also discordant with city authorities' perceptions on the causes of flooding as a hazard. The study suggests the integration of local perceptions and knowledge of climate change in adaptation planning in Accra and similar contexts.

Keywords: perceptions; informal settlements; scientific knowledge; climate change



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1. Introduction

Increased occurrence and intensity of climate change-related events, such as extreme weather and flooding, are experienced in developing countries [1]. The impacts of these events are likely to fall disproportionately on residents of informal settlements, who are mostly located in vulnerable spaces in cities [2–4]. While residents of informal settlements are currently coping with climate change, their future eviction and exclusion from city planning will expose them to new risks that arise from climate change [5]. Improving hazard resilience in cities where informal settlements exist will, therefore, require addressing climate change in informal settlements [6]. Accordingly, the extent to which informal settlers' perceptions about climate change are congruent with the knowledge of city officials will be crucial for planning purposes owing to the weak institutional capacity in developing countries [7–9].

Scholars have examined how urban dwellers' perceptions and knowledge of climate change influence both their vulnerability and responses to hazards [10–12]. They discussed the sources of knowledge of climate change, which include formal state sources, family, television and radio, all of which enable urban dwellers to prepare and respond to climate change in Africa [11], Asia [12] and Latin America [10]. Zoleta-Nantes [12], for instance, observed that “the settlement members' access to information and their knowledge related to the

occurrence and recurrence of disastrous events do affect the variation in their hazard experience” in Metro-Manila (Philippine) (p. 240). Wamsler et al. [10], also noted how the residents’ socio-economic characteristics were associated with their knowledge and capacity to respond to hazards in selected slums in Latin America. Long-term residents and those with formal education had more knowledge of climate change than other residents in the study. Also, the more educated residents were found as comparatively more capable of responding to climate change-related hazards [10]. Roy and Sharma [13], however, also found the residents of Jamnagar India had low levels of knowledge of climate change. This was partly associated with their low levels of education and limited access to knowledge-related assets, such as radio and television sets, for accessing climate education information. This scholarship has discussed grassroots knowledge and experiences with climate change. However, the extent to which the perspectives of urban dwellers relate to the perspectives of state officials on climate change has not received much attention [4]. Such attention is important as hazard vulnerability is context-specific and current formal disaster management systems in African cities remain weak [3,14,15].

Also, there is growing literature on the perceptions of climate change in developing countries [16–18], which shows the importance of perceptions for sustainable adaptation planning. Hilhorst [18], for instance, discussed the often-noticeable discrepancies between households’ and state officials’ perceptions of hazards. A household’s knowledge is embedded in their culture and often influences their decision to either accept or reject information from external sources. On the other hand, however, bureaucrats often neglect local knowledge if they consider it contrary to scientific knowledge [18]. This is despite the notion that the extent to which local knowledge can be integrated into adaptation planning will depend on its congruence with scientific knowledge [19,20].

Seminal work conducted by Codjoe et al. [11], found residents of three settlements in Accra knew about climate change which could enhance participation in adaptation planning in their settlements. In spite of the importance of this finding, the extent to which informal residents’ perceptions align with (1) scientific knowledge and (2) with the knowledge of institutional staff who are involved in adaptation planning, remains unexamined. Two specific questions emanating from this are: (1) what are the perceptions of climate-related environmental changes among residents of informal settlements and the potential congruence with scientific knowledge on climate change-related phenomena? and (2) to what extent do the perceptions and knowledge of residents of informal settlements align with perspectives of relevant state officials on climate change? Responding to these questions, this research uses four informal settlements in Accra (Adedenpko, Ga-Nshonaa, Gbegbeyise and Old Fadama) as study cases. Such an analysis has the potential for generating knowledge for adaptation planning in Accra and similar contexts.

2. Literature and Theory

Several concepts are often discussed in climate change and informal economy literature relating to informal settlement residents’ knowledge and capacity to respond to climate change. Among these is the concept of informality, often variously defined, but can be viewed as *“modes of human settlements and trade or exchange that occur outside of formal legal structures and processes”* [21] (p. 115). The concept of vulnerability is another, which refers to the *“characteristics of a person, a group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural disaster”* [22] (p. 9). A household’s perception of a hazard will, thus, be part of their vulnerability characteristics and can influence their capacity to respond to hazards.

The vulnerability of residents of informal settlements has long been discussed by the Intergovernmental Panel on Climate Change [23]. They noted that, *“squatter and other informal settlements with high population density, poor shelter, little or no access to resources such as safe water and public health services, and low adaptive capacity are highly vulnerable”* to climate change [23] (p. 13). Satterthwaite et. al. [24] have unpacked this vulnerability in two ways. The first is when informal settlers occupy flood-prone environments and become exposed

to flood-related hazards. The second is when informal settlers are excluded from city planning leading to the limited allocation of infrastructure and services, including hazard risk reduction information in informal settlements. Gencer [25] included other factors, such as little access to land, credit and information, all of which affect slum dwellers' ability to respond to floods. Forced eviction of informal settlements also limits their ability to accumulate risk-reduction assets in Latin America [26], Africa [27–30], and Asia [31]. The variety of ways by which the residents are often evicted, and the effects on their ability to accumulate assets, build social capital and knowledge for responding to risks, have been discussed in this literature.

Adaptation is another concept in the debates on the knowledge of climate change. Various conceptions of adaptation are often offered; however, adaptation has been widely viewed to comprise social and institutional dimensions. Nelson et al. [32]'s view of adaptation exemplifies this conception as they noted it as *"the decision-making process and a set of actions undertaken to maintain the capacity to deal with current and future predicted change or perturbations to a social-ecological system without undergoing significant changes in function, structural identity or feedbacks of that system while maintaining the option to develop"* (p. 397). Ensor and Berger [33] also discussed how a household's cultural beliefs tend to influence their risk perceptions and hazard response decision-making. Similarly, Hilhorst [18] discussed how a household may receive or reject external knowledge depending on whether external knowledge aligns with their local knowledge and cultural beliefs. On the other hand, bureaucrats may reject local knowledge if this is not congruent with the available knowledge [18]. Therefore, local perceptions are often integrated into formal adaptation planning only if they are aligned with knowledge from formal sources [18].

The theoretical framework for analysing perceptions and knowledge of climate change in informal settlements will include the role of institutions. Burton et al. [34] refer to institutions in their conception of adaptation as *a wider range of behavioural adjustments that households and institutions make (including practices, processes, legislation, regulations, and incentives) to mandate or facilitate changes in socio-economic systems, aimed at reducing vulnerability to climate variability and change* (p. 145). Hodgson [35] defined institutions as the *"systems of established and prevalent social rules that structure social interactions"* including organisations (p. 2). They may be formal when reference is to codified rules, or informal if reference is to the shared unwritten norms in a settlement [36]. Understood this way, Moser and Satterthwaite [20] assert that households' responses to climate change do not take place in a vacuum, but rather within their institutional settings.

Discrepancies between local perceptions and state officials' knowledge of climate change also affect knowledge integration in adaptation planning [17,19,37]. Hilhorst [18], for instance, noted discordant households' and state officials' perceptions about hazards, which affected knowledge integration for risk reduction planning. For a few scholars, such as Chatterjee [38], slum dwellers decide on their responses to hazards using their perceptions of the effects of the hazards, among others. The study by Codjoe et al. [11] in Accra discussed the importance of local knowledge in adaptation planning. However, the potential congruence of local perceptions about climate change with scientific knowledge remains unexamined. Furthermore, this study did not theorise informality and its influence on the interpretation of the study's findings. Such an analysis has the potential for improving adaptation planning in informal settlements in Accra and similar contexts.

Several theories of informality exist for contextualising the exclusion and vulnerability to climate-related hazards in informal settlements. The first theory of informality, referred to as dualism, explains the rise of informality from a mismatch between labour supply and labour demand in the modern economy [39]. Lewis [40,41], however, contended that both the traditional and modern sectors of the economy will transform and share labour in a 'dual sector economy' over time. When the informal sector is conceived as separate from the formal sector, only a little attention is often paid to the sector's actors' capacity to respond to their exclusion from state support and their consequent vulnerability to hazards. According to the proponents of this theory, responding to the sector's vulnerability will

involve the state's provision of technical assistance, including information on hazard risks to slum dwellers [42]. However, the dualism theory does not specifically address the underlying causes for informal settlers' vulnerability in a city.

Institutionalists also theorise informal settlers' vulnerability by explaining the role of institutions [43,44]. They contend that economies do not reach and rest at equilibrium, but continuously evolve with multiple interactions by institutions [45]. Understood this way, new institutionalists [43] consider informality as an entrepreneurial response to excessive regulations that exclude informal settlers from a free market. A response to such exclusion will involve simplification of regulations to allow their participation in the economy and asset accumulation [46] including risk-reduction information. However, the institutionalist solution overlooks the barriers that informal actors face, such as difficulty in accessing disaster prevention information due to their exclusion from city planning.

Relevant among the theories for examining knowledge among informal settlers is the neo-structuralist theory of informality. Neo-structuralist theorists [47,48] explain informality as a permanent condition that arises from capitalist-oriented development in a city. From this perspective, increased inequality and economic vulnerability arise from the state's adoption of market-driven mechanisms in the distribution of services [49] including information for responding to disasters. Responding to this vulnerability will involve the direct state support of informal dwellers, such as the provision of risk-reduction assets in informal settlements. Understood this way, Roy et al. [50] put together a theoretical framework that included the vulnerability of informal settlers to climate change. However, the study by Roy et al. [50] was not on local perceptions and institutional knowledge of climate change in informal settlements. This is against the backdrop that context makes a difference in hazard exposure as it influences peoples' perceptions and knowledge about the hazards [51]. This study adapted the theoretical framework of Roy et al. [50] (Figure 1) for analysing the case of Accra.

