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Implications of climate variability and change on urban and human health: A review

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ABSTRACT

Urban regions have exceptional attributes that leave their dwellers and properties vulnerable to climate variability and change. Global temperatures continue to change, reaching new levels almost every year for the past two decades. This review examines the scientific evidence on the impact of climate change on urban and human health. It identifies research progress and gaps in how human society may respond to, adapt to, and prepare for the related changes. However, the causes are debated; climate variability and change are real. Climate variability and disaster risk are one of the threats to human health that adversely reinforce each other. Better knowledge of the linkage between climate change, variability and extreme weather-related illness is needed and can aid strategies to reduce the vulnerability. However, from this comprehensive review, it can be suggested that increased temperature and radiation are one of the major cause of some heat-related diseases such as skin cancer, heat stroke, heart disease and diarrhea which might strongly influenced by extreme climate events. On the other hand, since the extreme heat-related illnesses occurrence is increasing alarmingly, prevention and control have become a preference in public health programs and other disease control agencies. The study also suggests that public health should be everybody's business. Furthermore, public health education concepts can improve by a broader understanding of the subjective factors that underlie risk-taking and precautionary when exposed to extreme weather events.

1. Introduction

The global climate assessments revealed that Africa is susceptible to climate variability (Howard-Grenville, Buckle, Hoskins, & George, 2014; Onyango, Sahin, Awiti, Chu, & Mackey, 2016). Studies have shown that frequent storm occurrences, extreme heat, drought and other climate-related events are projected to increase as a result of both natural and human-made activities (Handmer et al., 2012; Kuenzer & Renaud, 2012; Nadin, Opitz-Stapleton, & Yinlong, 2015). The recognition of risk posed by climate on human health has created thriving concern in the linkage between climate adaptation and health threat (Benedikter, Läderach, Eitzinger, Cook, & Bruni, 2013; Chen, Doherty, Coffee, Wong, & Hellmann, 2016; Venton & La Trobe, 2008) by inspecting in depth this interlink between climate variability, risk reduction and human well-being. This review explores and investigates the synergies between heat-related events and human health. Also, to take a broader view of how the risk of extreme weather affects human health and their wellbeing. Therefore, to understand the significance of these risks over the urban areas, how they affect the environment and the crucial basis of urban functions that can be inimical to human health should be assessed.

Reed et al. (2013) revealed that the pronounced impact of climate-related events on human health may increase in the nearest future although the interdependence of climate variability and extreme weather remains ambivalent. Better knowledge of this interdependence is required and this can help planning to reduce its vulnerability (Dube, Moyo, Ncube, & Nyathi, 2016; Reckien et al., 2014; Voskamp & Van de Ven, 2015). Climate variability has been identified to pose numerous risks to human health across the globe (Austin et al., 2015) especially Africa (Sewankambo, Tumwine, & Besada, 2016) including South Africa (Ropo, Perez, Werner, & Enoch, 2017; Wright et al., 2017). The effect of climate on the environment has been studied (Aswani, Vaccaro, Abernethy, Albert, & de Pablo, 2015) and cannot be overemphasized as it cuts across every area of human life including health, natural resources and agriculture (Orimoloye & Adigun, 2017; Orimoloye, Mazinyo, Nel, & Kalumba, 2018; Ropo et al., 2017).

Climate variability contribute to both human-induced and natural disasters such as floods, toxic emissions, global warming, nuclear

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explosions, fires, heat waves, drought, earthquake and rise in sea surface temperature as a result of thermal expansion with their related population shift, overcrowding and congestion which may support disease outbreak (Corcoran, 2016; Infield, Abunnasr, & Ryan, 2018). Many of the world's bothersome diseases that have lingered or persisted for years and are extensively influenced by climatic features include rainfall trend, extreme temperature (heat), humidity and wind patterns (El Morjani, Ebener, Boos, Ghaffar, & Musani, 2007; Ropo et al., 2017). More so, the incidence of extreme weather-related illness such as heart disease and skin cancers among others have continued to increase (Chang et al., 2016; Daniel, 2015; Xiang, Bi, Pisaniello, & Hansen, 2014) which might be as a result of increased climate variability globally. Therefore, the above-mentioned heat-related illnesses had been explored in this study globally and especially African countries including South Africa due to the recent changing climate potential impacts on human health (Ropo et al., 2017).

Studies have shown that change in climate parameters such as humidity, temperature, radiation and the wind correlates with these extreme weather-related illnesses (Glaser et al., 2016; Matysiak & Roess, 2017). Heat-related diseases such as cardiovascular disease, diarrhea, sunburn, heat stroke and skin cancer are among the dreaded diseases that trouble the world and as some of them kill faster than Tuberculosis and HIV/AIDS globally both in the developed and the developing nations including South Africa (CANSA REPORT, 2016). Preparedness and prevention have become vital themes in public health, emergency management and systems (Moore et al., 2007). In public health, risk reduction and management should be the focal point of the health experts and scientists. The idea and knowledge of climate variability are powerful scientific information that plays a significant role in human health management and risk reduction (Landauer, Juhola, & Klein, 2018; Rosenzweig et al., 2018). However, this idea of the linkage between extreme weather events and human is yet to be well explored or underutilized (Nehama et al., 2016; Patz & Frumkin, 2016). Therefore, this paper explored various studies on climate events-related impact on human and environmental health using information retrieved from Google Scholar and reports. The keywords for the search engine are climate variability, climate risk perspective and disaster in urban areas, spatial assessment of urban land surface heat and human health risk assessment, extreme heat and associated diseases.

