Hindrances to adaptation to water insecurity under climate variability in peri-urban Ghana

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Abstract: Water insecurity is a development challenge confronting households in the Wa municipality. This paper outlines the hindrances to climate variability adaptation to water insecurity among peri-urban residents within the Wa Municipality. A sample of 345 households was randomly selected from seven communities together with a staff from the Community Water and Sanitation Agency (CWSA) for interviews. The data were analyzed using the statistical tools embedded in the Statistical Product for Services Solution software. Results indicate that climate variability is the main contributing factor to water insecurity in the study area. Hindrances to adaptation to water insecurity include the cost of obtaining water, time spent and distance travelled to obtain water, low literacy levels, income poverty and language barriers to direct translation of climate terminology. The paper recommends that the Municipal Assembly in collaboration with Non-governmental organizations should provide alternative water sources in addition to rainwater for the people in the area.

Subjects: Sustainable Development; Rural Development; Biogeography

Keywords: climate variability; water insecurity; adaptation hindrances; Wa municipality; Ghana

ABOUT THE AUTHORS
My interest areas are climate and environmental management studies. My focus is in establishing the anthropogenic causes of climate variability and its impact on water scarcity or insecurity in especially arid and semi-arid environments. I am also interested in outlining the impact of water scarcity or insecurity on domestic and agricultural water needs in savannah regions such as the northern savannah in Ghana where rainfall is inadequate and relied on as the main water source for almost all purposes. Much focus is also placed on the adaptation strategies employed by rural and peri-urban communities (who are often the most affected), that is, the household’s and the collective communities’ efforts in mitigating water insecurity under climate variability. And also the possible hindrances that thwart the efforts of the individuals and communities to forestalling the adversities of water insecurity/scarcity as a result of climate variability.

PUBLIC INTEREST STATEMENT
Water insecurity is a developmental challenge confronting Ghana including people in the Wa Municipality. Rainfall is depended on for recharging almost all the water sources within the municipality. However rainfall in the area is highly unreliable and erratic posing an uncertainty in water availability coupled with the growing demand by the increasing population. The paper espouses hindrances to adaptation to water insecurity under climate variability in peri-urban Wa of Ghana. The absence of alternative livelihood activities, low literacy rates, poverty, and language barrier, largely hindered respondents from effectively adapting to climate variability and climate change-related water insecurity. Translating climate terminologies into local languages that is familiar to local people by language experts and also providing public health education and awareness campaigns on afforestation especially around water bodies can help improve and deepen the understanding of the relationship between water resources and climate variability in Ghana and other Sub-Saharan African Countries.

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1. Background to the paper

Water is an essential resource that has no substitute. It is an input to almost all production processes (Grey & Sadoff, 2007). However, evidence suggests that the world is approaching a water crisis leading to insecurity (Eckstein, 2009). Grey and Sadoff (2007), defined water security as the availability of a reliable and an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water related risk. Water crisis, water scarcity, water shortage, and water stress are sometimes used inter-changeably with water insecurity (Pereira, Cordery, & Iacovides, 2002). Water crisis, according to Suleiman (2012), is largely caused by climate variability and climate change, as well as human induced environmental deteriorating conditions. Water crisis/scarcity is one of several current and future critical issues facing Africa. Many countries on the African continent particularly sub-Saharan Africa live under considerable water stress conditions as a result of insufficient and unreliable rainfall (German Advisory Council on Global Change [WBGU], 2003). As of 2013, it was estimated that over 780 million people in Africa did not have adequate access to safe drinking water and adequate sanitation, making the continent the lowest in water supply coverage by any region in the world (World Health Organisation/United Nations Children Fund, 2012 cited in Cheng, Kelly, Renwick, & Yang, 2013). This access rate is much worse in the rural areas where there is only about 47% water coverage, compared with 85% coverage in the urban areas (Nkomero, Nyong, & Kulindwa, 2006). Apart from the general continental situation, there are interregional variations in the water security burden due to climate change on the continent (Tatlock, 2006). Notable among these are the climate-induced water stress condition in south-western and south central Africa, parts of the horn of Africa to the east, as well as the Sahelian regions have relatively lower per capita water usage on the continent of Africa (Awualchew, Sally, Bahri, Molden, & Giordano, 2008).

Water resources in Ghana play a central role in the promotion of living standards, enhancing economic growth, provision of food security and livelihood, as well as alleviation of poverty (Anayah & Kaluarachchi, 2009). As in most parts of the world, Ghana is experiencing continuous increase in population growth, with a corresponding increase in the demand for water (Anayah & Kaluarachchi, 2009). However, the impacts of erratic rainfall amount, especially in the Upper West Region; about an average figure of 750 mm, expressed in climate variability, significantly limits the volumes of water supply required, especially in savannah to semi-arid regions (Herrera-Pantoja & Hiscock, 2008). Currently, about 5 million people (representing 20% of the total population based on the 2010 population and housing census) living in Ghana experience water stress or scarcity (Suleiman, 2012). This scarcity is measured by the household per capita consumption of water, which is about 68 L per capita per day. This determines the level of water insecurity at the household level. It is projected that by 2020 the country’s per capita water availability will be a little over 1000 m³ per annum which will make Ghana a water-stressed country (Pagett & Acquah, 2012). This will further be exacerbated by observed and predicted impacts of climate variability and a consistent decrease in rainfall amount for 30 to 35 years as the climate changes, in the long term.

According to Drakakis-Smith (2000), poor people try to do anything and everything to survive. This leads them into doing things that are costly to or affect the environment (Robinson, 2002). In the study area, firewood is the main source of energy for cooking. The inhabitants also are engaged in commercial charcoal production. During the long dry season, while people fell trees to harvest the leaves and sell to herdsmen as fodder for their herds, herdsmen also deliberately burn the bush to instigate the germination of fresh grasses for their cattle to graze. Attempts are not made to replace the fell trees and the continuous bush burning in the dry season destroys regenerating tree saplings. Slash and burn is a common land preparation practice in the area. Sand mining and stone quarrying as livelihood activities are common and have led to land degradation in communities where they are
practiced. These activities acting in tandem have resulted in excessive erosion and deforestation in the area and have the potential to alter the rainfall pattern and amount needed to recharge surface and underground water.

