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Modelling Ecological Degradation: The Role of Urbanization, Natural Resource Extraction, Renewable Energy Use and Trade Openness in Sub-Saharan Africa

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Abstract

The paper assessed the ecological degradation in relation to urbanization, natural resources, renewable energy use and trade openness in Sub-Sahara African countries using STIRPAT (stochastic impacts by regression on population, affluence, and technology) analytical framework for modelling environmental impacts and data mostly generated from World Development Index (WDI). Using about 736 panel observations and 32 selected Sub-Sahara African countries, the estimate showed that the mean and distributional effect of urbanization, natural resource extraction and renewable energy use have significant effect on ecological degradation, while trade openness has positive but insignificant effect on ecological footprints. Also, the Shapiro-Francia W' test for normality examination showed that all the variables under investigation were statistically significant. Therefore, given the quick investigative outcome arising from the paper, it is suggested that policies on environmental clean -up, controlled urbanization, apposite renewable energy use and trade supervision should be adopted in order to limit ecological footprints in Sub-Sahara African countries.

Background to the Study

In most African countries, ecological degradation constitutes a great mutilation to the natural environment, which is deleterious to human existence. It causes a deterioration of the environment through exhaustion of natural resources and the ecosystem. Some studies have documented that adequate management of environmental hazard leads to economic growth (e.g. Emmanuel and Desmond, 2023; Joshua, Bekun, Sarkodie, 2020; Liu, Ren, Cheng and Wang, 2020; and Kongbuamai, Bui, Yousaf and Liu, 2020), while others maintained that ecological footprint triggers low economic activities at the long run (e.g. Ahmed, Asghar, Malik, and Nawaz, 2020b; and Meo, Nathaniel, Khan, Nisar and Fatima, 2020b). However, in an attempt to urbanize some regions in Africa, natural resources are eroded especially in extractive and renewable energy sectors. Under this scenario, economic growth is grossly affected especially when the economy is closed, where exports and imports of commodities are restricted. Apart from this, it has been documented that there is a very high degradation of environmental harzard in Sub-Sahara Africa, with relatively high ecological deficit territory (Global Footprint Network, 2019).

However, any nation can be regarded as ecological deficit when her bio-capacity is less than its ecological footprint (WWF, 2018 and Nathaniel, 2021). In figures 1 and 2 below explore the inclination of the ecological footprints in relation to urbanization, natural resource extraction, renewable energy use and trade openness of the selected 32 Sub-Sahara of African countries.

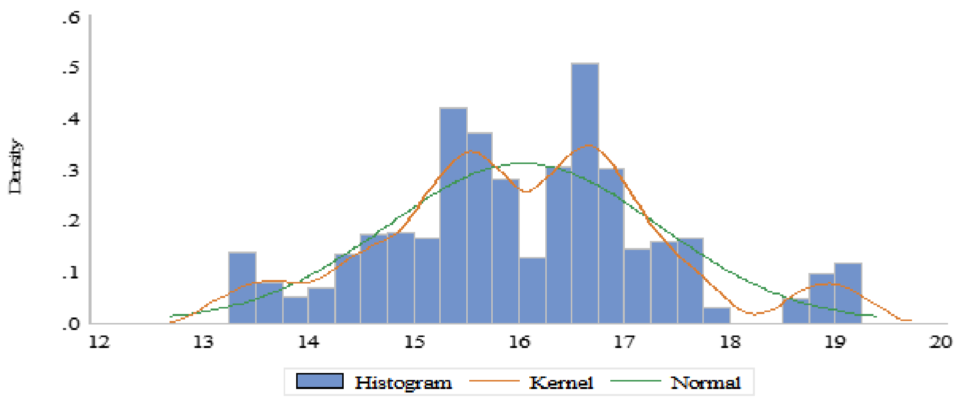
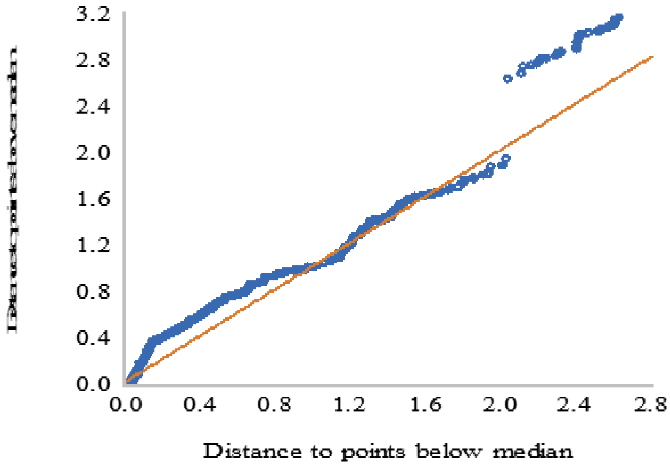