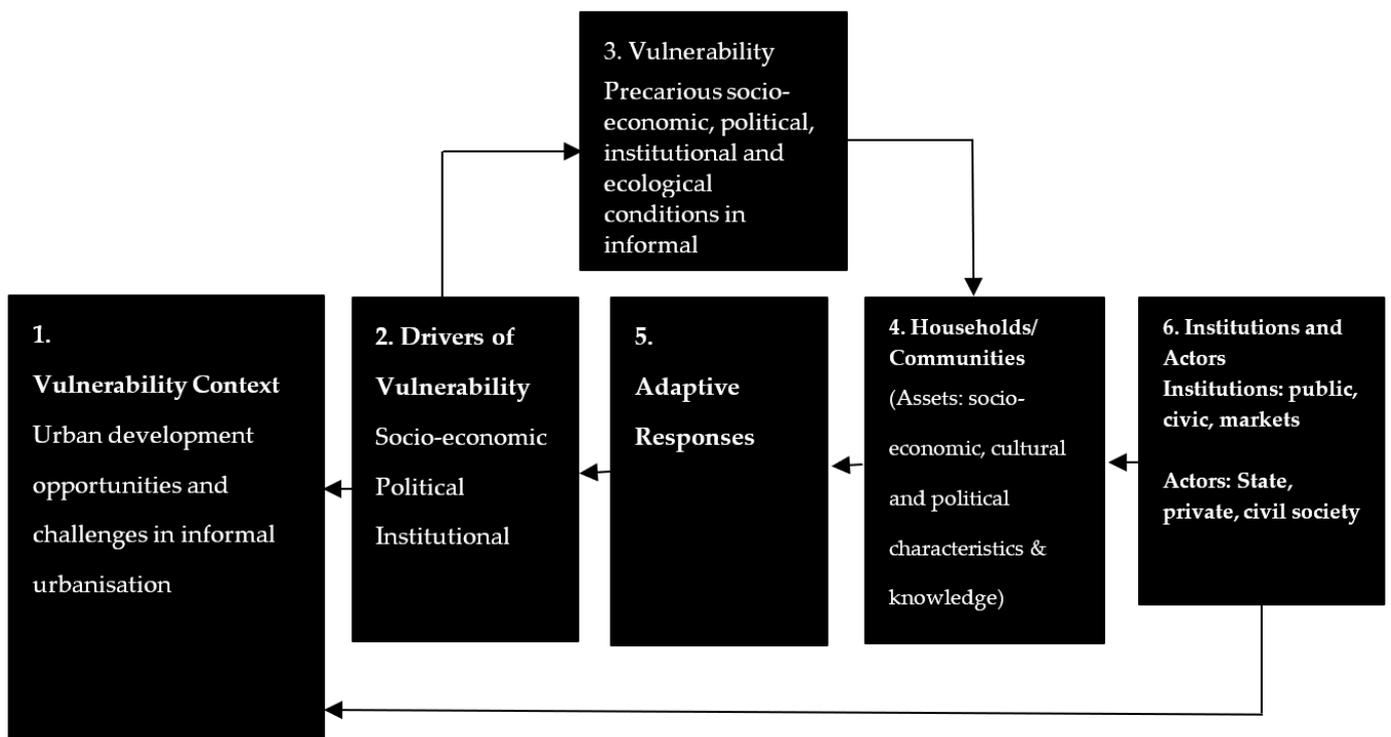


Figure 1. Theoretical framework. Source: Authors' adaptation of Roy et al. (2013) (p. 159).

From Figure 1, informal settlement dwellers are exposed to social and biophysical components of vulnerability [50] (p. 159). Social vulnerability arises from exclusion in informality: unavailability of infrastructure, precarious jobs, lack of assets to acquire infor-

mation from formal sources, limited presence of disaster-management institutions in their settlements, political exclusion, and non-recognition of informal property rights, among others. Hazards result from the climatic impacts, the knowledge of which comes from formal and informal sources. Capacity to respond is a function of the social characteristics of the residents, including knowledge of climate change. Institutions are both the formal and informal rules and norms by which society organises socio-economic and political relations, including their culture and perceptions of climate change.

3. Materials and Methods

3.1. Study Context

Accra is Ghana's administrative capital. With an estimated 1.9 million residents, the residents have been experiencing rapid urbanisation and the effects of climate change in recent decades [14]. Efforts to provide housing have led to an estimated 60% of the population now living in informal settlements, often in vulnerable locations [3] (Figure 2). Compounding the challenge are the effects of climate change, such as flooding, which destroys livelihoods, property and lives in informal settlements [52].

This study was conducted in four different categories of informal settlements in Accra, namely; Adedenpko, Ga-Nshonaa, Gbegbeyise, and Old Fadama (Figure 2). Adedenpko is an indigenous inland informal settlement while Ga-Nshonaa is a squatter shoreline settlement. Gbegbeyise is also a shoreline settlement located on land that is owned by indigenous Accra residents while Old Fadama is an inland squatter settlement [52].

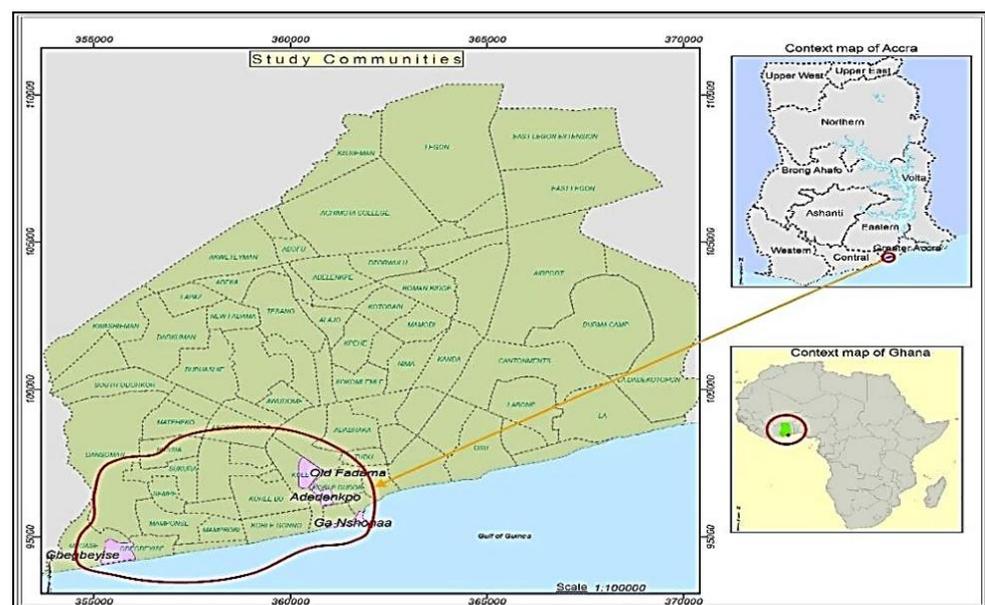


Figure 2. Map of Accra and study locations. Source: Authors' construct.

3.2. Data Collection

Both quantitative and qualitative data were collected using a mix of methods to examine the study respondents' perceptions and knowledge about climate change. A total of 582 households responded to a structured household questionnaire in the four informal settlements: Adedenpko, Ga-Nshonaa, Gbegbeyise, and Old Fadama. Households were selected through systematic sampling using maps in each settlement and samples were determined using the formula [53] (Table 1):

$$\text{as } n = \frac{Z^2 \times p(1-p)/(\alpha)^2}{1 + (Z^2 \times p(1-p)/(\alpha)^2 N)} \quad (1)$$

where Z = z-score for a given confidence level at a 95% interval in this case. p is the proportion of the population often considered at 50% to maximise samples with unknown proportions. α is the margin of error (0.08) while N is the estimated population, the total households in this case.

Collection of household data was carried out through the use of a questionnaire (Supplementary S1). The questionnaires were read out by trained data collection assistants and the first author of this article to the respondents, mainly in English and sometimes in a major local language to assist respondents' comprehension.

Qualitative data on the same themes in the questionnaire were collected from institutional key informants, representatives of trade groups, landlords and tenants' groups as well as youth. A total of 25 key informants were purposively selected and interviewed (Supplementary S2) while 14 focus groups meetings were conducted. Focus group discussion guides were used in focus group meetings while structured interview guides were used to conduct key informant interviews with institutions. Four focus groups for each of the two shoreline settlements were conducted involving members of the trade groups and a general group of settlement opinion leaders. The discussions involved their perceptions about climate change, experiences and responses.

Table 1. Sample population.

Settlement	Total Population	Household Size	Number of Households	Size of the Sample
Adedenpko	32,340	3.3	9800	148
Ga-Nshonaa	5001	3	1667	138
Gbegbeyise	13,349	2.7	4944	146
Old Fadama	81,325	2.2	36,966	150

Source: Authors' construct.

3.3. Data Analysis

Analysis of data involved the use of qualitative and quantitative techniques. The household data were entered into Statistical Package for Social Sciences (SPSS) Version 24, for cleaning and analysis. Scholars, such as Bryman [54] and Creswell and Creswell [55], have argued that where relationships between research variables can be observed through descriptive statistical analysis, conclusions can be drawn without a need for inferential statistical analysis. Therefore, descriptive statistical analyses were applied to show the relationships between socio-demographic characteristics, perceptions and experiences of climate change in this study.

Coded qualitative data were also manually analysed through thematic analysis to explain the survey data. The analyses involved repeatedly reading the transcripts of the interviews and focus group meetings, looking for patterns that related to the quantitative data. This analytical approach allowed us to reach our goal of a "detailed description of the case" Yin [56] (p. 14). Results of these analyses have been presented under four themes, namely; (1) demographic characteristics, (2) perceptions of long-term environmental changes and scientific data, (3) socio-demographic characteristics, perceptions and knowledge of climate change, and (4) the causes of climate change.

