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Full Length Research Paper

Geospatial analysis of potential impacts of climate change on coastal urban settlements in Nigeria for the 21st century

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At present, there are substantial scientific uncertainties about the nature and magnitude of climate change impacts that might result from an effective doubling of CO2 concentrations in the atmosphere of the coastal urban settlements of Nigeria. This is because large percentage of Nigeria's urban population lives in coastal cities. This study examines the potential impact of climate change on the coastal cities of Lagos and Port Harcourt using the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC-SCENGEN) and Geographical Information System (GIS) interpolation techniques. The results confirm that sea level rise may occur with a consequence of submerging all coastal cities of the Niger delta area and a larger part of Lagos. The parts left un-submerged may face the risk of incessant flooding. These will also disrupt communications, damage vital infrastructures and affect urban settlements along the coast. The impacts of climate change may be felt also by a wide spectrum of socio-economic variables like human health, transport, energy, industry and other service sectors.

Key words: Climate change; coastal cities, MAGICC-SCENGEN, GIS, temperature, precipitation.

INTRODUCTION

Climate change due to global warming is recently confirmed by significant observed increases in average temperatures and its impacts cannot be overemphasized on urban settlements that occupy millions of people in Nigeria. Climate change has been affecting and will continue to affect almost, if not all, the sectors of the urban economy including the most sensitive ones such as water and health sectors. At present, there are substantial uncertainties about the nature and magnitude of climatic changes that might result from an effective doubling of CO_2 concentrations in the atmosphere of the urban settlement (IPCC, 2007). However, it is necessary to make some assumptions about changes in climate in order to assess potential impacts that are due to these changes in coastal urban settlements of Nigeria. This is because a large percentage of Nigeria's urban population lives in coastal cities. For example, according National Population Commission report (NPC, 2006), about 30 million people, (21%) of the national population, live in coastal cities of Nigeria.

Recent evidence has shown that economic activities have contributed to an increase in the concentration of greenhouse gases in the atmosphere in the last 100 years, leading to the enhanced greenhouse effect (Adesina and Adejuwon, 1994; IPCC, 1996, 1998, 2004a, 2004b) which in turn is expected to result in climate change (Awosika et al., 1994; Carter et al., 1994; IPCC, 1995, 1997, 2000, 2001) . It is estimated that extraction and burning of fossil fuels is the source of about 70 - 90% of anthropogenic carbon dioxide emissions (Hulme et al., 2000), the most important greenhouse gas.

Greenhouse effect is a natural phenomenon. Natural mixes of certain greenhouse gases reside in the atmosphere. They allow the short-wave radiation from the sun to penetrate the atmosphere, but absorb the lower wavelength energy which is re- radiated from the earth's surface (IPCC, 2000). Because these greenhouse gases are good absorbers of heat radiation coming from the earth's surface, they act like a blanket over the earth's

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Table 1. Midyears and the periods they cover.

Midyear	Period
1975	1961-1990
2025	2010-2039
2054	2040-2069
2084	2070-2099

surface, keeping it warmer than it otherwise would be. Enhanced greenhouse effect, on the other hand, is not natural. It refers to the changes in the earth's radiation balance due to the anthropogenic accumulation in the atmosphere of radioactively active greenhouse gases. In addition to carbon dioxide, other greenhouse gases include methane, nitrous oxides, tropospheric ozone and chlorofluorocarbons. The globally averaged temperature of the air at the earth's surface has warmed between 0.3 and 0.6^{o}C since the late nineteenth century (IPCC, 1994, 1996). Records from measurements taken since 1860 indicate that the four warmest years on record have all occurred since 1990. Even, Nigeria as a country could be said to have warmed. A publication in This Day newspaper (31/12/02) put the surface air temperature rise in Calabar at 0.25^{o}C and that of Lagos between 0.25 and 0.50^{o}C**.** Other evidences of global temperature increases abound. These include the observed shrinkage of mountain glaciers (Hulme et al., 2002), a reduction in northern hemisphere snow cover and increasing subsurface ground temperatures.

It is estimated by the IPCC that the globally averaged surface temperature will increase by 1.1 – 3.5^{o}C by the year 2100 while a sea level rise of 15 – 95 cm is projected (IPCC, 2001). These changes may lead to a number of potentially serious consequences in coastal cities. There could be an increase in mortality rate as a result of heat stress; there will also be an increase in potential transmission of many infectious diseases (Hulme et al., 2002). Moreover, sea level rise would increase the number of people whose land will be at risk from serious flooding or permanent inundation. The projected impact of this on environmental stability and life in urban settlements of Nigeria (especially coastal urban settlements) is better imagined than experienced. They could include changes in the urban climate and the consequent disruption in the temporal and spatial distribution of temperature and precipitation.

