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Quantifying the Cost of Climate Change Impact in Nigeria: Emphasis on Wind and Rainstorms

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ABSTRACT Wind related hazards have not been adequately acknowledged as environmental problem like flooding and gully erosion that needs to be properly addressed by the Nigerian Government. This is in spite of the fact that it claims lives, destroys buildings and social infrastructure annually. This prompted this study that dwell on quantifying the cost of climate change impact in Nigeria with special emphasis on wind and rainstorm hazards on building and infrastructures between 1992 and 2007. Climate data (air temperature, rainfall, wind speed) and cost of wind/ rainstorm damage_were collected from 12 out of the 36 states in Nigeria. Time series, graphs and chi-square were the statistical tools used to evaluate the relationships between climate elements and rate of damage. The results show evidence of climate change with increasing temperature and decreasing rainfall. Wind and Rainstorm damage show evidence of seasonality, which is higher at the beginning and end of the rainy season, following the movement of the ITCZ. Total lives lost were 199 persons and cost of property damaged worth ₦85.03 billion ($720.6 million). It is recommended that while causes of climate change should be minimized, adequate developmental policies and planning that focus on wind and rainstorm hazards' awareness and preparedness should be vigorously pursued by both individuals and the government. Wind factors should be taken into consideration while building.

INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over a comparable time periods (IPCC 2001). Ayoade (2004) also defines climate change as a long-term shift, alteration or change in the type of climate prevailing over specific location, region or the entire planet. It is obvious from both definitions that change is an inherent attribute of climate, which is caused by both human activities (anthropogenic) and natural processes (Biogeographical).

The human factors that cause climate change have been identified as industrialization, technological development, urbanization, deforestation and burning of fossil among others, while the natural factors include solar radiation quality and quantity, astronomical position of the earth among others. These factors are conceptualised in Figure 1. Studies have shown that the currently on-going climate change is caused by anthropogenic factors. For example, unsustainable industrialization, which releases greenhouse gases, is viewed as the main cause (Odjugo 1999, 2001; Clerk 2002; Buba 2004; Nwafor 2007). Other contributing factors are urbanization, deforestation, burning of fossil fuel and water pollution (Odjugo and Ikhuoria 2003; Odjugo 2005; NEST 2003; De Weerdt 2007).

These factors have been observed to alter the climatic conditions of different parts of the world resulting in climate change and devastating extreme weather conditions (Odjugo 2000a, 2005; Adelekan 1998). The extreme weather conditions include global warming, drought, desertification, flood, sea-level rise, wind and rainstorm and thunderstorm among others. Various researchers have studied the causes and effects of extreme weather conditions as they relate to climate change and confirmed the fact that the impacts are becoming more devastating (Awosika et al. 1992; Adelekan 1998; Nyelong 2004; Odjugo 2000a, 2007; NEST 2004). On the other hand, there is a dearth of information on the economic cost of the impact of climate change. The few known studies to the researcher on economic cost of climate change include (Odinga 2004; Buadi and Ahmed 2006; Malun 2006; Reid et al. 2007) in Mozambique, Cameroon, Cuba and Namibia respectively. Apart from specific countries, other researchers tried to quantify the impact of climate change on natural resources in Africa (Velarde et