Figure 1: Trend analysis

Figure 2: Trend of EF



Extant Literature

Following the multi ferrous nature of the topic under investigation, not a few literatures have been documented on the area of ecological footprints. Drawing attention from the work of Emmanuel and Desmond (2023), where the Authors utilized Generalized Method of Moment (GMM) estimation and causality test, it was found that the overall effect of trade reduces environmental pollution by about 0.1 percent in the short run and 0.79 percent in long-run. In their work on international trade and environmental pollution in Sub-Sahara Africa, it was concluded that environmental pollution affects international trade adversely. Bright, Yifeng, Emmanuel, Gibbson and Dan (2022), found that the demand for renewable energy has been positive to the African economies in terms of environmental health, after investigating on the demand for renewable energy, financial reform and environmental hazard in West Africa. The Authors' conclusion points to the fact that renewable energy and environmental health generate a speedy outcome of West African countries. Solomon, Festus and Alimshan (2021), employed DOLS and FMOL method of estimation and documented among other things that the variables under focus (renewable energy, natural resource and human capital) had a positive relationship with environmental footprint.

Alex, Samuel and Elliot (2019), using fixed and random effect, documented that renewable energy and FDI exerted positive effect on carbon emission whereas trade openness had negative effect on the environmental footprint. While Nathaniel (2020) found a significant and positive effect of environmental degradation on ecological footprint, which agrees with those of Bright, Yifeng, Emmanuel, Gibbon and Dan (2023), Ahmed, Zafar and Ali (2020a) found a negative impact of environmental hazard on ecological footprint within the countries under review. Also, as documented by Hassan et al. (2019a) on the effect of natural resource and growth on ecological footprint, the Authors found that natural resources have negative effect on ecological footprints in Pakistan. This finding coincides with those of Zafar et.al. (2019) and Ahmed and Wang

(2019), who observed that human capital development affects ecological footprints adversely. Thus, the extant literature as explored here, none of them seem to have captured the manifold variables against ecological footprints, which incorporate the methodology of STIRPAT. This is indeed the gap, which this paper intends to fill the gap.

Methodological Issues

Model Specification

This paper relies heavily on the STIRPAT (stochastic impacts by regression on population, affluence, and technology) analytical framework for modelling environmental impacts (see Dietz and Rosa 1994), therefore, we specify as follows:

$$ECFP_{i,t} = \beta_0 + \beta_1 URB_{i,t} + \beta_2 PCI_{i,t} + \beta_3 PCIsq_{i,t} + \beta_4 NR_{i,t} + \beta_5 Ren_{i,t} + \beta_6 Trad_{i,t} + \varepsilon_{i,t}$$

Where;

ECFP is the ecological footprint, URB is the urbanization, PCI is economic growth, NR denotes natural resources, REN implies renewable energy, TRAD represents trade openness. To avoid the issue of heterosdasticity bias and improve the validity of the estimate, the log-linear specification is as follows:

$$LgECFP_{i,t} = \beta_0 + \beta_1 LgURB_{i,t} + \beta_2 LgPCI_{i,t} + \beta_3 LgPCIsq_{i,t} + \beta_4 LgNR_{i,t} + \beta_5 LgRen_{i,t} + \beta_6 LgTrad_{i,t} + \varepsilon_{i,t} \quad (2)$$

All series are expected to be non-negative excepting the trade openness.