Challenges associated with developing and managing water resources are becoming daunting. Climate variability and human-driven environmental degradation such as mining, waste disposal expansion of residential areas into new underdeveloped locations and water pollution as well as changes in agricultural land uses onto riparian zones have all contributed to the challenges (Narain, Khan, Sada, Singh, & Prakash, 2013). These human activities have diverse impacts on the water cycle, including altered river flows, changes in surface and groundwater recharge, more intense floods and surface runoff, longer droughts periods and rising temperatures, especially, in the savannah ecological zones of Ghana (Suleiman, 2012). The adverse impacts of water have affected many sectors of the economy and therefore increased the dimensions of water and related poverty issues, particularly in rural locations (Amokrane, Gaff, Loughborough, & Ruberti, 2007). The repercussions include declining crop yields affecting hundreds and limiting their abilities to produce or purchase sufficient water to enhance food security (Wateraid, 2007).

The impact of climate variability that is already being felt across the country is likely to be more intense in the savannah (northern part) of the country. The northern savannah ecological region is characterized by a unimodal pattern of rainfall with little and highly variable spatially-distributed rainfall (Yengoh, Armah, Ebo, & Odoi, 2010). Generally, average annual rainfall decreases from the southwestern part of the country (2,000 mm/year) towards the north (950 mm/year) (Logah, Obuobie, Ofori, & Kankam-Yeboah, 2013). The rainy period in the northern savannah area often lasts for a few months, usually between three and five months leaving the rest of the year dry. Water availability during this period is limited. In view of this both human beings and livestock have to share the limited available water for households and agricultural needs. This underscores the gravity of water scarcity and the insecurity it poses to many households in that part of Ghana.

Adaptation to climate variability in respect of water insecurity according to this paper entails the individual (household) and collective (community) efforts used to forestall the adversities of the water scarcity. These have emerged as a solution to addressing the impacts, already evident in some regions (Ngigi, 2009). This is particularly relevant for the Guinea Savannah ecological zones within which the Wa municipality is found where households are already struggling to meet the challenges posed by existing climate variability (Yamin, Rahman, & Huq, 2005) and are therefore identified as the most adversely affected by climate variability (McCarthy, Canziani, Leary, Dokken, & White, 2001).

Despite the significance attached to adaptation, there remains a lack of understanding of the key hindrances that impede the effective implementation of adaptation strategies by households across Sub-Saharan Africa (SSA) (Antwi-Agyei, Dougill, & Stringer, 2013). This is particularly so in the Upper West Region. Some research on climate adaptation have been conducted (see Ford, Berrang-Ford, & Paterson, 2011; Gifford, 2011), and efforts to facility adaptation to water insecurity has been undertaken, yet the majority of studies do not report on the hindrances to the household access to water supply due to climate variability and change in the Upper West Region. Much has been done in providing water for the Upper West Region for various applications but the problem still persists. The project to pipe water from the Black Volta to supplement the water needs of the Wa Municipality has been completed. However, significant climate variability within the region has the potential to hinder the sustainable access to water from the Black Volta.
Identification of some of these hindrances is essential for smooth implementation of the various adaptation strategies to climate variability and its associated water insecurity. It is in the light of this that this paper examines the hindrances to adaptation to climate variability-induced water insecurity at the household level in the Wa Municipality.

2. Profile of the study area
The Wa Municipal Assembly (WMA) is the only municipality in the Upper West Region. There are, however, ten (10) additional District Assemblies in the region. The WMA lies within latitudes 1°40′ to 2°45′ N and longitudes 9°32′ to 10°20′ W. It shares administrative boundaries with the Nadowli District to the North, Wa East District to the east, Wa West District to the West and to the South by the Tuna Kalba District in the Northern Region. Wa, which is the capital of the Municipal Assembly, also serves as the regional capital. It has a landmass area of approximately 234.74 km² (WMA, 2010).

The climate of the municipality is typical of tropical continental (WMA, 2010). The area experiences two seasons: the dry and wet seasons. The wet season lasts between June and September. The dry season starts in late October when the weather is cold and mean temperatures could be as low as 15 °C at night. This extend into the month of March when the weather is extremely hot with dry hazy winds and mean maximum diurnal temperatures of 45 °C (WMA, 2010). The annual mean rainfall ranges between 840 and 1400 mm and this has serious implications for food crop production and the availability of both surface and underground water sources (WMA, 2010). The rainfall pattern in this part of the country is as erratic as in most part of the north (Logah et al., 2013). This erratic rainfall pattern is one of the factors which render the area relatively dry, leading to limited access to water in any form.

According to the 2010 Population and Housing Census (PHC), the Wa Municipality had a total population of 107,214 with Wa town alone constituting about 65% of the total population (Ghana Statistical Service, 2012). By implication, there is a high density of population in Wa and consequently putting pressure on water resources, land and other socio-economic infrastructure. This pressure on land and water resources has also been extended to the peri-urban areas. Other issues of concern include housing, water management, streetism, conflict management and land-use planning as developmental challenges to be grappled with (WMA, 2010). Figure 1 is a map illustrating areas selected for the study within the Wa Municipality.

Human activities like bush burning, cutting of fuel wood, farming, over grazing, mining, road and dam construction have all combined to modify the natural environment. These have had significant impact on the natural environment in the form of loss of the vegetative cover and wildlife, and desertification. Gravel/burrow pits are fast becoming permanent features along roads in the Municipality and thus worsen the extent of land degradation (WMA, 2011).

There are two main types of soil. The laterite and the savannah ochrosols but there is also evidence of clay especially in the Charia community which is famous for pottery. The laterite soil occurs abundantly all over the Municipality and is excavated for roads and housing construction. Similarly, sand winning is done along roads and in river beds but much of the activity is done at Nakore (WMA, 2011).
3. Methodology

This section details the research methods and procedures of the study. It enumerates the research design, sampling techniques and procedures, data collection tools and tools of data analysis and presentation.

3.1. Research design

The cross-sectional survey was used to gather both qualitative and quantitative data through the use of questionnaires and interviews. This design was chosen because it involved a systematic approach to data collection and presentation to reflect a given situation within the period of the study. Thus, variables relevant to the study were gathered from a cross section of targeted communities to achieve the objectives of the study.

