Analysis of regional disparities in the impacts of anthropogenic factors on the environment in Africa

by

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Abstract.

The relationship between population and environment has been a contentious one. With the increasing concerns raised by climate change, African countries are faced with the onerous task of achieving MDGs through sustainable development. This work analyses the magnitude of the impacts of anthropogenic factors on the environment of these countries using the STIRPAT model. Findings of the study reveal regional disparities in the magnitudes of environmental impacts. The disparities in the estimated environmental impacts of these countries are attributable to differences in the values of their anthropogenic driving factors. Based on the magnitude of environmental impacts estimated from the STIRPAT model, countries are broadly grouped into areas with low, medium and high environmental impacts. Consequently, this work suggests the application of preventive and intervening measures if the quest of the region to achieve sustainable development and meet up with the targets of the millennium development goals could be realized.

Keywords: *Africa; Anthropogenic factors; Environment; Impact; STIRPAT model; Population.*

Introduction

It has been argued that at any level of development, any increase in population has a corresponding effect in energy use, resource consumption and impact on the environment (Nwafor and Madu, 2002). Studies by York et al(2001), Rosa and York(2002), York, Rosa, and Dietz 2003; Rosa, York, and Dietz 2004;Dietz (2007), Madu (2009a,b),and Ajaero (2009) have identified different anthropogenic factors as the primary drivers of environmental impact. They have also shown that the magnitude of anthropogenic -induced impact on the environment results from the interplay of various variables such as population size, per capita resource use, affluence, level of technological development, social organization among others. Most

importantly, however, and central to this study is the fact that the population of the developing countries of Africa are more often those most vulnerable to the consequences of environmental impact. The reason for their vulnerability stems from the dependence of majority of the population on primary economic activities such as fishing, agriculture, forestry, and hunting as their means of livelihoods (Ajaero, 2009). With the often unsustainable use of these natural resources, the environment usually suffers various types and degrees of degradation. Consequently, variations exist across countries in the region with regard to impacts of anthropogenic factors on the environment albeit in hitherto undefined magnitudes. It is, therefore, very important that the source(s) of impacts on the environment be identified, quantified and explained. This forms the crux of this work. It is only with such information that policy makers, development agencies, project proponents, environmental authorities, governments and other stakeholders could initiate appropriate policies and actions aimed at ensuring sustainable development and achievement of the Millennium Development Goals in the continent .

Methods

The data used for this research were obtained from two sources: The population size data, the carbon dioxide emission values, the literacy rate data and information on Gross National Income (GNI) per capita were obtained from "Gender, Poverty and Environmental Indicators on Africa" published by the Africa Development Bank in 2007 while the data on percentage urban population was obtained from "Rural and Urban Areas" published by the United Nations Department of Economic and Social Affairs (Population Division) in 2007. The study covers forty eight African countries for which there exist complete sets of data for the required analysis. The impact of anthropogenic factors on the environment in Africa is estimated with the use of

Weighted Least Squares Regression using natural log(ln) of values of carbon dioxide emission as the dependent variable while the independent variables used are the natural log values of population size, literacy rate, percentage of urban population and /wealth (measured by GNI per capita). Consequently, the magnitude of environmental impact is estimated using the IPAT model of Ehrlich and Holdren (1972) which is of the form:

$I = PAT$……(1)

In this model, *I* is used to represent estimated impact on the environment; *P* represents population size; *A* stands for affluence while *T* denotes level of technology. The IPAT model is often used by researchers when they wish to delineate the impact-driving factors since it allows for separate analysis of the driving factors of environmental impact (see, for example, Chertow, 2001; Shi, 2002; York et al 2003, 2005;Gans and Jost, 2005; Lantz and Fang,2005). However, for this study, a modified version of this model called Stochastic Regression of Impacts on Population, and Technology (STIRPAT) is used since unlike the original IPAT model, the STIRPAT model includes an error term which according to Javonovich (2007), allows for regression analysis. The STIRPAT model subsequently links the limited IPAT model to suit contemporary social science theory and methods (Dietz, Rosa and York, 2007).

