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Article

Linking waste management practices and climate change perception in Ghana: Empirical insight from Moshie Zongo

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Abstract: The issue of climate change cannot be overemphasized considering its negative repercussions on individuals, households, the environment, and nations at large. This necessitates urgent action, as highlighted by sustainable development goal (SDG) 13, which emphasizes how urgent it is to combat climate change and its effects. Innovative waste management is crucial as it helps reduce negative impacts of climate change while supporting social and economic sustainability. This paper contributes to climate change discourse by exploring the association between waste management practices and climate change perceptions. Specifically, this paper has four objectives: (1) examine the current waste management practices currently adopted by residents, (2) determine whether there is an association between waste management practices and climate change perceptions, (3) explore waste management practices that could help mitigate climate change-related challenges, and (4) investigate the current waste-sorting activities within the community. A structured questionnaire is utilized for the data collection. Pearson's Chi-square test is used to assess the association between waste management practices and climate change perception variables (such as rainfall and temperature). The results show, among other things, that the current waste management practices are landfill, open dumping, burning, and municipal waste collection. It is also revealed that there is a significant association between rainfall, extreme weather events like flooding, temperature, and waste management practices. Furthermore, recycling, reuse, and waste reduction are among the practices identified as having the potential to mitigate climate change-related challenges. Finally, it is revealed that residents sort their waste into plastic and paper. Given the significant association between climate change perceptions and waste practices, educational campaigns that connect waste management to perceived climate change impacts should be prioritized. Specifically, stakeholders should include climate literacy in municipal waste policies and community sensitization efforts. In addition, stakeholders should develop targeted programs that explain how poor waste disposal contributes to flooding, rising temperatures, and pollution.

Keywords: climate change perception; waste management practices; sustainable development goals; recycling and reuse

1. Introduction

One of the biggest problems the world is currently experiencing is climate change [1,2]. Many groups, researchers, and organizations have raised concerns about climate change, which has led to large-scale protests across nations and increased pressure on

governments to enact more drastic measures to tackle the issue [3,4]. Poor nations, such as those in sub-Saharan Africa, Latin America, and some Asian countries, typically dominate discussions on developmental challenges, such as poverty. However, climate change has become a major topic of discussion in international development circles [5]. Given the dire consequences of climate change, the United Nations (UN) has devoted one of its goals (goal 13) to climate action. To guarantee a sustainable and resilient future for all, SDG 13 emphasizes how urgent it is to combat climate change and its effects. It highlights how cooperative efforts at the local, national, and international levels are essential to lowering greenhouse gas emissions, enhancing climate resilience, and adjusting to changing weather patterns in order to lessen the effects of climate change on the environment and human society.

Pachauri and Reisinger [6] defined climate as generally understood to represent the average weather conditions, or more specifically, as the statistical depiction of key variables over time—ranging from months to thousands or even millions of years—considering both their average values and variability. Climate change is defined as a shift in the condition of the climate that lasts for a long time, usually decades or longer, and may be detected (e.g., by employing statistical tests) by changes in the mean and/or the variability of its properties. The air temperature over Ghana is predicted to rise by 1.7–3.7 ℃ (very likely range) by 2080 in response to rising greenhouse gas (GHG) concentrations. According to the Federal Ministry for Economic Cooperation and Development report (Climate risk profile: Ghana) in 2019, the median climate model projects 34 more very hot days annually in 2030 compared to the year 2000, 55 more in 2050, and 94 more in 2080 over the entire country. According to the Climate Change and Greenhouse Gas Inventory of Ghana report, carbon dioxide (CO_2) emissions account for 89% of all GHG emissions, with contributions of 11.1% and 0.1% coming from methane (CH_4) and nitrous oxide (N_2O), respectively. Generally, the maximum and minimum temperatures in Kumasi are approximately 30.7 and 21.5 degrees Celsius, respectively. At sunrise and sunset, the average humidity is approximately 84.16% and 60%, respectively [7]. It therefore goes without saying that the waste industry's substantial annual contributions to global greenhouse gas emissions have been the subject of a great deal of research and have stimulated innovation [8].

The 2024 climate change report highlighted that Ghana experienced unusually high temperatures, resulting in intense heat and sunlight. Typically, during June and July, Ghana would expect significant rainfall. However, the altered weather pattern suggests a deviation from the norm, likely influenced by broader climate change effects, which have disrupted traditional seasonal cycles and led to prolonged dry spells and extreme temperatures. These shifts in weather patterns could have far-reaching implications for agriculture, water resources, and overall living conditions in communities [9]. Furthermore, the World Meteorological Organization forecasts that the next five years (2024–2028) could be the hottest on record, necessitating an urgent need for immediate climate action. The above concerns make studies, such as the current paper that investigates climate change issues, an essential task. The atmosphere, crucial in shaping climate patterns, is impacted by human-induced greenhouse gases like ozone, carbon dioxide, and methane, among others [10]. These anthropogenic emissions are the major factors in climate change, fueling global

warming, causing air pollution, and leading to various health issues [11]. According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, vulnerable communities, such as small islands and underdeveloped nations like Ghana, are already experiencing disproportionate effects. The effects of climate change are often more severe in such countries, Ghana inclusive, where waste mismanagement remains a pressing issue. In Ghana, 69% of waste is openly dumped, contributing significantly to emissions [12]. The IPCC estimates that the waste sector accounts for approximately 3% of world emissions. When waste is not disposed of properly, and some is dumped into water bodies, it leads to sanitation and public health issues [13]; however, the decomposition of the waste is aerobic, releasing all of its carbon as carbon dioxide rather than methane [14]. As modern waste management practices develop, Ghana will transition from open dumping sites to sanitary landfills, releasing methane gas. Waste management is a potential area for reducing methane and carbon dioxide emissions. This challenge is particularly pronounced in deprived urban settlements like Moshie Zongo, a densely populated community characterized by limited access to essential public services. Due to its socio-economic vulnerabilities and environmental exposure, Moshie Zongo is highly susceptible to the health risks and ecological impacts associated with climate change, such as erratic rainfall patterns and droughts. Given these conditions, it becomes imperative to analyze the community's perception and awareness of climate change and how it relates to their waste management practices. Understanding local perceptions is critical to developing context-specific, community-based adaptation strategies and policies that are sustainable. While Ghana has initiated waste management efforts, the link between waste management and climate change remains a critical issue that requires empirical investigation, as this paper seeks to do.