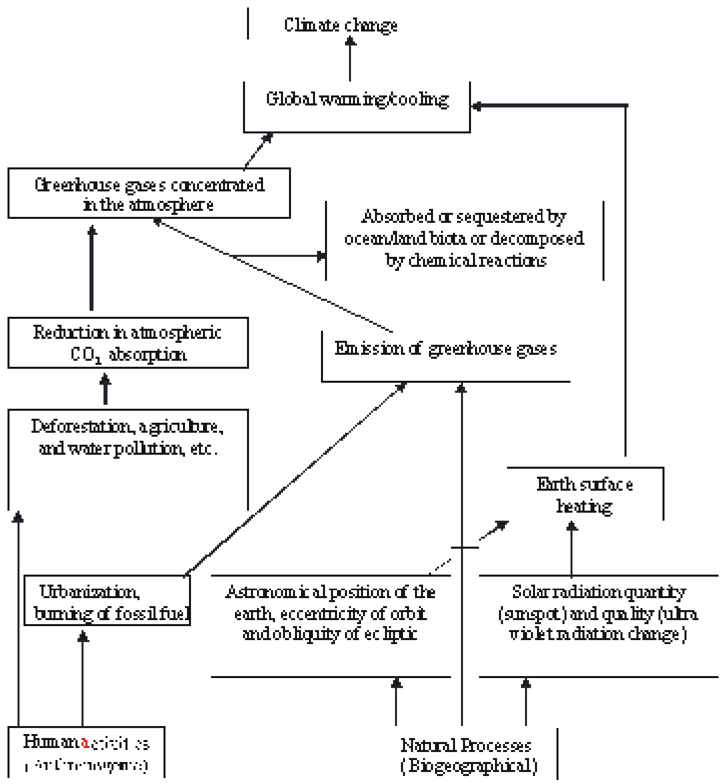

Fig. 1. Causal factors of climate change
Source: Author

al. 2005; Macgregor et al. 2006). Interesting enough, none of these studies is based on Nigeria. Adelekan (2000) and Dubu (2006) show that although wind related hazards have not been adequately acknowledged as environmental problems that need to be properly addressed in Nigeria as in the case of flooding and gully erosion, results have shown that it is a problem that requires in-depth research, and government intervention in view of global climate change and its consequent extreme weather events. A major way to raise climate change concerns further up the policymakers' agenda is to try to put an economic value on the environmental impacts of climate change. It is not possible for the Nigerian government to know exactly to what extent her citizens and properties are vulnerable to the on-going climate change and its associated wind and rainstorms, except these are valued or quantified in monetary terms. This prompted this study which investigated the cost of climate change impact in Nigeria, with special emphasis on destroyed buildings and social infrastructures by wind and rainstorms between 1992 and 2007.

MATERIALS AND METHODS

The study covers 12 states randomly sampled out of the 36 states in Nigeria (Table 1). The country was divided into the two climatic belt found in Nigeria following the Koppen's climatic classification. They include the Tropical rainforest climate (Af) and Savannah climate (Aw). The states in each climatic belt were written and kept in a box. Four states were randomly selected from the Af climatic belt and eight states were randomly selected from the Aw climatic belt. The variation in the number of states selected in each climatic belt is based on their sizes. While the Af climatic belt occupies about one third of the country, the Aw climatic belt covers approximately two-third of the country.

Climatic data (air temperature, rainfall and windspeed) were collected from Nigerian Meteorological Agency in Oshodi, Nigeria and some states' Meteorological Department of the airports, for the period of 1992 – 2007. The study is limited to this period because data were not available in most states beyond 1992 due to the creation of new states in 1991. The cost of wind and rainstorm damage to buildings, vehicles and social infrastructures (like markets, schools, hospitals, national electrical installations among others) and the number of people killed were collected from the archival data of the Federal and States Ministries of Environment, National and State Environmental Management Agencies (NEMA and SEMA) and the former Federal Environmental Protection Agency (FEPA), for the period of 1992 – 2007. Time series was used to analyse the temporal trend of the climatic and rain/windstorm hazards. Bar graphs were employed to analyse the spatial storm hazards and rain/wind velocity data. The chi-square was used to determine whether the hazards caused by the wind and rainstorms in the Af and Aw climatic belts were statistically significant.

RESULTS AND DISCUSSION

The rainfall trend shows a gradual decrease over time while temperatures were increasing (Fig. 2). This is a basic characteristic feature of climate change whereby temperatures are observed to be increasing with decreasing rainfall amount (Olaniran 2002; NEST 2003; Odjugo 2005; Mabo 2006). The highest air temperature (28.4°C) occurred in 1998 followed by 2002 (27.9°C). These are the known first and second hottest years ever recorded globally (Odjugo 2000a; Odjugo and Ikhuoria 2003; IPCC 2005: Mshelia 2005). The wind speed is also observed to be increasing, but the $R^2 = 0.44$ (Fig. 3) is an indication that the variation in wind velocity within the study period is statistically the same. The spatial air temperature and wind speed showed a steady increase from the southern to the northern part of the country while the reverse is true for rainfall (Table 1). The primary and secondary tropical rainforest in