The expanded STIRPAT model used for this work is of the form:

$\ln (I) = a + b (\ln (P)) + c (\ln (A)) + d (\ln(U)) + e (\ln(L)) + f$…… .....(2)

Where I is the estimation of impact on the environment represented by carbon dioxide emission, P is population size, A is level of affluence represented by GNI/capita, U represents the

percentage of the population living in urban areas, L stands for literacy rate while T is included in the error term *(f)* . The inclusion of T in the error term *f* is a consequence of the fact that an universal, appropriate, and generally accepted measure or indicator of technology is disputed and thus lacking. Our T as used in this work comprises other non-measurable variables such as culture, physical infrastructure, as well as other social and economic characteristics of the region which could not be appropriately explained by measurable anthropogenic indices. The *f* which is added to the effects of the anthropogenic factors is calculated as the antilog of the residual of our regression analysis.

In equation (2), the constant *a* scales the equation, while *b, c, d* and *e* are the coefficients of our independent variables obtained from the regression analysis. For ease of estimation and in order to eliminate the problem of heteroscedasticity, all the input variables are converted to natural logarithms (ln) (see table 1 below). These coefficients are, therefore, used to get the Ecological Elasticity (EE) which represents the net effect of our input variables. York et al (2003) defines Ecological Elasticity as the proportionate change in environmental impact which will result from a change in the driving (in this study, anthropogenic) factors.

Table 1: Anthropogenic variables used in the analysis (in natural log (ln) values)

Countries	***CO^2 Emission***	***Population Size***	***% Urban Population***	***Literacy Rate***	***GNI/Capita***
Algeria	18.31	17.32	4.10	3.41	7.91
Angola	15.67	16.61	3.64	3.48	7.21
Benin	14.30	15.98	3.85	4.18	6.23
Botswana	15.16	14.38	3.97	2.93	8.55
Burkina Faso	13.85	16.43	2.94	4.26	5.99
Burundi	12.40	15.87	2.40	3.71	4.61
Cameroon	15.69	16.63	3.98	3.47	6.92
Cape Verde	11.84	13.16	4.07	3.06	7.15
C.A.R	12.51	15.23	3.79	3.94	5.86
Chad	11.74	16.12	3.27	4.31	5.99
Comoros	11.30	13.62	3.61	3.76	6.46

Congo	14.41	15.23	4.00	2.60	6.86
Congo (DRC)	14.82	17.90	3.51	3.49	4.79
Cote D'Ivoire	16.17	16.73	3.84	3.94	6.73
Djibouti	12.86	13.60	4.44	3.36	6.93
Egypt	18.77	18.14	3.75	3.35	7.13
Eritrea	13.32	15.33	3.07	3.65	5.39
Ethiopia	15.53	18.19	2.80	3.98	5.08
Gambia	12.51	14.26	3.27	4.03	5.67
Ghana	15.59	16.93	3.85	3.74	6.11
Guinea	14.07	16.08	3.62	4.26	5.91
Guinea Bissau	12.48	14.31	3.60	3.99	5.19
Kenya	16.05	17.37	3.75	3.27	5.80
Liberia	12.90	15.03	3.88	3.69	4.87
Libya	17.86	15.60	4.47	2.73	8.62
Madagascar	14.63	16.77	3.31	3.38	5.67
Malawi	13.55	16.39	2.87	3.65	5.08
Mali	13.23	16.45	3.54	4.39	5.94
Mauritania	14.94	14.97	4.18	3.89	6.33
Mauritius	14.88	14.04	3.78	2.75	8.57
Morocco	17.41	17.28	4.08	3.87	7.46
Mozambique	13.98	16.82	3.66	3.88	5.74
Namibia	14.42	14.53	3.53	2.71	8.00
Niger	13.98	16.49	3.17	4.27	5.48
Nigeria	17.40	18.72	3.89	3.34	6.33
Rwanda	13.26	16.04	3.16	3.56	5.44
Sao Tome/Principe.	11.39	11.98	3.64	2.72	5.97
Senegal	15.25	16.30	3.95	4.11	6.35
Sierra Leone	13.24	15.55	3.71	4.17	5.39
South Africa	19.61	17.68	4.07	2.87	8.51
Sudan	15.47	17.43	3.73	3.67	6.46
Swaziland	12.85	13.84	3.18	3.02	7.73
Tanzania	15.28	17.48	3.65	3.42	5.83
Togo	14.40	15.66	3.61	3.85	5.86
Tunisia	16.73	16.14	4.12	3.25	7.97
Uganda	14.24	17.21	2.53	3.50	5.64
Zambia	14.42	16.29	3.61	3.47	5.25
Zimbabwe	16.51	16.39	3.60	2.03	5.83

