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WORKING PAPER

ADAPTING TO NATURAL DISASTERS IN AFRICA

What's in it for the Private Sector?

By Mounir Bari and Sébastien Dessus

International Finance Corporation
World Bank Group

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ABSTRACT

The private sector has an indispensable role to play in advancing climate adaptation and resilience building. The need for private sector solutions to address climate change impacts is even more pronounced in Africa given its sizable needs for adaptation and the limited fiscal space of most African states to adapt and build resilience to climate and disaster risks. However, mobilizing private investment in adaptation is made complicated by the difficulty for firms of measuring and internalizing the opportunity cost of no adaptation, and by limited practical knowledge on the bankability and cost-effectiveness of adaptation solutions. This paper tries to fill some of these knowledge gaps, first by assessing the economic costs of floods and droughts – the two most economically and socially damaging natural disasters in Africa; and second by measuring the upfront private investments needed in each African country to offset the losses induced by these disasters, assuming that such investments would generate a sufficient economic return. Using the traditional dynamic Solow model, we estimate the potential for private investment in adaptation to natural disasters in Africa by estimating the short- and long-term impact of floods and droughts on per capita GDP growth. As opposed to the more commonly used approaches of estimating the impact of natural disasters on productive assets, our methodology is very practical as it focuses on economic flows rather than stocks, is not data demanding, and does not require complex economic or environmental modelling, and can thus easily be applied on a large number of African countries to estimate the private investment potential in adapting to floods and droughts. Our empirical results suggest that the private sector could have an interest in investing up to about $100 billion cumulatively over the next 20 years, or $5 billion per year, to adapt to the current frequency and severity of floods and droughts in Africa. As such, our estimate corresponds to only a small fraction of what is projected by more traditional estimates which include public good requirements, cover a broader set of natural disasters and climate stressors, may project increases in the severity of natural disasters, and retain sometimes higher ambition than just to offset consequences of natural disasters. Nevertheless, our estimate is significant and well above current levels, especially in African countries most prone to floods and droughts.

Key Findings

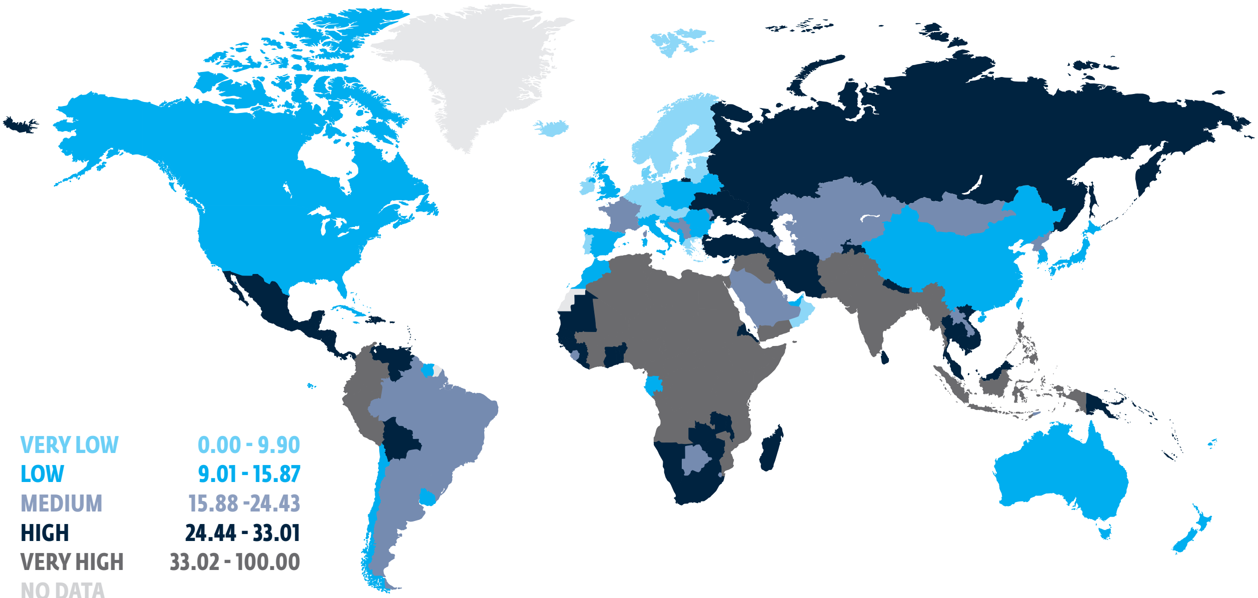
- Africa is the most vulnerable continent to climate change-induced natural disasters, such as droughts and floods.
- Most African governments do not have the capacity to finance the investments needed to respond and adapt to a higher frequency and severity of natural disasters.
- Floods and droughts have had a significant negative impact on African countries' GDP per capita over the period 1990–2019.
- The impact of natural disasters is long-lasting and smaller economies suffer disproportionally.
- Cumulatively, droughts and floods have lowered African countries' GDP levels by 0.7% and 0.4% respectively since 1990 on average.
- Under the assumption of unchanged severity and frequency of floods and droughts in the next 20 years, availability of adaptation technologies, and a favorable investment climate able to generate a private return of 8%, the private investment potential in upfront adaptation investments could amount to up to 4.0% of Africa's GDP, close to $100 billion in 2021, or US$ 5 billion a year.
- This amount would proportionately increase with the severity and frequency of natural disasters.
- By focusing only on bankable projects, this upper bound estimate represents only a small fraction of more general estimates that also comprise public objectives.
- De-risking instruments could attract higher private investments, bringing adaptation solutions to countries where they do not exist yet and demonstrating their impact and viability.