Table 1: Spatial variation of climatic elements

States	*Rainfall (mm)*	*Temperature (°C)*	*Wind speed (Km/hr)*
Delta*	2900	26.7	7.2
Lagos*	1560	26.4	7.3
Ondo*	2180	27.1	7.0
Imo*	2280	26.9	8.5
Kwara**	1180	27.2	13.2
Adamawa**	1130	28.3	20.1
Plateau**	1280	23.3	19.3
Benue**	1190	28.1	14.1
Sokoto**	620	29.8	23.8
Katsina**	552	29.6	23.6
Bauchi**	920	28.5	22.7
Yobe**	630	30.1	24.2

*Southern states or Af climatic belt
**Northern states or Aw climatic belt

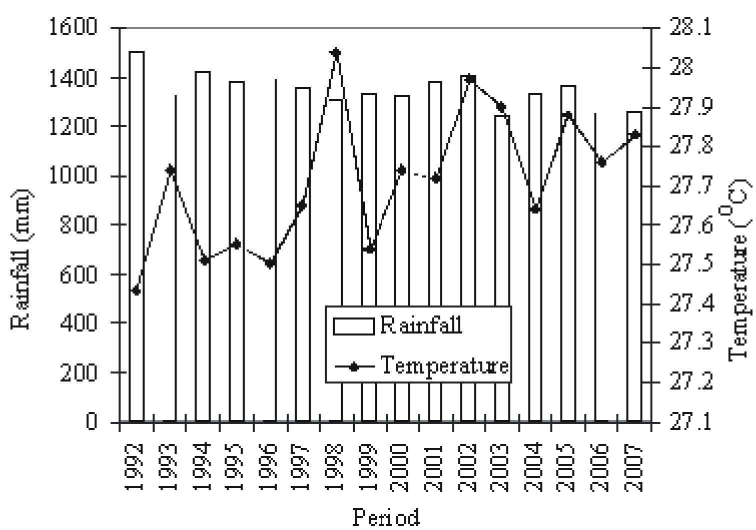

Fig. 2. Temporal variation of mean air temperature and total rainfall of the study area

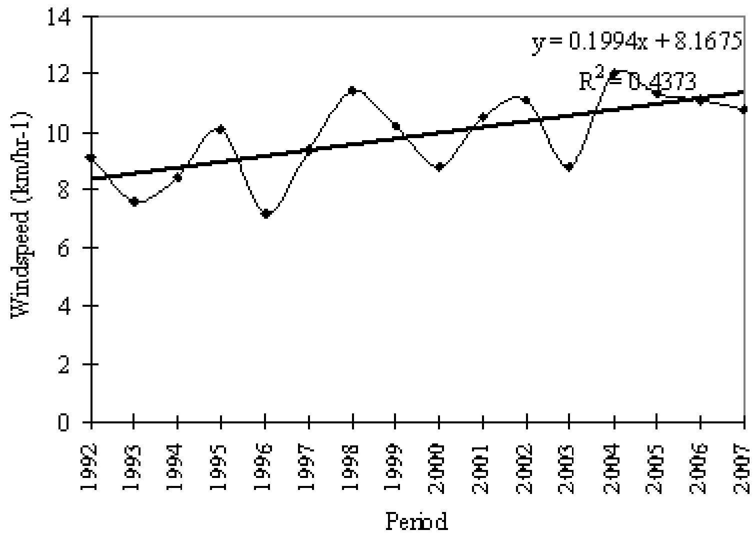

Fig. 3. Temporal windspeed variation

southern Nigeria must have acted as windbreak, hence the reduced wind speed recorded. The sparse Sudan and Sahel savannah vegetation with little frictional force on the wind resulted in the high wind velocity experienced in the northern Nigeria. Moreover, the high rainfall (Table 1) and relative humidity (Odjugo 2005) in southern Nigeria made the atmosphere to be damp and the associated heavy air slowed down the wind velocity. The reverse is true for northern Nigeria.