Many uncertainties, however, remain concerning the timing and degree of the enhanced greenhouse effect. Despite these uncertainties, the balance of opinion suggests that climate change is real and favours early action in tune with the precautionary principle. This has spawn into various abatement measures by international organizations like IPCC. Moreover, it is commonly argued by some people that the climate change issue should be paid only minor attention in Nigeria for three main reasons.

- Present greenhouse gas emissions from Nigeria (like other African countries) are negligible on a global scale.
- Climate change is a problem that is largely caused by emissions from industrial countries.
- Hence, these countries (Developed countries) should bear the main responsibility and the major costs of reducing emissions.

While the low contribution of Nigeria to climate change might seduce one into advocating for indifference on the part of Nigeria and for the buck to be passed to the developed countries that are the chief culprits historically, it should be noted, however, that effect of climate change such as a rise of 1m in sea level could seriously affect nearly millions of people along the coasts of Nigeria. Increases in population growth rates in the principal coastal cities of Nigeria, combined with a likelihood of a 1m sea-level rise, could create conditions for significant negative impacts on tourism-oriented economies, ecology, and human lives of this area.

Thus, this study examines the potential impact of climate change in coastal cities in Nigeria using the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC-SCENGEN) and Geographical Information System (GIS) interpolation techniques. The general objectives of this study include: to map out a composite of scenarios for climate change impacts on coastal cities in Nigeria and their implications on physical, economic and social environments.

MATERIALS AND METHODS

The data used in the study are acquired from computer simulations as described by Hulme et al. (2000). The baseline data is defined as that prevailing during the period 1961 to 1990 constructed specifically for MAGICC-SCENGEN (Hulme et al., 2000, for a detailed description of the baseline data). The baseline period is selected based on the following criteria (IPCC, 1994):

i. Representative of the present day or recent average climate in the study region.
ii. Covering a period for which data on all major climatological variables are abundant, adequately distributed over space and readily available.
iii. Including data of sufficiently high quality for use in evaluating impacts.
iv. Consistent or readily comparable with baseline climatologies used in other impact assessments.

The observed climate data of 1961 to 1990 baseline was used in order to ensure the provision of more detailed and refined scenario. The data includes average monthly, seasonal and annual fields at a spatial resolution of 5^{o} latitude by longitude for temperature and precipitation. For the projections, four time slices are used. These include: 1961 - 1990; 2010 - 2039; 2040 - 2069 and 2070 - 2099 (Table 1). The 1961 - 1990 data are observed data and are the baseline from which projections are made to the other time slices. This baseline data set was downloaded from the IPCC Data Distribution Center. To project the climate of the coastal cities for the 21st century time slices, relative to the observed data for the larger cells in which the meteorological stations are located are used, the GIS interpolation technique was used.

Table 2. Some stations in Nigeria that are close to the points developed to run MAGICC-SCENGEN.

Data points	Nearest Settlement/State
A	Birnin Kebbi, Kebbi
B	Gusau, Zamfara
C	Damaturu, Yobe
E	Meko, Ogun
F	Ankpa, Benue
G	Gasaka, Adamawa
H	Port Harcourt, Rivers, Lagos

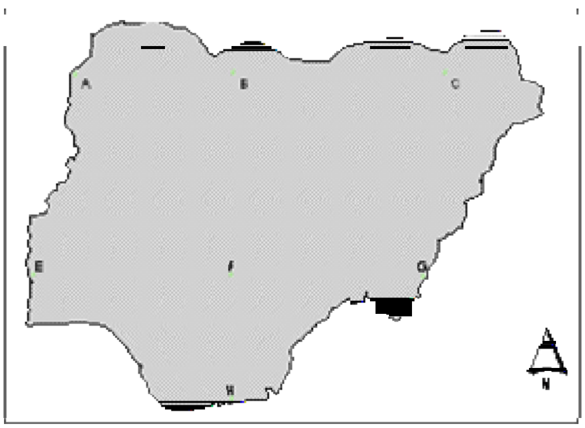

Figure 1. Map of Nigeria showing the points developed to run MAGICC-SCENGEN.