A. INTRODUCTION

There is clear recognition from the international community of the need to accelerate efforts to address the challenges posed by climate change. This is reflected in the Climate Change Action Plan (2021–2025) adopted by the World Bank Group in April 2021, which amounts to a commitment to identify the most effective ways to adapt to climate change and deploy climate finance while harnessing private capital in ways that deliver the best results.

The African continent is assessed to be the most vulnerable to the consequences of climate-induced natural disasters such as floods and droughts[1] (see Figure 1), in part because of its heavy reliance on rain-fed agriculture and its limited capacity to respond and adapt to shocks. And while if it needs to contribute to global mitigation efforts (in adopting notably the green technologies in housing, transport, and energy that will accompany its projected rapid development), adaptation efforts will be needed more in Africa than anywhere else. They include, inter alia, physical investments to better protect productive capacities (workers, natural capital, equipment, infrastructure) against natural disasters, and financial instruments to support these investments and to insure livelihoods against the economic damages created by natural disasters.

Figure 1. Vulnerability to climate change-induced natural disasters, 2022



Source: World Risk Index 2022. Note: Vulnerability comprises susceptibility, lack of coping capacities, and lack of adaptation capacities. It refers to social, physical, economic, and environmental factors that make people or systems vulnerable to the effects of natural hazards, the negative impacts of climate change, or other processes of change. Vulnerability also considers the capacities of people or systems to cope with and adapt to adverse impacts of natural hazards.

Estimates of how much investment is needed for Africa to adapt to climate change vary, reflecting uncertainty around the future growth trajectories of greenhouse gas emissions and their impact on environmental systems, differing definitions of adaptation needs, and diverse methodologies for assessing them (see Box 1). But there is some consensus that most African governments will not have the capacity to finance the necessary investments, including through the mobilization of official assistance, given their limited fiscal space and excessively high public debt levels.[2] A significant proportion of any investments in adaptation to climate change, therefore, will need to be implemented and financed directly by the private sector.

Mobilizing private investment toward adapting to climate change in Africa faces a number of obstacles, including the difficulty of measuring the opportunity cost for a firm of not undertaking such efforts, or of delaying them. There is also the challenge of insufficient practical knowledge around the economic efficiency of available and future adaptation solutions. These knowledge gaps, which compound structural issues in attracting private investment in Africa, act as strong deterrents to private sector investment in adaptation, as their viability cannot be properly assessed. As such, they also make it difficult to project, for macroeconomic management purposes, how much investment could realistically be mobilized from the private sector to enhance climate adaptation and resilience efforts.