1.1. The reality of climate variability

There are several adoptable pieces of literature that justify the fact that climate variability is really occurring and more evidence and research-based are being done to define this phenomenon (Abatzoglou, Rupp, & Mote, 2014; Kay et al., 2015; Orimoloye, Mazinyo, Nel, & Iortyom, 2018; Otto-Bliesner et al., 2016). Reports have shown that Southern Africa is experiencing climate variability which is evidenced by the occurrence of floods, extreme heat and droughts that are also predicted to be more visible or intensify in the nearest future (Alexander, Carzolio, Goodin, & Vance, 2013; Stringer et al., 2009; Ziervogel et al., 2014). Scientific research has also shown that the rising global air temperatures have a significant effect on the human health, rising sea levels and the environment (Turner et al., 2010; Venton & La Trobe, 2008; Watson, 2014).

Studies have equally indicated that there are scientific models that are more significant in analyzing climate scenarios as justification for climate variability (Berry & Richardson, 2016; Di Falco & Veronesi, 2014). According to Rosenzweig and Iglesias (1994) cited in Calzadilla et al. (2013), their models have been identified that climate variability is evident on agricultural productivity and verified how climate variability may alter the agricultural yields (Orimoloye & Adigun, 2017). The experimental findings on the effects of climate variability on crop yield summarized in Challinor et al. (2014) have, therefore, revealed a significant increase or rising global temperatures due to a warming climate.

ActionAid-Malawi (2006) states that many socio-economic problems which the poor societies in some part of the world for example, Malawi and other African countries are experiencing difficulties attributed to extreme weather events that closely associated with climate variability and its adverse impacts on human health. It is further highlighted that the climatic hazards are threatening the sustainable livelihoods of the majority family in the low-income nations (ActionAid-Malawi, 2006; Islam, 2013; Yawson et al., 2015). Studies have shown that a significant number of human are vulnerable to climate variability and their associated health threats (Deressa, Hassan, & Ringler, 2009; Islam, 2013; Nguyen, Bonetti, Rogers, & Woodroffe, 2016; Opiyo, 2014). Therefore, from the literature, it is evident that climate variability is real.

1.2. Global climate variability and its evidence in South Africa

The global warming prediction has revealed that the world will continue to experience increased warming and extreme climate events including heat waves, temperature and extreme heat are expected to annex in both intensity and frequency (Kendon et al., 2014; Moritz & Agudo, 2013). Findings have given its scientific evidence on various climatic scenarios that affect African nations and its population (Bryan, Deressa, Gbetibouo, & Ringler, 2009; Gbetibouo, 2009). Firstly, it is revealed that some countries such as South Africa experience a wide range of extreme climatic events that directly affect people's health and their well-being particularly those from rural areas because of their high dependence on climate-sensitive livelihood activities such as farming (Islam, 2013; Senapati & Gupta, 2017; Yawson et al., 2015). The most notable extreme climate events that affect human include extreme heat, droughts, floods, landslides, heat waves and the strong winds which have in many times contributed to poverty, famine, disease outbreak and loss of life among the populations. For example, the devastating floods of 1994–1995 in Western Cape (Lukamba, 2010), floods of 2000 in Limpopo (Reason & Keibel, 2004), extreme heat (Kruger & Sekele, 2013) and Floods of 2011 in KwaZulu-Natal (Dlamini et al., 2011). Table 1 present noticeable extreme weather event in South Africa;

Elasha, Elhassan, Ahmed, and Zakieldin (2005) observed that climate variability will adversely affect socio-economic sectors of the world in which both rural and urban livelihoods are built, particularly in Africa. These sectors include "human health, water resources, agriculture, forestry, fisheries and human settlements, ecological systems" (Sonwa, Somorin, Jum, Bele, & Nkem, 2012; Tirado, Cohen, Aberman, Meerman, & Thompson, 2010). Elasha et al. (2005) have also identified developing countries such as Malawi, South Africa in Southern Africa to

Table 1
Evidence of impacts of climate disasters in South Africa 1975–2006.

Year	Form of disasters	Place	Source
1981	Floods	Laingsburg, Western Cape	Lukamba, 2010
2010	Floods	Western Cape	Lukamba, 2010
1994–1995	Drought	Western Cape	Lukamba, 2010
2000	Floods	Limpopo	Reason & Keibel, 2004.
2013	Extreme heat (heatstroke)	North West	Kruger & Sekele, 2013
2011	Floods	KwaZulu-Natal province	Dlamini et al., 2011

be more vulnerable to extreme climate events because most of these countries have livelihood activities that are susceptible to climate events (Islam, 2013; Senapati & Gupta, 2017; Yawson et al., 2015). Studies have also revealed that most nations are affected by extreme climatic events such as extreme heat, droughts, heat waves, floods, strong winds and landslides every rainy season (Easterling et al., 2000; Kundzewicz, 2016).

Furthermore, it was also projected that the impacts of future climate extreme on health, economies and livelihood assets of poor societies in developing countries, predominantly among the poor urban, will be very devastating if proper measures for mitigation and adaptation are not put in place (Basher et al., 2015; Satterthwaite, 2007). In addition, climate variability is likely to impact negatively on health, environment, agriculture and development agenda of developing countries such as poverty reduction as the associated events have direct effects on poor people's livelihoods and the assets that determine their existence (Basher et al., 2015; Ibarrarán, Ruth, Ahmad, & London, 2009).

