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The Green Climate Fund: Climate Adaption and Climate Change Vulnerability and Readiness in Africa

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Abstract

Using data from 47 countries, this study analyses the distribution of climate adaptation projects in the areas targeted by the Green Climate Fund adaptation programme in Africa. The study uses a fixed effects estimator to empirically investigate the effect of adaptation financing on adaptation readiness and climate vulnerability. The key finding is that a majority of adaptation projects are funded by the private sector. Most projects are cross-cutting and include both adaptation and mitigation strategies. In addition, more than one-third of the projects are large and medium-sized due to their multi-country nature. Furthermore, a vast majority of the projects focus on the livelihoods of people and communities, and health, food, and water security. One-half of these projects focus on infrastructure and the built environment. Empirical evidence based on fixed effects estimates from the 47 countries spanning 2015-2022 reveals that adaptation financing has a positive effect on the climate change vulnerability and readiness index. Hence, adaptation investments may improve a country's adaptive capacity and readiness in responding to negative effects of climate change. Additionally, adaptation financing has a negative effect on climate vulnerability. This study therefore concludes that adaptation financing has the potential to enhance a country's resilience to climate change.

Keywords: Africa, climate adaptation, climate readiness, climate vulnerability, Green Climate Fund.

JEL classification: Q54, Q56, O55

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The Resilience and Adaptation Mainstreaming Program (RAMP) builds capacity in ministries of finance and other relevant public institutions in climate-vulnerable countries to embed climate adaptation into their core fiscal, budgetary and macro-economic functions, enabling governments to manage climate risks, design effective policy responses to build economy-wide resilience, and align adaptation funding with development priorities. RAMP is a strategic partner of the Coalition of Finance Ministers for Climate Action and works in close partnership with international financial institutions, regional development banks, and other stakeholders.

At the heart of RAMP's approach to capacity-building is its University Network for Strengthening Macrofinancial Resilience to Climate and Environmental Change ('the RAMP University Network'). Launched in 2022, the RAMP University Network consists of leading universities in vulnerable countries that seek to develop and deliver high-quality multi-disciplinary teaching and research on adaptation economics and climate risk management, train public officials, and serve as centres of expertise that ministries of finance and other public institutions can rely on. This approach ensures that skills and knowledge are embedded locally, strengthening partner countries' ability to integrate climate risks into economic decision-making.

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1 Introduction

While there has been an increase in climate related disasters globally, Africa suffers disproportionately from climate change. In addition, socio-economic, political, geographical, and environmental factors contribute to increased climate vulnerability in countries in sub-Saharan Africa (Maina & Parádi-Dolgos, 2024; Savvidou, Atteridge, Omari-Motsumi, & Trisos, 2021).

In 2010, the Green Climate Fund (GCF) was established to help developing countries meet their Nationally Determined Contributions (NDCs) to achieve low carbon emissions and enhance their resilience to climate change. Financial instruments used by the GCF include equity, grants, contingent grants, guarantees, concessional loans, and results-based finance (Green Climate Fund, 2023).

Notwithstanding, developing countries face huge budget constraints in financing climate change adaptation programs (Ford et al., 2015; Garschagen & Doshi, 2022; Timilsina, 2021). While around US$59 billion was committed to climate finance in Africa over 2019 and 2020, only 39 percent of the funds were dedicated to adaptation investment (Saghir & Ijjasz-Vasquez, 2023). Funding has typically focused on mitigation, which has direct benefits globally, rather than adaptation, which indirectly benefits fund contributors. Furthermore, there has been a lag in adaptation finance disbursement as compared to the commitments made (Savvidou et al., 2021).

The GCF forms part of the financial mechanism of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. This is in cognisance of the fact that developing countries are particularly vulnerable to the adverse effects of climate change (Garschagen & Doshi, 2022; Green Climate Fund, 2023). Hence, GCF's investments focus on achieving maximum impact in developing countries and striking a balance between adaptation and mitigation investments. Currently, GCF aims to invest at least 50% of the adaptation allocation in vulnerable countries including developing countries in Africa (Green Climate Fund, 2023; Timilsina, 2021).

Key result areas targeted by GCF investments to enhance climate change readiness and reduce vulnerability include buildings, cities, industries, and appliances, ecosystems and ecosystem services, energy generation and access, forests and land use, health, food and water security, infrastructure and the built environment, livelihoods of people and communities, and transport.

Using data from the GCF and the Notre Dame Global Adaptation Initiative (ND-GAIN), the proposed study seeks to address the following questions: (a) What is the distribution of adaptation projects and key result areas targeted by the GCF adaptation programmes in Africa? (b) What is the relationship between GCF adaptation financing and the climate change vulnerability and readiness index?

This study examines adaptation finance with a focus on analysing the role of GCF adaptation financing in reducing vulnerability to climate change, and in enhancing readiness to adapt in developing countries in sub-Saharan Africa (Afful-Koomson, 2015).

This study makes several contributions. First, the study analyses the distribution of adaptation projects and key result areas in Africa, which has been scarcely done by existing studies, despite African countries suffering disproportionate effects of climate change. Second, the study uses panel data methods including the fixed effects estimator to examine the effects of adaptation financing on the ND-GAIN index. The study distinguishes itself from existing studies that use qualitative methods to investigate private sector involvement in the GCF (Kalinowski, 2024) and empirical studies that focus on climate finance provided and mobilised by developing countries that do not distinguish between commitments and actual

disbursement of climate financing (Maina & Parádi-Dolgos, 2024). The African Union (AU) is working to increase climate finance in Africa to help the continent adapt to and mitigate the effects of climate change, hence this study provides empirical evidence that offers important insights to policy makers in support of achieving Sustainable Development Goal 13, climate action to strengthen resilience and adaptive capacity to climate change.

2 Data and Methods

2.1 Data

This study uses African data from the GCF projects, including programme data. It also uses the ND-GAIN database to address the highlighted questions on the distribution of adaptation projects and key result areas targeted by GCF investments, and the relationship between GCF adaptation financing and climate change vulnerability and readiness (Green Climate Fund, 2023; University of Notre Dame, 2023). Data from GCF projects contain country-level information on project portfolios including the sector, theme, project size, result areas, and financial resources devoted to adaptation. The GCF provides comprehensive data on funded activities from 2015 to 2023. As of 2023, 45 out of 49 countries in Africa had GCF funded projects. The countries with the highest number of funded projects include Madagascar, Senegal, and Kenya, while those with the largest adaptation financing investments include South Africa, Tanzania, and Ethiopia (see Table A1 in the Appendix for the list of countries, number of projects, and total adaptation financing (US$)).