This paper explores how waste management and climate change perception are related in Ghana, with a focus on insights from the Moshie Zongo community. Specifically, it aims to (1) examine current waste management practices among community residents, (2) determine whether waste management practices and climate change perceptions are dependent, (3) identify waste management practices that could help mitigate climate change-related challenges, and (4) identify the waste-sorting activities currently in use within the community.

To achieve these objectives, this paper is guided by the following research questions: (1) what are the current waste management practices among community residents? (2) are waste management practices and climate change perceptions dependent? (3) what are the waste management practices that could help mitigate climate change-related challenges, and (4) what are the waste-sorting activities currently in use within the community?

This paper contributes to the climate change discourse. Specifically, it adds to the discussion on waste management practices and climate change perceptions as far as the literature is concerned. In addition, it focuses on a micro-level analysis, targeting residents of a specific community—Moshie Zongo. Micro-level studies are valuable for several reasons, including detailed insight, contextual relevance, real-time data, and reduced generalization errors. For instance, micro-level studies provide a detailed view of behavior, relationships, and social processes that macro-level studies might miss due to aggregation. Also, micro-level analysis studies are able to account for the

specific context in which individuals function and therefore make it vital for comprehending the way these individuals behave, which in turn facilitates effective policy recommendations. Furthermore, given the fact that the micro-level involves direct data collection, it is able to capture current behavior and situations, which is essential for contemporary analysis compared with outdated secondary data; this is key considering the rapidly changing environment. In addition, micro-level analysis reduces generalization errors (in the case of secondary data, which tend to aggregate the data). Micro-level analysis curbs this issue by focusing on specific groups of individuals, and this is crucial as far as intervention programs and policies are concerned.

The rest of the paper is structured as follows: Section 2 focuses on the literature review, while Section 3 presents the methodology employed in this paper. Section 4 focuses on the discussion of results, and the last section presents conclusions and concluding remarks.

2. Literature review

Theoretical underpinning

Theories have evolved over time to explore the link between waste management practices and climate change perceptions. The theoretical review is grouped under two disciplines: social science and environmental. That of the social sciences focuses on human systems and socio-economic practices (e.g., the theory of waste management and the circular economy). The theory of anthropogenic global warming is within the environmental science discipline. The theory of waste management by Pongrácz [15] highlights that waste management prevents waste from endangering human health and the environment and also results in resource conservation. Waste management theory is constructed under the paradigm of industrial ecology because industrial ecology is flexible enough to integrate the objectives and values of waste minimization and/or resource use optimization. Industrial ecology has a principle that every particle that goes through a particular manufacturing process needs to come out of it as a component of a product that can be sold; every product should be made to be able to be recycled at the end of its useful life to make more products and others. The circular economy model by McGrath and Jonker [16] emphasizes wise resource use, prioritizing renewable resources. To manage waste, the model promotes reducing waste by using resources efficiently. Instead of discarding items in open dump sites, illegally dumping them in gutters, or relying on municipal collection, products are designed to last longer. After use, waste materials are recovered, recycled, or repurposed to create new products. Again, the theory of anthropogenic global warming (AGW) could be used to explain the link between waste management and climate change. According to this theory, greenhouse gas emissions from human activity, mainly carbon dioxide (CO_2), methane, and nitrous oxide, are the reason for the planet's catastrophic temperature increase. Effective waste management can minimize these emissions, helping counteract climate change impacts.

Empirically, some studies have been conducted on the link between waste management and perceived climate change. These have been grouped under social sciences and environmental or atmospheric science disciplines.

Within the social sciences discipline, studies have focused largely on behavioral, demographic, and institutional factors influencing waste management practices. For instance, Samson and Oluwatoyin [17] identified poor infrastructure, weak policies, and negative public attitudes as major waste management challenges in Nigeria, Lagos State Metropolis. The study concluded that integrated planning, public awareness, and sanitary landfills are essential to address environmental and health risks caused by improper disposal. Bowan et al. [18] assessed solid waste disposal practices in relation to sociodemographic factors such as sex, age, and educational level in the Wa Municipality, Ghana. Data was collected using a questionnaire, interview, and personal observation. A sample of one hundred and twenty (120) respondents was utilized, and a simple correlation analysis was performed. It was revealed that sex, age, and educational level negatively correlated with the solid waste disposal methods. The results further showed that open dumping of solid waste is a common practice in the municipality. While some use drains to dispose of their solid waste, others directly dump it by the roadside. One limitation of this paper is its assessment of waste disposal practices without linking them to perceived climate change variables, which the current paper aims to do. Onyanta [19] examined the relationship between municipal solid waste management and climate change, highlighting key differences between cities in the Global North and South. The author observed that while cities in the North had shifted their focus from environmental burdens to global climate matters, cities in the South remained preoccupied with immediate, practical challenges such as waste collection and disposal. Moshie Zongo, a densely populated and deprived urban community in Ghana, reflects this Southern context. Similar to many cities discussed in study by Onyanta [19], Moshie Zongo experiences limited access to waste management services, weak local governance structures, and heavy reliance on informal systems. While Onyanta [19] emphasized the political and developmental dimensions of waste and climate discourse, the present paper extended this discussion by examining how residents in marginalized communities perceive climate change in relation to their waste management practices. This perception-based approach provides a localized perspective through which climate and environmental policies can be more effectively aligned with community-specific needs. In a related study, Šedová [20] investigated the determinants of illegal waste dumping in Slovakia. The results indicated that a higher level of waste production leads to a higher rate of illegally dumped waste and a greater number of illegal dumping sites. It was also revealed that income has a positive relationship with the rate of illegal waste dumping, while poverty exhibited a negative relationship with the rate of illegal dumping. The study further revealed that education did not lead to more responsible waste management. Chikowore [21] investigated the factors that influence household waste management practices in Chitungwiza, Zimbabwe. Stratified and random sampling techniques were used to select 314 respondents. The study employed descriptive, Chi-square tests of association and Fisher's t for the analysis. The results from the Chi-square test of independence revealed a strong and significant association between gender and willingness to pay for fortnightly waste collection services. The results further showed that there is a significant connection between age and the person responsible for managing household waste. However, the study showed that there is no association between income and waste management. There was also an association

between income and waste containers used by the respondents. Using the descriptive and content analysis technique, Kihila et al. [22] examined waste segregation and the potential for recycling in Tanzania. The results indicated that the recycling and reuse of electronics, plastics, and metals are carried out informally. The study further showed that while the potential for reuse, recycling, and recovery is high, it is hindered by a lack of facilities, inadequate policy enforcement, and insufficient awareness and strategies for promotion. Community perceptions with respect to the ways to improve waste segregation include providing facilities for segregation and providing financial returns from recycling businesses to encourage reuse, recycling, and recovery.