Figure 1. Map of Wa municipality.
3.2. Sample and sampling procedure

The study population included some twenty communities and a staff from the Community Water and Sanitation Agency (CWSA) in the Wa Municipality. According to the database of the WMA, these twenty communities have homogeneous characteristics of water-related challenges within the municipality. A multistage sample approach was used in this study. A staff of the CWSA was purposively selected. A total of 345 household respondents were sampled using the formular below:

\[ N \frac{1}{1 + N \left( e^2 \right)} \]

where “N” represents total households and “e” is the margin of error. But the total households were 2,500, therefore,

\[ \frac{2500}{1 + 2500 \left( 0.05^2 \right)} = 345 \]

These household respondents were obtained from seven communities that were randomly selected the above mentioned twenty communities from the database of WMA. The names of the communities were written and folded into a container, mixed thoroughly and seven were randomly picked from among the rest. The rationale for using a simple random sampling technique was to ensure that all communities had a fair chance of being selected because of the principle of socioeconomic homogeneity. The sample size for the various communities was arrived at by proportionate sampling,

\[
\frac{\text{Total Sample Size} \times \text{No. of Households per community}}{\text{Total No. of households}}
\]

For example, Sombo = \( \frac{345}{2500} \times 973 = 134 \)

This was repeated for the rest of the communities. Table 1 illustrates the sample size of the various communities that were selected.

Women compared to men suffer most in times of water crises so it was appropriate that more of their views on hindrances to adaptation were taken. The systematic sampling technique was applied in selecting households from which respondents were to be drawn. The value of the total number of houses was used in dividing by the total sample size of each community to arrive at the interval (i.e. the Kth number) between the houses in which households were to be drawn from. This was repeated for the rest of the communities.

| Name of community | Number of households | Sample size per community |
|-------------------|----------------------|---------------------------|
| Sombo             | 973                  | 134                       |
| Charia            | 522                  | 72                        |
| Kpangu            | 408                  | 56                        |
| Danko             | 266                  | 37                        |
| Nakori            | 201                  | 28                        |
| Kunfabiela        | 69                   | 10                        |
| Dignafuro         | 61                   | 8                         |
| Total             | 2,500                | 345                       |
3.3. Data collection tools
Primary and secondary data sources were considered for the study. The primary data were gathered from the various households. The secondary data were obtained from the CWSA, and the Ghana Meteorological Agency (GMA) in Wa. Specific data gathering tools included an interview guide and a questionnaire.

The household questionnaires were designed to contain both closed and open-ended questions and were administered to the various households. Items in this research instrument included the contributing factors to water insecurity, time and length of rainfall, level of knowledge on climate variability, mode of adaptation to climate variability and water insecurity and hindrances to adaptation to climate variability and water insecurity. The rationale for the use of the questionnaire was to enable the study to collect both quantitative and qualitative data at the same time. Two research assistants were trained and used administer the questionnaire to the respondents in their local language.

An interview guide was used in interviewing a staff of the Municipal CWSA. Items that were included in the guide were based on the current water situation within the municipality, the types of water facilities that are provided, the reliability of these facilities in the face of climate variability and measures to improve inadequate water supply. The questions that were asked during the interview were open-ended. This enabled the interviewee to express himself to the fullest to help the study obtain accurate and necessary information.

3.4. Data analysis
Using the Statistical Package for Social Sciences (SPSS) version 20, the quantitative data were analyzed and the results presented employing descriptive statistics. The Mann-Kendall Test and Sen’s Slope Estimates for the Trend of Annual Data Version 1.0 Excel software was also employed in determining the degree of variation in the climatic data (rainfall, temperature and evaporation). Line charts, trend line and trend equation have been used to determine the nature of the inter-annual variation in the climatic data; i.e. rainfall, temperature (maximum and minimum) and evaporation (1983 to 2013) under investigation. The qualitative data were analyzed based on content analysis.

4. Results and discussions
4.1. Contribution of climate variability to water insecurity
In this paper, climate variability is identified as the main contributory factor to the water insecurity and the socio-environmental hindrances that reduce access to, and use of water in the study area.

4.1.1. Impact of climate variability on water
Rainfall, temperature and evaporation are determinants of water availability (Bates, Kundzewicz, Wu, & Palutikof, 2008). However, data on these climatic elements collected from the GMA exhibited variability within the municipality. These might have contributed to the water insecurity situation in the study area. Water availability is usually related to ample rainfall; however, with major climate variability, it becomes difficult determining the amount of water that would be available for use (Bates et al., 2008). Figures 2–5 illustrate the inter-annual rainfall deviations, maximum and minimum temperature records from 1983 to 2013 and evaporation from 1988 to 2013 respectively for the Wa Municipality. Inadequate rainfall coupled with rising temperatures and evaporation are capable of reducing stream flows and lowering of water tables which can cause the drying up of water wells within the municipality.

Figure 2 shows that rainfall variability is pronounced following the increase in climate variability. Generally, the rainfall trend over the period has been stable but slightly increasing as shown by the gradient of the trend line \(y = 8.669x-16309\). This was found to be inconsistent with Logah et al. (2013) who observed that rainfall distribution is continually declining in the Upper West region. It is also observed from Figures 3 and 4 that maximum and minimum temperatures over the period has
Figure 2. Trends in the inter-annual rainfall differentials in Wa from 1983 to 2013.

Source: Ghana Meteorological Agency, Wa, 2014.

Figure 3. Trends in annual mean maximum temperature in Wa from 1983 to 2013.

Source: Ghana Meteorological Agency, Wa, 2014.

Figure 4. Trends in annual mean minimum temperature in Wa from 1983 to 2013.

Source: Ghana Meteorological Agency, Wa, 2014.
been rising but quite steady as indicated by the gradient of the trend line \( y = 0.048x - 63.50 \) and \( y = 0.045x - 67.03 \) respectively. Evaporation as observed from Figure 5 has generally been increasing in a downward trend as indicated by the gradient of the trend line \( y = -0.013x + 35.62 \). Warm conditions under high temperature will lead to an increase in the rate of evaporation and hence the situation has the tendency of reducing the availability of water. High temperatures as observed by Gerstetter, McGlade, Vidaurre, Tedsen, and Bar-On (2012) lead to drought resulting in limited availability of clean water and its associated increase in incidence of disease.

