# Green Finance, Environmental Policy Stringency, and Biocapacity in Africa

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## Abstract

Climate funding alone is insufficient for achieving an environmentally benign future; policies enabling consumers and businesses to adopt eco-friendly products and adjust their consumption patterns are necessary. This study, therefore, aims to (i) investigate the effect of green finance on biocapacity in Africa and (ii) examine the moderating effect of stringent environmental policies on the relationship between green finance and biocapacity in the region. Due to data limitations, this study focuses on 24 African countries from 2000 to 2020. The results obtained through the FE Driscoll-Kraay, panel-corrected standard error (PCSE), and system GMM models are as follows: (i) Green finance positively enhances the biocapacity of African countries, with robust results observed across alternative specifications of biocapacity, including arable land, pasture, forest, and productive sea. (ii) The positive impact of green finance on biocapacity is modulated through increasingly stringent environmental policies. The results further suggest that green finance enhances biocapacity in countries with more stringent environmental regulations than in countries with less stringent regulations. The study recommends, among other things, the need for African countries to strengthen their environmental policies to enhance biocapacity.

**Keywords:** green finance; environmental policy; biocapcity; Africa

## 1. Introduction

In recent years, financing sustainable development has garnered attention and discussion worldwide (Nchofoung and Ojong, 2023). In this respect, several sources of finance have been explored in the literature, and empirical analyses have argued the importance of each of these sources of finance and their possibilities to be eco-friendly (Ozili, 2022; Lee and Lee, 2022). Green finance is one form of finance that governments and multilateral development agencies have advocated for recently (Sachs et al., 2019). Environmental funds, climate debt swaps, nature-linked securities, and ecological options are examples of the financial products available in the green finance market.

Insisting on the actual situation of this climate finance, multilateral development agencies pledged $30,165 million in 2018 to combat climate change, of which a staggering 71% of investment loans and another 7% of policy-based finance (Nawaz et al., 2021). These finances have mainly been invested in innovative eco-friendly projects across countries. They are regarded as sustainable eco-technologies that lessen the environmental load of addressing the unfavourable ecological effects. Moreover, environmentally conscious innovations prioritise creating clean energy sources, reduced resource waste, low air pollution, and efficient use of natural resources such as water, land, forests, and the ocean (Jin et al., 2021; Afshan et al., 2023). These environmental conscience innovations, including green technologies, necessitate massive financing, which has hindered continuous environmental sustainability in many developing economies in general and Africa in particular (Fotio et al., 2022). Human ingenuity to encourage the use of renewable and non-renewable natural resources has been demonstrated throughout history, and a contextualisation of these ideas is suggested, focusing on pertinent current studies. According to the research, some academic works stand out because they go beyond simple comprehension to develop and put into practice techniques to lessen ecological footprint and make the most of Biocapacity awareness (Moros-Ochoa et al., 2022).

Therefore, this study's objectives are: (i) to examine the effect of green finance on biocapacity in Africa and (ii) to examine the modulating effect of stringent environmental policies in the relationship between green finance and biocapacity in Africa. The research focuses on Africa because of several factors that make it unique. (i) Climate finance needs for the continent are estimated at $2.5 trillion between 2020 and 2030, or $250 billion per year. However, by 2020, only about $30 million was mobilised, representing just about 12% of the required amount (Climate

Policy Initiative, 2022). (ii) According to the African Development Bank (AfDB), there is much room for growth in climate finance in Africa. By late 2022, global pension fund assets in the 22 largest markets had risen to a new high of $56.6 trillion, while private equity funds under administration had reached a record $6.3 trillion in 2021 (AfDB, 2023). (iii) According to the Food and Agricultural Organisation (FAO) of the United Nations, Africa lost twice as much forest per year between 2015 and 2020 (4.4 million hectares) than the rest of the world. While deforestation increases the amount of land available for agriculture, it also depletes the soil of essential nutrients, resulting in only temporary crop growth. (iv) Over 50% of Africa's eco-regions have lost 50% of their land due to deterioration, agriculture, or urbanisation. The continent has an ecological deficit because its production footprints exceed its biocapacity, which suggests that domestic natural capital is being destroyed by carbon dioxide emissions that exceed the capacity of the environment to absorb them (Mansourian and Berrahmouni, 2021). In contrast to the global average of 2.8 hectares per person and a biocapacity of 1.15 hectares per person, Africa's ecological footprint in 2018 was 1.35 hectares per person (Mansourian and Berrahmouni, 2021; Yang et al., 2022). Ecological deficits, therefore, imply that the ecological footprint of the continent has exceeded its biocapacity, demonstrating that the continent's ecosphere is dangerous and unsustainable. (v) The rate of industrial growth in the continent is on a rapid rise at the same time when the population is growing briskly, with the natural environment increasingly being exploited, leading to a drop in the performance of ecological resources (Nkemgha et al., 2023; Nchofoung and Ojong, 2023).