Results and Discussion

The regression analysis yielded the results contained in Table 2.

Table 2: Results from the Regression analysis used in estimation of environmental impact

Input variables	***Regression co-efficient***	***t -value***	***P-value***	***R^2***	***F***	***Constant***
Population Size	1.083	15.431	0.000			
% Urban Population	-0.819	3.485	0.000			
Literacy Rate	1.083	-3.731	0.000			
GNI/Capita	0.953	5.431	0.000			
				0.889		
					85.674	
						-7.601

The constant of the equation *a* is -7.601, the coefficient of determination is 0.889(meaning that the regression analysis determines and or explains 89% of the environmental impact) while the F-value stands at 85.674. The coefficients of the independent anthropogenic factors are as follows; 1.083 for population size, 0.953 for affluence, -0.819 for the proportion of the urban population, and 0.687 for literacy rate. All the factors are also significant at 0.05 level of confidence. From the above figures, the interpretations of our ecological elasticity mean that:

- A unit change in population size translates into 1.083 changes in environmental impact.
- A unit change in affluence level results in 0.953 change in environmental impact.
- A unit change in the proportion of the urban population results in -0.819 change in environmental impact.
- A unit change in literacy rate results in 0.687 change in environmental impact.

It therefore appears that there exist positive correlations between environmental stress on one hand and each of population size, affluence and literacy rate on the other. Conversely, it appears

that there exists a negative correlation between environmental impact in Africa and the proportion of the urban population. From the foregoing, it seems that population size is the most important driving factor of environmental impact in Africa, followed by affluence and literacy rate. It also seems that the more urbanized the continent becomes, the less the magnitude of environmental impact. This may be due to the fact that most of the populations engage in primary economic activity in the rural areas. Consequently, the more they move to the urban centre, the less the demand they make on natural resources, as they engage more in secondary, tertiary and quaternary economic sectors.

Using the results of the regression analysis (Table 2 above) , and with the addition of technological impact which was calculated as the antilog of the residual of our regression analysis to be 3.143,the estimated anthropogenic- induced environmental impacts for countries in Africa were derived from the following equation.

$$\ln(I) = -7.601 + 1.083(\ln(P)) + 0.953(\ln(A)) - 0.819(\ln(U)) + 0.687(\ln(L)) + 3.143 \ldots\ldots\ldots\ldots (3)$$

Table 3 shows the magnitude of environmental impact for the different countries in Africa. The values of the environmental impact range from 13. 093 in Sao Tome and Principe to 21.438 in South Africa.

Table 3: Magnitude of estimated environmental impact in Africa.

Country	Environmental Impact
Algeria	20.823
Angola	19.811
Benin	18.504
Botswana	18.025
Burkina Faso	19.563

Burundi	17.706
Cameroon	19.271
Cape Verde	15.377
Central Africa Republic(CA.R)	17.223
Chad	18.991
Comoros	16.075
Congo	17.084
Congo (DRC)	19.016
Cote D'Ivoire	19.636
Djibouti	15.547
Egypt	21.213
Eritrea	17.274
Ethiopia	20.524
Gambia	16.480
Ghana	19.116
Guinea	18.551
Guinea Bissau	15.779
Kenya	19.056
Liberia	15.815
Libya	18.866
Madagascar	18.719
Malawi	18.291
Mali	19.135
Mauritania	17.036
Mauritius	17.708
Morocco	20.683
Mozambique	18.680
Namibia	17.873
Niger	18.960
Nigeria	20.957
Rwanda	17.955
Sao Tome and Principe	13.093
Senegal	18.835
Sierra Leone	17.346
South Africa	21.438
Sudan	20.041
Swaziland	17.368
Tanzania	19.389

