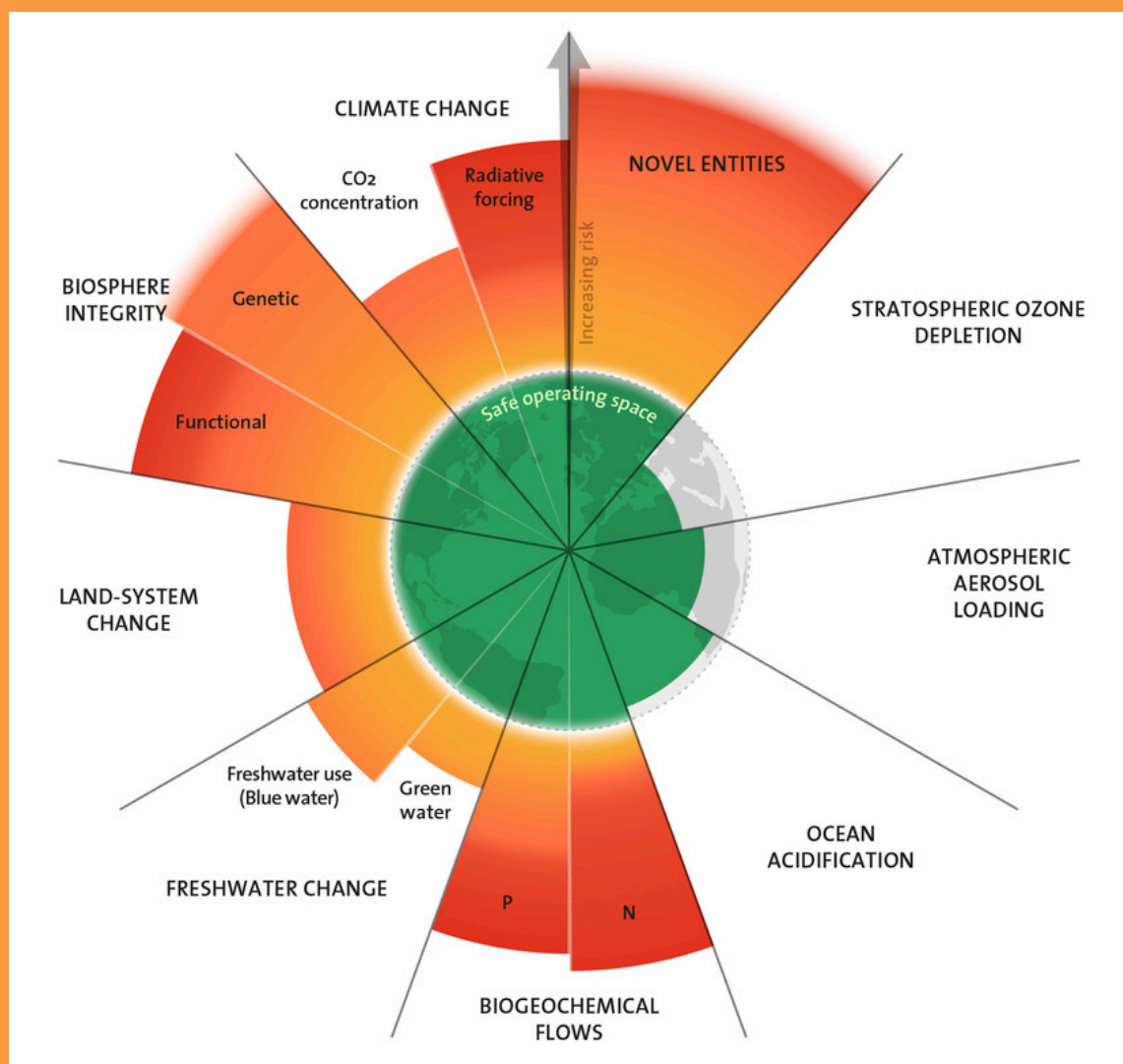




EVE FALL SCHOOL 2024 FINAL PAPERS



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EVE

**1. Understanding the Climate
Change planetary boundary
and resilience
development – perspectives from
Europe and Africa**

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UNDERSTANDING THE CLIMATE CHANGE PLANETARY BOUNDARY AND RESILIENCE DEVELOPMENT – PERSPECTIVES FROM EUROPE AND AFRICA

ABSTRACT

Climate change is the first planetary boundary to consider among the nine identified by scientists, as it represents a highly integrated, system-level phenomenon intricately linked to all other boundaries. The relevance of this anomaly is evident not only to scientists, but also discernible to the entire ecosystem, manifesting in a series of unexpected and disastrous with variable impacts depending on several factors mainly geographical location. In response, the international community, regional organizations, and individual nations are implementing adaptive and mitigation measures to halt the trajectory toward irreversible damage. This study aims to offer critical insights into the climate change planetary boundary and its interconnections with other planetary boundaries, adopting a nexus approach. The analysis compares two contrasting regions, i.e., Europe, representing the global north, and Africa, representing the global south, to explore how climate change impacts vary across geographical and socio-economic contexts. Key areas of focus include regional indicators, impacts, vulnerability levels, and mitigation and adaptation strategies. Additionally, the legislative frameworks of these regions will be evaluated to determine their alignment with actual needs and their capacity to support resilience. Finally, the study examines current international support and collaboration efforts in addressing this global challenge, concluding with our remarks to a bigger pending question: Are existing efforts sufficient to meet the scale of the problem?

INTRODUCTION

Climate change is one of the most pressing global challenges currently, threatening the stability of our planet's ecosystems and human societies. The interconnectedness between the Earth and humanity is evident, as all essential resources required for survival such as food, water, air, and shelter are derived from the planet (Fang et al., 2017; Pandit & Sharma, 2023; Damor, 2024).

Since the mid-20th century, the rapid growth of the human population has led to actions that have significantly impacted and shaped the state of planet Earth (Damor, 2024). The rise of human influence on the planet has prompted researchers to define a new geological epoch, known as the Anthropocene. This epoch signifies the onset of human-induced control over the Earth, underscoring the interdependent relationship between life on the planet and the planet itself.

Based to the fossil record, isotopic studies, and radioactive dating techniques, geologists can access and infer ancient life the existed and the prevailing climatic conditions during their tenure on earth. They reveal that the earth has experienced several climate changes in geologic time, all of which would have been deleterious for humans. The period marking the start of a human-friendly climatic conditions is the Holocene geologic epoch, which spans from 11,700 years to present. This Holocene – like climate conditions present itself as the human-supporting climate, beyond or below which the planet will no longer support the existence of humans and many other life forms on earth. However, the relatively stable, 11,700-year-long Holocene epoch, the only state of the planet that is known for certain can support contemporary human societies, is now being destabilized (Steffen et al., 2015).

This forms the basis of the planetary boundary (PB) concept, introduced in 2009, which aimed to define the environmental limits within which humanity can safely operate (Rockström et al., 2009). Rockström and the others defined nine boundaries that are critical to decide or control the planetary cycle. This comprehensive analysis explores the concept of climate change as a planetary boundary and examines perspectives from Europe and Africa.

Our research paper will start from the concept of Planetary Boundary to analyse the phenomenon of climate change. Despite the long interest that the scientific community has developed for climate and its change because of human activity, decision makers seemed to have started caring more after the Kyoto protocol of 1997, and then with the Paris COP in 2015. During the last decade the issue has become more and more urgent, which is why our aim is to frame in a comparison, not only the policies, but also the legislation that the EU and Africa have developed to adapt to and to mitigate climate change. Indeed, after having described the concept of climate change, we will directly analyse the measurement of it through indicators and the impacts that it has. Then, we will describe the policies that have been developed and the legislation in support of them both in the European and in the African contexts. Finally, we will present some common challenges, concluding with our remarks on the compared realities.

THE CONCEPT OF PLANETARY BOUNDARIES

The concept of planetary boundaries refers to a framework that defines the safe operating space for humanity in relation to the Earth's biophysical systems. It was introduced in 2009 by a group of Earth system scientists, led by Johan Rockström, to highlight the limits within which humanity can safely operate without causing irreversible environmental damage. That of planetary boundaries is a revolutionary approach for scientist and decision-makers, because it “defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth system” (Rockstrom, 2015). The planetary boundaries are nine: climate change, changes in biosphere integrity, stratospheric ozone depletion, ocean acidification, biogeochemical flows, land-system change, freshwater use, atmospheric aerosol loading and introduction of novel entities.

The science of planetary boundaries has advanced significantly since its introduction in 2009, when seven out of nine boundaries were assessed, revealing that three had already surpassed their safe limits: climate change, biodiversity loss, and disruptions to the global nitrogen cycle. By 2015, a fourth boundary (land system change) had also crossed its threshold. In September 2023, a team of scientists quantified, for the first time, all nine processes that regulate the stability and resilience of the Earth system (Richardson. They revealed that 6 out of the 9 critical boundaries have been transgressed (. Crossing boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes.

As shown in the figure below, the Anthropocene has certainly modified what the Earth looked like during the Holocene and the present situation represents a hard challenge for humanity. Among the crossed limits, we count climate change, which is now a high-risk zone because of radiative forcing.

Climate change is considered to be the first planetary boundary to take into account among the other eight provided by scientists, mainly because it represents a highly integrated and emergent system-level phenomenon that is connected to all the other boundaries (Rockstrom, 2015). The relevance of this anomaly is evident not only to scientists, but also to everyone's eyes, manifesting in a series of unexpected and disastrous events that have an impact on people at different intensities according to

where they live. As a planetary boundary, it is mainly affected by CO₂ concentration and radiative forcing as its main drivers.

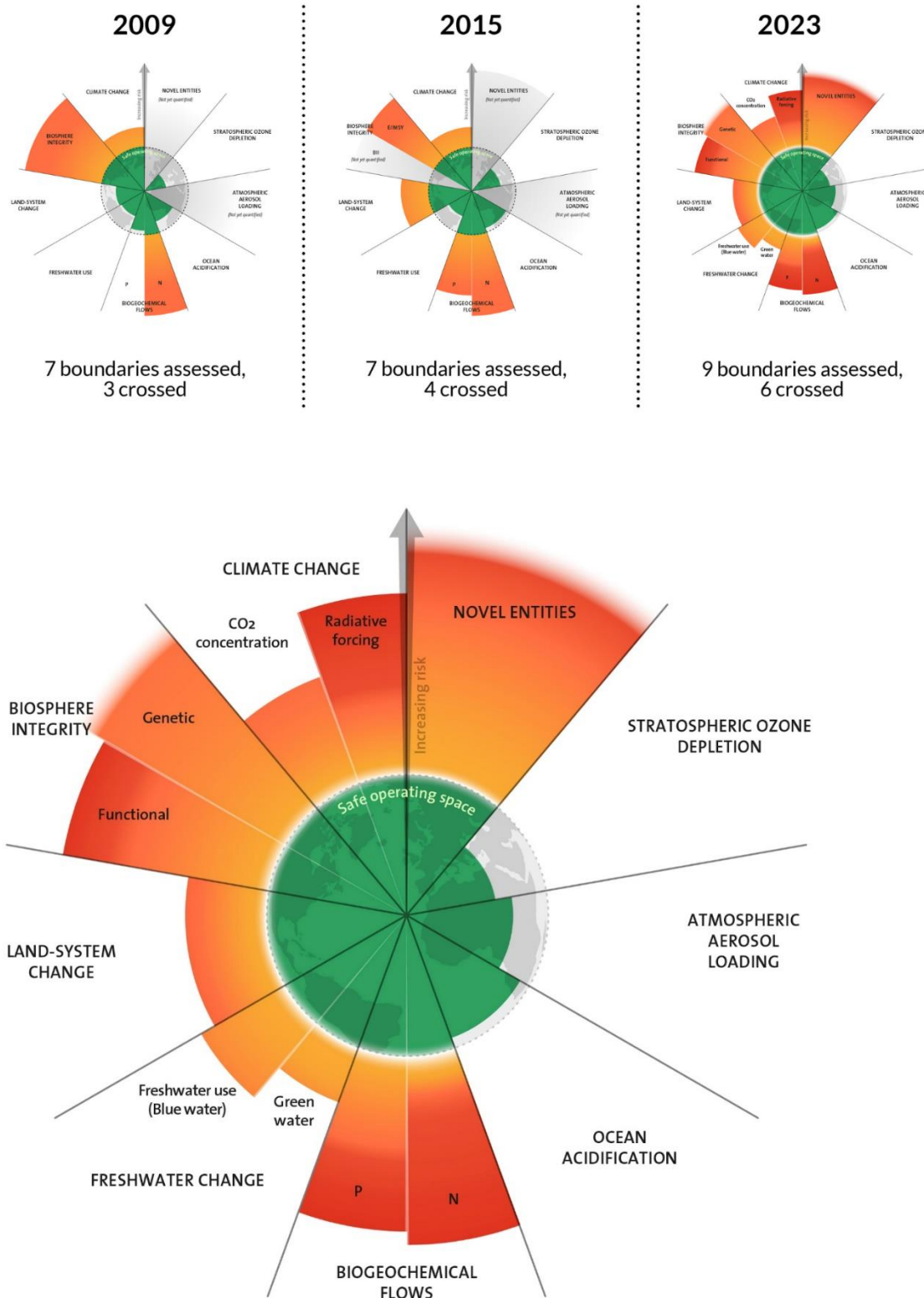


Illustration of planetary boundaries (Stockholm Resilience Center, 2024)

CLIMATE CHANGE AS A CRITICAL PLANETARY BOUNDARY; THE NEXUS PERSPECTIVE.

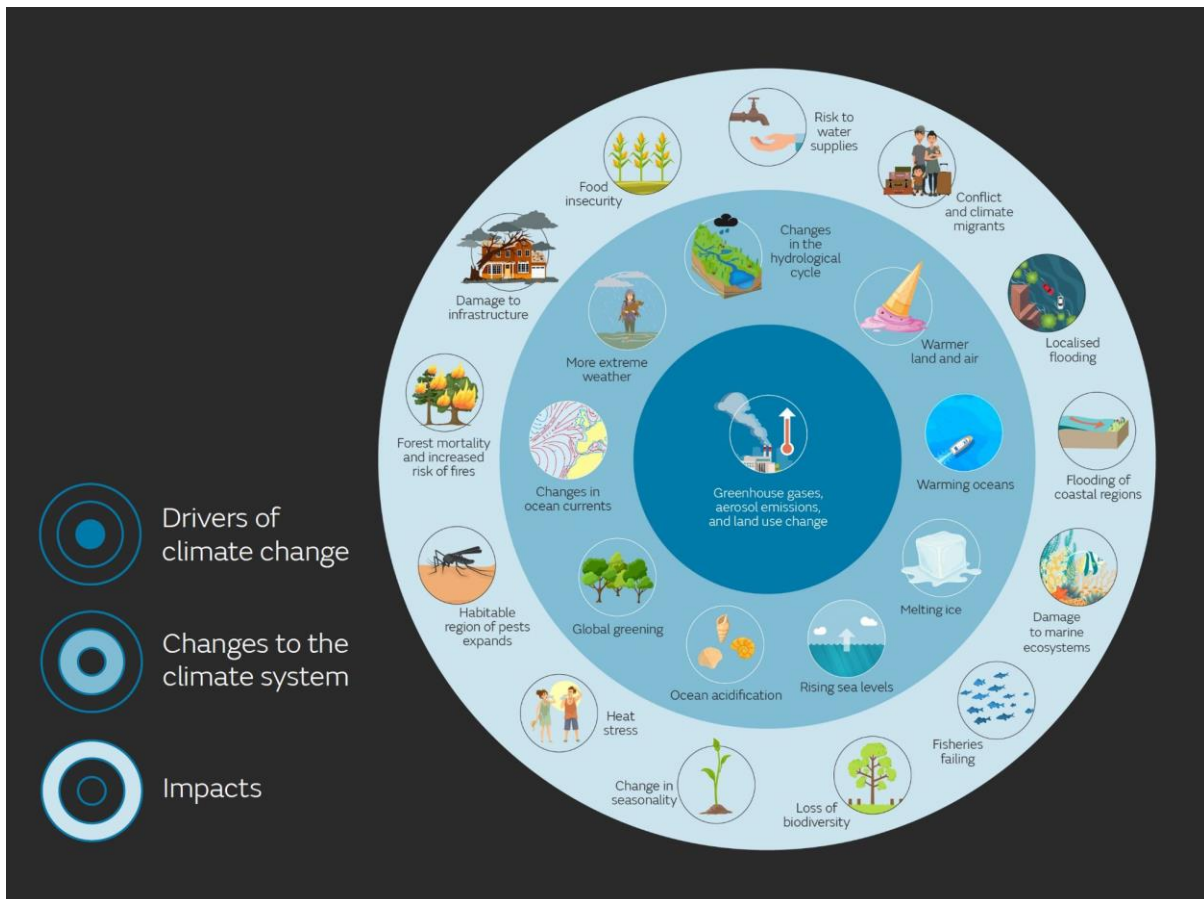
Climate change is a phenomenon that is defined by the Intergovernmental Panel on Climate Change (IPCC) as “a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer” (Glossary, 2024). Climate change is induced by global warming which is controlled by two main variables, CO₂ accumulation in the atmosphere and radiative forcing. Climate change is deemed very critical, forming the central part of most geopolitical conversations globally. Climate change is considered to be the first planetary boundary to take into account among the other eight provided by scientists, mainly because it represents a highly integrated and emergent system-level phenomenon that is connected to all the other boundaries (Rockstrom, 2015). The relevance of this anomaly is evident not only to scientists, but also to everyone’s eyes, manifesting in a series of unexpected and disastrous events that have an impact on people at different intensities according to their geographical location.

The climate-water nexus highlights how changing precipitation patterns and melting glaciers alter water availability and quality. Water scarcity directly affects agricultural irrigation, energy generation, and human consumption, exacerbating competition for resources, especially in water-stressed regions. For instance, prolonged droughts in regions like the Sahel have triggered food crises, migration, and conflict, showcasing the cascading effects of water shortages.

The climate-energy nexus emphasizes that rising temperatures increase energy demand for cooling while reducing the efficiency of power generation. Renewable energy sources, such as hydropower, are also vulnerable to changing water flows. Addressing climate change by transitioning to renewable energy sources like solar and wind not only reduces GHG emissions but also ensures a more resilient and sustainable energy supply.

The climate-food nexus illustrates how rising temperatures, extreme weather events, and water scarcity disrupt food production. Crops fail under extreme drought, livestock suffer heat stress, and fisheries decline as oceans warm. These challenges threaten food security, particularly in vulnerable regions with limited adaptive capacity. For example, the 2010 Russian heatwave drastically reduced wheat yields, causing global food price spikes and socio-economic instability.

The nexus approach demonstrates that disruptions in one system often cascade into others, amplifying vulnerabilities. A drought, for example, reduces water availability for agriculture and hydropower, which in turn impacts food production and energy supply. Similarly, increased energy demand during heatwaves strains electricity grids, which rely on water-intensive thermal power plants. These interconnected challenges highlight the systemic risks posed by climate change.



The scope of Climate change impacts. Copied from MetOffice.com

CLIMATE CHANGE INDICATORS EUROPE

Copernicus, the EU Space program that observes the Earth, has published the latest data about globally recognised climate change indicators that accurately frame the European situation. Indicators are essential to assess regional and global climate change in the longer period, and to do so, they present several key variables that are updated at least once a year in the European State of the Climate (ESOTC). There are four main indicators that are generally used as measurements for climate change: temperature, ice and glaciers, greenhouse gas emissions, and the ocean (Climate Indicators, 2024). Each of them is broken down into several other measures that are tailored to the regional area under observation. In the case of Europe, 2023 ESOTC presents many different variables. First and foremost, temperature has reached its highest peak during last year, achieving a record. As shown in the picture, almost the entire region had above-average temperatures. Indeed, Europe was 1°C above-average temperature and 2.6°C above pre-industrial levels. This says a lot about the direction that has been taken in regard to Paris Agreement, where it was decided to keep the temperature increase below 2°C for the next century. Of course these are yearly estimates, nevertheless they raise some questions.

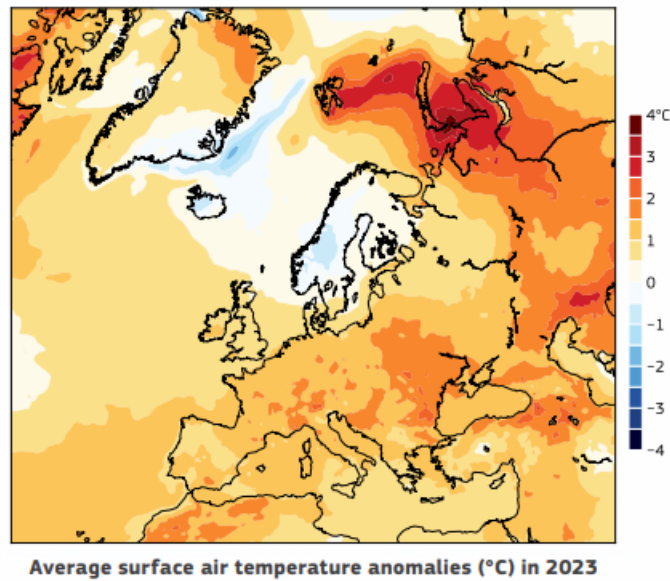


Figure 1: source Copernicus ESOTOC 2023

Temperatures were high also at the surface sea level – 0.55°C above the average – which plays a fundamental role shaping the weather and the climate. Moreover, “thermal stress” indices measured an increase in hot thermal stress over a rarer cold thermal stress, undermining human health. Then, the extreme temperatures, combined with a poor soil moisture – that determines the hydrological capability of handling copious rains and the probability of burning – have dramatically increased the risk and the happening of wildfires, especially in Southern Europe¹.