Data from the ND-GAIN initiative provides the ND-GAIN country index spanning 1995-2022. It consists of vulnerability and readiness as the primary dimensions of adaptation. The index aids governments, businesses, and communities to assess risks that are aggravated by climate change including over-crowding, civil conflicts, food insecurity, and inadequate infrastructure.

The ND-GAIN country index measures overall climate vulnerability using six life-supporting sectors. These include food, water, health, human habitat, ecosystems and ecosystem service, and infrastructure. Climate vulnerability represents the simple mean of the sector scores. They are measured using equally weighted average scores of component indicators. The component indicators measure the exposure, sensitivity, and capacity of a country to adapt to the adverse effects of climate change. Exposure reflects the biophysical perspective measuring the degree to which a system is exposed to significant changes in the climate. Sensitivity relates to the extent to which sectors are negatively affected by climate hazards or the proportion of the population that is especially susceptible to climate change hazards. Adaptive capacity represents the availability of sector-specific adaptation resources (University of Notre Dame, 2023).

Readiness reflects a country's ability to leverage and transform investments into adaptation action. The ND-GAIN country index measures readiness using average scores within and between equally weighted indicators, including economic, social, and governance readiness. Economic readiness represents the ability of a country's business environment to attract public and private investment that can be used in adaptation to reduce vulnerability by reducing sensitivity and improving adaptative capacity. It includes a doing-business indicator assessing the regulatory framework and public services targeting enterprises. Social readiness includes various factors that enhance investment mobility and adaptation actions. These include social inequality, education, ICT infrastructure, and innovation. Governance readiness constitutes institutional factors that foster the use of investments for adaptation. These include political stability and

non-violence, control of corruption, rule of law, and regulatory quality (Maina & Parádi-Dolgos, 2024; University of Notre Dame, 2023).

The ND-GAIN country index comprises a readiness score and a climate vulnerability score and is calculated as follows:

$$GAIN\ Index = (Readiness - Vulnerability + 1) * 50 \qquad (1)$$

where $GAIN\ Index$ is the ND-GAIN country index ranging from 0 to 100. The higher the score, the better a country's climate resilience, including its adaptive capacity and readiness in responding to the negative effects of climate change. $Readiness$ reflects an index computed from readiness indicators. It ranges from 0 to 1 with a higher score reflecting better readiness. In contrast, $Vulnerability$ is computed from various vulnerability indicators, ranging from 0 to 1, where a high score reflects a higher degree of vulnerability.[1]

2.2 Characteristics of the Green Climate Fund Adaptation Projects in Africa

2.2.1 Distribution of Adaptation Projects

Figure 1 shows the distribution of GCF adaptation projects by sector, theme, and project size for the period 2015-2023. Slightly more than one-half of the projects are funded by the private financing sector (53%). This suggests that the private sector is active in financing adaptation projects aimed at diminishing climate change vulnerability. Private sector financing has the ability to reach poorer countries and populations and thus plays a significant role (Pauw, 2015). Bilateral and multilateral development banks financing adaptation projects in partnership with GCF include Acumen Fund, French Development Agency (AFD), International Fund for Agricultural Development (IFAD), Africa Finance Corporation (AFC), Dutch Entrepreneurial Development Bank, African Development Bank (AfDB), Camco Management Ltd, and Japan's MUGF Bank. These organisations primarily offer international private financing of adaptation strategies targeting private sector projects (Kalinowski, 2024). Organisations such as the World Bank, the World Food Program, the Food and Agriculture Organisation, the United Nations Development Program, the German Development Bank, IFAD, AfDB, and AFD also fund projects in the public sector which accounts for 47% of the funded projects. While the role of the private sector in adaptation and adaptation financing is important, it cannot substitute and only complements the efforts of the public sector (Pauw, 2015).

Most projects are cross-cutting i.e., target both mitigation and adaptation themes (64%) rather than adaptation only (36%). This is likely caused by a previous focus on mitigation strategies which focus on reducing greenhouse gas emissions rather than adaptation interventions aimed at increasing the resilience of communities to climate change (Intergovernmental Panel on Climate Change, 2001). Traditionally, mitigation has received much more attention in climate change action plans compared to adaptation. Adaptation plans have typically remained less advanced due to weak institutional arrangements supporting adaptation action. Furthermore, adaptation targets have generally remained unclear as compared to mitigation targets (Dovie, 2019; Sharifi, 2021). However, the importance of climate adaptation has been increasingly acknowledged, especially for developing countries that contribute relatively less to emissions, but are more vulnerable to climate impacts (Dovie, 2019).

[1] Readiness is computed from 9 readiness indicators while vulnerability is computed from 36 vulnerability indicators. See https://gain.nd.edu/our-work/country-index/methodology/indicators/ for more details.

Accordingly, the GCF currently aims to strike a balance between mitigation and adaptation investments (Green Climate Fund, 2023).

Lastly, more than one-third of the projects are large (38%) and medium-sized (39%). This is mainly driven by multi-country projects that tend to be large and medium-sized, including private sector financed projects targeting several countries at a time (Kalinowski, 2024).

The largest multi-country project is a large private sector grant and equity funded adaptation project launched in 2023 in 19 countries[2]. It targets two result areas including infrastructure and the built environment, and livelihoods of people and communities. This project is funded by AFC, a regional entity established through a public-private partnership to provide financing solutions to address infrastructural gaps in Africa. Climate change threatens existing and yet-to-be-built infrastructure in Africa, which is characterised by infrastructure that is inaccessible, inadequate, and of poor quality. This is further compounded by barriers to financing climate resilient infrastructure. The GCF provides US$240 million to the Infrastructure Climate Resilient Fund, an innovative finance instrument through which the AFC finances greenfield and brownfield infrastructure which is planned, designed, built, and operated in a manner that adapts to the changing climate. The investment has the potential to benefit 50 million people directly, and 144 million indirectly by providing reliable infrastructure services (Green Climate Fund, 2023).