It is evident from Figures 2-5 that even though the overall rainfall trend has been increasing steadily over the years, temperatures and evaporation have also been rising steadily. The overall impact of the rising temperatures and evaporation is the occurrence of drought and a reduction in the amount of water that will be available for domestic activities and also for agricultural production causing general water insecurity. These occurrences are consistent with the observation by Yengoh et al. (2010) who assert that climatic factors play an important role in determining the availability of water for domestic and agricultural purposes in semi-arid regions.

The quantification of available quality water, according to the CWSA, who are the main providers of water at the community level within the municipality aside Ghana Water Company, is done through what they term “water pumping test”. In the test result, a borehole which is supposed to serve three hundred people in each community should also yield two litres of water per capita per minute. The total underground water is often not quantified. The water pumping test is also not done on a yearly basis. As a result, this study could not access data to conduct the seasonal changes in the water table in response to the changing rainfall-groundwater recharge pattern and on underground water availability.

In all the communities studied, the population was observed to have outnumbered the total number of boreholes provided for in the various communities. Through observation and feedback from the survey respondents, the study was able to establish that the average per capita water demand in the municipality was about 68 L of water per day. This was ascertained from the volume of water in liters used per day per person in each household. It was however not possible to determine the quantity of water that is available within the municipality. This was because the CWSA who are the main providers and managers of water did not have the data available. Hence the dependence on the respondents’ survey of per capita water demands in the municipality as the measure of security.
In view of the foregone, this paper argues that considering the rather minimal increase in rainfall which serves as the main recharge source of the groundwater coupled with the steady increase in both maximum and minimum temperature, alongside increasing evapotranspiration, the quantity of water available to the municipality could strongly be conjectured as dwindling. This is a clear indication of water stress towards insecurity among the populace in the Wa municipality.

4.2. Adaptation to water insecurity at the household level

All the respondents had different adaptation strategies to water insecurity at the household level. One of such strategies was water rationing. For example, households try to reduce the Volume water use per person per day, like sharing a bucket of water to bath by two people, in an attempt to conserve water. It will be rational for this strategy to be part of a behavioural change and not only during periods of water shortage. Secondly, during the rainy season, rainwater harvesting supported the other insufficient water sources. This is very necessary following periods of prolonged drought leading to the drying up of rivers and streams that were expected to have provided water all year round. However, in all the communities covered by the study, not enough rainwater was harvested. This was because of poor harvesting technology. Most of the respondents depended on the roofs of their buildings to harvest rainwater. However the roofing system which is predominantly thatch especially in the rural and peri-urban areas could not support efficient rainwater harvesting, since provisions were not often made to channel the rainwater into various reservoirs as per the roofing system. Only a small percentage of the rainwater could be harvested with a large quantity going untapped.

Thirdly, household members had to wake up in the middle of the night to draw enough water from the various water sources especially the borehole, which is the most depended upon water source in all the communities for use by households. Also, water obtained from rivers, dugouts, dams and wells were reserved for washing of clothes and bathing whiles borehole water was used for drinking and other domestic uses.

The CWSA has also introduced measures to reduce the problem of water insecurity. According to them, water is often piped from high yielding boreholes to places where there is inadequate or no water. For instance, water is currently being piped from Sing to Kunfabiela where the aquifers have low yielding water capacity. In communities where ground water sources are unavailable, they depend on surface water. Currently, there is on-going project that intends piping water from the Black Volta to supply the entire municipality. This project, if completed, could be affected by erratic rainfall since water from the Black Volta is normally replenished through rainfall.

4.3. Adaptation to climate variability

The data gathered revealed that all the respondents could provide evidences of climate variability and change within their environment. These evidences included; loss of the forest vegetation comparing the current vegetation with the vegetation twenty (20) years ago, low and patchy rainfall, delayed commencement of the farming period, low crop yield, excessive sunshine and heat intensity, increase in numerous diseases among other evidences. They however could not associate these changes to any concept. It was therefore not surprising that about 84% of the respondents claimed they were vulnerable to climate variability which could be as a result of their ignorance about the terminology of climate variability and change. This was consistent with a conclusion by Gyampoh et al. (2009) that the indigenous people may not understand the concept of global warming or climate change but they rightly observe and feel its effects.

Chapman, Slaymaker, and Young (2004) argue that awareness of, and sensitization to the development and utilization of new knowledge are also key to strengthening adaptive capacity. This is not achievable without knowledge of the issue that needs adaptation. People first need to recognise an issue that requires them to adapt to it. As claimed by Doss and Morris (2001), people first need to recognise that their climate has become variable or changed before suggesting an adaptation strategy. This will tune their minds to thinking about a possible adaptation mechanism. All these are achievable through capacity building in the form of formal education, workshops and sensitisation
programmes. However, the data indicated that none of the respondents had ever attended any sensitization workshop on climate variability or change.

It is observed from Table 2 that 63.9% of the respondents with no formal education had no idea of adapting to climate variability. They possibly did not know they have been adapting to climate variability since they have never had any sensitisation on adaptation to climate variability.

As suggested by Nelson, Adger, and Brown (2007), building adaptive capacity increases the ability of individuals, groups, or organizations to transform their adaptive capacity into action. Also Doss and Morris (2001) assert that, if indigenous people are to adopt water conservation techniques they must first be aware that the technology exists and perceive that it is profitable. This is achievable through building adaptive capacity. A \( \chi^2 \) test for significance between the respondents' educational background and their mode of adaptation was statistically significant at \( p = 0.000 \). The educational background of the respondents and their mode of adaptation to climate variability were directly related. People with high educational status are more likely to be able to adapt to climate variability than people with low educational status or without formal education. Capacity building is therefore an important component of any climate change adaptation strategy.