For related studies within the environmental or atmospheric sciences, Weitz et al. [23] estimated national landfill methane emissions from solid waste disposal sites in Panama. The study covered the period 1990–2020. The 2006 Intergovernmental Panel on Climate Change (IPCC) waste model spreadsheet and the default emissions estimate approach presented in the 1996 IPCC Good Practice Guidelines were utilized for the analysis. The results showed that solid waste disposals (SWDs) are a key source of emissions of greenhouse gases from Panama, emitting about 6% of the anthropogenic greenhouse gases, and emissions are even projected to rise. In a related study, Miezah et al. [24] investigated municipal solid waste characterization and quantification as a measure of effective waste management in Ghana. Households were randomly selected in each region. Data on the rate of waste generation, physical composition of waste, sorting and separation efficiency, and per capita waste from November 2013 to April 2014. The study revealed that the rate of waste generation was 0.47 kg/person/day, which is equivalent to about 12,710 tons of waste per day. Nationally, biodegradable waste (organics and papers) was 0.318 kg/person/day, and non-biodegradable or recyclable waste (metals, glass, textiles, leather, and rubbers) was 0.096 kg/person/day. Inert and miscellaneous waste was also estimated at 0.055 kg/person/day. The average household waste generation rate among the metropolitan cities was relatively high, 0.72 kg/person/day, except for Tamale. It was further revealed that metropolises generated higher waste (average 0.63 kg/person/day), and this was followed by the municipalities with a value of 0.40 kg/person/day. The least was in the districts with a corresponding value of 0.28 kg/person/day. Through the identification and integration of predictive spatial data in a geographic information system, Glanville and Chang [25] examined the applicability of mapping illegal domestic waste disposal potential to support waste management efforts in the Sunshine Coast (Queensland, Australia). It covered a total of 551 incidents of illegal waste disposal between December 2011 and February 2014. A binary logistic regression was used for the analysis. The study identified 6.9% of the study area as having very high illegal waste disposal potential, and 32.9% of known illegal waste disposal sites were located within the area. Rankoana [26] highlights that communities in Limpopo, South Africa, perceive climate change through temperature and rainfall variations, which negatively affect subsistence food production, water availability, and biodiversity, impacting livelihoods. Similarly, Mudu et al. [27] examined Urban Municipal Solid Waste Management in Accra. Specifically, the link between air pollution and health was assessed. Accra Metropolitan Assembly and some companies in Accra, including Accra Composting & Recycling Plant, Zoomlion Ghana Limited, Sewerage Systems Ghana Limited, Tema Landfill, Zoompark Teshie transfer station, J. Stanley Owusu

and Co. Limited, Metropolitan Waste and Allied Services, Meskworld Co. Limited, Tropical Waste Limited, and Jekora Ventures Limited, were interviewed. The analysis was conducted using the Excel-based Solid Waste Emissions Estimation Tool (SWEET) version 3 and the World Health Organization Air Q^+. The results suggested that, based on PM2.5 emissions (particulate matter 2.5 micrometers or less in diameter) from Accra's waste sector, shifting from business-as-usual to more sustainable practices could reduce air pollution and prevent 120 premature deaths by 2030.

The reviewed studies reveal a multidisciplinary approach to understanding waste management practices and perceived climate change events. These studies indicate that higher levels of waste production lead to an increased number of illegal dumping sites. Additionally, while there is considerable research on waste management practices, gaps remain, particularly in linking these practices to climate change. Related studies in the field of environmental or atmospheric science, like Weitz et al. [23], explored greenhouse gas emissions from landfills. The focus was limited to Panama without broader applications or comparisons across regions. Similarly, studies within the social sciences discipline, such as Bowan et al. [18] and Chikowore [21], examined social factors and demographics that influence waste disposal but did not examine the impact of these practices on climate-related outcomes. Notably, most studies, especially those focused on Ghana, have not linked waste management practices to climate-related variables like temperature and rainfall. These are key gaps in the literature that need to be considered. Therefore, this present paper aims to bridge these gaps by examining the link between waste management practices and climate change perceptions within the Ghanaian context, specifically, Moshie Zongo in the Ashanti region of Ghana.

3. Empirical methodology

This section outlines the methodology this paper adopts to achieve its objectives. It specifically focuses on issues including study setting, sample, sampling technique, data collection instruments, data analysis procedures, and ethical considerations.

3.1. Study setting, research design, sample size, and sampling technique

This paper is carried out in the Moshie Zongo. Moshie Zongo is selected because it is highly susceptible to the health risks and ecological impacts associated with climate change, such as erratic rainfall patterns and droughts. The Moshie Zongo community is located in Kumasi, the capital city of the Ashanti Region in southern Ghana. It is inhabited by settlers who are predominantly northern Ghanaians. Moshie Zongo is a densely populated area with a mix of residential and commercial activities. According to the Ghana Statistical Service, the Moshie Zongo community has a total population of 21,652, comprising 10,475 males and 11,176 females. The majority of individuals are employed in the informal sector. This paper employs a cross-sectional survey design, gathering data at one point in time. It is ideal for the paper due to its cost-effectiveness and time efficiency [28]. The Yamane formula is used to determine the sample size, given the known population size, to ensure a statistically representative sample for the research [29]. This formula is useful for studies where a

large population exists and ensures that the sample is representative while minimizing errors. The formula is given as:

$$n = \frac{N}{1 + N(e)^2},$$

where *n* is the sample size, *N* is the total population, and *e* is the margin of error (0.05 or 5%).

The sample size is then calculated as follows:

$$n = \frac{21{,}652}{1 + 21{,}652(0.05)^2},$$

$$n = 392.7 \approx 393.$$

Based on the formula and the total population of the study area, a sample size of 393 is obtained. Respondents are selected using a simple random sampling method, ensuring that each member of the community has an equal probability of being chosen. This approach minimizes selection bias and enhances the representativeness of the sample. Additionally, the fact that all respondents possess a general understanding of their waste disposal practices represents a key characteristic relevant to the study.