Togo	17.775
Tunisia	19.476
Uganda	19.888
Zambia	17.615
Zimbabwe	17.295

The countries in Africa are further classified according to the magnitude of the environmental impact they experience into ;

1. Countries that experience relatively high environmental impact (they have values of more than 19.500). Countries under this category are Algeria, Angola, Burkina Faso, Cote D'Ivoire, Egypt, Ethiopia, Morocco, Nigeria, South Africa, Sudan, and Uganda. Altogether they represent 23% of all the countries used in this study
2. Countries that experience relatively medium environmental impact (they have values of between 15.500- 19.499) They are Benin Republic, Botswana, Burundi, Cameroon, Central Africa Republic, Chad, Comoros, Congo, Congo(DRC), Djibouti, Eritrea, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger Republic, Rwanda, Senegal, Sierra Leone, Swaziland, Tanzania, Togo, Tunisia, Zambia, and Zimbabwe. This category accounts for 73% of all the countries used in this study.
3. Countries that experience relatively low environmental impact (they have values between 13.093-15.499). Only Sao Tome and Principe, and Cape Verde are in this category and they constitute only 4% of all the countries used for the study.

Figures 1-5 below portray graphical representation of environmental impact felt in the constituent countries of the major regional divisions of the continents. These figures easily

allows for comparative appreciation of the magnitude of environmental impact estimated for these countrie