1.3. Climate risk perspective and disaster in urban areas

World cities, especially in the developing nations are faced with enormous problems such as a potential decline in the economic and human resources resulted from natural woes aggravated by the rate of unhindered urban growth and climate variability (González, Monsalve, Moris, & Herrera, 2018; Tan et al., 2010). There are several environmental dilemmas varieties of impact on cities (Neira & Prüss-Ustün, 2016) and the citizens' livelihoods due to climate variability (González et al., 2018). Inhabitants of the poor suburb areas and informal settlements are more vulnerable to hazards due to living in a high-risk environment such as slums, shanty, faulty shelters, blighted zone and as well as limited access to some basic services (Blaikie, Cannon, Davis, & Wisner, 2014; Mahmood et al., 2014). Consequently, there are tendencies of disease outbreaks in such areas.

Studies also revealed that, in the urban areas, the future heat extremes will be aggravated by the phenomenon called urban heat island and will in turn significantly influence urban health and the welfare of urban dwellers negatively (González et al., 2018; Tan et al., 2010). However, these can also trigger the existing illnesses that are related to the extreme heat and have effects on the ecosystem in the urban areas. Urban areas, in most cases, are more prone to disaster risk perhaps due to congestion, urban expansion, industrialization and inadequate or improper management (Begum, Sarkar, Jaafar, & Pereira, 2014; Schipper, 2009). Moreover, disaster risk is patterned over a period of time in the consequence of a critical interaction between development dynamics that bring about hazards and vulnerability. Unplanned urban settings are high-risk regions as rapid urbanization is accompanied by changes in land use, deforestation and reduction in vegetation cover and changes in climate variables, as the natural land surface are replaced by concrete, asphalt and structure which can influence or modify urban climate (Balica, Wright, & van der Meulen, 2012; Jha, Bloch, & Lamond, 2012).

In urban risk assessment, the hazard can be described as a harmful and dangerous phenomenon. Sometimes, human activities can create hazards, the substance that may cause a health-related problem, injury, loss of properties, decline in income, environmental degradation, economic disruption and as well as the loss of life (Hallegatte, 2014). The impacts of climate variability and hazards vary significantly with important variance in spatial pattern and location. For instance, slums that are located at the inner core of a city and overcrowded especially in developing nations, face many health threats and are vulnerable to hazards as a result of the dilapidated structures, congestion, difficulty in relocating and getting services (El-Fadel et al., 2014; Shaw, 2018). In the same way, suburb slums face other challenges for example, narrow road, drainage problem, unplanned layout, poor services and closeness to the environmental hazard.

Cities have exceptional attributes that leave their dwellers and valuable assets vulnerable to climate variability hazards. Many big cities, especially in low-income nations are found in the areas along the coast, slums and shanty, that are prone to hazards (Gasper, Blohm, & Ruth, 2011; Shamsuddoha, Ullah, & Shahjahan, 2014) these locations usually place human health and the economy at risk of extreme weather-related illnesses and disease outbreaks such as cholera, non-cholera diarrhea and cardiovascular disease. But this is not applicable only to city centers even the entire urban health can be affected by the threat caused by climate variability. The environmental aftermath of climate event is one of those that directly or indirectly affect the behavior and physical fitness of the dwellers including health impacts, water dearth and livelihood (Alexander et al., 2013; Braga, Zanobetti, & Schwartz, 2001). Climate extreme event is seen to be slow and advancing challenges combined with causes from multiple sources that are influenced by both anthropogenic and natural activities (Alexander et al., 2013; Anderegg, Prall, Harold, & Schneider, 2010).

Urban areas are the hotspots for identifying climate event risks. As a result of potential extreme weather exposure and climate-related illnesses, more than half of the city dwellers worldwide resided in the hazardous zones including congested zones, shanty, blighted areas and coastal areas (McGranahan, Balk, & Anderson, 2007). On the hand, urban regions also host the aforementioned crucial roles for wider socio-economy systems and often described by deep-rooted instability and vulnerability particular in big cities of the developing nations (Bull-Kamanga et al., 2003; Kraas, 2008). *Per contra*, climate change is not only peculiar to urban areas, but its impact also extends to the small cities and rural areas where human health, agriculture and economy are equally affected by the extreme weather due to climate variability.

Satterthwaite (2007) opined that inadequate attention has been given to the climate variability in the city areas and also to the extreme weather exposure of the city's population. In a contrary opinion, Mutunga and Hardee (2010) under the canopy of National Adaptation Programmes of Action (NAPA) reveals that almost all the focus of NAPA is on rural areas initiatives. But some of the developing countries are characterized by large numbers of people residing in rural areas. It is, however, noteworthy that these initiatives encompass strategies are few focused on climate and its effect on human well-being in the urban areas (Nkonya, Place, Kato, & Mwanjololo, 2015). Nevertheless, urban environment is home to the hotspot for a growing world's population. In this regards, full attention and concern of the urban environment are crucial in climate change implications on human health.

Moreover, urban areas comprehensively add to ecological degradation that ensnares significant risks of climate variability impact (Nkonya et al., 2015). The further amelioration of urban mitigation approach is a key obligation in managing the risks that posed by the extreme climate events and its adverse effect on the human health and environment. Additionally, more attention should be on the uniqueness or peculiarities of urban areas which frequently denote different scales, particularly in terms of built-up areas, population density and size, infrastructure, environmental degradation and rapid development compared to the rural areas (Carter et al., 2015; Tietenberg & Lewis, 2016).