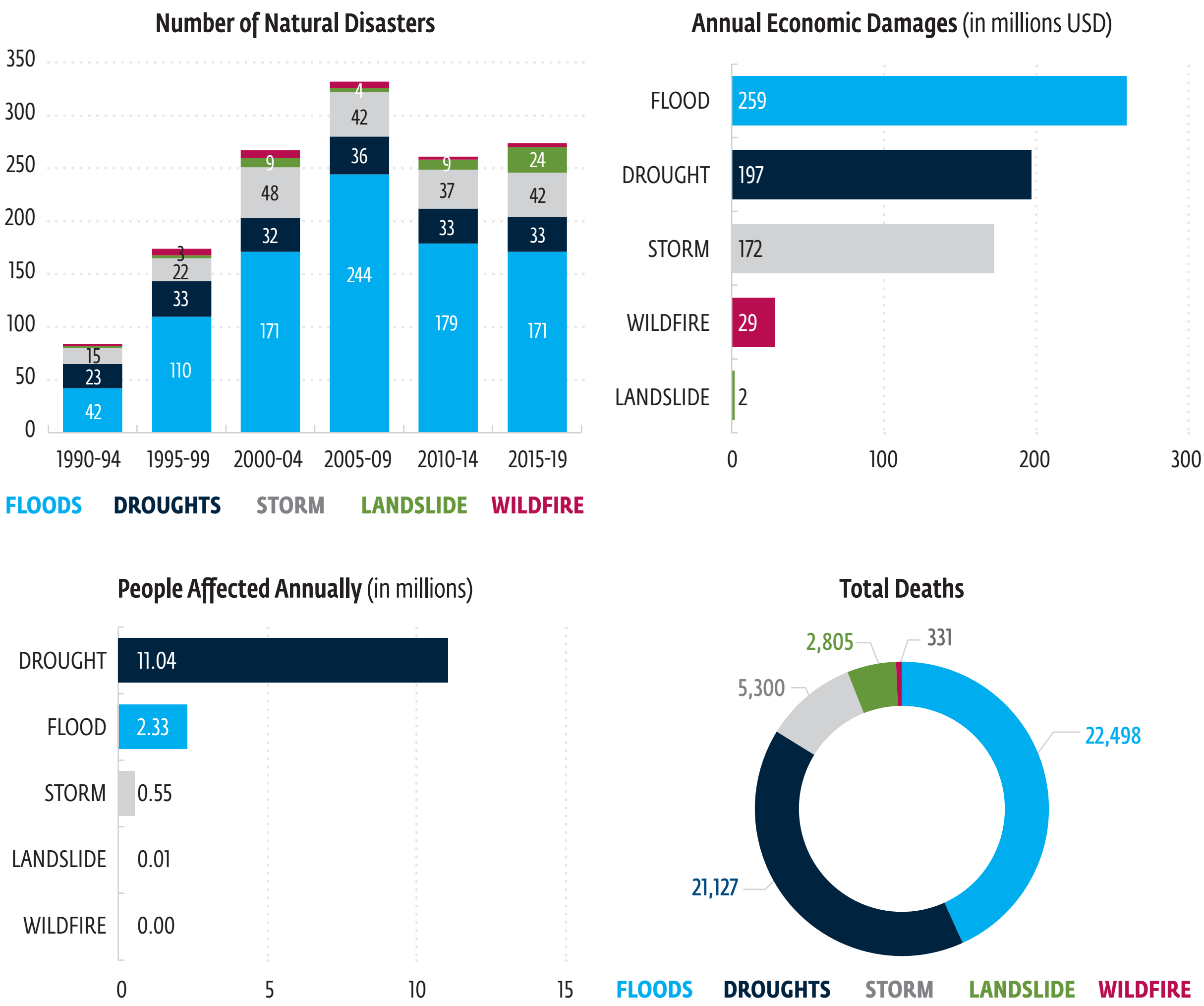
B. MAIN OBJECTIVE

This study aims to help fill these knowledge gaps in several ways. First, it systematically assesses econometrically the short- and long-term impact of specific natural disasters–namely droughts and floods, on per capita GDP growth in African countries. Second, it measures the upfront investments needed in each country to offset the losses induced by droughts and floods, assuming that such investments, as undertaken by the private sector, would generate a sufficient return over a 20-year period. Given that profitable investment may not necessarily always be possible in the absence of relevant technologies or a favorable investment climate, our estimate represents an upper bound for a given frequency and severity of future floods and droughts.

Our approach differs from others on several grounds:

By only focusing on floods and droughts, this approach does not seek to cover all adaptation needs stemming from climate change. While these two types of natural disaster are among the most common in Africa and the most damaging to livelihoods and infrastructure, there are many more consequences of climate change on the environment including precipitation abnormalities, rising sea levels, biodiversity loss, and heatwaves. In fact, Africa suffered from 1,107 climate-induced floods and droughts during the period 1990–2019, causing a total of 43,625 deaths, affecting 13.4 million people annually, and eading to at least $456 million in economic damages annually. (see Figure 2). On a continent already grappling with high levels of poverty and food insecurity, the current climate crisis is expected to especially amplify the devastating impact of floods and droughts,[3] making adaptation to climate change an urgent priority.

Figure 2. Africa: Impacts of Natural Disasters, 1990-2019



Source: Authors' calculations using Centre for Research on the Epidemiology of Disasters, Emergency Events (EM-DAT) Database. Note: Damages represent the total amount of damage to property, crops, and livestock at the moment of the disaster, measured by cost of repair. Actual damages are likely much higher as a number of reported disasters lack data on damage.

Another difference in our approach from previous studies is we aim to identify what could constitute the best private response to floods and droughts, as opposed to what the response from governments should be. Governments typically prioritize protecting public goods damaged by natural disasters such as infrastructure as well as protecting the most vulnerable households. This means governments adopt longer-term approaches with discount rates much lower than those retained by the private sector.[4] They also focus on structural measures to strengthen institutional capacity to cope with natural disasters in areas such as social protection and information systems.[5]

In contrast, private operators may decide not to invest in adaptation if they are uncertain the investments can be amortized rapidly (using higher discount rates) and generate sufficient economic returns. Inferior solutions, from a micro-economic perspective (a lower internal rate of return) but presenting high social returns and/or generating positive externalities, would need to be harnessed directly by the public sector (or indirectly by the private sector with subsidies to compensate for insufficient risk-adjusted returns, through the mobilization of de-risking instruments).

We also adopt a very simple methodology, which focuses on economic flows instead of stocks, is not data demanding, does not require complex economic or environmental modelling, and can thus easily be applied to a large number of African countries to calculate the private investment potential in adapting to floods and droughts. This departs from the more commonly used approaches of estimating the impact of natural disasters on productive assets through a cost of repairing or replacing approach, which cannot directly indicate the induced loss of future revenue and makes it difficult to compare potential private investments across countries.

Box 1. Investments Needed for Climate Adaptation in Africa: Unpacking the Existing Literature

The contribution of Africa to global greenhouse gas emissions is negligible, at just 3.8 percent.[6] Yet, a combination of geographical and socioeconomic factors coupled with its dependence on climate-sensitive sectors makes the region particularly vulnerable to natural disasters induced by climate change. As most African states lack the necessary financial clout to adapt and build climate resilience, climate change increasingly compromises Africa's sustainable development and upends millions of lives and livelihoods. This makes climate adaptation an urgent priority for the continent.

How much investment would be needed in adaptation and who will finance it are therefore crucial questions. Answering them, however, has proven to be a daunting task given mounting uncertainty surrounding climate change impacts and the required level of adaptation. In addition, estimates of adaptation needs are subject to large margins of error because of important information gaps and divergences of assumptions underlying the various estimates. These are mainly related to (i) the scope of adaptation needs (whether all relevant types should be covered), (ii) the scale of the estimates (whether, for a given impact, sector, or country, all relevant adaptation needs and tradeoffs are considered), (iii) the costing of adaptation measures (whether all relevant costs are considered), (iv) the time horizon of the estimates, and (v) the treatment of uncertainty (how uncertainty about future climate-induced shocks and technological advancement affect adaptation measures and their costing). These information gaps are further compounded by the lack of clear evidence of what adaptation measures are cost effective today, making estimates of investment needed for adaptation an important area for future study.[7]

Notwithstanding these information gaps, the literature points to various estimates of adaptation needs in Africa, which range between $7–15 billion per year by 2020.[8] These costs are projected to rise rapidly (e.g., $50 billion annually by 2050) as increased global warming results in higher costs associated with more frequent and more severe natural disasters (see Table 1). These estimates, however, often fail to disclose inter alia the scope of adaptation needs considered and the underlying methodology used, thereby limiting the scope of a proper benchmarking exercise.