For green finance to have a long-run impact on the environment, there is a need for stringent environmental policies to be put in place in the continent. Environmental regulations will only substantially impact development and environmental protection in Africa if policymakers pay attention to the main factors that drive biodiversity conservation and environmentally friendly practices (Kelbessa, 2014). In reality, if investments in environmentally friendly projects continue to rise, the products of these projects are often more expensive than non-environmentally friendly products. Most people, particularly in Africa, will continue to use non-environmentally friendly products. Renewable energy is a clear example on the continent, with a higher acquisition cost than non-renewable energy. Fossil foil supplies are abundant throughout the continent at a low cost. Climate funding is thus not a good step towards an environmentally benign future; policies that enable consumers and businesses to adjust their consumption patterns towards adopting these eco-friendly products have yet to be implemented.

Environmental stringent policies are quickly becoming the bedrock of environmental sustainability and a remedy for environmental degradation. They are documented in the pollution heaven hypothesis as a channel through which financial resources can be mobilised to enhance environmental productivity (Solarin et al., 2017). Nonetheless, this policy instrument is just one of many available to combat the adverse effects of global warming and climate change and preserve the earth's surface's biodiversity (Wang et al., 2022). However, the relationship between ecological footprint and biocapacity is still being determined, making policies in this respect more complex. An increase in the ecological footprint in developing countries would weaken biocapacity. In contrast, biocapacity will be strengthened by an increase in the ecological footprint in developed countries, showing that biocapacity is affected differently depending on the state's level of development (Shen and Yue, 2023). For policies towards sustainability to be effective, there is, therefore, the need to examine the determinants of biocapacity different from those of ecological footprint. First, some studies argue that policies reduce human pressure on the environment by reducing the ecological footprint (Nathaniel et al., 2019; Emmanuel et al., 2023). Other studies argue that policies that increase the biocapacity of the ecosystem are the best policy for handling this distress (Dinga, 2023). In this regard, Celik and Alola (2023) argue the importance of implementing labour standards and increasing financial globalisation to limit ecological deficiencies. This study, therefore, seeks to answer the following research questions: (i) what is the effect of green finance on biocapacity in Africa? (ii) What is the modulating effect of environmental stringency in the green finance-biocapacity relationship?

The study contributes to the extant literature on environmental sustainability and biodiversity conservation by explaining the factors of biocapacity. This is the first study to examine the combined effect of stringent environmental policies and green finance on biocapacity. The closest studies to this effect are those of Afshan et al. (2023) for China and Sampene et al. (2022) for South Asian economies. These studies focused on ecological footprint and ignored biodiversity as a measure of sustainability. At the same time, closing the ecological deficiency gap requires the mastery of both the biocapacity and the ecological footprint of the economy. Also, underlined studies have yet to examine an African case, whereas the continent is unique in its climate financing needs and ecological deficiency pattern. Besides, this is the first study that examines the modulating effect of stringent environmental policies on the relationship between climate finance and environmental sustainability.

Away from this introductory part, this paper is further organised as follows: Section 2 examines the literature review, section 3 focuses on the methodology and data, section 4 presents and discusses the results and finally, section 5 concludes.

## 2. Literature review

### 2.1 Theoretical underpinnings

Section 2.1 presents the theoretical underpinnings and the empirical literature on green financing and biocapacity, considering the role of stringent environmental policies. The environmental economics literature attempts to address environmental degradation issues at the advent of the fourth industrial revolution. To address the adverse ecological spillovers, ecological productivity is discussed to be impacted by man's intervention in exploring the natural environment. Among the theories documented explaining the effect of man's activities on the environment comes the environmental Kuznets curve, which posits that environmental degradation increases at the early growth phases than at the later stages (Grossman and Krueger, 1991, 1996). This theory changed the discussions of a sustained environment from the limited capacity of the planet to absorb industrial waste to developing stringent policies to reduce greenhouse gases and counteract poor technologies (Solarin et al., 2017; Gill, 2018). In addition, this theory posits that stringent environmental policies and other environmentally friendly strategies, such as clean technologies and the creation of renewable energy sources, are introduced in later stages of production, where the welfare of individuals tends to be a priority.

Moreover, the pollution heaven hypothesis is also one of the prevalent theories underpinnings green investments and environmental quality. This theory posits that firms seek to relocate to environments with relaxed environmental norms to avoid the cost of stringent environmental regulations (Zhong, 2022). This theory applies to Africa and is considered by industries in developed economies as a pollution heaven with relaxed environmental norms. As per green financing, the price for environmental taxes has to be increased by integrating the banking sector to provide financial resources and contributions for maintaining environmental quality. Predicting the cost of stringent policies to preserve ecological biodiversity, this theory presents the relaxation of environmental norms as the leading cause of environmental deterioration that has to be counteracted by green financing and clean environmental technologies. As the focus of this study discussed in the present work, green financing is considered the most efficient technique for enhancing environmental quality, supported by contemporary literature (Afshan et al., 2022; Sharif et al., 2022). Supporting the two theoretical underpinnings, the ideology initiated by Fussler and

James (1996) underpins the relationship between green financing, environmental technology and sustainability. This initiation supported that financial resources contribute to enhancing environmental quality through the income generated to finance environmental technologies and innovative technical creations that can reduce the ecological footprint and embrace green technologies.