The climate-related breakdown of the urban areas (big cities in particular) would imply challenges at broader scales beyond the city size (Kraas, 2008). But sometimes, the environmental problems or challenges of a particular area have nothing to do with the size of the city, for example, a city that is relatively small in size but located in the hazards prone. However, it is, therefore, essential to observe not only the bigger systems revolving around the processes or function depicted in the urban. But also, that the urban depend on the functions of environmental degradation surrounding it, as a result of climate events and its adverse indications on human health.

1.4. Geospatial appraisal of urban land surface heat and human health risk assessment

There is a developing acknowledgment in the fields of bio-meteorology and environmental health which posit that heat risk in urban

Table 2
HI algorithms used in extreme weather events and its impact on human and environmental health.

No	Algorithm	Findings/gaps	References
1	$HI_c = T - 1.0799e_c^{0.03755T} (1 - e_c^{0.0801(D-14)})$	The model work perfectly at very low temperature but NWS model gives unrealistic value.	Schoen, 2005
2	$HI = -42.379 + 2.04901523T_f + 10.14333127H - 0.22475541T_f H - (6.83783 \times 10–3) T_f^2 - (5.481717 \times 10^{-2}) H^2 + (1.22874 \times 10^{-3}) T_f^2 H + (8.5282 \times 10^{-4}) T_f H^2 - (1.99 \times 10^{-6}) T_f^2 H^2$.	This is more suitable when temperatures are above 80 °F and relative humidity above 40%.	El Morjani et al., 2007
3	$HI_c = -2.719 + 0.994T_c + 0.016D_c^2$. Correction factor: $HIC = TC$ when $TC < 25\,°C$	Applicable when temperatures are greater and equal to 25 °C.	Smoyer-Tomic & Rainham, 2001
4	$HI = 8.784695 + 1.61139411\,T + 2.338549RH - 0.14611605\,T * R\,H + 1.2308094 * 10^{-2}T^2 - 1.6424828 * 10^{-2}\,R\,H^2 + 2.211732 * 10^{-3}T^2\,R\,H + 7.2546\,10^{-4} * T * R\,H^2 - 3.582 * 10^{-6} * T^2$	This is valid only for air temperatures above 20 °C and its values are categorized due to possible heat perceived by human body.	Blazejczyk et al., 2012
5	$Hmidex(°C) = T_a + 0.555\,(e - 10)$ where $a = 6.11 * e^{(5417.7530*(\frac{1}{273.16} - \frac{1}{dew\ point + 273.16}))}$	Only endorsed for workplaces that have no "hot processes" as the main source of heat.	Jay and Kenny, 2010
6	$HI_c = T_C - 0.55 \times (1 - 0.001\,H)\,(T_C - 14.5)$	Recommended for both indoors and outdoors studies but may vary geographically and with locations.	Perry et al., 2011
7	$HI = K_1 + K_2 T + K_3R + K_4TR + K_5 T^2 + K_6R^2 + K_7T^2R + K_8TR^2 + K_9T^2R^2 + K_{10} T^3 + K_{11}R^3 + K_{12}T^3R + K_{13}TR^3 + K_{14}T^3R^2 + K_{15}T^2R^3 + K_{16}T^3R^3$	Recommended for both indoors and outdoors studies and this also vary with climatic parameters and locations.	Stull, 2000; Ropo et al., 2017

areas is a serious concern globally for example, USA (Basu & Samet, 2002; O'Neill & Ebi, 2009), South Africa (Orimoloye, Mazinyo, Nel, & Kalumba, 2018; Ropo et al., 2017; Wright et al., 2017), Australia (Vaneckova, Hart, Beggs, & De Dear, 2008) and Asia (Honda, 2007). Land use and land cover change (LULCC) is the investigation of land surface changes. Land use defines anthropogenic activities on land, while land cover explains the biophysical characteristics of the land surface. Land use change oft-times influence land cover features, thermal characteristics while changing land cover can likewise affect land use. Urbanization is essential evidence of LULCC which is synonymous with the modification of the surface energy budget resulting in rising temperature which can, in turn, have a significant impact on human health (Ige, Ajayi, Adeyeri, & Oyekan, 2017; Ogunjobi, Adamu, Akinsanola, & Orimoloye, 2018; Tursilowati & Djundjunan, 2007).

Land surface thermal signals such as land surface temperature which modifies the air temperature of the lower layers of the atmosphere are of prime significance to the urban context due to its important role in the energy balance of the surface. Land surface temperature not only helps to determine the internal climate among buildings but also influences energy exchanges that affect the comfort of city residents (Ogunjobi et al., 2018; Quan et al., 2014; Voogt & Oke, 2003). Alteration of the natural landscape in urban regions has been identified to make both local air and surface temperatures to rise a few degrees higher than that of surrounding rural areas (Streutker, 2003). Extreme heat affects health when there is thermal discomfort, this occurs when the body becomes too hot and there is no thermal equilibrium between the environment and the human body (Xu, Hu, Guan, & He, 2017).

Local micro-climatic parameters such as wind, air temperature, land surface temperature and radiation are often affected by natural objects and anthropogenic activities including built up, asphalted roads, pavement present in an environment. The disparity in the absorptive and reflective capabilities of objects to radiation associated with the heterogeneity of their physical characteristics often leads to the variation of these climatic elements which might affect the mental satisfaction of people and health in general (Lo & Quattrochi, 2003; Tursilowati & Djundjunan, 2007).