Regardless of the respondents’ vulnerability to climate variability, they still had ways of adapting to it. About 28% of them indicated they try to engage in more than one economic activity so that if one fails due to climate variability, the other might succeed. Respondents from Sombo, Charia, Kunfabiela and Dignafuro communities were those basically into such alternative practices. Some had added food vending, including the preparation of local beans cake called koose to the brewing of pito, a local beer; but their challenge was how to raise capital for these economic ventures. Nevertheless, this kind of adaptive mechanism to climate variability and water insecurity is not tenable because both pito brewing and frying koose require the use of water which might not be readily available at all times due to water shortages emanating from climate variability. One would have expected to hear about adaptation practices geared towards protection of various water bodies such that they could last for a long time support economic activities but the contrary was observed. This paper agrees with a suggestion by Schipper (2007) that, work on adaptation should not only be focused on addressing the impacts of climate change, but rather be extended to addressing the underlying factors such as inadequate capacity building that cause vulnerability to it.

| Mode of coping with climate variability | Count and percentage | % | % |
|----------------------------------------|----------------------|----|----|
| Educational status of respondents      | Count | Engaging in other economic activities | planting trees | No idea | Relying on God | Giving education to people | Total |
| No Education                           | 45    | 38 | 101 | 20 | 0 | 0 | 204 |
| %                                      | 52.3  | 62.3 | 63.9 | 57.1 | 0 | 0 | 59.1 |
| Primary School                         | 14    | 9 | 21 | 7 | 0 | 0 | 51 |
| %                                      | 16.3  | 14.8 | 13.3 | 20 | 0 | 0 | 14.8 |
| Junior High School                     | 18    | 5 | 24 | 8 | 1 | 0 | 56 |
| %                                      | 20.9  | 8.2 | 15.2 | 22.9 | 20 | 0 | 16.2 |
| Senior High School and Above           | 9     | 9 | 12 | 0 | 4 | 80 | 34 |
| %                                      | 10.5  | 14.8 | 7.6 | 0 | 0 | 80 | 9.9 |
| Total                                  | 86    | 61 | 158 | 35 | 5 | 100 | 345 |
| %                                      | 100.1 | 100 | 100 | 100 | 100 | 100 | 100 |
A few respondents representing 19% from Sombo and Charia communities practiced tree planting either around their houses or on their farms. This adaptive mechanism was good but also needed to have been practiced around their water bodies to reduce the rate of evaporation. Majority of the respondents representing about 54% were those who did not have any way of adapting to climate variability. For them, climate variability is a punishment from God for their wrong doings.

4.4. Hindered access in terms of cost of obtaining water

The main water contact points in the communities studied were; wells, boreholes, ponds, dug-outs, streams and mechanized boreholes. Access to these sources was determined by their availability and in most cases its affordability to the community members. According to the municipal profile, income and other forms of poverty is endemic especially among rural and peri-urban communities, where peasant farming is mostly practiced (WMA, 2010). This situation makes it difficult for the people to meet the cost of most utilities including water. Poverty as applied in the context of this paper is the income poverty as defined by the World Bank (2004) as a condition of insufficient resources or income, which in its most extreme form is the lack of basic needs such as insufficient land, tools, education, drinking water, supportive network of friends and families among others. The cost of obtaining water for peri-urban households within the municipality was identified as one of the contributing factors to water insecurity among the respondents. This observation is consistent with Howard and Bartram (2003) who assert that a high proportion of household expenditure on water supplies in many poor communities arise from the need to purchase water and/or time and energy expended in water collection which contributes to the ongoing poverty in those communities. On the average, the cost of obtaining water ranged between Gh¢ 1 and Gh¢ 20 per household per week (1Gh¢ = USD 0.39 as of mid-year, 2016). Those who fetched water from boreholes provided by the CWSA and managed by community water committee (CWC) paid a token of about Gh¢ 1 monthly for the routine maintenance of the facilities. But those who paid up to Gh¢ 20 for obtaining water were those who mostly fetched water from the various mechanized boreholes owned individuals. A volumetric bowl (68 L) of water from these facilities costs about 20 Ghp. The size of the household and their financial status to a large extent determined how much water in terms of cost and the quantity that could be acquired to meet the needs of the household.

Most of the households purchased between one and about a ten basins (between 34 and 68 L) of water in a week depending on the household size and their ability to pay for it. The per capita access to water per day in most households was estimated at 68 L for all domestic purposes (bathing, drinking, cooking and for sanitation purposes). The (World Health Organisation/United Nations Children Fund, 2000) estimate of reasonable access of 200 L per capita per day is in far excess of what pertains in the study areas; and further away from Gleick’s (1996) estimate of 500 L per capita per day for similar purposes. Those households that could only afford 34 L of potable water a week could use this quantity on an individual for up to five days. This means that the demand for water is higher than their ability to purchase. This form of water scarcity does not conform to Winpenny (1997) who defines water scarcity as excess demand over supply and also Abrams (2009), who describes water scarcity as a relationship between demand for water and its availability. It was observed that as the cost of water increases, the respondents were not able to buy enough water for their household needs especially those with large household sizes.

For instance respondents from Kpongul, Danko, and Nakori communities had large household sizes (21–25) as compared to the rest of the communities except Kunfabiela that had the largest household size of 26–30. The respondents with large household sizes in these communities except Nakori were not capable of purchasing adequate water for all their domestic activities. In the Nakori community, the respondents with large household sizes of 21–25 could only pay between Gh¢ 1.00–5.00 for water in a week. This amount could afford between 5–25 basins of water per week for a household size of 21–25. The inability of the respondents to spend more for water disenabled them from drawing more water to satisfy their domestic and socioeconomic needs. This situation can even further worsen or increase their poverty levels thereby increasing their inability to purchase water.
4.5. Time and distance factors of access to water

As a result of the insufficiency of water in the studied communities, majority of the respondents mostly joined long queues to draw water. Spending too much time at various water contact points affect the people in several ways. The effects include their inability to draw enough water for the house, having less time for their farm work, their inability to complete other household chores, school children’s inability to finish homework given to them by their teachers and going to school late. These effects emanating from the time they have to spend in collecting water affects their productivity which further enhanced their poverty levels. This finding supports the observation by the United Nations Development Programme [UNDP] (2006) that time spent in collecting water reinforces time poverty, dis-empowers women and lowers income that affects the socioeconomic development of women who shoulder the responsibility for managing household water, sanitation and health in African homes.

In order to avoid the queues at nearby water sources, some of the respondents travelled between 100 m to a little beyond a kilometer on foot to obtain water. But this also comes with some challenges. Walking long distances to fetch water, they normally returned very tired and are unable to attend to other economic activities including household chores and even not being able to fill enough water containers for use in the house. Another effect mentioned was that, they were often exposed to reptiles and robbers at night or dawn. They also risked being knocked down by moving vehicles or the water getting contaminated with dust as the containers are not covered.