### 2.2. Empirical literature

Empirically, studies establishing the relationship between green financing and environmental quality present different stringent environmental policies depending on the various objectives and growth phases. The first strand of this work examines the direct link between green financing and environmental productivity, followed by the moderating channels through which the possible spillovers could be moderated or influenced.

#### 2.2.1. A review of the direct linkage between green financing on biocapacity

The initiative of green financing is promoted to preserve biodiversity and needs to be applauded and enhanced. This financing involves investments in the industrial, manufacturing, agricultural and service sectors by adopting sustainable ways of production and developing ecological productivity strategies of surveillance and preservation of biodiversity. Green financing is critical in the era of structural transformation, where technology is becoming the other of the day. The nexus between green economies and financing remains a vibrating research topic, especially in the pollution heaven hypothesis, where green financing is seemingly less, if present. Studies conducted on the direct relationship between green financing have supported its enhancing effects on biocapacities and environmental productivity, such as Wang et al. (2021); Saeed Meo and Karim (2022), who found that green financing encourages enterprises to invest in new clean technologies such as non-fossil innovation investment which helps to reduce the detrimental impacts of global warming. These authors found a significant enhancing effect of green financing on environmental sustainability. This strand of literature is supported by the works of Kirikkaleli and Adebayo (2021) and Du et al. (2019), whose findings indicate how green investments funds environmental policies. Other studies, such as Sampene et al. (2022), demonstrated how financially incapacitated developing countries can be to enhance ecological productivity, considering what is demonstrated in Kuznet's hypothesis in the early growth stages. In this strand, green financing in the early stages of growth is always very low and tends to be insignificant in enhancing environmental quality. Among the studies that supported this relation are mostly the proponents of the Kuznet hypothesis, who considered the biocapacity levels of the environment to be enhanced through environmental regulation and financing cleaner environmental technologies; which in this study, we consider the environmental policy as a channel through which the highlighted insignificant relationship can be activated to enhance biocapacity. Employing ecological debt as an indicator of green financing, Cranston et al. (2010) found that environmental debt significantly enhances environmental productivity at varying geographic characteristics. Though the findings of Cranston et al. (2010) tend to be refuted by Akam et al. (2022), who argued on the basis that external debts in Africa are attributed to the industrial sector that generates more greenhouse gases than the insufficient environmentally controlled investments cannot control. The findings of Akam et al. (2022) reveal that external debt increases the ecological footprint and reduces biocapacity in South Africa and Algeria. In addition, Nketiah et al. (2022) support this strand of literature by demonstrating how financing renewable energies as an indicator of green financing help boost biocapacity and reduce the ecological footprint.

#### 2.2.2. The moderating role of environmental policies in the green financing-biocapacity relationship

This section justifies the channels through which environmental policies enhance green financing to protect biodiversity loss. The argument is drawn from the pollution heaven hypothesis, in which authors have sought to determine the strictness or severeness of restrictions imposed on productive agents of the economy. The stringent policies are documented in the pollution heaven hypothesis as a channel through which financial resources can be mobilised to enhance environmental productivity (Solarin et al., 2017). Similarly, the Pigovian theory, which stipulates an imposition of tax to discourage activities that impose a cost of production onto third parties and society, underpins this section of the study (Puaschunder, 2020; Hancock, 2019). These two theories support stringent environmental policies to limit activities and create a platform that encourages innovative and improved production methods. This part of the review made us understand the importance of setting stringent policies that must be doable and communicable to ensure advancements in other goals of ensuring economic and financial sustainability rather than putting regulations that will slow economic performance (Sampene et al., 2022). A lot has to be done to determine the channels to enhance green financing for biocapacity in scientific research. In this study, we have chosen environmental policy as a channel considering other possible channels, such as renewable energies, technology intensity and human capital development, which have to a certain extent, been explored in literature. In these channels, Sampene et al. (2022) found that green financing and financing renewable energies enhances biocapacity and reduces ecological footprint. In addition, in support of technology as a channel moderating the biocapacity-green financing nexus, Awawdeh et al. (2021) found that environmental quality is enhanced by financing clean technologies. This work focuses on environmental policies to establish appropriate and doable strategic policies to enhance green financing for biocapacity in Africa.

## 3. Data and Methodology

### 3.1. Data and description of variables

The data for this study are collected from several sources; that on green finance is obtained from the OECD database, data on environmental stringency is collected from the Yale University database, that on biocapacity is collected from the footprint initiative of the York University and the rest of the variables are from the World Development Indicators of the World Bank. The period of study spans from 2000-2020 for 24 African countries[1]. The choices of countries and study periods are constrained by data availability on the principal variables under investigation.