Figure 1: Distribution of environmental impact in Central Africa

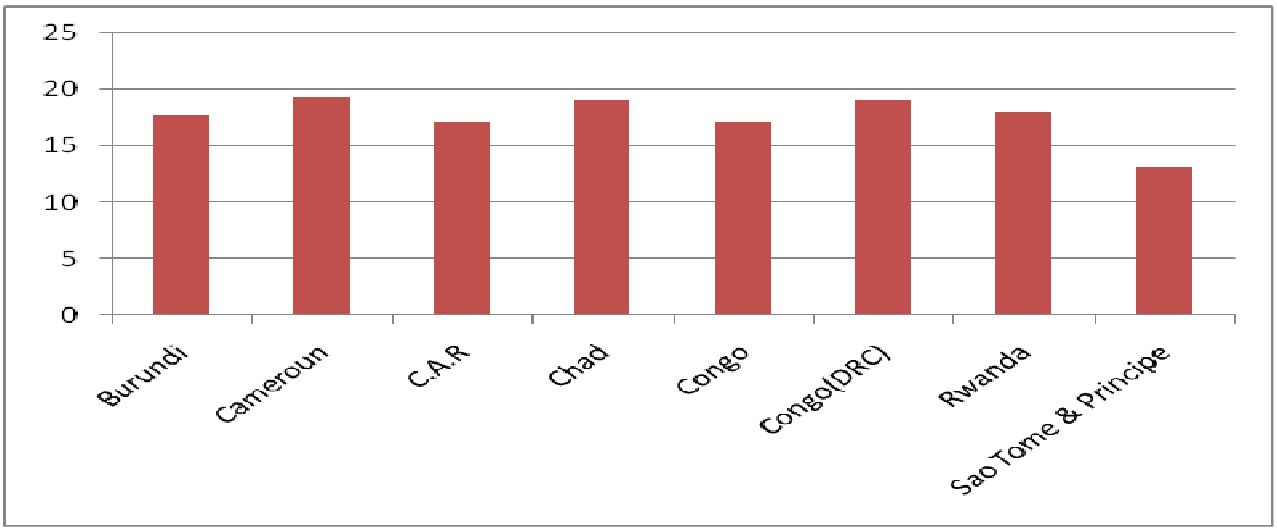
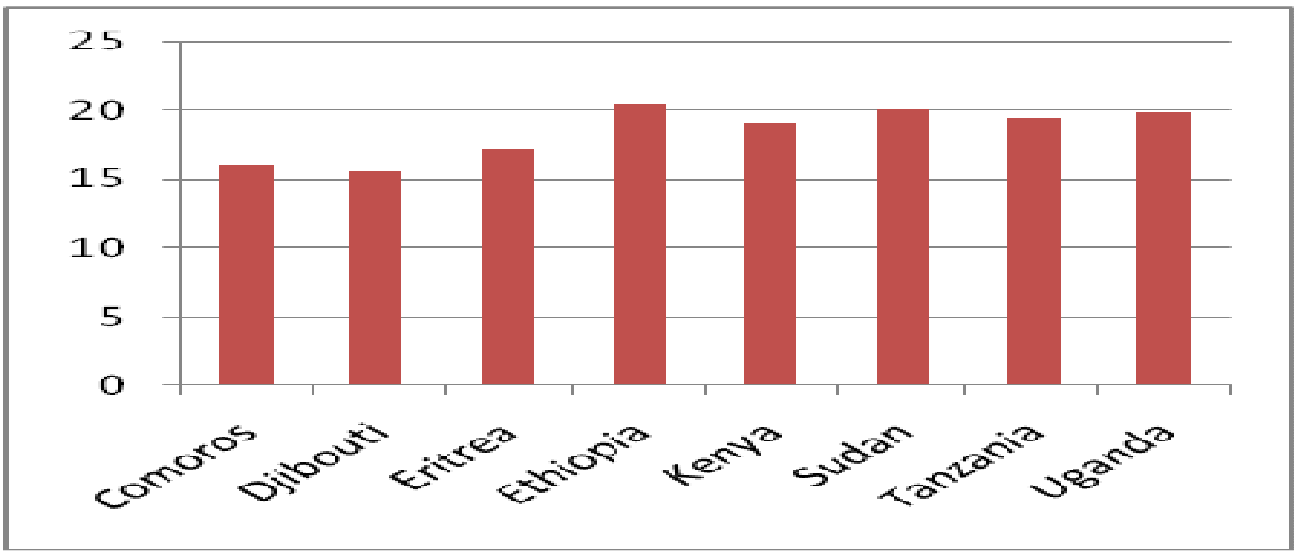


Figure 1 shows that Cameroon experience the highest environmental impact of 19.271 and is closely followed by Congo(DRC) while Sao Tome and Principe experience the least impact of 13.093 in the sub-region and in the entire continent.

Figure 2: Distribution of environmental impact in East Africa



Our figure 2 identifies Ethiopia as the country within the Eastern Africa sub-region that has the highest estimate of environmental impact of 20.524. It is closely followed in magnitude of impact by Sudan and Uganda. On the other hand, Djibouti with an estimate of 15.547 experiences the least environmental impact in this sub-region.

The estimates of environmental impacts in figure 3 shows that Egypt experience the highest impact in the sub-region with an estimate of 21.213 while Libya with a value of 18.866 manifest the least environmental impact in the sub-region.