4. Results and Discussion

4.1. Demographic Characteristics of the Study Respondents

Over half (53.6%) of the respondents were youth, aged between 18 and 35 years while three (3) percent were older than the retirement age in Ghana (Table 2). 80% of respondents had lower to no formal education, explaining their predominant sustenance from the informal sector. In addition, respondents were mainly migrants (63%) as 35.7% claimed to originate from Accra. Also, the majority of respondents (63.3%) reported having lived in the settlements for very long (between 10 years and 20 years). Differences in the length of stay

in a settlement are associated with residents' ability to establish and maintain social ties and determine their social capital [6,9]. With the respondents' incomes generally low, high levels of inequality were, however, found with a maximum monthly earning of AU\$4327 and a minimum of AU\$7 (Table 2).

Table 2. Socio-demographic characteristics of the households.

Variable	Sub-Category	%
Age of household head	Between 18 and 25 years	6.9
	Between 26 and 35 years	46.7
	Between 36 and 45 years	22.9
	Between 46 and 55 years	12.5
	Between 56 and 60 years	7.9
	61+ years	3.1
Gender of the household head	Male	87.5
	Female	12.5
The ethnicity of the household head	Ga	35.7
	Akan	28.2
	Ewe	8.4
	Guan	0.2
	Gurma	1.7
	Mole-Dagbani	19.6
	Grusi	2.9
	Mande	0.3
	Other	2.9
Education of household head	Primary	27.5
	Junior High School	30.4
	Middle School Leaving Certificate	10.1
	Secondary	12
	Vocational/Technical	5.2
	Tertiary	3.8
	Professional	0.2
Length of stay in the settlement	None	10
	Less than ten years	34.2
	Between 11 and 20 years	29.7
	Between 21 and 30 years	18.6
	Over 30 years	17.5
Incomes per month/households	Less than AU\$100 (AU\$1 = GHC3.3)	4.6
	Between AU\$100–AU\$200	23.7
	Between AU\$201 and AU\$300	22.2
	Between AU\$301 and AU\$400	12.37
	Between AU\$401 and AU\$500	16.2
	Between AU\$501 and AU\$1000	9.8
	Over AU\$1000	2.7
Mean income per month/households	AU\$361	

Source: Authors' construct based on households survey.

4.2. Perception of Long-Term Environmental Changes and Scientific Data

Peoples' perceptions of environmental risks influence their decisions to respond to such risks [18]. Yet, whether local perceptions of climate change can be integrated with scientific knowledge would depend on the congruence between the two. Respondents' views on environmental changes, which are often associated with climate change/variability: temperature changes, rainfall patterns, coastal erosion, sea-level rise, saltwater intrusion, and flooding [57] are discussed in this section. Comparative data obtained from the Ghana Meteorological Agency for Accra are also discussed and compared with these perceptions.

4.2.1. Perceived Changes in Temperature

Most respondents in each settlement reported a perception of changes/increases in temperature (Figure 3). Proportions of the respondents holding this perception differed according to the settlements; all respondents in Gbegbeyise, compared to 80.7% in Old Fadama, perceived so. Nevertheless, the survey results did not show a relationship between the respondents' length of stay and their perceptions of change in temperature (Figure 3). Findings from focus group meetings in the study settlements were consistent with the survey findings. This is exemplified by a participant in Adedenkpo who said:

For some time now, we have been experiencing very high, and scorching temperatures both during the daytime and at night. But this is more seriously felt between December and March (FGD# 6, General Focus Group, Adedenkpo).

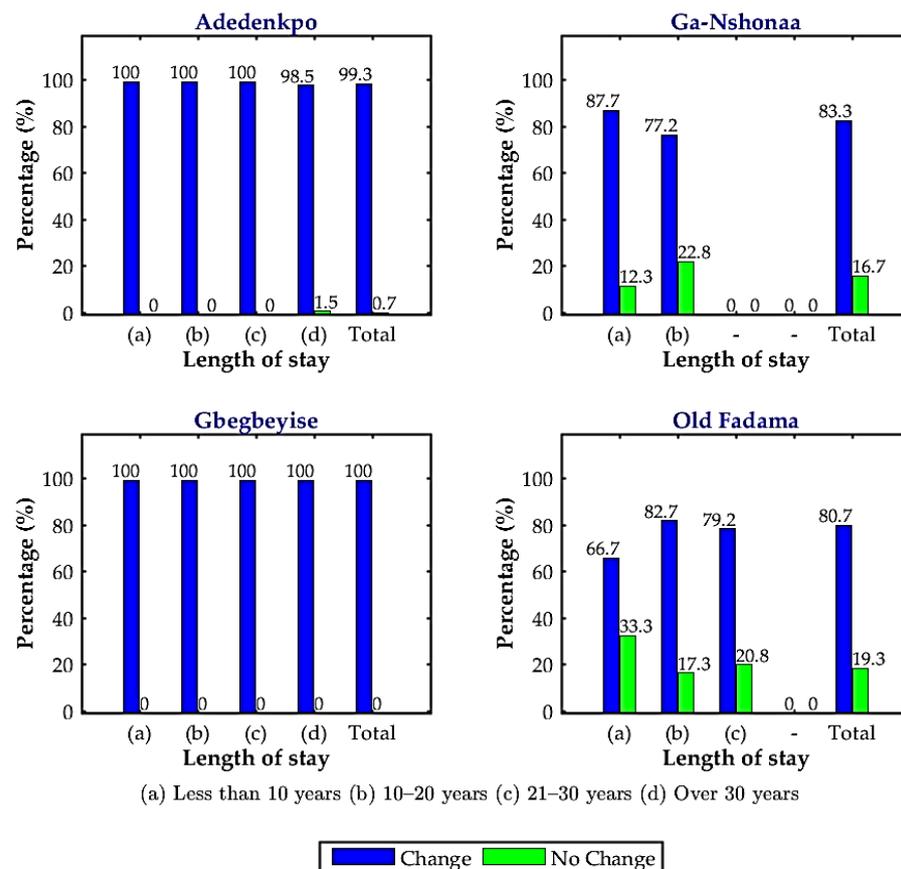


Figure 3. Length of stay and perceived changes in temperature. Source: Authors' construct based on the household survey.

Also important in determining how people may respond to climate change is their knowledge about when climate change-related events do occur [58]. This study sought to assess the respondents' perception of the time of occurrence of different climatic variables in

Accra. Survey results show that most respondents perceived temperature changes to have taken place during a December to March period (Figure 4). However, fewer respondents in each settlement perceived temperature increases as taking place from April to August in a year; or were not sure of the timing of these increases. These perceptions are similar to the less than six (6) percent of the respondents in each settlement who held the perception that temperature changes were throughout the year.

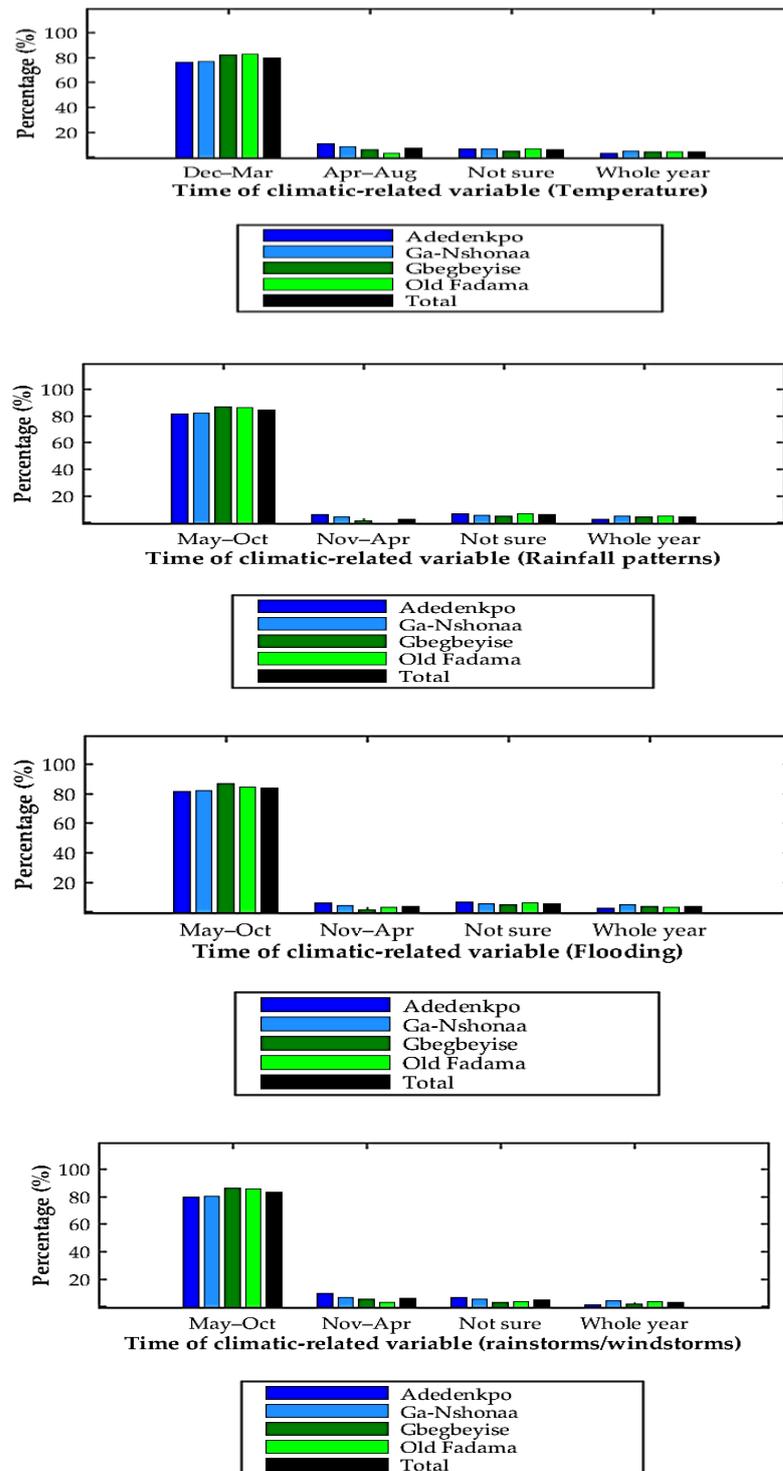


Figure 4. Time of perceived changes in temperature, rainfall patterns, flooding, and storms. Source: Authors’ construct based on the household survey.