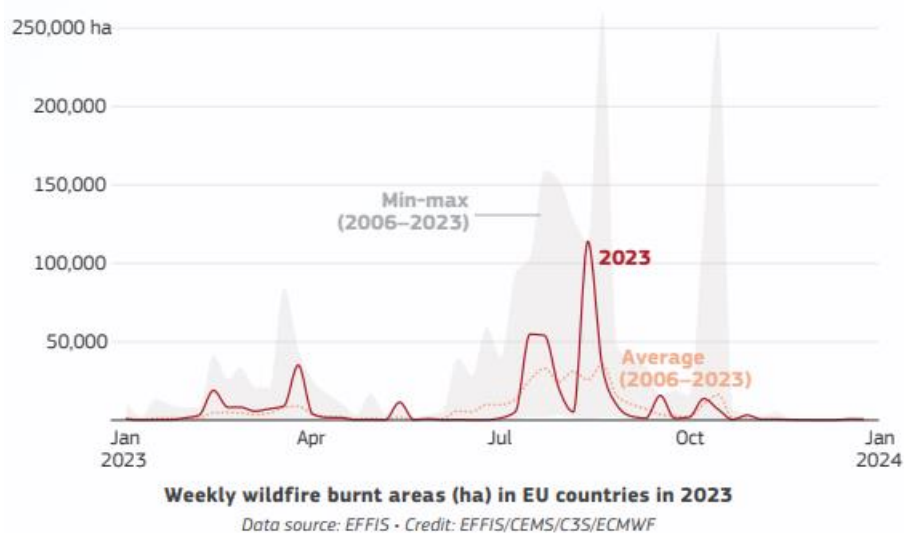


Figure 2: Source Copernicus ESOTOC 2023

Coming back to soil moisture, its anomalous condition has contributed to several floods with 16 percent point excess over the “severe” flood threshold. Despite many storms hitting Europe, snow has been decreasing, because of the high temperatures and even glaciers’ extension has been decreasing.

¹ Greece experienced the largest ever recorded wildfire in the EU (ca. 96 000 ha).

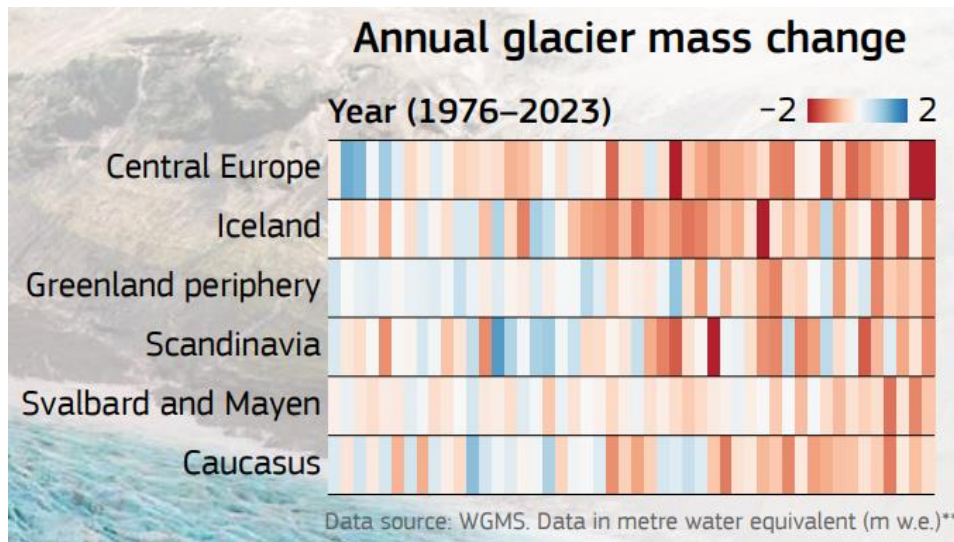


Figure 3: Copernicus ESOTOC 2023

These numbers represent a dramatic measurement to reflect on, especially for addressing policies effects over the unstoppable transition we are in. Indeed, highly overcoming indicators thresholds is not just a matter of numbers, but it effectively produces dramatic impacts on people’s health and everyday life, as much as on the environment and the economy. The indicators previously mentioned are not the only drawn by the scientific community, nonetheless they can be used as keys to open the doors to the actual European situation, which has been significantly signed by extraordinary climate and weather events, especially during the last few years.

CLIMATE CHANGE IMPACTS IN EUROPE

In its latest report, the European environment Agency (EEA) has defined Climate Change as a “risk multiplier” (EEA, European Climate Risk Assessment, 2024), able to exacerbate already existing risks and crises. This means that climate impacts can produce a snowball effect that might have repercussions on an entire system, threatening food security, public health, ecosystems, infrastructures, and the economy. Of course, climate risks not only depend on climate-related hazards, indeed, the latter have a deadly interaction with non-climatic risk drivers generated by human behaviour. An example of this might be seen in Land-system Change, which is also one of the Planetary Boundaries. A very common practice is to deforest areas of land in order to grow crops there, maybe, even close to a river so that it is easier to irrigate. Although, it might be that in presence of a very conspicuous rain, not only there is a flood, that wastes all the crops, but the land might not be able to sustain the pressure and will crumble or collapse. This, as many other possible examples, gives an idea of how climate change is both the cause and the main result of severe disasters, that come out as a product of a now malfunctioning system. Therefore, the EU needs EEA’s reports for designing a suitable adaptation policy.

Moreover, in order to assess impacts, the EU needs to know the risks that might become impacts themselves, which is why the report presents 36 major climate risks for Europe. Those risks are also varying in probability according to the area of interest, though, among the most vulnerable areas it is possible to count Southern Europe, which has lately been particularly exposed to high temperatures, increasing the probability of droughts and fires, which affect the ecosystem, people’s health, crops

and the economy in general. Nonetheless, coastal and outermost regions are at risk of floods and also suffer the lack of infrastructure.

Then, to come back to the economic impact, the EEA has also published in October 2024, another important report, accounting for all the economic losses caused by weather and climate-related extreme events have caused to EU member states.

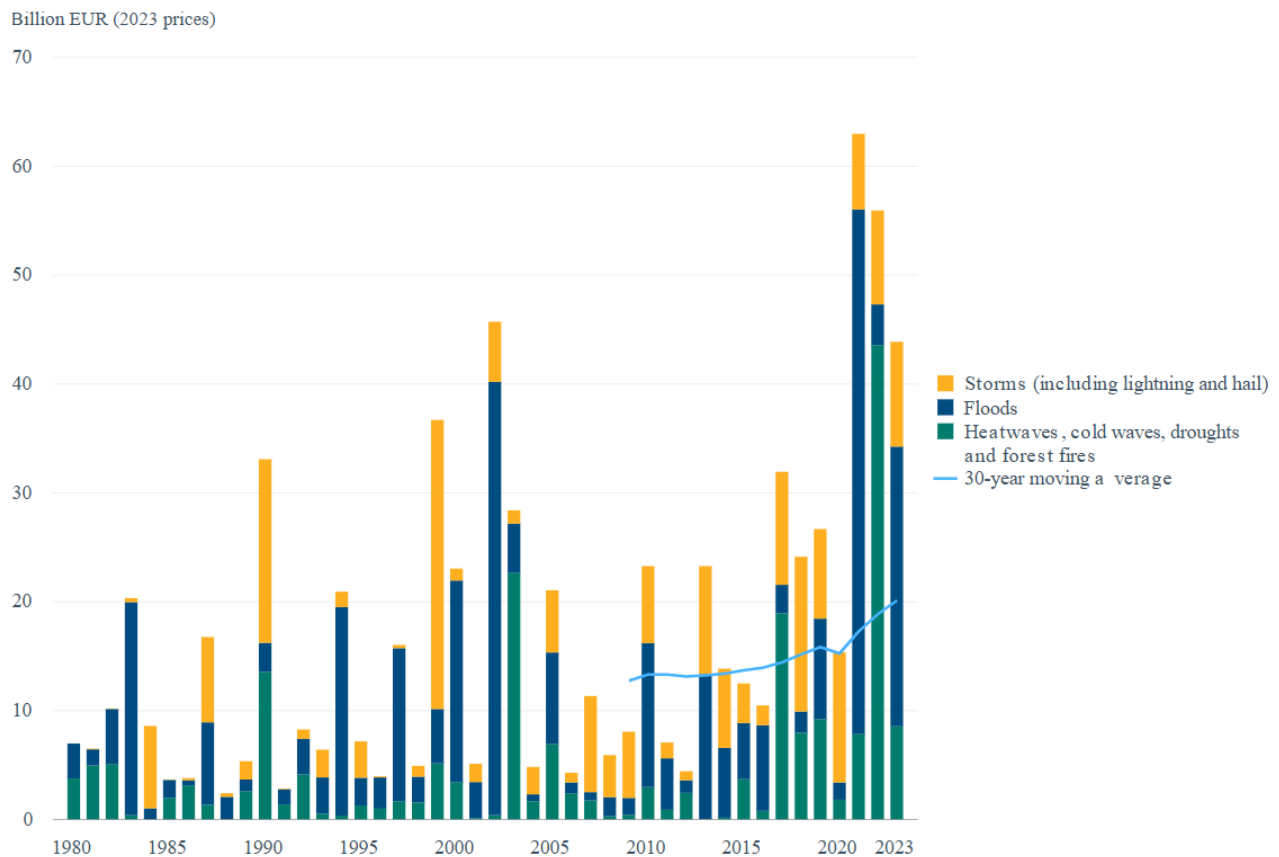


Figure 4: Annual Economic losses caused by weather and climate-related extreme events in EU member states. Source: [EEA](#)

As shown in the graph above, the last three years have dramatically increased the economic losses, because of both more severe and more frequent extreme events in the EU. It has also been calculated that between 1980 and 2023 climate-related extremes in the EU amounted to 738 billion euros, and over 162 billion (22%) between 2021 and 2023 (EEA, Economic losses from weather- and climate-related extremes in Europe, 2024). Hydrological hazard, like floods, account for a 44%, while meteorological hazard for about the 29%. On the other hand, climatological hazards attribute the 19% to heat waves and the 8% to wildfires, droughts, and cold waves together.

Furthermore, the impact of climate-related extreme events hit member states in a different way. In absolute terms, those that suffered the highest economic losses between 1980 and 2023 were Germany, Italy and France.

EU CLIMATE POLICY

European Union's engagement to environmental protection dates back to Maastricht Treaty in 1992. Nevertheless, during the years, there has been a continuous exchange in views and perspectives with the international community. Indeed, the EU climate policy at the present day, finds its origins in the

2015 Paris Agreement. The UN Climate Change Conference (COP21) saw the participation of 196 signatory countries, that committed themselves to fight to limit the temperature increase to just 1.5°C above pre-industrial levels. The decision to keep the temperature increase below 2°C comes from a proposal of the International Panel on Climate Change (IPCC), which has estimated that overcoming the 1.5°C threshold would mean to face severe climate change impacts. Since the Paris Agreement is a legally binding instrument, the signatory states had to engage actively in its implementation that, though, requires economic and social transformation. The agreement was structured on a five-year cycle, at the end of which the EU has published its own climate strategy, the European Green Deal. Proposed by the European Commission in December 2019, the Green Deal represents the European strategy towards a smart, sustainable and inclusive growth, with a commitment to tackle climate and environmental challenges as the main priority of the union for the future. As Schunz suggests, the Green Deal “marks a historic breakthrough with its ambitious, challenging, and feasible plan” (Schunz, 2022), while others argue that it doesn’t provide enough paradigm changes in respect to previous EU climate policies. Nonetheless, it shall be highlighted that it is both a very ambitious and a long-term commitment.

One of its highest priorities is, indeed, for the EU to reach climate neutrality by 2050, which means being able to produce no net emissions of greenhouse gases by that date, still being capable of decoupling the growth of economy. Among the other objectives, it “aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts” (COM/2019/640 final, 2024). Therefore, as the EC has clarified in its Communication, the EU, shall aim at becoming leader and an example in designing environmental measures, consumer protection, and workers’ rights. The Green Deal came with a foreseen need for reforms, including private and public sectors to go through the green transition and leaving no one behind in doing so.

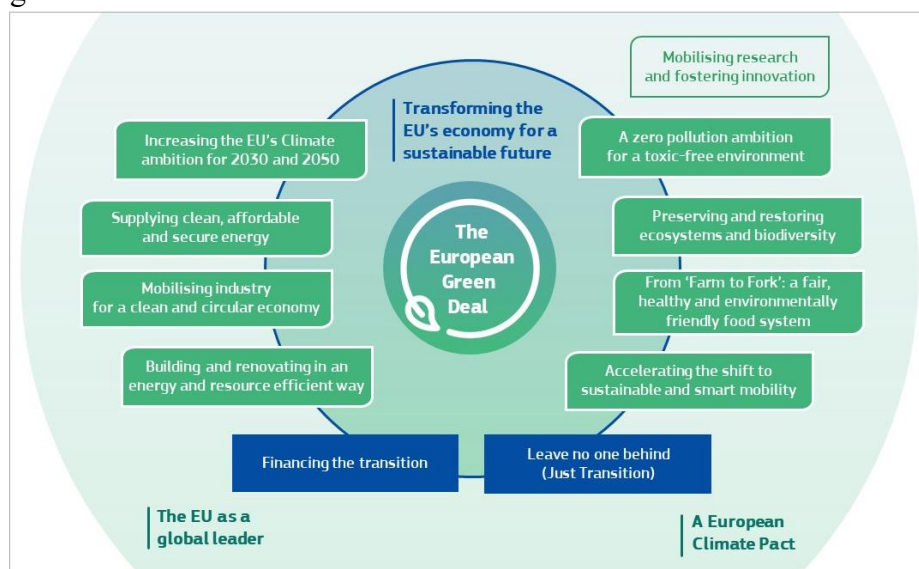


Figure 5: Source COM (2019) 640

As it is shown in the figure, the transformation of EU’s economy is crucial for being able to make the transition, since it produces many negative externalities² on the environment. Moreover, to make an

² Externalities are those costs that affect subjects and objects out of the economic transaction and, those that fall on the environment generally affect it in a negative manner, and pollution from Greenhouse gases emissions is an example.

observation on the EU, it is first and foremost an economic union, which explains why it has such a big concern about the economic transition as much as the social implications connected to this change. Following, it is possible to synthesise the Green Deal in six key goals highlighted by the European Council. First it stresses the relevance of Climate Neutrality, to be achieved through a drastic reduction in emissions with the aim to become the first climate-neutral continent. Secondly, there is the need to become a circular economy, where products are reused, repaired and recycled, in order to reduce the waste. As third, the European Council presents a clean industry, to transform European industries into energy-efficient factories. This objective has been pursued with instruments like the ETS and the CBAM³. Then, it stresses the importance of having a healthier environment and sustainable farming, that will have positive effects not only on the environment but will also produce healthier food. Finally, climate justice and fairness goal closes the list by reminding the social aspect of this transition, where the EU doesn't want to leave people nor firms behind (European Green Deal, 2024).

Despite all these purposes and good practices, the EU found itself very tight between the ambitiousness of its aims and the feasibility of them, especially during the Pandemic, requiring an additional financial help from the Next Generation EU, which was designed as a complement to the 2021-2027 Multiannual Financial Framework, the instrument that usually defines the management of EU budget. Then, later in the process, another event contributed to make the mission even more difficult, and it was Russian invasion of Ukraine, to which the EU – strongly dependent on Russian oil and gas – had to change its energy mix trying to cope both with the transition process and the geopolitical environment. Because of this reason the Repower EU was created. The plan, based on the “Fit for 55” package⁴, aims at strengthening energy autonomy in the EU and supports the green transition.

Although, as the last few years have shown, the obstacles are many and permanently rising when the EU less expects them. Moreover, still coming out of a huge crisis, the results are quite far to be seen whether they will be negative or positive. The midterm of 2021-2027 has already passed and MS are still late in the process. Additionally, the time to restore the Stability and Growth Pact rules⁵ will come and MS have to be steady, otherwise the transition will become an unbearable burden for their economies.

EU LEGISLATION

The European Green Deal is the policy outcome of a long-term EU's commitment to the environment. Already in 1987, with the Single European Act (SEA), the European Community introduced the “Environment Title” (Title VII), providing the first legal basis for a common environmental policy. Article 130r opens the title by presenting the main objectives pursued by the Community, which was determined to preserve and protect the environment and human health, by ensuring the prudent and rational use of resources. Then, in the following points, the article expresses the way through which

³ The ETS is the Emission Trading System, while CBAM is the Carbon Border Adjustment Mechanism. They both give a price to emissions, meaning that industries will pay to produce, according to the amount of their emissions.

⁴ It is a set of proposals for the revision and the update of existing EU legislation. It aims to contribute to facilitate the transition in a way that is fair, strengthening innovation and making the EU a global leader in this field <https://www.consilium.europa.eu/en/policies/fit-for-55/>

⁵ Member States must have a deficit that doesn't exceed the 3% of their GDP and a public debt that is not higher than 60% of their GDP.

reaching the previously mentioned objectives, as the principle of preventive action, the use of available scientific data, and the consideration of the economic and social development of its regions. Additionally, the SEA specifies the procedure leading climate policies in the Community, determined by unanimity in the Council in art. 130s (Single European Act, 2024). Few years later, in the Maastricht Treaty (1993) the EU made the environment an official EU policy area with Title XVI, introducing the co-decision procedure in art. 130s par. 2 (Maastricht Treaty, 2024). After that came the Treaty of Amsterdam (1999), which imposed the integration of environmental protection into all EU sectoral policies in art. 3c (Amsterdam Treaty, 2024). Finally, in 2007, the Lisbon Treaty made climate change and sustainable development a priority, attributing to the EU the legal personality to conclude international agreements with art. 2c (Lisbon Treaty, 2024).

Hence, the long historical evolution of EU law, has prepared the way for both the Green Deal – announced by the European Commission in December 2019 with the Communication No. 640 – and for the “European Climate Law” - established by Regulation (EU) 2021/1119 of the European parliament and the Council, amending Regulations (EC) No. 401/2009 and (EU) 2018/1999. This legal framework legitimises EU’s commitment “to stepping up efforts to tackle climate change and to delivering on the implementation of the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (the ‘Paris Agreement’), guided by its principles and on the basis of the best available scientific knowledge, in the context of the long-term temperature goal of the Paris Agreement” (REG 2021/1119, 2024). Moreover, the document represents a proper guideline for both the EU and member states to build up their strategies to become smarter and more sustainable, while also taking care of the social dimension. Indeed, the regulation provides a list of objectives, targets, measures and practices that aims not only at reaching member states and stakeholders, but all parts of society – public participation, art.9 – because climate action should be a priority of everyone. Articles 1 to 5 and article 7 significantly summarize the core elements of the path towards climate neutrality. Indeed, art. 1 and 2 present the scope of the regulation and the “climate-neutrality objective”, not only contextualizing the document in its legal framework – in pursuit of the long-term temperature goal set out in point (a) of Article 2(1) of the Paris Agreement (The Paris Agreement, 2024) – but also underlying the need of measures both at the Union and National levels. Article 3, then, in line with previous legal acts on the subject, requires a scientific advice, that will act as a point of reference for Union’s scientific knowledge for acting with “best available and more recent scientific evidence”. Following, art. 4 is dedicated to the intermediate climate targets that are supposed to work both as mid-term objectives and checks in itinere. Additionally, article 5 brings to discussion another crucial issue, which is adaptation to climate change. Indeed, the EU has mainly produced mitigation and adaptation policies and the latter represent the hard reality at stake. Climate change is not going to stop, and MS need to be able to build resilience. This doesn’t mean that there will be even a bigger effort to mitigate this change, although, it is essential to act to control and resist to the extreme events that have been hitting Europe during the latest years. Finally, article seven underlines the supranational role of the Commission in assessing the consistency of national measures, affirming another time the shared competences over the issue.