3.2. Data collection, data analysis procedure, and ethical consideration

This paper utilizes a well-structured questionnaire consisting of closed-ended questions to facilitate face-to-face data collection. The questionnaire is divided into seven sections. The first section captures the demographic characteristics of respondents, such as age, gender, and other relevant factors. Sections two through five address various waste management practices, and sections six and seven explore respondents' knowledge of climate change, including changes in climate variables (such as rainfall, temperature, wind, and extreme/unusual events like flooding) and sustainable waste management practices. The data collection exercise started on 16th September 2024 and ended on 20th September 2024. Before the administration of the questionnaires to the respondents, a pilot survey was carried out using about 30 respondents who reside within the Oforikrom Municipality (which is also in the Ashanti region, Ghana). This helped to restructure some of the ambiguous questions. In this paper, both self and assisted approaches to data collection are employed. For the former, the questionnaires were given to respondents to fill out by themselves since they could read, understand, and write in the language (English) used in the design of the questionnaire. For the latter, the questions were read and translated into the local language for the respondents to understand, and their responses were used to fill out the questionnaires. These two approaches were used in order not to ignore individuals who could not read, understand, and write in English. The questionnaire was administered to a diverse group of individuals, regardless of occupation, gender, income level, or education. This approach ensured that everyone within the study area had an equal chance of being included in the study.

Since all the variables are categorical, a Chi-square test of independence is used to explore the associations. This paper tests the hypothesis of whether perceived climate change variables are dependent or independent of waste management practices. Waste management practice represents the independent variable. Perceived

rainfall, perceived temperature, perceived wind, and perceived extreme or unusual weather events like flooding are the dependent variables. With regard to waste management practices, respondents were asked about their primary waste disposal method(s). Responses were categorized into four: landfill, open dumping, burning, and municipal collection. With respect to perceived rainfall change, respondents were asked to indicate if they have observed no change, less, or more rain over recent years. In terms of perceived temperature change, the respondents were asked to indicate whether they perceived no change, hotter, or cooler in local temperature. Participants were also asked to report on perceived changes in wind intensity. Last but not least, respondents were asked whether they have experienced flooding or other unusual weather events in recent years.

This paper follows [30] and applies the following Chi-square test formula:

$$\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \tag{1}$$

where O_{ij} is the observed frequency in each cell and E_{ij} is the expected frequency in each cell under the assumption of independence calculated as follows:

$$E_{ij} = \frac{\text{Row total} \times \text{Column total}}{\text{Grand total}} \tag{2}$$

Concerning the data analysis, the statistical software (STATA SE 17) and Microsoft Excel are utilized. Descriptive statistics are employed to present the demographic characteristics of the respondents. Pearson's Chi-square test (at the 5% level of significance) is used to assess the association between the perceived climate change variables (rainfall, temperature, wind, and extreme/unusual events like flooding) and waste management practices (landfill, open dumping, burning, and municipal waste collection). Separate Chi-square tests for each independent variable against the dependent variable are conducted, and the association is reported. A *p*-value of less than 0.05 indicates a statistically significant association [31]. Unlike a regression model, the Chi-square model is a non-parametric technique, and it analyzes categorical variables using contingency tables [30]. A contingency table cross-tabulates the frequency of respondents' reports on different waste management practices against different categories of perceived climate change variables. In addition, a reliability test using Cronbach's alpha is also conducted to evaluate the internal consistency of the set of questions.

For ethical consideration, formal approval was granted by the Kumasi Metropolitan Assembly (KMA), allowing the team, led by a KMA official, to meet the chiefs to explain the purpose of the study to them. Participation was voluntary, with the right to withdraw at any time, and confidentiality was assured. Again, any information that has the potential to identify any of the respondents, such as names, telephone numbers, and house numbers, is not reported in the paper to ensure anonymity.

4. Results and discussion

This section presents the results and further discusses the findings in relation to the objectives of the paper.

4.1. Descriptive analysis

After data cleaning, a total of 392 respondents (representing a response rate of 99.75%) are used for the analysis. The descriptive statistics of the respondents' demographic and socioeconomic characteristics are presented in **Table 1**. Descriptive statistics on waste management practices and perceived changes in climate change are also reported.

It is observed from **Table 1** that there is a greater proportion of females (252 females [64.29%]) than males (140 males [35.71%]). With regard to employment status, 270 respondents (68.88%) are employed, compared to 122 (31.12%) who are unemployed. The results reveal that artisanship and craftsmanship are the major occupations in the community (118 respondents [30.10%]), followed by trading and commerce (103 [26.28%]). The least is found in agriculture and farming (23 [5.87%]). 114 respondents, representing 29.08%, are included in the "Others" category, which reflects a variety of occupations not included in the primary categories. These include those in the healthcare and education sectors. 144 respondents (36.73%) have never received any formal education, with primary education (114 [29.08%]) and secondary education (95 [24.23%]) being the next dominant levels of education. With regard to the age of the respondents, the largest age group is between the ages of 18 and 24 years (174, [44.39%]), while the smallest age group is under 18 years (25 respondents, [6.38%]). Additionally, it is revealed that 359 respondents (91.58%) earn between GH₵0 and GH₵1000.00, 23 respondents (5.87%) earn between GH₵1001.00 and GH₵2000.00, while 10 respondents (2.55%) earn GH₵2001.00 or more. The majority of households consist of 1 to 9 people, whereas fewer have 10 to 15 or 16 or more, suggesting a preference for smaller family sizes. These statistics to a greater extent reflect the national data according to the Population and Housing Census (PHC) in 2021 [32]. For instance, the national data on gender shows that the female population (50.7%) is slightly greater than the male population (49.3%), which is consistent with what is found in this paper. In addition, national data shows that Ghana has a relatively young population (15–64 years, 60.4%), and the analysis in this paper also reveals that the majority of the respondents are relatively young (18 to 44 years, 78%). For education, national data shows that those with "no education" to "Senior High Education" constitute the larger percentage (90.5%), and this paper also found that the majority of the respondents fall within "no education" to Senior High School (above 90%). Last but not least, national data, according to PHC, indicates that the average household size is about 4, which falls within the majority category of the household size (1 to 9) in this paper and this paper (256 respondents, 65.3%).

Table 1. Descriptive statistics.

Variable	Frequency	Percentage
Waste management practices		
Landfill	12	3.06
Open dumping	24	6.12
Burning	19	4.85
Municipal waste collection	337	85.97
Total	392	100.00

Table 1. (*Continued*).