Table 1. Literature Review: Estimates of Annual Adaptation Needs in Africa (in billion $)

	By 2020	By 2030	By 2050
AfDB, 2019; Schaeffer et al., 2013; Zhang & Pan, 2016; UNEP, 2015	**7–15**		
The Global Center on Adaptation [based on submitted Nationally Determined Contributions (NDCs) of 40 African countries]		**33**	
IMF, 2020		**30–50**	**>= 50**
AfDB, 2021		**30**	
UNEP, 2015; World Meteorological Organization, 2020		**7–15**	**50**
Puig et al., 2016		**44–74**	**89 – 163**
The Africa NDC Hub, 2021		**26–41**	
Chapagain et al., 2020			**11 – 36** (~1.5°C scenario) **18 – 59** (~ 2°C scenario)
Parry et al. (2009); Fankhauser & Schmidt-Traub (2010); Watkiss et al. (2010); AfDB, (2011); Dodman & Carmin (2011); LDC Expert Group (2011); Smith et al. (2011)		**=< 60**	

The Global Center on Adaptation highlights in its 2021 State and Trends in Adaptation Report that the NDCs of 40 African countries cumulatively show a need for an estimated $331 billion in investments in adaptation through 2030 ($33 billion annually, or about 1.4 percent of regional GDP).[9] The report shows that 15 countries[10] provided a breakdown of conditional[11] vs. unconditional cost estimates, with an average ratio of 80:20. Investment needs to be met by donors and the private sector would thus amount to $26 billion annually.

The International Monetary Fund (IMF) reports in its April 2020 Regional Economic Outlook for Sub-Saharan Africa that adaptation for the region will be expensive—estimated at $30–50 billion (2–3 percent of regional GDP) each year over the next decade—but less costly than frequent disaster relief.[12] If no concerted efforts are made, the IMF estimates that the cost could rise to at least $50 billion per year by 2050.[13]

The African Development Bank (AfDB) argues that climate adaptation could cost Africa over $30 billion per year by 2030, noting that the current levels of public finance are insufficient at a time when the private sector is largely absent from adaptation.[14]

The United Nations Environment Programme (UNEP) estimates that Africa requires $7–15 billion annually by 2030 to adapt to climate change and $50 billion annually by 2050 under a 2-degree warming scenario.[15] These estimates were corroborated by **the World Meteorological Organization (WMO)**, noting that African countries spent 2-9 percent of GDP to respond to climate events and environmental degradation (such as storms, floods, and landslides) in 2019.[16]

Puig et al. (2016) indicate that investments in adaptation will need to increase to six to 10 times the current threshold for African countries to meet their NDC goals and targets for 2030. They added that African countries could meet the 2050 targets for adaptation if they increase current investments by at least 12 to 22 times. It follows from their logic that the annual adaptation expenses of $7.4 billion[17] will need to increase to between $44–74 billion to meet the adaptation commitments for 2030. In a similar vein, adaptation investments will need to be in the range of $89 billion to $163 billion to meet all climate commitments for 2050.

The Africa NDC Hub estimates total adaptation needs for African countries for the period 2020-2030 to range between $259 billion and $407 billion, representing an annual average need comprised between $26 billion and $41 billion.[18] These estimates assume a linear increase in the project adapation cost during the considered period and are derived by multiplying the annual adaptation expenses for African countries of around $7.4 billion per year until 2020[19] by the increase in adaptation needs in 2030 relative to 2020, estimated to be factor of 6 to 10[20] (as previously discussed).

Chapagain et al. (2020) projects adaptation costs for Africa by 2050 to range between $11.5 billion and $36 billion per year for global warming around 1.5 degree Celsius, and $18–59 billion per year for global warming around 2 degrees Celsius. These estimates are based on a meta-analysis of the projected adaptation cost estimates and assume that future socio-economic trends do not shift markedly from historical trends. Other estimates reach $50–100 billion in scenarios for 2050[21] and 2100[22], respectively.

A number of studies have stressed the large-scale financial resources and technological support needed to both address Africa's current adaptation deficit and to protect rural and urban livelihoods, societies, and economies from climate change impacts at different local scales, with estimates of adaptation costs reaching up to $60 billion per annum by 2030.[23]

C. ESTIMATION METHOD AND RESULTS

In order to estimate the short- and long-term effects of droughts and floods on GDP, we use the traditional dynamic Solow model,[24] in which per capita GDP, *yc*, transitionally converges towards its steady state defined by investment (gross fixed capital formation) over GDP, *cf*, deflated by annual population growth, g, plus 5%[25]; and by the frequency and severity of natural disasters, d:

$$\ln\left(\frac{yc_{i,\,t}}{yc_{i,\,t\text{-}1}}\right) = \alpha \ln\left(yc_{i,\,t\text{-}1}\right) + \beta \ln\left(\frac{cf_{i,t\text{-}1}}{g_{i,t\text{-}1} + 0.05}\right) \gamma d_{i,\,t} + \rho_i + \delta_t + u_{i,t}$$

Per capita GDP is measured in purchasing power parity at constant price; investment comprises public and private investment; and natural disasters[26] reflect the proportion of the population affected[27] in a given year,[28] *t*, and country, *i*, by droughts[29] or floods[30] separately (sources: World Bank Development Indicators and EM-DAT database). As only capturing populations in need of emergency assistance as a result of a disaster, the natural disaster variables used in the analysis combine dimensions of breadth (number of people affected) and depth, or severity.[31] In addition, as implicitly retaining a Cobb-Douglas production (in line with the Solow model), we are capturing the impact of a disaster on GDP conditional on the level of capital stock (public and private infrastructure) present in the country at the time of the disaster. In other words, the same disaster will have a larger impact, in absolute terms, in a country with a larger capital stock.