Sources of Data and Description of the Variables

Table 1: Definition of Variables and Sources of Data

Variables	Symbols	Definitions and measurements	Data Sources
Ecological footprint	ECFP	Ecological footprint (global hectares, gha)	2021 National Footprint and Biocapacity Accounts, Global Footprint Network
Urbanization	URB	Urban population (% of total population)	World development Indicators (WDI) and World Bank
Economic growth	PCI	GDP per capita (constant 2015 US$)	WDI and World Bank
Natural resources	NR	Total natural resources rents (% of GDP)	WDI and World Bank
Renewable Energy	Ren,	Renewable energy consumption (% of total final energy consumption)	WDI and World Bank
Trade Openness	Trad.	Trade as a percentage of GDP	WDI and World Bank

Source: Authors' Compilation, 2023

Results and Discussion

The result of the descriptive statistics is as contained in table 2 below, the Jarque-Bera statistic rejected the null hypothesis of normal distribution for the values of ECFP, PCI, URB, NR, REN and TRAD variables. (see p= 0.00). However, the kurtosis of all the series were normally distributed while asymmetry of the series were positively skewed, indicating that the series were statistically significant.

Table 2: Descriptive Statistics

	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Obs.
ECFP	22131007	1.98E+08	610780.7	39651331	3.28453	13.0821	4440.576	0.000	736
PCI	1820.151	9966.770	219.193	1974.164	1.934	6.055	744.936	0.000	736
URB	38.570	88.976	7.211	15.632	0.575	3.517	48.813	0.000	736
NR	10.161	58.650	0.001	9.914	1.966	7.594	1121.559	0.000	736
Ren	67.491	98.139	9.422	23.528	-0.888	2.631	100.837	0.000	736
Trad	66.069	175.798	20.723	28.460	0.949	3.427	115.981	0.000	736

Source: Stata 17.0

Table 3: Pesaran (2004, 2015) Cross-section dependence test

Variable	CD-test	p-value	average joint	mean ρ	mean abs(ρ)
lnECFP	77.519***	0.000	23.00	0.73	0.73
lnURB	75.895***	0.000	23.00	0.71	0.85
lnPCI	37.584***	0.000	23.00	0.35	0.60
lnPCIsq	37.72***	0.000	23.00	0.35	0.60
lnNR	15.644***	0.000	23.00	0.15	0.35
lnRen	30.268***	0.000	23.00	0.28	0.49
lnTrad	6.932***	0.000	23.00	0.06	0.37

Note: A*** p<0.01, ** p<0.05, * p<0.1;

Source: Stata 17.0

Table 4: Shapiro-Francia W' test for Normality

Variables	Observations	W'	V'	Z	Prob>z
InECFP	736	0.98041	9.996	4.951***	0.0000
InURB	736	0.96051	20.149	6.316***	0.0000
InPCI	736	0.94957	25.730	6.778***	0.0000
InPCIsq	736	0.92731	37.089	7.455***	0.0000
InNR	736	0.77732	113.618	9.430***	0.0000
InRen	736	0.76834	118.202	9.497***	0.0000
InTrad	736	0.98681	6.731	4.152***	0.0000

Source: Stata 17.0

Further analysis on the cross-sectional dependence test suggested that all the series were statistically significant, just like that of the W' test for normally. This implied that within the context of Sub-Sahara African countries, urbanization, natural resources, renewable energy use and trade openness have not been affected by the ecological footprints within the period under review. This could be attributed to effectiveness in the management of these environmental hazards. These findings contradicted with the recent work of Emmanuel and Desmond (2023), who utilized Generalized Method of Moment (GMM) estimation and causality test and documented that the overall effect of trade openness reduces environmental hazard.

