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# The Economic Stakes of Biodiversity Loss in Africa and Measures Implemented to Limit It

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## Abstract

While African countries have a particularly rich biodiversity, this has been deteriorating markedly for several decades, and seems to be accelerating in recent years. This degradation of biodiversity has consequences both at local level—African populations, mostly rural, are heavily dependent on ecosystem services—and at global level, given the major implications of biodiversity degradation for global warming, health, food security and global financial stability. Biodiversity conservation in Africa is therefore a major challenge, and its linkage with the continent's economic development objectives raises a number of issues. This article studies the impact of economic activity on biodiversity. Using geo-located databases from 1990 to 2015, it shows that an increase in local economic activity is associated with a decline in local vertebrate populations. The article also discusses the protection measures implemented both locally and globally to promote biodiversity preservation, as well as the challenges they face.

**Keywords:** biodiversity, growth, Africa, development.

**JEL Codes:** Q57, Q54

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## Introduction

**The acceleration of biodiversity loss, observed at the world level since several decades, is particularly affecting Africa.** On the one hand, African populations are among the most vulnerable to biodiversity loss: a majority of rural population indeed depends on ecosystem services for food, water, energy, healthcare and the satisfaction of vital needs (IPBES, 2018). On the other hand, biodiversity has diminished particularly rapidly since the 1970s in Africa compared to other regions in the world (-66 % between 1970 and 2018 according to the *Living Planet Index,* well over Europe and Central Asia (-18 %), North America (-20 %), Asia-Pacific (-55 %), but below Latin America (-94 %))[1].

**The biodiversity loss of African countries could be further exacerbated by the economic growth expected on the continent in the next decades.** We illustrate this by evaluating, at the global scale, the effect of a rise in local GDP (estimated at a 5-arcmin resolution, corresponding to about 9km at the equator) on local biodiversity (measured through the geolocalized measures underlying the *Living Planet Index*). We document that a 1 % rise in local GDP reduces the level of biodiversity by about 0.5 %. An evaluation using instrumental variables methodology suggests that this effect could represent a lower bound.

**We explore several mechanisms that are relevant for African economies, and discuss the factors that might explain their contributions.** In particular, our results suggest that the effect of GDP on biodiversity is more strongly due to higher population than to higher GDP per capita. Furthermore, biodiversity loss varies depending on the initial level of economic activity. The strongest losses are observed for intermediary initial levels of economic activity. These results are compatible with the existence of a Kuznets curve of biodiversity, and can be explained by several factors relating to the effects of sectoral economic transformation or of the quality of institutions. All of these results suggest that economic policy choices of African countries in the upcoming years will crucially determine the balance between economic development and preserving biodiversity.

**However, issues specific to Africa regarding biodiversity cannot be considered separately from the rest of the world, since local biodiversity loss have both local and global effects.** On the one hand, because of the global importance of African ecosystems, biodiversity losses on the continent could have consequences on the global economy. On the other hand, in case of a brutal loss of biodiversity at the global level, African economies would be among the most exposed, with GDP losses amounting to -10 % in case of global collapse of biodiversity by 2030, against -2 % in advanced economies.

**In this context, an enhanced coordination of local and international policies is warranted, not only to preserve African and global biodiversity, but also to limit the consequences for Africa of a global diversity loss.** While the need to protect biodiversity is covered by international agreements since the 1990s, the acceleration of its deterioration during the last decades reinforced the importance of this topic in the international fora, leading to a multiplication of initiatives. The conclusion of the 15$^{th}$ Conference of the Parties to the United Nations Convention on Biological Diversity, which was held from December 7$^{th}$ to 19$^{th}$ 2022 in Montreal, established the Kunming-Montreal Global Diversity Framework, which sets targets in terms of preserving and restoring biodiversity by 2030 and 2050, as the Paris Agreement did for climate. Furthermore, the organization of the One Forest Summit in Gabon in March 2023 testifies to a growing awareness of the central role of African ecosystems, and of the strong vulnerability of the continent to local and global biodiversity losses.

**However, financial commitments remain below the estimated needs, and the integration of risks related to biodiversity in bilateral or multilateral financial programs could be reinforced.** While numerous tools to preserve biodiversity have been proposed, their rollout will depend on the development of robust evaluation system of ecosystem services, and their efficiency will depend non only on their consistence, and on the close involvement of local populations in their elaboration and implementation.

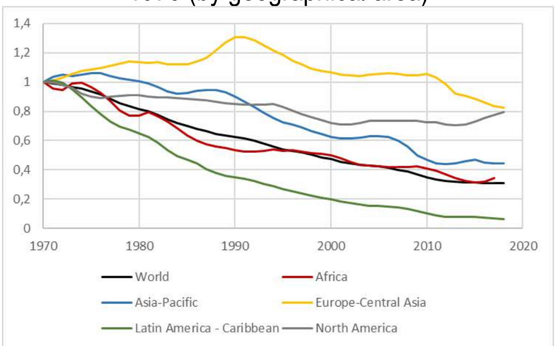
[1] The Living Planet figures in this article, as well as the underlying data used in the econometric analysis, come from the 2022 version of the report. The latter has been updated in 2024 (see footnote 4 for updated figures).

1. **Are preserving biodiversity and economic development incompatible objectives for African economies?**

A. **African countries are facing a strong decrease in their biodiversity since the 1970s, which threatens their development prospects**

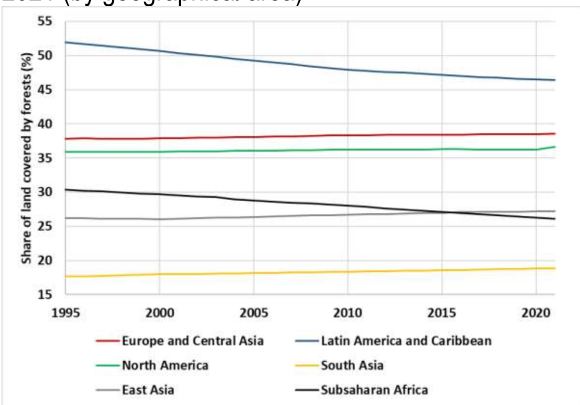
**Africa's biodiversity[2] is particularly rich (IPBES, 2018).** The continent is the last place in the world with a wide variety of large mammals. Almost a quarter of its surface area is forest, while another quarter is arable land (of which only a fifth is cultivated). The rest - half the continent - is savannah, grassland, arid zones and deserts. Wetlands make up almost 1% of the continent's surface area, which is also surrounded by six marine ecosystems (three of which rank among the world's four most productive marine ecosystems). Three of the continent's countries are also considered mega-diverse (Madagascar, Democratic Republic of Congo, South Africa), and the continent contains eight of the world's 36 biodiversity hotspots.[3]

**Figure 1** – Evolution of the Living Planet Index since 1970 (by geographical area)




**Source**: Living Planet Report 2022, WWF/ZSL

**Figure 2** - Evolution of forest cover between 1995 and 2021 (by geographical area)




**Source**: World Bank

**Numerous studies document a massive loss of biodiversity worldwide, and particularly in Africa.** The global rate of species extinction is tens, if not hundreds, of times higher than that observed over the long term (IPBES, 2019). According to the Living Planet Index (Figure 1), the global population of vertebrate species declined by 69% between 1970 and 2018. While Africa is within the global average, with an estimated decline of 66%, this rate is well above that of Europe and Central Asia (18%), North America (20%) and the Asia-Pacific region (55%), but below that of Latin America (94%)[4]. The African continent is also particularly prone to deforestation (Figure 2). Agricultural land expanded by around 3% per year in Africa during the 2010s, whereas it remained stable in other low- and middle-income countries (Barrett, 2021)[5], and between 2001 and 2015, 92% of forest loss in Africa is thought to be attributable to the expansion of agricultural land by smallholders (Curtis et al., 2018). Overall, according to Weber et al. (2024), between 2005 and 2019, the continent's ecosystem capabilities (synthesizing measures relating to land cover, ecosystem infrastructure, water availability and carbon emissions) declined by 5.6%. There is marked heterogeneity between regions (-13.9% in Madagascar, -7.5% in Southern Africa, -6.5% in East Africa, -6.0% in Central Africa and -5.1% in North Africa), with a particularly sharp deterioration in recent years in West Africa (-7.0% between 2015 and 2019), Central Africa and Madagascar (both -5.8%). On a per capita basis, the continent's ecosystem capacity fell by 35% between 2010 and 2019.

[2] See Appendix A for a brief overview of definitions and measures of biodiversity.
[3] Biodiversity hotspots are areas with a strong concentration of endemic species (more than 1,500 vascular plants), and having lost at least 70 % of its primary vegetation.
[4] In the latest version of the Living Planet Index (2024), the decrease of population of vertebrate species between 1970 and 2020 is estimated to be of 73 % worldwide, 76 % in Africa, 35 % in Europe and Central Asia, 39 % in North America, 60 % in Asia-Pacific and 95 % in Latin America.
[5] At the global level, the extension of agricultural lands would be responsible for 83 % of forest losses between 1983 and 2000 (Gibbs et al., 2010).

**Global warming is likely to accelerate the loss of biodiversity, and Africa is particularly exposed to this feedback loop.** According to the IPCC, the average temperature on the African continent has already risen by 1.4°C compared with the pre-industrial average, which is higher than the global average (+1.1°C). In the IPCC report's median scenario, the average temperature rise by the end of the century could be 4°C in summer, and 2.5°C in winter. At 3°C, almost the entire continent would lose 25-50% of its biodiversity (Woillez, 2023).

**African populations are thus among the most vulnerable to a deterioration of ecosystem services[6].** 62% of the rural population of African countries are in fact dependent on ecosystem services for their food, water and energy requirements, healthcare and the satisfaction of their vital needs (IPBES, 2018). According to the Notre Dame Global Adaptation Initiative (ND-GAIN) ranking, which proposes a specific ecosystem services vulnerability score, half of African economies would be located in the bottom third of the global ranking in terms of their ecosystem services vulnerability, and three-quarters of them would have a vulnerability above the global median. According to Weber et al. (2024), more than half of Africa's ecozones are classified as "unsustainable", affecting 750 million people (including 157 million in critically endangered ecozones). The least sustainable ecozones are located in North Africa (Maghreb Atlantic coast, Nile Valley), West and Southern Africa, and Madagascar. The loss of the continent's biodiversity could directly affect the agricultural sector - in terms of both crops (increase in infection episodes) and livestock (Woillez, 2023) - fishing or tourism (Klöck and Woillez, 2023). This could increase food insecurity, which is already marked on the continent, and is likely to be all the more so given that the African population could almost double by 2050.

**The vulnerability of African countries to biodiversity loss occurs against a backdrop of economic and institutional fragility.** African countries are also among the most vulnerable to climate change, and among those with the lowest degree of preparedness in the world (Debels-Lamblin and Jacolin, 2020). The loss of biodiversity on the continent could directly affect the agricultural sector, both in terms of crops (increase in infection episodes) and livestock (Woillez, 2023). This could increase food insecurity, which is already marked on the continent: since the second half of the 2010s, the number of food-insecure people has risen sharply in African countries, and this trend has been accentuated by the Covid-19 pandemic and the sharp rise in global prices in 2022 (Lemaire and Vertier, 2023). The challenges of food security and maintaining agricultural yields are all the more significant for the continent as its population is set to almost double by 2050, even though the agricultural sector suffers from a lack of attractiveness (Lee et al., 2022).

**Biodiversity losses in Africa are thus very high, even though the population is particularly vulnerable to them. The deterioration in biodiversity observed over the long term must be combined in African countries with ambitious economic development objectives.**

## B. Fostering economic development and preserving biodiversity on the African continent: a complex, yet understudied articulation.

### a. A still fragmented literature

**The high exposure of African economies to biodiversity loss at a time when development challenges remain essential means that trade-offs between economic activity and biodiversity need to be studied in greater depth, and calls to develop such studies are multiplying (Dasgupta, 2021).** However, the number of economic studies on biodiversity remains limited[7], due to a number of factors. On the one hand, these two variables are interdependent: economic activity is likely to reduce biodiversity, and biodiversity loss is likely to reduce economic activity (Giglio et al., 2024). On the other hand, matching biodiversity data with traditional economic activity data is sometimes complex, as biodiversity data evolve with a certain inertia, and the links between biodiversity and economic activity give rise to numerous indirect effects that are difficult to capture empirically (Svartzman et al., 2021).

**Among existing studies, the most influential aim to quantify the dependence of economic activity on ecosystem services (Costanza 2014; Johnson et al., 2021), while those attempting to establish the effect of economic growth on biodiversity are less conclusive.** Certainly, work in environmental biology has led to a consensus that biodiversity loss is linked to economic activity, and various works document the effects of certain

[6] Direct and indirect returns that humans benefit from nature.