The relationship between local microclimate pattern and human thermal sensation has led to the development of several bio-meteorological indices which have been used to define human thermal comfort level (Ige et al., 2017; Ogunjobi et al., 2018). However, remote sensing and GIS techniques are considered to assess the impact of land use and land change on thermal characteristics and its consequences on human health because of its adequacy to obtain LULCC influenced surface thermal signal changes which often reshape people's health. For urban planning and environmental protection purposes monitoring human comfort shifts over various land use classifications is very important. Remote sensing information has been widely used in mapping the influence of human's activities on the environment taking remote sensing and geographic information system as tools for over the last two decades (Adefisan, Bayo, & Ropo, 2015; Adeola et al., 2017; Ogunjobi et al., 2018; Onamuti, Okogbue, & Orimoloye, 2017; Stephen, Iortyom, Ropo, & Daniel, 2017).

1.5. Extreme weather exposure and heat index (HI)

It is well known that discomfort that occurred in warm weather depends on the degree of temperature and humidity available in the air. The linkage between mortality and temperature has been examined by some researchers (Curriero et al., 2002; Gasparrini et al., 2015; Guo et al., 2014; McMichael et al., 2008). But more still need to be done regarding the geographical location and climatic features. The climate in recent years is characterized by the unusual increased in the intensity of extreme weather events and these have numerous effects on human health and the environment. The health implications of climate extreme have become a focal point and considered a crucial issue among climate researchers (Anderson, Bell, & Peng, 2013).

Several indices have been employed in studying the human health implications of climate variability and extreme weather. Some of the studies used HI (United State weather service (Hartz, Golden, Sister, Chuang, & Brazel, 2012; Metzger, Ito, & Matte, 2010)), humidex (Canadian meteorologist; Smoyer-Tomic & Rainham, 2001), wet-bulb globe temperature (Kjellstrom, Holmer, & Lemke, 2009; Moran & Epstein, 2006) and apparent temperature (Anderson & Bell, 2009; Chung et al., 2009) to assess HI indications of climate variability on human health and other researchers have used different algorithm to assess HI although with varying shortcomings (Table 2). Most studies in assessing the extreme heat implications on human thermal comfort and health have used ambient temperature (maximum, minimum and average temperature) to investigate heat-related illnesses (Hajat, O'Connor, & Kosatsky, 2010; Lin, de Dear, & Hwang, 2011; Wang, Hamann, Spittlehouse, & Murdock, 2012; Yu, Vaneckova, Mengersen, Pan, & Tong, 2010). Moreover, extreme weather implications cannot be fully assessed with the temperature only but other indicators such as radiation, wind and relative humidity should be considered to give a precise effect on human health (Lung, Lavalle, Hiederer, Dosio, & Bouwer, 2013). Among these indicators, the immediate surrounding has more effects on wind and radiation for example, wind speed is reduced by building effects or trees around and solar radiation is affected by localizing events include cloudiness and visibility (Parsons, 2014). If these factors (wind and radiation) are to be considered as variables and they are most suitable for a location as they can vary significantly in values over a short distance. The other two factors which are popularly used include relative humidity and air temperature because they are not spatially varied and these can be utilized to give a signal of the thermal comfort status over a large area (Commonwealth of Australia, 2005; Queiroz, Naas, & Sampaio, 2005; Ropo et al., 2017).

Heat index methods are statistically obtained equations that are analyzed (Table 2) to recreate the figures or values in Steadman (1979). These methods are substitutes to Steadman's algorithm for public and environmental health study and the latter algorithms considered the shortcomings of the former algorithm and modified it to be more accurate and efficient. Also, these algorithms can adequately calculate a longer sequence of heat stress index values based on the relative humidity and air temperature data. Moreover, these methods are popularly used to appraise HI thresholds for public health studies although there are variations in the use of the algorithm across the studies (Table 2). In reviewing the environmental studies literature this review pinpoints several heat stress indices algorithm but some are closely related and the present study suggests some of the algorithms and listed their findings and gaps. In public health and HI study, easier HI methods are less complex (for example, Halonen, Zanobetti, Sparrow, Vokonas, & Schwartz, 2011; Zanobetti & Schwartz, 2005; Vaneckova et al., 2011; Smoyer-Tomic & Rainham, 2001; Barnett, Tong, & Clements, 2010). More complex methods or formula that had been used in climate studies for example (Fischer & Schär, 2010; Oka, 2011).

1.6. The incidence of heart disease and climate variability

Excessive extreme heat exposure creates risks of some extreme heat-related problems including heat stroke, heart failure and inhibitions to sustain physical activities (Jendritzky & Tinz, 2009; Sahu, Sett, & Kjellstrom, 2013). The mortality due to extreme heat-related varies significantly by locations and climate zone. Studies have shown that people who reside in colder cities are affected by increased temperature while the hotter city dwellers are affected by colder temperatures (Curriero et al., 2002; Shanklin, 2004). A positive relationship between extreme heat and mortality (heart disease) has also been revealed, especially among the minors and elderly people (Basu & Samet, 2002; McGeehin & Mirabelli, 2001; Ropo et al., 2017). However, extreme weather can have detrimental effects on human health in both hotter and colder cities because thermal characteristics vary and sometimes maybe a personal experience-dependent and can be different from one person to another at the same time and space (Basu & Samet, 2002; Ryti, Guo, & Jaakkola, 2015).