Table 5: Parameter Estimates Based on mean Effect Analysis

VARIABLES	(1) FMOLS	(2) DOLS	(3) CCR	(4) FE with DK
*ln*URB	-0.454	-0.452	-0.471	0.991***
	(0.470)	(0.549)	(0.470)	(0.044)
	[-0.968]	[-0.825]	[-1.002]	[22.668]
*ln*PCI	3.208	3.306	3.213	2.057***
	(2.866)	(3.359)	(2.899)	(0.174)
	[1.119]	[0.984]	[1.108]	[11.792]
*ln*PCISQ	-0.214	-0.204	-0.214	-0.130***
	(0.194)	(0.228)	(0.196)	(0.015)
	[-1.103]	[-0.895]	[-1.090]	[-8.571]
*ln*NR	0.281**	0.370**	0.283**	0.025
	(0.139)	(0.165)	(0.141)	(0.019)
	[2.020]	[2.249]	[2.007]	[1.294]
*ln*Ren	-0.963*	-0.773	-0.958*	-0.431***
	(0.522)	(0.614)	(0.529)	(0.082)
	[-1.843]	[-1.258]	[-1.809]	[-5.252]
*ln*Trad	-1.022**	-1.071*	-1.021**	-0.099***
	(0.459)	(0.563)	(0.474)	(0.029)
	[-2.228]	[-1.903]	[-2.154]	[-3.406]
Constant	13.532	11.571	13.525	6.724***
	(10.273)	(12.030)	(10.397)	(0.374)
	[1.317]	[0.962]	[1.301]	[17.974]
Observations	735	733	735	736
R-squared	0.018	0.216	0.036	

Standard errors in brackets
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Stata 17.0

Table 6: Cointegration and Hausman Tests

Statistic	Value	Z-value	P-value	Robust P-value
		Panel A: Cointegration test (Westerlund, 2007)		
Gt	-3.731***	-5.269***	0.000	0.020
Ga	-3.616	8.555	1.000	0.972
Pt	-16.436**	-1.729**	0.042	0.040
Pa	-4.050	5.824	1.000	0.728
		Panel B: Estimates from Hausman test		
chi2(6)	17.77			
Prob>chi2	0.0068			

Notes: *** p<0.01, ** p<0.05, * p<0.1; Robust *P*-Value are from 100 Bootstrap replications of the critical values

Source: Stata 17.0

In the panel unit root analysis, where the paper adopted CADF and CIPS approach, all series were found to be 1(1), which suggested that the series were useable at order one. Consequently, a co-integration test was conducted using Westerlund and Hausman method and the series maintained a stable long-run effect. This further advocated that there is a stable long-run bond among the series under investigation.

Table 7: Panel Unit Root Tests

Variables	CADF unit root test				CIPS unit root test				Decision
	Level I(0)		1st Difference I(1)		Level I(0)		1st Difference I(1)		
	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend	
lnECFP	-1.859	-1.928	-3.555***	-3.549***	-1.947	-1.861	-5.353***	-5.320***	I(1)
lnURB	-1.114	-1.855	-3.7692***	-3.8456***	-2.110*	-1.499	-4.714 ***	-4.931***	I(1)
lnPCI	-1.497	-1.893	-3.154***	-3.578***	-1.685	-2.135	-4.021***	-4.293***	I(1)
lnPCIsq	-1.469	-1.882	-3.137***	-3.565***	-1.641	-2.115	-4.004***	-4.257***	I(1)
lnNR	-1.814	- 2.570*	-3.255***	-3.399***	-1.724	-2.120	-4.198***	-4.201***	I(1)
lnRen	-1.774	-2.077	-3.356***	-3.531***	-1.948	-2.445	-4.262***	-4.413***	I(1)
lnTrad	-1.523	-1.870	-3.359***	-3.415***	-2.062	-2.056	-4.671***	-4.653***	I(1)

Note: *** p<0.01, ** p<0.05, * p<0.1;