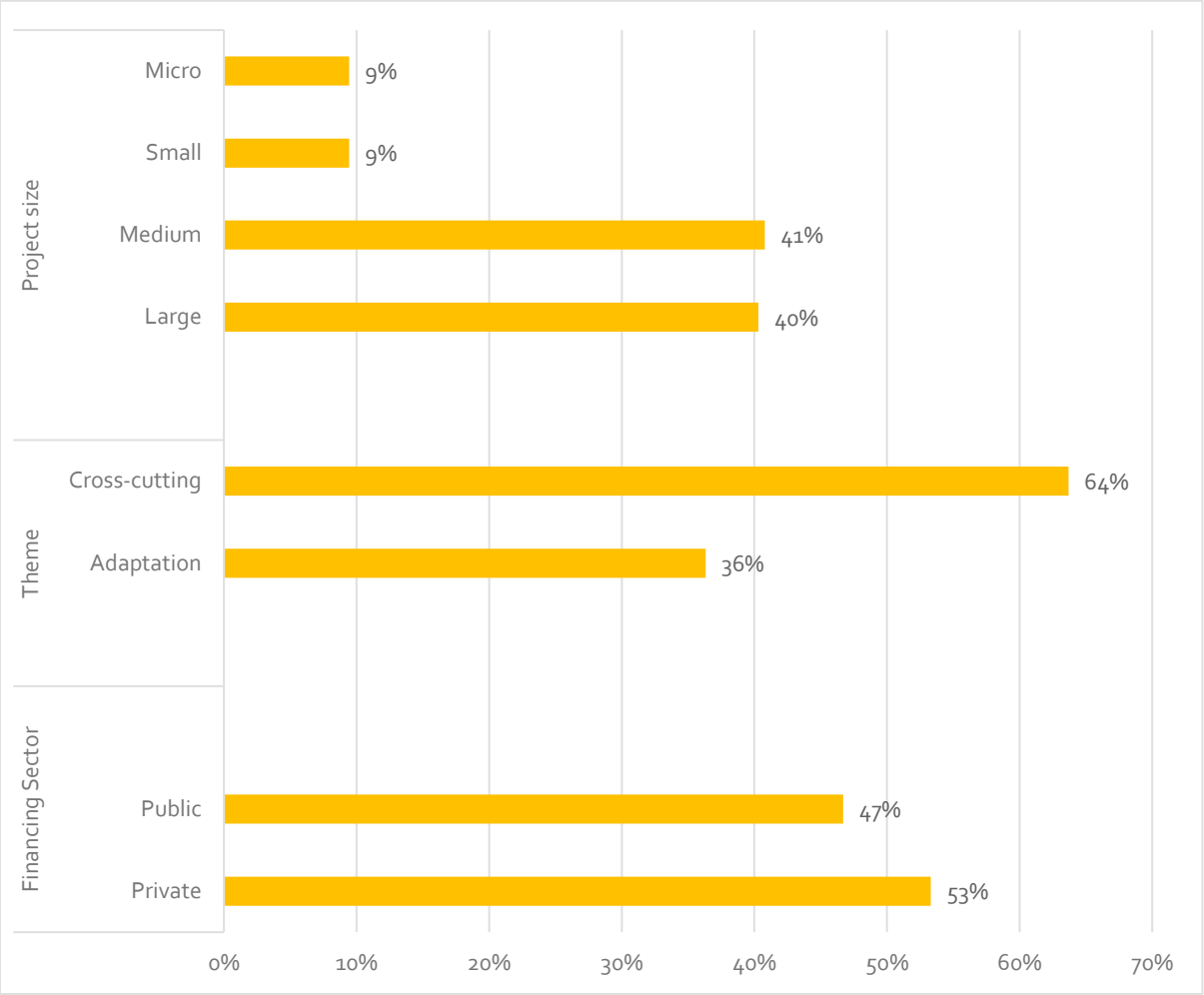
The second largest multi-country project i.e., Hardest-to-Reach is a US$250 million medium-sized grant and equity private sector financed project launched in 2023 in 16 countries[3]. This project is funded by Acumen Fund, a non-profit impact investment fund that executes equity investment opportunities in clean energy, agriculture, and health sectors, which deliver environmental and livelihood impacts. Acumen Fund's activities overlap with GCF's result areas and impacts. The Hardest-to-Reach project is cross-cutting, targeting energy generation and access, health, food, and water security, and livelihoods of people and communities as key result areas. About 560 million people in sub-Saharan Africa live without electricity. Lack of supporting infrastructure keeps traditional off-grid solar enterprises from investing in projects that can benefit hard-to-reach populations. This increases their vulnerability to climate change. The project aims to expand access to clean and affordable energy to close the persistent energy gap in Africa. It offers flexible financing to off-grid solar enterprises and provides solutions to underserved markets through pay-as-you-go financing models (Green Climate Fund, 2023).

Overall, multi-country projects are implemented across countries facing similar challenges, resulting in lower relative overhead costs. They generally have reinforced impacts because they are transferable and scalable. However, they can also be problematic because they are less adjusted to country-specific contextual factors (Kalinowski, 2024).

[2] The Infrastructure Climate Resilient Fund was launched in 2023 in Benin, Cameroon, Chad, Cote d'Ivoire, Democratic Republic of the Congo, Djibouti, Gabon, Gambia, Ghana, Guinea, Kenya, Mali, Mauritania, Namibia, Nigeria, Rwanda, Sierra Leone, Togo, and Zambia.

[3] The Hardest-to-Reach project was launched in 2023 in Benin, Burkina Faso, Burundi, Chad, Democratic Republic of the Congo (the), Guinea, Guinea-Bissau, Lesotho, Malawi, Mozambique, Niger (the), Sierra Leone, Somalia, Togo, Uganda, and Zambia.

Figure 1. Distribution of adaptation projects, 2015-2023[4]



Source: Author's calculations based on data from 212 GCF funded projects

2.2.2 Distribution of Key Result Areas

Figure 2 shows the frequency of the distribution of adaptation and key result areas from 2015 to 2023. There is significant overlap in adaptation financing with projects focusing on multiple key result areas that include both mitigation and adaptation. Key result areas in adaptation include livelihoods of people and communities, health, food and water security, infrastructure and built environment, and ecosystems and ecosystem services. Key result areas in mitigation include buildings, cities, industries, and appliances, transport, energy generation and access, and forests and land use.