More so, in some cases, extreme heat-related mortality occur in people with existing illnesses which include heart attack, heart failure and stroke. Urban dwellers are vulnerable to this risk than those who reside in rural areas (Basu & Samet, 2002; McGeehin & Mirabelli, 2001) because of their environments which have low ventilation and high thermal characteristics. Meteorologically this process is called urban heat island, a process where city or metropolitan region is significantly warmer than its surrounding suburban areas as a result of human activities. However, this can affect human health (Ketterer & Matzarakis, 2014; Vargo, Stone, Habeeb, Liu, & Russell, 2016). Behavioral and physiological adaptation as well as public health awareness can play a vital role in extreme heat morbidity and mortality reduction (Weisskopf et al., 2002). If the extreme heat is properly managed, the risk posed by the climate change will be minimal and extreme weather-related mortality can change over time by improving health care, public awareness, a study of this kind and personal understanding of climate change-related issues.

Schwartz, Samet, and Patz (2004) researched the impacts of temperature and humidity on human health and discovered that the hospital's admission (heart disease cases) increased after a few days of exposure to extreme weather. It has also been documented that hospital's admission for heart disease in the cities during hot and cold weather increases monotonically with increased temperature (both hot and cold weather) before admission (Mitchell & Chakraborty, 2015). However, this, therefore, connotes that the extreme weather contributes greatly to disease occurrence including cardiovascular disease regardless of age group. Seasonal extremes of weather are linked with increased mortality and are associated with weather-related illnesses while extreme heat and high temperatures have been linked with death among the minors and the olds (Lorenzini, Nali, & Pellegrini, 2014; Mitchell & Chakraborty, 2015; Suomi, 2014). In one hand, both hot and cold temperature-related mortality are dependents of latitude and locations (Braga et al., 2001; Davis, Hondula, & Patel, 2016; Kinney et al., 2015; Shi, Kloog, Zanobetti, Liu, & Schwartz, 2015). Therefore, extreme weather and health are significantly linked, however, most of the study on weather-related illnesses focused mostly on extreme temperatures while the impacts of humidity on human health and mortality rate have received little or no attention, the relative humidity plays a key role in determining human thermal stress index (Ropo et al., 2017).

1.7. Linkage between climate change and diarrhea incidence

Diarrhea is among the major causes of morbidity and mortality, particularly in developing nations. Hashizume et al. (2007) investigated the relationship between non-cholera diarrhea and climate events and the result revealed that the cases of hospital admission increase with increased temperature, especially in those respective at lower sanitation, social and economic status. Some studies suggest that about 4 billion episodes of diarrhea occurred in every year of which > 90% of this incidence takes place in the low-income nations (Aaronson, Marsh, Guha, Schuur, & Rouhani, 2015; Von-Doellinger, Campos, Mendes, & Schramm, 2014).

Investigations have shown seasonal coincidence of diarrhea incidence with the rainfall period, however, ambient temperature could also strengthen the diarrhea occurrence (Bush et al., 2014; Carlton, Woster, DeWitt, Goldstein, & Levy, 2015). In one hand, elucidating the significant role of extreme weather on the incidence and conveyance of diarrhea disease could help by bringing a broad insight into the mechanisms of the periodic of the disease. Multiple weather variables may contribute to the increased occurrence and outbreak of gastrointestinal illness. The infectious gastrointestinal is one of the most prevalent diseases globally and its principal symptom is diarrhea which caused about 3 million deaths annually among people of age 5 years and below especially in developing nations (Onozuka, Hashizume, & Hagihara, 2010). In developed nations, the related mortality may be low but the rate of morbidity remains high. The most incidences of diarrhea and related illnesses are brief and most times do not require medical attention but the socio-economic concerns are significant due to the high incidence of the disease. In recent years, with rapid concerns about climate variability globally few works have studied on the linkage between change in weather variables and variation in the diarrhea incidences and other related illnesses (Levy, Woster, Goldstein, & Carlton, 2016; Mellor et al., 2016; Phung et al., 2016).

Assessing the diarrhea occurrence is difficult by several significant risk factors and the issues of complication even without considering climate events impact (Mellor et al., 2016). These complexities include local disease etiology, inadequate hospital records, individual physiology, environmental factors, individual genetics, personal savior, engineered infrastructure, also as well as geographical, political, cultural and socio-economic elements (Rehfuess & Bartram, 2014). Moreover, environmental factors impacts such as temperature, humidity and wind trend might be altered by many factors such as available infrastructure, social condition and anthropogenic activities.

The changes in climate have been identified to pose several fundamental threats to human fitness (McMichael, 2014; Soret et al., 2014). The observation of climate trend at regional level (such as rising temperatures) and illnesses among children revealed positive relationship in Kenya since 1975. This was also projected that the drying and warming climate will continue to unveil as the population and anthropogenic activities continue to increased (Grace, Davenport, Funk, & Lerner, 2012).

Epidemiological analyses have helped in building an impression of the linkage between climate-related diarrhea occurrences. Nevertheless, given the inescapable threat of climate variability, there is a need for various strategies or approach in understanding the hazard occurrence of diarrhea and to plan viable ways to deal with enhancing and the perils that can be postured by environmental change and unusual heat.

This review identified several analytical studies that considered epidemiological and climatic variables that were linked together in order to appraise the linkage between extreme weather (extreme heat) and extreme heat-born disease outbreaks or the epidemic incidence. Ten of these studies were presented in the tabular form to know the types of weather variables they considered and also the temporal reference of the study (Table 3). The findings identified in the different studies but their results were varied, highlighted the linkage between extreme heat driven force and extreme weather-borne infections.

Table 3
Climate change and extreme heat-borne diseases, continent, country, period of study, Author, Data, and Data source.