The total cost of wind/rainstorm damage is shown in Figure 4. The total cost of damage to properties (buildings, vehicles and social infrastructures) was valued to be eighty five billion and three million Naira (₦ 85.03b) ($720.6 million) within the 16 years. That is an average of ₦ 5.31 billon ($45 million) per year. The study covers 12 states out of the 36 states and the Federal Capital Territory in Nigeria. That is one-third of the states (33%) in Nigeria. By implication, Nigeria must have lost roughly ₦ 255.84 billion ($2.2 billion) in the 36 states to wind and rainstorms alone within 16 years. Although data collected for this study ended in 2007, published information on the cost of wind hazards in Nigeria show that in the month of March 2008, rainstorm in Oyo and Ogun States, Nigeria destroyed over 3,000 houses and properties worth millions of Naira (Olugbile 2008; Sunday Tribune 9, March 2008). In April 2008 alone, over 500 persons were rendered homeless, while property worth over ₦ 900 million ($7.63 million) were destroyed in Makurdi, Benue State, Nigeria by a rainstorm (Ejembi 2008).

The rate of destruction was steadily increasing prior to the year 2000 and thereafter it became erratic (Fig. 4 and 5). This could be linked to increasing rain and windstorms in the late 1990 and the 2000s as reported by (Dubu 2006). The total cost of damage to buildings, cars, electrical installations, and markets among others rose from ₦2.78 billion ($23.6 million) in 1992 to ₦ 9.7 billion ($82.2 million) in 2007 with the peak of ₦ 10.8 billion ($91.5 million) in 2006 and the least of ₦2.12 billion ($17.97 million) in 1994 (Fig. 4). The temporal change or increase was $R^2 = 0.81$ (Fig. 4). This signifies a positively strong increase in the rate of destruction within the study period. The data were separated into the two climatic belts in Nigeria, the Af and Aw. The damage was more in the Af climatic belt than the Aw (Fig. 5). The pattern of destruction was more erratic in the Af than the Aw climatic belt. This is in line with the findings of Odjugo (2005) who observed that while rainstorms increased by 38% in Nigeria south of 8^{O}N, it was 6% between 8^{O}N and 14^{O}N. χ^2 of 5.11 shows that the difference in the rate of destruction between the Af and Aw climatic belts was statistically significant at $p < 0.05$. The spatial variation in the cost of rain and windstorm