Figure 3: Distribution of environmental impact in North Africa

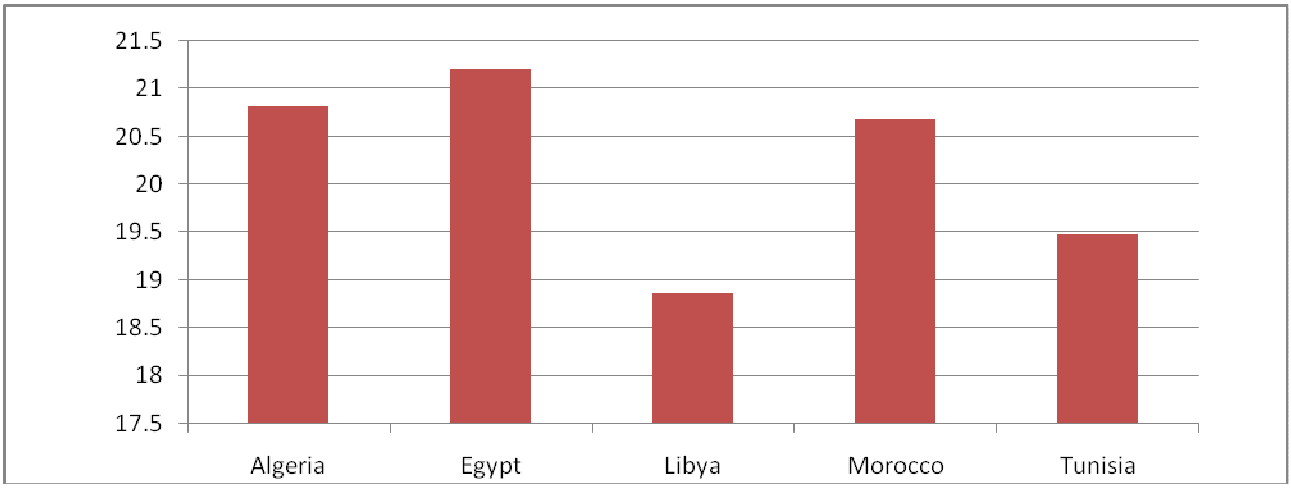