[7] It is even largely smaller than the number of economic studies focusing on climate change: according to the website REPEC, in 2022, economic studies on climate change (JEL code Q54) were about 5 times more numerous than those on biodiversity (Q57).

sectors of economic activity on biodiversity, such as road construction (Asher et al. 2020), land use (Cole et al. 2021, Newbold et al. 2015, Marques et al., 2019), manufacturing or extractive industries (Kinda and Thiombiano, 2023). In addition, a large interdisciplinary literature, following the work of Ostrom (1990), has documented the impact of institutional arrangements on biodiversity preservation at the local level. To date, however, there are few studies demonstrating the link between general economic activity and biodiversity loss. Indeed, while a GDP-based approach may prove useful for policy-makers (GDP remaining, despite its well-identified limitations, the main indicator of economic activity produced systematically and comparably across countries, and targeted by policy-makers), a surprisingly small number of studies make the link between GDP variation and biodiversity loss. While the concept of the environmental Kuznets curve provides a frequently used starting point for investigating the link between economic activity and environmental degradation, it has mostly been applied to pollution[8], and little to biodiversity (Parrique et al., 2019). What's more, the conclusions of the few studies on the subject are on the whole contradictory, not least because they mobilize aggregated biodiversity and activity data, which may limit the ability to detect a significant link, due to the complexity of biodiversity measurements[9].

**However, the recent availability of granular data on both the level of economic activity and biodiversity means that progress can be envisaged in this area.** For example, Liang et al (2023), using local economic data (at state level in the United States) and biodiversity measurements from the BioTime database, show a marked effect of economic activity on biodiversity. However, this work does not show any difference in effect depending on the initial level of activity (which could be explained by the fact that the heterogeneity of activity levels is limited, as the study focuses only on the United States).

### b. A proposal of quantification of the effect of economic activity on biodiversity

*OLS analysis*

**We propose an evaluation of the correlation between increased economic activity and biodiversity loss, across countries between 1990 and 2015, leveraging geolocalized measures of biodiversity and of activity.** Our evaluation hinges upon on a methodology close to that of Liang et al. (2023), i.e. it uses biodiversity records at a disaggregated level, but extending it to a global scale. To do so, we use granular GDP data at 5-arcmin scale (approximatively 9 km at the equator) from Kummu et al. (2018) between 1990 and 2015. We match them with data from the *Living Planet* dataset, listing about 30 000 populations of close to 5 000 species, studied over several years at a fixed location (identified by GPS coordinates based on longitude and latitude[10]). The methodological details of the matching are presented in Appendix B.

**Our analysis consists in regressing the variations of population measures of local species on the GDP variations in the area where the study takes place.** Our explained variable corresponds to the rate of change of the population measures of the species studied, between two surveys in a given Living Planet study. Our explanatory variable corresponds to the local GDP growth rate (where GDP corresponds to that of the area in which

[8] The Kuznets curve is a hypothesis that was first formulated with regard to inequality (Kuznets, 1955), according to which the level of inequality would first increase with the level of development, until a certain threshold was reached, and then decrease, forming an inverted U-shaped curve. Since the pioneering contribution of Grossman and Krueger (1991), this hypothesis has been applied to pollutant emissions, and a great many studies have attempted to demonstrate a Kuznets curve of pollutant emissions in different settings (Jalil and Mahmud, 2009; Ahmed and Long, 2012; Iwata et al., 2010; Li et al., 2016; Fang et al., 2020). Meta-analyses on the subject give rise to contrasting conclusions (Parrique et al.; 2019; Saqib and Benhmad, 2021), and the interpretation of results suggesting the existence of environmental Kuznets curves is strongly debated (Stern, 2004; Stern, 2017).

[9] Kauppi et al (2006) showed that above a GDP per capita of 4,600 USD, no country saw its forest cover decrease. Tan et al (2022) also demonstrated an inverted U-shaped curve in the number of threatened species in South and Southeast Asia. In contrast, Dietz and Adger (2003), Mozumder et al. (2006) and Mills and Waite (2009) found no evidence for a Kuznets curve in biodiversity.

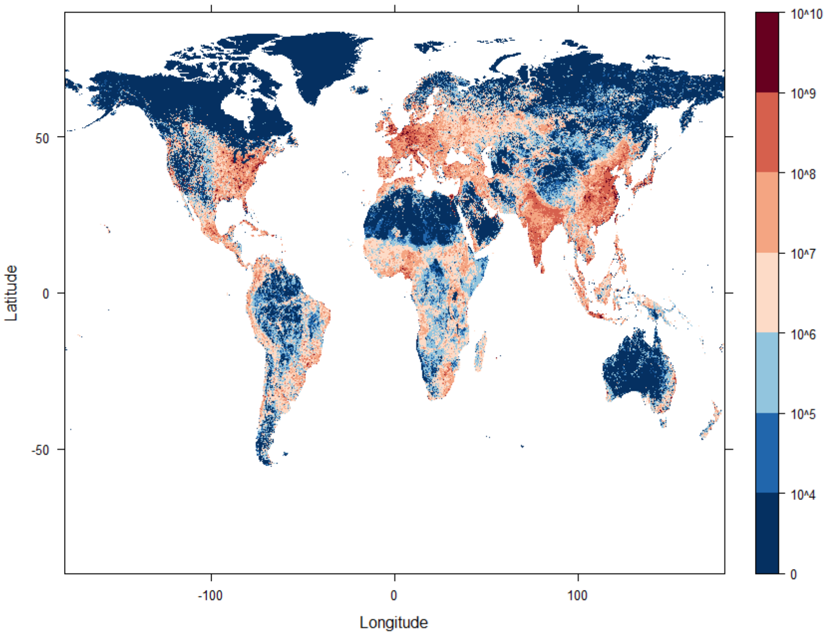
[10] We prefer this dataset to the the BioTime dataset, in which observations from North America and New Zealand are neatly overrepresented.

the study takes place) between two surveys[11][12]. More specifically, our baseline analysis is made through a panel regression of the form:

$$\Delta\log(1+Y)_{i,t1,t2} = \alpha + \beta \times \Delta\log(1+GDP)_{c(i),t1,t2} + \theta X_{i,t1} + \vartheta_i + \mu_{t1,t2} + \varepsilon_{i,c,t1,t2} \quad (1)$$

where *i* stands for a study, *c* stands for the area (cell) where the GDP is measured for study *i,* and *t* corresponds to a year. The variable $\Delta\log(1+Y)_{i,t1,t2}$ represents the variation of population measure within study *i,* between years *t1* and *t2*[13]. The variable $\Delta\log(1+PIB)_{c(i),t1,t2}$ corresponds to the GDP variation within the area *c(i)* in which study *i* takes place, computed between years *t1* and *t2.* In the baseline analysis, the variable $\Delta\log(1+PIB)_{c(i),t1,t2}$ is winsorized at the top and bottom percentile so that the results do not depend on extreme values. $\vartheta_i$ is a study fixed effect. $\mu_{t1,t2}$ is a fixed effect proper to the pair of years between which the variations of biodiversity and GDP are computed The equation also considers the possibility of including controls $X_{i,t1}$, measured in *t1* for study *i,* such as the local GDP growth rate before *t1*, or the level of GDP in *t1.* In alternative specifications, we test other definitions of the variation of economic activity or of species population.

**Figure 3 –** GDP in 2015, in constant 2011 USD (at purchasing power parity)




**Source** : Kummu et al. (2018), authors' computation.

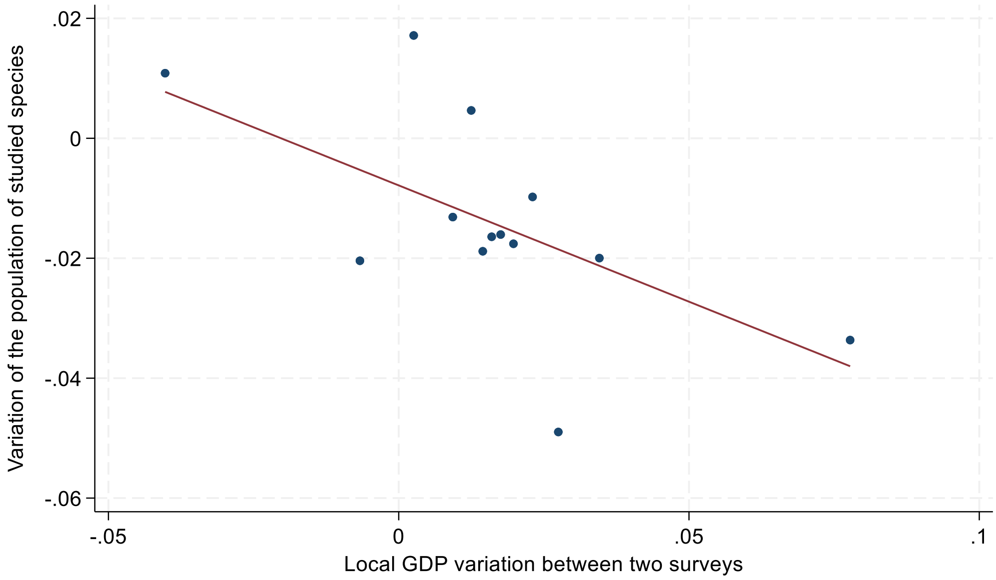
[11] Importantly, the cells in Kummu et al. (2018) do not have a constant surface depending on latitude: 5 arcmin represent about 9 kms at the equator, but 6.7 kms at the 44th parallel. Therefore, the GDP measure is not homogeneous across latitudes. Several factors limit the risks in terms of estimation. On the one hand, we are interested in the effects of GDP *variations,* and for each Living Planet study, the location is constant over time: the GDP cell matched to each study is therefore identical over time, and from one year to another, the GDP variations corresponding to a given study are computed on a constant surface. On the other hand, the main analysis, we introduce study fixed effects : the effect is therefore estimated on average *within* each study, and the potential effect of surface is absorbed in the fixed effect, since the surface of the matched GDP cell is constant over time for each study. Finally, in the cases where we do not control for study fixed effects, we control for the surface, in km², of the matched 5-arcmin GDP cell. The results are overall invariant to including or not this variable as a control.

[12] Here, because of a large number of cells with null GDP (43.6 % of cells in which the surveys take place), the variation is computed based on a transformation of GDP. In this case, we consider differences of log(1+GDP), which is a reasonable approximation since, conditionnally on being non-null, GDP values are very high (200 minimum, and 3.1 x $10^8$ on average). Adding 1 to these values have little effect on the resulting logarithm value.

[13] In order to take into account the fact that many surveys are null (15.2 %), the rates of variation are, in the main specification, proxied by differences of log(1+x). By an abuse of language, we interpret this difference as an evolution in percent: indeed, this measure is correlated at 95 % with computable log differences (i.e. in cases where there is no null survey in any of the two periods). However, this normalization can prove problematic in a case where, as it is the case here, *x* values can be very different across species, and where a large number of small values exist (for which a 1+x normalization is non-neutral). In an alternative exercise, we test specifications where the variation of population is expressed as difference of arcinsh of population *x,* where $\text{arcsinh}(x) = \log(x + \sqrt{x^2+1})$. The results presented thereafter are largely robust to choices of different specifications (Tables 1 et 2).

**Depending on estimations, we find that 1 % increase in local GDP would on average be associated with a 0.5 % drop of the studied population** (Figure 4 and Tables 1-2)**.** Focusing uniquely on the presence or not of a population of species (column 5 of Table 1), a 1 % increase in GDP reduced by 11 points the probability of observing at least one individual of the studied population (from a baseline share of 85 % of non-null surveys).

**Figure 4 –** Correlation between the variation of economic activity and the variation of population of the studied species




**Source** : *Living Planet Database,* Kummu et al. (2018), authors' computation.
**Note :** the figure is a binscatter plot, net of fixed effects with respect to Living Planet study and to pairs of years between which the variations of biodiversity and GDP are computed, but without control variables. The estimation corresponds the coefficient estimated in column (1) of table 1. GDP is expressed in 2011 USD at purchasing power parity.

**These results must be interpreted with caution for several reasons. On the one hand, the estimated results in this regression are subject to several caveats inherent to the framework of analysis.** In particular, our results do not enable us to evaluate the global interdependencies in terms of biodiversity (Lenzen et al., 2012), because the GDP measure that is used is not informative of whether the consumption incorporated in local GDP is based on local production or imports. Furthermore, each study within the Living Planet dataset documents the population of a single species: our estimations are therefore not informative about the effect of GDP on the whole of local biodiversity. From this standpoint, developing datasets including abundance and richness measures at the local level over a long period will be key to better characterize the effects of economic activity on biodiversity[14].

[14] Importantly, while we do not test the existence of non-linear effects of GDP growth on biodiversity, complementary analyses using quadratic forms of GDP growth do not support the existence of non-linear effects in this framework.

**Table 1** – Correlation between the variation of population of studied species and the growth rate of local GDP, using different measures of biodiversity variation

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Effect of 1 % variation of GDP | -0.388<br>(0.0913) | -0.445<br>(0.104) | -0.324<br>(0.080) | -0.376<br>(0.093) | -0.114<br>(0.029) | -0.497<br>(0.129) | -0.230<br>(0.122) |
| Observations | 167,960 | 167,960 | 167,960 | 167,960 | 167,960 | 166,476 | 134,054 |
| R² | 0.059 | 0.059 | 0.063 | 0.063 | 0.052 | 0.067 | 0.060 |
| *Fixed effects*<br>Study<br>Pair of years | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y |
| Controls | N | N | N | N | N | N | N |
| Sample | 1990-2015 | 1990-2015 | 1990-2015 | 1990-2015 | 1990-2015 | 1990-2015 | 1990-2015 |
| Variation of vertebrate population (*x*) | Δlog(1+x) | Δarcsinh(x) | Δlog(1+x), winsor 1 % | Δarcsinh(x), winsor à 1 % | Δ(x>0) | Δ arcsinh($\frac{100\,x}{\max(x)}$) | Δlog(x) |

**Note** : robust standard errors in parentheses. In the whole table, GDP variations correspond to Δlog(1+PIB), winsorized at the 1 % level in the top and the bottom of the distribution.