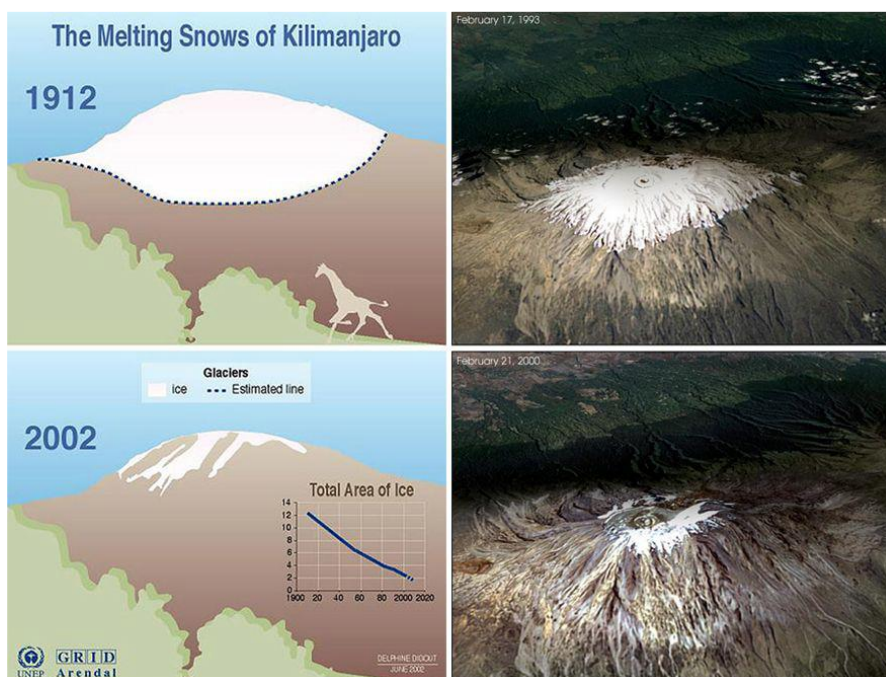
CLIMATE CHANGE INDICATORS IN AFRICA

The impacts of climate change are experienced differently across various regions of the world, with varying degrees and manifestations depending on the location. In Africa, climate change is increasingly evident through a range of observable signs at continental and sub-continental levels. Africa is experiencing a significant increase in temperatures, with some regions warming at more than twice the global rate (IPCC, 2022). This trend is particularly pronounced in the subtropics and central tropical Africa, where temperatures are projected to rise by 4-6°C over the subtropics and 3-5°C over the tropics by the end of the century under low mitigation scenarios (Weber et al., 2018).

One major indicator is the rise in air and ocean temperatures, which is contributing to hotter conditions in many areas, affecting both human health and ecosystems (Damor, 2024). Alongside temperature increases, sea levels are also rising, particularly along the coasts, threatening low-lying areas with flooding and erosion (IPCC, 2022; Norgie et al., 2024; Damor, 2024).

Additionally, there has been a noticeable reduction in the extent of snow and ice, particularly in mountainous and polar regions, which impacts freshwater availability for both ecosystems and human populations. About 80% of the ice sheets on the Mount Kilimanjaro has been melted since 1912 (Figure ...). Changes in precipitation patterns are also a significant sign of climate change, with some areas experiencing more intense rainfall and flooding, while others face prolonged droughts and water scarcity (Almazroui et al., 2020).

The effects of climate change are also apparent in both terrestrial and marine biological systems. On land, changing temperatures and rainfall patterns are altering ecosystems, affecting plant growth, wildlife habitats, and agricultural yields (Sintayehu et al., 2018). In the oceans, rising temperatures and increased CO₂ emissions are leading to ocean acidification, which threatens marine life, particularly coral reefs and fisheries (Sintayehu et al., 2018). These interconnected changes underscore the diverse and widespread impacts of climate change across Africa, affecting both natural and human systems.



Melting ice cap of Mount Kilimanjaro EarthKAM

CLIMATE CHANGE IMPACT AND RISK IN AFRICA

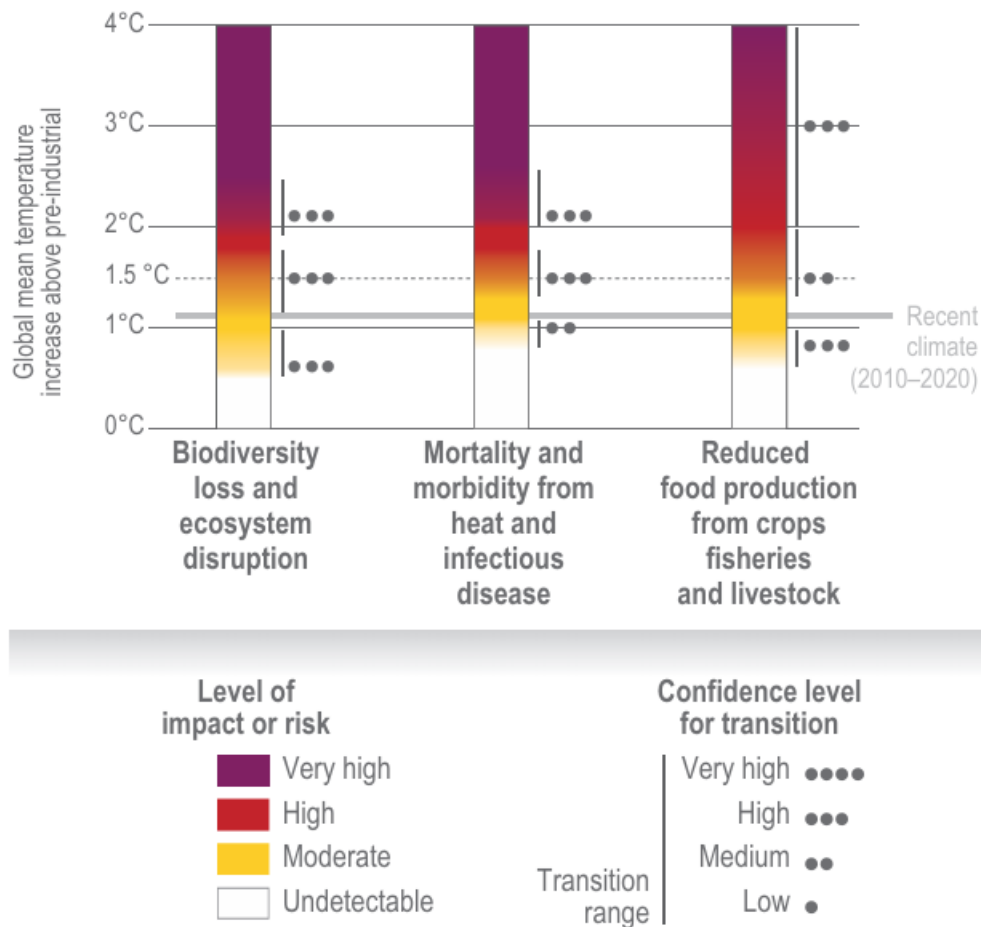
The impacts of climate change are vast and interconnected. Using the nexus approach, the importance of addressing climate change becomes even clearer as it reveals the intricate connections between climate, water, energy, and food systems. These systems are essential for human survival and socio-economic development, and climate change disrupts their delicate balance. Climate change have impacted Africa considerably more than any other continent (IPCC, 2022). The vast landmass of Africa presents a disproportionate impact often dependent on geographical location. In rural Africa, poor and female-headed households face greater livelihood risks from climate hazards. In urban areas, growing informal settlements without basic services increase the vulnerability of large populations to climate hazards (Trisos et al., 2022).

Climate change causes an increase in global average temperatures, leading to frequent and severe heatwaves, melting glaciers, and rising sea levels. Severe heat waves not only pose health risks, such as heat-related illnesses, but also stress ecosystems, impacting wildlife and plant growth. Higher temperatures also accelerate the melting of glaciers and polar ice caps, contributing to rising sea levels (Nyadzi et al., 2020). This process threatens coastal cities like Accra in Ghana, Lagos in Nigeria, and Banjul in Gambia with flooding, erosion, and habitat loss, particularly for communities living in low-lying areas proximal to the shoreline.

Climate change alters rainfall patterns, resulting in some regions experiencing excessive rainfall and floods, while others face prolonged droughts. Droughts can lead to water scarcity, severely affecting agriculture and drinking water supplies. Conversely, floods can destroy homes, infrastructure, and agricultural lands, making recovery difficult for affected communities. Among Africans living in coastal areas, about 30 million live in areas considered flood hazard zones (Oppenheimer, et al., 2019; Dada, et al., 2023). Settlements long the Lake Victoria in Uganda and the Nile River in northern Africa experience recurrent and frequent flooding which can be linked to climate change. Flooding significantly alters the lifestyle of residents and destroys the livelihood and shelter of many. This does not only pose a treat to human health but disrupts the ecosystem, leading to biodiversity loss (Trisos et al., 2022).

Africans are disproportionately employed in climate-exposed sectors. According to Trisos et al., (2022), about 55–62% of the sub-Saharan workforce is employed in agriculture and 95% of cropland is rainfed. With changing rainfall patterns, the agricultural sector becomes unpredictable and vulnerable. Agricultural productivity growth has been reduced by 34% since 1961 due to climate change, more than any other region (Trisos et al., 2022). Climate change has impacted food production creating an impression of food insecurity in Africa.

Climate variability and change are already having a profound negative impact on the health of tens of millions of Africans (Trisos et al., 2022). Rising exposure to non-optimal temperatures and an increasing frequency of extreme weather events are straining the resilience of populations across the continent. Additionally, climate change has expanded the geographic range and transmission of infectious diseases, creating new public health challenges. These combined effects exacerbate existing vulnerabilities and disproportionately affect communities with limited resources to adapt or mitigate the consequences.



Risks increase with increasing levels of global warming Trisos et al., 2022

AFRICA'S UNIQUE CHALLENGES

Africa has the lowest historical emission but have been significantly impacted and remains unequally vulnerable to climate change. Africa is one of the lowest contributors to greenhouse gas emissions causing climate change, yet key development sectors have already experienced widespread losses and damages attributable to human-induced climate change, including biodiversity loss, water shortages, reduced food production, loss of lives and reduced economic growth (Trisos et al., 2022)

Gender inequality in the African continent amid climate change impacts further exacerbate the disproportionate impacts on women (Fonjong & Zama, 2023; Assefa & Gebrehiwot, 2023).

Africa is particularly vulnerable to climate change impacts due to:

1. High dependence on climate-sensitive sectors like agriculture
2. Limited adaptive capacity
3. Existing developmental challenges

CLIMATE RESILIENCE; MITIGATION AND ADAPTATION STRATEGY IN AFRICA.

Climate resilient development (CRD) is a process of implementing GHG mitigation and adaptation measures to support sustainable development (Trisos et al., 2022). Africa is identified to be the most vulnerable to climate change among other regions. However, in the vast landmass of Africa, the Sub-Saharan region is identified as the most vulnerable to the changing climate due to its very low capacity to adapt to or mitigate climate change. Many African regions are vulnerable to food insecurity, facing dwindling food production, food access, stocks and income due to low adaptive capacity. This situation underscores the need for a comprehensive resilience development. Five key dimensions of Climate Resilience Development have been identified for Africa: climate finance, governance, cross-sectoral and transboundary solutions, adaptation law, and climate services and literacy (Trisos et al., 2022).

Access to adequate financial resources is essential for climate change adaptation in Africa (Trisos et al., 2020). However, the continent remains at the lowest tier in terms of climate financing. Adapting to climate change often involves the development of resilient infrastructure, including flood defences, water management systems, and drought-resistant agricultural practices, all of which require significant capital. Without sufficient funding, vulnerable communities are unable to establish or sustain these critical systems. Financial resources also facilitate investments in research to better understand localized climate impacts and to develop innovative strategies for adaptation.

Alternatively, direct human dependence on ecosystem services in Africa is high. Implementing policies focused on ecosystem protection and restoration, conservation agriculture practices, sustainable land management, and integrated catchment management can support climate resilience. Ecosystem based adaptation can cost less than grey infrastructure in human settlements (e.g., using wetlands and mangroves as coastal protection). A befitting example is the “smile earth project” which was a community led project that transformed a bare land into secondary forest in Pemamoto, Tanzania (Figure ...). Community-based adaptation is essential for creating bottom-up resilience that is context-specific and rooted in local knowledge and practices.



Community-led land transformation in response to climate change. Pemamoto, TANZANIA (Image copied from; Justdigit.com)

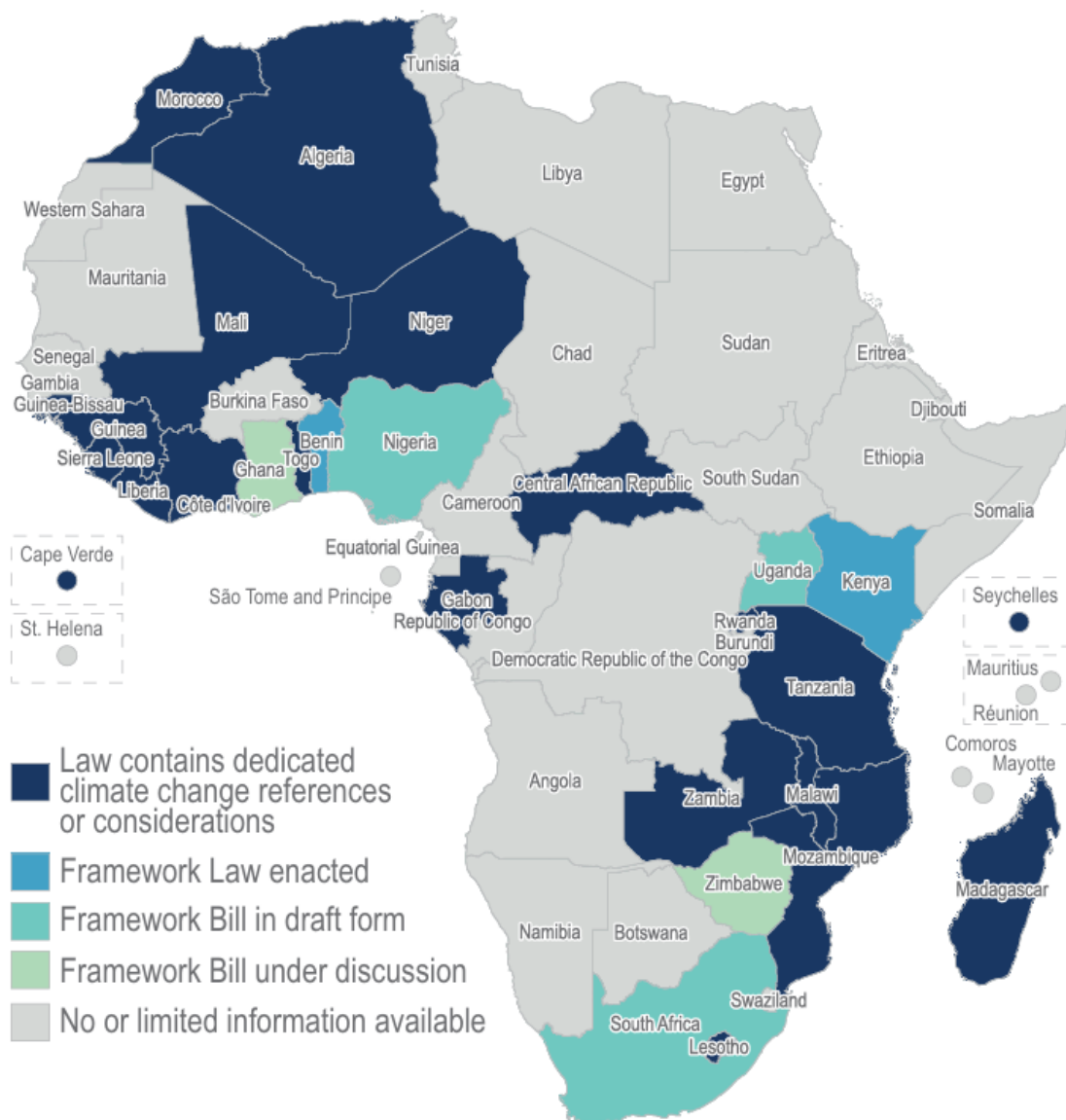
ADAPTATION AND MITIGATION POLICIES IN AFRICA

Given Africa's high vulnerability to climate-related challenges such as droughts, floods, and desertification, adaptation policies focused on reducing the vulnerability of communities and ecosystems to the adverse impacts of climate change are essential for ensuring sustainable development and safeguarding livelihoods. Various policies and actions have been implemented across the continent to address these challenges, with varying degrees of success and focus (Figure ...). Many African countries have developed National Adaptation Plans (NAPs) to systematically address the impacts of climate change. These plans outline specific actions, strategies, and measures to adapt to climate risks in sectors like agriculture, water resources, health, and infrastructure.

The Africa Adaptation Initiative, launched by African heads of state and government, seeks to enhance the continent's ability to adapt to climate change. The initiative aims to promote resilience by supporting the implementation of NAPs and providing access to climate finance for adaptation

projects. It also encourages knowledge sharing and collaboration between African nations and international partners. The African Union's Programme for Infrastructure Development (PIDA), together with other national energy plans, collectively known as PIDA+, seeks to expand hydropower capacity by nearly six times, increase irrigation capacity by more than 60%, and boost hydropower storage capacity by over 80% in key African river basins (Cervigni et al., 2015).

Local communities are often at the forefront of climate change impacts, and many adaptation policies in Africa emphasize community-based approaches. These policies empower local communities to identify climate risks, develop localized adaptation strategies, and improve their resilience through capacity-building, knowledge exchange, and resource management.



Legislation and policies on climate change in Africa. (Trisos et al., 2022)

COMPARATIVE INSIGHTS; EUROPE VS AFRICA.

Europe and Africa are two distinct landmasses, each facing different levels of impact and vulnerability to climate change. Europe benefits from advanced technologies, robust financial resources, and well-established climate governance frameworks, which help in addressing the challenges posed by climate change. In contrast, Africa, while lacking access to advanced technologies and financial resources, possesses significant potential to harness renewable energy. The continent is rich in natural and mineral resources, many of which are vital for the green energy transition. Africa's vast inland water bodies offer immense potential for hydropower generation, while countries like the Democratic Republic of Congo, endowed with abundant minerals, have the capacity to deploy renewable energy solutions if resources are managed effectively.

Regarding climate governance, Europe is known for its strong policy frameworks and strategic approaches to addressing climate change. In comparison, Africa faces challenges in establishing similar governance structures, due to financial constraints and institutional weaknesses. However, Africa can leverage Indigenous Knowledge systems to facilitate community-based adaptation strategies. Indigenous communities have accumulated profound knowledge of their local environments over centuries, based on practical experience, observation, and oral traditions. This includes sustainable agricultural practices, water management techniques, and strategies to cope with environmental changes such as droughts and floods. By integrating this knowledge into national legal frameworks, African governments can protect and preserve these practices, ensuring their continued relevance for future generations.

Despite their differences, both Europe and Africa face shared challenges in combating climate change. Both regions must work towards ensuring equitable global climate action and financing, as climate change is a global issue that requires cooperation. The transition from fossil fuels will also have economic implications for both regions. African countries like Nigeria, which depend heavily on crude oil exports, and European countries with significant investments in the oil and gas industry, will experience ripple effects from this global shift. It is essential for both regions to adapt to these changes while securing a just transition for affected communities and economies.

CONCLUSION

In conclusion, climate change is a global phenomenon that transcends national boundaries and is a critical factor in determining the fate of the planet and its inhabitants. The battle against climate change cannot be personalized or confined to individual nations but rather requires dedicated and collective efforts from all regions, religions, and races. Europe and Africa, while facing distinct vulnerabilities and challenges, must collaborate in addressing this shared threat. Europe benefits from advanced technologies and robust financial resources, while Africa, despite its limited access to these resources, holds significant potential through its vast renewable energy capacities and Indigenous Knowledge systems. By integrating Indigenous Knowledge into adaptation strategies, Africa can strengthen community resilience and contribute to global climate action.

At the same time, both continents, along with other global actors, must ensure equitable climate action and financing, particularly in the face of the economic shifts caused by the transition from fossil fuels. The future of our planet depends on our collective ability to combine policy initiatives, technological innovations, and behavioral changes to stay within the safe operating space for biodiversity, while ensuring a healthy, sustainable future for humanity. Through cooperation, shared knowledge, and a just transition, we can build resilience and work together towards a more sustainable world in the face of climate change.

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EVE

2. Reflections on Sugar and biosphere integrity: what nature gives and what humans do

Diana Sfetlana Stoica

Sibongile Mlotya

Reflections on Sugar and biosphere integrity: what nature gives and what humans do

Abstract:

This is a critical look at the interdependence between human action, health and nutrition issues, and environmental change, related to humanity's ideals of reaching the biosphere integrity in conditions of problematic biosphere change.

The purpose of this critical perspective is to find the bindings between the three elements cited above, in viewing the case of sugar processing and consumption, as a triggering element to realizing a conceptual map of nutritional/ health preservation values that humans could follow to both help environmental positive change and assure biosphere integrity. This study uses a qualitative method and secondary data, to contextualize different approaches in countries from Africa and Europe, regarding nutrition challenges and shortcomings that might mitigate biosphere integrity.

The processing and consumption of sugar, as a fundamental element jeopardizing public health, is herein considered both a positive and negative vector to the balancing of the ecosystem, nature, and public health. The aim of this reflection is to conclude if sugar may be ethically included in a discourse of biosphere integrity, and what alternatives to think on the mutual contributions of nature and humans to the biosphere change. Moreover, a second interest of this paper is to contextualize in academic debate the complexities of the narrative nature-culture in reference to the use, consumption, dependency and in the end the harming effects over people's health, of sugar.