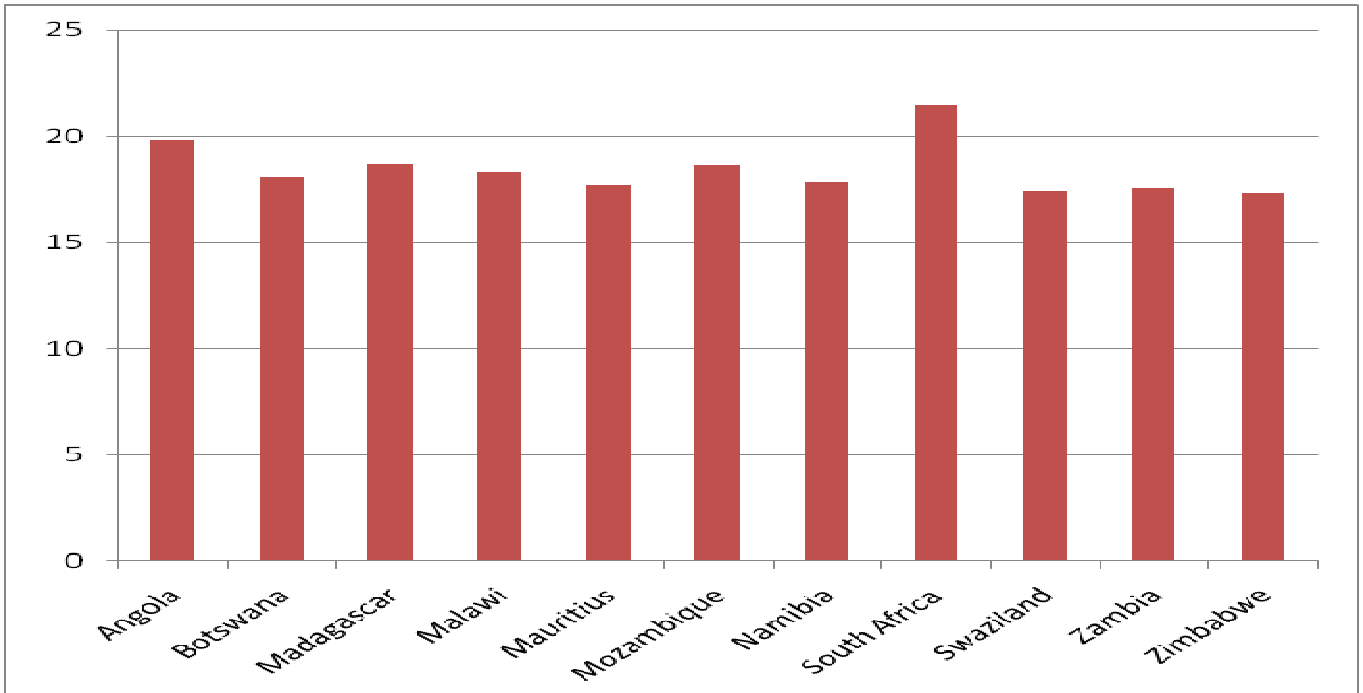
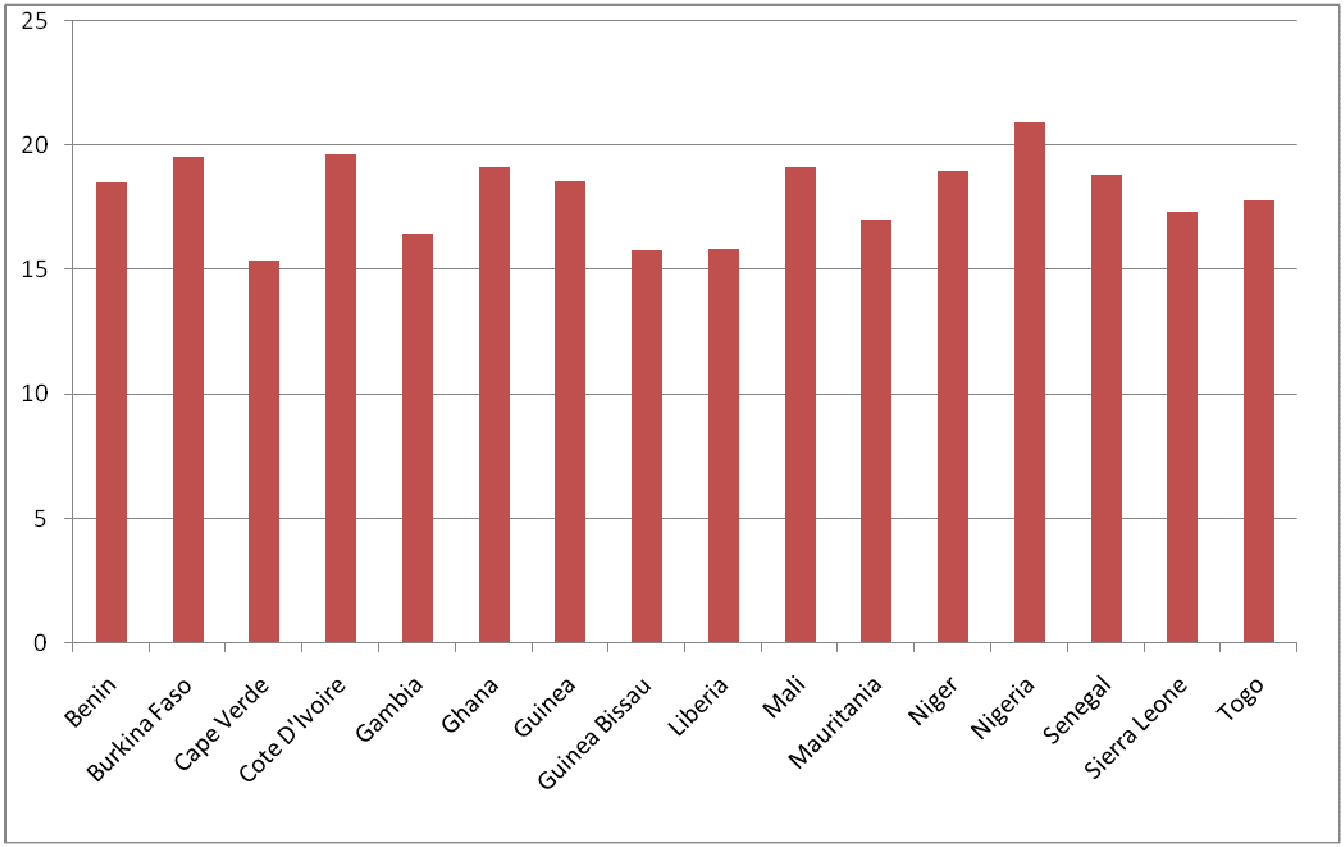