**On the other hand, not all countries contribute equally to the results.** Even though the Living Planet dataset has a broad geographical coverage, observations are clustered in a small number of countries. Indeed, as indicated in Appendix B, despite the dataset containing 171 countries (for approximately 200,000 surveys), only 10 countries have more than 2,000 observations and represent about 81 % of the dataset: Australia (31 %), Canada (30 %), Spain (5 %), USA (4 %), Norway (3 %), France (2 %), Brazil (2 %), United Kingdom (2 %), South Africa (1 %), Germany (1 %). All remaining countries represent less than 1 % of observations. A country-by-country estimation of the coefficients for each of the 10 countries having more than 2,000 observations (Figure 5), highlights that, even though Australia drives the aggregated results, the coefficients are mostly negative (in 7 countries out 10). The negative coefficients are significant in 4 countries out of 7 (Norway, Brazil, Germany and Australia; by contrast, France, Spain and Canada have negative but non-significant coefficients). The three positive coefficients (United-Kingdom, USA, South Africa), are not significant. While this analysis should be considered with caution, the Living Planet observations being unrepresentative of the biodiversity of each country, the fact that the estimated coefficients in the most represented countries are overall negative and significant suggests that our results are not driven by a single country.

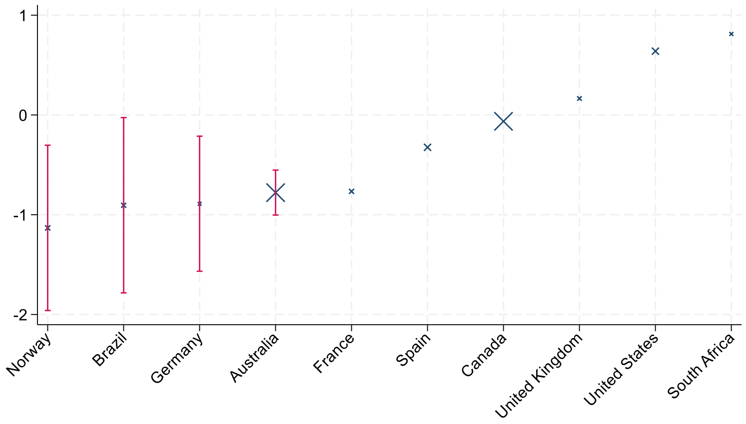
**Table 2** – Correlation between the variation of population of studied species and the growth rate of local GDP, using different definition of GDP variation, control variables and samples

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Effect of 1 % variation of GDP | -0.388<br>(0.0913) | -0.627<br>(0.186) | -0.503<br>(0.101) | -0.533<br>(0.108) | -0.549<br>(0.122) | -0.699<br>(0.148) | -0.402<br>(0.108) | -0.270<br>(0.100) |
| Observations | 167,960 | 167,690 | 135,754 | 106,920 | 68,836 | 32,900 | 104,371 | 139,410 |
| R² | 0.059 | 0.059 | 0.060 | 0.070 | 0.089 | 0.116 | 0.0590 | 0.062 |
| *Effets fixes*<br>Study<br>Pair of years | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y |
| Controls | N | N | Y | N | N | N | N | N |
| Sample | 1990-2015 | 1990-2015 | 1990-2015 | 2000-2015 | 2005-2015 | 2010-2015 | 1990-2015, dist<4kms | 1990-2015, années contigues |
| GDP variation | winsor 1% | winsor 5% | winsor 1% | winsor 1% | winsor 1% | winsor 1% | winsor 1% | winsor 1% |

**Note**: robust standard errors in parentheses. In the whole table, variations of vertebrate population correspond to Δlog(1+x) and the variations of GDP correspond to Δlog(1+PIB), winsorized at the 1 % or 5 % levels. In column (3), control variables include GDP variation in the 5 years preceding *t1,* and the average GDP level (in logarithm) during the 5 years preceding *t1.*

**Finally, while several factors suggest that the result mainly reflect negative effects of economic activity on biodiversity, the framework analysis is insufficient to claim a causal interpretation.** While one cannot exclude that the estimated correlation partly reflects a negative effect of higher biodiversity on economic activity (for instance through the implementation of protected areas), it is unlikely that this canal predominates. Indeed, in the matched sample, the average GDP between two years is of 1.6 %. To the contrary, within this sample, biodiversity indicators decrease on average by 1 % every year. These elements suggest that most of the effects stems from a drop in biodiversity in connection with increased economic activity. However, it is not impossible that the results be affected by other factors not included as control variables, and correlated with both species population and economic activity. In the next section, we propose some pathways for a causal interpretation of estimated coefficients.

**Figure 5 –** Correlation between the variation of economic activity and the variation of population of studied species, estimation for each of the main countries of the dataset




**Source** : *Living Planet Database,* Kummu et al. (2018), authors' computation.
**Note :** the figure represents, for each country, the estimated coefficient of the main equation (specification of column (1) in Table 1), for each of the 10 countries with at least 2,000 observations in the dataset. Only the confidence intervals corresponding to a 10 % significance are represented. The size of the cross for each country is proportional to its number of observations in the dataset.

*Instrumental variable analysis*

**In order to provide a more causal interpretation of the results, we propose an instrumental variable approach, where economic activity is instrumented by a shock which, upon all likelihood, does not affect directly biodiversity, but increases economic activity.** The proposed instrument hinges upon the construction of power plants close to the location of the Living Planet study, namely less than 100 kms but more than 10 kms away from the latter. To do so, we use the Global Database of Power Plants, published by the World Resources Institute (2021). This dataset indicates the location of 34,936 power plants commissioned worldwide since 1900. However, the commissioning dates of these plants are available for only 45 % of observations. Furthermore, between 1990 and 2015, while 9,760 commissioning dates are available, 66 % of them come from the period 2005-2015. In order to limit the risk of measurement error of the instrumental variable, which might bias the analysis, we therefore focus on the 2005-2015 period. For each study location in the Living Planet Index dataset, and for each year over this period, we identify the number of power plants commissioned between 10 to 100 kms: 31,972 survey location-years have at least one power plant commissioned in a distance comprised between 10 and 100 kms. Among them, 48 % have only one power plant commissioned during the year and 52 % have at least two (with an average value of 4).

**The instrumental variable analysis is made on the period 2005-2015, by estimating the following equations using a two-stage least square (2SLS):**

$$\Delta\log(1+GDP)_{c(i),t1,t2} = \alpha + \gamma Z_{i,t1,t2} + \theta X_{i,t1} + \mu_{t1,t2,p(i)} + \varepsilon^{0}_{i,c,t1,t2} \qquad (2)$$

$$\Delta\log(1+Y)_{i,t1,t2} = \alpha + \beta \times \Delta\log(1+\widehat{GDP})_{c(i),t1,t2} + \theta X_{i,t1} + \mu_{t1,t2,p(i)} + \varepsilon^{1}_{i,c,t1,t2} \qquad (3)$$

**Equation (2) corresponds to the first stage equation,** where the GDP growth rate of the area *c* in which study *i* takes places between years *t1* and *t1* ($\Delta\log(1+GDP)_{c(i),t1,t2}$)), is regressed on the instrument $Z_{i,t1,t2}$ corresponding to the number of power plants commissioned between 10 and 100 kms away from the location of the study *i* between these two years. More specifically, in order to capture possible non-linear effects of power plants on GDP in a parsimonious way (in a context where there observations with more than one power plant commissioned between two surveys), our instrumental variables takes three values. It takes a value 0 if no power plant is commissioned, 1 if only one power plant is commissioned, and 2 if more than one power plant is commissioned. Contrarily to our baseline analysis, we only include a fixed effect proper to pairs of year *t1* and *t2* in country *p(i)* where study *i* takes place. The difference with the fixed effects of the baseline analysis (which controlled for study *i* fixed effects) comes from the fact that, even though the instruments provide some variability, there exists a large number of observation (i.e. of intervals between two surveys) where no power plant was commissioned between 10 to 100 kms away from study location (92 % between 2005 and 2015). Such a fixed effect would therefore restrain the analysis to a small number of studies. The instrumental variable analysis therefore hinges not on the variation of economic activity *within* each study location (as it is the case in our baseline analysis), but also on the variation of activity *across* study locations, due to the variations in instruments. However, the regression controls for temporal trends that are proper to each country, which might be correlated with both vertebrate populations and economic activity. Furthermore, as in the baseline analysis, the regression includes the possibility of controlling for control variables observed in the initial period *t1* ($X_{i,t1,}$), such as the GDP growth rate or level in the 5 years preceding *t1.* In the framework of this instrumental variable strategy, such controls notably i) limit the risk of selection into the instrument (for example if the power plants are located in areas with high growth or high GDP level) and ii) control for potential effects that the construction of power plant could have on GDP even prior to their commissioning.

**Equation (3) corresponds to the second stage equation**, where the rate of variation of the vertebrate population in study *i* between *t1* and *t2* is regressed on the predicted value of GDP growth taken from equation (2), and on the same fixed effects and control variables.

**Table 3** – Instrumental variable analysis, first stage

| *First stage* | (1) | (2) |
|---|---|---|
| Commissioned power plant = 1 | 0.006<br>(0.001) | 0.004<br>(0.001) |
| Commissioned power plants > 1 | 0.018<br>(0.001) | 0.015<br>(0.001) |
| Observations | 72,762 | 72,529 |
| F-Stat | 98.758 | 79.223 |
| $R^2$ | 0.146 | 0.151 |
| *Fixed effects*<br>Country x Year of first observation x Year of second observation | Y | Y |
| Controls | N | Y |
| Estimation period | 2005-2015 | 2005-2015 |

**Note** : robust standard errors in parentheses. In the whole table, the explained variable corresponds to GDP variations, expressed as $\Delta$log(1+PIB), winsorized at the 1 % level in the top and bottom of the distribution. In column (2), control variables include GDP variation over the 5 years preceding *t1,* and the average GDP (in logarithm) during the 5 years preceding *t1.* All regressions control for the area, in km², of the GDP grid cell.

**The chosen instruments must meet a relevance condition.** The commissioning of a new power plant must positively predict economic growth at the survey location, as documented in the literature (Montrone et al., 2022). In the framework of our analysis, in a given survey location of the Living Planet Index, the number of commissioned power plants between two survey dates is associated to a strong increase in economic growth (Table 3). On average, the commissioning of a new power plant between two survey years is associated with an additional 0.6 pp in local GDP growth, and the commissioning of at least two power plants is associated with an additional 1.8 pp in local GDP growth. The associated F-statistic indicates that the instrument is likely to be a strong instrument.

**The chosen instrument must also meet an exclusion restriction.** The commissioning of a new power plant must not affect directly the local measure of biodiversity. This is why we count only power plants commissioned more than 10 kms away from survey locations: we therefore eliminate plants located so close to the survey location that they could, by themselves, affect local biodiversity. The threshold of 10 kms is chosen to be coherent with the resolution of GDP data from Kummu et al. (2018).[15]

**Therefore, our identification hinges on the fact that new power plants are localized close enough to the survey location so that they have an effect on local economic activity, but far enough so that they do not affect biodiversity directly.**

**Table 4** – Instrumental variable analysis, second stage

| *Second stage* | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | OLS, no controls | OLS, with controls | IV, no controls | IV, no controls |
| Effect of a 1% variation of GDP | -0.563<br>(0.103) | -0.506<br>(0.105) | -2.199<br>(0.774) | -2.123<br>(0.881) |
| Observations | 72,762 | 72,529 | 72,762 | 72,529 |
| *Effets fixes*<br>Country x Year of first observation x Year of second observation | Y | Y | Y | Y |
| Controls | N | Y | N | Y |
| Estimation period | 2005-2015 | 2005-2015 | 2005-2015 | 2005-2015 |

**Note**: robust standard errors in parentheses In the whole table, the explained variable corresponds to variations of vertebrate populations- ∆log(1+x). In columns (2) to (4), control variables include GDP variation over the 5 years preceding *t1,* and the average GDP (in logarithm) during the 5 years preceding *t1.* All regressions control for the area, in km², of the GDP grid cell.

**In this framework, we keep finding important effects of economic activity on biodiversity (Table 4).** The estimated elasticity in the instrumental variable regression is of -2, suggesting that a 1% increase in production decreases the population measure by about 2 %. This value is significantly higher, in absolute values, than the one obtained in the simple OLS framework: the latter was of about 0.5 %, and could represent a lower bound of the effect of economic activity on local biodiversity. However while, contrarily to the elasticity estimated in the OLS, the one estimated in the IV is greater than 1 in absolute value, none of these elasticities is significantly different from the unity: none of these results helps establishing whether local economic activity has an effect more or less than proportional on local biodiversity.