Period and country-specific fixed effects are introduced to control for common temporal shocks across Africa, and to control for countries' permanent characteristics. As such, the estimated coefficients of the impact of natural disasters on per capita GDP growth only capture information contained in within-country co-movements between GDP and natural disasters. It does not, on the other hand, capture the information that could be contained in permanent differences between countries regarding GDP growth and the frequency and severity of natural disasters. We also use lagged investment to avoid endogeneity biases. Our coefficient of interest, γ, is obviously a reduced form of a complex relationship between economic activity and natural disasters,[32] but we believe it to be a robust one to capture the short- and longer-term impact of natural disasters on economic activity, as derived from a well-accepted growth specification and a sound econometric method.

We test this specification, using a GMM procedure[33] over the period 1990-2019 for all African countries which experienced at least one event of drought or flood and use annual data to best assess the short- versus longer-term dynamics between growth and natural disasters.

Results are reported in Table 1. All coefficients have the expected sign,[34] and are statistically significant.[35] Floods have a more adverse effect on per capita GDP than droughts. After one year, a flood (respectively a drought) affecting 1 percent of the population results in a drop in GDP per capita of 0.09 percent (respectively 0.03 percent). Assuming that floods and droughts only affect economically those affected by the disaster (i.e., with no spillovers to the rest of the population), one can infer that affected populations see their per capita GDP contract respectively by 9.0 percent and 2.7 percent a year after the disaster. Nevertheless, the long-term effect is much more pronounced: from our results one can infer that the impact of a natural disaster is long-lasting, as it takes about 11 years for countries to absorb half the total cumulative impact of floods and droughts. While the impact progressively dissipates over time, the cumulative impact over 11 years of a flood affecting 1 percent of the population will nonetheless be 0.36 percent of initial GDP (against 0.09 percent for the first year only). As for droughts, the cumulative effect over 11 years amounts to 0.10 percent (against 0.03 percent for the first year only).

Table 1. Estimated Impact of Floods and Droughts on per capita GDP Growth in Africa, 1990-2019

COEFFICIENT	FLOODS	DROUGHTS
α	-0.059 (6.1)	-0.063 (5.0)
β	0.015 (2.7)	0.021 (3.1)
γ	-0.090 (2.2)	-0.027 (2.1)
Number of countries	43	27
Observations	1244	780
Adjusted R^2	0.171	0.218
Durbin Watson	1.881	1.871

Source: Authors' computations. Note: T-statistics are reported in brackets.

Yet, while floods are more impactful, droughts have been more frequent in Africa over the period 1990–2019. On average, in each country, 1.9 percent of the population was affected by droughts every year, against 0.3 percent for floods. Thus, the actual average impact of droughts on GDP has been more pronounced, resulting in a GDP per capita 0.7 percent lower in 2019 than in a counterfactual scenario without droughts throughout the whole period, against 0.4 percent for floods. These are very similar results to IMF (2020) which imply a GDP per capita 1.3 percent lower after 30 years of average floods and droughts (although with a higher relative contribution of droughts).[36]

D. THE POTENTIAL FOR PRIVATE INVESTMENT IN ADAPTATION TO FLOODS AND DROUGHTS

From the results above, we can derive the potential for private investment in adaptation in each African country and across the continent, assuming (i) that such investments would generate a sufficient return over a reasonable period of time; (ii) that relevant technologies are available to adapt to climate change; and (iii) that the investment climate is overall favorable to attract private investment.

As a working assumption, we retain a real risk-adjusted rate of return of 8 percent, which is the lower threshold used at IFC to select investments, and an investment period of 20 years. Upfront investment needed to adapt is the amount that would generate a stream of future revenue exactly offsetting the output losses induced by the natural disaster with an internal rate of return of 8 percent. Thus, we also assume that the introduction of adaptation solutions only requires additional capital (as opposed to labor). While adaptation technologies are likely to require a combination of capital and labor, this assumption allows us to determine the maximum possible level of investment needed to adapt.

For an average African country (i.e., exposed to average floods and droughts as recorded since 1990), upfront investments needed today to adapt to droughts and floods over the next 20 years (assuming no change in the frequency and severity of droughts and floods) respectively amount to 5.1 percent and 3.1 percent of GDP.

Nevertheless, the severity of droughts and floods varies greatly across countries, and as such upfront investment needs could vary accordingly, from 0–21 percent of GDP for droughts and 0–16 percent for floods (see Figure 3 and Annex 1). In some countries, such as Eswatini, Malawi, Mauritania, Namibia, and Niger, the combined investment needs exceed 20 percent to adapt to the average frequency of droughts and floods recorded over the period 1990–2019.