Analyses of data obtained from the Ghana Meteorological Agency for February and March, reveal a consistency of scientific data with the predominant respondents’ perception of temperature increase in Accra (Figure 5). The two months are the hottest period in Accra’s tropical climate [59]. Average monthly temperature has been rising over a 55 year-period (Figure 5), in a similar way to rises in average day and night temperatures (Supplementary S3). The results offer proof of the increasing temperature in Accra over a period that allows for two climatic horizons of 25 years each [59].

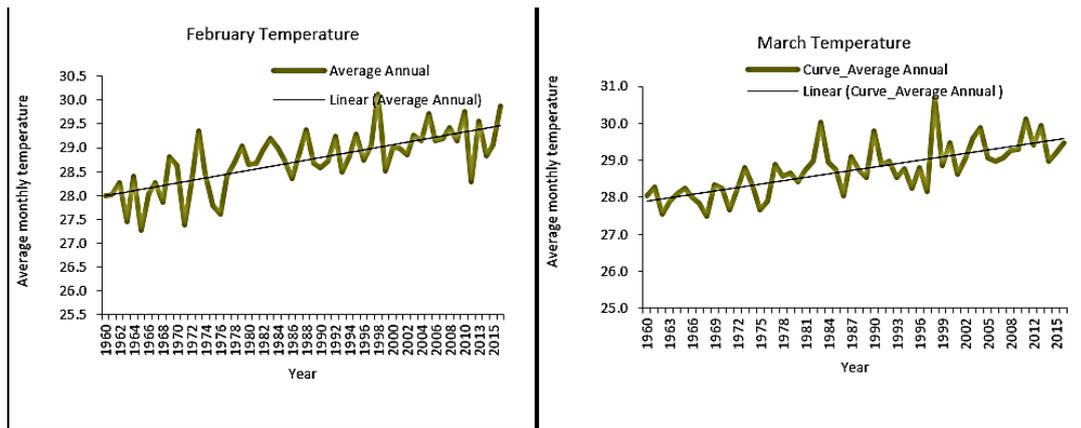


Figure 5. Changes in temperature in Accra in degrees celsius: February and March 1960–2015. Source: Authors’ construct based on data collected from Ghana Meteorological Agency.

4.2.2. Perceived Changes in Rainfall Patterns and Less Predictability

Perceived changes in rainfall patterns (onset and ending periods) were also reported by most respondents in each study settlement (Figure 6). This view was similarly held among the respondents in Adedenkpo, Ga-Nshonaa, Gbegbeyise, and Old Fadama. In addition, major differences were not found on the relationship between the respondents’ perceptions and their length of stay in the settlements (Figure 6).

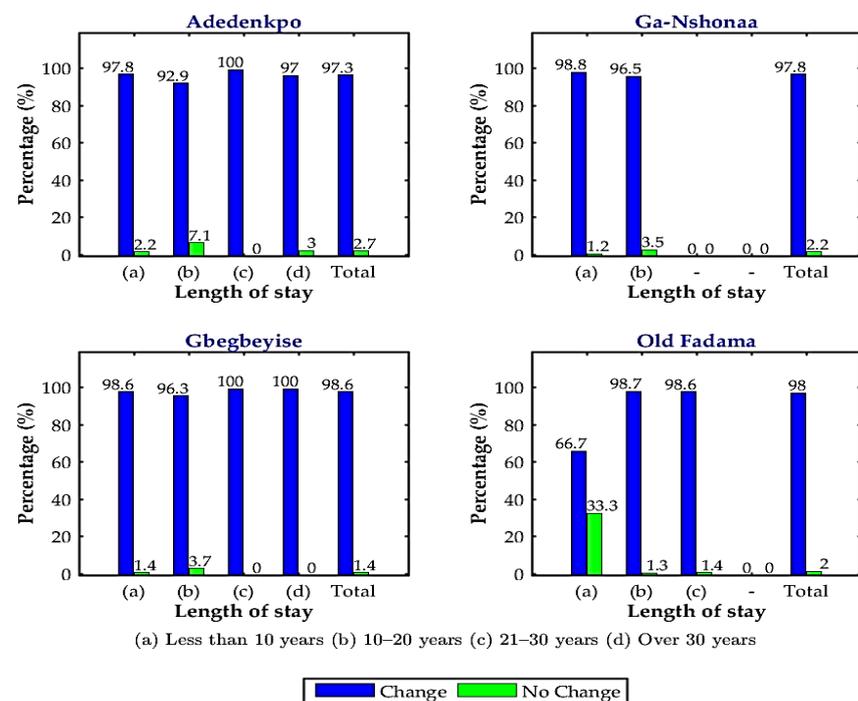


Figure 6. Perceived changes in rainfall patterns and/or intensity by length of stay. Source: Authors’ construct based on the household survey.

It was also found that most respondents in each study settlement perceived the timing of rainfall as between May to October each year (Figure 4). Nevertheless, fewer (less than 7% in each settlement) respondents perceived the period of rainfall as November to April each year. Additionally, the respondents who reported being unsure of the timing of rainfall were relatively higher than those who reported the timing as from November to April each year. Moreover, comparatively lower percentages of respondents reported the timing of rainfall as ‘throughout the year’ in all of the settlements. Overall, most respondents’ perception of the time of rainfall is consistent with scientific data on Accra (Figure 7).

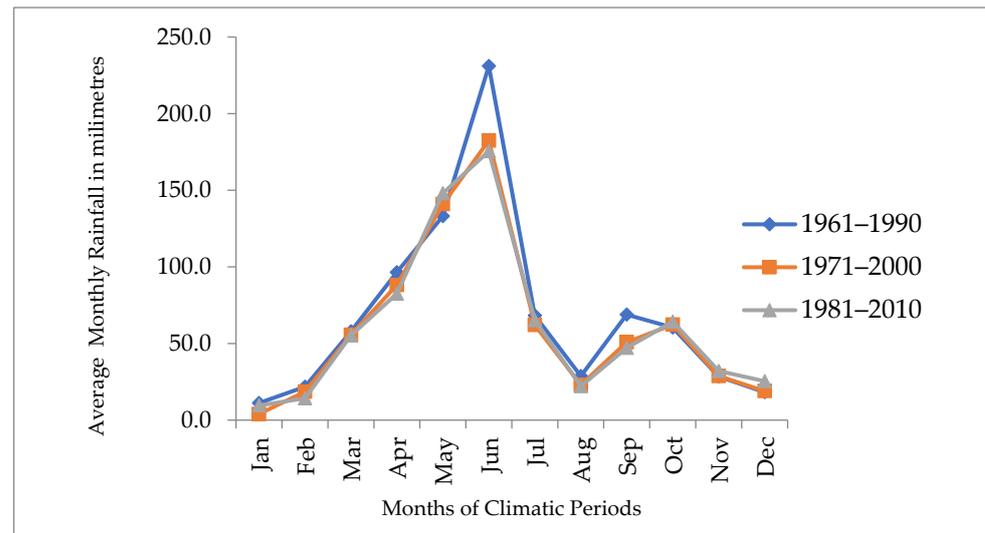


Figure 7. Average monthly rainfall for three climatic scenarios from 1961 to 2010 in Accra. Source: Authors’ construct based on data collected from Ghana Meteorological Agency.

Findings from the survey were supported during focus group meetings in all of the settlements. An example is a comment that was made in Adedenkpo when a focus group participant said:

In the past, rainfalls were immediately preceded by strong winds, but nowadays, it is not always like that in June. Because the timing has changed. Unexpectedly one would see the rain falling, mostly in other months (Participant #5, Focus Group, Adedenkpo).

The findings of changes in rainfall patterns were also consistent with the views that were expressed during an interview with a climatologist at the Ghana Meteorological Agency when he noted that:

The onset date on the average has become late—September has become an important month for rainfall. And we also have early seizers on the average, which also translate to shorter rainy seasons. This is expected to continue (Interview #17).

The above quotes do indicate consistency between the perceptions held by informal settlement residents and key state officials, with scientific data on changes in the onset and seizure periods of rainfall in Accra (Figure 7). The reported perceived changes in rainfall are consistent with the results from analysis of rainfall data on Accra, which indicates a minor shift in the patterns of rainfall (Figure 7). It is shown that the average monthly rainfall had fallen in June for an assumed climate period of 1971 to 2000 (182 mm) or from 1981 to 2010 (176 mm) when compared to a 1961 to 1990 (231 mm) climate period.