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Key words:

Sugar, contribution, people, nature, biosphere

Introduction

Thinking of the major planetary boundaries, the attention to the biosphere integrity should be regarded as special, from a social, political, and psychological point of view. Maybe it is not a coincidence the fact that in the Planetary Boundaries diagram proposed by The Stockholm Resilience Center¹, the biosphere integrity is placed on the top, at the left, right there where it starts the visual route of the audience, like in the Z pattern of a promotional banner's organization – to assure the most of the audience's retention capabilities. Biosphere integrity is mostly connected to the sense of humanity's preservation and the struggle to achieve a better and longer life on the earth. Since this aim is dependent on factors attaining to the interdependency between human action, health and nutrition as a set of behaviors and policies, and environmental change, our major interest was to reflect critically on how this interdependency is reflected when we consider specific elements being part of the daily nutrition of most people on the globe, like the sugar, whether consumed in original form or as an ingredient of many other products. We have chosen

¹ [Planetary boundaries - Stockholm Resilience Centre](#)

sugar, since, from various points of view, sugar is a central element of humanity's physical, psychological, social, economic, political and epistemic features. Putting sugar at the center of our preoccupations in the context of biosphere changes, that are revealed as a consequence of human actions and environmental changes, but also as a consequence of human behavior and ontology in reference to health and nutrition, is important in order to assess if sugar represents a triggering element to this conceptual map of relations between what nature gives and what humans do.

Our intention is to unpack the sugar also as a concept, from its processing and consumption, the narrative around them, in order to reflect critically and comparatively on the relation between human actions and behaviors, on one side, and on the environmental changes that are directly and indirectly caused by them, all related to one central element, the sugar. The perspective is holistic, but the context of secondary data that is used in the content analysis are the regions of Europe and Africa, with particular look into the cases of Romania and South Africa. However, our intention is to use the comparative analysis in order to define the narratives of sugar that reflect positive or negative outcomes in the relation nature-culture, or what natures gives and what human do, posing in the first instance the question if sugar in itself could be possibly put at the center of the processes of preservation of a biosphere integrity, from an research ethic's perspective.

Sugar – at the center of a research in humanities and ecology

For several years, different medical research have reflected the critical outcomes of sugar consumption on public health. However, a point of view from the humanities and human ecology should still be nurtured. Narratives on sugar start from its production, from sugar cane or sugar beet plant. Both of them represent basic challenges as: land use, the opportunity costs of the crop choice, the use of pesticides, and, for sugar cane especially, the utilization of bone's char for the whitening of sugar, putting sugar production in connection to fauna changes. On the other side, the utilization of coal-based activated carbon as an alternative to bone's char, which actions the slight toxin elimination, would suggest the benefits of its use in comparison to the latter one, and, as a consequence, the doubled action on preserving the equilibrium of the biosphere.

Beyond the narratives of sugar production, there are the narratives of consumption which keep at the center of their discourse the challenge of the pure sucrose contained in the sugar to the formation and evolution of relevant contemporary globally widespread health problems such as: obesity, heart disease, diabetes, liver problems, teeth problems and not only. Medical data on pure sucrose and globalization trends, with consequent action of the enterprises and corporations to use sucrose for various other food products, show that the Anthroposphere's integrity depends on the rates of sugar used in the daily nutrition of people, and although there are differences given by social status, wealth, nutritional education, lifestyle, economy features of the region, climatic needs, consumption trends, globalization rates, the issue is revealed with the same amplitude in every country, and at a global scale. For this reason, questioning the Anthroposphere in direct relation with the Biosphere, while the aim is to achieve the integrity of both, signaled the ethical issue of putting the production and consumption of sugar at the center of global concern on biosphere changes.

To reveal how and why sugar was put at the center of such a discourse and research also in humanities, we used three levels of reading: the caloric intake from sugar and fruit, as alternatives (the nutritional level), the consumption of sugar (the economic-ecologic level) and the sugar consumption outcomes (the health and socio-political level).

A diagram of the caloric intake of main food groups from 2011 reflected a value of 8 % from sugar and confectionary products in Romania, only 4% from fruit and fruit products, the intake from sugar being

almost the same as from meat (9 %), while from vegetables the intake was only at 11 % (Costandache & Menciu, 2013). Data from South Africa reveal that less importance was given to the caloric intake from sugar than other food categories. Considering the national South African caloric intake of fruit (which contains an alternative to fructose of sugar) is under 25%, and only halfway to achieving the global level of almost 50%, according to the Global Nutrition Report from 2022(GNR, 2022), and seeing that the prevalence of overweight has doubled in the last 20 years (GNR,2022), it would be appropriate, also in line with global trends, to think that, since overweight is largely advantaged by the consumption of sucrose, the intake from sugar and confectionary products could be increasing in South Africa, too.

For the year 2018-2019, the sugar consumption in Romania was estimated at 0.74 kg/capita/ month (Petre & Draghici, 2021, p. 445), while the OECD library estimated the consumption of sugar at the level of 25.1 kg/capita/ year, namely 2.09 kg/capita/ month in South Africa (OECD/FAO, 2021). Looking beyond these data, and coining them to the estimated real GDP per capita in Romania for 2021, presented at the level of 3166 USD/ month, while the same parameter in South Africa is at 1183 USD/ month, according to World Factbook (cia.gov), the consumption of sugar seems inversely correlated to the level of development given by the GDP/ capita, while the consumption of fruits, as recommended diet for the reduction of sugar consumption, is in the same inverse correlation. This situation should define the look on the comparative analysis of health issues caused by sugar consumption to support the idea that low levels of GDP should also mean lower levels of health problems caused by such consumption if sugar is separated as a nutrient from other categories of nutrients and is studied in absolute values, finally capitalized in narratives of production and consumption. So, in Romania, the production of sugar from sugar beet plants had the same levels in 2019 as in 2010, and although in this period the population decreased, the cases of diabetes increased by 33 % in 2021 (Statista.com). 58 % of these were in the urban areas (Petre & Draghici, 2021, p. 445), where health prevention is supposedly higher. In South Africa, the production of sugar cane increased, after some variations, by 30% from 2010 to 2019 (Statista.com), while the population also increased by 15 % in the same period, and the cases of diabetes have triplicated (Sifunda et al, 2023, p. 2).

All these data, reflected in the frame of comparison between a lower middle-income country in Europe and an upper-middle-income country in Africa, are instruments to assess our fundamental schema of relations between sugar, human actions, biosphere integrity and environmental change, that the narratives of sugar become socio-political and ethical ones. They start from the consideration of poverty or marginalization, characterizing rural areas, in the context of less access to prevention medication that requires socio-political intervention and less awareness of healthy nutrition although there could be an opportunity for more alternatives to sugar consumption (e.g. fruit consumption). On the other hand, the sugar narrative highlights the potentiation of rural areas due to the major contributions of sugar mills and plantations to the development of rural areas, as a consequence of necessary rapid post-harvest processing (SASA, 2024), in the context of an urbanization trend that is below 2 % in South-Africa, between 2015 and 2020 (UN, 2022), while the urban population growth in Romania was preponderantly negative in the same period (World Bank, 2024).

Seeing the different trends and contexts, as well as contrary demographic, social and cultural structures and realities, between Romania and South Africa, integrated with data that seem dispersive as they describe the narrative of sugar production and consumption from a holistic perspective, the common concern regarding sugar is the increasing consumption, requiring increasing production, that finally brings, beyond economic reasons, challenges to the biosphere integrity. These challenges are capitalized in interlinked positive and negative outcomes that have to be studied in particular and in common as well.

Sugar narratives and reciprocal contributions nature-people values (NCP and PCN)

In 2005, an example of interdependency between elements that influences the biosphere integrity or the Anthroposphere preservation in the context of a climatic concern, not necessarily related to sugar, was discussed in terms of a parameter to be secured, defined as NCP, namely the nature's contribution to the people (Brown et al., 2005). We interpret this parameter as a functional one for a broader discourse on the relation between nature and culture, which is highly debated in interdisciplinary literature. In line with preoccupations to preserve nature in the context of changes that are, in the short term at least, not always dependent on human action, but also to assess in this context the impacts of it, related to the consumption and production needs related to sugar, we have extended the parameter and tried to see it in the context with its epistemic antonym, the PCN, namely the people's contribution to the nature.

We hypothesize that each human action that is related to the consumption and production of sugar could be positive or negative, reflecting on one side how it affects nature, but also how nature guides it. Therefore, after critically viewing some correlations of data in Romania and South Africa, and after seeing that no matter the trends and realities, the narrative of sugar is relevant to biosphere integrity and should be better contained in humanity research, our paper looks into the two parameters NCP and PCN, in connection with sugar, at a holistic and global level. To simplify this critical look and be able to take conclusions from it, we have tried to reflect upon facts and imagine their consequences, identifying opportunities and foreseeing their perceptions, assigning positive (+) or negative (-) values to each action, fact or reality that reflects a nature's contribution to the people (NCP) or a people's contribution to the nature (PCN).

One of the most important contributions that people brought to nature about sugar, was the legislation posing different limitations to production and consumption, to preserve the integrity of the biosphere. In this category, taxation was fundamental to reducing the negative impacts of consumption on public health burdens and also the negative ones of biofuels on the environment (King & van den Bergh, 2022). We considered this reduction of negative impacts a positive contribution that people brought to nature (PCN+). However, taxation brought mass adversities, especially regarding the increase in the prices of goods which are related to the use of sugar as a principal, side ingredient or a preserving agent. As Aguirre suggested (2015) less costly products that should respond to a lower-income market contain more sugar. Taxation and awareness of this reality, combined with the public policies for the improvement of nutrition, take us to consider that humanity's control of nature in this sense is positive, and poverty paradigm shifts are changing at a nutritional level, too. In this case the nature's contribution to the people is positive, too (NCP+).

In fact, a report from the World Health Organization (2015) stated that Mediterranean, Vegan, and Vegetarian diets would *“reduce global agricultural greenhouse gas emissions, reduce land clearing and resultant species extinctions, and help prevent diet-related chronic non-communicable diseases.”*

However, the negative impacts of such diets are not without relevance in certain food industries, producing losses and causing several debates around genetics, geographically determined nutrition, and health issues caused by improper nutrition. Considering diets as a recommendation reflecting the aim of people to contribute to biosphere integrity or nature preservation, the PCN would present, at this level, positive and negative values, as well (PCN+/-). Ambivalent positive and negative values can be assigned to the parameter NCP also in the case of the liberalisation of sugar production, as the one from 2005, consequent to that one of the trade and having unevenly distributed consequences (FAO, 2015, p. 15). It supported the economic reasoning of production and commercialization increases, the resulting possible reduction of garden fruit consumption, letting them in despair along with the lands awaiting to be destined to utilization, while allowing unemployment to increase, urbanization to grow, poverty to boost and make populations vulnerable to health risks due to higher sugar consumption. We will consider these consequences a contribution of nature to people, a gift of nature to the human (fruits and sugar beet or sugar

cane) questioning the outcomes of his actions related to both consumption and production of sugar (NCP +/-).

Liberalizing the production of sugar may be seen also from the economic perspective of the basic narrative: “more consumption = more production”. This contributes to an increase of land use for sugar beet plants or sugar cane plantations, with consequent reduction of flora species (PCN-), which would be negative for nature in itself, but, since some of the species would be weed and would harm nearby crops, and this would have negative impacts on biosphere integrity at its turn, in the end the result would consist in a positive contribution of people to the nature (PCN+). However, considering the interdependencies of agriculture (so culture) with nature, the equilibrium of nature is affected, especially by the consequent increase of 80% of greenhouse gas emissions associated with low-cost dietary trends rich in refined sugars according to Tilman and Clark (2014) cited in the WHO report (2015), thus, this a negative contribution of people to nature (PCN-).

One of the major uses of pesticides was noted for the sugar cane plantations in Malawi (Donga & Eklo, 2018), and the overall use of pesticides contributes to the major poisoning of water. Seen as a negative contribution of nature to the people, with the capitalization of water as a natural resource for the biosphere integrity (NCP-), the relation between pesticides-water is an element of the negative contribution of people to nature, at the same time (PCN-). However, the use of pesticides allowed crops to be more safe and predictable for the economic feature of human action and effectively great competition is registered on the sugar market, corresponding to income increase, overall social development and the rise of importance of certain markets that were marginalized before. This would be another positive contribution of nature to the people (NCP+), which would be doubled, in the context of the evidencing of the top 5 major sugar exporters in 2022 (Morocco, Eswatini, South Africa, Mauritius and Egypt), according to Mabeta and Smutka (2023), that sugar economic narrative could give rise to a recapitalization of new economic centers as centers of power, from a regional, and global perspective.

The narrative of sugar and the concept of power, in the context of Africa-Europe dialogue occasions the look unto historical connections, as well. Sugar plantations are a symbol of the locus and a medium for coloniality expressions, which re-propose the nexus of power on African slaves, the forced labor and displacement to other parts of the world, also on sugar cane plantations. The slave trade itself would have represented the European weapon to maintain the possession of resources (Mbembe, 2017, p. 79), with an evident negative contribution of nature to the people (NCP-). The slave trade as a symbol of the dark face of modernity proposed by Europeans (Ndlovu-Gatsheni, 2013, p. 69) is related to plantations of cotton and sugar, commodities that the ex-colonies continued to supply the Western world with. But around this trade, the debate continued on liberalization as a step in the decolonization process, through the recommendations of the Commission of Africa on the elimination of trade-distorting support on cotton and sugar (Bongmba, 2006, p.212).

But there is another key element of the trade that made sugar be regarded in the nexus of power, namely the domination of processes on sugar that were taken away from the supplier countries, according to what was described by Rodney (1973) as an action through which Europe underdeveloped Africa². In certain communities of Zambia, sugar has also the quality of a currency (Chipere-Ngazimbi, 2020, p. 110), highlighting how processing and consumption of sugar are only transitory and barometers of social development. This functional role in society would allow reflections on the lower permeability of substitutes, especially chemical ones, in consumption behaviors in African countries, compared to countries from Europe. In the latter region, chemical substitutes were proven to be harmful, causing also sufficient emissions to be considered a negative contribution of people to nature (PCN-).

² Having written the book with the homonymous title.

The discourse on the substitutes of sugar points to the most recommended alternative element, the fruit. In the context of the liberalization of the sugar markets, which brought economic advantages, sugar consumption increased, causing less fruit consumption in the logic “if not non-A, then A”. Although there were dietary trends to support fruit rather than sugar consumption, the consumption of fruit could not increase disproportionately, a situation highly sustained by the narrative that addiction to sweets is more directly satisfied by confectionary products and not fruit. Globalization, including the confection of food articles with the use of large amounts of sugar, poverty, social status and nutrition mindsets, as well as the trends of consumption, have shown that the discourse on sugar is directly linked with one of the evolution trends in fruit consumption. Their perishability, requiring intervention, was qualified as a negative contribution of the people to nature (PCN-) because, on one hand, it assumed the continuation of a long-term sugar consumption, on the other hand, because sugar itself was largely used as a method of conservation for the fruits, and any major desire to consume fruits, would mean to consume also sugar.

Addiction to sweets was artificially caused by the liberalization of the market of sugar, and it is capitalized as a nature’s contribution to people, due to it being linked with the human body, but also a consequence of nature’s gift to humans. Considering the hedonistic aspect of the tastes, this nature’s contribution to people is both negative and positive (NCP+/-) because it occasioned positive concern on nutrition and lifetime maladies, the critical look on sugar, unpacking fruitarian diets (which at their turn could have caused maladies), but also the negative experiences of resulting social and health issues. More health problems the humanity experience, major is the need for diagnosis, treatment, and prevention meaning also the need for medical equipment, medicines and more frequent use of equipment which potentially releases emissions, being threats to the climate and the biosphere integrity. People's contribution to nature is therefore negative (PCN-) in this case, as well.

But not only the Anthropocene is implied in this balance of positive-negative outcomes from the reciprocal contribution of culture-nature, but also fauna. The phenomenon of less fruit consumption and of fruit in despair means that migratory birds would search less for insects and eat more fruit (which is at hand), causing the phenomenon of the “humanization of the birds” , with impacts on the biosphere equilibrium and integrity (Hannay et al, 2019). Therefore, people’s contribution to nature is both positive and negative (PCN+/-). Unfortunately, human deaths due to lifetime diseases caused by sugar (especially diabetes) are very numerous at a global scale, so we have translated this into a non-pimping parameter of nature’s contribution to the people, which is negative (NCP-).

The use of cattle bones to whiten the sugar is also fundamental for establishing the effects of sugar on biodiversity, as it involves cattle farming activities regulating the sustainable use of bones, resulting in a positive contribution of nature to the people (NCP+). On the other hand, the same positive contribution is given by nature to people (NCP+) when capitalizing on the possibility of using silica and zirconium for the carries, taking into account that oral cavity protection and treatment has to rise in the context of widespread sugar consumption increase. The use of these elements is not necessarily relevant on the short term, but on the long term it might sustain a natural development of biosphere equilibrium or (in)equilibrium, reason for which, in terms of change, and without any information on the direction of this change, the use of minerals could represent a positive contribution of people to nature (PCN+).

One of the most important human corrective actions over the nature in terms of ecology is the recycling of plastics. When it comes to parallel actions related to sugar, it is important to reflect upon the use of sugar canes for the ecologic packaging, which is per se a positive contribution of people to nature (PCN+), but this raises the backyard problem of the failure to recycle plastic materials. Therefore, people's negative contribution to nature could be highlighted (PCN-).

Last but not least, in our study, the consumption of sugar was related to psychological reasons, trends and addictions or needs framed at a hedonistic level, for which the proposed trend of mindful eating,

namely getting more satisfaction from less quantities consumed, or “less is more”, forwarded by Meier, Romani, Kateman and Nori (2023) represents the key to further considerations on the role of sugar consumption rationalization in the context of a desire to preserve biosphere integrity. The mindful consumption would represent a positive people contribution to nature (PCN+).

A few Conclusive reflections on sugar and biosphere integrity

Reflecting upon all processes, connections and thoughts about sugar production and consumption, taking into account the huge amount of medical expertise on sugar and its effects on human health, our hypothesis that sugar consumption and production or processing into confectionaries and regular food is a core element of biosphere integrity could be validated. This position of sugar, as a concept, reflects the vital and sensitive links between human health, human action, environmental change and biodiversity. But sugar is not only a relevant element to links between them, but it also mirrors the paradigm of relations between humans (people, or “culture”) and “nature” on which literature is exhaustive, from a multidisciplinary perspective.

At the center of our analysis were precisely the reciprocal contributions of nature and culture (or people) to each other. Based on this, we draw on the question if sugar consumption and production have to be taken into account when conceptualizing the actions humans should take to preserve biosphere integrity, in the limits of an equilibrium between “what nature gives” and “what humans already do”. The example of People’s Contribution to Nature (PCN) coined already, was taken to assess the type of changes (positive or negative) that sugar consumption and production determine in nature (from the biosphere to the Anthroposphere). The same analysis was applied also to the contrary, critically thinking on an eventual (NCP) – Nature’s Contribution to the People, when changes in biodiversity or, limitations imposed by nature to human action, but reflected in the main interest of the humans to preserve nature, determine the changes in human actions over the nature. Therefore, sugar was analyzed from the point of view of positive –negative aspects of PCN and NCP that are sometimes co-dependent, as elements taken into account for their measurement are floating around perspectives on the notions of good for, nature or people, which are many times contrary to each other.

The results of the analysis show that there are 6 positive and 12 negative people contributions to the nature, meanwhile, there are 7 negative and 7 positive nature contributions to people (PCN : 6 + / 12-; NCP: 7 + / 7 -). So, from this point of view, nature’s contribution to people would be neutral, and the people’s contribution to nature is negative.

Despite the simplicity and limitations of this study, the critical perspective uses also the idea from nutrition research on “less is more” that should be applied to sugar consumption and production. A less positive contribution of people to nature would mean a less negative contribution in the end (report 1:2 if considering PCN) so finally a more positive one (“more”), which could be finally translated, regarding to sugar, into the reflection that non-contribution of people to nature could be a solution. Namely, the non-contribution could be the limitation of sugar consumption through methods of coercive limitation of the addiction to it. All this in the context of finding different ways to use the sugar beet plant and the cane in such a way to receive a similar amount of satisfaction and benefits as people were used to, traditionally, by the innovation of consumption trends and education in the direction of preserving biosphere integrity through understanding the limitations and the role of Anthropocene in this.