At the aggregate level, accounting for the GDP sizes of the African countries considered,[37] the investment potential is lower than the unweighted average discussed above, as it only represents 2.2 percent and 1.8 percent of the total GDP of the 43 countries considered, hence suggesting that smaller economies have been disproportionally impacted by droughts and floods. This represents some $100 billion, to be spread over the next 20 years to adapt to these shocks.

Obviously, climate change is by definition dynamic, and climate projections unanimously anticipate an increased frequency and severity of floods and droughts, although within a wide range. Our specification implies a linear relationship between the frequency and severity of natural disasters and the potential for private investments to adapt.[38] Thus, a tripling of the frequency and severity of natural disasters in the period 2021–2040 compared with that recorded from 1990–2019 would imply a tripling in the potential for private investment to adapt to it (equivalent to 12 percent of GDP in 2021), assuming the bankability of such projects through the availability of relevant technologies, and a favorable investment climate. Our specification also implies a quasi-linear relationship between the requested return on investment and investment potential. As potential for savings are capped by the cost of not adapting to a given frequency and severity of natural disasters, the higher the expected return on the initial investment needed to generate these savings, the lower the investment amount itself (see Table 2).

Table 2. Potential for Private Investment in Adaptation in Africa, under Different Climate Scenario and Return Requirements (upfront investment, % of current Africa Total GDP, 43 countries)

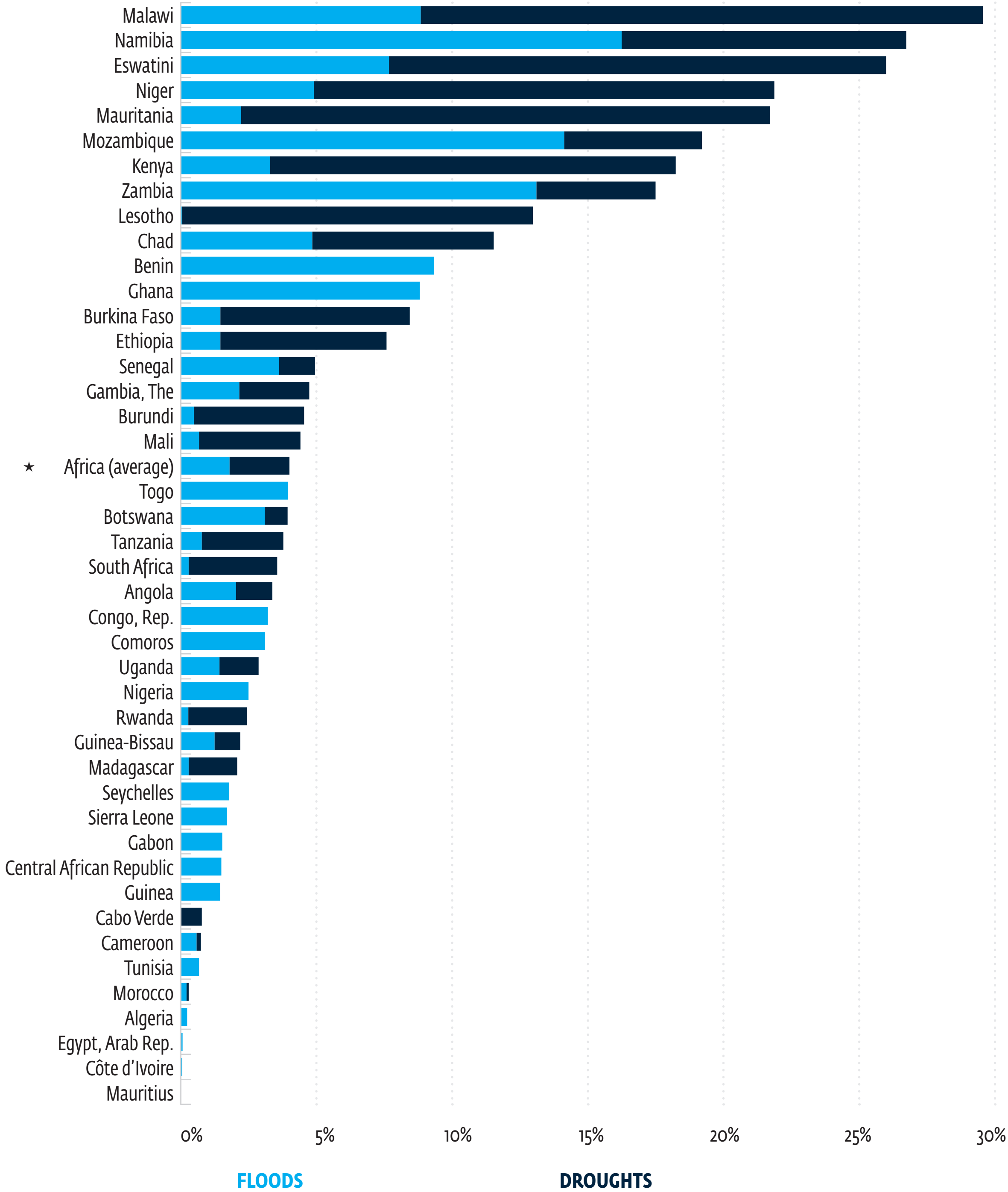
Climate/Return	5%	8%	11%
1990-2019 average	5.7%	4.0%	2.9%
Doubling by 2040	11.4%	8.0%	5.8%
Tripling by 2040	17.1%	12.0%	8.7%

Source: Authors' computations.

Thus, assuming that the severity of natural disasters would be thrice that recorded over the period 1990–2019 would imply generating private adaptation investment opportunities of up to $15 billion a year until 2040, for a return of 8 percent.