Added to the fluctuating rainfall values, is a bimodal rainfall regime of a major rainy season and a minor rainy season for Accra (Figure 8). While the peak period of the major rainy season is in June for all of the three climatic scenarios, the peak of the minor rainy season has only minimally shifted from September to October for the 1981–2010 scenario. In terms of volumes of rainfall, a new average monthly lower of 64.2 mm is also observed when compared to 68.9 mm of rainfall in the 1961–1990 climatic scenario. Furthermore, it

was observed that the two annual rainy seasons in Accra are interspersed by a dry period from November to February and in August. This finding is consistent with the predominant view that is held by most respondents on the timing of rainfall (May to October). The finding that informal settlements' residents are aware of minor changes in the rainfall patterns in Accra is consistent with Douglas et al. [60]'s finding in their study in Alajo settlement in Accra.

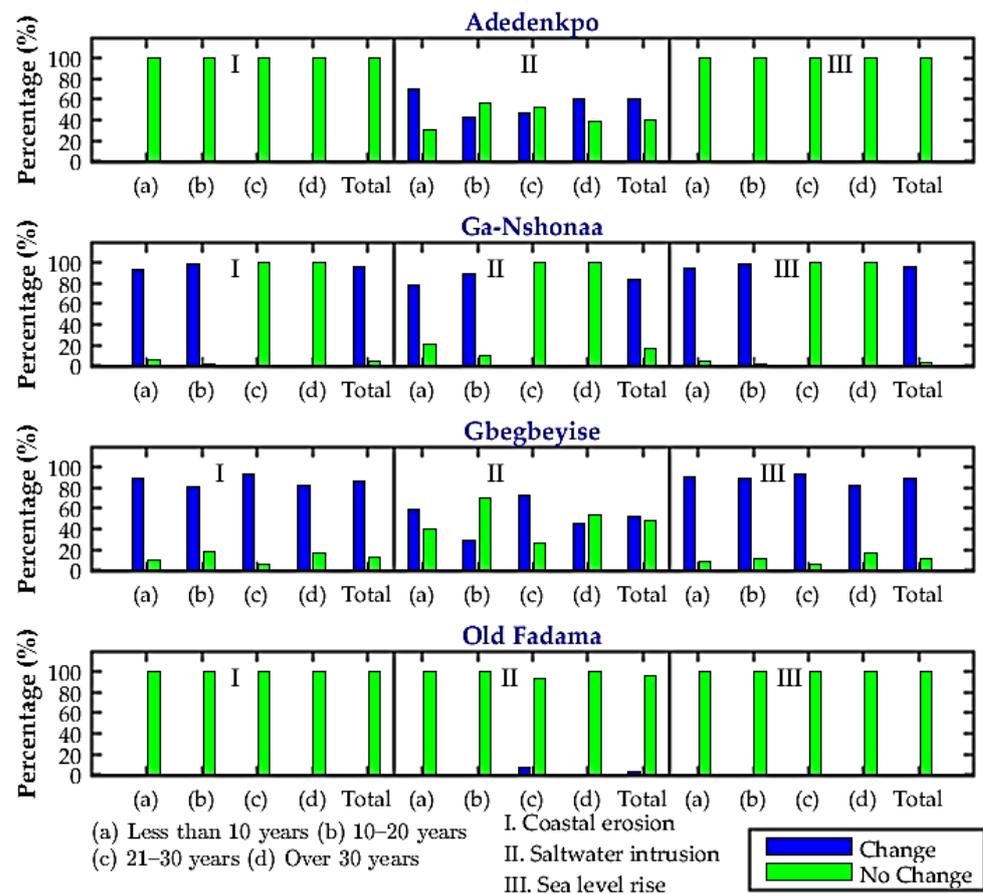


Figure 8. Perceived changes/increase in coastal erosion, sea level rise, and saltwater intrusion according to length of stay. Source: Authors' construct based on the household survey.

4.2.3. Perceived Changes/Increase in Coastal Erosion, Sea Level Rise, and Saltwater Intrusion

Perceptions of changes in temperature, coastal erosion, sea level rise and salt water intrusion differed among respondents in the study settlements (Figure 8). Over 80% of the respondents in Ga-Nshonaa and Gbegbeyise reported a perception of a change/increase in coastal erosion, or sea-level rise (Figure 8). In contrast, most respondents in Old Fadama and Adedenkpo did not perceive this change in the two climate change related variables. The perception of changed/increased saltwater intrusion was also spatially differentiated among the respondents: 83% in Ga-Nshonaa, compared to only 3.3% in Old Fadama, reported so. The differences are accounted for by the locational differences of the settlements; Ga-Nshonaa and Gbegbeyise are shoreline settlements, while Old Fadama is an inland settlement. Residents of the inland settlements are less regularly exposed to coastal erosion which may have made them less concerned about its occurrence. However, there was no relationship between the length of stay of the respondents and their perception of changes in sea-level rise, coastal erosion and saltwater intrusion in the study settlements (Figure 8).

The perception that coastal erosion had increased is consistent with the findings from a scientific study that was conducted by Appeaning-Addo and colleagues [61]. The scholars estimated the incidence at $1.13 \text{ m/year} \pm 0.17 \text{ m/year}$. They further suggested that future

erosion will affect large swaths of land that are presently occupied by informal settlements along the western shoreline of Accra.

Also, the finding of this study which shows most respondents in the shoreline settlements have perceived changes/increases in sea levels is supported by findings from a study that was conducted by Appeaning-Addo et al. [62]. The scholars estimated sea levels to rise at 2 mm/year in Accra. Coastal erosion in Accra was also reported to be caused by the rises in sea levels, coupled with winds and tidal waves of 0.5 m/s and 1.5 m/s, respectively [61]. The finding on the perceived increase in groundwater salinity is also supported by a scientific study that was conducted by Kortatasi and Jorensen [63] in Accra.

4.2.4. Perceived Changes in Flooding

The survey results further show most respondents in Adedenpko, Ga- Nshonaa, Gbegbeyise, and Old Fadama perceived increases in the frequency of flooding in their settlements (Figure 9). Although this view is unsupported by scientific data on Accra, it differed among respondents of the various settlements. It was highest in Ga-Nshonaa (84%) and lowest in Old Fadama (72%). The nature of these settlements may have influenced the perceptions held by the responds; Ga-Nshonaa lies below mean sea level while Old Fadama is located above sea level, making the former more exposed to flooding. However, the perception of a change in flooding did not show a relationship with the respondents' length of stay in the settlements (Figure 9).

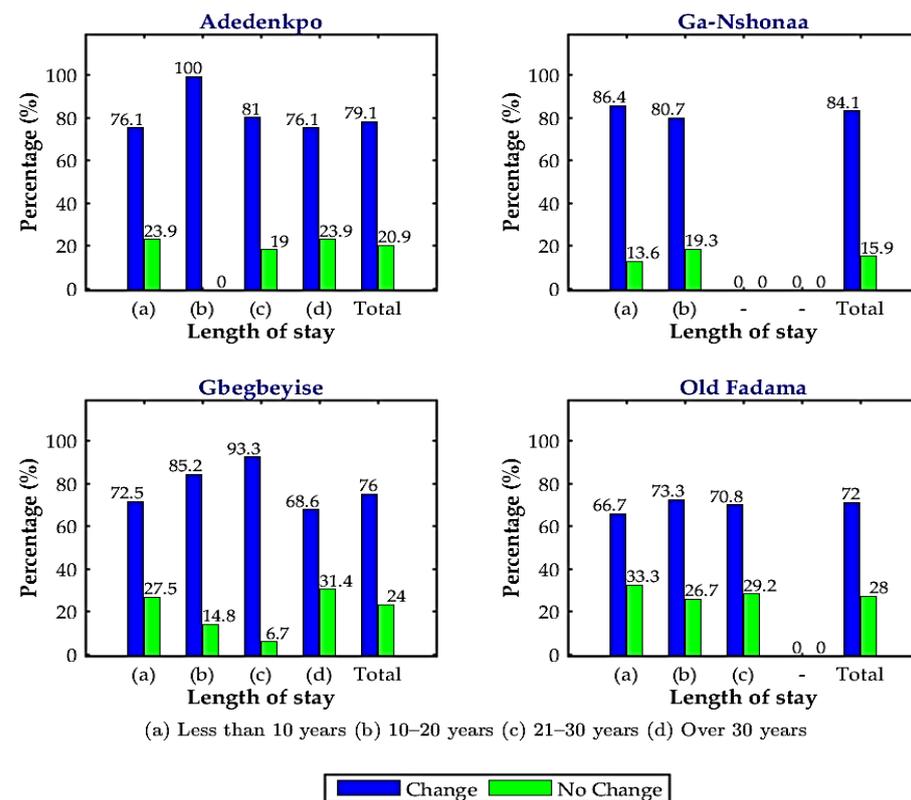


Figure 9. Perceived increase in flooding by length of stay. Source: Authors' construct based on the household survey.

In terms of the timing of flooding, most respondents perceived the occurrence of flooding in their settlements from May to October each year (Figure 4). Similar percentages; up to 82.4% in Adedenpko, 82.6% in Ga-Nshonaa, 87.7% in Gbegbeyise and 85% in Old Fadama, reported this perception. Fewer respondents also perceived the period of flooding to occur from November to April each year; while a similar percentage reported 'not being sure' of the time of the time of flooding in each settlement. However, a much

lower percentage of respondents in all of the four settlements reported flooding occurred throughout the year. The majority of respondents' view on the timing of flooding was found to coincide with the period of rainfall in Accra (Figure 7). Nevertheless, the claim that flooding had increased in the four settlements could not be substantiated as there was no means for tracking this assertion. Therefore, the reported increase in flooding by the respondents in Accra may only be their perception.