Variable	Frequency	Percentage
Gender		
Male	140	35.71
Female	252	64.29
Total	392	100.00
Employment status		
Employed	270	68.88
Unemployed	122	31.12
Total	392	100.00
Occupational status		
Agriculture and Farming	23	5.87
Trading and Commerce	103	26.28
Craftsmanship/Artisanship	118	30.10
Construction and Carpentry	6	1.53
Transportation, Mechanic and Logistics	28	7.14
Others	114	29.08
Total	392	100.00
Educational level		
No formal education	144	36.73
Primary education	114	29.08
Junior High School	29	7.40
Secondary Education	95	24.23
Tertiary education	10	2.55
Total	392	100.00
Age (Years)		
Under 18	25	6.38
18–24	174	44.39
25–34	70	17.86
35–44	38	9.69
45–54	52	13.27
55 and above	33	8.42
Total	392	100.00
Income (GHS)		
0–1000	359	91.58
1001–2000	23	5.87
2001 or more	10	2.55
Total	392	100.00
Household size		
1–9	256	65.31
10–15	76	19.39
16 or more	60	15.31
Total	392	100.00

Table 1. (*Continued*).

Variable	Frequency	Percentage
Perceived changes in the environment or weather		
Rainfall		
No change	29	7.40
Less rain	240	61.22
More rain	72	18.37
Do not know	51	13.01
Total	392	100
Temperature		
No change	19	4.85
Hotter	166	42.35
Cooler	148	37.76
Do not know	59	15.05
Total	392	100
Wind		
No change	141	35.97
Stronger	170	43.37
Do not know	81	20.66
Total	392	100
Extreme weather event		
Yes (Have experienced it)	167	42.60
No (Have not experiences)	155	39.54
Cannot remember	70	17.86
Total	392	100

Note: The "Do not know" option for the perceived climate change variables means that the respondents cannot tell whether there has been more rain, less rain, hot temperature, cool temperature, or strong wind for the past 10 to 20 years.
Source: Researchers' estimation.

Concerning the various waste management practices, it is observed that municipal waste collection accounts for 85.97% (337 respondents). This is the predominant approach. The next highest waste management practice is open dumping (24 respondents [6.12%]), and this is followed by burning (19 respondents [4.85%]), and landfill (12 respondents [3.06%]). On the specific perceived climate change variables, the respondents were asked to indicate whether they have noticed any change in weather over the past ten to twenty years. The analysis showed that 72 (18.37%), 240 (61.22%), and 29 (7.40%) respondents reported that they have noticed more rain, less rain, and no change in rainfall, respectively. For temperature, it is revealed that 166 (42.35%), 148 (37.76%), and 19 (4.85%) of the respondents reported there has been hotter temperature, cooler temperature, and no change, respectively. With respect to wind, the analysis revealed that 170 (43.37%) and 141 (35.97%) of the respondents indicated that there has been strong wind and no change in the wind. For extreme weather (such as flooding), the results showed that 167 (42.60%) and 155 (39.54%) of the respondents reported that they had experienced flooding and no

flooding, respectively. However, 70 (17.86%) reported that they cannot remember any extreme event. These figures show that the respondents are highly conscious of environmental changes, even though a few of them are either ignorant or unsure of such developments over the years.

Furthermore, **Figure 1** shows the municipal waste collection system in Moshie Zongo, where they use motorized tricycles ("Aboboyaa") to facilitate waste disposal and enhance access to remote areas, which inspires people to take part in sustainable waste management practices.

Figure 1. Municipal waste collection activity in the Moshie Zongo's community.
Source: Researchers' own.

4.2. Reliability test analysis

The results of the reliability tests are summarized in **Table 2**.

Table 2. Reliability test results.

Item	Alpha value
Waste management practices	
Landfill	0.6214
Open dumping	0.6146
Burning	0.6101
Municipal waste collection	0.5845
Rainfall	
No change	0.6083
Less rain	0.5929
More rain	0.6260
Temperature	
No change	0.6332
Hotter	0.6073
Cooler	0.6028
Other	0.6281

Table 2. (*Continued*).

Item	Alpha value
Wind	
No change	0.5692
Stronger	0.5965
Other	0.6307
Extreme weather events	
Yes	0.6147
No	0.6008
Can't remember	0.6310
Test scale	0.6255

Source: Researchers' estimation.

The overall Cronbach's alpha is approximately 0.63, which falls within the acceptable range of 0.5 to 0.7 proposed by Taber [33], indicating moderate reliability. This suggests a fair level of internal consistency among the questionnaire items, though some variability in responses may exist. Cortina [34] notes that alpha values can increase with more items. Adding climate variables such as CO_2 and methane emissions could improve the reliability. Improper waste disposal, such as landfills and incinerators, increases greenhouse gas emissions [11]. However, due to measurement challenges, particularly in Moshie Zongo (study setting), this paper focuses on temperature, rainfall, wind, and extreme weather events like floods.

4.3. Analysis of the results based on the objectives of the paper

4.3.1. Current waste management practices in Moshie Zongo community

This section examines the various waste management practices (landfill, open dumping, burning, and municipal waste collection). It further analyzes the practices based on the sociodemographic characteristics of the respondents. The results are reported in **Tables 3** and **4**, respectively.

Table 3. Waste management practices in the Moshie Zongo community.

Waste management Practice	Frequency	Percentage
Land-fill	12	3.06
Open dumping	24	6.12
Burning	19	4.85
Municipal waste collection	337	8597

Source: Researchers' estimation.

It is observed that the waste management practices in the study area are landfill, open dumping, burning, and municipal waste collection. Specifically, the results revealed that the majority of the respondents utilize municipal waste collection, and this is followed by open dumping, burning, and landfill in that order. This outcome could be attributed to the fact that the respondents are aware of the negative repercussions associated with improper waste disposal practices such as burning, open dumping, and landfill. Hence, they rely on the municipal waste collection practice,

which is an effective waste management practice. This is because the municipal authority manages the waste in a way that reduces its environmental impact through recycling and reuse.

Table 4. Current waste management practices based on sociodemographic characteristics of respondents.