Dependent variable

The dependent variable of the study is biocapacity. It is measured at the first instance through total biocapacity per capita, which is the sum of the capacity of cropland, grazing land, fishing grounds, built-up land, and forest carbon uptake. These sub-indicators are further integrated as dependent variables for robustness purposes. Recent literature has used similar indicators for measuring biocapacity (Shen and Yue, 2023; Celik and Alola, 2023).

**Independent variables of interest**

The first independent variable of interest is green finance, proxied by all donors' total mitigation-related climate finance. Doku et al. (2021) argue about a climfin's effect of green finance on deforestation in Sub-Saharan Africa. The effect of green finance on biocapacity can therefore be positive or negative in this study depending on the policies for biocapacity conservation. Also, stringent environmental policies are the next explanatory variable of interest and are expected to

[1] These countries are: Botswana, Burkina Faso, Burundi, Cameroon, Central Africa Republic, Chad, Congo. Rep., Congo. Dem. Rep., Côte d'Ivoire, Lesotho, Madagascar, Malawi, Mali, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zambia

yield a positive sign per the study of Appiah et al. (2023). The variable ranges between 0 and 100, with 100 indicating the most stringent policy.

**Control variables**

To limit possible variable omission bias in our model, control variables are included based on attendant literature on the determinants of biocapacity (Doku et al., 2021; Dinga, 2023). The control variables are the population growth rate, renewable energy, technology, and financial development. A developed financial system facilitates the award of credits to green investors for green development, consequently closing the ecological gap through biocapacity preservation. Also, production technology, which is derived from the IPAT identity (Perman et al., 2011)[2], is used to capture the efficiency of production technologies on the environment. It represents the waste generated per unit of production and is expected to be negative. If more efficient and environmentally friendly technologies are used, there will be less gaseous emission into the environment and hence, environmental sustainability. This aligns with an increase in population growth, given that population growth leads to the destruction of biocapacity for human settlement and productive activities for sustainable livelihood. Renewable energy, on its part, is expected to enhance biocapacity due to its ability to close the ecological deficit gap, as water pollution from fossil fuel use can be controlled (Appiah et al., 2023). Table 1 summarises the variables with their expected signs.

**Table 1. Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max | Expected sign |
|---|---|---|---|---|---|---|
| Biocapacity | 456 | 16.693 | 1.014 | 14.266 | 18.748 | |
| green finance | 466 | 9.475 | 2.541 | .286 | 14.458 | + |
| Environmental stringency | 492 | 35.446 | 9.814 | 15.136 | 60.436 | + |
| Population growth | 504 | 2.575 | .889 | -.616 | 5.605 | - |
| Renewable energy | 480 | 75.199 | 20.859 | 10.45 | 98.34 | + |
| Technology | 504 | 0.000363 | 1.024 | 0.000195 | 0.000985 | - |
| Financial development | 497 | 14.962 | 11.661 | .491 | 71.638 | + |
| Bio built-up land | 437 | 13.117 | 1.373 | 8.841 | 16.214 | |
| Bio carbon | 19 | 15.011 | .32 | 14.491 | 15.375 | |
| Bio cropland | 418 | 15.089 | 1.545 | 10.804 | 18.406 | |
| Bio fishing grounds | 399 | 13.434 | 1.769 | 9.29 | 16.682 | |
| Bio forest products | 437 | 14.633 | 2.136 | 8.25 | 17.304 | |
| Bio grazing land | 437 | 15.502 | 1.347 | 13.269 | 18.866 | |

[2] The identity is given as $I = PAT$, where I is CO2 emission, P is the population size, A is per capita growth domestic product, and T is technology (waste generated per unit of production). Therefore, $T = {}^{I}/_{PA}$

Table 1 shows that biocapacity in our sample is distributed around the mean value (low standard deviation scores), with a similar trend observed for green finance. However, the environmentally stringent policy variable is highly dispersed from the mean, with a mean value of 35.446, a minimum value of 15.136 and a maximum value of 60.436. Before proceeding to our model specification and choice of regression methodology, we test the presence of cross-sectional dependence in our data. In this respect, the Pesaran (2015) test of weak cross-sectional dependence is apparent in Table 2.

Table 2. Test of cross-sectional dependence

| Variable | CD-test | p-value | average joint | mean ρ | mean abs(ρ) |
|---|---|---|---|---|---|
| Biocapacity | 11.756 | 0 | 19 | 0.16 | 0.61 |
| Green finance | 39.78 | 0 | 18.17 | 0.56 | 0.56 |
| Environmental stringency | 10.094 | 0 | 20 | 0.13 | 0.62 |
| Population growth | 0.13 | 0.896 | 21 | 0 | 0.48 |
| Renewable energy | 29.737 | 0 | 20 | 0.4 | 0.54 |
| Technology | 80.615 | 0 | 19.20 | 0.91 | 0.91 |
| Financial development | 54.179 | 0 | 20.43 | 0.72 | 0.72 |
| Bio built-up land | 48.867 | 0 | 19 | 0.65 | 0.7 |
| Bio carbon | 10.250 | 0 | 20 | 0.12 | 0.12 |
| Bio crop land | 32.03 | 0 | 19 | 0.4 | 0.53 |
| Bio fishing ground | 43.055 | 0 | 19 | 0.52 | 0.71 |
| Bio forest product | 45.512 | 0 | 19 | 0.6 | 0.85 |
| Bio grazing land | 19.41 | 0 | 19 | 0.26 | 0.54 |

Table 2 shows that there is cross-sectional dependence between the variables under study except for population growth which is cross-sectional dependent.