4.6. Hindrances to adaptation to water insecurity and climate variability

Adaptation to climate variability and climate change has become a vital issue globally. However, researchers, policymakers and scientists encounter and report on many hindrances that impede adaptation planning and implementation (Burton & van Aalst, 2004). Implementation of adaptation is not keeping pace with the ever-increasing need; the “adaptation deficit” is getting wider (Tompkins et al., 2010). This section enumerates some of the various hindrances to adaptation to water insecurity under climate variability in the peri-urban areas of the Wa municipality.

Observed hindrances in the study area include changes in the rainfall pattern. Over the years, it has been very difficult for farmers to plan their cropping season to coincide with the rainy season. This situation, according to the respondents, could have been minimized if they had resources to enable them construct dams in the communities to store water for cultivation and domestic purposes. However, the communities’ inability to raise funds coupled with the little interest of government to commit resources towards the construction of water reservoirs, are some of the reasons for the respondents’ inability to adapt to water insecurity. This situation is consistent with Ekstrom and Moser (2014), who identified inadequate financial resources and political support as the common barriers encountered by local people in their adaptation efforts to climate variability and climate change.

The inability of the respondents to adequately harvest rainwater to support the insufficient water supply during prolonged dry spells also constitutes a hindrance to the adaptation process. This is because many of the streams and rivers expected to provide water for domestic and agricultural activities for most parts of the year, dry up in the dry season. In all the communities studied, inadequate rainwater was harvested per household because of poor rainwater harvesting techniques employed. Most of the respondents depended on the roof tops of their buildings to harvest rainwater. The roofing system being predominantly thatch, this did not support effective rainwater harvesting. This was the case because they lacked the financial strength to afford modern housing system with proper roofing and piping techniques of channeling adequate rainwater into reservoirs. Poverty according to the (Intergovernmental Panel on Climate Change [IPCC], 2001, cited in Ngigi, 2003) is directly related to vulnerability, and is therefore a rough indicator of the ability of a vulnerable group
to cope and adapt to hazards. In another submission, Lawrence, Meigh, and Sullivan (2002), argue that in many parts of Africa, the poverty index is directly proportional to water availability, especially for rural and peri-urban communities. The difficulty in harvesting enough rain-water constrained the respondents’ ability to adapt to water insecurity in the Wa municipality.

The quest for survival among the respondents often influenced them to engage in all kinds of livelihood activities such as charcoal production, sand mining and stone quarrying that contribute to the deterioration of the environment. For Amokrane et al. (2007), poverty compounds the issues of water scarcity in many regions of the world causing a vicious cycle. The respondents wished that government and nongovernmental organizations could assist in creating alternative livelihoods, as they are aware that their current livelihood activities contribute to the degradation of their environmental resources.

The provision of mechanized boreholes by the Municipal Assembly and some private individuals meant to improve the water supply situation and enhance water security at the household level within the Wa municipality have not yielded the desired results. It has rather become a setback to the adaptation process as respondents especially from the Nakori, Kpongu and Danko communities were unable to pay the tariffs on electricity used for pumping water so they could access water from common points in their respective communities. According to the Municipal profile, severe poverty conditions of the people, makes it difficult for them to meet the cost of utilities including electricity and water (WMA, 2010).

According to the respondents, they prefer ordinary boreholes from which they can draw water for free and not mechanized ones that will attract payment for usage. This situation has occurred because the Municipal Assembly failed to consult broadly with the communities before providing them with the water facilities. This finding is corroborates that of Ngigi (2009) who asserts that adaptation strategies are expected to reflect the needs and aspirations of the society or the community it is meant to benefit. Most of those who could not afford the electricity and water bills, accessed water for household use mostly from contaminated dug-outs and streams further worsening their health status.

Low literacy is another hindrance to adaptation to water insecurity, caused by climate variability. It was observed that many of the respondents who indicated their vulnerability to climate variability was as a result of the fact that they had no formal education and hence have limited knowledge about the concept of climate variability and climate change. This has the tendency of limiting their ability to choose from the list of appropriate technological adaptation options that are available for use, to minimize the impact of climate variability on their livelihoods. As suggested by Lee (2007), successful adaptation requires appreciation of the necessity to adapt, knowledge about available options, the capacity to assess the options, and the ability to choose and implement the most suitable ones. This requires capacity building in the form of providing formal education. Nelson et al. (2007) argue that building adaptive capacity increases the ability of individuals, groups and organizations to transform the adaptive capacity into action. It has also been argued by Maddison (2006) that people need to be able to acknowledge that their climate has become variable before identifying the appropriate adaptation strategies for them. All these arguments reinforce the observation of this study that low literacy among people posed a significant hindrance to adapting to climate variability therefore, aggravating water insecurity in the Wa Municipality.

The English language, as the main medium of communicating climate variability and climate change, is a major hindrance to its adaptation by the local people. The local language predominantly spoken by the respondents did not have any direct translation equivalent to the terms “climate variability” and “climate change”, “adaptation” and “mitigation”. The conflicting views expressed in the local language purported to be refereeing to these concepts, presents misconstrued approaches for effective adaptation strategies to climate-induced water challenges. This has compounded the lack of knowledge on mitigation and adaptation strategies to climate variability. This supports the claim
by Ungar (2000) that climate terminologies do not have standard translations in the local languages.

5. Conclusion and recommendations

This study has observed that there is climate variability within the Wa municipality which affects water resources and its security at the household level. This situation impacts on domestic and economic water needs of peri-urban residents within the Wa municipality. The respondents like many people throughout Ghana and beyond, are experiencing by inference, the impact of climate variability. However, they are unable to proffer appropriately adaption measures, due to the various identified hindrances. Climate variability, coupled with population growth in the peri-urban areas within the municipality, has affected the ease of availability of water resources for domestic, cottage industrial and agricultural applications. Limited knowledge of climate variability and over dependence on climate sensitive resources has aggravated the vulnerability of local people to climate variability.

Respondents from the study area have seeming improvised certain survival measures akin to adaptation strategies, in order to continue their socioeconomic livelihood activities. However, their adaptation strategies contribute very little to the minimization of the impact of climate variability on water scarcity in the municipality. The study also observed that farmers’ initial ethno-meteorological forecasts based on natural environmental changes have been distorted. This has affected their ability to plan their cropping season appropriately. The absence of alternative livelihood activities, low literacy rates, poverty, and language barrier, largely hindered respondents from effectively adapting to climate variability and climate change-related water insecurity.