This finding is against the backdrop that, studies conducted by scholars in Accra suggest a reduction in rainy days from about 90 days to fewer than 80 days per annum over four decades [64]. This reported reduction in rainy days suggests that this study's respondents' reported increases in flooding may have been accounted for by other factors other than climate change. Low elevation of settlement, poor drainage infrastructure and indiscriminate siting of houses can lead to more frequent flooding in a settlement. Other scholars have also reported this finding in their studies [3,14,65]. Karley observed that: "... there is no evidence that unusual rainfall has been occurring recently that could explain the increased occurrences of flooding being experienced. Rather, the cause of the problem is the lack of drainage facilities to collect stormwater for safe disposal in Accra" [65] (p. 25). The finding, however, highlights the need for climate change adaptation scholars to pay attention to the differences between local perceptions and the actual evidence of climate change.

4.2.5. Perceived Changes/Increase in Storms (Rainstorms/Windstorms)

Increasing storms were also perceived by most respondents in the the study settlements. At least 89.1% of the respondents in each of the settlements reported this perception (Figure 10). There were, however, marginal differences in the proportions of respondents who held this perception, although no known reason explains these differences. However, the majority perception was not associated with the length of stay of the respondents (Figure 10).

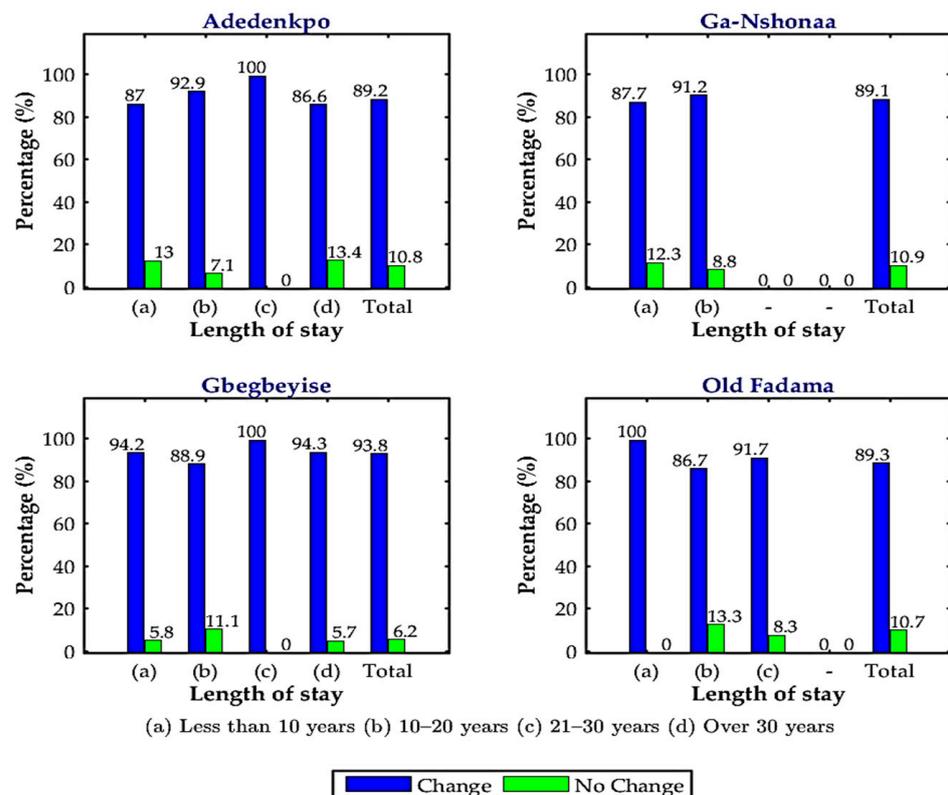


Figure 10. Perceived changes in storms by length of stay. Source: Authors' construct based on the household survey.

Also, in terms of the time of the occurrence of storms, most respondents (at least 81%) in all settlements perceived storms as occurring from May to October each year (Figure 4). In addition, less than a tenth of the respondents in each settlement perceived storms to occur from November to April each year while much lesser proportion of respondents in each settlement reported the changes in storms occurred throughout the year. Yet, other smaller proportions of respondents also reported not being sure of the time at which increasing storms occurred (Figure 4). The majority of the respondents' views of the time of increases in storms are consistent with the period of rainfall in Accra. Storms (rain/windstorms) mostly occur in the rainy season in Accra (Figure 7).

Further examination of data on wind gusts for over 30 years shed light on the reported storms in Accra (Figure 11). It is shown that winds blew mostly in April, August and September each year between 1987 and 2016 (Figure 11B). However, the average wind speed had remained steady over the same period. As April to July is the major rainy season in Accra and September to November is the minor season, wind gusts were found to lower in November and were less frequent in the dryer months of January and February. The results suggest evidence of increases in windstorms over the period from 1987 to 2016 and is concordant with the majority of survey respondents' perceptions in this study.

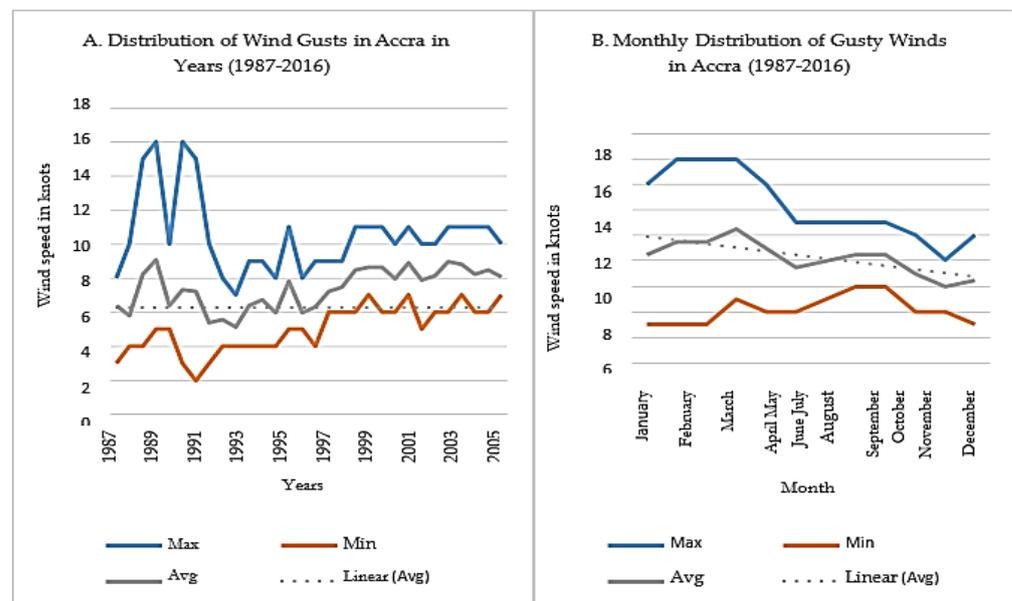


Figure 11. (A) Distribution of Wind Gusts in Accra in Years (1987–2016); (B) Monthly Distribution of gusty winds in Accra (1987–2016). Source: Authors' construct based on data collected from the Ghana Meteorological Agency.

4.2.6. Synthesis: Concordance between Perceptions and Scientific Sources

A synthesis of the respondents' perceptions and scientific sources shows both concordance and discordance between the two sources of knowledge (Table 3). Firstly, the reported perceived change in temperature is consistent with scientific data on Accra. Both night and daily maximum temperature values have increased as was also reported during focus group meetings in the settlements. Secondly, respondents' perceived changes in rainfall patterns are also consistent with scientific data on Accra. In addition, the onset period for rainfall in the minor rainy season has shifted slightly to October (Figure 7). Thirdly, respondents' reported increase in coastal erosion, storms and sea-level rises have been consistent with scientific studies on Accra. However, the claim by respondents of an increase in flooding frequency was unsupported by scientific studies or data on the same.

Table 3. Concordance between perceptions and scientific sources.

Climate Variable	Perceptions and Knowledge	Trends in Scientific Data	Synergies
Temperature	Day and night temperatures have risen in all settlements.	Day and night temperatures have risen.	Perceptions and formal data are in agreement on temperature rise both at night and day.
Rainfall patterns and intensity	Delays in onset, less rain in the peak of June, July and unpredictability in June, July and August.	Delays in onset by a few weeks in March, a new peak in October. Significant reductions in amounts in June.	There is an agreement between perceptions and scientific data on delays in onset, less predictability, and reduction in volumes of rain in June.
Salt water intrusion	While many households believe in changes in water salinity, this has not been experienced by many.	Scientific studies offer evidence of increasing water salinity.	There is concordance between perceptions of residents and scientific studies on saltwater intrusion in Accra.
Flooding	Reported predominant perception of an increase in floods in all settlements.	There is no flooding knowledge specific to local settlements, hence no basis for comparison.	While flooding relates to rainfall, the many intervening factors involved in transforming rains into floods are not easily observable to compare the perceptions with scientific data.
Storms (rain/wind storms)	There is a predominant perception of increasing storms (rain and wind storms) in all settlements.	Wind distribution over 1987–2016 suggests a steadily increasing trend.	There is an agreement in the timing of distribution of winds and evidence to support increasing wind intensity.
Coastal erosion and sea-level rise	While many households do not directly experience coastal erosion, their long period of exposure to it allows them to report its increases.	Scientific studies offer evidence of coastal erosion	Perceptions and scientific data are in concordance, showing coastal erosion and rising sea levels.

Source: Authors' synthesis based on the survey, focus groups, interviews, and climate data.

The finding of concordance between perceptions of the respondents and meteorological data on temperature and rainfall changes are similar to findings from a study that was conducted in northern Ghana [37]. In their study, Dickinson et al. [37], reported consistency in survey respondents' perceptions of meteorological data on both temperature and rainfall patterns over 35 years. This suggests the importance for noting the differences between local perceptions and scientific facts on climate change-related phenomena when planning adaptation interventions.