While methodologically difficult to compare with estimates reported in Box 1, our estimates represent a small fraction of broader estimates encompassing a larger set of climate stressors, natural disasters, and public investments amongst others. Their relevance stems from their micro-economic rationality, as opposed to macroeconomic ones summing up costs of investments deemed necessary to adapt to climate change in Africa.

Figure 3. **Upfront Private Investment Potential to Adapt to Droughts and Floods (% of GDP).**



Source: Author's computations. Note: figures reported indicate the upfront investment which would generate a stream of revenue equal to anticipated GDP losses from floods and droughts and an internal rate of return of 8%.

E. CONCLUSION

In Africa and elsewhere, the private sector has an evident interest in investing in adaptation to climate change, as it will directly internalize all its consequences. But it will only do so if it is convinced that this can provide positive economic returns, which remains a concern today, given firms' general lack of awareness of the opportunity costs of not acting and of the potential technologies that could be deployed. Additionally, adaptation investments tend to be cost saving in nature which, for various behavioral reasons, may be less attractive than revenue generating investments,[39] especially if cost-savings are only realized in the medium term (as private investors typically retain high discount rates).

Our estimate of the potential for private investment in adaptation against droughts and floods in Africa is only a small fraction of most estimates of climate change adaptation needs which consider public good requirements and a broader set of climatic consequences of greenhouse gas emissions. And it is an even smaller fraction when realizing that this estimate is an upper bound one. But it nonetheless remains very significant, and should be mobilized to the extent possible, given the very limited fiscal capacity of most African governments to finance adaptation investments. This calls for accelerated and coordinated efforts to encourage private investment in adaptation through general improvement in investment climates, and specific institutional and regulatory reforms[40] to promote the development of information systems on climate, weather-risk insurance, green finance, and easier access to adaptation technologies amongst others.

As investors tend to perceive higher risks in Africa than in other developing markets, support from development finance institutions will be equally important to help mitigate those risks, thereby shifting the balance between perceived risks and rewards through demonstration effects and the application of de-risking tools like guarantees and blended finance.

ABOUT THE AUTHORS

Mounir Bari is an Associate Economist covering the Horn of Africa at IFC's Regional Economics Unit for Africa, providing macroeconomic analysis, country diagnostics, strategies, and climate analytics that inform IFC investments and mobilization of private capital for development.

Sébastien Dessus was Manager of IFC's Regional Economics Unit for Africa when he co-authored this article and now manages the Global Trade and Regional Integration Unit at the World Bank. He holds a PhD in economics and has published extensively on growth and environmental issues.

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NOTES

1 Africa is home to 13 of the 15 world's most vulnerable countries, according to The World Risk Index (2022).

2 Average public debt over GDP in Africa reached 66 percent in 2021 (up from 39 percent in 2014), increasing debt service obligations and reducing countries' attractiveness for creditors, given heightened risks of debt distress.

3 Floods and droughts were identified as the natural disasters of greatest concern for the African region in the 2020 World Meteorological Organization's analysis of the nationally determined contributions (NDCs) of 53 countries in Africa.

4 See Heal (2009) for a discussion of discount rates used in public adaptation projects.

5 See Noble et al. (2014) for a discussion on the evolution of the definition of adaptation needs as understood by governments: "Assessments of adaptation needs, both in developing and developed countries, have often taken a hazard-based approach with a focus on drivers of impacts and options to moderate them. See Moser (2009); Finzi Hart et al. (2012). But more recently, the focus has been on tackling the underlying causes of vulnerability. See Füssel (2007). One of the few categorizations of needs is that of Burton et al. (2006), which recognizes information, capacity, financial, institutional, and technological needs.

6 See CDP Africa report, Benchmarking Progress towards climate safe cities, states, and regions (March 2020).

7 This view was corroborated by Solomon Hsiang in an exchange with the authors at the Economic Effects and Policy Reponses to Climate Change and Natural Disasters Conference, December 2021.

8 AfDB (2019); Schaeffer et al. (2013); Zhang & Pan (2016).

9 CPI analysis based on submitted NDC documents. As the methodologies for providing investment estimates varied widely, this aggregate figure should be considered only a rough estimate of the lower bound of investment needs, given 14 countries have not provided estimates and the scale of climate adaptation needs are likely to increase through 2030 beyond what is addressed by current finance.

10 Angola, Benin, Central African Republic, Chad, Democratic Republic of the Congo, Eritrea, Ethiopia, Ghana, Kenya, Niger, Republic of Congo, Rwanda, Senegal, Sudan, and Zimbabwe.

11 Conditional" refers to funding dependent on international support.

12 This is derived from Narain, Margulis, and Essam (2011) and United Nations Environment Programme (UNEP) (2016).

13 Africa Adaptation Acceleration Program Delivery Through COP26, AfDB (2021).

14 COP26: African Development Bank forges ahead with new Adaptation Benefits Mechanism, AfDB (2021).

15 Africa's Adaptation Gap 2: Bridging the Gap – mobilizing resources, UNEP (2015).

16 State of the Climate in Africa 2020, World Meteorological Organization (2020), library.wmo.int.

17 In several submissions under the UNFCCC, African governments identified billions of dollars in climate finance needs, with adaptation costs of at least $7.4 billion per year by 2020 for the subset of adaptation needs listed in the NDCs. See AfDB (2019); Zhang & Pan (2016).