S/no	Climate change borne disease	Continent	Country/region	Duration	Author	Data source (epidemic and climatic data)	Data
1	Diarrhea	Asia	Taiwan	1996–2007 (11 years)	Chou et al., 2010	National Health Insurance Research data base and Taiwan Central Weather Bureau	Temperature, relative humidity, and rainfall and diarrhea incidence
2	Diarrhea	Asia	China	2004–2011 (7 years)	Phung et al., 2015	Can-Tho Preventive Medicine Centre and Southern Regional Hydro-Meteorological Centre	Average temperature (°C), daily rainfall (mm) and average relative humidity (%) and epidemiological data.
3	Cardiovascular, diarrhea, and respiratory disease	South America, Asia,	London, Sao Paulo, and Delhi	1991–1994 (4 years)	Hajat, Armstrong, Gouveia, & Wilkinson, 2005	Epidemic data (World Bank) Climatic data (unspecified)	Daily minimum &maximum temperature, relative humidity, Rainfall
4	Diarrhea	Africa	Botswana	1974–2003 (30 years)	Alexander et al., 2013	Climatic Data (Meteorology Department and Climate Research Unit)	Rainfall, temperature, and pressure.
5	Cardiovascular disease	North America	United States	19,986–1994 (8 years)	Schwartz et al., 2004	Climatic data (nearest airport) epidemiological data (Health Care Financing Admin.)	Temperature and relative humidity
6	Non-cholera diarrhea	Asia	Bangladesh	1996–2002 (7 years)	Hashizume et al., 2007	Climatic data (Bangladesh Meteorological Department) and epidemic data (International Centre for Diarrhea Disease Research, Bangladesh)	Rainfall and temperature
7	Diarrhea	Oceania (technically not a continent)	South Pacific	1993–1998 (5 years)	Singh et al., 2001	International Research Institute for climate and South Pacific Epidemiological service	Temperature, rainfall
8	General	Africa	South Africa	2015–2016 (6 months)	Wright et al., 2017	Field work	Temperature and humidity
9	Skin diseases	Global	Global	1990–2010 (20 years)	Hay et al., 2014	Systematic review and WHO	General
10	Skin cancer	London, Barcelona, Canary Islands	Europe	1979–1992 (13 years) & (2005–2014)	Grigalavicius, Moan, Dahlback, & Juzeniene, 2016	Nimbus 7 satellite and Institute of Health and Welfare, New Zealand Cancer Registry	UV Radiation, cloud cover, surface albedo, snow cover

Moreover, most of the studies revealed that there exists a positive relationship between the increased heat and epidemic incidence, also some revealed negative association that is there is an increase in diseases outbreak with decreased heat or temperature.

1.8. Skin diseases and climate variability

Cancer refers to the disease that affects the human body in which cells divide abnormally without restraint and infect other tissues in the human body. It is inimical impacts on health stretch from physical ineffectuality to demise (Andersen, Hercogová, Wollina, & Davis, 2012; Lavda, 2010). There are several forms of cancer and most times they are named after the name of the affected organ for example, skin, breast, lung and prostate cancers. Cancer is among the leading causes of mortality both in developed and under-developed nations after heart disease killing millions annually (Portier et al., 2017; Seyfried, 2015). There are potential skin cancers of both indirect and direct implication of climate variability. Climate variability may lead to a higher ambient temperature which can result in extreme weather event and change the subsequent human health exposures (Macdonald, Mackay, Li, & Hickie, 2003). Climate variability is also forecasted such as the increase in temperature and extreme weather events which will have impacts on human skin, extreme heat exposure can damage the skin (Andersen et al., 2012; Hunt & Watkiss, 2011). Moreover, more study is needed to determine the possibility of these issues of extreme heat-related disease, the location, geographical areas, the group of the population and people that are likely to be affected and its health implication or the outcome that could result. Albeit, the definite causes of cancer in human are yet to be understood absolutely for all classes of cancer, cancer growth factors or evolution include environmental contaminants, pathogens, age, genetic and sex (Kovarik & Kovarik, 2016). Highlighting the difficulties of understanding the inception or causes of skin disease and its related ailments, the connection among climate variability and skin malignancy is a blend of reality and speculation and studies are required to fill in the break in what we know to be achieved.

One of the likely direct effects of climate on skin disease can be as a result of much exposure to the extreme heat and radiation which might result in skin cancer. Most times, extreme heat effects on human skin are dependent on individual skin color. Skin color is one of the most apparent of human polymorphism (Avise & Ayala, 2010; Jablonski & Chaplin, 2010). One of the purposes of this study is to provide an encyclopedic review of epidemiology, etiology and climate change-related disease includes skin cancer. A clear understanding of the etiological factors is a crucial step in the avoidance of skin cancer (Schrempf et al., 2016).

Studies have shown that the aggregate of lifetime exposure to both artificial-natural heats is linked with persistent skin disorder such as skin cancer. Several studies that are epidemiologically oriented prove the elemental role of ultra-violet radiation in the provenance of skin cancer (Armstrong & Kricker, 2001; De Gruijl, van Kranen, & Mullenders, 2001; Haluza, Simic, Höltge, Cervinka, & Moshammer, 2014; Schrempf et al., 2016) in which most of the hazards result to melanoma. Study on the incidence of skin cancer in Florida (Rouhani et al., 2010), Chile (Rivas, Araya, Caba, Rojas, & Calaf, 2011) and Spain (Aceituno-Madera, Buendía-Eisman, Olmo, Jiménez-Moleón, & Serrano-Ortega, 2011) and related illness has been associated with a location, altitude and latitude. Moreover, it has been noted that the personal extreme heat exposure firmly depends on the behavioral elements or factors and also construed by the span of exposure, sun angle, geometry, clothing, surface, hair cover an hour of the day (Seckmeyer et al., 2013; Weihs et al., 2013).