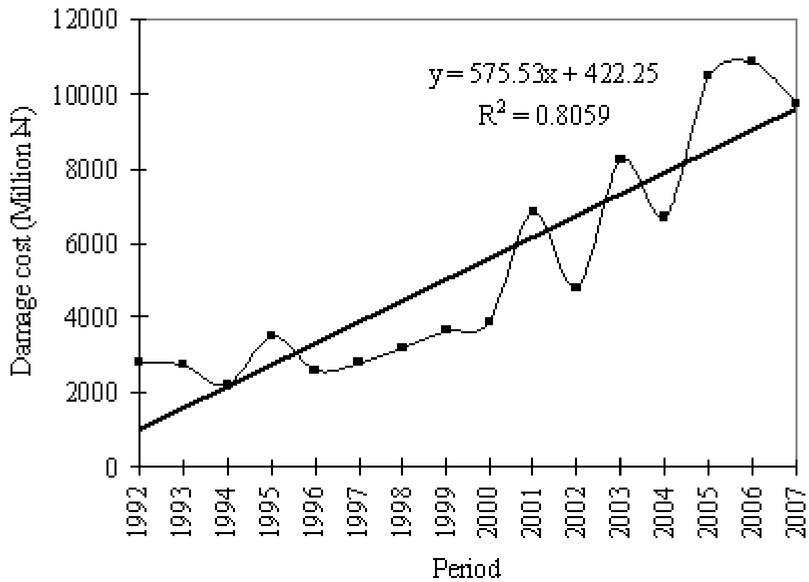

Fig. 4. Temporal variation of total cost of storm damage

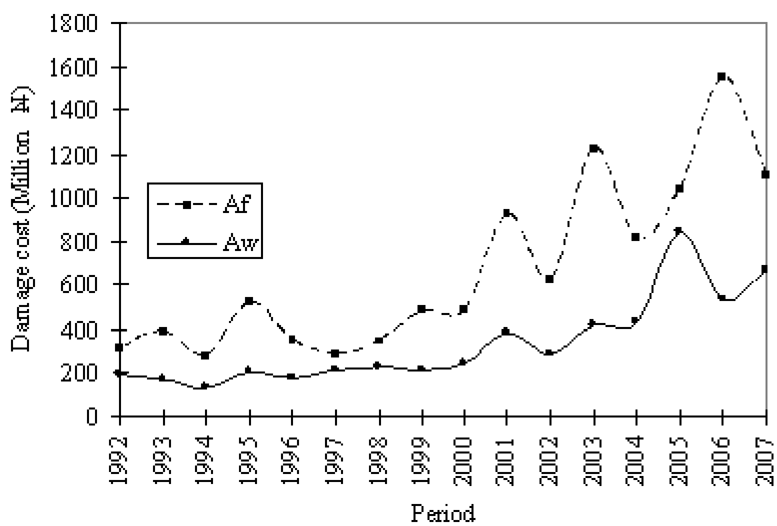

Fig. 5. Mean variation in damage (cost) between Af and Aw climatic types

damage is shown in Figure 6. The coastal states like Lagos, Delta and Ondo with the highest rainfall experienced the highest destruction, while the semi-arid states like Yobe and Sokoto experienced the least destruction.

The causes of the damage experienced are attributed to four basic factors. These include the population and housing density, the building design, position of the inter-tropical convergence zone (ITCZ) and urban forestry. The impact was severest in Lagos State, which had the highest housing and population density among the states studied and Delta, and Ondo followed this in that order. The shape of the building (architectural design) in the Af climatic region is mostly rectangular. The rectangular shape resists the

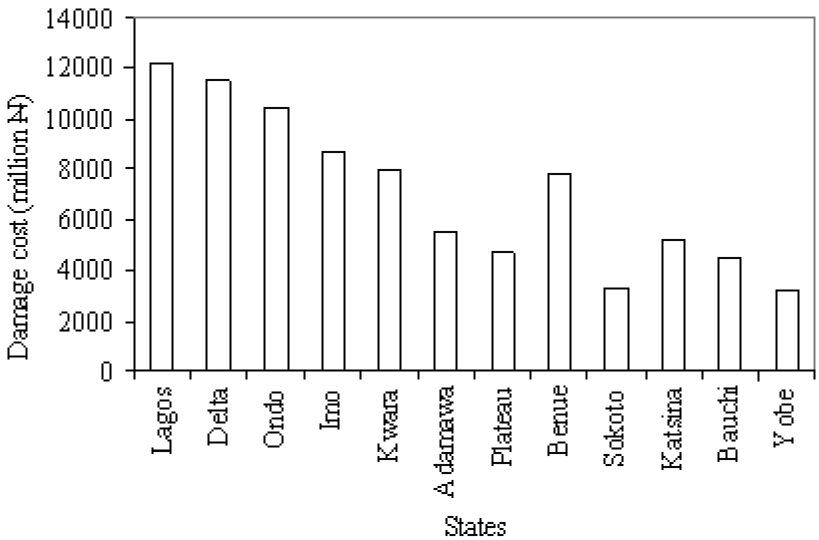

Fig. 6. Spatial variation of the cost of damage

prevailing wind thereby allowing the wind to move up the walls and this makes it easy to blow off their roofs. The shape of most buildings in the Aw climatic belt is round with either conical or flat roofs. The round shape with conical roof has lesser resistance to the prevailing wind – allowing the wind to blow through the circular shape of the building- thereby reducing the destructive impact of the wind. Adelekan (2000) earlier shows that poor building designs that have not taken into consideration the wind environment are the major causes of wind damage to houses in Nigeria.

Annually, the ITCZ is always in the coastal states (Af climatic belt) for at least 5 months. By January of every year the ITCZ is along the coastal region. It starts its journey up north by February of every year and before it finally leaves the Af climatic belt, it is already April or May and by October or November, it is already back to the Af climatic belt. In this case, the linesqualls that is associated with the position of the ITCZ that actually cause the windstorm and property damage stays longer in the Af climatic belt. In both climatic belts, the damage is more during the beginning and toward the end of the raining season. . In the Af climatic belt, rainstorm hazards were recorded as from January when the ITCZ is along the coastline. As it progresses into the continental interior with its associated linesqualls that actually cause the rainstorm, the rate of destruction increases as more settled areas are involved. Darlong (2005) also related the rainstorm damage to the position of the ITCZ in Ghana. Although the damage cut across the urban and rural areas, the destruction was more in the urban areas because of higher housing density and limited trees in the cities. Urban forestry is not a common practice in the cities of southern Nigeria (Af climatic belt) but a major practice in the cities of northern Nigeria (Aw climatic belt) (Odjugo and Iweka 2006) and in the rural areas of both climatic belts. The trees that are supposed to act as windbreaks are not many especially in the southern cities where urban forestry is not a common practice. That is why the storm damage is greater in the urban centres than in the rural areas.