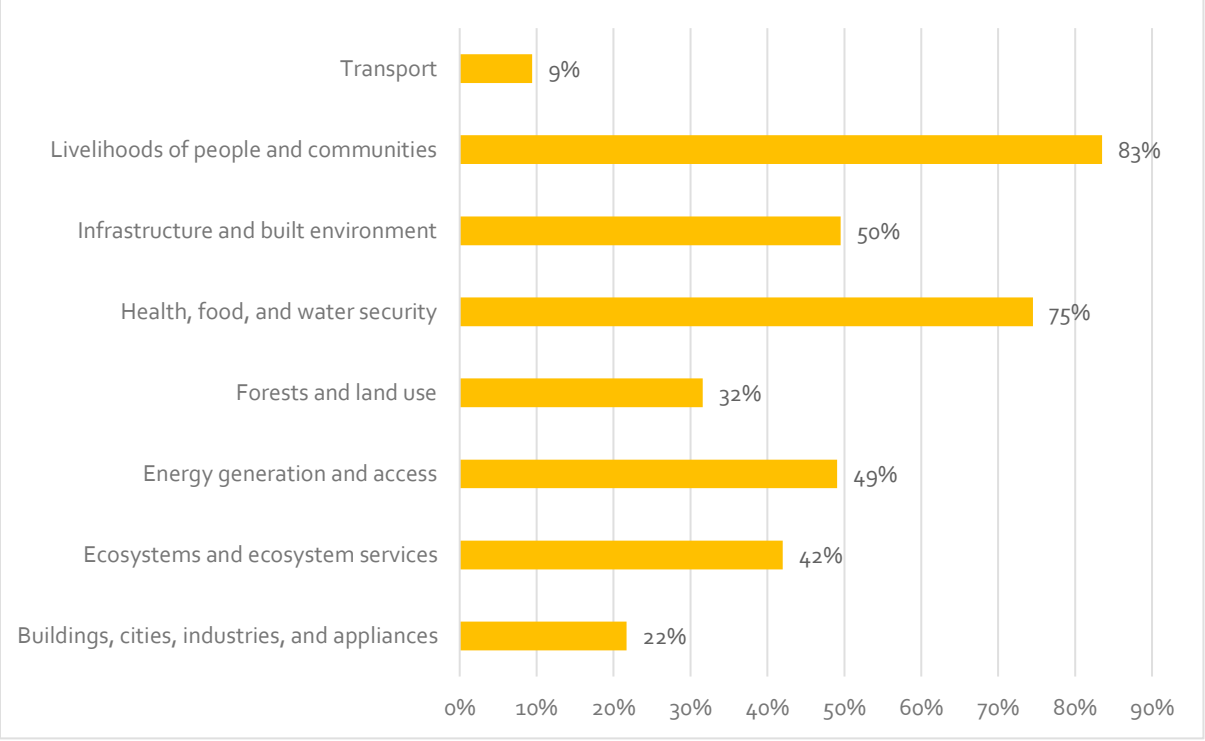
Figure 2 shows that more than three-quarters of the projects focus on the livelihoods of people and communities (83%), and health, food, and water security (75%). These key areas are typically those that are most vulnerable to the adverse effects of climate change as it affects livelihoods in terms of farm and non-farm employment and exacerbates food and water insecurity (Pauw, 2015; Sharifi, 2021). Livelihoods comprise activities, capabilities, and assets required for living. A sustainable livelihood is achieved when an individual can cope with and recover from shocks and enhance or maintain assets and capabilities without undermining the natural resource base. In addition, many livelihoods in Africa typically rely on

[4] The project size percentage adds up to 99% due to a 1% rounding error.

rainfed agriculture, which has become increasingly vulnerable to climate change (Lobell, Bänziger, Magorokosho, & Vivek, 2011; Maina & Parádi-Dolgos, 2024; Sarr, Bezabih Ayele, Kimani, & Ruhinduka, 2021). This poses a threat to health, food, and water security (Green Climate Fund, 2023).

Figure 2 also shows that one-half of the projects focus on infrastructure and the built environment (50%). Extreme weather events linked to climate change cause significant damage to infrastructure. Notwithstanding, infrastructure plays a key role in various sectors including energy, water, telecommunications, and transportation. Hence, adaptation programs generally focus on building climate-resilient infrastructure including nature-based solutions or green infrastructure (Sharifi, 2021). Green infrastructure is typically associated with improved economic and social resilience, and improved water and food security (Sharifi, 2021). Very few projects focus on transport (9%) relative to other key result areas. While transport contributes to nearly one-quarter of all energy related greenhouse gas emissions, developing countries in sub-Saharan Africa lack access to efficient and low emissions public transport systems. This is driven by high costs associated with the adoption of low emissions transportation technologies (Green Climate Fund, 2023). Yet, public transportation can strengthen the coping and adaptive capacity of vulnerable populations by easing economic activity and reducing accessibility inequalities (Sharifi, 2021).

Figure 2. Distribution of key result areas based on adaptation and cross-cutting themes, 2015-2023