Variable (%)	Landfill	Open dumping	Burning	Municipal waste collection	*P*-value
Gender (*N* = 392)					
Male	4(33.33)	19(79.17)	11(57.89)	106(31.45)	0.000
Female	8(66.67)	5(20.83)	8(42.11)	231(68.55)	
Occupational status (*N* = 392)					
Agriculture and Farming	0(0.00)	0(0.00)	2(10.53)	21(6.23)	0.000
Trading and Commerce	5(41.67)	6(25.00)	4(21.05)	88(26.11)	
Craftsmanship and Artisanship	4(33.33)	3(12.50)	5(26.32)	106(31.45)	
Construction and Carpentry	0(0.00)	4(16.67)	0(0.00)	2(0.590)	
Transportation, Mechanics	0(0.00)	5(20.83)	6(31.58)	17(5.04)	
Others	3(25.0)	6(25.0)	2(10.53)	103(30.56)	
Employment status (*N* = 392)					
Employed	9(75.00)	101(45.830)	16(84.21)	234(69.440)	0.040
Unemployed	3(25.00)	13(54.17)	3(15.79)	103(30.56)	
Educational level (*N* = 392)					
No formal education	4(33.33)	9(37.50)	6(31.58)	125(37.09)	0.000
Primary education	6(50.00)	0(0.00)	3(15.79)	105(31.16)	
Junior High School	0(0.00)	3(12.50)	4(21.05)	22(6.53)	
Secondary education	2(16.67)	10(41.67)	0(0.00)	83(24.63)	
Tertiary education	0(0.00)	2(8.33)	6(31.58)	2(0.59)	
Age (*N* = 392)					
Under 18	3(25.00)	2(8.33)	0(0.00)	20(5.93)	0.001
18–24	4(33.33)	7(29.17)	14(73.68)	149(44.21)	
25–34	0(0.00)	8(33.33)	5(26.32)	57(16.91)	
35–44	0(0.00)	2(8.33)	0(0.00)	36(10.68)	
45–54	5(41.67)	5(20.83)	0(0.00)	42(12.46)	
55 and above	0(0.00)	0(0.00)	0(0.00)	33(9.79)	
Income (GHS) (*N* = 392)					
0–1000	10(83.33)	17(70.83)	19(100.00)	313(92.88)	0.000
1001–2000	0(0.00)	5(20.83)	0(0.00)	18(5.34)	
2001 or more	2(16.67)	2(8.33)	0(0.00)	6(1.78)	
Household size (*N* = 392)					
1–9	9(75.00)	11(45.83)	13(68.42)	223(66.17)	0.121
10–15	3(25.00)	8(33.33)	1(5.26)	64(18.99)	
16 or more	0(0.00)	5(20.83)	5(26.32)	50(14.84)	

Note: In parenthesis is percentages. Source: Researchers' estimation.

This paper further examines the association (using the Chi-square test) between the various waste management practices and socio-demographic characteristics of the

respondents (see **Table 4**).

The significance level of the association between waste management practices based on the sociodemographic characteristics of the respondents is determined by the *p*-values (from the Chi-square test of independence). At the 1% level of significance, there is a significant association between gender and waste management practices. There is a tendency toward organized waste disposal as both genders favor municipal waste collection, with females leading at 68.55%. There is also a significant association between employment status and waste management practices. People who are employed have a preference for burning (84.21%) and landfills (75.00%). Unemployed counterparts indulge in open dumping (54.17%). Again, 69.44% of those who are employed used municipal waste collection. This implies that enhancing employment could result in a higher dependence on waste services provided by municipalities since they can afford the cost involved, encouraging effective waste management and reducing the burden linked to environmental deterioration and climate change. Also, there is a significant association between occupational status and waste management practices. Artisanship and craftsmanship account for the majority of municipal waste collection (31.45%). Open dumping (25.00%) and landfills (41.67%) are mostly used by those in trade and commerce. Agriculture is the least involved in open dumping, and mechanics and transportation are not involved in landfills (0%). This indicates that various sectors have different waste management practices.

Furthermore, people without a formal education are primarily involved in municipal waste collection (37.09%). About 50.00% of people with only a primary education prefer landfills, while 41.67% of people with a secondary education choose open dumping. Burning is used by those in tertiary education (31.58%). This is significant at the 1% level. Thus, levels of education and waste management decisions are dependent; raising education can result in better practices and more effective perceived climate change responses. This finding is consistent with the study by Ishi [35]. There is a significant association between age and waste management practices. The age group of 18 to 24 years old is the most active in terms of burning (73.68%). The majority of people (41.67%) who use landfill practices are 45 to 54 years old. The older group (55 and above) exhibits limited activity in all waste management practices, particularly open dumping and burning, whereas younger people (under 18) prefer landfills (25.00%) to all the waste management practices. Thus, burning and landfilling of waste by younger age groups highlights the need for education to promote sustainable practices, which will ultimately help solve perceived climate change issues more successfully. Waste management is most prevalent in the GH₵0–GH₵1000 income category, where 83.33% of waste is disposed of in landfills and municipal waste collection accounts for 92.88%. It can be deduced that lower-income groups demonstrate higher reliance on municipal waste collection, suggesting that affordability and access influence disposal choices, as reported in previous studies [36,37].

In contrast, the GH₵1001–GH₵2000 and GH₵2001 or more income groups exhibit much lower engagement across all waste management practices. The association between household size and waste management practices is, however, insignificant. Despite this insignificant association, the majority of respondents with a

household size of 1 to 9 use municipal waste collection (66.17%). Larger households, on the other hand, rely more on burning and open dumping, which has an adverse consequence on the environment.

4.3.2. Association between waste management practices and perceived climate change

The results from the Chi-square test regarding the association between waste management practices and climate change are reported in **Table 5** (see **Table A1** for the full Chi-square test results in the Appendix).

Table 5. Chi-square test results for the association between waste management practices and perceived climate change.

Variable	Chi-square value	*P*-value
Rainfall	53.5737	0.000
Temperature	16.7897	0.052
Wind	9.2779	0.159
Extreme/unusual events (Flooding)	13.8803	0.031

Source: Researchers' estimation.

The Chi-square analysis shows that there is a significant association between waste management practices and rainfall at a 1% significance level. There is also a relatively weak significant (10% significance level) association between temperature and waste management practices. These suggest that variations in the perceived climate change, notably in rainfall patterns and temperature, are associated with changes in waste management practices. Hence, efficient waste management practices, such as minimizing burning and landfill practices, can lower greenhouse gas emissions that influence perceived climate change. These behaviors have an impact on waste decomposition and pollutant discharge, which in turn affect perceived climate change. The analysis further indicates that there is a significant (5% significance level) association between waste management practices and extreme occurrences like floods. Efficient waste management can lessen the adverse influence of flooding by ensuring appropriate disposal of waste and reducing pollutants. This highlights how preventive measures can improve community resilience to extreme weather events, highlighting the importance of adaptive waste management systems in addressing perceived climate change issues. The result, however, shows no significant association between waste management practices and wind. This suggests that, considering the study setting, waste management practices are not associated with wind, all other things being equal. Previous studies [26,38–40] have also found a significant association between waste management practices and perceived climate change.