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EVE

3. Land-system change and sustainable development in Ghana: the impacts of artisanal mining

Obed Harrison

Riccardo Angius

TITLE: LAND-SYSTEM CHANGE AND SUISTAINABLE DEVELOPMENT IN GHANA: THE IMPACTS OF ARTISANAL MINING

ABSTRACT

In 2009, the Stockholm Resilience Centre at Stockholm University introduced a novel framework for addressing global sustainability, now widely recognised as the Planetary Boundaries. This framework outlines the ecological limits within which humanity can operate safely. This paper employs the Planetary Boundaries framework as a basis for examining the impacts of human activities on the Earth, with particular attention to the third planetary boundary: Land-System Change. According to the most recent update of the Planetary Boundaries (2023) by the Stockholm Resilience Centre, the boundary for Land-System Change has been exceeded. A significant issue within land-system change is mining, which will serve as a focal point in our examination of the transformation of land systems due to human activity. Sub-Saharan Africa, specifically Ghana, provides a clear example of the impacts of mining on landscapes and land systems. Special emphasis will be placed on artisanal and small-scale mining, particularly “Galamsey,” which plays a critical role in local economies by providing income and employment, especially in resource-rich regions. While the economic benefits of artisanal mining are substantial, its environmental impact is severe, leading to deforestation, pollution, and land degradation that endanger local ecosystems and sustainable land use. This study focuses on regions in Ghana with high levels of artisanal mining, especially in the Western and Ashanti regions. The paper will utilise satellite imagery and field data to quantify changes in land use and land cover over recent decades. Additionally, a socio-economic analysis gleaned from secondary data sources will contextualise local motivations for participation in artisanal mining, examining its effects on food security and rural livelihoods.

INTRODUCTION

The 2023 update to the Planetary Boundaries framework identifies that the Land-System Change boundary has been crossed due to human activities such as deforestation, urbanization, and mining. Mining, particularly artisanal and small-scale operations, has been a key driver of land-system change, causing ecological imbalances, biodiversity losses, and disruptions to agricultural productivity (Quarm et al., 2022; Hilson, 2002).

In Ghana, artisanal gold mining, locally known as "Galamsey," is a critical livelihood activity, especially in resource-abundant regions like Western and Ashanti. While ASM contributes to local economies, its environmental toll is significant, including deforestation, water pollution, and mercury contamination, which threaten ecosystems and sustainable development (Adu-Baffour et al., 2021; Barenblitt et al., 2021). As global demand for gold rises, the need to understand how ASM drives land-use changes and contributes to environmental degradation becomes imperative. This paper investigates the economic benefits and ecological costs of ASM in Ghana, focusing on its socio-economic drivers and policy implications.

STATEMENT OF PURPOSE

This study seeks to examine the environmental and socio-economic impacts of artisanal gold mining in Ghana. It quantifies deforestation rates, farmland losses, and water contamination caused by ASM while exploring the socio-economic factors motivating mining practices. It also evaluates the effectiveness of governance policies in regulating the ASM sector, providing recommendations for sustainable land management strategies.

SCOPE OF THE STUDY

The research focuses on regions in Ghana with high ASM activity, particularly the Western and Ashanti regions. By combining satellite imagery, field data, and socio-economic analysis, the study identifies the changes in land use over recent decades. Additionally, it examines the motivations driving ASM engagement and its implications for food security and rural livelihoods (Awotwi et al., 2018; Nyame & Blocher, 2010). This approach offers actionable insights for policymakers to promote balanced strategies that align economic growth with environmental preservation.

MINING AND LAND OWNERSHIP IN GHANA

Ghana's long history with mining predates British colonization, when the region's rich natural resources earned it the moniker "Gold Coast" (Ntewusu, 2015). However, the modern boom in the mining sector can largely be attributed to the Structural Adjustment Programs (SAPs) of the 1980s, which particularly stimulated small-scale mining.

Faced with an economic downturn in the 1970s, the government of Jerry John Rawlings opened Ghana's economy to foreign aid and investments. Collaborating with international financial institutions, the government embarked on the privatization and liberalization of the economic structure, identifying the mining sector as a pivotal area for economic recovery (Minerals Commission of Ghana, 2014).

A commission on gold mining was subsequently established, and recommendations were made to attract foreign investment and regulate the sector. Notably, the legalization of small-scale mining was emphasized as a means to formalize the sector, reduce poverty, and improve livelihoods (Hilson, 2004). The legalization strategy was built on the premise that artisanal mining could be a vital tool for income generation and poverty alleviation (Ntewusu, *ibid.*). Despite its promise, the adoption of Economic Recovery Programs under SAPs had a dual impact. On one hand, it improved Ghana's macroeconomic indicators, but on the other, it caused severe disruptions to agriculture, especially in the Northern region, with minimal benefits for local communities (Ntewusu, *ibid.*). Additionally, the SAPs led to significant legislative changes, including new laws on land property and natural resource use, further reshaping Ghana's economic and environmental landscape.

Land ownership in Ghana operates on a dual system, comprising public and customary land. Public land, managed by the President of Ghana, is intended for public benefit, while customary land belongs to families or clans, typically under the stewardship of chiefs (World Bank, 2023). A 2023 World Bank report on Ghana's forestry sector highlighted the challenges surrounding land ownership, use, and transactions, which often serve as sources of community weakness and conflict. Under the Ghanaian Constitution, the state can acquire land for public interest; however, the vague definition of "public interest" has fuelled disputes over compulsory acquisitions (Bugri & Yeboah, 2017). Since independence, Ghana's land acquisition policies

have undergone continuous reform. From early attempts by President Kwame Nkrumah to bring all customary lands under state control to later recognitions of chiefs' authority over land in the 1960s, legislative reforms have been a constant feature of land management in Ghana (Ackah-Baidoo, Collins, & Grant, 2022).

IMPACT OF STRUCTURAL ADJUSTMENT PROGRAMS ON LAND USE

The SAPs of the 1980s played a central role in shaping land use and ownership in Ghana. Increased international investment placed immense pressure on land use, particularly in sectors tied to primary goods production, such as agriculture and mining. Policies enacted during this period facilitated easier access to the mining sector for both large-scale and small-scale operations, attracting local and foreign investors alike (Ackah-Baidoo et al., *ibid*).

According to a Minerals Commission policy document, the liberalized market enabled approximately 250 companies to explore mining opportunities, both locally and internationally. However, these developments brought new challenges related to land ownership, natural resources, and governance. While Ghanaian law states that all minerals belong to the government, most land remains under the control of traditional leaders and chiefs. This duality necessitates authorization from these leaders for mining activities, resulting in widespread allegations of mismanagement and failure to translate royalties into tangible community benefits (Bugri & Yeboah, 2017).

The SAP era also introduced a bureaucratic framework for mining-related negotiations and compensations. However, this apparatus became a breeding ground for conflicts between mining companies and local communities. Analysts argue that the bureaucratic system fostered poor land governance and hindered the formalization of artisanal miners. Moreover, the complexities of licensing and permitting processes inadvertently encouraged illegal mining activities. Some traditional authorities, perceiving dispossession of their lands, even collaborated in illegal mining ventures, further complicating governance efforts (Ackah-Baidoo et al., 2022; World Bank, 2023).

INSTITUTIONAL COMPLEXITY IN THE MINING SECTOR

The institutional framework governing Ghana's mining sector is exceedingly complex, involving over 20 actors. Key players include four ministries (Lands and Natural Resources; Finance; Local Government and Rural Development; Environment, Science, and Technology), five commissions (National Development Planning Commission, Minerals Commission, Forestry Commission, Water Resources Commission, Lands Commission), and several national agencies. This intricate system creates significant barriers to transparency and accessibility, complicating efforts to formalize mining operations and streamline information dissemination.

ASM AND RURAL LIVELIHOODS

In recent years, ASM has witnessed significant growth among locals, largely due to its potential for higher income compared to agriculture. For many, ASM offers a viable alternative to farming, especially in regions where agriculture faces environmental challenges or declining profitability. However, the farming-mining dichotomy often leads to resource conflicts and rivalries, further exacerbating rural poverty (Brown, 2020).

While international economic restructuring has improved Ghana's macroeconomic performance, the early 2000s were characterized by high unemployment rates. The simultaneous rise in global gold prices created the conditions for a surge in small-scale mining. These factors underscore the importance of ASM not only as a livelihood option but also as a critical economic activity for many locals.

Small-scale mining has become an indispensable part of Ghana's economy, particularly as a subsistence activity for the youth population. However, its expansion is not without challenges. The dual nature of land ownership, coupled with bureaucratic inefficiencies and poor governance, has hindered efforts to formalize the sector. Traditional leaders' involvement in illegal mining and systemic corruption further complicate the issue.

While ASM provides critical income for rural communities, its environmental and social costs are undeniable. Addressing these challenges requires a nuanced approach that integrates land reforms, governance improvements, and strategies to balance economic development with

environmental sustainability. The lessons from Ghana's mining sector serve as a vital case study for understanding the broader implications of land-use policies and artisanal mining in resource-rich regions.

ARTISANAL MINING AND ENVIRONMENTAL IMPACTS

Several have been the effects of the boom of Ghanaian mining sector after the Eighties. Ones of the most striking are related to their impacts on environment, and for what concerns this paper to the land use. Mining in Ghana has meant loss on tree cover and increase in the deforestation rate, land degradation, several have been the effects on waterbodies and in soil contamination, as well as quite huge has been the effect on human health.

One of the major issues related to environmental destruction in relation to mining has been the land degradation. According to some data¹ Ghana since 2000 has lost around 24% in tree cover, particularly in the Ashanti Region and Western region, responsible for “58 percent of all tree cover loss” in the period 2001-2023. These two regions at the same time are the two most involved regions in mining activities.

Using satellite images is possible to see how this loss on tree cover occurred in the two regions.

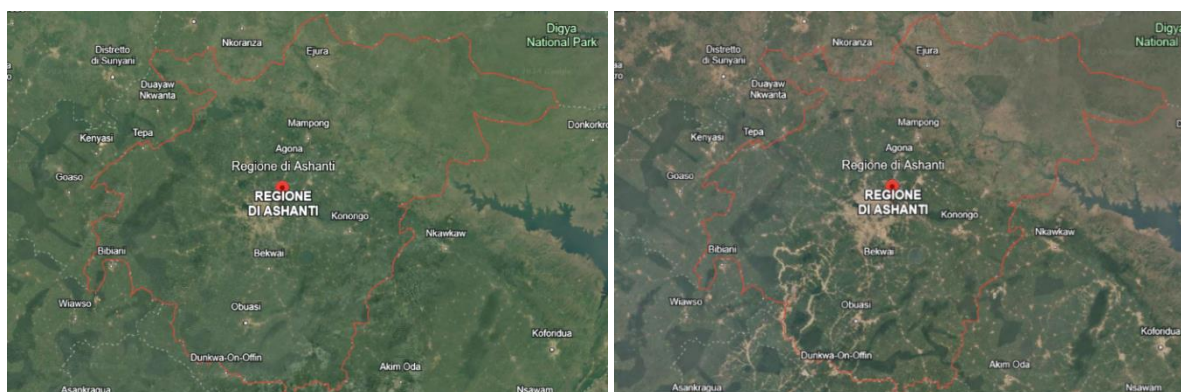


Figure 1: Ashanti region 2008, satellite image from Google Earth Figure 2: Ashanti region 2020, satellite image from Google Earth

In these two images above is possible to define the change on natural landscape (not only related to mining activities) in the Ashanti region between 2008 and 2020. Meanwhile in those below the change in the Western Region between 2007 and 2020.

¹ Available to the Global Forest Watch, an online platform involved in the monitoring of forests around the globe through data, [Ghana Deforestation Rates & Statistics | GFW](#).



Figure 3: Western region 2007, Satellite image from Google Earth

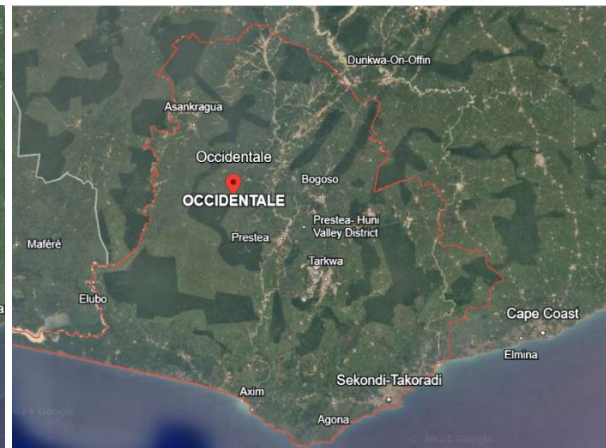


Figure 4: Western region 2020, Satellite image from Google Earth

The deforestation rate has meant that possible useful lands are left at the mercy of several extreme weather conditions, undermining their capabilities of avoiding extreme events on the land surface, such as floods. At the same time deforestation for mining (especially in small-scale) may take place without prior study on the mining and gold deposits, with the effects of damaging the natural landscape with no benefit from mining. Moreover, mines are abandoned once the mining activities are over, and this further undermines the possibilities for a recovery of the land for other purposes (Hilson, *ibid.*).

There is then a double problem related to the mercury pollution, one concerns the environmental impact of a such harmful element in the environment and the other one concerns the human health. Mercury is used in Artisanal small-scale mining in order to isolate the gold from other elements, making easier the extraction of gold. The process of extracting gold through mercury has the effect of releasing the harmful element on the environment, contaminating the atmosphere, the soil and the ecosystems. In some study (UNEP, 2013, cited in Rajaei et al., 2015) mercury in Artisanal small-scale mining has been found responsible for almost 37 percent of total anthropogenic global mercury emissions per year. This contamination goes directly to affect ecosystems and groundwater resources, becoming a major problem if related to food production.

By the other hand mercury constitutes a health problem for humans employed in the mining sector, especially for those involved in *Galamsey*. In fact, beyond mercury poisoning due to the consumption of contaminated food and water, many miners carry on their duties at work without personal safety equipment, working with mercury without gloves and masks in order to protect

respiratory tract and skin (Hilson, *ibid*; Strouboulis, Yayboke, & Edwards, 2023). Ultimately is useful to stress the impacts that Artisanal small-scale mining has on waterbodies. Mining is responsible for the contamination of several rivers in the nearby of mining sites. According to some study Ghana has lost almost 40 percent of its groundwater resources (Fagariba, Sumani, & Mohammed, 2024).

An example of that can be the Ankobra basin, part of which is in the Western region. According to the Water Resources Commission the Ankobra river is the “most exploited in terms of natural resources”, surrounded by several mining sites involved in the production of gold, diamond, manganese, bauxite².

The multiple presence of mining sites constitutes a major problem for the sustainability of the basin, by one hand using the water during the extracting process (as already outlined is necessary to the extraction through mercury) and by the other hand the closeness of such activities to the waterbodies (the river in this case) leads to the release of toxic elements in the groundwater system in huge concentration (*ibid.*).

Moreover, Ankobra Basin is essential to many basic activities for the local population, not only as source of drinking water but for irrigation activities and food production as well.



Figure 5: Ankobra river; 2003, satellite image, from Google Earth.



Figure 6: Ankobra river; 2020, satellite image from Google Earth.

ARTISANAL MINING, DRIVER OF SOCIAL INSECURITY

² Ankobra Basin overview by the Water Resources Commission website, <https://www.wrc-gh.org/index.php/basins/ankobra/>

As previously outlined, artisanal mining in Ghana has significant environmental effects. However, from a broader perspective, it is essential to examine its overall social impacts. While the economic pull of ASM has been highlighted, the broader discussion must delve into how it affects societal dynamics. Climate change has emerged as a critical driver of social conflict globally, with profound impacts on livelihoods and rising challenges for local populations. In Ghana, these effects manifest in various forms, including rising sea levels (leading to coastal erosion, salinization of water bodies, and freshwater scarcity), desertification in the northern regions (resulting in reduced farming land and agricultural productivity), and an increase in extreme weather events, such as heatwaves, droughts, and floods. These environmental disruptions are intricately linked to social insecurity and vulnerability, often triggering instability and clashes.

The relationship between climate change and Ghana's economy is particularly strong, given the nation's reliance on agriculture and primary goods. The combined impact of climate change and reduced land availability is a significant driver of social insecurity. In 2023, the Centre for Strategic and International Studies (CSIS) identified four primary ways through which climate change may instigate social conflict in Ghana: chieftaincy disputes, farmer-herder clashes, violent extremism, and illegal artisanal mining (Galamsey). This analysis focuses on Galamsey. The problems associated with Galamsey are multifaceted and interconnected. On one hand, it shifts land use from farming to mining, creating a stark dichotomy. On the other hand, it pollutes land and water resources, releasing toxic elements that hinder future agricultural activities and water usability. Galamsey has also been directly linked to social conflict. The competition for land between farmers, herders, and miners exacerbates tensions within communities.

The shift in land use from farming to mining is particularly concerning. This change has been identified as a key contributor to the decline in agricultural productivity, including damage to cocoa-producing croplands. This, in turn, creates two interrelated challenges. First, the loss of cocoa and other agricultural products negatively impacts Ghana's economy, which remains heavily reliant on cash crop exports. Second, it undermines national food security by reducing the availability of essential components of the Ghanaian diet. Subsistence agriculture suffers as lands are reallocated for mining, reducing food security for families and perpetuating gender-based disparities in land use (Ackah-Baidoo, Collins, & Grant, 2022).

The interconnections between environmental degradation, land availability for farming, and food production are clear. Analysts have noted a negative correlation between mining activities and agricultural yields. As mining activities increase, agricultural production declines (Obodai, Bhagwat, & Mohan, 2024). Additionally, workforce shortages in the farming sector due to the economic allure of mining have been well-documented. Brown (2020) notes that "mining can pay up to three times as much as farming, leading to a 'get-rich-quick' mentality among the youth population in resource-rich rural areas of Ghana." Consequently, many, especially young people, opt for mining over farming due to its faster income generation potential.

From the perspective of farmers and herders, the expansion of the mining sector reduces land availability for agricultural use and creates a labour shortage for farming activities. Unsurprisingly, this situation has led to clashes between individuals involved in these competing sectors. The overall impact of prioritizing mining over farming fosters resource-based conflicts (Strouboulis, Yayboke, & Edwards, *ibid.*). In regions already grappling with desertification (e.g., northern Ghana) or coastal erosion (e.g., southern Ghana), the likelihood of future conflicts rises, worsening already precarious conditions.

In response to these concerns, the Ghanaian government has adopted a securitized approach to addressing Galamsey. In 2017, the administration of Nana Akufo-Addo launched "Operation Vanguard," a military initiative aimed at curbing illegal mining. However, corruption, extortion, and collusion among state officials, coupled with the militarization of the response, have revealed significant contradictions in efforts to combat illegal mining. In some cases, the very individuals tasked with addressing the issue are complicit in the illicit activities they are fighting. Consequently, these measures have disproportionately targeted low-level miners—the last links in the chain—while failing to address systemic problems (Crawford & Botchwey, 2018).

Finally, it is crucial to address the gender-based discrimination inherent in land use, which exacerbates social instability. As previously mentioned, land ownership in Ghana is predominantly customary and traditionally controlled by men. While women can access land for use, they have minimal decision-making power regarding land-related issues and acquisition systems. Despite their significant contributions to subsistence agriculture and housekeeping activities, women are often excluded from land-use decisions, depriving the system of valuable

knowledge. This exclusion perpetuates gender-based discrimination in society and undermines the effectiveness of land-use governance (Ackah-Baidoo, Collins, & Grant, *ibid.*).

Thus, Galamsey not only poses environmental challenges but also drives social insecurity, conflicts, and inequalities. The interwoven dynamics of land use, economic priorities, and governance responses require holistic approaches that consider environmental sustainability, social equity, and inclusive decision-making.

CONCLUSION

The impacts of artisanal and small-scale mining (ASM) in Ghana encapsulate a multidimensional crisis, interweaving environmental degradation, socio-economic challenges, and governance inadequacies. While ASM, particularly "Galamsey," has provided significant economic opportunities, its ecological toll—manifested through deforestation, land degradation, water contamination, and biodiversity loss—signals a clear violation of the Planetary Boundary of Land-System Change. These environmental impacts are compounded by socio-economic pressures, including food insecurity, rural livelihood disruptions, and the exacerbation of gender-based inequalities in land ownership and use.

Moreover, the systemic challenges of governance, characterized by overlapping institutional mandates, bureaucratic inefficiencies, and corruption, have not only failed to mitigate the adverse effects of ASM but have often perpetuated illegal practices. The militarized responses, such as Operation Vanguard, highlight the contradictions inherent in addressing the problem—disproportionately targeting low-level miners while ignoring deeper structural issues tied to land tenure systems, resource distribution, and socio-economic inequalities.

Looking forward, Ghana's sustainable development demands a comprehensive rethinking of its mining governance frameworks. This rethinking must balance the economic benefits of ASM with its environmental and social costs by embracing innovative policies. These could include stricter enforcement of environmental regulations, technological upgrades for sustainable mining, community-driven land use planning, and the inclusion of marginalized groups—especially women—in decision-making processes.

Ultimately, the story of artisanal mining in Ghana serves as a microcosm of the broader global challenge: finding equilibrium between economic aspirations and ecological imperatives.

Ghana's ability to address these issues effectively will not only redefine the trajectory of its local landscapes but will also contribute valuable lessons to global discourses on sustainable land management.