Another notable feature of the wind and rainstorm hazards is its seasonality. The severity of the general destruction is highest within the months of February to June with the peak in the month of April (Fig 7). This declines sharply from the month of June to August. The impact is more in the months of March through May when the southwest trade wind must have pushed the Northeast trade wind with its divide (ITCZ) to the northernmost part of the Af climatic belt. By the month of April, the southern part of the Aw climatic belt must have experienced the ITCZ with its associated wind and rainstorms. This gradually shifts northward and by July the ITCZ must have left Nigeria into the Niger Republic. This brings about the very low impact recorded in the months of July and August. Windstorms usually cause severe damage to houses and infrastructure during the months of January to April in the Aw climatic belt. As the windstorms recede, the rains set in with their rainstorms in the months of April through June.

The Af climatic belt did not record any rainstorm hazards in the months of July and August. This is the period of short - dry - season (locally known as August break) in the Af climatic belt where there is reduced rainfall (Odjugo 2005). The renewed concluding heavy rainfall in the Af climatic belt with its associated rainstorms resulted to some hazards recorded in the months of September and October in the Af climatic belt (Fig. 8). By December or January, the ITCZ had descended southward to the coastal region and taken over almost the entire country with the dry northeast trade wind dominating the entire country. This resulted in the low rate of rainstorm hazards recorded in these months (Fig 7 and 8). Personal observation showed that the blown off roofs and pulled down building walls were mainly older ones with some of them built of mud.

The total number of deaths recorded was 199 persons (Table 2). The mean number of people that were killed was highest in the Af climatic belt. This recorded a mean of 23 deaths per state between 1992 and 2007 while the Aw climatic belt had a mean of 13.4 deaths per state. Lagos State topped the list followed by Ondo State while Yobe State recorded the least (Table 2). Buadi and Ahmed (2006) had similar result when they reported that rainstorm claimed 42 lives in southern Cameroon between 2000 and 2005. On Monday 31, March 2008, 13 pupils were reported dead in a nursery and primary school in Ibadan

Table 2: Number of deaths occasioned by wind and rainstorms in Nigeria (1992-2007)

Af climatic belt	*Number of deaths*
Lagos state	38
Ondo state	26
Delta state	18
Imo state	10
Total	92
Mean	23
Aw climatic belt	*Number of deaths*
Kwara state	21
Adamawa state	10
Plateau state	15
Benue state	19
Sokoto state	8
Katsina state	11
Bauchi state	16
Yobe state	7
Total	107
Mean	13.4