The paper recommends that; government investment in the water sector in water stressed areas as the Wa Municipal should be increased. The WMA in collaboration with the CWSA and Non-governmental organizations (NGOs) should provide sustainable alternative sources of water such as the provision of more sustainable groundwater sources as well as the building and rehabilitation of new and old dams respectively, to enhance water supply.

Again, climate terminologies should be translated into local languages by experts, for easy understanding by the local people with limited understanding of the English language. Public health education and awareness campaigns should also be undertaken by the Municipal Assembly and other relevant stakeholders to improve knowledge of the issues as well as deepen their understanding of the relationship between water resources and climate variability in the Municipality. The Forestry Services Division (FSD) in collaboration with the Municipal Assembly should also educate the public on the need to practice afforestation around streams and other water bodies so as to conserve surface water resources. Tree planting through afforestation and reforestation which has started by individuals in their compounds could be extended to the fringes of dams and water bodies in the area to reduce evapotranspiration as well as change the micro climatic conditions of the area. Cutting down of trees for fodder and bush burning for regrowth of new shoots could be reduced if fast growing nitrogen fixing trees like *Glyricidia* species could be introduced by the FSD to the study area. The branches could be harvested as fodder for livestock whilst the twigs could be used as fuel wood and the plant itself is nitrogen-fixing. This could change the biophysical status of the environment. The Municipal Assembly should also see to the enforcement of bye-laws, to prevent deforestation, sand mining and stone quarrying activities in the study area. These will ameliorate the excessive anthropogenic activities that contribute to climate variability in the study area.

It is also recommended that, for enough water to be harvested, appropriate techniques could be designed to harvest flood water for storage in surface dams and underground reservoirs for future use. It is further suggested that, climate smart water harvesting techniques should be funded by NGOs and other development agencies for the benefit of residents of the peri-urban areas within the Wa municipality. Also, households and farmer-to-farmer uptake of best practices of adaptation should be introduced and encouraged by the CWSA in the Municipality. It is also recommended that the Regional Irrigation Development Authority (RIDA) revamps all broken down dams to facilitate...
water harvesting and storage. These recommendations are meant to obviate the hindrances to ad-
aptation against water insecurity caused by climate variability and climate change in the Wa
municipality.

Acknowledgments
We acknowledge the CWSA, the Wa Municipal Disease
Control Unit (WMDCU) and GMA all within the Wa
municipality for providing available information to us which
supported the success of this paper. We thank greatly the
household respondents for their time in availing information
during the field survey. Finally we acknowledge the
secondary sources cited as well as thank the anonymous
reviewers of this manuscript for their constructive critique
of the paper.

Funding
The authors received no direct funding for this research.

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Citation information
Cite this article as: Hindrances to adaptation to water
insecurity under climate variability in peri-urban Ghana,
Patrick Benebere, Felix Asante & Divine Odame Appiah,
Cogent Social Sciences (2017), 3: 1394786.

References
Abrams, L. (2009). Determining water shortage and water
scarcity. Retrieved May 24, 2014, from http://www.africanwater.org/drought_water_scarcity.htm. www.africanwater.org/drought_water_scarcity.htm
Amokrane, N., Gaff, E., Loughborough, W., & Ruberti, R. (2007).
Access to water and the burden of disease. Retrieved June
9, 2014, from http://www.the_ancetstudent.com/2007/08/03/access-to-water-and-the-burden-of-disease
Anayah, F., & Kaluarachchi, J. J. (2009). Groundwater resources of Northern Ghana: Initial assessment of data availability.
Logan, UT: Utah State University.
Antwi-Agyei, P., Dougill, A. J., & Stringer, L. C. (2013). Barriers to climate change adaptation in Sub-Saharan Africa: Evidence from Northeast Ghana and systematic literature review. Leeds: Sustainability Research Institute (SRI) University of Leeds.
Awulachew, S. B., Sally, H., Bohri, A., Molden, D., & Giordano, M. (2008, March 26–28). Water security for food security: Gaps, needs and potential for growth in Sub-Saharan Africa. Paper for presentation at the First African Water Week, Tunis.
Bates, B. C., Kundzewicz, Z. W., Wu, S., & Palutikof, J. P. (2008, March 24). Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.
Burton, L., & von Aalst, M. (2004). Look before you leap: A risk management approach for incorporating climate change adaptation into world bank operation. Washington, DC: The World Bank.
Chapman, R., Slyomaker, T., & Young, J. (2004). Livelihoods approaches to information and communication in support of rural poverty elimination and food security: The
literature update. Overseas Development Institute (ODI). Retrieved November 3, 2013, from www.fao.org/ddp/doc/ SPPSSILiteratureUpdate.pdf
Cheng, K., Kelly, A. K., Renwick, D. V., & Yang, S. (2013, May 23). Evaluation of access to drinking water in Northern Ghana (Group Report). Cambridge, MA: Massachusetts Institute of Technology Civil and Environmental Engineering Department.
Doss, C., & Morris, M. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural Economics, 25(1), 27–39. https://doi.org/10.1016/S0169-5150(00)00096-7
Drakakis-Smith, D. (2000). Third world cities. London: Routledge.
Eckstein, G. (2009). Water scarcity, conflict, and security in a climate change world: Challenges and opportunities for international law and policy. Wisconsin International Law Journal, 2(3), 410–460.
Ekstrom, J. A., & Moser, S. C. (2014). Identifying and overcoming barriers in urban adaptation efforts to climate change: Case study findings from the San Francisco Bay Area, California, USA. Urban Climate. Retrieved May 7, 2015, from https://doi.org/10.1016/j.urclim.2014.06.002
Ford, J. D., Berarg-Ford, L., & Paterson, J. (2011). A systematic review of observed climate change adaptation in developed nations. Climate Change, 106(2), 327–336. https://doi.org/10.1007/s10584-011-0045-5
German Advisory Council on Global Change. (2003). Climate protection strategies for the 21st century: Kyoto and beyond. Berlin: German Advisory Council of Global Change Secretariat.
Gerstetter, C., McClade, K., Vidaurre, R., Tedsen, E., & Bar-On, H. (2012, September 3). The effectiveness of policy frameworks for addressing climate-induced risks to human security and conflict (CLICO Working Paper No. 10). Berlin: ECOLOGIC Institute.
Ghana Statistical Service. (2012). 2010 population and housing census (Summary of Final Report). Accra: Author.
Gifford, R. (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. American Psychologist, 66(4), 290–302. https://doi.org/10.1037/a0023566
Gleick, P. (1996). Basic water requirements for human activities: Meeting basic needs. Water International, 21(2), 83–92. https://doi.org/10.2166/wi.2007.021
Grey, D., & Sadoof, C. W. (2007). Sink or swim? Water security for growth and development. Water Policy, 9(5), 545–571. https://doi.org/10.2166/wp.2007.021
Gaymohr, B. A., Amish, S., & Idinoba, M. (2009). Using traditional knowledge to cope with climate change in rural Ghana. Kumasi: Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology (KNUST). Retrieved from http://www.fao.org/3/a-0670e0a0670e14.pdf
Herrera-Pantoja, M., & Hiscock, K. M. (2008). The effects of climate change on potential groundwater recharge in Great Britain. Hydrological Processes, 22(1), 73–86.
Howard, G., & Bartram, J. (2003). Domestic water quantity, service level and health. Geneva: WHO Press.
IPCC. (2001). Climate change 2001: Impacts, adaptation and vulnerability. Cambridge: Cambridge University Press.
Lawrence, P., Meigh, J., & Sullivan, C. (2002, October). The water poverty index: An international comparison (Keele Economics Research Papers, KERP, NO. 19). Staffordshire: Keele Economics Department, Keele University.
Lee, B. L. (2007). Information technology and decision support system for on-farm applications to cope effectively with agrometeorological risks and uncertainties. Retrieved August 19, 2013, from http://www.springerlink.com/content/n07834253472x7q4/