A number of modeling experiments exist. Among them are the Hadley Unified Model 2 Transient Ensemble-mean (HADCM2), UK Meteorological Office/ Hadley Centre Transient (UKTR), Commonwealth Scientific and Industrial Research Organization, Transient (Australia) (CSIRO-TR) and many more. Each has its peculiarities, that is, its strengths and weaknesses. However, MAGICC-SCENGEN model computer simulations of the climate incorporate the basic physics and dynamics of the climate systems and take into account the interactions between the different components of the climate systems (the atmosphere, oceans, land, ice and the biosphere) (IPCC, 2007).

Data analysis

MAGICC-SCENGEN was run for the whole country (Figure 1), out of which full observation were carried out for the coastal region of the country. As earlier mentioned, MAGICC-SCENGEN provides climate change fields at 5^{o} latitude/longitude resolution (a coarse one). In order to get a finer result, the downscaling technique becomes imperative. For instance, the result generated for Nigeria at resolution of 5^{o} latitude/longitude is nearly useless because Nigeria as a country falls between longitude $2^{o}45'$ and $14^{o}30'$ and b while the rest fall outside. But since three points are somehow inadequate for reasonable interpolation of a surface as large as Nigeria, some adaptations were made. Some points (A, E, G and H) between the highest and the lowest latitudes is 10^{o}. The resultant effect of this is that only three points (B, C and F) fall within Nigeria two extremes of the country is $11^{o}45'$ while latitudinal difference initially lying outside, but close to Nigeria were latitude 4^{o} and 14^{o}.

Thus the longitudinal difference between the highest and the lowest latitudes is 10o. The resultant effect of this is that only three points (B, C and F) fall within Nigeria while the rest fall outside. But since three points are somehow inadequate for reasonable interpolation of a surface as large as Nigeria, some adaptations were made. Some points (A, E, G and H) initially lying outside, but close to Nigeria were dragged inside Nigeria making the points increase from three to seven. The basis for this adaptation is that one point relates to a 5^{o} latitude/longitude cell. Therefore, any point that falls outside Nigeria (but falls) within a cell inside Nigeria is dragged inside Nigeria to make the interpolation work reasonable. Points A, E, G and H were thus dragged in. The only one left outside is the point D; this is because it does not fall on any cell within Nigeria. However, other settlement like Lagos was later included in this study to make the research more robust and to have detail information on coastal areas of the country (Table 2 and Figure 1).

The results from the model runs were presented in tables and maps. Computed indices for each grid point were imported into Geographic Information System software and interpolated on a base outline map of coastal area of Nigeria. GIS files were converted into PC compatible formats for printing and inserting into documents. Four maps were generated for precipitation and temperature each i.e the indices of climate investigated in this work. Three of the maps relate to future periods (2024, 2054 and 2084). Scenarios building for the 21^{st} century have been made in accordance with two different emissions scenarios by IPCC Special Report on Emission Scenarios (SRES). These are the - SRESA2 and SRESB1. Calculated values are presented by 30 year average annual values e.g. average annual values for year 2024 covers a period of 2010 -2039 (Table1).

Interpolation procedure

Interpolation is the process of predicting the values of attributes at unsampled sites from measurements made at point locations within the same area or region. The Inverse Distance Weighted (IDW) interpolator assumes that each input point has a local influence that diminishes with distance. It weighs the points closer to the processing cell greater than those farther away. A specified number of points, or optionally all points within a specified radius, can be used to determine the output value for each location. The power parameter in the IDW interpolation controls the significance of the surrounding points upon the interpolated value. A higher power results in less influence from distant points. The low spatial resolution data is linked to an ArcView surface theme at points representing the centre of each cell of the Hadley data set network. The IDW method converts data from these point observations to contiguous fields (a raster surface) by interpolation to derive a grid cell of 0.01^{0} lat. by 0.01^{0} long. The rationale behind this technique is that, on the average, values of the attributes are more likely to be similar at points close together than at those further apart (Daly et al., 2004).