4.3.3. Waste management practices that could mitigate perceived climate change-related challenges

This section outlines some waste management practices that could mitigate perceived climate change-related challenges. The result from the analysis is presented in **Figure 2**.

It is revealed that approximately 29.08%, 7.65%, and 27.04% of the respondents

perceive reducing, reusing, and recycling, respectively, as sustainable waste management practices to mitigate climate change. Cooper and Gutowski [41] argue that reusing materials reduces the need for new production and waste disposal, promoting sustainability, reducing waste, and lowering carbon footprints, which affect climate change variables such as rainfall and temperature. Previous studies (such as Mohan et al. [42], Nnaji et al. [43], Minunno et al. [44]) have linked recycling to reduced greenhouse gas emissions. Additionally, 4.34% advocated for composting, which enriches soil and reduces methane emissions by diverting organic waste from landfills. Waste-to-energy (1.28%) is also supported as an efficient strategy. This is consistent with assertion by Tahiru et al. [45] that waste-to-energy as a waste management strategy has the potential to mitigate climate change-related challenges. Lastly, 30.61% of the respondents emphasize community engagement and education as vital for sustainable waste management.

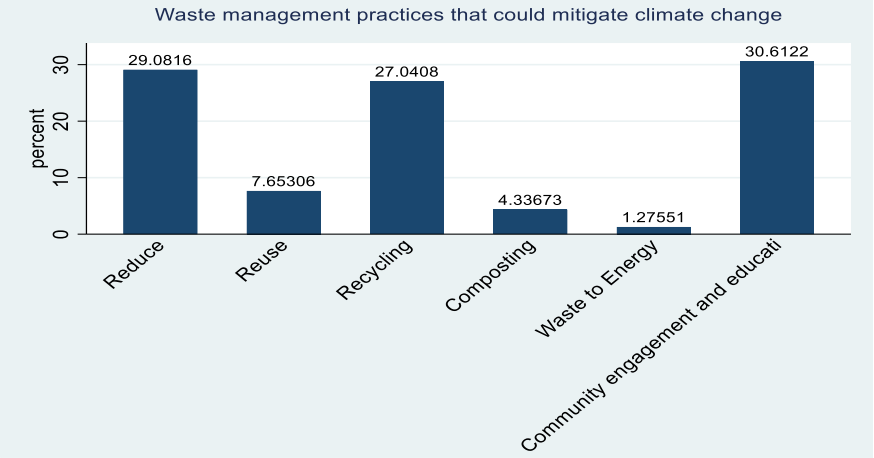

Figure 2. Sustainable waste management practices.

Source: Researchers' estimation.

4.3.4. Waste-sorting activities currently in use within the community

The sorting activities related to waste management in the Moshie Zongo community are presented in **Figure 3**.

Figure 3. Sorting activities in the Moshie Zongo's community.

Source: Researchers' own.

Specifically, the community engages in sorting waste into plastic and paper, showcasing their commitment to efficient waste management practices and promoting

recycling and sustainability in the area.

5. Concluding remarks

This paper investigates the link between waste management practices and climate change perceptions in Ghana with empirical insight from the Moshie Zongo community in the Ashanti region. Specifically, this paper examines the current waste management practices adopted by the residents and the association between these practices and climate change perceptions. It further identifies waste management practices that could mitigate climate change-related challenges and finally investigates the sorting activities about waste management in the community. This paper employs a well-structured questionnaire for the data collection and utilizes descriptive statistics and Pearson's Chi-square test for the analysis. The conclusions emerging from the findings are as follows: (1) The current waste management practices in the community are landfill, open dumping, burning, and municipal waste collection; municipal waste collection is the predominant one used. (2) There is a significant association between rainfall, temperatures, and extreme weather events, such as flooding and waste management practices. (3) Waste management practices that have the potential to mitigate perceived climate change-related challenges include reducing, reusing, and recycling waste, composting, and waste-to-energy. Community engagement and education on waste management are also emphasized. (4) The community sorts its waste into plastics and papers.

On the policy front, it is suggested that local governments should upgrade infrastructure to increase the number of collection points. This recommendation is based on the finding that municipal waste collection is the most commonly used waste collection strategy. Additionally, the municipality should adopt demographic-specific policies tailored to the unique demands of various groups to enhance waste management practices. For example, policies aimed at gathering and sorting waste (e.g., into plastics and papers) should consider the educational level of the populace. Other demographic characteristics, such as income, should also be taken into account when implementing waste collection strategies. Last but not least, it is suggested that policymakers, municipal authorities, and environmental stakeholders should integrate climate education into waste management initiatives. Doing so will not only enhance community resilience but also advance the goals of sustainable development and climate action as outlined in SDG 13.

A key limitation of this paper is that the research was conducted in a single community—Moshie Zongo in the Ashanti Region of Ghana. While this may limit the generalizability of the findings, it does not undermine their relevance and validity within the specific context studied. As a result, caution should be exercised when extending these findings to other communities or regions of Ghana. Given this, it is recommended that future research should include multiple communities within the Ashanti Region and other regions across the country to allow for comparative analysis and broader applicability.

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RAA; formal analysis, JAL, STB, CMA and RAA; investigation, JAL, STB, CMA and RAA; resources, JAL, STB, CMA, RAA, JG and CO; data curation, JAL, STB, CMA, RAA, JG and CO; writing—original draft preparation, JAL, STB, CMA, and RAA; writing—review and editing, JAL, STB, CMA, RAA, JG and CO; visualization, JAL, STB and CMA; supervision, STB; project administration, JAL and STB; funding acquisition, JAL. All authors have read and agreed to the published version of the manuscript.

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Appendix

Table A1. Chi-square test results for the relationship between waste management practices and perceived climate change variables.

Variable	Landfill	Open Dumping	Burning	Municipal Waste Collection
Rainfall				
No change	6	2	2	19
Less rain	6	15	3	216
More rain	0	5	11	56
Pearson chi(X^2) = 53.5737 Pr = 0.000				
Temperature				
No change	3	0	0	16
Hotter	7	13	11	135
Cooler	2	9	5	132
Other	0	0	0	8
Pearson chi2(X^2) = 16.7897 Pr = 0.052				
Wind				
No Change	3	14	8	116
Stronger	7	8	8	147
other	2	0	0	28
Pearson chi2(X^2) = 9.2779 Pr = 0.159				
Extreme/Unusual Event				
Yes (have experienced change	4	7	4	152
No (have experienced no change)	7	15	12	121
Cannot remember	1	0	0	18
Pearson chi2(X^2) = 13.8803 Pr = 0.031				

Source: Researchers' estimation.