**Table 5 –** Correlation between anterior variations of biodiversity and instrumental variables

| | (1) | (2) |
|---|---|---|
| Commissioned power plant = 1 | -0.017<br>(0.017) | -0.018<br>(0.017) |
| Commissioned power plants > 1 | -0.003<br>(0.014) | -0.003<br>(0.014) |
| Observations | 66,686 | 66,620 |
| $R^2$ | 0,003 | 0,003 |
| *Fixed effects*<br>Country x Year of first observation x Year of second observation | Y | Y |
| Controls | N | Y |
| Estimation period | 2005-2015 | 2005-2015 |

**Note** : robust standard errors in parentheses In the whole table, the explained variable corresponds to variations of vertebrate populations- ∆log(1+x). In column (2), control variables include GDP variation over the 5 years preceding *t1,* and the average GDP (in logarithm) during the 5 years preceding *t1.* All regressions control for the area, in km², of the GDP grid cell.

[15] A complementary point of attention is that the location of new power plants might have been selected based on past evolutions of biodiversity. This risk appears quite unlikely, precisely since survey location and power plants used as instruments are distant by at least 10 kms. Results from Table 5 suggest that the commissioning of a new power plant in the vicinity of a study location is not correlated with prior growth rates of biodiversity.

### c. Possible transmission channels

**In this section, we test different channels through which the estimated results might transit, in the light of the factors that might play a role in Africa.** We notably explore i) the relative contributions of population and GDP, ii) the contributions of agricultural sector and iii) the existence of Kuznets effects. We first present the results of the empirical analysis, before providing possible interpretation in the next section.

*Effects of population and GDP per capita*

**Africa's population growth is likely to be strong in the next decades, and it is therefore useful to decompose the effects of GDP between effects of population and of GDP per capita.** The dataset by Kummu et al. (2018) allows for such a decomposition, since it provides data on both GDP and GDP per capita. Table 6 presents the results obtained in the same framework as equation (1), but replacing GDP variations with variations of population and GDP per capita (here again, winsorized at the top and bottom percentiles).

**The results suggest that the estimated effects on GDP are largely due to variations of population.** For a 1 % increase in population, vertebrate populations would decrease by 1.6 %, why they would decrease by 0.3 % for a 1 % increase in GDP per capita. These results should however interpreted with caution, as GDP per capita data are available on a less granular level than those of population in the dataset by Kummu et al. (2018), and since GDP per capita is supposed to be uniformly spread within the area for which it is available.

**Table 6** – Correlation between the rates of variation of the population of studied species and of local GDP, GDP per capita and population

| | (1) | (2) | (3) |
|---|---|---|---|
| ∆log(1+GDP) | -0.387<br>(0.0913) | | |
| ∆log(1+pop) | | -1.651<br>(0.361) | |
| ∆log(1+GDP per capita) | | | -0.026<br>(0.072) |
| Observations | 167,960 | 167,960 | 167,960 |
| $R^2$ | 0,059 | 0,059 | 0,063 |
| *Fixed effects*<br>Study<br>Pair of years | <br>Y<br>Y | <br>Y<br>Y | <br>Y<br>Y |
| Controls | N | N | N |
| Survey | 1990-2015 | 1990-2015 | 1990-2015 |
| Variation of vertebrate population (*x*) | ∆log(1+x) | ∆log(1+x) | ∆log(1+x) |

**Note** : robust standard errors in parentheses. In the whole table, GDP variation are computed as ∆log(1+GDP), and are winsorized at the 1% level at the top and bottom of the distribution.

*Effects of agriculture*

**As mentioned above, Africa is particularly subject to deforestation, notably because of the extension of agricultural expansion, and the share of agriculture in value added is higher in Africa than in the rest of the world.** It is therefore useful to study the extent to which the estimated effects of GDP on local biodiversity are due to agriculture.

**In order to shed light on this topic, we combine the data from the Living Planet Index with GGCP10 data (Global Gridded Crop Production Dataset at 10 km resolution from 2010 to 2020) from Qin et al. (2023).** These data provide estimate the level of production of maize, rice, soybean and wheat at a 10 km resolution between 2010 and 2020.

**Table 7** – Correlation between the variation of population of studied species and the growth rate of agricultural production

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Produced cereal* | Maize | Rice | Soybean | Wheat | Total | Maize | Rice | Soybean | Wheat | Total |
| Effect of a 1% increase in agricultural production | 0.003<br>(0.014) | -0.037<br>(0.039) | 0.0004<br>(0.200) | 0.022<br>(0.007) | -0.011<br>(0.029) | 0.035<br>(0.023) | 0.005<br>(0.049) | 0.092<br>(0.211) | 0.011<br>(0.011) | -0.002<br>(0.007) |
| Observations | 30,472 | 30,472 | 30,472 | 30,472 | 30,472 | 30,472 | 30,472 | 30,472 | 30,472 | 30,472 |
| $R^2$ | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 |
| *Fixed effects* | | | | | | | | | | |
| Study | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Pair of years | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Controls | N | N | N | N | N | Y | Y | Y | Y | Y |
| Sample | 2010-15 | 2010-15 | 2010-15 | 2010-15 | 2010-15 | 2010-15 | 2010-15 | 2010-15 | 2010-15 | 2010-15 |

**Note**: robust standard errors in parentheses. In the whole table the variation of cereal production are computed as ∆log(1+x), winsorized at the 1% level at the top and bottom of the distribution, with x espressed in tons. The variations of vertebrate population are expressed as ∆log(1+x), robust standard errors in parentheses. The control variables integrated to the analysis correspond to the production level in year *t1* (expressed in log).

**The estimation is made on the period 2010-2015, using the same baseline framework analysis as for the effects of GDP (equation (1)). It suggests that local agricultural production have a weak effect on the variation of local vertebrate population (Table 7).** For each studied cereal, the effects are weak and non-significant. The only exception is for wheat, for which we find a positive effect of production on biodiversity in the regression without controls. However, this effect is not robust to including controls for the production in initial year *t1.* The evolution of the sum of cereal production is also weakly and non-significantly correlated with the variation of biodiversity. Importantly, while the sample is much smaller than the one used to estimated the effects of GDP, since cereal production data is available only since 2010, the difference in sample size is unlikely to explain the differences of effect between GDP and cereal production. Indeed, between 2010 and 2015, the correlation between GDP variation and biodiversity is negative and significant (with an elasticity of -0.7, as indicated in column 6 of Table 2).

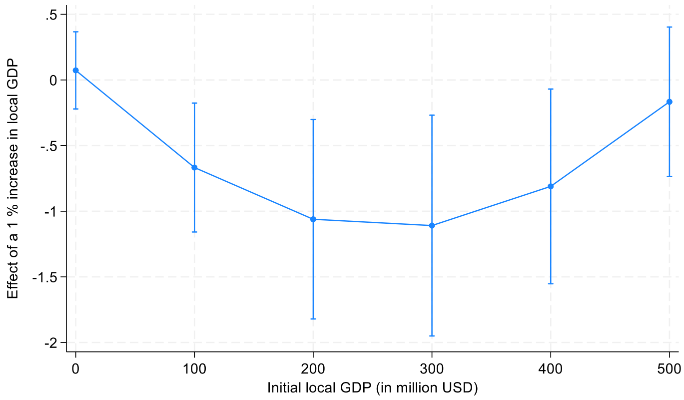
*Kuznets effects*

**In this section, we study the differences of effect of an increase in economic activity alon different initial levels of local GDP.** To do so, we interact the variation of local GDP between periods t1 and t2 with its level in year t1-1, taken in square values and winsorized at the 5% level at the top of the distribution (corresponding to about 500 million USD). The estimated equation is of the following form:

$$\Delta\log(1+Y)_{i,t1,t2} = \alpha + \beta \times \Delta\log(1+GDP)_{c(i),t1,t2} + \delta \times f(GDP_{c(i),t1-1}) + \theta \times f(GDP_{c(i),t1-1}) \times \Delta\log(1+GDP)_{c(i),t1,t2} + \vartheta_i + \mu_{t1,t2} + \varepsilon_{i,t1,t2} \quad (4)$$

where $f(GDP_{c(i),t1-1})$ is second order polynom of $GDP_{c(i),t1-1}$. We estimate this equation only in cases where $GDP_{c(i),t1-1}$ is strictly positive.

**Figure 6** – Correlation between the variation of economic activity and the variation of biodiversity measures, for different initial levels of economic activity




**Source** : *Living Planet Database,* Kummu et al. (2018), authors' computation.
**Note :** the figure presents the correlations between the variation of economic activity and the variation of biodiversity measures, along different initial levels of economic activity. The results are obtained using a regression of the variation of population of studied species on a double interaction between the % increase of GDP on the one hand, and the initial level of GDP, in square form, on the other hand. The estimation is made only for cases where initial GDP is non-nul. It includes fixed effects for Living Planet study and for pairs of years between which the variation of population and GDP are computed. The confidence intervals are the 95%. GDP is expressed in millions 2011 USD, at purchasing power parity.

**Our analysis suggests the presence of effects compatible with the existence of Kuznets curve of biodiversity (Figure 6).** The evolution of effects depending on initial local GDP indeed followa U-shaped curve. First, the effects are increasingly negative when the local GDP increases. It reaches a minimum when local GDP is of about 200-300 million USD (i.e. a value that is close to the average value observed when GDP is not null), and then attenuates before becoming almost null for the highest observed GDP levels.[16]

### d. Discussion of the results

**Several hypotheses can be made to explain the previous results, with various implications for African economies. On the one hand, the negative correlation between economic activity and biodiversity might largely reflect effects of urbanization, as suggested by the stronger contribution of effects relates to population.** While such an interpretation is coherent with previous contributions (Newbold et al., 2015), the impact of urbanization on biodiversity is likely to differ depending on whether it translates into urban sprawl or a higher density of already constructed area. Prospectively, the strongest biodiversity losses by 2020 might be observed in Africa (notably in West Africa), but also in North America (Li et al., 2024), as these areas are those where urban sprawl is the most dynamic in the world (Behnish et al., 2022). From this standpoint, the tradeoff between economic growth and biodiversity conservation will crucially depend on urbanization policies.

**On the other hand, the weak estimated effects of cereal production on biodiversity are surprising, and should be interpreted with caution.** Indeed, a very large literature documented the massive effects of agriculture on biodiversity loss, notably through production intensification, associated with higher land conversion and fertilizer use (Raven and Wagner, 2021). The absence of significant relationship in our data might be explained by the narrow temporal window we consider (2010-2015), which prevents from capturing the important biodiversity losses which occurred during periods of strong intensification of agricultural production, notably following the Second World War (see also below the discussion of analogous selection biases for the analysis of GDP). Another possible interpretation of these results is that biodiversity losses mainly depend, beyond the produced quantity, on the types

[16] On an indicative basis, in the matched data, the first quartile of local GDP (among non-null values) is of 2 million USD, the median is of 12 million USD, and the third quartile is of 100 million USD. The distribution is strongly asymmetric (average of 300 millions, last decile at 500 millions) and is not representative of the global distribution of GDP, since advanced economies (Australia and Canada notably) are overrepresented the Living Planet data. However, in the raw data of Kummu et al. (2018), a level greater than 500 million USD correspond to dense areas of advanced economies.

of agricultural practices that are implemented (Arslan, 2018). While increased production is often associated with more intensive production, which is likely to deteriorate biodiversity, many contributions documented the key role of biodiversity in maintaining agricultural yields (Binder et al., 2018 ; Dainese et al., 2019) or suggest that the adoption of agricultural practices that are more respectful of ecosystems might lead to higher yields, notably in developing economies (Di Falco et al., 2011, Abdulai et Huffman, 2014)[17]. The absence of correlation between increased production and biodiversity loss might therefore reflect a strong heterogeneity of agricultural practices underlying the increase of agricultural production in the sample. Therefore, the orientations of African economies in terms of agricultural policies might have a key role in conciliating both the preservation of biodiversity and of agricultural yields.

**Finally, the Kuznets effects we estimate might be due to many mechanisms.** They might reflect effects of sectoral transformation of the economy[18], through the successive stepping up, along development paths of many countries, of industry in place of agriculture, and of services in place of industry[19]. While this aspect of the environmental Kuznets curve has so far not been tested in the literature focusing on biodiversity, several factors suggest it could play a role. The high elasticity between biodiversity loss and economic activity estimated for intermediary levels of GDP might reflect a stronger presence of manufacturing or extractive industry. The latter have well documented effects on pollution (Balietti et al., 2018 ; Von der Goltz et Barnwal, 2019 ; Gonzalez et al., 2022 ; Gittard et Hu, 2023), animal populations  (Junker, 2024) and vegetal populations (Giljum et al., 2022, González-González et al., 2021). The low elasticity in areas with low GDP might correspond to a higher prevalence of the agricultural sector, which is likely to contribute to deforestation through the extension of agricultural parcels, but with a less intensive use of fertilizers. Indeed, in low income economies, and notably in Africa, the extension of agricultural parcels is faster than elsewhere (Barrett, 2021), but the use of fertilizers is also less intensive (computed by hectare of arable land, it is ten times lower in low income countries than elsewhere according to the World Bak data). This latter factor likely to dampen the effect of agricultural intensification. Finally, the weak elasticity estimated for areas with high GDP might reflect a prevalence of services: in this case, it might reflect greater measurement errors in local GDP, since the income generated by services might depend on primary or secondary productions (Baldwin et Lopez-Gonzalez, 2015), or more generally on ecosystem services (Svartzman et al., 2021) localized in different places. Finally, differences in income might lead to different priorities regarding the temporality of economic gains. Economies with intermediary levels of GDP might prioritize more often the present and short term gains, at the expense of the longer term benefits of conserving biodiversity (Perrings et Gadgil, 2003), which might explain that the elastictity between biodiversity loss and economic activity be more important in these areas.