RESULTS AND DISCUSSION

Diurnal temperature range: With respect to the baseline period, diurnal temperature range is highest during the dry season from December to February, when it stands above $10^{o}C$ (Tables 3 and 4). As the rainy season increases in intensity there is a fall from over $9^{o}C$ in March to about $6^{o}C$ in August. Projections indicate that this pattern will be maintained during the 21^{st} Century. However, average diurnal monthly temperature range will be from 0.1 to $1.2^{o}C$ lower towards the end of the century than it was during the baseline years of 1961 to 1990

Table 3. Port Harcourt changes in diurnal temperature ranges from 1961 to 2099 (in ^{0}C).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	10.60	10.30	9.40	8.80	8.20	7.20	6.40	6.20	6.90	7.70	8.60	10.00
2010-2039	10.58	10.33	9.40	8.72	8.14	7.17	6.35	6.14	6.87	7.69	8.59	9.94
2040-2069	10.54	10.29	9.35	8.69	8.15	7.19	6.36	6.14	6.89	7.70	8.55	9.90
2070-2099	10.49	10.29	9.35	8.68	8.16	7.20	6.37	6.16	6.89	7.67	8.51	9.85

Table 4. Lagos changes in diurnal temperature ranges from 1961 to 2099 (in ^{0}C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	10.40	10.20	9.40	8.60	8.10	7.10	6.10	6.10	6.80	7.70	9.10	9.60
2010-2039	10.19	9.97	8.93	8.43	7.99	6.90	6.19	6.11	6.73	8.17	9.38	7.41
2040-2069	10.16	9.95	9.04	8.04	8.53	6.35	5.92	5.89	6.95	7.80	8.66	9.25
2070-2099	9.77	9.60	8.70	8.20	8.21	6.59	5.66	5.69	6.59	7.02	8.12	8.83

Table 5. Port Harcourt: Changes in mean minimum temperature from 1961 to 2099 (in ^{0}C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DE C
1961-1990	21.40	22.80	23.10	23.10	22.80	22.40	22.20	22.30	22.30	22.20	22.30	21.50
2010-2039	22.48	23.78	24.11	24.36	24.26	23.88	23.62	23.73	23.62	23.54	23.65	22.80
2040-2069	23.48	24.74	25.13	25.42	25.22	24.68	24.56	24.56	24.52	24.51	24.70	23.81
2070-2099	24.61	25.82	26.34	26.73	26.40	25.91	25.55	25.67	25.52	25.54	25.81	25.02

Table 6. Lagos: Changes in mean minimum temperature from 1961 to 2099 (in ^{0}C)

	JAN	FEB	MAR	APR	MAY	JU N	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	20.20	21.80	23.10	23.10	22.80	21.40	22.20	22.30	22.30	21.20	21.20	20.40
2010-2039	21.41	22.68	24.11	24.60	24.26	22.23	23.62	23.73	23.62	22.54	22.35	21.60
2040-2069	22.23	23.54	25.13	25.52	25.22	22.45	24.56	24.56	24.52	23.51	23.71	22.45
2070-2099	19.61	24.72	26.34	26.34	26.40	24.78	25.55	25.67	25.52	24.74	24.70	24.14

Projections for Port Harcourt are depicted on Table 2 as an example of what is expected generally in the coastal cities in southern Nigeria.

Mean monthly minimum temperatures: In the tropics, the lowest temperature during each day, which is usually described as minimum temperature is experienced during the night. Mean minimum temperature, as an element in Port Harcourt and Lagos are lowest in January with about 21^O C and highest in March or April at about 23^O C (Tables 5 and 6). There is thus a correspondence between the period of low angle incidence of the solar radiation and the period of low minimum temperature. However, the period of high altitude sun does not correspond to the period of high minimum temperature. According to cli-mate change projections, this general pattern will be maintained as the climate changes during the 21st Cen-tury. However, there are indications in the projections, as it is going to happen worldwide, that as the century pro-gresses, the night will become significantly warmer. For example, in the Port Harcourt example presented in Table 5, January minimum temperature is projected to rise from 21.4 to 24.61^{O}C towards the end of the century. In the same vein April minimum temperature is projected to rise from 23.1 to 26.73^{O}C.