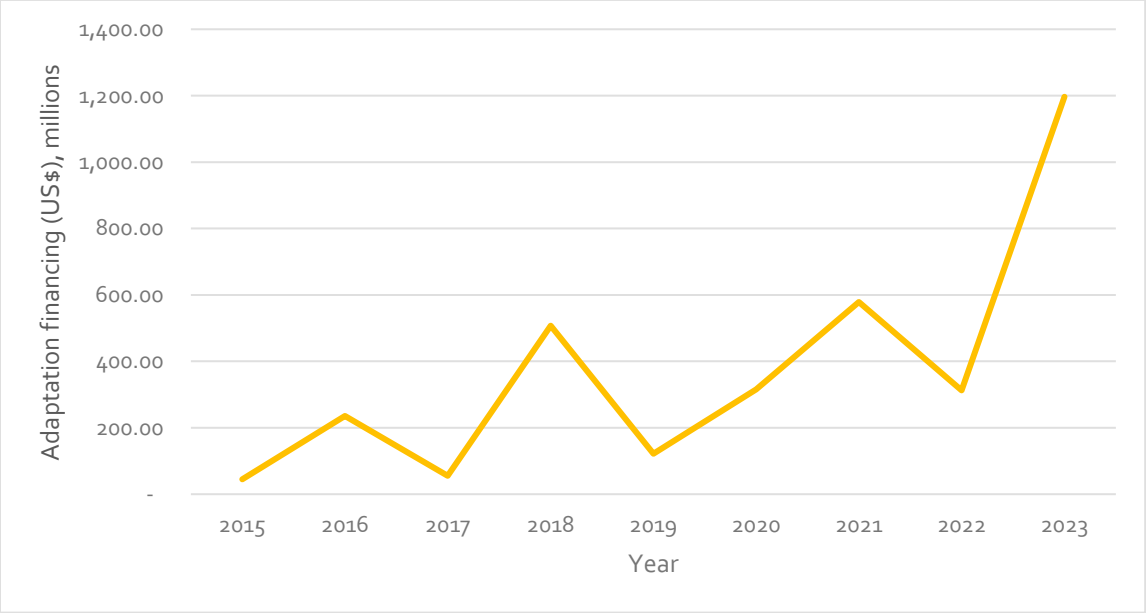


Source: Author's calculations based on data from 212 GCF funded projects

2.3 Trends in Adaptation Financing and the ND-GAIN Index

Figure 3 illustrates striking variability in adaptation financing in Africa. It is noteworthy that many countries experienced adverse effects of extreme weather and climate-related disasters in 2017 and 2020 (Ramírez & Briones, 2017; Tozier de la Poterie et al., 2022), which likely explains the sharp increase in adaptation financing in 2018 and 2021. Additionally, the growth in adaptation financing over the years has primarily been driven by an increase in climate finance options for adaptation by multilateral development banks (Savvidou et al., 2021). Furthermore, adaptation financing is generally delivered as a part of development financing because of the significant complementarity between adaptation and development (Organisation for Economic Co-operation and Development [OECD], 2023). There is also a marked increase in adaptation financing in 2023. The GCF diversified its portfolio in 2023 by including underrepresented regions and areas that are less programmed, including locally led adaptation and ecosystems. It also made progress in supporting new areas like health and education, and in early warning systems (Green Climate Fund, 2023).

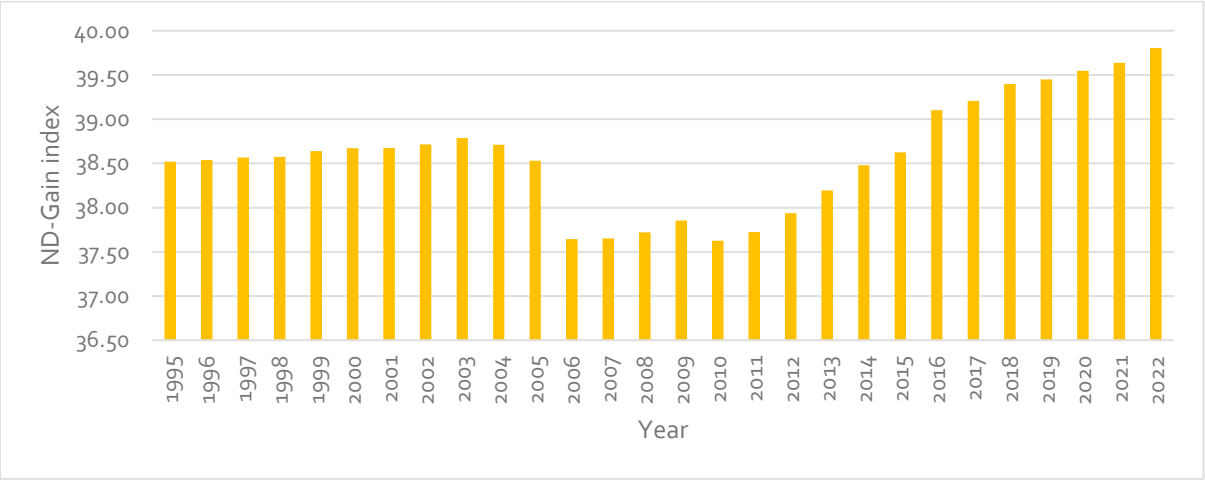
Figure 3. Adaptation Financing in Africa, 2015-2023



Source: Author's calculations based on data from 212 GCF funded projects

Figure 4 shows that there was a slight but steady increase in the mean ND-GAIN index in Africa between 1995 and 2005. The marginal improvements in the ND-GAIN index before the implementation of the GCF likely arose from public grants and private financing that primarily came from UNFCCC developed member countries (Pauw, 2015). However, a sharp decline is observed from 2006 with the lowest score being recorded in 2010. This marked decline is likely associated with the 2007 global financial crisis that led to a severe liquidity contraction in financial markets and a subsequent global recession (Leichenko, O'Brien, & Solecki, 2010). A marginal increase in the ND-GAIN index was again recorded from 2011 and a steady sharp increase is noted after the implementation of the GCF 2015. This is likely a result from increased investments in adaptation financing (Maina & Parádi-Dolgos, 2024; OECD, 2023; Savvidou et al., 2021; Timilsina, 2021). This suggests that there are likely to be improvements in climate resilience due to enhanced adaptation readiness coupled with a reduction in climate vulnerability.