**The smaller correlation between economic activity and biodiversity for the highest GDP levels in the sample might also reflect a better governance, likely to better dampen the effect of economic activity on biodiversity.** Such a hypothesis would be compatible with several contributions documenting the importance of the quality of local institutions to curb biodiversity deterioration (Souza-Rodrigues, 2015; Lipscomb and Mobarak, 2017 Burgess et al., 2012 ; Cust et al., 2023)[20]. In line with this hypothesis, higher income level could reduce the dependence of populations on local ecosystems, thus fostering the implementation of protected areas (see below). The latter are frequent sources of conflicts with local populations (Bontempi et al., 2023).

**The smaller correlation observed for high levels of economic activity could also reflect effects of historical composition, linked to the fact the analysis bears on a recent period (1990-2015).** This period of analysis does not capture biodiversity losses that might have occurred, in the past, during intensive industrialization periods of currently advanced economies. Therefore, it is possible that between two areas with identical initial levels of biodiversity, the one that experienced earlier industrialization observed a stronger decrease and currently has a lower level of biodiversity. However, the comparisons of *levels* of biodiversity of and of economic activity in our framework would be unlikely to yield convincing results.[21] Several contributions mobilizing data on a long period

[17] These effects are not homogeneous and depend on practices : for instance, the literature focusing on the effect of transition to organic agriculture suggests negative effects of organic certifications on yields (Lassalas et al., 2024).

[18] This aspect, which is at the heat of Kuznet's initial theory, gave rise to contrasted interpretations not only regarding inequalities (Baymul et Sen (2020), Ravallion et Chen (2021)), but also on pollution (Wolfersberger, 2019 ; Tatoglu et Polat, 2021).

[19] This regularity has been observed in global sectoral data : the share of agriculture in value added is the highest in low income countries , the share of industry is the highest in middle income economies, and the share of services is the highest in advanced economies.

[20] Beyond the quality of institution, the methods used to govern commons are key determinants of their sustainability (Ostrom, 1990).

[21] These biases can emerge for two reasons. On the one hand, studied animal species are not necessarily representative of the whole of local biodiversity. Indeed, a low population of a given species in a given location does necessarily mean a low biodiversity level in this location. Using variations in the analysis helps circumventing this issue, by studying effects *within* a given species. On the other hand, an

suggest that the Second Industrial Revolution could have led to a particularly severe decrease in biodiversity (Liao et al., 2022; McCauley et al., 2015). The fact that it began in the United Kingdom could partly explain why this country is among those with the most deteriorated biodiversity compared to the level that would have prevailed absent human activities[22][23].

**Overall, while these results should be interpreted with caution[24], the multiple mechanisms underlying them suggest that it might be possible to reach simultaneously development and biodiversity preservation targets.** While African biodiversity is likely to experience increased pressure because of the expected increase in economic activity on the continent, the types of economic growth, governance and environmental protection that will be implement are likely to play a major role in preserving biodiversity. Furthermore, because the impacts of biodiversity loss on the African continent are likely to be both local and global, a good articulation between local and international policies will be essential.

analysis in level might be more prone to selection biases. Indeed, areas with lower initial levels of biodiversity (such as deserts), might represent a less favorable for human activities. This can lead to a positive correlation between the current levels of biodiversity and economic activity, even in a case where an increase in economic activity decreases biodiversity. In fact, the correlation between local levels of GDP and biodiversity is positive. Using rates of variation can help circumventing this bias, but, for the same reason, prevents from reaching a conclusion between the level of economic activity and the level of biodiversity.

[22] According to the biodiversity intactness index (estimating the gap between observed biodiversity level and the level that would be observed absent human activity), developed in the London's Natural History Museum, the UK might have lost 60% of its initial biodiversity, against 20 % in the world. These levels have hardly evolved in the last decades.

[23] A last hypothesis to explain this lower correlation at high levels of economic activity could be the existence of a homogenization of species in postindustrial economies (Smart et al., 2006 ; Daru et al., 2021), notably through the development of generalist species, that potentially resist better to human perturbation of their environment (Devictor et al., 2008). This last point is however subject to debate (Clavel et al., 2011).

[24] It is worth noting that these results are estimated on data ranging only until 2015. Therefore, they do not take into account the policies implemented or considered in African economies in order to reconcile economic development and biodiversity conservation.

2. **Numerous public policies, both international and local, are being implemented to enable African countries to combine economic growth with biodiversity conservation.**

A. **Africa is both affected by and contributing to global biodiversity loss, calling for coordinated action**

**As in the case of global warming, the issue of biodiversity loss needs to be approached from a global perspective.** Biodiversity is, of course, intrinsically local and, in view of the local services it provides, can be understood as a "local public good" (Perrings et al., 2009). In fact, biodiversity conservation is first and foremost beneficial to the economies that implement it. In addition to the benefits it brings to populations whose livelihoods depend directly on local ecosystem services, preserving local biodiversity can also be an asset in terms of tourism, as has been documented, for example, in Brazil (Zhu et al., 2021) or Costa Rica (Etcheverri et al., 2022). It can even be a tool of diplomatic influence (Ellwanger et al., 2022). However, the benefits provided by biodiversity are not only reaped by the countries that make the effort to preserve it, and its degradation is likely to have global consequences in terms of economic stability, global warming, health or even food security. This justifies considering biodiversity conservation, like climate protection, as a "global public good" (Chin, 2021) or as a « global common » (Global Environment Facility)[25].

**The key role played by global ecosystem services in global economic activity poses high risks for the latter, as well as for global financial stability.** At a global scale, according to Costanza et al. (2014 the ecosystem services rendered by biodiversity are estimated to represent approximately 125,000 billion USD, i.e. almost 1.5 times world GDP, an estimate that would constitute a lower limit, as the indirect effects are particularly complex to evaluate (Svartzman et al., 2021). In France, 42 % of the assets held by French financial institutions depend strongly or very strongly on ecosystem services according to Svartzman et al. [2021]). A global collapse of ecosystem services brought by pollination, ocean floors and indigenous forests could lead, by 2030, to a decrease in GDP of 2,700 billion USD (Johnson et al., 2021).

**Global biodiversity losses put African economies at particular risk.** In emerging and developing economies, the potential economic losses associated with biodiversity loss would be greater than those observed in the Covid-19, and these differences would be particularly marked for African economies. A partial collapse of biodiversity would result in a GDP loss of 9.7% in sub-Saharan Africa by 2030, compared with 6.5% in South Asia, around 3% in East Asia and Latin America, 2% in the Middle East and North Africa, and less than 1% in Europe and North America. (Johnson et al., 2021; Kraemer et Volz, 2022). Losses could reach almost 20% in Madagascar and the DRC, 15% in Ethiopia, 10% in Nigeria, and 5% in Egypt. These higher losses can be explained by the greater dependence of African economies on pollinated crops and forestry products, and less economic diversification.

**Given the global importance of these ecosystems, Africa could make a significant contribution to these global effects.** Insofar as Africa is home to forests that constitute some of the world's most important carbon sinks (notably the Congo Basin), their disappearance is likely to accelerate global warming. In addition, the disappearance of animal biodiversity is likely to favor the emergence of zoonoses, increasing the risk of pandemics. According to the IPBES, 30% of zoonotic diseases are attributable to changes in land use. The hardening of living conditions linked to the loss of local biodiversity, which could be particularly marked in Africa, could also lead to population movements or conflicts, as has been demonstrated with regard to global warming and natural disasters**.** (Miguel et al. 2004 ; Le Goff and Lemaire 2022 ; Cruz and Rossi-Hansberg, 2021).

**This interdependence between preserving biodiversity and improving people's living conditions is enshrined in the United Nations' Sustainable Development Goals (SDGs).** Indeed, the fifteenth SDG stipulates the need to "restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss".

**Biodiversity is therefore a "global public good", and its preservation requires greater international coordination.** As the benefits provided by biodiversity are not only reaped by those countries that make the effort to preserve it, it is crucial to provide financial incentives for countries to make the necessary efforts to preserve biodiversity. This is particularly important for carbon sinks such as forests, which play an essential role in reducing

[25] Despite theoretical differences existing between public goods (non excludable and non rival) and common goods (non-excludable but rival), both terms tend to be used indistinctly (Cogolati et al., 2015) to name the global benefits of preserving biodiversity.

net $CO_2$ emissions. While the need to protect biodiversity has been the subject of international agreements since the early 1990s[26], the acceleration of its deterioration in recent decades has heightened the importance of this issue within the discussions of the international community, leading to a multiplication of initiatives in this field.

### B. At the international level, a rise in public financing, a multiplication of financial instruments, and a heightened role of African economies in the negotiations

**In order to reinforce biodiversity conservation, the international community increased financing through dedicated facilities, or through public development banks.** According to the OECD (2020), average annual biodiversity-related financial flows ranged from 78 to 91 billion USD over 2015-2017, comprising domestic and international public expenditure, but also private expenditure. Regarding international public expenditure, they are estimated to 6.1 billion USD every year, and mostly stem from bilateral financing (Table 8).

**Table 8 –** International public biodiversity finance: bilateral and multilateral flows (annual, 2015-2017 average, USD millions)

| | Mid-range estimate |
|---|---|
| **Bilateral** | |
| Biodiversity-related allocable bilateral ODA (% of total allocable bilateral ODA) | 5,474 (4 %) |
| Biodiversity-related other official flows | 13 |
| Bilateral total | 5,487 |
| **Multilateral** | |
| Biodiversity-related multilateral ODA | 482 |
| Biodiversity-related multilateral non-concessional flows | 83 |
| Multilateral total | 565 |
| **Total bilateral and multilateral** | **6,052** |

**Source :** table taken from OECD (2020).

**Multilateral financing aiming at protecting biodiversity increase in recent years.** The latest replenishment cycle of the Global Environment Facility (GEF), for the period 2022-2026 reached 5.3 billion USD, against 4.1 to 4.4 billion USD for the three cycles between 2010 and 2022 (source : GEF). Regarding the World Bank, which is the main multilateral donor regarding biodiversity, its biodiversity-related portfolio continuously increased in recent years: it reached 2.8 billion USD in 2022, up by 700 million compared to 2021, and reached 3.7 billion USD in 2023, a 31 % increase compared to the previous year.

**The Kunming-Montreal Global Biodiversity Framework adopted in December 2022 stipulates that, to achieve the targets that were set, biodiversity-related financial resources must be increased to at least 200 billion USD a year by 2030.** A principle of solidarity between advanced economies and developing countries has also been established, implying an increase in funding from developed countries to developing countries of at least 20 billion dollars per year by 2025 and at least 30 billion dollars per year by 2030.

**In that respect, the framework plans for the creation, with the GEF, of a Global Biodiversity Framework Fund (GBFF),** whose statuses were adopted in the seventh GEF assembly in August 2023, in Vancouver. Canada and the United Kingdom announced on this occasion respective contributions of 200 million Canadian dollars (127 million euros) and 10 million pound sterling (11.5 million euros). This assembly was marked by the adoption of the eighth GEF replenishment, with a specific focus on biodiversity. A first assessment of the new fund's efficiency will be carried out during COP 16 that will occur in 2024, and a new assessment will be carried out during the COP 18, in 2028.

**While the creation of a dedicated trust fund is an important step towards financing biodiversity protection, additional funding from multilateral development banks and development finance institutes is also needed to achieve the targets set.** The expected strengthening of the World Bank's mandate to protect "global public goods" could help to further increase funding for biodiversity**.** Regarding development banks, the IDFC network (*International Development Finance Club*), gathering 27 national, regional and bilateral development banks, including numerous institutions from emerging and developing countries, committed, ahead of COP 15 in 2022, to

[26] Appendix C presents a brief historical overview of international measures to protect biodiversity

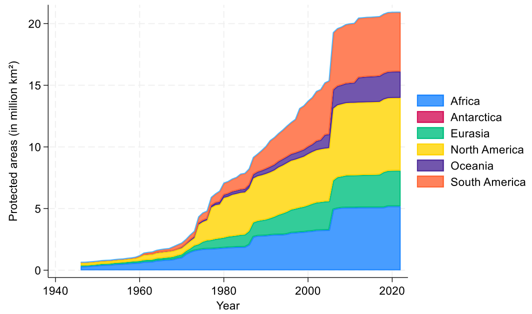
mobilize more than 100 billion euros of financing for biodiversity by 2027 (IDFC, 2022). In 2020, climate-related financing from IDFC members reached close to 185 billion USD, of which 27.4 billion targeted adaptation projects, and 14 billion targeted biodiversity[27]. In France, the French Development Agency (AFD) announced, prior to COP 15, that 30 % of its climate-related financing would have biodiversity co-benefits by 2025[28].