18 Africa's NDC Journey and the Imperative for Climate Finance Innovation, the Africa NDC Hub (November 2021).

19 Analysis of Adaptation Components of Africa's Nationally Determined Contributions (NDCs), AfDB (2019).

20 The Adaptation Finance Gap Report 2016. UNEP (2016).

21 See Schaeffer et al. (2013).

22 See Schaeffer et al. (2015).

23 Parry et al. (2009); Fankhauser and Schmidt-Traub (2010); Watkiss et al. (2010); AfDB (2011); Dodman and Carmin, (2011); LDC Expert Group, (2011); Smith et al. (2011). Niang et al. (2014) cautioned that these estimates are likely to be underestimates, as studies upon which these estimates are based do not always include the costs of overcoming Africa's current adaptation deficit, may be run for one scenario at a time, and do not factor in a range of uncertainties in the planning environment.

24 We selected the Solow model as our empirical specification for being the most consensual, robust and simplest growth model while taking into consideration the dearth of annual data for a number of African countries. See Makiw et al. (1992) for a discussion of this specification, which reflects the dynamic nature of the Solow Model. See Solow (1956). The robustness of the Solow model was reaffirmed in recent literature, see Kremer et al. (2021).

25 Corresponding to the sum of the annual depreciation rate of the capital stock and the annual rate of technological progress, that we fix at 5 percent in line with the literature.

26 A disaster is defined by a situation or event which overwhelms local capacity, necessitating a request at national or international level for external assistance. More specifically, a disaster would have fulfilled at least one of the following criteria to be reported in the EM-DAT database: 10 or more people dead; 100 or more people affected; the declaration of a state of emergency; and/or a call for international assistance.

27 Affected populations are populations requiring immediate assistance during a period of emergency, i.e., requiring basic survival needs such as food, water, shelter, sanitation, or immediate medical assistance after a disaster.

28 A person affected twice during the year by two unconnected floods (or droughts) will be counted twice.

29 An extended period of unusually low precipitation that produces a shortage of water for people, animals, and plants.

30 A general term for the overflow of water from a stream channel onto normally dry land in the floodplain (riverine flooding), higher-than-normal levels along the coast and in lakes or reservoirs (coastal flooding) as well as pooling of water at or near the point where the rain fell (flash floods).

31 Attempts to introduce other variables to capture the severity of the disaster proved to be unsuccessful statistically, such as the number of deaths resulting from the disaster not improving the explanatory power of our model.

32 See Hallegate et al. (2020) for a detailed discussion of the various channels of influence of natural disasters on macroeconomic aggregates in the short and long term, and feedback loops.

33 Estimates are obtained through a Generalized Method of Moments (GMM) procedure to control for potential biases inherent in dynamic panels with fixed effects Nickell (1981).

34 The estimated coefficient for the investment variable implies a marginal elasticity of GDP to physical of about 0.5, in line with literature and observation of the share of capital remuneration over GDP in Africa.

35 Combining both droughts and floods in a single estimation generates similar results.

36 IMF (2020) uses a similar theoretical specification (introducing more control variables), though applied to the period 1960-2018, only to Sub-Saharan Africa and using 5-year periods instead of annual data in our case. Using a 5-year period, however, makes it easier to introduce control variables as they are more widely available.

37 Our sample of 43 countries represented 93.2 percent of African GDP in 2019.

38 Our approach is closer to the wider concept of adaptation finance for being context-specific, dynamic, and goes beyond just finance, see Terpstra and Ofstedahl (2013).

39 UNEP (2016)

40 World Bank Group (2021)

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ANNEX 1: PRIVATE INVESTMENT POTENTIAL IN ADAPTATION (% OF GDP IN THE INITIAL YEAR)

COUNTRY	FLOODS	DROUGHTS
Algeria	0.3%	0.0%
Angola	2.0%	1.3%
Benin	9.3%	0.0%
Botswana	3.1%	0.8%
Burkina Faso	1.5%	7.0%
Burundi	0.5%	4.1%
Cabo Verde	0.0%	0.8%
Cameroon	0.6%	0.2%
Central African Republic	1.5%	0.0%
Chad	4.9%	6.7%
Comoros	3.1%	0.0%
Congo, Rep.	3.2%	0.0%
Côte d'Ivoire	0.1%	0.0%
Egypt, Arab Rep.	0.1%	0.0%
Eswatini	7.7%	18.3%
Ethiopia	1.5%	6.1%
Gabon	1.5%	0.0%
Gambia, The	2.2%	2.6%
Ghana	8.8%	0.0%
Guinea	1.5%	0.0%
Guinea-Bissau	1.3%	0.9%
Kenya	3.3%	14.9%
Lesotho	0.1%	12.9%

COUNTRY	FLOODS	DROUGHTS
Madagascar	0.3%	1.8%
Malawi	8.8%	20.7%
Mali	0.7%	3.7%
Mauritania	2.2%	19.5%
Mauritius	0.0%	0.0%
Morocco	0.2%	0.1%
Mozambique	14.1%	5.1%
Namibia	16.2%	10.5%
Niger	4.9%	16.9%
Nigeria	2.5%	0.0%
Rwanda	0.3%	2.2%
Senegal	3.6%	1.3%
Seychelles	1.8%	0.0%
Sierra Leone	1.7%	0.0%
South Africa	0.3%	3.3%
Tanzania	0.8%	3.0%
Togo	4.0%	0.0%
Tunisia	0.7%	0.0%
Uganda	1.4%	1.4%
Zambia	13.1%	4.4%

Africa (43 countries), unweighted average	3.1%	5.1%
Africa (43 countries), weighted average	1.8%	2.2%