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EVE

4. The Rippling Effects: How Unsustainable Economic Activities Threaten Lake Ecosystems and Livelihoods—A Comparative Study of Lake Victoria, Uganda and Lake Bosomtwe, Ghana

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EVE

The Rippling Effects: How Unsustainable Economic Activities Threaten Lake Ecosystems and Livelihoods—A Comparative Study of Lake Victoria, Uganda and Lake Bosomtwe, Ghana

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Abstract

This study examines the environmental and socioeconomic pressures faced by Lake Victoria in East Africa and Lake Bosomtwe in West Africa, focusing on the impacts of unsustainable economic activities. Both lakes support vital economic activities such as fishing, agriculture, and tourism but face challenges including pollution, deforestation, overfishing, and waste mismanagement. A comparative analysis highlights the scale and nature of these issues, emphasizing the interconnected ecological and livelihood implications. The study proposes actionable policy recommendations, including sustainable resource management, reforestation, enhanced waste management, and regional collaboration. These strategies aim to mitigate environmental degradation and safeguard the lakes' ecological and economic significance for future generations.

Introduction and Background

Lakes play a crucial role in supporting biodiversity, regulating local hydrological systems, and sustaining the livelihoods of communities through activities such as fishing, agriculture, and tourism (Smith & Schindler 2009). These freshwater systems, however, are increasingly under threat from unsustainable economic activities such as agriculture, fishing, industrialisation and sand mining, that degrade water quality, alter hydrological balances, and disrupt ecological functions. Globally, the exploitation of lakes for industrial purposes, urban development, and agricultural expansion has led to eutrophication, habitat destruction, and the loss of vital ecosystem services.

For instance, global studies have shown that increased nutrient loads from agricultural runoff, untreated sewage, and industrial waste contribute to harmful algal blooms and oxygen depletion in lakes, severely impacting aquatic biodiversity and water quality (Anderson, Glibert, & Burkholder, 2002; Nzungu & Gugolz 2022; Devlin & Brodie, 2023). This trend has been observed in shallow lakes like Lake Taihu in China, where cyanobacterial blooms have disrupted biodiversity and human activities such as fishing and water supply (Wang *et al.* 2019 and Lan *et al.* 2024).

This trend is no difference from the African context with the freshwater lake ecosystems across the continent facing mounting environmental and socioeconomic pressures due to unsustainable human activities. This study examines the interconnected ecological and livelihood challenges posed by such activities in two significant lake systems: Lake Victoria in Uganda and Lake Bosomtwe in Ghana. These ecosystems, vital for their respective regions,

are increasingly threatened by pollution, deforestation, and overexploitation, resulting in declining fish populations, deteriorating water quality, and heightened vulnerability of local communities dependent on these resources.

The cumulative effects of these activities threaten the ecological balance and the socioeconomic resilience of communities that depend on these lakes. Despite global recognition of these challenges, there remains limited comparative research on how such activities impact lake ecosystems and the livelihoods they sustain, particularly in the context of Africa's unique environmental and socioeconomic dynamics.

This paper seeks to investigate the impact of unsustainable economic activities on the hydrology, water quality, and biodiversity of Lake Victoria and Lake Bosomtwe and to assess their implications for the livelihoods of surrounding communities, thereby providing insights into sustainable management interventions. By studying lakes in East and West Africa, this paper will offer insights into shared and unique challenges, contributing to region-specific and continent-wide solutions. This paper specifically intends to:

1. Explore the effects of industrial, agricultural, and urban activities on water quality and hydrology in Lake Victoria and Lake Bosomtwe.
2. Assess the socioeconomic consequences of lake degradation on local communities, focusing on livelihoods and food security.
3. Recommend sustainable management practices that balance economic development with ecological conservation for the two lakes.

Lake Victoria Basin: A Critical Transboundary Resource

The Lake Victoria Basin (LVB) is a pivotal transboundary natural resource in East Africa, underpinning the livelihoods and economies of millions within its catchment area. The lake serves as a critical source of food, energy, irrigation, drinking water, tourism, and transportation. Additionally, as the source of the White Nile, Lake Victoria supports the livelihoods of populations in downstream countries such as Egypt, Sudan, and South Sudan (Awange et al., 2014). The lake also plays a crucial role in regional climate regulation (Nicholson et al., 2003). Despite its ecological and socioeconomic importance, Lake Victoria has endured decades of intense environmental degradation, leading to profound ecological and economic challenges.

Ecologically, Lake Victoria has experienced significant biodiversity loss, including the probable extinction of several endemic fish species (Verschuren *et al.*, 2002; Balirwa *et al.*, 2003). The basin's freshwater biodiversity continues to decline, with an average loss of 10.8% in species richness attributed to unsustainable land use practices (Soesbergen *et al.*, 2019). Pollution from agricultural runoff, industrial discharges, and domestic waste further exacerbates the degradation of water quality, while overfishing and habitat destruction contribute to the declining fish stocks. These ecological pressures directly threaten the livelihoods of communities dependent on the lake for sustenance and economic activities.

Lakes Victoria's Hydrology and Pollution: Implications for Water Quality and Biodiversity

In recent years, the Lake Victoria basin in East Africa has experienced frequent episodes of flooding, raising fears of the lake overflowing among communities in Uganda, Kenya, and Tanzania. By May 2020, these floods had displaced nearly half a million people and caused extensive property damage valued at billions of Uganda Shillings (UGX). According to the Ministry of Water and Environment (MWE, 2020), the prolonged and intense rainfall in 2020, driven by the Indian Ocean Dipole (commonly referred to as the Indian Niño) and linked to climate change, significantly elevated water levels in Lake Victoria and other regional water bodies. As indicated in Figure 1, with a catchment area of 169,858 km², the lake is fed by 23 major rivers from Kenya, Tanzania, Rwanda, Burundi, and Uganda, along with contributions from smaller rivers, drainage channels, direct rainfall, runoff, and groundwater flow (WMO, 2020). These factors have compounded the basin's vulnerability to climate variability and its associated socioeconomic impacts.

Figure 1: Lake Victoria's Water Inflow Sources



Source: WMO (2020).

Lake Sedimentation due to Catchment degradation from unsustainable economic activities and Buffer zone encroachment.

The significant transport of nutrients and sediments into Lake Victoria is a clear indication of catchment degradation (MWE, 2018). Progressive degradation has occurred due to farming activities, deforestation, overgrazing, settlements, and other income-generating ventures (Thuita et al., 2006). These activities have led to increased soil erosion, sediment transport, and pollution of the lake ecosystem, primarily due to the diminished buffering capacity of wetlands and their macrophytes. According to UNEP (2008), over 75% of the wetlands within the Lake Victoria catchment have been affected by human activities, with 13% experiencing severe degradation. Historical evidence suggests that even prior to the 2020 floods, human settlements had encroached upon the lake's buffer zones for decades. This encroachment not only accelerated sediment inflow into the lake, reducing its water-holding capacity, but also heightened the vulnerability of nearby communities to flooding due to their proximity to the lake.

Pollution of Lake Victoria from Unsustainable economic activities and urban settlements

The water level of Lake Victoria is influenced by hydro-meteorological conditions, including surface and subsurface runoff, which contribute to sedimentation and pollution (Okungu *et al.*, 2014). In recent decades, many rivers and streams feeding the lake have become significantly polluted by untreated or partially treated municipal waste, industrial effluents, urban runoff, and raw sewage from settlements (LVEMP, 2005). Nutrient pollution, primarily from organic and inorganic wastes linked to intensive agriculture, municipal sewage, and livestock activities, remains a critical issue. Rivers transport these contaminants directly to the lake, along with industrial discharges and urban effluents draining into nearshore areas (Kundu *et al.*, 2017). Malfunctioning sewage treatment plants have exacerbated the problem by releasing inadequately treated wastewater into the rivers, which eventually flows into the lake (Christopher *et al.*, 2014). Similarly, agricultural and chemical industries contribute to pollution by discharging chemicals directly into the lake ecosystem (Christopher *et al.*, 2014).

On the Tanzanian side of Lake Victoria, small-scale gold mining activities have introduced heavy metals into the ecosystem, while effluents from agriculture have increased pesticide and nutrient loads (LVEMP, 2005; Shayo & Limbu, 2018). In Uganda, heavy metal contamination from urban settlements and remote inland areas has been documented. Industrial activities, such as food processing, textiles, leather tanning, paper production, and metallurgy, particularly in Jinja, as well as pollution from Murchison Bay, have significantly affected the nearshore areas of Uganda's side of the lake (Kabenge, Wang, & Li, 2016).



Figure 2: Polluted Lake Victoria water at one of the landing sites

LIVELIHOOD/SOCIO-ECONOMIC IMPACTS OF CHANGES IN LAKE VICTORIA ECO-SYSTEM

Declining fish biomass, catch and exports. Over years, the role of pollution on fish catch has always been underestimated. There is some evidence however, to suggest that the limnological characteristics of Lake Victoria affect the recruitment and survival of fish in the lake. (Njiru et al., 2008) argue that the main threat to the Lake Victoria fishery is hyper-eutrophication, rather than overexploitation, as claimed by other researchers (Cowx 2005; Njiru et al. 2007). Since the year 2005, Uganda has registered a significant decline in volume of fish exports. This has been mainly attributed to the decreasing biomass of high value species especially Nile perch and tilapia. Records from MAAIF show that in the last decade, the fish export index dropped from 36,616 tons in 2005 to 17,597 tons by 2015.

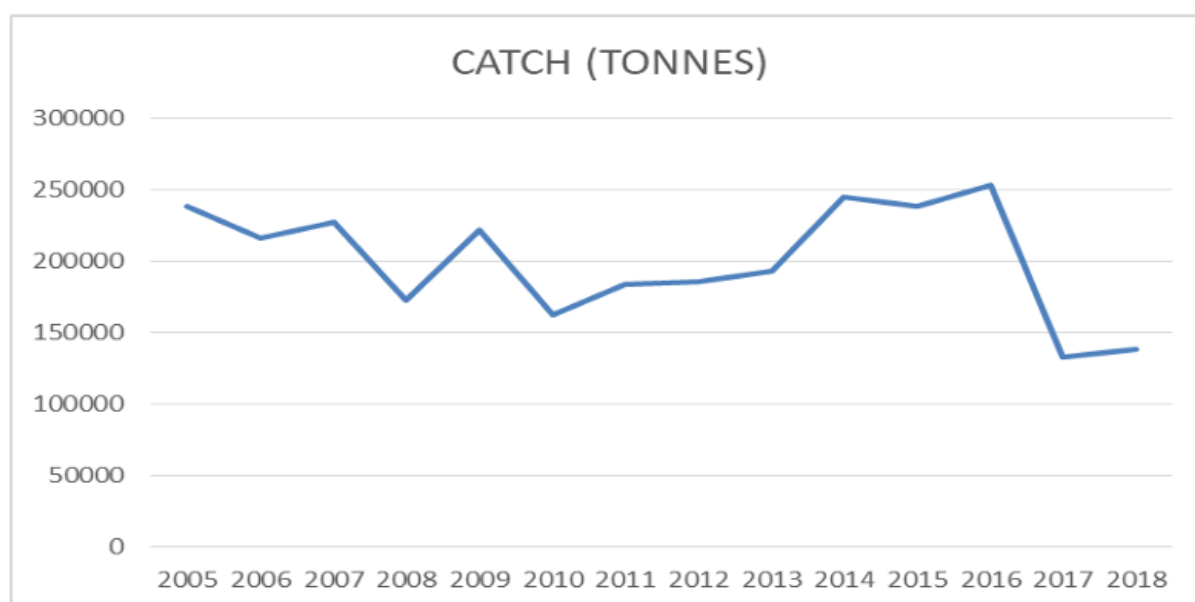


Figure 3: Lake Victoria fish catch 2005 to 2018 (NARO and UBOS)

Reduced business activity along the landing sites, poverty and unemployment plus high crime risks. According to NaFFIRI (2011) and Nakiyende *et al* (2016), the Nile perch declined from an average of 1.2 million tons between 1999 and 2007, to about 0.8 million in 2013. The declining stocks of high value species affected fisheries activities and by 2017, over 13 fish processing factories had been kicked out of business due to the declining catch. As a result, hundreds of Ugandans were left jobless. The declining stocks have therefore led to a drop in fishermen's' and traders' incomes. Furthermore, the 2020 rising water levels submerged most of the landing sites making livelihoods hard to sustain.

Health and gender related issues. The highest percentage of men have been fishermen and fish traders plus other small scale business owners; therefore, the current situation has not spared them from the financial hardships of providing for their families. However, most women too are low-income earners depending on small businesses such as food kiosks, bars, market stalls, salons while others are housewives who depend solely on their husbands. The poverty effects such as increased crime rates are more likely to affect children and women through increased gender-based violence. The children are not only susceptible to school dropouts due to lack of resources, but also serious health threats due to malnutrition and sexual abuse which can intensify sexually transmitted diseases and early pregnancies for girls among communities along the lake shores. Furthermore, the rising water levels leading to floods pose a risk of putting millions of people along lake shores to exposure to water borne diseases due to contamination from submerged latrines and polluted runoff.



Figure 4: A woman carrying a jerrycan of water wades through garbage on shores of Lake Victoria at Lambu Landing Site in Bukakkata Sub-County in Masaka District-Uganda (Daily Monitor Photo, December 12, 2018).

Lake Bosomtwe: A Fragile Ecosystem Under Threat

Lake Bosomtwe, located in Ghana's Ashanti Region, is the country's only endorheic (closed) lake and the third largest of its kind globally (Amu-Mensah et al., 2019). The lake primarily relies on direct rainfall and runoff from the crater's slopes for replenishment. Over 44 stream

channels contribute runoff during rainfall events, although most of these streams, flow intermittently through flash floods. Figure 2 represents Lake Bosomtwe's water inflows and the catchment areas.

Figure 5: The Catchment Area of Lake Bosomtwe

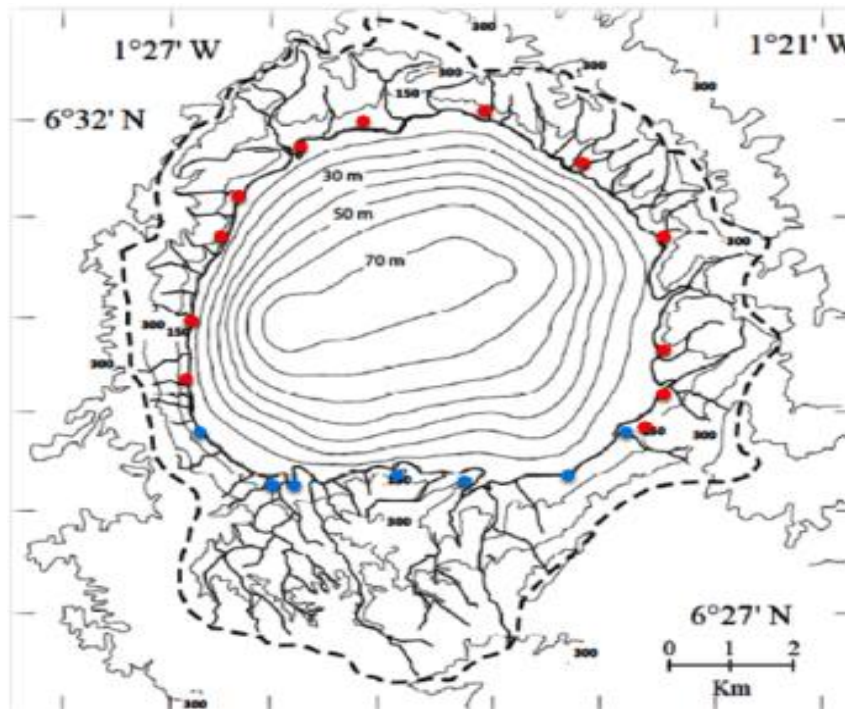


Figure 5: Distribution of stream channels and communities within the catchment Source: Amu-Mensah et al., (2019). - Bosomtwe District Community, - Bosome-Freho Community.

Historically, Lake Bosomtwe has supported livelihoods through fishing and agriculture, with traditional practices promoting the preservation of its natural state (Agyemang et al., 2019). However, recent expansion in economic activities around the lake has intensified pressure on its resources, contributing to environmental degradation and increasing the vulnerabilities of surrounding communities (Obodai et al., 2011).

Substantial environmental challenges stemming from unsustainable economic activities have continuously affected the lake ecosystem. Studies have identified deforestation, agricultural runoff, and improper waste disposal as major contributors to pollution in the lake (Obodai et al., 2011). The use of chemical fertilizers and pesticides in farming activities around the lake's catchment area has led to nutrient loading, causing eutrophication and harming aquatic ecosystems. In addition, sedimentation from soil erosion due to deforestation further degrades water quality and reduces the lake's depth.

Urbanization and population growth around Lake Bosomtwe have exacerbated waste management issues. Improperly disposed of solid waste and untreated domestic effluents are common sources of pollution, introducing pathogens and organic matter that degrade the lake's ecological health (Dumenu & Obeng, 2016). Additionally, plastic waste accumulation poses a long-term environmental challenge, disrupting both terrestrial and aquatic life in the region.

Industrial activities, though limited in scale around Lake Bosomtwe as is the case of Lake Victoria, also contribute to pollution. Small-scale mining operations in nearby areas have been identified as potential sources of heavy metals, including mercury, which can accumulate in the lake's sediments and enter the food chain (Boadi & Kuitunen, 2002).

These environmental issues not only jeopardize the ecological integrity of Lake Bosomtwe but also pose significant risks to the local communities who rely on the lake for fishing, tourism, and agricultural activities. The compounded effects of pollution and habitat loss have led to a decline in fish populations, directly impacting food security and income generation for these communities.

Despite these challenges, efforts to conserve Lake Bosomtwe remain inadequate. Weak enforcement of environmental regulations, combined with limited community awareness of sustainable practices, has allowed pollution levels to persist. Addressing these issues requires comprehensive strategies involving local stakeholders, policymakers, and environmental organizations to protect this unique ecosystem.

Comparative Context

The cases of Lake Victoria and Lake Bosomtwe illustrate the broader implications of unsustainable human activities on lake ecosystems and the livelihoods they sustain. While these lakes differ in scale and geographic context, the parallels in environmental degradation and socioeconomic vulnerability highlight the urgency for targeted conservation and sustainable resource management strategies.

Comparative Analysis of Economic Activities and Environmental Impacts

Fishing Industry

Both Lake Victoria and Lake Bosomtwe support vital fishing industries that sustain local economies. In Lake Victoria, overfishing, illegal fishing practices, and the introduction of invasive species like the Nile perch have severely disrupted the ecological balance, leading to

the decline of native fish species (Njiru et al., 2008). Similarly, Lake Bosomtwe faces overfishing and the use of unsustainable fishing methods, threatening fish stocks and aquatic biodiversity. While Lake Victoria's fishing industry operates on a much larger scale due to the lake's size and transboundary nature, both lakes experience significant pressure from fishing-related activities.

Agriculture

Agricultural activities are primary livelihoods around both lakes but contribute to environmental degradation. Around Lake Victoria, large-scale agricultural projects and irrigation schemes exacerbate deforestation, soil erosion, and chemical runoff. In contrast, Lake Bosomtwe's agriculture is predominantly subsistence-based but has intensified due to population pressures (Obodai et al., 2011). The result in both cases is nutrient loading and pollution, leading to eutrophication and reduced water quality.

Tourism

Tourism is an economic driver in both regions, albeit with differences in scale and focus. Lake Victoria attracts international tourists due to its vast expanse and biodiversity, while Lake Bosomtwe's unique crater lake setting draws domestic and regional visitors. However, environmental degradation, inadequate waste management, and poor infrastructure pose challenges to sustainable tourism development in both areas (Agyemang et al., 2019).

Urbanization and Industrialization

Urbanization and industrialization have disproportionately impacted Lake Victoria compared to Lake Bosomtwe. Major cities like Kampala and Kisumu have introduced significant pollution through industrial effluents, untreated sewage, and plastic waste, contributing to habitat destruction and poor water quality (Odada et al., 2006). Lake Bosomtwe, with limited industrial activity, faces growing challenges from urbanization and infrastructure development, albeit on a smaller scale.

Other Activities

Lake Victoria supports extensive transportation and trade due to its vast waterway network, which has implications for pollution and habitat disruption. Conversely, Lake Bosomtwe's economic activities are more localized due to its smaller size. Both lakes hold cultural and

spiritual significance, with local communities engaging in traditional practices and ceremonies linked to the lakes (Nunan & Scullion, 2004).

Unsustainable Practices and Their Impacts

Overfishing and Illegal Fishing Methods

Both lakes suffer from overfishing and the use of illegal fishing methods, such as dynamite and poison. These practices deplete fish stocks, disrupt aquatic ecosystems, and threaten the livelihoods of communities reliant on fisheries (Njiru et al., 2008).

Agricultural Runoff and Pollution

Agricultural runoff carrying fertilizers, pesticides, and sediments contributes to water pollution and eutrophication in both lakes. This nutrient loading causes algal blooms, depleting oxygen levels and harming aquatic life. These pollutants also affect water quality, making it unsafe for domestic use (Obodai et al., 2011).

Deforestation and Land Degradation

Deforestation in the catchment areas of both lakes results in soil erosion, sedimentation, and habitat loss. The removal of vegetation reduces the land's water retention capacity, leading to increased runoff and sediment deposition, which degrade water quality and reduce lake depth (Odada et al., 2006).