1.9. Climate variability and human responses

Climate variability has been investigated to poses profound, direct or indirect and well-known threats to the human health and environment (Turner et al., 2010; Venton & La Trobe, 2008; Watson, 2014). A substantial portion of earth's species is projected to be vulnerable to decimation due to the increased temperature and other related extreme weather events due to changing climate and variability. There is rapid awareness of responses and the degree of risk, in both ardent and active that human will tackle as properties and lives are impaired by climate variability (Field, 2012). Climate variability can affect human health and the biological communities both indirect and direct impact. The direct human distress of climate variability includes changes in rainfall pattern, increased temperature, acidify and rising oceans, loss of ecosystems habitat (Ho, Knudby, Xu, Hodul, & Aminipouri, 2016; Parmesan & Yohe, 2003; Walther, 2010). However, the indirect aspect of climate may also affect the variety of life and ecosystem, sometimes more than the immediate consequence of climate variability.

The indirect effects arise as a result of attempts to both adapt and mitigate as to reduce or manage the climate variability adverse effect (Böckmann, 2015; Rounsevell, Dawson, & Harrison, 2010; Turner et al., 2010). There are many ways to this, but two are very crucial in addressing the undesirable concerns of climate variability on human fitness and well-being, these include adaptation and mitigation. Adapting to climate variability is crucial in order to avert the nonessential effects and to manage or improve the ecosystem resilience to simple stress (IPCC, 2014). The adaptation part was further divided by IPCC and recognized that there are two forms of adaptation which are spontaneous or autonomous adaptation and the second societal or planned adaptation. Spontaneous adaptation is when habitats and species include the various responses to the already observed adverse effect of climate. And the latter includes human risk reduction, policy and management process anticipated at expediting adaptation.

Several studies on mitigation and adaptation tend to research on their specific domain and few studies analyze the trivial consequences including adaptation options and the effects of migration assessment of impacts of climate variability (Birkmann, Garschagen, Kraas, & Quang, 2010; Füssel & Klein, 2006). Climate variability also has enormous responses or consequences on agriculture, human health, water, environment, where we live, what we eat and even the air we breathe. Moreover, climate variability can cause increase or decrease in agricultural output. They are some areas that experience an increase in agricultural potency because of climate variability. For instances, increased winter temperature could strengthen agricultural efficiency (Trnka et al., 2011) additionally summer temperature can diminish farming produce (Elliott et al., 2014).

Studies have opined that individual and societies can reduce their risk or threats posed by the climatic conditions by putting in place mitigation and adaptation strategies that best sustain their livelihoods (Kim et al., 2017; Waas & Hugé, 2012). The impacts of climate variability on livelihoods and human health are manifested by extreme events (extreme heat), floods, droughts, erratic rains and other environmental factors as established by Lema and Majule (2009). Africa has been categorized as one of the most vulnerable regions to climate variability because of its geographical location, incompetent leaders, widespread poverty compounded by these recurrent extreme weather events which limit the individual and communities' capacity to effectively cope and adapt to these challenges (Lema & Majule, 2009).

Studies have also revealed that the consequences of climate variability are potentially more substantial for the poor in low-income nations than for those living in more developed countries (Haines, Kovats, Campbell-Lendrum, & Corvalán, 2006; Seaman, Sawdon, Acidri, & Petty, 2014). Moreover, it is argued that vulnerability to the impacts of climate variability is a function of exposure to environmental factors or variables, sensitivity to those variables and the adaptive capacity of the affected individual or communities.

Krantz (2001) proposed and defined sustainable livelihood as follow:

> Right off the bat, "A livelihood involves the capacities, resources (stores, assets, claims and get to) and exercises required for a

method for a living. A livelihood is economical when it can adapt to and recoup from stress and stuns, keep up or upgrade its capacities and resources and give manageable livelihood opportunities to the present and the next generation; and which contributes net advantages to different livelihood at the neighborhood and global levels and in the short and long term".

From the above illustration, the ability of livelihood to be able to effectively adapt or cope with and recover from environmental stressors and shocks associated with climate and environmental change include extreme events, droughts, floods and extreme heat is central to the definition of sustainable livelihoods and environment (Carney, 2003).

2. Summary

In summary, the studies on climate-related events and heat-related diseases have been reviewed in this paper. Human health, diverse global socio-economic change, demographics, environment and climate variability are linked, such as the increased prevalence of heat-related disease, the emergence of infectious disease and the persistence of health disparity. Moreover, all these can be initiated and influenced by climate variability. Undertaking prevention at the local level to manage and reduce risks that may arise from these global climate influences is essential. Therefore, extreme weather and health are significantly linked, this review noted that most of the study on weather-related illnesses focused mostly on extreme temperatures but the impacts of humidity on human health and mortality rate have received little or no attention. Moreover, relative humidity plays a key role in determining human thermal stress index; this review opines that in the subsequent study of climate impacts on human health and their thermal comfort index more attention should be on humidity and other climatic variables.

There is an urgent demand to recognize the human health implications of climate change and variability. This will need the adaptation of present policies and approaches, a focus on an individual, public health education, institutions, government, and increase the awareness and communication across different sectors.

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