Furthermore, it was found that a household's length of stay in a settlement was not associated with the respondents' knowledge of climate change-related variables in each settlement. This finding contrasts with the often-suggested relationship between the longevity of residents' stay as associated with their knowledge about changes in their environment, such as by Orlove et al. [16]. However, the finding that the respondents' knowledge about changes in their environment was also associated with their location, supports the known argument that perceptions about environmental risks are location-specific.

4.3. Education, Age, Perception and Knowledge of Climate Change

People's demographic factors, such as age and education, influence their knowledge about climate change [66]. The education level and age of a person do influence his/her analytical ability of the changes in the environment. They may also influence their ability to gain employment from which they can acquire assets, such as radio sets and television sets, to access early warning information. How the study respondents' demographic factors relate to their knowledge of climate change are presented in this section.

4.3.1. Perception of Climate Change and Variability

Results from the household survey show most (at least 97.3%) of the respondents in each settlement perceived that observed local environmental changes have a relationship with or manifest climate change/variability (Figure 12). The proportions of this perception were very similar across the study settlements. Similarly, the perception was similarly held among all age groups of the respondents; no respondents were aged 61 and older in Old Fadama and Ga-Nshonaa, which accounts for the current nature their response in Figure 12.

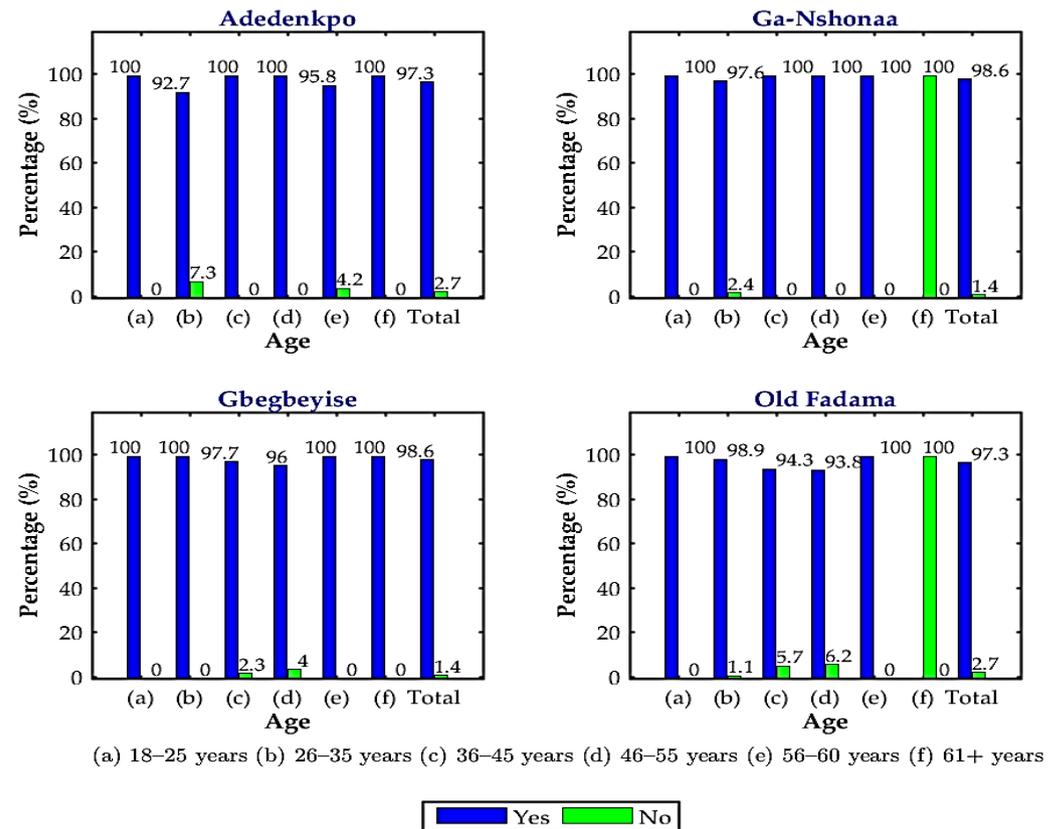


Figure 12. Perceived linkage between environmental changes and climate change by the age. Source: Authors' construct, based on the household survey.

This finding does not support that finding reported by Jabeen et al. [9] among the respondents in their study. The scholars reported from their study in Korail, Dhaka, that older respondents were more aware of changes in rainfall patterns than younger settlement residents. This was due to their long stay and familiarity with their environment.

The higher levels of responses in our study who perceived some relationship between climate change/variability and their perceived environmental changes may also be associated with ongoing education on climate change/variability in the settlements. For example, climate change clubs were found in the Ga-Mashie area which includes the settlements of Ga-Nshonaa and Adedenkpo, as well as in Gbegbeyise. Nevertheless, it was found during focus group meetings in the settlements that the residents had awareness of climate change as they referred to this in their local language. These findings are contrary to the findings of similar studies conducted in informal settlements in developing countries [10,13]. Roy and Sharma [13] reported low levels of knowledge of climate change among residents of slums in Jamnagar (India). Also, the findings are contrary to the often suggested view that poor people tend to cause environmental pollution in cities due to their low levels of knowledge about their environment [67].

4.3.2. Perceived Causes of Climate Change

Perceptions and knowledge about the causes of global climate change are important in planning for improving households' capacity for responding to the impacts. It has been suggested that people's perceptions do influence how they accept responsibility for action on climate change [16,68]. Moreover, people's perceptions of the causes of climate change influence how they may plan to respond to its impacts [69]. Survey results show at least 74% of the respondents in each settlement perceived climate change as mainly caused by local level pollution activities (Table 4). Local level activities include the burning of lorry tyres and other forms of air pollution. This perception was consistent with the views expressed in focus groups meetings. For instance, a participant in Old Fadama noted that:

We the settlement members are responsible for this climate change. People have been burning car tyres all over the place, to heat water. This pollutes the air and causes climate change (Participant #2, Focus Group, Old Fadama).

The perception that climate change is caused by local level pollution activities was held more among respondents in Gbegbeyise than in Adedenpko, Ga-Nshonaa, and Old Fadama (Table 4).

Table 4. Perceived main causes of climate change according to education level.

Cause of Climate Change/Settlement	Level of Education									Total	
	Primary	Jun. High.	Mid. Sch. Leave. Cert.	Sen. High.	Vocational	Tertiary	Professional	None			
Act of God	Adedenpko	%	0	2.4	2.9	0	0	0	0	100	7.4
	Ga-Nshonaa	%	0	0	0	0	0	0	0	100	18.1
	Gbegbeyise	%	0	0	0	0	0	0	0	83.3	3.4
	Old Fadama	%	0	0	0	0	0	0	0	95.7	14.7
Settlement/local activities	Adedenpko	%	100	92.7	97.1	100	0	0	0	0	76.4
	Ga-Nshonaa	%	100	95.1	100	100	0	0	0	0	74.6
	Gbegbeyise	%	95.2	96	100	93.9	20	10	0	16.7	84.2
	Old Fadama	%	93.5	91.1	100	90	12.5	0	0	4.3	74.7
Global industrial activity	Adedenpko	%	0	0	0	0	100	100	100	0	14.9
	Ga-Nshonaa	%	0	0	0	0	100	100	0	0	5.8
	Gbegbeyise	%	0	0	0	0	80	90	0	0	8.9
	Old Fadama	%	0	0	0	0	87.5	0	0	0	4.7
Other	Adedenpko	%	0	4.9	0	0	0	0	0	0	1.4
	Ga-Nshonaa	%	0	4.9	0	0	0	0	0	0	1.4
	Gbegbeyise	%	4.8	4	0	6.1	0	0	0	0	3.4
	Old Fadama	%	6.5	8.9	0	10	0	0	0	0	6

Source: Authors' construct from household survey.

Following this view was another that climate change is mainly an 'Act of God'. Up to 18.1% of the respondents from Ga-Nshonaa compared to only 3.4% in Gbegbeyise reported this view. Also, the view of climate change as an 'Act of God' was related to the educational levels of the respondents. At least 83.3% of the respondents in each settlement

who supported this view were without formal education (Table 4). This finding contrasts with a higher percentage (at least 80%) of respondents in each of the four settlements who linked climate change to global industrial activities and claimed to also have vocational or technical or tertiary level qualifications (Table 4). Moreover, the respondents who associated climate change with the ‘Act of God’ also had lower educational levels and could be associated with superstition in some of the settlements. For instance, a fetish shrine was found in Adedenpko and Ga-Nshonaa (a native settlement). However, it was observed during focus group meetings that the view that climate change is an ‘Act of God’ was mainly expressed by the elderly, as in Ga-Nshonaa when one participant said:

I do not agree with any of these reasons others have given here. These changes are caused by God because morality in society continues to decay. We have abandoned all our spiritual responsibilities as people, and expect things to remain the same way. These are all punishments we have invited upon ourselves, which affect our fishing activities (Participant #2, Focus Group, Ga-Nshonaa).

The finding that many respondents perceived climate change as an ‘Act of God’ while others associated the cause with local environmental polluting activities, was also reported in a study conducted in three other settlements in Accra [11]. This, however, suggests older residents may not be easily motivated to participate in climate mitigation planning since they feel climate change is caused by God.