### 3.2. Model specification and regression methodology

Based on extant studies on the determinants of biocapacity conservation (Shen and Yue, 2023; Celik and Alola, 2023), we specify a linear model with biocapacity as the dependent variable and the explanatory variables as defined in the previous section.

$$\boldsymbol{Biocap_{it} = \beta_0 + \beta_1 G\_Fin_{it} + \beta_2 ESP_{it} + \beta_j X_{it}} + \mu_{it} \qquad (\mathbf{1})$$

*Biocap* is the biocapacity, G_fin is green finance, ESP is environmental policy stringency, X is a vector of control variables, μ is the error term, β is the coefficient of the explanatory variables, and j is the number of control variables. We specify a model considering an interactive relationship to evaluate the modulating effect of environmental stringency on the relationship between green finance and biocapacity.

$$\boldsymbol{Biocap_{it} = \beta_0 + \beta_1 G\_Fin_{it} + \beta_2 ESP_{it} + \beta_j X_{it} + \pi(G\_fin * ESP)_{it} + \mu_{it}} \quad (2)$$

Where π is the coefficient of the modulating variable and can take either a positive or negative sign. If π and $\beta_1$ have the same signs, then there is a synergy effect between the direct and the indirect effects. However, if the signs are opposing, then there is a need to specify the net effect, which is calculated as follows:

$$Net\ effect = \beta_1 + (\pi * \overline{ESP}) \qquad (3)$$

$\overline{ESP}$ is the modulating variable's average (environmental stringency) and can be negative or positive depending on the signs and magnitude of $\beta_1$ and π.

Given the presence of cross-sectional dependence in our data, we estimate equation 1 in the first place through the Driscoll and Kraay (1998) standard error estimator. The limiting behaviour of the number of panels is unaffected by this nonparametric method of computing standard errors, even if the number of cross-sections is substantially greater than the time period (Hoechle, 2007). The error structure is assumed to be heteroskedastic, auto-correlated up to a certain lag, and maybe correlated between the groups (panels). To test the robustness of our results, we further use the panel-corrected standard error estimator, which also corrects for cross-sectional dependence under the assumption that the error structures are heteroscedastic and correlated between panels (Greene, 2012). However, these highlighted methods cannot correct for possible endogeneity resulting from double causality or model misspecification. In this regard, we use the system GMM methodology developed by Arellano and Bond (1991) and extended by Arellano and Bover (1995) and Blundell and Bond (1998).

In the system GMM estimation strategy, one encounters several problems, which are the problems of identification, simultaneity and exclusion restrictions. To solve these problems, the explanatory variables are treated as endogenous per the recent literature on the GMM specification (Asongu and Nwachukwu, 2017; Nchofoung et al., 2023). Also, the lagged values of the explanatory variables are retained as instruments and further collapse to limit their proliferation. Following the study of Roodman (2009), the forward orthogonal deviation is used, which adjusts the instruments so that they are exogenous to the fixed effects. Besides, the two-step procedure is preferred because Windmeijer (2005) claims that two-step GMM estimates coefficients slightly and performs better than one-step GMM, with lower bias and standard errors. Furthermore, with his modification, the reported two-step standard errors are exact, appearing to outperform the cluster-robust one-step estimation corrected standard errors marginally.

## 4. Results and discussions

This section begins by presenting the results of the effect of green finance on biodiversity using the different regression methods, the different proxies for biodiversity, and the indirect effect regression.

### 4.1. Baseline results

Table 3 shows that green finance, environmental stringency and renewable energy enhance biocapacity conservation in Africa, while population growth and technology have negative effects. The results are robust across the different estimation methods.

**Table 3. Effect of green finance and environmental stringency on biocapacity**

| Variable | (1) FE_DK | (2) PCSE | (3) GMM |
|---|---|---|---|
| L.biocapacity | | | 0.78983 *** |
| | | | (0.0119) |
| Green finance | 0.0170*** | 0.0184*** | 0.00422*** |
| | (0.00413) | (0.00484) | (0.000950) |
| Environmental stringency | 0.00414*** | 0.0123*** | 0.00109*** |
| | (0.00139) | (0.00315) | (0.000278) |
| Population growth | -0.0192*** | -0.0934*** | -0.0134*** |
| | (0.00581) | (0.0314) | (0.00408) |
| Renewable energy | 0.00692*** | 0.0124*** | 0.000811** |
| | (0.00115) | (0.00237) | (0.000375) |
| Technology | -0.00570 | -0.00986 | -0.0359*** |
| | (0.00384) | (0.0154) | (0.00991) |
| Financial development | 0.00307** | 0.00292 | 0.000564 |
| | (0.00111) | (0.00453) | (0.000355) |
| Constant | 17.14*** | 15.36*** | 0.0574 |
| | (0.124) | (0.281) | (0.187) |
| Observations | 409 | 409 | 393 |
| R-squared | | 0.985 | |
| Number of countries | 24 | 24 | 24 |
| Fisher | 408.4*** | | 10043*** |
| chi2 | | 68.58*** | |
| Prop>AR1 | | | 0.0176 |
| Prop>AR2 | | | 0.1657 |