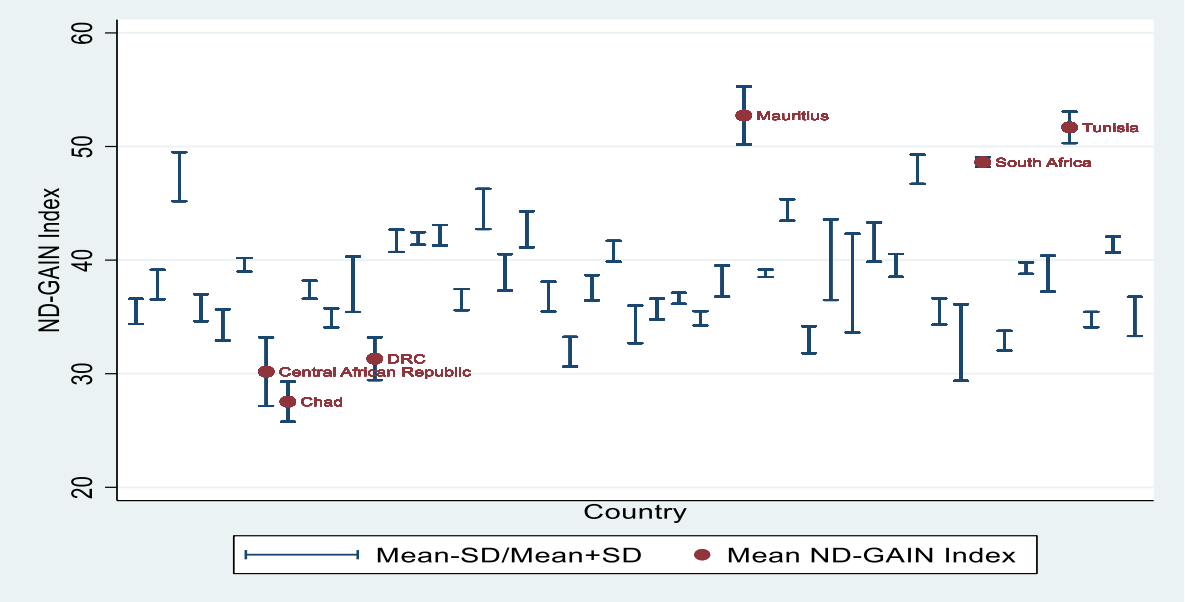
Figure 4. Trend in ND-GAIN index trend in Africa, 1995-2022



Source: Notre Dame Global Adaptation Initiative, 2023

Figure 5 illustrates the ND-GAIN country index averages in Africa. Mauritius, Tunisia, and South Africa have the highest mean values, while Chad, Central African Republic (CAR), and Democratic Republic of Congo (DRC) have the lowest mean values. Low indices signal a great need for investment to reduce climate vulnerability and improve readiness. However, Chad, Central African Republic, and DRC have generally suffered a long history of conflict and political instability which undermines overall investment and economic progress (Clément, 2004).

Figure 5. ND-GAIN Index country average, 1995-2022



Source: Notre Dame Global Adaptation Initiative, 2023

2.4 Empirical strategy

This study explores the relationship between GCF adaptation financing and the climate change vulnerability index using a fixed effects estimator to analyse panel data over the period 2015-2022[5]. Time-invariant characteristics such as the type of government, political environment, public policies, and cultural norms can affect a country's climate change vulnerability. The fixed effects estimator controls for time-invariant differences between countries using country fixed effects. Furthermore, the effect of GCF adaptation financing on the climate change vulnerability index might not be immediate. This study therefore uses the lagged GCF adaptation financing as the explanatory variable. Hence, this study employs the following model:

$$Y_{it} = \beta_1 ADAPFIN_{it-k} + \beta_1 CONTROLS_{it} + \alpha_i + \varepsilon_{it} \quad (2)$$

where Y_{it} represents the outcome of interest, the ND-GAIN country index for country $i, i = 1, \dots, N$ in time $t, t = 1, \dots, T$. The term $ADAPFIN_{it-k}$ represents the lagged GCF adaptation financing. $CONTROLS_{it}$ represent a vector of control variables including climate-related disasters, voice and accountability, and government effectiveness. $\alpha_i$represents time-invariant country-specific unobserved effects, and ε_{it} is the idiosyncratic error term.

The optimal lag length selection is based on information criteria that minimizes the moment model selection criteria (MMSC)-Akaike information criterion (MAIC), MMSC-Bayesian information criterion (MBIC), and the MMSC-Hannan and Quinn information criterion (MQIC) (Andrews & Lu, 2001). The optimal lag length for annual data is typically 1 or 2 lags (Wooldridge, 2019). Based on the information criteria that minimises MAIC, MBIC, and MQIC information criteria, this study finds that 2 lags are appropriate for the analysis. This study therefore estimates the following model consisting of the twice lagged value of GCF adaptation financing:

$$Y_{it} = \beta_1 ADAPFIN_{it-2} + \beta_1 CONTROLS_{it} + \alpha_i + \varepsilon_{it} \quad (3)$$

where all the variables are defined as in Equation (1).

3 Results and Discussion

3.1 Descriptive Statistics

Table 1 shows the summary statistics of the variables used to investigate the relationship between adaptation financing, i.e., GCF adaptation financing, and the climate change vulnerability index. The average ND-GAIN country index is about 39%, which is below average, and the maximum value is slightly above average at around 58%. At about 31%, the adaptation readiness index is also relatively low. The climate vulnerability index is about 52%, which is slightly above average. The average value of adaptation financing is about US$5.6 million and the maximum value is about US$165 million. About 26% of countries in the sample have received GCF adaptation financing. The climate disaster index represents the annual frequency of climate-related disasters. It includes the total number of occurrences of droughts, floods, extreme temperatures, landslides, storms, and wildfires in a country (International Monetary Fund, 2024).

[5] The period 2015-2022 reflects the overlap between the GCF data i.e., 2015-2023 and the ND-GAIN country index data i.e., 1995-2022. The GCF began disbursing funds in 2015 and the last data point for the ND-GAIN country index is 2022.

The average number of annual occurrences of climate-related disasters in a country is one, and the maximum number is eight.

Voice and accountability and government effectiveness are control variables from the Worldwide Governance Indicators that are excluded from the computation of the readiness index. Voice and accountability and government effectiveness range from -2.5 to 2.5, with a higher estimate indicating well-functioning institutions (Kaufmann, Kraay, & Mastruzzi, 2011). Voice and accountability capture perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. Government effectiveness captures perceptions of a country's capacity and measures the quality of public services, the civil service, and policy formulation and implementation. It also measures the credibility of a government's commitment to improving or maintaining these aspects. The mean values of voice and accountability and government effectiveness are negative, which reflects poorly functioning institutions (Table 1).