Mean monthly maximum temperatures*:* Maximum tem-peratures are usually recorded during daytime. In Port Harcourt and Lagos (Tables 7 and 8), the highest month-ly maximum temperatures are recorded during dry sea-son, while the lowest monthly maximum temperatures are recorded during the wet months of June, July and Au-gust. In the Port Harcourt example presented in Table 6, the highest monthly maximum temperatures are recorded during the dry month of February, while the lowest monthly maximum temperatures are r ecorded during

Table 7. Port Harcourt: Changes in mean maximum temperatures from 1961 to 2099(in ^{0}C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	32.00	33.10	32.50	31.90	31.00	29.60	28.60	28.50	29.20	29.90	30.90	31.50
2010-2039	33.06	34.11	33.51	33.08	32.40	31.05	29.97	29.87	30.49	31.23	32.24	32.74
2040-2069	34.02	35.30	34.48	34.11	33.51	31.87	30.92	30.82	31.41	32.21	33.25	33.71
2070-2099	35.10	36.11	35.69	35.41	34.56	33.11	31.92	31.83	32.41	33.21	34.32	34.87

Table 8. Lagos: Changes in mean maximum temperatures from 1961 to 2099 (in ^{0}C).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	31.02	32.12	31.15	31.67	31.00	28.26	28.60	28.50	29.20	29.90	29.19	33.10
2010-2039	32.26	33.13	3241	32.08	32.40	29.15	29.97	29.87	30.49	31.23	31.14	32.12
2040-2069	33.82	34.31	33.38	33.11	33.51	29.28	30.92	30.82	31.41	32.21	32.35	32.80
2070-2099	34.21	35.21	34.39	34.31	34.56	31.21	31.92	31.83	32.41	33.21	32.42	33.23

Table 9. Port Harcourt: Changes in mean monthly temperature from 1961 to 2099 (in ^{0}C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	26.70	27.90	27.80	27.50	26.90	26.00	25.40	25.40	25.70	26.00	26.60	26.50
2010-2039	27.91	29.05	29.05	29.14	28.44	27.38	26.73	26.72	26.91	27.27	27.96	27.83
2040-2069	28.75	29.84	29.81	29.75	29.44	28.27	27.73	27.75	27.91	28.30	28.97	28.75
2070-2099	29.86	30.92	31.02	31.06	30.48	29.50	28.73	28.75	28.92	29.32	30.06	29.94

Table 10. Lagos: Changes in Mean Monthly Temperature from 1961 to 2099(in ^{0}C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	25.30	26.23	27.80	27.50	26.90	26.01	25.40	25.40	25.70	25.47	25.26	25.32
2010-2039	26.81	24.15	29.05	29.14	28.44	27.18	26.73	26.72	26.91	26.17	26.46	26.70
2040-2069	27.45	28.74	29.81	29.75	29.44	28.07	27.73	27.75	27.91	27.23	27.67	27.48
2070-2099	28.66	30.01	31.02	31.06	30.48	29.15	28.73	28.75	28.92	29.02	29.96	28.56

the wet month of August. As it is well known, temperature in the coastal cities of Nigeria is determined by what proportion of incident solar radiation penetrates through the atmosphere to be converted to heat at the earth's surface (Ojo and Oni, 2001). Thus, it is the rainy season months with their thick cloud cover that record the lowest monthly maximum temperatures while the dry season months, despite the low angle of the sun, record the highest monthly maximum temperatures. This pattern of seasonal distribution of monthly maximum temperature will be maintained during the century. The highest monthly maximum temperatures will continue to be recorded in February while the lowest monthly maximum temperatures will continue to be recorded in August. The difference in the monthly maximum temperatures between the two months will remain at about 4^{o}C. However, our projections indicate that as the century progresses, the coastal cities in Nigeria will become warmer as day time temperatures rise by about 3 to 4^{o}C.

Mean monthly temperatures: Mean monthly temperature averages the mean monthly minimum and the mean monthly maximum. Its main features, therefore**,** reflect the spatial and temporal characteristics of the monthly minimum and monthly maximum. For the baseline period, mean monthly temperature varies in Port Harcourt and Lagos from a minimum of 25.4^{o}C in August to a maximum of 27.9^{o}C in February. In consonance with the expected global warming, mean monthly temperature is projected to increase steadily to the end of the 21st Century. Increases from 3.1 to 3.5^o are projected for each month (Tables 9 and 10; Figure 2).