Waste Management and Pollution

Improper waste management, including the disposal of domestic, industrial, and plastic waste, has resulted in severe pollution in both lakes. The accumulation of solid waste disrupts aquatic ecosystems, poses health risks to local communities, and diminishes the lakes' aesthetic value, negatively affecting tourism (Nunan & Scullion, 2004).

Conclusion and Policy Recommendations

The comparative analysis of economic activities around Lake Victoria and Lake Bosomtwe reveals striking similarities in the environmental challenges they face, despite differences in scale and economic focus. Both lakes experience significant pressures from fishing, agriculture, tourism, and urbanization, which contribute to pollution and ecological degradation. Addressing these challenges requires coordinated efforts to promote sustainable

practices, enforce environmental regulations, and enhance community awareness to preserve these vital ecosystems for future generations.

Policy Recommendations

To address the challenges affecting Lake Victoria and Lake Bosomtwe, the following action-based and practical policy recommendations are proposed:

1. Promote Sustainable Fishing Practices:

- Establish and enforce regulations against illegal fishing methods, including the use of poisons and dynamite.
- Develop community-based fisheries management programs to encourage sustainable harvesting and conservation of fish stocks.
- Provide alternative livelihoods to reduce dependency on fishing.

2. Implement Sustainable Agricultural Practices:

- Promote agroecological farming techniques to minimize chemical runoff and soil erosion.
- Develop buffer zones along lake shores with vegetation to reduce sedimentation and nutrient inflow.
- Introduce policies to regulate and monitor the use of chemical fertilizers and pesticides.

3. Enhance Waste Management Systems:

- Invest in modern waste treatment facilities to manage domestic and industrial waste effectively.
- Develop community-led waste collection and recycling programs to reduce plastic pollution.
- Implement strict penalties for illegal dumping of waste into water bodies.

4. Reforest and Conserve Catchment Areas:

- Launch afforestation and reforestation campaigns in the lakes' catchment areas.

- Promote sustainable land-use planning to prevent encroachment and deforestation.
- Collaborate with local communities to integrate traditional conservation practices.

5. Strengthen Infrastructure for Sustainable Tourism:

- Improve infrastructure around the lakes to support eco-tourism while minimizing environmental impact.
- Develop educational programs to raise awareness among tourists and locals about the importance of preserving lake ecosystems.
- Create guidelines for sustainable tourism practices.

6. Facilitate Regional and International Collaboration:

- Foster cross-border collaborations among countries sharing Lake Victoria to harmonize conservation efforts.
- Establish knowledge-sharing platforms for stakeholders managing Lake Bosomtwe to learn from Lake Victoria's transboundary management experiences.
- Seek support from international environmental organizations to fund conservation projects.

7. Enhance Monitoring and Research:

- Establish continuous monitoring systems to track water quality and biodiversity in both lakes.
- Conduct regular assessments of the socioeconomic impacts of lake degradation on local communities.
- Invest in research to develop innovative solutions for managing pollution and restoring lake ecosystems.

Conclusion

The comparative analysis of economic activities around Lake Victoria and Lake Bosomtwe reveals striking similarities in the environmental challenges they face, despite differences in

scale and economic focus. The proposed policy recommendations aim to address these challenges holistically by promoting sustainable practices, enhancing community engagement, and fostering regional collaboration. These interventions are essential to preserve the ecological and socioeconomic value of these lakes for future generations.

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IEVE

5. Nutrient Divide: Global Nitrogen and Phosphorus Imbalances and Their Impact on Ecosystems and Food Security, insights from the Olifants River.

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Introduction

In the ongoing discourse surrounding climate change, discussions regarding nitrogen (N) and phosphorus (P) often do not occupy a central or prominent role. Nevertheless, the study and management of biogeochemical cycles—of which nitrogen and phosphorus are major components—constitute a fundamental aspect of environmental science. Imbalances within these cycles, often arising from agricultural fertilizers, can lead to significant environmental consequences on multiple fronts. For this reason, despite being less salient in public debate, recent scientific literature has increasingly and more precisely investigated biogeochemical imbalances, identifying both critical present and future risks as well as political and technical recommendations for addressing the issue.

This paper aims to further underscore the urgency of addressing these imbalances, to emphasize the importance of mitigating nutrient pollution resulting from excessive nitrogen and phosphorus dispersion in the environment. Furthermore, while this issue has global implications, this study also seeks to compare worldwide challenges and vulnerabilities with those specific to the African context, where the needs regarding nutrient management starkly contrast with those of other regions. This paper is therefore organized into two main sections.

The first section addresses nutrient pollution from a general, descriptive perspective. It examines the importance of monitoring nitrogen and phosphorus cycles to understand the causes and consequences of current biogeochemical imbalances. This section specifically explores how anthropogenic impacts underpin these imbalances, identifying practices that most significantly alter the environmental chemical balance. Subsequently, the issue of biogeochemical flows is considered within the African context, where, at a continental level, bio-ecological characteristics necessitate almost opposite interventions compared to other regions. Here, the challenge is more about nutrient deficit rather than excess and dispersion.

The second section expands on this theme through a detailed case study, adding an additional layer of complexity to the analysis. It focuses on the Olifants River in South Africa, a region experiencing severe environmental challenges with grave implications for local populations. Through this case study, this paper aims to highlight that, despite a general nutrient deficit across Africa, there are specific areas where environmental conditions reflect an opposite scenario.

This paper, therefore, does not aim to produce a purely scientific analysis of the issue, which would be beyond the expertise of the authors. Instead, the goal is to explore policy recommendations that could support technical actions for regulating global biogeochemical flows, especially given the current climate situation.

1 Nitrogen and Phosphorus Cycles

1.1 Why Nitrogen and Phosphorus are important?

Over the past 150 years, the global population has continued to grow at an exponential rate. Numerous studies have analyzed the causes of this phenomenon across various fields, filling the pages of books and articles. However, one aspect is indisputable: the global demand for food has reached unprecedented levels, particularly over the past century and in recent decades. Alongside population growth—or, more accurately, in tandem with the rising consumption of certain segments of the global population—food production has also escalated, as has the use of natural land for cultivation. To support increasingly high agricultural yields, both natural and synthetic fertilizers have played a fundamental role. Within this broader category, nitrogen and phosphorus are crucial chemical components for fertilizers and are thus aptly defined as soil nutrients. They are applied globally in large quantities, playing an essential role in boosting crop yields to meet the ever-increasing demand for food.

However, these macronutrients, in addition to being key components in fertilizers, are naturally present in the environment, such as in soil and in wastewater from both animal and human sources. For simplicity, this paper focuses on the total quantities of nitrogen (N) and phosphorus (P) dispersed into the environment, analyzed from a general perspective without categorizing specific sources. Nonetheless, it remains evident that any quantitative study on the amounts of N and P—and the resulting nutrient imbalances—must necessarily emphasize their use as fertilizers in global agriculture.

1.2 The Human impact on the biogeochemical flows

As briefly mentioned in the introductory lines, nitrogen, and phosphorus are essential chemical components of natural biogeochemical cycles. Classified as nutrients, they enable biodiversity and thereby regulate the natural equilibrium of ecosystems. Due to their nutrient properties, N and P form the basis of the most commonly used fertilizers for agricultural purposes. However, their usage has sharply increased in recent decades, and despite being macronutrients, their excessive presence leads to serious environmental harm. Indeed, an overabundance of N and P dispersed in the environment—due to excessive fertilizer application, poor wastewater management, or organic material waste—can trigger eutrophication. Eutrophication is a phenomenon characterized by an excessive concentration of nutrients in aquatic environments, leading to severe ecosystem imbalances. In essence, the overloading of aquatic ecosystems, both marine and freshwater, with these macronutrients results in a rapid and unnatural algae bloom, which depletes oxygen levels and renders the environment inhospitable for other life forms (UN Environment Programme, 2024). Additionally, excessive algae growth, particularly in potable water sources, causes water pollution, making these sources unusable for drinking purposes.

Consequently, nutrient flow management becomes imperative to prevent contamination of aquatic ecosystems, not only to preserve their biodiversity but also to protect human access to freshwater

sources, particularly in water-scarce regions. For these reasons, Rockström et al. (2009) identified N and P levels, specifically their ratio, as one of the critical “planetary boundaries” that require strict monitoring. Yet, as is the case with other climate imbalances, despite repeated warnings from the scientific community and certain organizations, nutrient dispersion into the environment remains high, with significant regional disparities worldwide. The true challenge, however, is not merely to reduce or redistribute nutrient levels globally, but to achieve more efficient waste management and reduction of nutrient losses. Indeed, just to mention an example, around 80% of phosphorus is lost or wasted during its use.

This factor highlights one of the central themes of this paper: that efficiency and redistribution are foundational to the solutions needed to address the imbalance in biogeochemical cycles. As will be examined in the following paragraph, these imbalances vary significantly by global region, with a spectrum ranging from areas with high dispersion of N and P into the environment to areas experiencing nutrient deficits. This phenomenon demonstrates the need for strategies to prevent nutrient overuse and waste in certain areas, thereby allowing greater availability of nutrients in others without resulting in an overall increase in global N and P levels.

1.3 Different footprints around the world

As previously mentioned, nutrient excess represents a global phenomenon that manifests with varying intensity depending on the region. In so-called advanced economies, significant nutrient surpluses are more likely due to the extensive use of fertilizers. As Steffen et al. (2015) highlight:

“Observations point toward a few agricultural regions of very high P application rates as the main contributors to the transgression of this boundary and suggest that a redistribution of P from areas where it is currently in excess to areas where the soil is naturally P-poor may simultaneously boost global crop production and reduce the transgression of the regional-level P boundary... As for the P boundary, a few agricultural regions of very high N application rates are the main contributors to the transgression of this boundary. This suggests that a redistribution of N could simultaneously boost global crop production and reduce the transgression of the regional level boundary.”

Such regions and economies are primarily found in countries with high levels of demand or consumption and relatively high population density. For example, phosphorus imbalances have been examined by MacDonald et al. (2011), whose study provides insights that align with the aforementioned findings. North American and Asian economies (as well as certain European areas) report pronounced phosphorus surpluses, exceeding the limits set by the “planetary boundary.” These regions, therefore, significantly elevate the global nutrient dispersion level despite the presence of areas with moderate surpluses or even deficits. The same study indicates that more moderate phosphorus surpluses, as well as deficits, are found in some parts of the world, including Africa. For this reason, a specific African case study will be analyzed in the next chapter of this paper.

In Africa, the dynamics surrounding biogeochemical flows are particularly complex and important to address. The continent, particularly in agricultural terms, faces the opposite problem to the global trend: a lack of soil nutrients, rather than an excess, is at the heart of agricultural challenges. This deficiency is due to economic barriers that limit access to fertilizers within African agricultural sectors, exacerbated by the rising and volatile prices of fertilizers in recent years (Van der Velde et al. 2014). Consequently, Africa continues to face issues of under-fertilization and reduced agricultural productivity, resulting in the “yield gap”—the disparity between the potential and actual productivity of African soils. This discussion aligns with recommendations from the scientific community

advocating for more efficient use and better global distribution of nutrient flows to increase agricultural production without further disrupting biogeochemical cycles.

In practice, however, implementing such recommendations remains challenging. Effective policy action requires stable and functional governance, which has unfortunately been lacking in parts of Africa in recent years. This issue is underscored in a recent study by Magnone et al. (2022), which presents various political scenarios impacting phosphorus use and regional food security in sub-Saharan Africa. According to the authors, a political scenario marked by increased nationalism and isolation—trends prevalent in recent African politics—would likely lead to inadequate phosphorus utilization and minimal improvements in food security, despite significant population growth.

In light of these considerations, the African context presents a complex policy challenge for managing nutrient flows effectively. While some areas of the continent suffer from general nutrient deficits and an urgent need for increased agricultural production through enhanced fertilization, economic and technical limitations, there are other zones presenting high nutrient pollution, primarily due to inadequate wastewater regulation and management. Given this intricate situation, it is crucial to examine a specific case study in greater detail.

2 A South-African case study: the Olifants River

2.1 Background and Context

The Olifants River is one of the major river systems in South Africa and a tributary to the country's "hardest-working river", the Limpopo River (Ashton and Dabrowski, 2011). The Olifants River catchment is about 85 000 km² and flows northward from Mpumalanga Highveld for 560 km into Mozambique and finally settles in the Indian Ocean, north of Maputo (Figure 1). The Olifants River has a dense network of tributaries and plays a vital role in the regional ecosystem and supports about 4.2 million people of which 70% live in rural areas (Van Vuuren, 2010). The river is fundamental to many activities including agricultural activities for irrigation, mining, and hydroelectric power. Furthermore, local communities also use the river for domestic use, subsistence farming, fishing, and game viewing (Ramudzuli, 2019). According to McCartney and Arranz (2007), these activities are critical for the economic development of the basin and local communities.

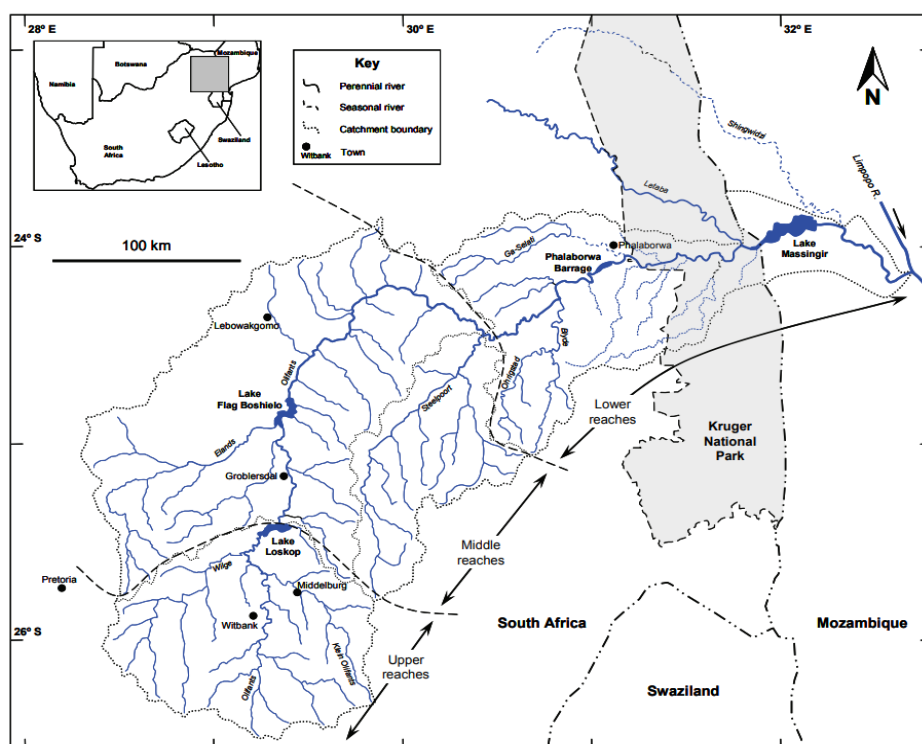


Figure 1: A map illustrating the Olifants River Catchment highlights its full extent, including the major tributaries, and delineates the lower, middle, and upper sections of the catchment, (after Ashton and Dabrowski, 2011).

2.2 Hydrology and Ecosystems

The Olifants River supports various ecosystems, including Grasslands, Savannas, Riparian Forests, and Wetlands, each of which is affected by its hydrology and nutrient dynamics (Pollard and Laporte, 2014). Grasslands and savanna ecosystems benefit from seasonal flooding, which provides the nutrients required to sustain plant growth. Any changes in nitrogen and phosphorous levels would affect and even alter the composition of plant species. These effects consequently impact herbivores and predators that depend on them for survival. On the other hand, Riparian Forests are habitats for a wide range of species and are also crucial for soil stabilization (Gerber, 2022). In cases of elevated nutrients, certain plant species can be favored, causing a disruption in the balance of native vegetation, consequently, reducing biodiversity. Lastly, the Wetlands play a critical role in filtering nutrients, sediments, and pollutants from the water. According to Staebe (2015), the high level of nutrients in the water, unfortunately, overwhelms their capacity limiting their effectiveness for filtration, and this consequently leads to changes in plant communities as well as wildlife.

2.3 Existing Environmental Issues and Sources

Nutrient pollution, particularly nitrogen and phosphorous has been a great concern in the Olifants River. According to Dabrowski and De Klerk (2013), the cause of nutrient pollution in the river is largely driven by runoff from agricultural practices, where the use of excessive fertilizer leads to the leaching of nitrogen and phosphorus from these agricultural fields and into the rivers. Furthermore, industrial wastewater containing excess nutrients is discharged from coal and platinum mining, coal-fired power generation plants, chemical manufacturing, and paper mills. This nutrient-rich wastewater eventually enters the Olifants River and causes various challenges with the major being

eutrophication, where the excess nutrients trigger algae growth which eventually results in decreased oxygen levels, and harms aquatic life by causing a disruption of the food chains and ecosystem dynamics (Harding, 2015). Furthermore, the contaminated water causes health risks, when the local communities consume it. This results in health complications including gastrointestinal, neurological, and cancer challenges (Farhang, 2020).

The different anthropogenic activities have a wide range of implications for the nutrient level of the Olifants River catchment. The Upper and middle reaches of the catchment are valued and used for the provision of irrigated agriculture (Heath, et al., 2010). According to Ashton et al. (2001), return flows from these irrigated agricultural lands, where synthetic fertilizers are used to enhance crop yields, deposit various chemicals including nitrogen and phosphorous into the Olifants River. During irrigation events, some of the excess fertilizers that are not absorbed by the plants are washed into the river system. This surface runoff is exacerbated when farmers apply more of these fertilizers than are needed by the crops. Furthermore, flooding and storm events worsen the issue of surface runoff by accelerating the movement of water from one area to the next. Additionally, livestock farming conducted in the region, including cattle and poultry production contributes to nutrient pollution through nitrogen and phosphorous-rich animal waste which can wash off into the river system when not well managed (Ashton and Dabrowski, 2011). As per Mudaly and Van Der Laan (2020), the concentration of nitrogen and phosphorous in the Olifants River catchment is mostly higher during summer rainfall, supporting agriculture and fertilization events as the source.

The upper reaches of the Olifants River and some of its tributaries drain the large Mpumalanga coal fields (Ramudzuli, 2019). The coal in the Mpumalanga fields is mined for the generation of electricity through coal-fired power plants. These coal-fired power plants emit large amounts of nitrogen oxides most of which end up being deposited in the upper reaches of the Olifants catchment. According to Ashton and Dabrowski (2011), these atmospheric emissions are transported to the lower reaches of the Olifants catchment through the network of tributaries where they cause changes to the structure and chemistry of the soil. In addition, mining is a critical economic activity in the region, with an abundance of coal, gold, and platinum. The Middle reaches of the catchment form part of the Bushveld Complex which contains the country's most valued deposits of the platinum group elements. Unfortunately, these mining operations discharge large volumes of wastewater, mostly containing nutrients from substances such as ammonium nitrate-based explosives, processing chemicals, which often contain nitrogen and phosphorous, and wastewater from rock piles and tailings storage facilities (Addo-Bediako, 2022). Mining effluent is, however, not the only way in which mining operations contribute to nutrient pollution, mining operations also disturb large areas of land, making soils more susceptible to erosion. In this way, phosphorous-rich soils get transported into the river by rain or surface runoff, contributing to nutrient pollution.

The N: P ratio data by Ashton and Dabrowski (2011) shown in Figure 2, reveals that the water throughout the measured length of the Olifants River (using 11 sites) is eutrophic. As explained by (Ashton and Dabrowski, 2011: p.32) "The relatively low values for the inorganic N: P ratio (most values are less than 10) plus the gradually increasing concentrations of orthophosphate suggest that the water is being enriched with nutrients". Mudaly and Van Der Laan (2020) attribute these low N: P ratios, meaning high phosphorous values in the Olifants River system to the failing wastewater treatment works. Most cities and towns discharge a lot of untreated or partially treated domestic and industrial wastewater into the river system, which according to Addo-Bediako (2023) is likely the biggest contributor to nutrient enrichment. A study by Dabrowski (2014) looked at the orthophosphate loads of four of the river sites within the Olifants River catchment within which, three of the four sites were found to be heavily impacted by orthophosphate loading sourced from poorly

treated wastewater, particularly from sewage works. The inadequacy to treat wastewater often results from aging infrastructure, lack of maintenance, and insufficient capacity to handle increasing waste loads (Le Rouw et al., 2012).