Table 1. Summary statistics, 2015-2022

Variable	Mean	Std. Dev.	Min	Max
ND-GAIN country index	39.35	5.86	25.90	57.77
Adaptation readiness index	0.31	0.07	0.12	0.57
Climate vulnerability index	0.52	0.06	0.37	0.66
Adaptation financing (US$)	5,564,858.15	14,756,465.15	0.00	165,237,592.00
Adaptation financing dummy	0.26	0.44	0.00	1.00
Climate disaster index	1.11	1.47	0.00	8.00
Voice and accountability	-0.55	0.70	-2.00	0.83
Government effectiveness	-0.81	0.63	-2.28	1.13
No. of time periods	8	8	8	8
No. of countries	47	47	47	47
No. of observations	376	376	376	376

3.2 Empirical Results

Table 2 shows the fixed effects coefficients from estimating Equation (2). The reported results show that adaptation financing has a positive and statistically significant effect on the ND-GAIN country index (model 1). This study finds that a 10% increase in adaptation financing is associated with a 0.0001% increase in the ND-GAIN country index, which has negligible economic significance. Considering that the ND-GAIN country index summarises vulnerability to climate change together with a country's readiness to improve resilience, this result offers suggestive evidence that GCF adaptation investments may reduce climate vulnerability and improve a country's adaptive capacity and readiness in leveraging public and private sector climate financing to respond to the adverse effects of climate change (Maina & Parádi-Dolgos, 2024).

Table 2 shows that the relationship between GCF adaptation financing and the adaptation readiness score is positive, but statistically nonsignificant (model 2). However, adaptation financing has a statistically significant negative association with climate vulnerability, which measures a country's sensitivity, exposure, and ability to adapt to the adverse effects of climate change (model 3). Even though the economic significance of the effect is very small, this finding suggests that adaptation financing has the potential to reduce climate vulnerability.

Table 2. Effect of adaptation financing on climate resilience

Variable	Model 1 ND-GAIN country index	Model 2 Adaptation readiness	Model 3 Climate vulnerability
L2.Ln Adaptation financing (US$)	0.011*	0.0001	-0.0002***
	(0.006)	(0.000)	(0.000)
Climate disaster	-0.054	-0.000	-0.000
	(0.033)	(0.000)	(0.000)
Voice and accountability	0.354	0.007*	-0.001
	(0.308)	(0.004)	(0.003)
Government effectiveness	1.691***	0.029***	-0.002
	(0.385)	(0.005)	(0.004)
Constant	41.095***	0.337***	0.517***
	(0.361)	(0.004)	(0.004)
Observations	282	282	282
R-squared	0.098	0.160	0.048

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Furthermore, this study considers that adaptation financing is typically implemented in response to climate-related disasters. Hence, there is likely to be a response lag between the time the financing is implemented and the time its impact is felt. The study therefore examines the effect of the once and twice lagged adaptation financing variable. Table 3 shows that the effect of adaptation financing is evident when adaptation financing is lagged twice. This suggests that adaptation financing effects climate resilience significantly after two years.

Table 3. Effect of adaptation financing on climate resilience

Variable	Model 1 ND-GAIN country index	Model 2 Adaptation readiness	Model 3 Climate vulnerability
L1.Ln Adaptation financing (US$)	0.005	0.00004	-0.0001
	(0.006)	(0.000)	(0.000)
L2.Ln Adaptation financing (US$)	0.012*	0.0001	-0.0002***
	(0.006)	(0.000)	(0.000)
Climate disaster	-0.053	-0.001	-0.0002
	(0.033)	(0.000)	(0.000)
Voice and accountability	0.344	0.007*	-0.001
	(0.308)	(0.004)	(0.003)
Government effectiveness	1.680***	0.029***	-0.002
	(0.385)	(0.005)	(0.004)
Constant	41.056***	0.336***	0.517***
	(0.363)	(0.004)	(0.004)
Observations	282	282	282
R-squared	0.102	0.161	0.058

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

3.3 Robustness Checks

Table 4 shows robustness checks from using the gross domestic product (GDP) adjusted ND-GAIN score. This score accounts for the correlation between the ND-GAIN score and GDP per capita. The GDP adjusted ND-GAIN score is measured as the distance of a country's ND-GAIN score and its expected value from the regression of the ND-GAIN score and GDP. This also applies to the GDP adjusted adaptation readiness scores, and the GDP adjusted climate vulnerability scores. Positive values of the GDP adjusted ND-GAIN reflect better climate resilience, i.e., adaptive capacity and readiness than expected. Positive values for climate vulnerability and adaptation readiness reflect lower vulnerability and higher readiness than expected for a given level of GDP per capita (University of Notre Dame, 2024).

The results from using the GDP adjusted measures of climate resilience remain similar to those of the main model (Table 4). Adaptation financing has a positive and statistically significant effect on the GDP adjusted ND-GAIN country index (model 1) and a negative effect on the GDP adjusted climate vulnerability score (model 3). The effect of adaptation financing is positive but statistically nonsignificant for the GDP adjusted adaptation readiness score (model 2); however, this coefficient retains it sign as compared to the main model. Hence, our qualitative conclusions remain the same.

Table 4. Effect of adaptation financing on gross domestic product adjusted climate resilience

Variable	Model 1 ND-GAIN country index	Model 2 Adaptation readiness	Model 3 Climate vulnerability
L2.Ln Adaptation financing (US$)	0.013**	0.0001	-0.0002***
	(0.005)	(0.000)	(0.000)
Climate disaster	0.005	-0.000	-0.000
	(0.030)	(0.000)	(0.000)
Voice and accountability	0.603**	0.009**	-0.003
	(0.276)	(0.004)	(0.003)
Government effectiveness	1.005***	0.022***	0.002
	(0.344)	(0.005)	(0.004)
Constant	-3.543***	-0.026***	0.044***
	(0.323)	(0.005)	(0.004)
Observations	282	282	282
R-squared	0.077	0.104	0.053

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 5 provides robustness checks from measuring adaptation financing as a dummy variable, which takes the value 1 if a country receives GCF adaptation financing in a given year and 0 otherwise. The results from using this measure of adaptation financing are similar to the main results. Adaptation financing has a positive and statistically significant effect on the ND-GAIN country index (model 1) and a negative effect on climate vulnerability (model 3). Its effect on readiness remains statistically nonsignificant (model 2). Hence, our qualitative conclusions remain the same.

Table 5. Effect of adaptation financing on climate resilience

Variable	Model 1 ND-GAIN country index	Model 2 Adaptation readiness	Model 3 Climate vulnerability
L2.Adaptation financing dummy	0.182*	0.001	-0.003***
	(0.100)	(0.001)	(0.001)
Climate disaster	-0.054	-0.000	-0.000
	(0.033)	(0.000)	(0.000)
Voice and accountability	0.356	0.007*	-0.001
	(0.308)	(0.004)	(0.003)
Government effectiveness	1.690***	0.029***	-0.002
	(0.385)	(0.005)	(0.004)
Constant	41.095***	0.337***	0.517***
	(0.361)	(0.004)	(0.004)
Observations	282	282	282
R-squared	0.099	0.160	0.049

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

This study also explores heterogeneous effects of interacting our control variables—voice and accountability and government effectiveness—with the adaptation financing dummy to examine whether our main results hold (Table 6). The results show that adaptation financing has a positive and statistically significant effect on the ND-GAIN country index (model 1) and adaptation readiness (model 2). This study also finds that adaptation financing has a negative and statistically significant effect on climate vulnerability (model 3). Hence, the qualitative conclusions remain the same.