Rainfall changes: Rainfall in the coastal cities of Nigeria follows the typical tropical rain forest climate. There is rainfall during each month. However, there is a relatively dry part of the year from December to February when

Table 11. Port Harcourt: Changes in precipitation from 1961 to 2099 {in mm).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	37.20	58.8	133.30	189.00	241.80	285.00	350.30	313.10	357.00	285.20	102.00	37.20
2010-2039	36.27	62.16	124.62	157.20	229.09	310.50	344.10	299.15	356.70	281.48	111.00	34.72
2040-2069	25.42	53.20	124.31	154.80	249.86	339.00	360.22	313.10	357.00	291.71	111.00	30.07
2070-2099	22.32	50.96	113.46	152.10	282.72	348.90	371.07	318.37	365.4	332.94	126.00	19.22

Table 12. Lagos Changes in Precipitation from 1961 to 2099 {in mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-1990	27.90	44.80	99.20	141.00	192.20	255.00	170.50	105.40	174.00	164.30	60.00	31.00
2010-2039	26.97	43.92	98.27	139.80	190.34	254.40	169.26	105.09	174.00	161.82	58.50	31.00
2040-2069	19.22	39.20	91.45	127.56	178.56	174.60	161.20	101.06	162.60	148.80	69.60	31.62
2070-2099	21.39	37.52	86.80	110.40	200.57	315.30	180.11	110.05	187.50	212.35	80.70	30.69

monthly rainfall is low (Tables 11 and 12; Figure 3). Usually in Lagos and Port Harcourt, there is a ‘Little Dry Season’ (Adejuwon and Odekunle, 2006) that occurs from the middle of July to the end of August. There is no indication from the projections that this pattern will change during the 21st century. The projections, however, indicate an increase in rainfall during the rainy season months and a decrease during the dry season months. Thus, there is the probability of the dry season becoming drier while the rainy season becomes wetter. The exam-ple of Port Harcourt presented in Table 11 clearly demon-strates this. While the rainfall of each of the dry season months of December, January, and February is projected to decline respectively by 18, 15 and 10 mm, the respect-tive rainfall of June, July and October will increase by 65, 20 and 47 mm. It should be noted that the “Little Dry Season” is not well represented in the Port Harcourt example.

It appears that changes in precipitation will have greater and wider impact than changes in temperature because the temperature of Nigeria is not significantly differrent from that of most tropical countries (Ojo and Oni, 2001). A combination of temperature and rainfall will have variable effects on coastal cities Nigeria during the 21st century. The impacts will range from marginal to substantive. Precipitation with increased temperature will very likely have serious impact on the social-economic state of people living in the coastal area of Nigeria. Heavy rainfall could induce water logging, frequency of floods and cause serious soil leaching and erosion. Sea level rise could occur with a consequence of submerging all coastal cities of the Niger delta area and a larger part of Lagos (Figure 3 and 4). The parts left un-submerged could face an incessant risk of flooding. These can disrupt communications, damage vital infrastructures and affect urban settlements along the coast. The impacts of climate change will be felt by a wide spectrum of socio-economic variables like human health, transport, energy, industry and other service sectors (Figures 2 and 3). This may result into low economic growth of Nigeria as a whole. The trend in the country is not likely to be different from what obtains globally. The air temperature will increase and the precipitation patterns will change. Meteorological data on surface air temperatures for many locations show evidence of increasing surface air temperature in the country since the 1920s (This Day, 31/12/02). There would be distortions of local climate patterns in the form of changes in seasonal patterns as a result of the influence of global climate change, late arrivals of rains during the rainy seasons as well as unpredictability of cessation of the rainy season. Adaptation to changing climate will be difficult firstly because the rate of global climate change is projected to be more rapid than any to have occurred in the last 10, 000 years; secondly, humans have altered the structure of many of the world’s ecosystems.

For the mitigation of increasing emission and concentration of carbon dioxide leading to global warming, the strategy is joint action by all countries. In order to reverse the effect of global warming, all the countries of the world should combine efforts because global warming is a global issue. Such joint action is what the Kyoto Protocol is about. However, adaptation, which is anticipating and forestalling the negative consequences of climate change, is a problem, which has to be addressed regionnally, nationally and locally. This is because the impacts of climate change are projected to differ substantially from one major region to the other. In some areas, the impacts will be negative while in others, they will be positive. Specifically in the developing world of the Tropics, the impacts are projected to be negative. In some areas, there will be increases in the frequencies of extreme weather events such as droughts and floods. Whatever successes attained on the implementation of the Kyoto Protocol, the climate will continue to change, and there is therefore the need to take steps to adapt to