Source: Stata 17.0

Table 8: Panel Unit Root Tests

	CADF unit root test				CIPS unit root test				
	Level I(0)		1st Difference I(1)		Level I(0)		1st Difference I(1)		
Variables	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend	Decision
lnECFP	-1.859	-1.928	-3.555***	-3.549***	-1.947	-1.861	-5.353***	-5.320***	I(1)
lnURB	-1.114	-1.855	-3.7692***	-3.8456***	-2.110*	-1.499	-4.714 ***	-4.931***	I(1)
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	(0.470)	(0.549)	(0.470)	(0.044)
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*ln*PCI	3.208	3.306	3.213	2.057***
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	[-1.103]	[-0.895]	[-1.090]	[-8.571]
*ln*NR	0.281**	0.370**	0.283**	0.025
	(0.139)	(0.165)	(0.141)	(0.019)
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*ln*Ren	-0.963*	-0.773	-0.958*	-0.431***
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*ln*Trad	-1.022**	-1.071*	-1.021**	-0.099***
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Constant	13.532	11.571	13.525	6.724***
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Observations	735	733	735	736
R-squared	0.018	0.216	0.036	

Standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

Table 11: MM-Qreg Estimates with Distributional Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
VARIABLES	Location	Scale	Qtile_10	Qtile_20	Qtile_30	Qtile_40	Qtile_50	Qtile_60	Qtile_70	Qtile_80	Qtile_90
*ln*URB	0.991***	-0.072*	1.106***	1.070***	1.039***	1.014***	0.991***	0.964***	0.942***	0.913***	0.876***
	(0.071)	(0.041)	(0.098)	(0.085)	(0.077)	(0.073)	(0.071)	(0.073)	(0.076)	(0.084)	(0.096)
	[13.916]	[-1.739]	[11.303]	[12.573]	[13.538]	[13.958]	[13.892]	[13.269]	[12.341]	[10.911]	[9.097]
*ln*PCISQ	2.057***	-0.090	2.201***	2.156***	2.117***	2.085***	2.057***	2.024***	1.996***	1.960***	1.914***
	(0.317)	(0.184)	(0.435)	(0.378)	(0.341)	(0.323)	(0.317)	(0.323)	(0.339)	(0.372)	(0.428)
	[6.498]	[-0.489]	[5.062]	[5.699]	[6.212]	[6.464]	[6.497]	[6.269]	[5.885]	[5.271]	[4.468]
*ln*PCISQ	-0.130***	0.008	-0.143***	-0.139***	-0.135***	-0.133***	-0.130***	-0.127***	-0.125***	-0.122***	-0.118***
	(0.024)	(0.014)	(0.033)	(0.029)	(0.026)	(0.025)	(0.024)	(0.025)	(0.026)	(0.029)	(0.033)
	[-5.366]	[0.546]	[-4.277]	[-4.784]	[-5.181]	[-5.365]	[-5.365]	[-5.148]	[-4.808]	[-4.277]	[-3.593]
*ln*NR	0.025*	-0.005	0.032	0.030*	0.028*	0.026*	0.025*	0.023	0.022	0.020	0.017
	(0.015)	(0.009)	(0.020)	(0.017)	(0.016)	(0.015)	(0.015)	(0.015)	(0.016)	(0.017)	(0.020)
	[1.688]	[-0.533]	[1.590]	[1.699]	[1.760]	[1.754]	[1.688]	[1.545]	[1.379]	[1.153]	[0.884]
*ln*Ren	-0.431***	-0.033	-0.378***	-0.394***	-0.409***	-0.420***	-0.431***	-0.443***	-0.453***	-0.466***	-0.483***
	(0.057)	(0.033)	(0.079)	(0.068)	(0.062)	(0.058)	(0.057)	(0.058)	(0.061)	(0.067)	(0.077)
	[-7.523]	[-0.982]	[-4.811]	[-5.764]	[-6.633]	[-7.200]	[-7.519]	[-7.577]	[-7.383]	[-6.928]	[-6.228]
*ln*Trad	-0.099***	0.001	-0.102**	-0.101***	-0.100***	-0.100***	-0.099***	-0.099***	-0.098***	-0.098***	-0.097**
	(0.032)	(0.019)	(0.044)	(0.038)	(0.034)	(0.032)	(0.032)	(0.033)	(0.034)	(0.037)	(0.043)
	[-3.114]	[0.080]	[-2.321]	[-2.648]	[-2.921]	[-3.070]	[-3.114]	[-3.037]	[-2.877]	[-2.609]	[-2.247]
Constant	6.724***	0.738	5.545***	5.908***	6.233***	6.488***	6.724***	6.992***	7.225***	7.519***	7.893***
	(0.933)	(0.543)	(1.282)	(1.116)	(1.005)	(0.951)	(0.934)	(0.952)	(1.000)	(1.096)	(1.263)
	[7.207]	[1.358]	[4.325]	[5.295]	[6.201]	[6.819]	[7.199]	[7.342]	[7.226]	[6.858]	[6.251]
Observations	736	736	736	736	736	736	736	736	736	736	736

Standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1

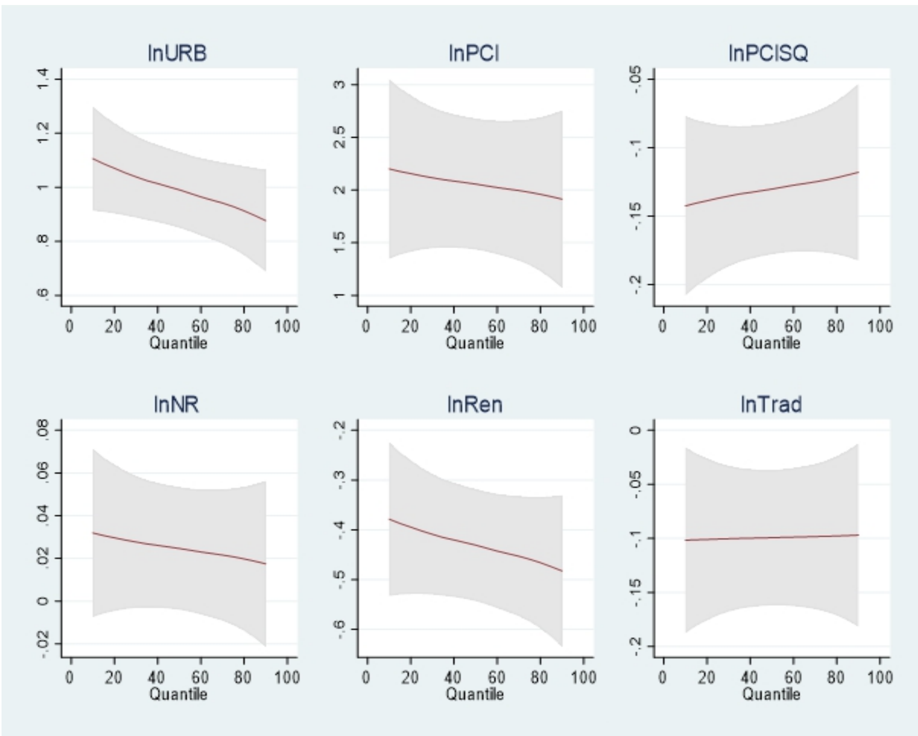

Figure 3: Quantile plots

Conclusion and Recommendation

The objective of this paper is to investigate whether there is a significant effect of ecological degradation on urbanization, natural resources, renewable energy use and trade openness in Sub-Sahara African countries using the method of STIRPAT (stochastic impacts by regression on population, affluence, and technology). Adopting about 736 panel observations and 32 selected Sub-Sahara African countries, the result showed that the mean and distributional effect of urbanization, natural resource extraction and renewable energy use have significant effect on ecological degradation, while trade openness has positive but insignificant effect on ecological footprints. Based on the result, the paper recommended that policies on environmental clean -up, controlled urbanization, pertinent renewable energy use and trade supervision should be adopted in order to limit ecological footprints in Sub-Sahara African countries.

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Table 12: Selected Sub-Saharan African Countries

Benin	Eswatini	Mozambique
Botswana	Gabon	Namibia
Burkina Faso	Gambia, The	Nigeria
Burundi	Ghana	Rwanda
Cabo Verde	Guinea	Senegal
Cameroon	Guinea-Bissau	Sierra Leone
Central African Republic	Kenya	South Africa
Chad	Madagascar	Togo
Comoros	Mali	Uganda
Congo, Rep.	Mauritania	Zimbabwe
Cote d'Ivoire	Mauritius	