**Finally, in order to increase financing dedicated to biodiversity protection, several financial mechanisms are planned and start to be developed**[29]. The 2022 Kunming-Montreal Biodiversity Framework states, in its target 19, that in order to increase biodiversity-related funding, « *stimulating innovative schemes such as payment for ecosystem services, green bonds, biodiversity offsets and credits, benefit-sharing mechanisms, with environmental and social safeguards* » should be developed. The GEF presented during the One Forest Summit (March 2023), a report on innovative financial mechanisms for biodiversity (FEM, 2023), with a focus on new instruments: biodiversity-positive carbon credits and nature certificates. The Summit on a New Global Financing Pact, held in Paris in June 2023, maintained the momentum, as France and the United Kingdom launched a roadmap on high integrity biodiversity credits, based on report from NatureFinance and Carbone4 (2023), with the contribution of the GEF.

**Given its major role in protecting the world's biodiversity, the African continent is playing an increasingly important role in international negotiations**. In March 2023, the One Forest Summit, co-organized by France and Gabon, brought together some twenty countries representing the world's major forest basins, and led to the development of the Libreville Plan, which aims to protect tropical forests as major carbon and biodiversity sinks.[30].

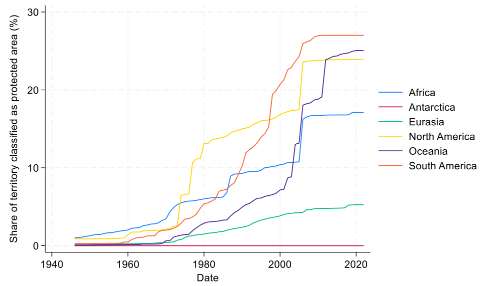
**Additionally, African countries implemented several policies to protect diversity, notably by deploying protected areas.** The latter are defined as "*clearly defined geographical spaces, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values*" (IPBES).

**Figure 7 :** Total of global protected areas




**Source :** *World Database on Protected Areas*
**Note:** protected areas encompass land, coastal and marine areas.

**Figure 8 :** share of terrestrial surface covered by protected area, by continent




**Source :** *World Database on Protected Areas*
**Note:** protected areas encompass land, coastal and marine areas.

**The establishment of protected areas is at the heart of the multilateral approach to biodiversity protection.** The 2011-2020 Strategic Plan for Biodiversity, adopted in 2010 at the Conference of the Parties to the Convention on Biological Diversity, set a target of protecting 17% of land and 10% of marine and coastal areas (Aichi target 11, Lo et Jang (2022)). This target was reinforced with the adoption of the Kunming-Montreal Global Biodiversity Framework at COP 15 in December 2022, which proposes the "30 x 30" target, i.e. a target of 30% of land and ocean area conserved by 2030 in protected areas or local conservation measures.

[27] IDFC | AFD - Agence Française de Développement
[28] One Planet Summit: AFD undertakes to allocate at least 30% of its climate funding to biodiversity | AFD - Agence Française de Développement
[29] Appendix D presents a brief summary of thse financial mechanisms (payment for ecosystem services, markets for high integrity biodiversity credits or biodiversity certificates, systems of biodiversity compensation – implementation of sovereign guarantees, debt for nature swaps, greening of the financial system), as well as the main challenges in their implementation (measurement, implementation, risks of non-additionality and of greenwashing).
[30] Primary forests, mangroves and bogs represent 15 % of Earth surface, 75 % of unrecoverable sequestrated carbon. They constitute the ecosystems of more than 90 % of vertebrate species.

**Africa appears as a proactive continent on this topic (Figures 7 and 8), even though its surface of protected areas stagnated in recent years.** According to the IPBES (2019), 14 % of its land and 2.6 % of its oceans are classified as protected. The continent has 369 wetlands of international importance (according to the Ramsar convention[31]), 142 UNESCO world heritage sites, 1,255 important areas of bird population and biodiversity, 158 Alliance for Zero Extinction sites.

**Another type of measure implemented by African countries to protect biodiversity is the introduction of forest management certifications.** These certifications aim to assess whether forests are responsibly managed, and whether the goods derived from them follow a chain of custody to ensure traceability. In the Congo Basin, 5.4 million hectares of forest (i.e. around 10% of exploitable forest) are Forest Stewardship Council (FSC) certified, straddling three countries (Cameroon, Gabon and Congo).

**Several African countries are also implementing innovative financial instruments to secure the funding needed to protect biodiversity.** Debt-for-nature swaps, which aim to exchange part of the beneficiary countries' foreign debt for funding for climate change adaptation or biodiversity protection projects, have thus been implemented in some African countries. In 2016, the Seychelles issued a blue bond with The Nature Conservancy (TNC), aimed at financing the transition to sustainable fishing. Gabon, for its part, entered into a 500 million USD debt conversion agreement in 2023, expected to generate 163 million USD in funding dedicated to marine conservation over the next 15 years. Some African countries are also considering mobilizing private financing by issuing bonds incorporating biodiversity protection measures. In March 2023, South Africa, in partnership with the World Bank (IBRD), issued a 5-year, 150 million USD "rhino bond" (« *Wildlife Conservation Bond* »). This scheme aims to protect and increase black rhino populations in two of the country's protected areas, while improving protected area management and creating jobs for local communities. This bond includes a potential performance payment from the Global Environment Facility (GEF): no coupon is paid to investors, who will receive at the end of the bond period, in addition to the principal, a grant of USD 13.76 million from the GEF based on rhino population growth results. This is an innovative mechanism, in which investors bear the risk of project performance. Such a mechanism, supported by the World Bank, could be replicated in other African countries to channel more private funding towards biodiversity conservation actions.

## 3. International and local initiatives will only be able to halt the decline in biodiversity in Africa if sufficient funding is secured and local populations are involved.

### A. At the international level, a necessary increase in funding for biodiversity, particularly for Africa

**According to the panel of experts of the Convention on Biological Diversity (2021), funding requirements for biodiversity could range from 105 to 306 billion USD per year.** The report by the Independent High-Level Expert Group on Climate Finance (Songwe et al., 2022), meanwhile, estimates that protecting natural capital in developing countries (excluding China) would require investments of 275-400 billion USD per year by 2030. According to Deutz et al (2020), biodiversity protection needs will average between 722 and 967 billion USD per year by 2030, whereas current spending on biodiversity conservation is between 124 and 143 billion USD per year, resulting in a biodiversity funding gap of between 598 and 824 billion USD a year.

**Financing needs are particularly pressing for Africa, which is not only more vulnerable than average to biodiversity loss, but also has narrower financial margins.** For several years now, the continent has been hit by a decline in external financing and a rise in public debt and its interest burden (IMF, 2023). In order to support African economies in the fight against biodiversity loss and its economic consequences, it may be necessary to take these risks into account in bilateral and multilateral financial support programs. While there is an increasing number of schemes to deal with the economic consequences of climate-related disasters, there are still few schemes to mitigate the effects of biodiversity loss, which can be explained by as yet unresolved measurement difficulties. Calls were also made to integrate biodiversity-related risks to debt sustainability analyses (Kraemer et Volz, 2022). Indeed, while climate risks are progressively incorporates to the analyses of the IMF (as part of its debt sustainability analyses or Article IV reports), this is not the case of risks related to biodiversity losses. Similarly, while the IMF has been implemented an increasing number of mechanisms aiming at addressing the economic consequences of climate change, whether in the short run (*Catastrophe Containment and Relief Trust* – CCRT) or

[31] The Ramsar Convention was signed in 1971 by 171 countries, and enacted in 1975. Ramsar sites are wetlands of international importance that must meet nine criteria, bearing notably on the presence of birds and fishes.

in the longer run (Resilience and Sustainability Trust – RST), risks associated with biodiversity losses are not explicitly included in these mechanisms. Finally, while initiatives focusing on debt instrument including contingency clauses in case of natural disasters are being developed (for instance, the AFD implemented such instruments in 2007, as does the United Kingdom in the framework of its bilateral loans), biodiversity remains absent of these considerations.

**Last but not least, African countries will not be able to increase their financial margins without greater access to innovative financial instruments and greater mobilization of private funding.** Payments for ecosystem services (PES), which refer to the direct and indirect benefits that humans derive from nature, correspond to "transfers of resources between social actors, with the aim of creating incentives to align individual and/or collective land-use decisions with the social interest in natural resource management" (Muradian et al., 2010; Karsenty, 2019). The REDD+ program (Reducing emissions from deforestation and forest degradation in developing countries) of the United Nations Framework Convention on Climate Change is an example of payment for ecosystem services, which aims to reduce emissions from deforestation and forest degradation by providing financing for the conservation and sustainable management of forests. Positive Conservation Partnerships (PCP), introduced at the Libreville Summit in March 2023, are part of a similar approach, enabling countries to be remunerated for preserving forests on their territories, which are carbon and biodiversity reserves, via the creation of "biodiversity certificates" that could be purchased by governments or private players. An initial budget of 100 million euros has been allocated for the implementation of PCP. The Libreville Plan also calls for a scientific project ("One Forest Vision") to map the world's main carbon and biodiversity reserves, in order to better measure the value of forests. The private sector has also committed to the Libreville Plan through the "10by30" initiative, which aims to create 10 million jobs in sustainable forest management by 2030. Finally, while debt-for-nature swaps are the subject of much debate within the international community, and have been implemented by some African countries, this mechanism remains little used, particularly in Africa. Indeed, between 1987 and 2015, only 39 countries benefited from it, to the tune of 99 billion USD, but the majority of the funds generated concerned Latin America and the Caribbean, with sub-Saharan Africa only benefiting to the tune of 12 billion USD. Since 2021, only four other countries have had recourse to the system, for a total of 2.8 billion USD in restructured debt[32], and Gabon was the only African country among them. The development of such instruments remains limited in view of the complexity of their implementation, involving lengthy negotiations and high monitoring costs to verify the proper implementation of the projects decided upon within the framework of the debt swap. Furthermore, the effectiveness of this type of mechanism, in terms of both debt restructuring and biodiversity protection, remains to be proven, as it generally results only in the implementation of protected areas, without targeting the causes of biodiversity loss.

### B. The need for a holistic approach that takes into account governance issues and includes local populations

**The effectiveness of forest certification and protected areas, which have been widely developed on the African continent to protect biodiversity, is in some respects contested.**

**The economic impact of forest certification is mixed, and the obstacles to its effectiveness are particularly marked in Africa.** While some studies show that increasing the number of forest certifications reduces deforestation (Damette and Delacote, 2011), others find zero (Zubizarreta et al., 2023) or even negative (Bouslah et al., 2010) effects on the performance of certified companies. Zubizarreta et al. (2023) even identify a marked selection effect: companies that embark on a certification process are those with the best upstream economic and financial performance. Finally, according to Chen et al. (2020), forest certification could constitute a barrier to trade, weighing particularly heavily on developing economies. In Africa, more specifically, the fragility of regulations and the lack of transparency in certification processes are likely to limit the effectiveness of these systems. They also face illegal logging, which governments sometimes find difficult to curb.

**Similarly, there is no complete consensus on the effectiveness of protected areas, and case studies from Africa highlight significant implementation difficulties.** Some studies point to significant economic and financial gains if the global target of 30% protected areas is achieved, with estimates of avoided economic losses in the order of 64 to 534 billion USD per year by 2050 (Waldron et al., 2020). Nevertheless, the quality of protected area

[32] Belize (2021) ; Barbados (2022) ; Ecuador (2023) ; Gabon (2023). Voir Pérez-Beltràn et Landry (2023).

governance is a key factor in their effectiveness in preserving the environment. In fact, of all the marine protected areas in the world, only a third guarantee effective protection of biodiversity, mainly due to inadequate regulation and management (Pike et al., 2024). In Africa, the report of the [Observatory of Central African Forests (OFAC)](#) (Doumenge et al., 2021), highlights import progress of protected areas in central Africa[33]. However, it also brings to the fore a lack of human and financial resources, a low participation of local populations, a lack of data regarding areas that should be controlled, a need to modernize and strengthen the legal framework, and a need for a better regional cooperation, as numerous areas are cross-borders. Furthermore, it is often difficult to simultaneously reach biodiversity conservation targets and maintain the wellbeing of local populations (West et al., 2006), whose point of view is sometimes incompletely taken into account (West, 2006). The resources that protected areas aim at preserving can also be coveted by local population, and even trigger conflict (Bontempi et al., 2023), in particular when local population have low income and depend local ecosystem services.

**The establishment of protected areas has thus been accompanied by difficulties relating to the treatment of indigenous peoples and local communities, as the conservation measures implemented can lead to forced population displacements.** Based on a broad synthesis of scientific literature, Woodford et al. (2022) show that the scientific literature does not support the commonly developed narrative that protected areas are necessarily beneficial for the most vulnerable populations. In the case of Africa, the number of people expelled from African national parks in the twentieth century could reach several million farmers and herders (Blanc, 2020). The exclusion of populations from certain national parks is even more likely to occur in African countries, where land tenure law is often underdeveloped, and protected areas are often managed by govenments (Belle, 2015). Here again, the literature review by Woodford et al. (2022) suggests that financial compensation for displaced populations is not sufficient to offset the costs borne by local populations.