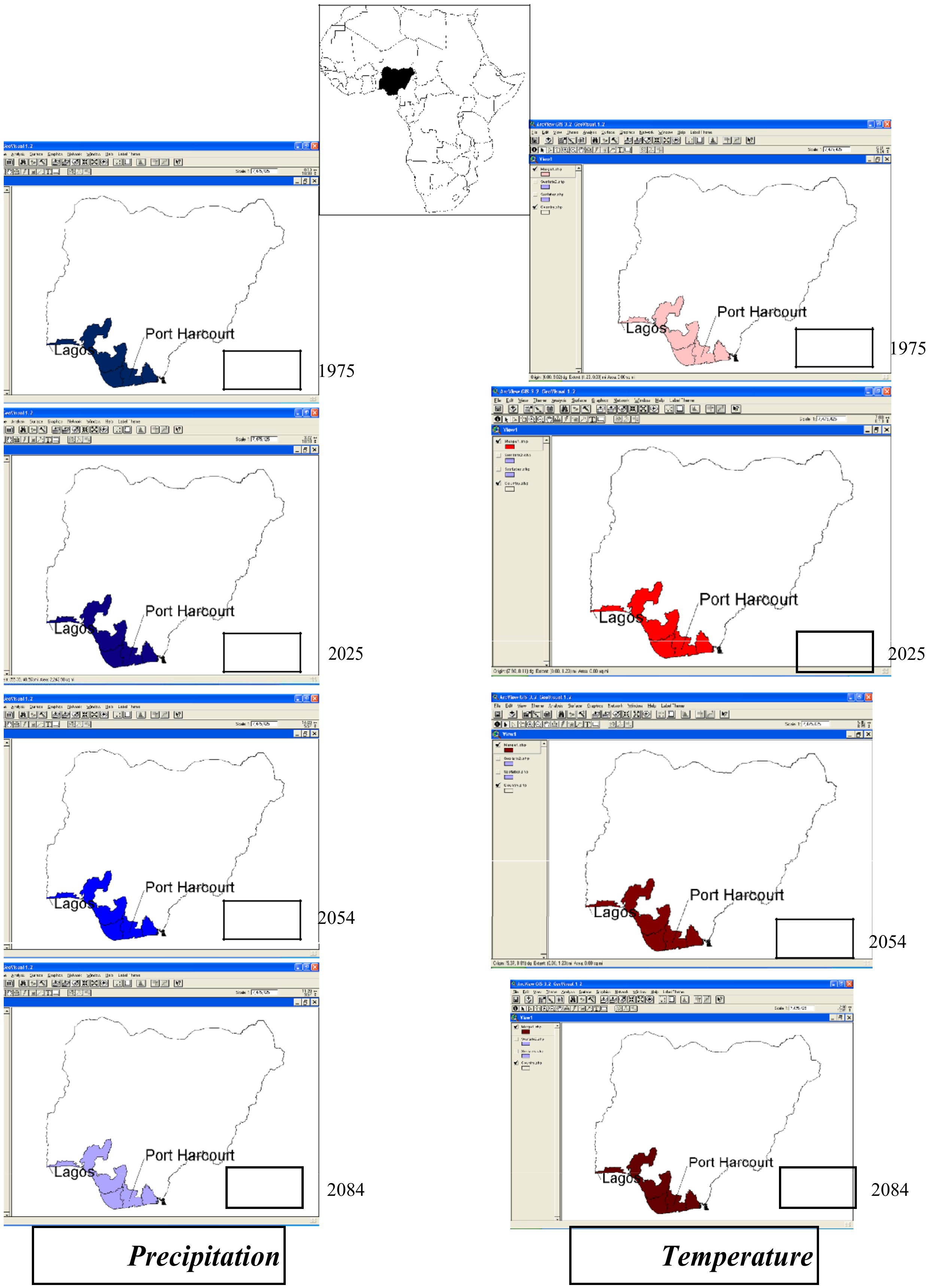

Figure 2. Changes in precipitation (in mm) and mean temperature from 1961 to 2099

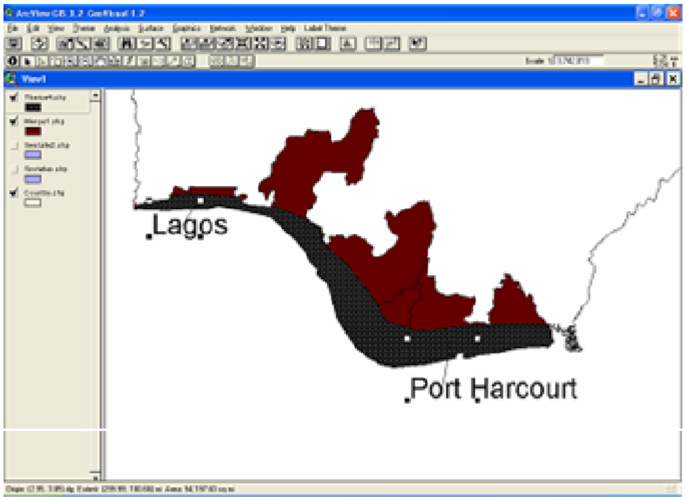

Figure 3. Danger zone during 1m rise in sea level.