Figure 4: Distribution of environmental impact in Southern Africa.



From figure 4 above, South Africa has the highest estimate of environmental impact in the Southern Africa sub-region and also in the entire continent with a value of 21.436. Angola is the next country following South Africa in environmental impact with a value of 19.811. These figures represent the widest gap in environmental impact between the first two countries that experience highest impact in all the sub-regions in Africa. With a value of 17.295, Zimbabwe is the country that experiences the least environmental impact in the sub-region.

Figure 5: Distribution of environmental impact in West Africa.



West Africa has the Nigeria as the country with the highest estimate of environmental impact. It is also the only country in the sub-region with an impact value of above 20.00. Figure 5 also

shows that Nigeria is followed by four countries namely, Cote D'Ivoire, Burkina Faso, Mali and Ghana which have estimated impacts of more than 19.00. On the other hand Cape Verde with an impact value of 15.377 experiences the least environmental impact in the sub-region.

Subsequent upon the grouping of the countries under different impact categories and the graphical grouping of the countries into sub-regions, table 4 shows the summary of the regional disparities in the impact of anthropogenic factors on the environment of Africa. The table shows that Central Africa has no country with relatively high environmental impact while Eastern, Southern and Northern Africa Sub-regions have no country with an estimated relatively low environmental impact. Furthermore, Central Africa has the highest range value of 6.18 between the country with the highest impact and the country with the lowest impact. Conversely, Northern Africa, Southern Africa and Eastern Africa have the lowest range values of impact between the countries with the highest impact and those with the lowest impact. On the whole, Northern Africa has the greatest proportion of countries that experience relatively high environmental impact and is followed by Eastern Africa.

Table 4: Summary of regional environmental impact.

Region	High impact	Medium Impact	Low Impact	Range of impact
Central Africa	0.00	87.50	12.50	6.18
Eastern Africa	37.50	62.50	0.00	4.98
Northern Africa	60.00	40.00	0.00	2.35
Southern Africa	18.18	81.82	0.00	4.14
Western Africa	18.75	75.00	6.25	5.58

Summary of findings and recommendations.

This study carried out an empirical analysis of the impact of anthropogenic factors on the environment in Africa using the STIPAT model. The regression analysis explains 89% of the impact of anthropogenic factors on the environment. The factors of population size, affluence, and literacy rate have positive regression coefficients of 1.083, 0.953 and 0.687 respectively while that of the proportion of urban population showed negative coefficient of 0.819. However, the regression coefficients of all the anthropogenic factors are significant at 0.05 level of confidence .The results of the regression analysis suggests therefore that population size is the major anthropogenic driving factor of environmental impact in Africa followed by affluence. Our results also showed that proportion of population living in urban area seems to increase as the impact on the environment decreases. Another finding of this study is that the magnitude of impact on the environment of Africa range from 13.093 in Sao Tome to 21.436 in South Africa. Furthermore, 23% of the countries in Africa experience relatively high impact, 73% experience relatively medium impact while 4% of the countries experience relatively low impact.

The work also produced graphical distribution of the impact of anthropogenic factors on the environment of the five sub-regions of Africa. The values ranges of the environmental impact between the regions range from 6.18 in Central Africa to 2.35 in Northern Africa. Finally, Northern Africa has the highest proportion of countries that experience relatively high impact while no country in Central Africa experience relatively high environmental impact. Conversely, Eastern, Northern and Southern Africa sub-regions have no country that experience relatively low impact of anthropogenic factors on their environments.

From the above summary of findings, the following recommendations are suggested for sustainable management of the environment in the continent.

1. Integration of socioeconomic development plans with environmental management practices.
2. Initiation of appropriate sustainable population policies with regards to fertility, mortality and migration issues
3. Education of the populace on the linkage between anthropogenic factors /activities and environmental impact.

In conclusion, as the different countries apply intervention measures as outlined above, efforts should be made to tie such measure(s) to the major driving factors of environmental impact in that country.

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