**The difficulties encountered by protected areas in dealing with local communities are thus leading to some questioning of this approach (Obura and Treyer, 2023).** The development of more holistic approaches, closely integrating the point of view of local populations, thus aims to take into account the distributive and social dimension of nature protection, in particular the protection of the most vulnerable people. This is particularly important for African populations, who are heavily dependent on ecosystem services. Such an approach could also be a lever for the effectiveness of protected areas: indeed, numerous studies show that the participation of local populations and the securing of their property rights are effective levers for promoting biodiversity (Woodford et al., 2022).

**While the Kunming-Montreal Global Biodiversity Framework adopted in 2022 puts forward a quantified target for protected areas, it also includes in its target 10 the need to guarantee the sustainable management of all spaces**, ensuring that "*areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, in particular through the sustainable use of biodiversity*"**.**

**At the crossroads of these approaches, the "shared land" approach could be particularly well suited to the African context.** Developed by African scientists and local leaders, it aims to achieve the "30 x 30" objective by distributing protected areas as evenly as possible across the territory, so that local populations can benefit from the services provided by protected areas (Obura and Treyer, 2023).

**The introduction of payment systems for environmental services, based on co-investment with local communities, is part of a similar approach (Treyer et al., 2023).** The aim is to reconcile the protection of biodiversity and the development of local populations by enabling them to adopt activities that meet the dual objective of satisfying their needs while putting in place a sustainable development trajectory. According to Karsenty (2019), payments for such services are also more effective in protecting biodiversity, whereas protected areas or environmental regulations, which sometimes remain unenforced, are not always effective protection measures. However, the introduction of such payments requires greater coordination with stakeholders to avoid moral hazard phenomena.

**This recognition of the rights of indigenous peoples and local communities to the natural resources of their ancestral lands was given legal expression by the African Commission on Human and Peoples' Rights (a body of the African Union)**. In 2009, it condemned the Kenyan government for evicting the Endorois people from

[33] The number of protected areas in this region strongly increased in the last decades, reaching a number of 206 over 799 000 km², i.e. 15 % of the region's land area and 5 % of the marine area in 2020, corresponding to a 50 % increase in the number and superficy of protected areas in 20 years.

their lands around Lake Bogoria in order to create a protected area, and ordered the government to return their lands and compensate them for their losses.

**While the establishment of protected areas appears to be a preferred approach in African countries for protecting biodiversity, in line with the definition of global objectives in this area, this approach needs to be reconciled with the rights of indigenous peoples and local communities in a shared development goal.**

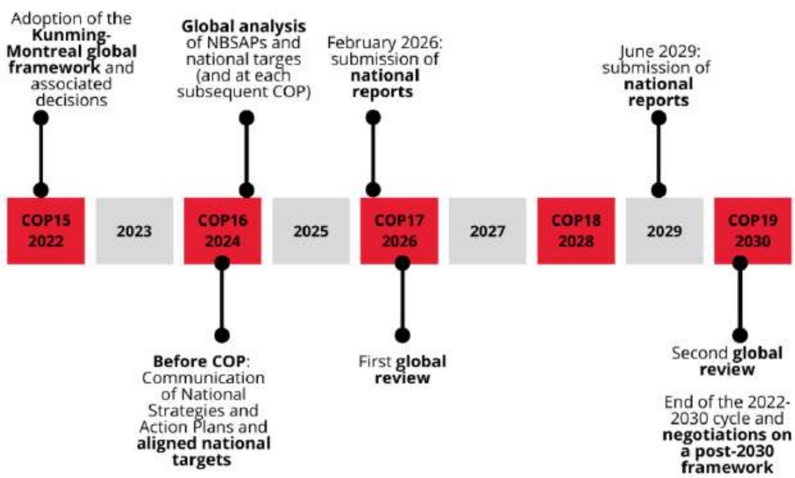
### Conclusion

**African countries' biodiversity is particularly rich, but declined sharply for several decades.** Biodiversity loss is a global trend, but it is particularly acute in Africa, where populations, mostly rural, are extremely dependent on ecosystem services. Preserving biodiversity in Africa is therefore a major challenge, and one that must be combined with ambitious economic development objectives**.** Yet, this combination is not without difficulties, as economic activity negatively affects biodiversity. We show that a 1 % increase in local GDP tends to reduce local biodiversity by 0.5 %. Our results suggest predominating effects of demographic growth and the existence of Kuznets curve of biodiversity, indicating that biodiversity losses are strongest for intermediary levels of initial activity. In this context, economic policy choices made by African countries in the upcoming years will be key to build a development pathway that is compatible with biodiversity conservation.

**From this perspective, international coordination in biodiversity protection is essential, as biodiversity is a "global public good", and the implementation of global measures in this field, as well as an increase in dedicated funding for the African continent, which is a major biodiversity reserve, are necessary.** At local level, African countries have implemented dynamic policies to protect biodiversity, but these often face governance challenges. The development of innovative financial mechanisms, as well as the implementation of biodiversity protection policies involving indigenous populations and local communities, are all measures that should make it possible to articulate biodiversity preservation and economic development objectives.

**In order to combat the loss of biodiversity, it is essential to coordinate these various tools and ensure their coherence with international initiatives.** 2024 is a key year in this respect. Indeed, the organization of the Summit for the Future in September 2024 provided an opportunity to reaffirm existing commitments to sustainable development goals. Furthermore, the 16th COP on Biological Diversity, held in Colombia in October 2024, should provide an initial assessment of the implementation of the Kunming-Montreal Global Biodiversity Framework, as well as a review of countries' national biodiversity strategies and action plans, in line with the global objectives set out in the Kunming-Montreal agreement.

**Figure 8**: Global targets of the Kunming-Montreal Biodiversity Framework




**Source** : Landry et al. (2023)

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## Appendix A – Defining and measuring biodiversity : some landmarks

**The concept of biodiversity is multidimensional (Svartzman et al., 2021).** Biodiversity is defined as "the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part" (IPBES). It thus refers to i) diversity within species, which may be genetic, behavioral, cultural or morphological; ii) diversity between species, i.e. the variety of existing species; iii) diversity between the ecosystems in which species live. Biodiversity cannot be understood without taking into account, on the one hand, its integration into wider systems (biome, biosphere) ensuring the interconnection of ecosystems, and on the other hand, its interconnection with human activities (Latour, 2015). Biodiversity can be understood in terms of the ecosystem services it provides to people. According to the classification proposed by the United Nations, these can be broken down into four types: i) provisioning services, corresponding to the material benefits that enable us to meet human needs in terms of food, energy, medicine, etc.; ii) regulating services, which refer to the benefits linked to the regulation of ecosystems (such as pollination, which is essential to the world's food crops); iii) socio-cultural services, corresponding to the non-material contributions of biodiversity; iv) services supporting human environments, which enable the production of all other services.

**Given the multidimensional nature of biodiversity, it can be measured using a variety of metrics.** Species diversity can be measured in terms of richness (number of different species in an ecosystem), abundance (number of individuals of the same species in an ecosystem), or relative abundance between species. The measure of richness within a territory can itself be broken down into alpha diversity (i.e. the number of species observed within each of the sub-territories that make it up), beta diversity (i.e. the number of species observed in a given sub-territory and only in this sub-territory)[34].

**Numerous indicators have been developed to provide a synthetic measure of biodiversity trends.** The Red List Index, based on the work of the International Union for Conservation of Nature, measures trends in species extinction risk. The Biodiversity Intactness Index estimates the proportion of a terrestrial habitat's biodiversity that has remained intact in the face of land-use pressures. The Biodiversity Habitat Index estimates the impact of habitat loss on biodiversity loss. The Mean Species Abundance, developed by CDC Biodiversité, measures the average abundance of species in a habitat compared to that which would have been observed in a theoretically intact ecosystem. Finally, the Living Planet Index (LPI), which underpins WWF's Living Planet report, published every two years, and which serves as the basis for the United Nations Convention on Biological Diversity, measures trends in various species population measures[35].

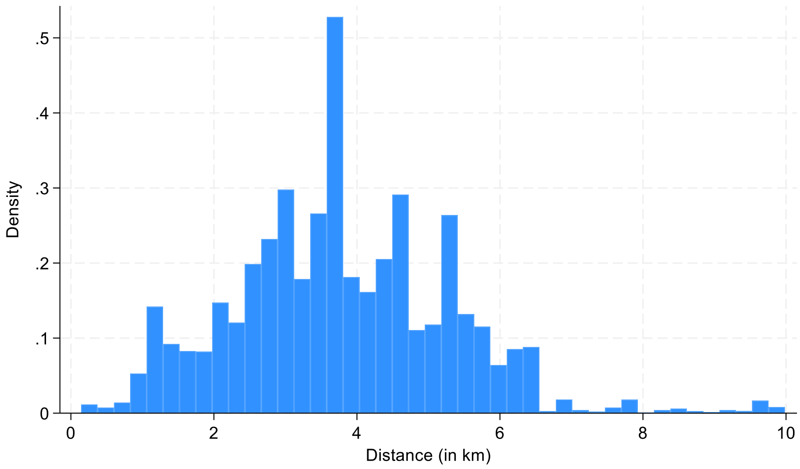
[34] See also Cognie et Péron (2020) for a summary of biodiversity measures.

[35] Some recent contributions challenge question the fact the Living Planet Index represents an abundance measure stricto sensu, because of how it aggregates underlying data (Puurtinen et al., 2022). Likewise, while the Living Planet Index suggests a generalized drop of the index, as more than half of studied species saw their population decrease, Leung et al. (2020) show that the decrease in the index is due to a small fraction of species with rapidly declining populations.

## Appendix B – Methodological details on the data matching

The matching of local GDP and local biodiversity data is made by comparing the GPS coordinates (longitude and latitude) of the Living Planet Index studies with those of the grid cells in Kummu et al. (2018). Each Living Planet Index study is matched yearly to the closest grid cell in Kummu et al. (2018) using an Haversine distance. We keep only matched data when the location study and the centroid of the closest grid cell are less than 10 kms away. Eventually, our sample consists in 22,726 studies out of 30,504 studies with GDP coordinates, i.e. 75 % of the latter. On average, among matching studies that are distant by less than 10 kms from the centroid of the closest, the average distance between the study and the centroid of the closest grid cell is 3.7 kms (Figure B1). The average time interval between two population surveys within a given study is of 1.3 years (and 91 % of surveys are yearly).

**Figure B1**. Histogram of distances between Living Planet studies and their closest GDP grid cells (among matching pairs with a distance lower than 10 kms)




On the 195,361 observations of our study, 72 % focus on birds, 13 % on fishes (or related), 11 % on mammals, 2 % on reptiles and 1 % on amphibians (Table B1).

**Table B1**. Distribution of studied species

| | Frequency | Percent |
|---|---|---|
| Actinoperi (fishes) | 25,299 | 12.95 |
| Amphibia (amphibians) | 2,655 | 1.36 |
| Aves (birds) | 141,518 | 72.44 |
| Coelacanthi (fishes) | 2 | 0.00 |
| Dipneusti (fishes) | 7 | 0.00 |
| Elasmobranchii (fishes) | 670 | 0.34 |
| Holocephali (fishes) | 10 | 0.01 |
| Mammalia (mammals) | 20,932 | 10.71 |
| Myxini (fishes) | 4 | 0.00 |
| Petromyzonti (fishes) | 65 | 0.03 |
| Reptilia (reptiles) | 4,199 | 2,15 |
| Total | 195,361 | |

A majority of observations are located in North America (35 %) and in Asia-Pacific-Oceania (34 %). Europe and Central Asia represent 21 % of observations. Africa and Latin America-Caribbean represent 4 % of observations each (Table B2).

**Table B2**. Distribution of observations across continents

| | Number of observations | | Single studies | | Average number of obs. per study |
|---|---|---|---|---|---|
| **Continent** | **N** | **%** | **N** | **%** | |
| Africa | 8,340 | 4.27 % | 1,677 | 7.38 % | 4.97 |
| Asia – Pacific - Oceania | 66,546 | 34.06 % | 8,222 | 36.18 % | 8.09 |
| Europe – Central Asia | 40,158 | 20.56 % | 4,445 | 19.56 % | 9.03 |
| Latin America - Caribbean | 8,892 | 4.55 % | 2,481 | 10.92 % | 3.58 |
| North America | 68,727 | 35.18 % | 5,637 | 24.80 % | 12.19 |
| Others | 2,698 | 1.38 % | 264 | 1.16 % | 11.24 |
| Total | 195,361 | | 22,726 | | 8.60 |

**Table B3**. Distribution of observations by countries

| | Number of observations | |
|---|---|---|
| **Continent** | **N** | **%** |
| Australia | 59,885 | 30.65 % |
| Canada | 59,347 | 30.38 % |
| Spain | 8,913 | 4.56 % |
| United States | 8,749 | 4.48 % |
| Norway | 4,884 | 2.50 % |
| France | 4,389 | 2.25 % |
| Brazil | 3,417 | 1.75 % |
| South Africa | 2,655 | 1.36 % |
| Germany | 2,377 | 1.22 % |
| Others | 40,745 | 20.9 % |
| Total | 195,361 | |

**Appendix C – Historical overview of international measures to protect biodiversity**

**At international level, the importance of protecting biodiversity for all mankind was recognized by the Convention on Biological Diversity (CBD), signed at the Earth Summit in Rio de Janeiro on June 5, 1992.** The convention had three main objectives: i) the conservation of biological diversity; ii) the sustainable use of the components of biological diversity; iii) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. The Convention came into force in December 1993, and now has 193 signatories. The Conference of the Parties (COP), the CBD's governing body, meets every two years to assess progress and decide on work programs. The Convention has been supplemented by two protocols: i) the Cartagena Protocol on Biosafety, which aims to regulate the transboundary movement of living modified organisms resulting from modern biotechnology; ii) the Nagoya Protocol on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization.