| | |
|---|---|
| Instruments | 19 |
| Prop>Hansen | 0.199 |

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The positive effect of green finance corroborates the results of Doku et al. (2021) for Sub-Saharan Africa, and several factors can explain these results: green finance can act as existing capital that helps finance green investment projects such as renewable energy. Renewable energy, on its part, replaces fossil fuels, whose pollution effect on water sources and air quality has been eminent. With green finance, adequate R&D funding can assist the development of clean technologies, directing the restructuring of high-consumption companies' energy consumption patterns to reduce carbon emissions. The long-term viability of the green economy is ensured by investing in green securities, as businesses employ eco-friendly practices in their production processes to ensure the welfare of society as a whole and biocapacity conservation in particular (Mngumi et al., 2022).

Also, the positive effect of stringent environmental policies on biocapacity is in line with the study of Appiah et al. (2023) for OECD economies. The environmental policy addresses water and air pollution, chemical and oil spills, smog, drinking water quality, land conservation and management, and wildlife protection, such as preserving endangered species. Environmental stringent policies would cause companies to adopt environmentally friendly production techniques to adapt to the environmental regulations in force. Each year, Africa loses 1.3 million hectares of forest. Since 1950, 65% of the agricultural land on the continent, or an estimated 500 million hectares, has been impacted by soil degradation; much of this is due to overgrazing. By 2025, eleven African countries are anticipated to join the fourteen that now experience water stress or scarcity.[3]. In this regard, there is an urgent need to address inadequate land management practises and improper land tenure structures, which cause soil degradation and non-optimal land use, given that most people in Africa depend on land and forest resources for their livelihoods. This can only come through the putting in place of stringent environmental policies, which can cause individuals and firms to adopt an environmentally friendly consumption pattern.

Looking at the control variables, the negative effect of population growth on biocapacity sustains the results of Zakari et al. (2022) for African top carbon consumers. In reality, an increase in population increases the human pressure on the environment, as the excess population require lands to settle and cultivate for livelihood. Also, their activities lead to an increase in gaseous

[3] See AfDB at: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/10000027-EN-BANK-GROUP-POLICY-ON-THE-ENVIRONMENT.PDF.

emission, which pollutes water bodies. That goes the same for technology, which Nchofoung and Asongu (2022) argue is detrimental to sustainable development. This is remarkably realistic in Africa given that dirty energy is still widely used for production and the production systems are still very inefficient, leading to continuous environmental degradation of productive activities.

### 4.2. Robustness Analyses

In this sub-section, we use alternative measures of biocapacity and the effects of green finance and environmental policy stringency examine once more.

Table 4. Alternative specification of biocapacity

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variable | Bio built-up land | Bio carbon | Bio cropland | Bio fishing grounds | Bio forest products | Bio grazing land |
| Green finance | 0.236*** | 0.00565 | 0.231*** | 0.171*** | 0.122** | 0.116*** |
| | (0.0306) | (0.00695) | (0.0342) | (0.0336) | (0.0507) | (0.0174) |
| Environmental stringency | 0.00547 | 0.00181 | 0.00974*** | 0.00817*** | 0.0687*** | 0.0480*** |
| | (0.00336) | (0.00617) | (0.00331) | (0.00364) | (0.00535) | (0.00304) |
| Population growth | -0.429*** | -2.094*** | -0.604*** | -0.110** | -0.0383 | -0.0983*** |
| | (0.0291) | (0.465) | (0.0311) | (0.0501) | (0.0555) | (0.0310) |
| Renewable energy | 0.0414*** | 0.000690 | 0.0506*** | -0.0304*** | 0.0154*** | -0.000580 |
| | (0.00192) | (0.0106) | (0.00194) | (0.00497) | (0.00458) | (0.00240) |
| Technology | -0.00751 | 1.659*** | 0.0794 | -2.066*** | -0.0677 | 0.0202 |
| | (0.0779) | (0.595) | (0.0850) | (0.210) | (0.212) | (0.0184) |
| Financial development | 0.0244*** | 0.0981*** | 0.0211*** | 0.112*** | 0.0315** | 0.0841*** |
| | (0.00742) | (0.0103) | (0.00795) | (0.0135) | (0.0130) | (0.00871) |
| Constant | 9.054*** | 7.660*** | 11.33*** | 16.02*** | 10.31*** | 14.13*** |
| | (0.251) | (2.375) | (0.258) | (0.330) | (0.427) | (0.219) |
| Observations | 390 | 19 | 372 | 357 | 390 | 390 |
| R-squared | 0.563 | 0.985 | 0.552 | 0.606 | 0.548 | 0.582 |
| chi2 | 1786*** | 1210*** | 2021*** | 234.8*** | 733.2*** | 1828*** |

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4 shows that the positive effect of green finance and stringent environmental policies is robust across alternative specifications of biocapacity, including arable land, pasture, forest, and productive sea.