Logah, F. Y., Obabue, E., Ofosu, D., & Kankam-Yeboah, K. (2013). Analysis of rainfall variability in Ghana. Latest Research in Engineering and Computing, 1(1), 1-8.

Maddison, D. (2006, July 6). The perception of an adaptation to climate change in Africa (CEPPA Discussion Paper No.10). Pretoria: Centre for Environmental and Economic Policy in Africa, University of Pretoria.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & Maodison, D. (2006, July 6). The perception of an adaptation to climate change in Africa (CEPPA Discussion Paper No.10). Pretoria: Centre for Environmental and Economic Policy in Africa, University of Pretoria.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (2001). Impacts, adaptation, and vulnerability to climate change. Cambridge: Cambridge University Press.

Narain, V., Khan, M. S. A., Sada, R., Singh, S., & Prakash, A. (2013). Urbanization, peri-urban water (in)security and human well-being: A perspective from four South Asian cities. Water International, 38(7), 930–940. https://doi.org/10.1080/02508060.2013.851930

Ngigi, S. N. (2003). Rainwater harvesting for improved food security: Promising technologies in the greater horn of Africa. Nairobi: Great Horn of Africa Rainwater Partnership (GHARP), Kenya Rainwater Association (KRA).

Selby, J., & Thomas, A. (2010). Climate change adaptation and vulnerability: A case study of smallholder farming systems in Sub-Saharan Africa. New York, NY: The MDG Centre for East and Southern Africa at the Earth Institute at Columbia University.

Nkomo, J. C., Nyong, A. O., & Kulindwa, K. (2006). The impacts of climate change in Africa. Cape Town: University of Cape Town.

Pogett, R., & Acquah, P. (2012, December). Country environmental profile, Republic of Ghana (Final Report, No. 2012/295-545). EURONET Consortium: Accra.

Pereira, L. S., Corder, I., & Isacovides, I. (2002, April 4). Coping with water scarcity (International Hydrological Programme, Technical Documents in Hydrology, No. 58). Paris: UNESCO.

Robinson, J. (2002). Global and world cities: A view from off the map. International Journal of Urban and Regional Research, 26(3), 531–554. https://doi.org/10.1111/ijur.2002.26.issue-3

Schipper, L. (2007). Disaster risk, climate change and international development: Scope for, and challenges to integration. Disaster, 30(1), 19–38.

Soleiman, M. (2012, September 7). Climate change makes Ghana water-stressed. Daily Graphic, pp. 30.

Tatlock, C. W. (2006). Water stress in Sub-Saharan Africa. Backgrounder by Council on Foreign Relations.

Tompkins, E. L., Adger, W. N., Boyd, E., Nicholson-Cole, S., Weatherhead, K., & Arnell, N. (2010). Observed adaptation to climate change: UK evidence of transition to a well-adapting society. Global Environmental Change, 20(4), 627–635. https://doi.org/10.1016/j.gloenvcha.2010.05.001

UNDP. (2006). Adaptation policy frameworks (APF) for climate change: Developing strategies, policies and measures. Retrieved November 4, 2013, from http://www.undp.org/climatechange/adapt/aph.html

Ungar, S. (2006). Knowledge, ignorance and the popular culture: Climate change versus the ozone hole. Climate Change, 9(3), 297–312.

WMA. (2010). Human development report (HDR), resource endowment, investment opportunities and the attainment of MDGs. Accra: United Nations Development Programme, Ghana Office.

WMA. (2011). Wm municipal medium term development plan 2011. Ghana: Wa.

Wateraid. (2007). Water and sanitation issues for persons with disabilities in low and middle income countries. Retrieved April 25, 2013, from http://www.ucl.ac.uk/lc-ccr/centrepublications/workingpapers/wp12

Wingeny, J. T. (1997). Managing water scarcity for water security. London: E and FN Spon.

World Bank. (2004). Poverty reduction strategy sourcebook. Retrieved June 6, 2015, from http://poverty.worldbank.org/files/5798chap19.pdf

World Health Organisation/United Nations Children Fund. (2005). Vulnerability, adaptation and climate disasters: A conceptual overview. IDS Bulletin, 36(4), 1–14. https://doi.org/10.1111/dsbb.2005.36.issue-4

Yengoh, G. T., Armah, F. A., Ebo, E. O., & Odoi, J. O. (2010). Trends in agriculturally-relevant rainfall characteristics for small-scale agriculture in Northern Ghana. Agricultural Science, 2(3), 141–163.