4.4. State Officials’ Perspectives on the Link between Environmental Changes and Climate Change

The extent to which city residents’ knowledge about climate change can be integrated within adaptation planning depends on the congruence with state officials’ knowledge about climate change. This is important as the nature of short-term or long-term adaptation planning that city planners may adopt is also informed by the extent to which residents may accept the proposed mitigation interventions [70]. In this study, the perspectives of state officials were elicited by posing a simple question of whether they perceived a linkage between current environmental changes and climate change. All of the institutional respondents answered in the affirmative. Interviewees included a representative from the National Disaster Management Organisation (NADMO), the organisation responsible for disaster prevention and responses. For instance, a senior staff of NADMO said:

Of course, climate change and its impacts are with us. Hardly in the olden days do we get rains in a month like August, but these days, because of the change in climate, sometimes, it rains in August. But the peak of the rain should start from June, July. Moreover, do not be surprised that in some years, it delays, sometimes in June, the whole of June, we do not even have rains compared to 30 years back. We know that this drought—Harmattan—is from December and then January thereabouts; but this time it has changed. Drought or harmattan can happen in March, which should not be the case, compared to what we used to have (Interview #12).

The view of the interviewee from NADMO did match with that of senior staff of the second institution—the Ministry of Environment, Science and Technology (MEST)—when he noted that:

The evidence abounds in terms of climate variability and change in terms of rainfall patterns, temperature or extreme weather occurrences and events clearly demonstrate that climate change and variability are with us. For example, we never had rains in August, as we presently do. The height of the rainfall too was in June, but these days we are not sure what it is as it sometimes does not even rain in June. Temperatures have risen both at night and during daytime (Interview #12).

Moreover, this reported view is consistent with that of an official of AMA who noted that: “... there is no doubt about a connection between the current events, rains, floods, temperature excesses and so forth we see, and climate change” (Interview #13). Similarly, a Sub-Metropolitan District Council staff in Accra City Authority noted that:

As we speak, climate change is affecting us and will do so in a much harder way to the people of Ga-Nshonaa, in particular. For instance, just recently, there were these tidal waves that flowed into the settlement to the extent that they took away outboard motors, fishing nets and a whole lot of properties over there. These waves have become more frequent and more devastating (Interview #15).

However, the majority of perceptions that associated environmental changes and climate change, can be understood they were referring to both climate change and climate variability although they are distinct from each other. Such distinction was aptly pointed to by a meteorologist of Ghana Meteorological Agency who opined that:

Very often, what the government staff refers to is climate variability, the short-term changes in weather conditions, that when they become long-term and reflect in changes in the mean averages of climatic variables, e.g., temperature, humidity and wind speed; then become climate change. According to the World Meteorological Organisation, for the climate of an area to have been considered changed, one requires proof of changes in the mean averages of climatic variables for at least 30 years. Given what we see from our data of over 60 years, most of the current events in Accra are associated with climate change (Interview #17).

Climate variability is part of the processes of climate change, and whether there is one or another at play often requires a systematic observation and analysis of climatic variables over at least 30 years [57]. A similar finding was reported in a study conducted by Jabeen and Johnson [6] in Korail, Dhaka (Bangladesh) and among residents of Mohammadpur. This finding shows that adaptation scholars need to pay attention to the differences between the perception of climate variability and climate change.

There was also a contrast between the predominant view held by the settlement level study participants that climate change was caused by local activities, with the view of the state officials. The state officials interviewed opined that climate change is caused by the production activities of industrialised countries. An example of this is a comment from a Senior Officer in Ghana's Environmental Protection Agency (EPA):

Climate change is a global environmental change phenomenon. For instance, if you look at the contribution of carbon emissions, Africa as a whole contributes next to nothing to global climate change. But the impacts are not localised, so we all share in the costs of the emissions which is more from the developed world due to their higher use of fossil fuels. So we, the governments of developing countries, have always asked that they do more in the interests of climate justice (Interview #12).

Similarly, an interviewee at the Ministry of Environment Science and Technology opined that climate change is caused by global industrial activities:

Indeed, climate change is a global environmental issue of concern. But the effects are local. The changes in rainfall patterns we see in Accra are obvious signs of climate change. We all know that it is increasing industrial activity in the developed countries that cause climate change, but we feel the brunt more such as increasing heat and floods. Those who create this problem have to do more to assist us in adapting to it (Interview #10).

The finding from the majority of survey respondents who claimed to be knowledgeable about climate change and its causes is contrary to the often-held view that environmental problems in cities are usually caused by the poor due to their lack of knowledge [5,71]. However, the responses from the state officials also support the commonly held view that those responsible for climate change must account more for it, supporting the discourse on climate justice in cities [72,73].

This notwithstanding, it was found that perceptions of the causes of flooding as a potential climate change-related hazard were framed within the politics of tenure insecurity and informal development in Accra. Two main and opposite views were expressed by the respondents in the settlements on the one hand, and among city officials interviewed on the other. The first view during focus group meetings with settlements is related to

the conduct of government officials and city authorities. Settlement members blamed city authorities for not providing drainage infrastructure in informal settlements. This view was expressed in Old Fadama as stated by this participant who said:

The refusal of AMA to provide drains in this settlement affects the flooding problem here. If they [Accra city authorities] continue to refuse to provide drains or even give us our peace of mind to do our own thing, how can we properly deal with the flooding problem in this settlement? (Participant #4, Focus Group, Old Fadama).

A study conducted by Douglas et al. [60] also reported the same problem among residents of Alajo settlement in Accra. In this study, the respondents associated flooding with “poor drainage, lack of consultation by officials and insensitivity to their problems” (p. 194).

The second view, which contrasts with the blame of city authorities by settlement members, was from city officials interviewed. To these officials, the flooding problem in Accra was rather partially caused by residents of informal settlements who build indiscriminately and dump waste in different locations in the city. This act of indiscriminate waste disposal obstructs the passage of water, thus exacerbating flooding in Accra as was expressed by an interviewee from the Physical Planning Department who said this:

The indiscriminate dwelling processes of Sodom and Gomorrah [Old Fadama] and other settlements which are located along the Korle Lagoon have not only created problems for their inhabitants but also the whole of Accra. They have obstructed the waterways with unauthorised structures, and dump their waste into the lagoon. They also keep fighting against their relocation and made it difficult for the government to complete the Korle Lagoon Ecological Restoration Project (Interview #13).

The findings of contested views about the causes of flooding among residents of the informal settlements and state officials in this study, are consistent with findings from other studies on informal settlements in Accra [3,74] and globally [75]. For example, Pelling [75] observed in George Town (Guyana), that:

... ‘bad citizens’ are blamed directly for dumping garbage and waste into the drainage canal, ... and for colonising seawall or canal reserves for informal housing. In this way, the structural problems underlying individual acts are overlooked and proximate causes of vulnerability and risk too easily become the core concern of managerial discourse (p. 259).

The results of this paper show that the politics of tenure security and informal development may have influenced the framing of the flooding problem among the study respondents and city officials. Therefore, adaptation research needs to pay attention to power relations between local settlements and state officials relative to knowledge production on climate change when developing early warning systems in urban areas.

5. Conclusions

Effects of climate change-related hazards are notably experienced in cities of developing countries [23,76,77]. Residents of informal settlements are disproportionately affected by the effects of climate change [23]. Understanding their perceptions and knowledge about climate change will thus be crucial for sustainable adaptation in African cities. However, there is a paucity of knowledge on the extent to which informal residents’ perceptions and knowledge align with scientific knowledge and the knowledge of institutional staff who are involved in adaptation planning. This study has filled this knowledge void, using Accra as a case.

5.1. Implications to Literature

The relationship between perception as well as knowledge in responding to risks has been studied by scholars who observe that people’s perception of a particular risk invariably influences their response to the same [78–81]. Grothman and Patt [80] argue that this perception or actual knowledge about the severity and impacts of risks tend to be influenced by past events. In this present study, most respondents reported changes in

temperature, rainfall patterns, floods and storms in tandem with changes in their environment. Also, most respondents were found to be aware of climate change. This is against the backdrop that access to early warning information is critical for minimising vulnerability to hazards [82].

The relationship between households' perception and knowledge about hazards and their location has received the attention of various scholars [10,83–85]. Wamsler [10] argues that the educational levels of households and their geographical location tend to be associated with their knowledge and capacity to respond to climate change. For Cutter et al. [83] people's perceptions and knowledge about environmental risks do not only differ according to the social context but also according to their location [83]. The finding from this study portraying an association between the geographical location and levels of education of the respondents does confirm this existing knowledge about hazards risk perception and geographic location. The findings emphasise the suggested importance for adaptation scholars to pay attention to the differentiated socio-economic contexts of households, relative to the packaging and delivery of hazard reduction information. However, this study adds the importance of understanding power dynamics between settlement members and city authorities in the production of hazard knowledge, often overlooked in the literature.

5.2. Practical Implications

From the paper's findings, two important entry points could be considered in the design of integrated climate change-related vulnerability management plans for Accra and similar contexts. First is the integration of informal knowledge of climate change in the local adaptation policy frameworks, such as in the Medium-Term Development Plans. This will work towards the development and subsequent implementation of climate change communication strategies, to target different cohorts of residents of informal settlements aimed at addressing their diverse information needs and concerns.

The second implication relates to climate change vulnerability assessments for disaster planning. Integration of local knowledge in defining the patterns and distribution of vulnerability to climate change-related phenomena in informal settlements has the potential for improving adaptation planning. In general, planners determine uncertainties about short- and long-term climate effects to integrate the appropriate risk management mechanisms that affect the urban poor into municipal adaptation plans. By integrating local knowledge, residents of informal settlements will be viewed both as producers and consumers of such information. Integrating local knowledge into climate change vulnerability assessments and adaptation planning has the potential to further reduce the present level of mistrust between state officials and residents of informal settlements. An examination of the influence of the perceptions and knowledge on their actual adaptive responses to hazards will extend this discourse. Also, examination of the potential differences between household members' perceptions could improve our understanding of the intra-household perceptions about their experience with climate change.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su14095080/s1>, Supplementary S1: List and number of interviewees, Supplementary S2: Household Survey Questionnaire, and Supplementary S3: Average day and night temperature values in Accra for February.

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