### 4.3. Indirect effect

Table 5 shows the indirect effect regression of the interactive effect of green finance and environmental stringency on biocapacity. The results show that environmental policies interact with green finance, producing positive and negative indirect effects. However, the positive direct effect outperforms the negative indirect effect producing positive net effects. Keeping in mind that the environmental policies variable ranges between 0 and 100, with 100 indicating the most stringent policy, the thresholds of the policies required for green finance to continue enhancing biocapacity are calculated. In light of these results, Table 5 shows that green finance requires strict environmental policies in Africa to enhance biocapacity. However, these policy values should be tailored around the 59.6708 thresholds for green finance to continue yielding favourable fruits on environmental sustainability. For the moment, Table 1 reveals that the average value on the continent is still just about 35.4, indicating the need for efforts to be doubled in that regard. Above the 59.6708 threshold, several factors may come in; foreign direct investment into the continent and domestic investments may drop, as investments in eco-friendly technologies are expensive, and businesses that are not eco-friendly and cannot afford investments in eco-friendly initiatives may shut down due to the high environmental cost. Also, some firms' shutting down of businesses increases the informal sector's size. Chu (2022) recently argues that the informal economy undermines the positive effect of green innovation on environmental sustainability.

Table 5. Indirect effect regression

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Variable | biocapacity | Bio built-up land | Bio carbon | Bio cropland | Bio fishing grounds | Bio forest products | Bio grazing land |
| Green finance | 0.290*** | 0.413*** | 0.159 | 0.310*** | 0.381*** | 0.371** | 0.263*** |
| | (0.0715) | (0.101) | (0.125) | (0.0982) | (0.116) | (0.150) | (0.0847) |
| Environmental stringency(A) | 0.0624*** | 0.0482** | 0.0334 | 0.00964 | 0.0490** | 0.129*** | 0.0835*** |
| | (0.0183) | (0.0200) | (0.0264) | (0.0196) | (0.0220) | (0.0296) | (0.0182) |
| Population growth | -0.147*** | -0.446*** | 1.908*** | -0.611*** | -0.0836* | -0.0617 | -0.112*** |
| | (0.0508) | (0.0344) | (0.472) | (0.0352) | (0.0460) | (0.0541) | (0.0288) |
| Renewable energy | 0.00870** | 0.0410*** | 0.000458 | 0.0505*** | 0.0301*** | 0.0148*** | 0.000907 |
| | (0.00381) | (0.00184) | (0.0102) | (0.00195) | (0.00477) | (0.00464) | (0.00235) |
| Technology | -0.0215 | -0.0210 | -1.795*** | -0.0734 | -2.080*** | -0.0867 | -0.00897 |
| | (0.0670) | (0.0776) | (0.583) | (0.0838) | (0.213) | (0.211) | (0.0200) |
| Financial development | 0.00856 | 0.0271*** | 0.0975*** | 0.0225*** | 0.115*** | 0.0353** | 0.0864*** |
| | (0.00688) | (0.00793) | (0.00991) | (0.00841) | (0.0140) | (0.0138) | (0.00946) |
| Green finance*A | -0.00486** | -0.00492** | -0.00418 | -0.00222 | -0.00563** | -0.00692** | -0.00408** |
| | (0.00189) | (0.00223) | (0.00341) | (0.00219) | (0.00249) | (0.00332) | (0.00202) |
| Constant | 13.25*** | 7.643*** | 7.068*** | 10.70*** | 14.26*** | 8.327*** | 12.96*** |
| | (0.803) | (0.747) | (2.337) | (0.716) | (0.723) | (1.133) | (0.555) |
| Net effect | 0.1177 | 0.2386 | ----- | ----- | 0.1814 | 0.1257 | 0.1183 |
| Threshold of A | 59.6708 | --- | ----- | ----- | ------ | 53.6127 | ----- |
| Observations | 409 | 390 | 19 | 372 | 357 | 390 | 390 |
| R-squared | 0.206 | 0.570 | 0.986 | 0.554 | 0.310 | 0.153 | 0.286 |
| chi2 | 90.91*** | 1514*** | 1308*** | 1902*** | 246.5*** | 716.7*** | 1910*** |