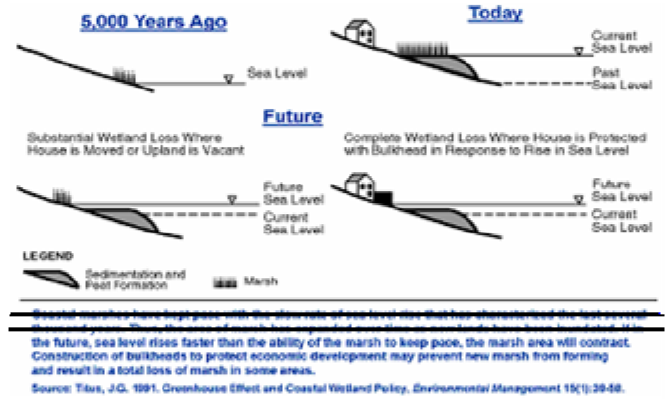

Figure 4. Evolution of a march as sea level raises.

the consequences of climate change.

Thus, before a developing country such as Nigeria can devise a strategy for combating the negative consequences of climate change in the 21st century, it must be able to map out the course of climate change within its borders as the century unfolds. Therefore, the first step in attempting to adapt to climate change is to know precisely its direction and magnitude especially with regards to such important environmental factors as temperature and rainfall. The current study is designed as part of such a first step. Up till now, there is not a single study that policy makers can use for formulating strategies for adapting to climate change. This study, in a modest way, will help policy makers in identifying the climate scenario to adapt to.

Currently action to stem the emission of greenhouse gases as encapsulated in the Kyoto protocol is restricted to the developed countries or Annex 1 countries. This requires the so- called Annex 1 countries to cut their greenhouse gas emissions by 5% compared to 1990 levels by the period between 2008 and 2012. Nigeria which belongs to the non-Annex 1 countries is thus not required to take any abatement action now, rather the impact of global warming on Nigeria for which we are concerned in this paper stems from the threat to Nigeria's economy posed by the response measures being adopted by the international community. Nigeria stands to suffer income losses when the global community begins to substitute renewable energy alternatives for fossil fuels. Given the exclusive reliance on fossil fuels for foreign exchange and the predominant focus on further expansion of this sector of the economy by the Nigerian government, the impact of the global shift away from fossil fuels is bound to cripple the Nigerian economy.

Already developed countries are channeling huge resources into research and development of alternative and renewable energy sources that would enable the transition away from fossil fuels, signaling their resolve to transit away from the fossil fuel economy. Likewise, government policies and regulations are providing incentives to the private sector to expedite this shift. Despite this huge implication of climate change response measures for Nigerian economy, it is appalling that there is no visible demonstration of the preparedness of the government to tackle this issue. The greatest cause for concern is that the blueprint for Nigeria development Vision 2010 fails to give a mere acknowledgement of the importance of climate change to Nigerian economy, let alone stipulate the development strategy with which to tackle it. But the observations above show that the danger signals are clear.

Conclusion

This study was designed to present a clearer understanding of what type of climate that coastal cities of Nigeria are to experience during the 21st century going by the current trends. The results indicate that the average surface temperature in coastal cities of Nigeria will increase by 1.1 – 2.8^{o}C by the year 2099. This change may lead to a number of potentially serious consequences in the coastal cities in Nigeria. There may be an increase in mortality rates as a result of heat stress and in potential transmission of many infectious diseases (Hulme et al., 2002). Moreover, sea level rise would increase the number of people whose lives and properties may be at risk from serious flooding or permanent inundation. The precipitation variability with increased temperature will have serious impacts on the social-economic state of the people living in the coastal cities of Nigeria. The projected impact of this on environmental stability and life in the coastal urban settlements of Nigeria is better imagined than experienced. The above analysis clearly suggest that it will not only be economically beneficial for Nigeria to craft a climate change-response development strategy, but that factoring climate change abatement into the overall economic development plan is also crucial for its own self preservation. Therefore, there may be a need to have a coastal zone management plan to address the possible coastal zone problems indicated in this study.

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