**In 2010, the Conference of the Parties to the Convention on Biological Diversity adopted the 2011-2020 Strategic Plan for Biological Diversity. The aim was to establish a framework for action to preserve biodiversity, through the definition of 20 objectives relating to biological diversity: the Aichi Biodiversity Targets.** These objectives are broken down into 5 strategic goals: i) to address the underlying causes of biodiversity loss by integrating diversity; ii) to reduce direct pressures on biodiversity and promote sustainable use; iii) to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity; iv) to enhance the benefits for all from biodiversity and ecosystem services; v) to strengthen implementation through participatory planning, knowledge management and capacity building. States have committed themselves to implementing the Aichi targets at national level through National Biodiversity Strategies and Action Plans (NBSAPs). However, the United Nations' 2020 assessment of the Aichi Targets shows that, at global level, no target has been fully achieved (six have been partially achieved), while at national level results remain limited, with on average only one-third of all targets on track to be achieved.

**COP 15 in Montreal in December 2022 saw the adoption of a new ten-year framework for the protection of biodiversity up to 2030: the Kunming-Montreal Global Biodiversity Framework.** The Kunming-Montreal Global Biodiversity Framework has four objectives for 2050: i) to preserve and restore ecosystems; ii) to manage biodiversity sustainably; iii) to share the monetary and non-monetary benefits of biodiversity fairly and equitably; iv) to mobilize adequate resources so that all parties can fully implement the agreement. In particular, the agreement calls for the protection of 30% of land and 30% of sea by 2030.

**Beyond COP 15 in December 2022, the year 2023 was marked by several advances aimed at strengthening biodiversity protection.** It includes notably the organization of the One Forest Summit in Libreville, Gabon, in March 2023, the adoption of the International Treaty on the Protection of the High Seas in June 2023, the organization of the Summit for a New Global Financial Pact in Paris in June 2023, and the organization of the fourth edition of the Finance in Common Summit (FiCS) in Cartagena, Colombia, in September 2023.

**The protection of marine biodiversity also made significant progress in 2023, with the adoption by the 193 UN member states of the Marine Biodiversity of Areas Beyond National Jurisdiction (BBNJ) Treaty in June 2023, after almost two decades of discussions.** This treaty aims to ensure the conservation and sustainable use of marine biodiversity in international waters. Although the high seas account for over 60% of the world's oceans and half of its land surface, they had no protection whatsoever before the adoption of this new global legal framework. It is an essential step towards achieving the goal of protecting 30% of the oceans by 2030, as set out in the Kumming-Montreal agreement, while only around 1% of the high seas are currently subject to conservation measures. The treaty also includes provisions for the fair and equitable sharing of benefits arising from activities relating to marine biodiversity on the high seas, and for building the capacity of developing states to carry out such activities. Open for signature for 2 years, the treaty has already been signed by over 80 countries, and could come into force in June 2025, at the next United Nations Ocean Conference in Nice.

**The Summit for a New Global Financial Pact held in Paris in June 2023 was an opportunity to reiterate the international community's commitment to building a financial system that combats inequality and climate change and protects biodiversity.** At the Summit, France and the UK launched a global roadmap to develop high-integrity biodiversity credit markets (see below).

**At its fourth meeting, to be held in Cartagena, Colombia, in September 2023, the Finance in Common Summit, which brings together public development banks, adopted a blue finance roadmap to strengthen the protection and sustainable use of the oceans.** The aim is both to protect marine biodiversity and to support a sustainable blue economy, notably by reducing ocean pollution through the development of wastewater infrastructure, investment in marine protected areas, ecoports, greener shipping systems, renewable ocean energy, and emerging sectors such as sustainable aquaculture, including seaweed and mariculture, blue biotechnology, restoration and blue carbon sequestration. The UN Oceans Conference in 2025 will provide an opportunity to measure progress against this roadmap.

## Appendix D – Financial mechanisms to protect biodiversity

### 1. Typology

➢ **Payments for ecosystem services (PES)**

**Payments for ecosystem services, which refer to the direct and indirect benefits that humans derive from nature, correspond to "transfers of resources between social actors, with the aim of creating incentives to align individual and/or collective land-use decisions with social interest in natural resource management" (Muradian et al., 2010; Karsenty, 2019).** Payments for ecosystem services generally involve remunerating certain actors for land use that is deemed to be protective of biodiversity. A distinction can be made between "land use restricting" PES and "asset building" PES (Wunder, 2005), the former referring to remuneration for the abandonment of biodiversity-damaging practices, while the latter refers to remuneration for new biodiversity-preserving practices or activities. Karsenty (2019) also suggests distinguishing between PES aimed at local public goods ("short-circuit PES") and PES aimed at global public goods ("long-circuit PES"). This distinction plays an essential role in determining the identity of the remunerating entity. Indeed, while in "short-circuit PES", private actors have historically played an important role as "beneficiary-payers", such as actors in the water sector who had an interest in maintaining water availability and quality, the reality is quite different in the case of "long-circuit PES" aimed at preserving biodiversity as a "global public good", as beneficiaries cannot be identified individually. Remuneration for this type of PES therefore requires public funding. The United Nations Framework Convention on Climate Change's REDD+ (Reducing emissions from deforestation and forest degradation in developing countries) program is an example of payment for ecosystem services, aimed at reducing emissions from deforestation and forest degradation through the provision of financing for forest conservation and sustainable management. Positive conservation partnerships, introduced at the Libreville Summit in March 2023, follow a similar approach, targeting forest protection.

➢ **Markets of high integrity biodiversity credits or biodiversity certificates**

**Like voluntary carbon credits, which can be obtained by a public or private entity in return for financing a project to reduce or sequester greenhouse gas emissions, biodiversity credits are credits or certificates that operate in a similar way, but include specific measures to enhance, conserve and/or restore biodiversity.** They are instruments designed to finance additional actions in favor of biodiversity. The "high integrity" of these credits refers to their environmental integrity. The strengthening of CSR policies in developed countries should thus increase demand for such credits or certificates. According to Karsenty (2022), however, such mechanisms should not be called credits, which leads to semantic confusion, suggesting that their purpose is to offset an activity with negative consequences for biodiversity (see below), but could rather be called "certificates of positive impacts on biodiversity", better reflecting their vocation of additional biodiversity protection. Entities acquiring such certificates should therefore demonstrate that, in addition to their commitment to biodiversity and the reduction of their impact, they support biodiversity-friendly investments in developing countries (Treyer, 2023).

➢ **Biodiversity compensation systems**

**Unlike biodiversity credits or certificates, biodiversity compensation systems, which can be either voluntary or regulatory, can also exist (Karsenty, 2022).** Such systems do not aim at financing additional actions in favor of biodiversity. Instead, they aim to compensate projects with a negative impact on biodiversity, through the restoration or protection of other sites, for example.

➢ **Sovereign guarantees through conservation trust funds (CTF)**

**Biodiversity Conservation Trust Funds (CTFs) are "private, legally independent institutions that provide sustainable financing for biodiversity conservation" (Conservation Finance Alliance).** They are private financial institutions whose resources come from international donors, governments and the private sector, and whose investments are intended to generate financial income for reinvestment in biodiversity protection. There are around a hundred such funds, created since the 1990s, with a notable acceleration since the 2010s. CFCs have enabled the financing of 2 billion USD in conservation projects and programs worldwide between 2009 and 2018 (Hartmann, 2020; Bath et al., 2020). In order to increase the financing available under these funds and strengthen private sector participation, proposals are emerging to set up sovereign guarantees aimed at de-risking investment projects incorporating a biodiversity protection dimension (Karsenty, 2023; Treyer, 2023). According to the authors, these guarantees should enable investors to insure themselves against the loss of capital at the end of the investment period, and provide an additional guarantee on a remuneration floor.

- **Debt-for-nature swaps**

**Developing countries have major biodiversity resources whose protection has global implications, such as the Amazon rainforest or the Congo Basin forest (see section I); yet these countries generally have limited resources to finance biodiversity protection measures, and are also constrained by high levels of indebtedness.** In 2022, 60% of low-income countries will be at high risk of debt distress, compared with 30% in 2015 (Chabert et al., 2022). Numerous discussions are therefore underway to meet the dual challenge of financing biodiversity issues in developing countries, while maintaining the sustainability of their debt. Debt-for-nature swaps are part of this approach (Paul et al., 2023). Such instruments, although still limited, aim to swap part of the foreign debt of beneficiary countries for the financing of climate change adaptation or biodiversity protection projects.

- **Greening the financial system and integrating biodiversity in bond emissions**

**According to the OECD (2020), private funding for biodiversity is estimated at between 6.6 and 13.6 billion USD per year over the period 2015-2017.** While the mobilization of private funding is essential in view of the scale of the financing needs required to protect biodiversity, preserving biodiversity is also in the interests of private sector players, who are highly dependent on biodiversity and ecosystem services in order to produce goods and services. In 2022, the Network for Greening the Financial System (NGFS) highlighted the risks posed by biodiversity loss to global financial stability (NGFS-INSPIRE, 2022), justifying greater coordination between regulatory and supervisory bodies.

**The development of financial instruments such as green bonds can also help to increase funding for biodiversity.** According to Michetti et al (2023), green bond issuance would have reached 487.1 billion USD in 2022, compared with 270 billion USD in 2020, and according to a report by Fitch (2023), 16% of green, social and sustainable bonds issued in 2023 included measures to conserve terrestrial or aquatic biodiversity, compared with 5% in 2020.

### 2. Challenges to the implementation of these mechanisms

**First of all, there is a real methodological difficulty linked to the difficulty of measuring the state of biodiversity, on the one hand, and the economic value of the services rendered by biodiversity, on the other.** Indeed, given its multidimensional nature, the state of biodiversity cannot be measured by a single indicator, unlike climate change, for which the international community relies on a reference indicator linked to the measurement of the emission and concentration of greenhouse gases in the atmosphere. IPBES thus proposes twenty indicators, which goes some way towards understanding the multidimensional nature of biodiversity, even if this cannot be totally overcome (Cognie and Péron, 2020). Measuring the economic value of biodiversity services is also complex, and a vast literature has developed to propose measurement methodologies (Costanza et al., 1997, 2014). However, the measurement of this economic value remains difficult to systematize, as it remains intrinsically local and specific, due to the multidimensional nature of biodiversity, which makes it difficult to compare the value of ecosystem services rendered between different regions, and partial, as the interdependencies between ecosystem services cannot be apprehended (Bouchet et al., 2021). Other difficulties, linked in particular to the governance, harmonization and regulation of these financial mechanisms, also explain their relatively low level of development.

**In the case of payment for ecosystem services (PES), the difficulty lies in the complexity of measuring the value of the service rendered.** What's more, the development of this type of instrument can be hampered by the risk of major windfall effects. According to Treyer et al (2023), a distinction needs to be made between ecosystem services and environmental services, enabling a shift from a remuneration rationale to an investment rationale. Indeed, while ecosystem services refer to the functions of an ecosystem that enable us to derive a benefit from it, environmental services refer to the actions or management methods of stakeholders that improve the state of the environment by enabling an increase in an ecosystem service. The authors argue that payment for environmental services should be based on co-investment with local communities, to encourage them to adopt biodiversity-friendly practices and thus establish sustainable development trajectories.

**The introduction of markets for high-integrity biodiversity credits or biodiversity certificates is also fraught with difficulties, linked in particular to the risk of non-additionality and greenwashing, and to the absence of a harmonized framework and regulation**. Furthermore, these are voluntary instruments, acquired for example by a private actor with a view to strengthening its CSR policy. It is therefore a market that is still largely undeveloped, but one that is giving rise to a great deal of thought within the international community, as demonstrated by the launch by France and the UK on the sidelines of the June 2023 Summit for a New Financial Pact of a roadmap on high-integrity biodiversity credit markets (see above).

**Regarding debt-for-nature swaps, the limited development of such instruments is due in particular to the complexity of their implementation, involving lengthy negotiations and high monitoring costs in order to verify the proper implementation of the projects decided as part of the debt swap**. What's more, their effectiveness remains to be proven, both in terms of debt restructuring and biodiversity protection, as this type of instrument generally results only in the implementation of protected areas, without targeting the causes of biodiversity loss. Furthermore, the question of creditor cooperation is not necessarily a foregone conclusion, since the initiative presupposes that creditors will agree to buy back the debt of beneficiary countries at a reduced price.

*“Sur quoi la fondera-t-il l’économie du monde qu’il veut gouverner? Sera-ce sur le caprice de chaque particulier? Quelle confusion! Sera-ce sur la justice? Il l’ignore.”*

Pascal

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