Research questionnaire

We are a team conducting research aimed at exploring the link between waste management practices and climate change perceptions, focusing specifically on the Moshie Zongo community in Ghana. Your insights and experiences are invaluable to our understanding of how waste management practices are associated with perceived climate change issues.

Please be assured that your responses will remain confidential and will be used solely for research purposes. Participation in this study is voluntary, and you may choose to withdraw at any time without any consequences.

[Please provide your responses by checking the box or writing where necessary].

Section 1: Demographic Information

1) Age

[ ] Under 18; [ ] 18–24; [ ] 25–34; [ ] 35–44; [ ] 45–54; [ ] 55 and above

2) Gender

[ ] Male; [ ] Female

3) Employment status

[ ] Employed [ ] Unemployed

4) Occupation

(select one that best applies) [ ] Agriculture and Farming; [ ] Trading and Commerce; [ ] Craftsmanship and Artisanship; [ ] Construction and Carpentry; [ ] Transportation, Mechanic and Logistics; [ ] Others (Please specify)…

5) Level of Education

[ ] No formal education; [ ] Primary education; [ ] Secondary education; [ ] Tertiary education

6) What is monthly income? (in Ghc)

[ ] 0–400; [ ] 401–800; [ ] 801–1000; [ ]1001–1200; [ ] 1201–1400; [ ] 1401–1600; [ ] 1601–1800; [ ] 1801–2000

7) How many people currently live in your household?

[ ] 1–3; [ ] 4–6; [ ] 7–9; [ ] 10–12; [ ] 13–15; [ ] 15 and more

Section 2: Waste Management Practices

8) How do you dispose of your household waste? (Select all that apply)

[ ] Landfilling; [ ] Dumping in open; [ ] Burning; [ ] Burying areas; [ ] Municipal waste collection; [ ] Other (please specify): ……..……

9) Do you sort your waste before disposal?

[ ] Yes; [ ] No

Which of these waste management practices do you frequently use? (Select one)

[ ] Landfilling; [ ] Burning; [ ] Open dumping site; [ ] others

Section 3: Landfilling

10) How many landfilling sites do you know of in this community?

[ ] 1; [ ] 2; [ ] 3; [ ] 4; [ ] 5; [ ] 6; [ ] 7 or more

11) What is the primary type of waste being deposited in the landfill?

[ ] Organic; [ ] Plastic/rubber; [ ] Paper; [ ] Metal

12) Is the site far from human reach, example house, market, water bodies and others?

[ ] Yes; [ ] No

13) Are there measures for the closure of the landfill when it reaches capacity?

[ ] Yes; [ ] No

14) Would you opt for other waste management practices if there are any?

[ ] Yes; [ ] No

15) Does the landfill manage odor, pests and other potential nuisance?

[ ] Yes; [ ] No

16) Are there any monitoring units that keep the place in check?

[ ] Yes; [ ] No

Section 4: Open dumping sites

17) How many open dumping sites do you know of in this community?

[ ] 1; [ ] 2; [ ] 3; [ ] 4; [ ] 5; [ ] 6; [ ] 7 or more

18) What is the primary type of waste being deposited in the open dumping sites?

[ ] Organic; [ ] Plastic/ rubber; [ ] Paper; [ ] Metal

19) Is the site far from human reach, example house, market, water bodies and others?

[ ] Yes; [ ] No

20) Are there measures for the closure of the open dumping sites when it reaches capacity?

[ ] Yes; [ ] No

21) Would you opt for other waste management practices if there are any?

[ ] Yes; [ ] No

22) Does the open dumping sites manage odor, pests, heat and other potential nuisance?

[ ] Yes; [ ] No

23) Have you or any member of your household experienced any health risks associated with open dumping sites?

[ ] Yes; [ ] No

Section 5: Burning

24) How many times do you burn waste in a month?

[ ] 1; [ ] 2; [ ] 3; [ ] 4; [ ] 5; [ ] 6; [ ] 7 or more

25) What type of waste do you burn?

[ ] Organic; [ ] Plastic/ rubber; [ ] Paper; [ ] Metal

26) Is the site far from human reach, example house, market, water bodies and others?

[ ] Yes; [ ] No

27) Are there measures for the closure of the burning sites when it reaches capacity?

[ ] Yes; [ ] No

28. Would you opt for other waste management practices if there are any?

[ ] Yes [ ] No

29) Does the burning sites manage odor, pests, heat and other potential nuisance?

[ ] Yes; [ ] No

30) Have you or any member of your household experienced any health risks associated with burning?

[ ] Yes; [ ] No

31) Are there any monitoring units that keep the place in check?

[ ] Yes; [ ] No

Section 6: Climate Change Knowledge

32) Have you noticed any changes in your environment/weather over the past 10–20 years?

[ ] Yes; [ ] No; [ ] unsure

33) If “yes” to Q32, can you tell me what changes you have noticed in the rainfall?

[ ] No change; [ ] Less rain; [ ] More rain; [ ] Do not know

34) If “yes” to Q32, can you tell me what changes you have noticed in the temperature?

[ ] No change; [ ] Hotter; [ ] Cooler; [ ] Do not know

35) If “yes” to Q32, can you tell me what changes you have noticed in the wind?

[ ] No Change; [ ] Stronger; [ ] Do not know

36) Have you recently experienced any extreme/unusual weather events for example, storms, and floods?

[ ] Yes; [ ] No; [ ] do not know/cannot remember

37) Do you believe that waste management practices affect climate change?

[ ] Yes; [ ] No; [ ] Unsure

38) How would you rate your knowledge of climate change?

[ ] Very knowledgeable; [ ] Somewhat knowledgeable; [ ] Not knowledgeable

39) What sources do you rely on for information about climate change? (Select all that apply)

[ ] Social media; [ ] Television/radio; [ ] Community workshops; [ ] Schools/universities; [ ] Family/friends;

[ ] Other (please specify): ……..

Section 7: Sustainable Waste Management Practices

40) What waste management practices do you think it would help mitigate climate change related challenges?

[ ] Reduce; [ ] Reuse; [ ] Recycling; [ ] Composting; [ ] Waste to Energy; [ ] Extended Producer Responsibility;

[ ] Community engagement and education; [ ] Innovative Technology

41) Any other comment: ……

Thank you for your time.