Table 6. Effect of adaptation financing on climate resilience

Variable	Model 1 ND-GAIN country index	Model 2 Adaptation readiness	Model 3 Climate vulnerability
L2.Adaptation financing dummy	0.361**	0.004**	-0.006***
	(0.171)	(0.002)	(0.002)
Climate disaster	-0.057	-0.001	-0.0004
	(0.035)	(0.000)	(0.000)
Voice and accountability	0.361	0.007*	-0.001
	(0.309)	(0.004)	(0.003)
Government effectiveness	1.701***	0.029***	-0.003
	(0.386)	(0.005)	(0.004)
Interaction terms			
Climate disaster*L2.Adaptation financing dummy	-0.011	-0.0002	0.002**
	(0.069)	(0.001)	(0.001)
Voice and accountability*L2.Adaptation financing dummy	0.015	-0.002	-0.0003
	(0.205)	(0.002)	(0.002)
Government effectiveness*L2.Adaptation financing dummy	0.249	0.006**	-0.002
	(0.219)	(0.003)	(0.002)

Constant	41.109***	0.337***	0.516***
	(0.362)	(0.004)	(0.004)
Observations	282	282	282
R-squared	0.108	0.183	0.076

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

4 Conclusion

Using data from 47 countries in Africa from the 2015-2023 GCF projects and programs data, and the 1995-2022 ND-GAIN database, this study analyses the distribution of adaptation projects and key result areas targeted by GCF adaptation programs in Africa. The study also uses a fixed effects estimator to analyse panel data spanning 2015-2022 to investigate the effect of GCF adaptation financing on the ND-GAIN country index, climate vulnerability index and the adaptation readiness index in Africa.

The study finds that most GCF adaptation projects benefit from private sector financing, suggesting its active involvement in climate financing. In addition, few projects focus on adaptation only. Most projects are cross-cutting and include mitigation. However, the GCF has in the recent past aimed to strike a balance between climate mitigation and adaptation projects. Most projects are also large and medium-sized, spanning multiple countries.

Considering the key result areas, the vast majority of projects focus on the livelihoods of people and communities, health, food, and water security. Typically, these key result areas represent areas that are most vulnerable to adverse effects of climate change as it effects livelihoods in terms of farm and non-farm employment and exacerbates food and water insecurity. One-half of the projects focus on infrastructure and the built environment.

The empirical results reveal that GCF adaptation financing has a positive but negligible effect on the ND-GAIN country index. However, this study argues that this finding provides suggestive evidence that adaptation investments may improve a country's adaptive capacity and readiness in responding to the negative effects from climate change. Furthermore, adaptation financing has a negative effect on climate vulnerability. The findings of this study also show that adaptation financing effects the ND-GAIN country index after two years. This finding suggests that adaptation financing has a lagged effect on climate resilience, providing suggestive evidence of the response lag between project financing and implementation, and the project impact. Overall, the study concludes that adaptation financing has the potential to enhance a country's resilience to the adverse effects of climate change.

While this study offers important insights into the distribution of adaptation projects and key result areas of GCF adaptation financing, and its effect on the climate change vulnerability and readiness index, its main limitation relates to the limited distinction between adaptation financing and mitigation financing for projects with cross-cutting themes. Future avenues of research would therefore benefit from the availability of comprehensive climate finance data that clearly distinguishes between the funding allocated to adaptation activities and mitigation activities within projects.

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Appendix A

Table A1. Number of Green Climate Fund Projects in Africa, 2015-2023

	Country	No. of projects	Adaptation financing (US$)
1	Madagascar	7	78,372,081.00
2	Senegal	7	104,924,387.70
3	Kenya	6	156,860,971.26
4	Ghana	5	86,896,312.00
5	Mali	5	64,386,140.00
6	Namibia	5	88,262,470.00
7	Niger	5	75,227,433.64
8	Rwanda	5	217,262,310.00
9	South Africa	5	297,193,694.00
10	Tanzania	5	278,761,079.71
11	Benin	4	85,485,166.00
12	Burkina Faso	4	70,511,979.00
13	Chad	4	45,698,640.00
14	Ethiopia	4	236,932,599.00
15	Gambia	4	62,937,982.00
16	Mauritius	4	46,387,178.00
17	Uganda	4	79,252,944.00
18	Comoros	3	71,964,746.00
19	Cote d'Ivoire	3	94,840,716.00
20	Liberia	3	44,469,391.00
21	Malawi	3	61,163,056.00
22	Mauritania	3	34,105,696.00
23	Mozambique	3	28,989,525.00
24	Nigeria	3	94,404,498.00
25	Seychelles	3	47,822,716.00
26	Botswana	2	44,391,973.00
27	Burundi	2	14,057,000.00
28	Cameroon	2	59,324,027.00
29	Djibouti	2	51,649,633.00
30	Gabon	2	35,631,662.00
31	Guinea	2	59,212,133.00
32	Guinea-Bissau	2	31,648,078.00
33	Lesotho	2	23,520,556.00
34	Sierra Leone	2	45,699,425.00
35	Somalia	2	61,090,278.00
36	Sudan	2	44,534,584.00
37	Togo	2	75,376,870.00
38	Tunisia	2	39,525,836.00
39	Zambia	2	79,687,218.00
40	Zimbabwe	2	35,432,883.00
41	Democratic Republic of Congo (DRC)	1	47,687,218.00
42	Eritrea	1	8,914,470.00
43	Eswatini	1	13,902,500.00
44	Niger	1	5,555,556.00
45	Sao Tome and Principe	1	39,250,000.00
46	Angola	0	0.00
47	Central African Republic	0	0.00
48	Congo	0	0.00
49	Equatorial Guinea	0	0.00
	Total	142	3,369,205,611.31