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

## 5. Conclusion and Policy Implications

Considering several factors, this study focused on the unique importance of sustainable finance in Africa. Firstly, the estimated climate finance needs for the continent between 2020 and 2030 amount to $2.5 trillion or $250 billion annually. However, by 2020, only about $30 million had been mobilised, representing merely 12% of the required amount (Climate Policy Initiative, 2022). Secondly, the African Development Bank (AfDB) suggests significant potential for growth in climate finance in Africa. By late 2022, global pension fund assets in the 22 largest markets had reached a record high of $56.6 trillion, while private equity funds under administration amounted to $6.3 trillion in 2021 (AfDB, 2023). Thirdly, according to the United Nations Food and Agricultural Organization (FAO), Africa lost twice as much forest per year between 2015 and 2020 (4.4 million hectares) compared to the rest of the world. Deforestation increases land availability for agriculture but, at the same time, depletes essential nutrients in the soil, rendering productivity temporary.

Additionally, over 50% of Africa's eco-regions have lost 50% of their land due to deterioration, agriculture, or urbanisation, resulting in an ecological deficit in recent years. As a result, Africa's ecological footprint in 2018 was 1.35 hectares per person, contrasting with the global average of 2.8 hectares per person and a biocapacity of 1.15 hectares per person, indicating the continent's dangerous and unsustainable ecosphere (Mansourian and Berrahmouni, 2021). Lastly, the high poverty rate in Africa makes green investment products, such as renewable energy, unaffordable for many due to their higher acquisition costs than non-renewable energy. Also, fossil fuels remain abundant and relatively cheaper throughout the continent. Consequently, climate funding alone is insufficient for achieving an environmentally benign future; policies enabling consumers and businesses to adopt eco-friendly products and adjust their consumption patterns are necessary. Against this backdrop, this study aimed to (i) investigate the effect of green finance on biocapacity in Africa and (ii) examine the moderating effect of stringent environmental policies on the relationship between green finance and biocapacity in the region.

Due to data limitations, this study focused on 24 African countries from 2000 to 2020. The results obtained through the FE_Driscoll Kraay, panel-corrected standard error (PCSE), and system GMM models are as follows: (i) Green finance positively enhances the biocapacity of African countries, with robust results observed across alternative specifications of biocapacity, including arable land, pasture, forest, and productive sea. (ii) Environmental regulations (stringent policies) interact with green finance, resulting in positive net effects. In other words, the positive impact of green finance on biocapacity is modulated through increasingly stringent environmental policies. The results further suggest that green finance enhances biocapacity in countries with more stringent environmental regulations than in countries with less stringent regulations.

Based on the findings of this study, several policy recommendations arise. Firstly, African countries must strengthen their environmental policies as an initial measure towards enhancing biocapacity. These policies should incorporate mechanisms that impose costs on exploiting land, forests, and water bodies. In doing so, it is critical to promote policies that enhance the efficiency of productive areas, including the effective utilisation of fertilisers. Furthermore, African policymakers should explore and consider the various climate finance options available, such as debt-for-climate swap deals, which the continent has yet to implement effectively. By implementing these recommendations, African countries can make significant strides towards sustainable environmental practices and the preservation of biocapacity.

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Appendix

## Matrix of correlations

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) biocapacity | 1.000 | | | | | | | | | | | | |
| (2) green finance | 0.640 | 1.000 | | | | | | | | | | | |
| (3) environmental policy | -0.065 | 0.092 | 1.000 | | | | | | | | | | |
| (4) population growth | 0.148 | -0.207 | -0.548 | 1.000 | | | | | | | | | |
| (5) renewable energy | -0.911 | -0.534 | -0.076 | -0.258 | 1.000 | | | | | | | | |
| (6) technology | 0.828 | 0.699 | 0.170 | -0.400 | -0.650 | 1.000 | | | | | | | |
| (7) financial development | 0.947 | 0.671 | 0.100 | -0.121 | -0.847 | 0.902 | 1.000 | | | | | | |
| (8) bio built-up land | 0.997 | 0.656 | -0.045 | 0.108 | -0.890 | 0.855 | 0.946 | 1.000 | | | | | |
| (9) bio carbon | 0.990 | 0.634 | -0.021 | 0.150 | -0.927 | 0.807 | 0.949 | 0.983 | 1.000 | | | | |
| (10) bio cropland | 0.997 | 0.626 | -0.065 | 0.181 | -0.912 | 0.806 | 0.933 | 0.994 | 0.985 | 1.000 | | | |
| (11) bio fishing grounds | 0.969 | 0.590 | -0.038 | 0.185 | -0.917 | 0.767 | 0.927 | 0.961 | 0.974 | 0.958 | 1.000 | | |
| (12) bio forest products | 0.824 | 0.588 | -0.299 | 0.064 | -0.640 | 0.778 | 0.737 | 0.829 | 0.764 | 0.804 | 0.737 | 1.000 | |
| (13) bio grazing land | 0.622 | 0.567 | 0.039 | -0.344 | -0.514 | 0.717 | 0.762 | 0.627 | 0.627 | 0.596 | 0.653 | 0.445 | 1.000 |