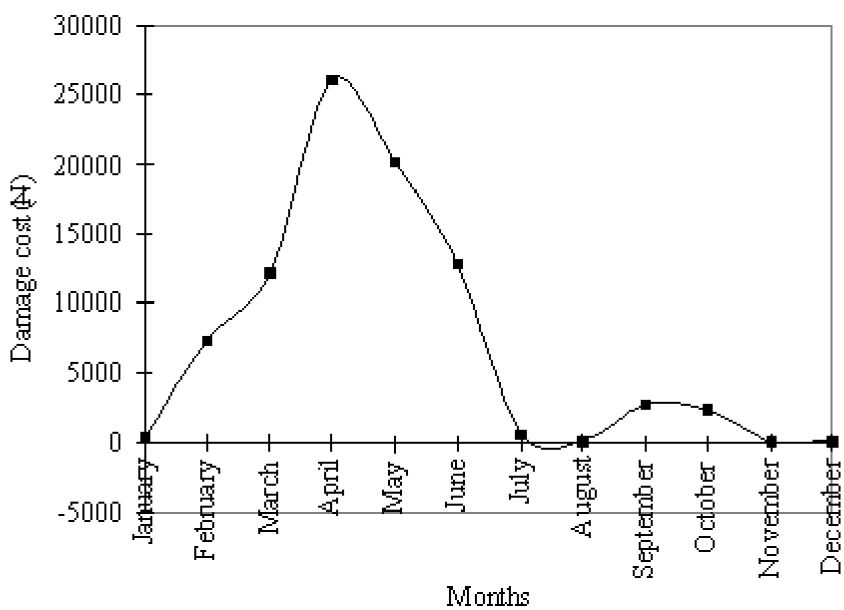

Fig. 7. Spatial variation of damage cost

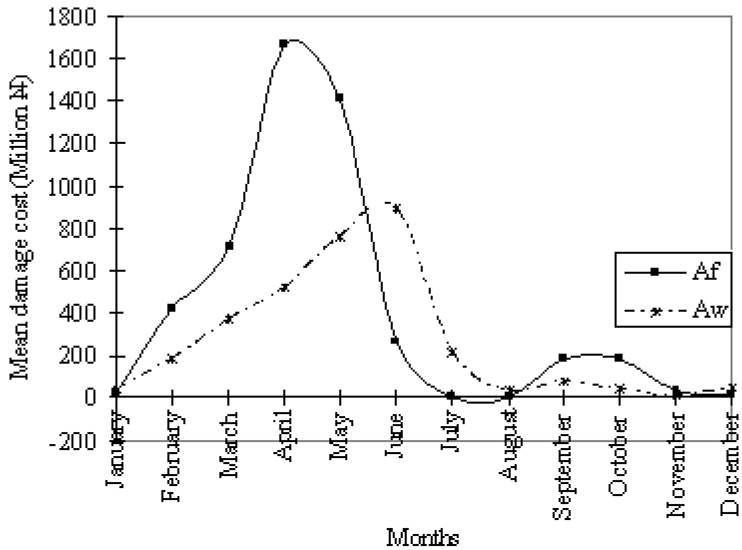

Fig. 8. Spatial variation of damage cost base on climatic belts

as a result of a rainstorm (Ejembi 2008). The implication of this finding is that, if wind and rainstorms in 12 states killed 199 persons in 16 years then, about 597 persons may have lost their lives in the same period to wind related hazards in the 36 states and the Federal Capital Territory of Nigeria.

CONCLUSION

The increasing temperature and decreasing rainfall recorded in this study show evidence of climate change in Nigeria. This is manifested in the increasing damage caused by wind and rainstorms – an extreme weather condition - which is a major characteristic feature of climate change. The total cost of damage to buildings, cars, electrical installations, and markets among others rose from ₦2.78 billion ($23.6 million) in 1992 to ₦ 9.7 billion ($82.2 million) in 2007 with the peak of ₦ 10.8 billion ($91.5 million) in 2006.

The severity of the damage was more in the Af climatic belt than the Aw climatic belt. The causes of damage was limited to basic factors like the impact of the ITCZ and its associated linesqualls, population/housing density, limited urban forestry especially in the southern cities of Nigeria and building designs that do not take into consideration the wind factor. With regard to cost of damage, Lagos State recorded the highest, followed by Delta and Ondo States, while Yobe State was at the bottom of the table. Lagos State also recorded the highest number of person killed by the actions of the wind and rainstorms, followed by Ondo and Delta States with Yobe State at the least position. The study also shows seasonality in the destructive pattern of the rain/windstorms. It is more at the beginning and toward the end of the rainy season.

The huge sum of money and number of lives lost to wind and rainstorm hazards in Nigeria, is an indication that wind related hazards are a major problem. This calls for the attention of the Federal, State and Local Governments to come up with adequate developmental policies and planning that will focus on raising awareness on the danger of wind hazards and the necessary preparedness to curtail same. There is also the need to mainstream climate change into national policies and planning. The current bill on climate change commission is in the right direction and it will help to tackle climate change problems if passed into law. Both the National Emergency Management Agency (NEMA) and the States Emergency Management Agency (SEMA) should be empowered for prompt rescue mission in case of wind hazards and to assist the victims financially and materially in order to alleviate their suffering. Such prompt rescue action will save more lives. All causes of global warming and climate change such as emission of green house gases should be drastically reduced and environment friendly production processes should be vigorously pursued.

As adaptive measures, afforestation programme together with urban forestry, landscape and greenery should be a major practice. These will serve as windbreaks that would cushion the hazardous effects of the wind, while at the same time acting as carbon sink. Building designs and materials should be those that take the wind factor into consideration and can withstand wind and rainstorms. Buildings as much as possible should carry concrete parapets to protect the roofs from the adverse effects of the storms.

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