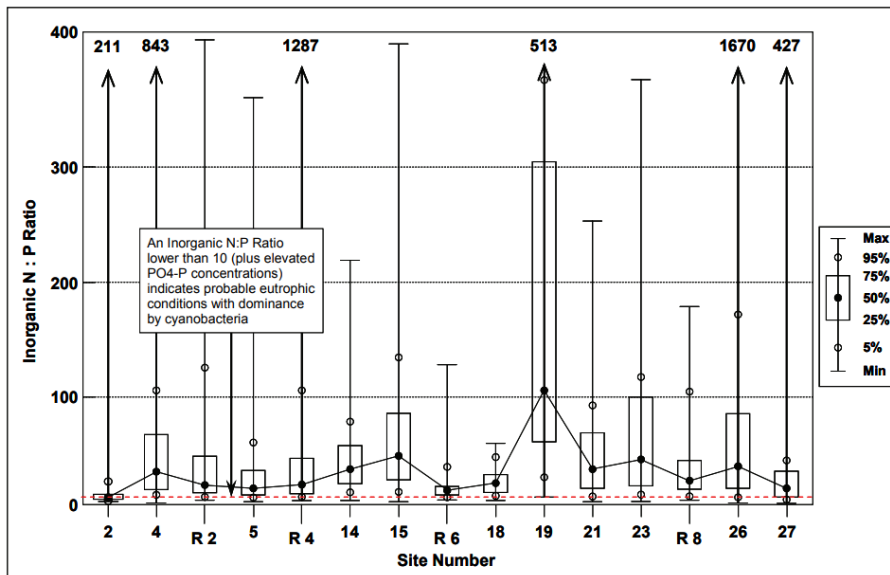


Figure 2: A box-and-whisker plot illustrating the percentile values of the inorganic nitrogen-to-phosphorus ratio, as determined in a study by Ashton and Dabrowski (2011), at 11 river sites along the Olifants River. These values are compared to the recommended threshold below which water is classified as eutrophic (Ashton and Dabrowski, 2011).

As can be noted, poor wastewater regulation and management is a significant contributor to nutrient pollution in the Olifants River and is often compounded and exacerbated by other sources of nutrient overload including agricultural runoff, mining operations, etc. Furthermore, the impacts brought about by this nutrient pollution are broad and mainly affect food security and cause ecosystem collapse with long-term contribution to climate change. It is therefore critical that much more integrated strategies are designed to overcome the Nitrogen and Phosphorous imbalances which could include upgrading and maintaining wastewater treatment plants, regulating agricultural practices, and ensuring that there is efficiency which is not only necessary in South Africa but across the globe and lastly great enforcement of stricter environmental control on mining operations from the government is critical.

Discussion

As highlighted in the previous paragraphs it becomes clear how the discourse around the biogeochemical imbalances is characterized by a complexity, which is not evident at first sight. Usually, talking about planetary boundaries creates a dichotomous way to respect those boundaries, namely overcome or not overcome a certain threshold. However, the situation regarding the biogeochemical flows is lightly different. As we described, the nutrients footprints around the world are often very diverse, generating the need to provide a global response which should be both sensible for some areas and useful for some others. Indeed, like many environmental issues, the alteration of biogeochemical flows is correlated with other crucial problems, strictly related or not to the environment. One of these is the food security issue: a challenge that stands at the core of the current

and future objectives of many regions of the world, especially Africa. For this particular reason inside this paper, we decided to analyze the biogeochemical alterations related to the African context, since it provides an interesting perspective on the complexity of the problem. In fact, only limiting the global amount of nutrients could not be considered a meaningful way to address the problem in the African point of view. The yield gaps and the nutrients deficit of some African areas are a challenge that the African administrations will have to overcome in order to increase the food security of the population, which is still at the lowest levels in the world. Consequently, it would be not only necessary, but even desirable, to generate an increase in the use of fertilizers in the continent. Hence, the African situation poses the need to respond to the problem with a solution that leads to a redistribution of nutrients on a global scale, reducing the surpluses in other areas of the world to increase the food productivity in others, without promoting a mere decrease of the fertilizers on a global scale.

However, the Olifants River case study in South Africa shows how, paradoxically, nutrient pollution can also be a major problem without a fertilizing use comparable to other parts of the world. The eutrophication of the Olifant's waters, as described previously, is caused by many factors (clearly including fertilizers) which all have common points: inefficiency and mismanagement. For this reason, it is sadly possible to find critical examples of eutrophication even if, at the aggregate level, the amount of nutrients present in the environment is considerably less than the one of other regions of the world, characterized by overproduction and massive use of fertilizers.

Conclusion

To conclude this work, it is necessary to highlight the key interpretative lens that emerged during our analysis: the concept of efficiency. Throughout the paper, it became evident that, in the context of Africa, there will be a pressing demographic and social need to increase continental food production. This is essential to address the challenge of food security, which represents one of the most significant present and future battles for African states. Achieving this goal will also depend on expanding the use of all available tools to enhance agricultural productivity, including fertilizers.

However, as we have observed, this trend must inevitably be balanced by the efficient utilization of nutrients, both globally and domestically. Domestically, this entails improving the management of various wastewater treatment processes to prevent the loss of valuable nutrients that could otherwise harm ecosystems. Globally, it will be crucial to reduce nutrient wastage in regions with significant nutrient surpluses, thereby mitigating the impact that increasing nutrient use in other countries, necessary for addressing food security, could have on global biogeochemical flows.

Nevertheless, achieving these objectives requires the implementation of highly complex policies, particularly due to their international and intergovernmental dimensions. Unfortunately, it must be acknowledged that, in the current historical context, envisioning such policies is exceptionally challenging, as they demand a level of cooperation far exceeding what is presently observed on a global scale. Consequently, the political intricacies surrounding these issues will ultimately determine the future management of nutrients worldwide.

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EVE

6. The Changing Trends in Atmospheric CO₂ and Global Increase in Ocean Acidification, their effects on Aquatic Ecosystems.

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EVE

The Changing Trends in Atmospheric CO₂ and Global Increase
in Ocean Acidification, their effects on Aquatic Ecosystems.

By

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Abstract

Ocean acidification is a major climatic issue, being one of the climatic boundaries, effort is being made to understand its seriousness and to limit the human activities that drive it. The aim of this study was to examine the relationship between Atmospheric CO_2 and Ocean Acidification. Its specific objectives were to: identify the changes in atmospheric CO_2 and Ocean Acidification over time and space, examine the relationship between atmospheric CO_2 and Ocean Acidification, and suggest possible best practices to reduce the rate of ocean acidification. Data on atmospheric CO_2 and Ocean pH was analyzed using regression method. Findings were, that Ocean Acidification varied over time and across oceans, a strong inverse relationship was observed between Atmospheric CO_2 and Change in Ocean pH levels ($r = -0.98651$), for every unit change in Atmospheric CO_2 , there was a corresponding drop in Ocean pH level by 0.0036. the standard Ocean pH level was confirmed to be 8.2.

Diversion from use of fossil fuels to renewable energies and continued education aimed at fostering renewed awareness, were recognized as foremost strategies in reducing Ocean Acidification. The research concluded that Ocean Acidification was a direct consequence of Increased Atmospheric CO_2 absorbed by the Ocean and brought about by the industrial and socio-economic activities of humans. Behavioral change, global change in consumption patterns and collaboration among nations is needed to stem the trend. It is vital that the safe zone of this climatic boundary is not breached because the consequences is better imagined.

Introduction

Ocean pH level was stable in prehistoric times, this however has changed since the beginning of the industrial revolution which started around 1750 (Rafferty, 2024), resulting in one of the most fundamental phenomena of modern times, “Ocean Acidification”. The Oceans of the earth covers about 71 per cent of the entire globe and serves as reservoir for nutrients, food, and assortments of Aquatic life. The Ocean also ensures energy exchange between it and the land surface through convection currents and heat exchanges, thereby regulating seasons and weather conditions on the earth. The ocean ultimately helps regulate climate, is home to much of the world’s bio diversities, anchors economic prosperity of nations and produces about half of the entire oxygen needs of the earth (Jewell, 2023).

Ocean Acidification results from the change in the pH level of the ocean. The lower the pH level, the more acidic is the Ocean. pH is a measure of the concentration of hydrogen ions in an aqueous solution (NOAA, 2020). Ocean water is normally slightly basic, with a surface-water pH of about 8.2. A decrease of 0.1 pH units, which has occurred in the oceans may not seem like much, but because the pH scale is logarithmic, each unit on the pH scale represents a tenfold change in acidity level, so the enormity and implication of the growing Ocean acidification has seemed to elude researchers because of the seemingly minute change in the pH scale which in reality represents a major shift and has several implications for the ocean ecosystem and the global human population at large. According to Honisch *et al*, 2012, the pH level of the entire world’s Oceans has continually dropped by 0.1, which is 50 times more than in pre-industrial times. A drop in Ocean alkalinity by this number means a 26 per cent increase in Acidity (The Ocean Portal Team, 2018). The change in Ocean Acidification therefore represents an unprecedented shift in the natural balance in the global aquatic ecosystem.

Statement of Research problem

The Ocean has absorbed about half of the excess Co₂ produced by man from the atmosphere since the 1850s, while this has helped slow down the overall impact of climate change, it did create another problem in the form of Ocean acidification which is known to impact many ocean species and microorganisms, organisms that are very fundamental for the health of the ocean and sustenance of the livelihood of those that depend on the ocean for daily living. Creatures that make hard shells and skeletons by combining calcium and carbonate from seawater are unable to do so

due to increased acidity of ocean water, a situation critically referred to as the Osteoporosis of the ocean.

Researchers have opined that the observed effects of ocean acidity on ocean plants and animals have gone far beyond the individual organisms to challenging the entire marine ecosystem (Langdon *et al*, 2000). A safe boundary has therefore been advocated to help arrest the growing trend. Understanding the relationship between atmospheric CO₂ and Ocean Acidification will help in managing these changes and the negative impact to life that they portend as well as identify and monitor the best actions towards mitigating future deviations.

Evidence indicate that Ocean Acidification is a direct result of anthropogenic (human caused) activities, thereby making man directly responsible and quite able to control the change. This understanding should underlie every research purpose: to identify ways that man through adjusting his living pattern, can reduce the elements that exacerbate Ocean Acidification.

This research therefore seeks to answer the following questions:

- I. How have atmospheric CO₂ levels and ocean pH levels changed over the study period (1985-2022)?
- II. What is the statistical relationship between atmospheric CO₂ levels and ocean pH levels, that drives Ocean Acidification?
- III. What best practices can mitigate ocean acidification and its impacts on marine ecosystems?

Objective and hypothesis of the study

The aim of the study was to identify the changing trends in atmospheric CO₂ and their link to Ocean Acidification. The specific objectives of the study were to:

- i. Identify the changes in atmospheric CO₂ and Ocean Acidification over time,
- ii. Examine the relationship between atmospheric CO₂ and Ocean Acidification,
- iii. Suggest possible best practices to reduce the rate of ocean acidification.

Based on the general objective, the study posits the hypothesis that increasing atmospheric CO₂ levels are negatively associated with ocean pH levels, suggesting that higher CO₂ concentrations contribute to increased ocean acidification. This relationship highlights the chemical interaction between CO₂ absorption and the resultant decrease in pH levels.

Scope of the Study

The research reviewed global atmospheric CO₂ data and Ocean Acidity data from 1985 to 2022. The period saw a remarkable transition from the view of ocean CO₂ uptake as a blessing that needs not be a concern, to the emergence of empirical evidence as the full-scale impact of Ocean Acidification became apparent to scientists from data on research conducted (Brewer, 2013). The Intergovernmental panel on Climate Change (IPCC) at this period for the first time produced an authoritative document showing CO₂ emission projections and relating them to changes in Ocean Acid levels (Brewer, 2003).

Justification of the study

Ocean Acidification is one of the planetary boundaries that represents systems that help regulate the earth and ensure sustainability of human and animal species. Maintaining a safe limit ensures that humans do not become catalysts for extreme natural occurrences like extinction of plant and animal species and extreme weather conditions.

Literature review

According to Figuerola *et al*, (2021), The continuous decline in carbonate ions, and increase in Hydrogen ions in the Ocean resulting from the absorption of CO₂ from the atmosphere is resulting in the reduction of carbonates in the ocean, which adversely affect the formation and maintenance of shells and skeletons in various marine calcifiers such as foraminifera, corals, echinoderms, mollusks, and bryozoans, it is also a causal factor in Coral bleaching (UNEP, 2024). These changes in ocean chemistry represent a significant shift in the marine environment with potential impacts on marine biodiversity and ecosystem health, on a global scale.

Kleypas, 2019 is of the view that changes in Ocean Acidification level represent a troubling trend given the profound impact on marine ecosystems, because it compromises the ability of corals mollusks and Clams from building shells and skeletons, which are crucial for their survival and, by so doing, altering the health of the entire marine ecosystem. He further opined that the current rate of acidification of the Ocean presents an unprecedented challenge with studies suggesting that the current rate is over ten times faster than any acidification rates in the last 55 million years.

In relation to the human time scales, the process of acidification seems slow and the planetary boundary it represents does not seem to be in danger just yet, but on geological time scales, the recent acidification process is faster than any change documented over the last 300 million years, thereby making it hard for organisms to cope, this definitely should be a reason for urgent concern.

While a lot of empirical data has been generated in the last decade to highlight the growing menace of CO₂ impact on Ocean acidification, Wallace *et al*, (2014) observed that in coastal areas, nitrogen from sewages and fertilizers seep into coastal marine waters and further worsen the CO₂ concentration in the Ocean by stimulating excessive biological growth of marine algae, which eventually die off and decompose, releasing carbon dioxide into the water.

The National Oceanic and Atmospheric Administration (NOAA) identified atmospheric CO₂ as the most critical factor driving the increase in Ocean Acidification on a global scale, with levels rising from about 280 parts per million (ppm) in the pre-industrial era to over 410 ppm in present day, mainly because of human activities which includes fossil fuel combustion, deforestation, and harmful land use practices. According to the agency, the increase in CO₂ emissions, along with the rising carbon footprint results in climate change-induced human migrations as well as animal species movements. Other industrial and agricultural practices contributing to ocean acidification, were cement manufacturing plants that release substantial CO₂, nutrient run-off from agricultural fields, practices like deforestation and land use changes that decrease the Earth's capacity to absorb CO₂, leading to higher concentrations of the gas in the atmosphere (Smith, *et al*, 2016).

Bryne (2011) observed a direct correlation between acidification and the reduced ability of species like mollusks and certain plankton to maintain their calcium carbonate shells. The weakening leads to higher mortality rates and reproductive challenges among these sea creatures, acidification is also known to disrupt neural processes in fishes by altering their behavior and diminishing their ability to detect predators.

The European Project on Ocean Acidification has conducted extensive researches that revealed how acidification alters nutrient cycles, food webs, and overall marine productivity. These findings have become crucial for predicting the broader ecological consequences of ongoing ocean pH change in the Oceans of the world, however, questions remain regarding what future

socio-economic impacts will arise from ocean acidification, how to quantify the risks to non-market aquatic ecosystem services such as storm protection provided by tropical coral reefs, as well as to aquaculture and fisheries (Abuzer and Ozgur, 2024). It also raises questions about how adaptation strategies can be identified for vulnerable people, industries and communities that rely on the ocean for sustenance. This research will further broaden awareness about ocean acidification, contribute to better risk management practices and help drive sustainable use of natural resources at a larger scale than is currently observed.

The pH Scale

pH (potential for Hydrogen ion) scale is a measure of the relative amount of free hydrogen and hydroxyl ions in water. The more the free hydrogen ions, the more acidic. pH is an important indicator of chemical change in water. pH is reported in "logarithmic units". A unit change in pH represents a tenfold change in acidity, base or alkalinity of water. Water that has a pH of 6 is ten times more acidic than water with pH of 7. The most acidic substance therefore has a pH of zero. (McCarthy, *et al*, 2006)

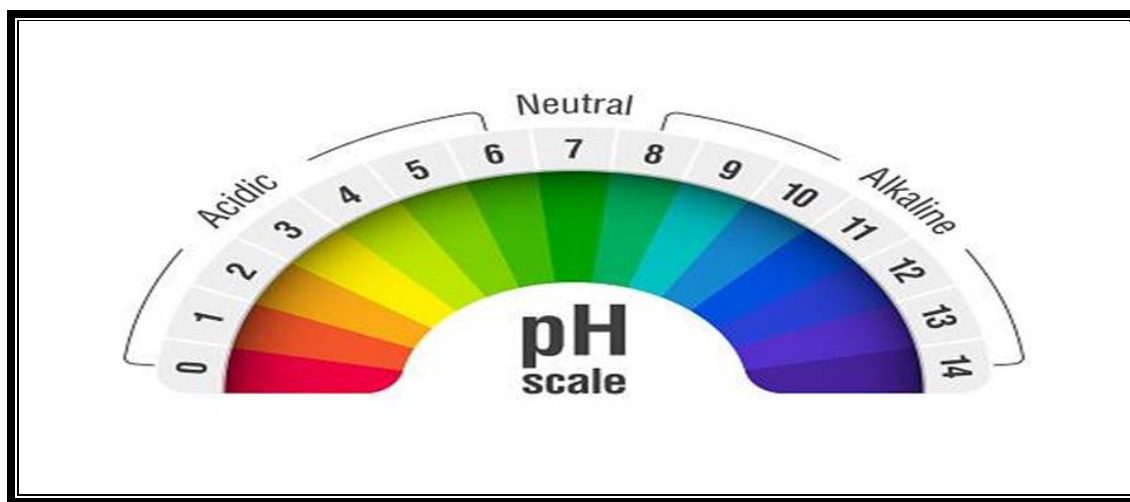


Figure 1: The pH Scale
Source: www.google.com

Over the last 200 years' seawater acidity has increased by 30 per cent, and if nothing is done, by 2060, it is predicted that seawater acidity could have increased by 120 per cent. Interestingly, it has been well documented in literature that the current rate of change is over 10 times faster than anything recorded in the last 55 million years (Laffoley, *et al* 2017).

Spatial Variations in Global pH levels

The highest rates of Ocean pH decline are found around the Southern Ocean and in the high latitudes of the North Atlantic and North Pacific which are about 15 per cent higher than the global mean values. The lowest rates of change are found in the subtropical basins with rates that are about 25 per cent lower than the global mean. The Pacific areas are also higher than those in the Atlantic for similar latitudes.

A rate of change higher than the global average was recorded in the eastern and central Pacific Ocean. (Jiang *et al.* 2019) All these changes highlight the importance of the regional perspective when investigating Ocean Acidity and can assist researchers to relate these changes with human social economic activities that seem to exacerbate the problem of excess CO₂ in the atmosphere. Some of these variations are equally driven by processes of ecosystem metabolism such as photosynthesis and respiration, chemicals, dissolved oxygen, and variation in length and intensity of sunlight (Silbiger and Sorte 2018, Gruber *et al.*, 2023).

Research methodology

This Research relied on data from measurements of atmospheric CO₂ and Ocean acidification collected by the National Oceanic and Atmospheric Administration (NOAA) under the United States Department of Commerce. NOAA, through its Ocean services carry out Ocean periodic surveys using Ocean observing systems (IOOS). The National Environmental Satellite, Data, and Information Services (NESDIS), an arm of the NOAA, processes the research data and make it available as primary data for various research fields. Data obtained covered a period of 37 years (1985 to 2022). Secondary data for the research was sourced from published books and journals by both government and private agencies as well as reports from climate summits.

Method of data analysis

The research relied on published works and online data to evaluate the changes in CO₂ and Ocean acidification over time. Empirical data on atmospheric CO₂ and Ocean Acidification were tabulated and a graphical representation of the various values shown. Regression analysis was carried out using Microsoft excel 2023 to examine the relationship between the annual changes in

Atmospheric Co2 and Ocean Acidification data. Suggestions on environmental best practices was based on review of published works.

Table 1: Atmospheric C02 level and Ocean pH levels (1985-2022)

YEAR	Atmospheric C02	OCEAN pH level
1985	20.31	8.11
1990	22.75	8.10
1995	23.52	8.10
2000	25.50	8.09
2005	29.59	8.08
2010	33.31	8.07
2015	35.46	8.06
2020	35.01	8.05
2021	36.82	8.05
2022	37.15	8.05
TOTAL	299.42	80.76
AVERAGE	29.94	8.10

Sources: National Oceanic and Atmospheric Administration (NOAA,2023)

Regression Equation

The relationship between atmospheric CO₂ and ocean pH levels was modeled using the following linear regression equation:

$$y=mx+c$$

Where:

- y represents ocean pH levels.
- x denotes atmospheric CO₂ levels.
- m is the slope of the regression line, indicating the rate of change in ocean pH per unit increase in atmospheric CO₂.
- c is the y-intercept, representing the estimated ocean pH when atmospheric CO₂ levels are at zero.

Data Analysis and Discussion of Results

This section will be discussed under, changes in Ocean acidification and Atmospheric Co2 over time, the causal relationship between them; and the possible best practices to mitigate their effects.

(1) CO2 Change and Ocean Acidification

The impact of Atmospheric CO2 levels rises and the attendant change in ocean pH level, had by the mid-1990s become a concern to scientists studying changes in aquatic ecosystems. While they were not yet certain about the role played by the ocean flora and fauna in the CO2 balance. The report by the IPCC team generated awareness and revealed the chemical long term impact of CO2 change projections over future calcification rates in the ocean. Data compiled in a major review of coralline species sensitivity to the CO2 status of the ocean showed that coralline calcification rates were severely impacted by declining ocean carbonate ion levels (Gattuso *et al.*, 1999)

(2) Causal relationship between Atmospheric CO2 and Ocean pH levels

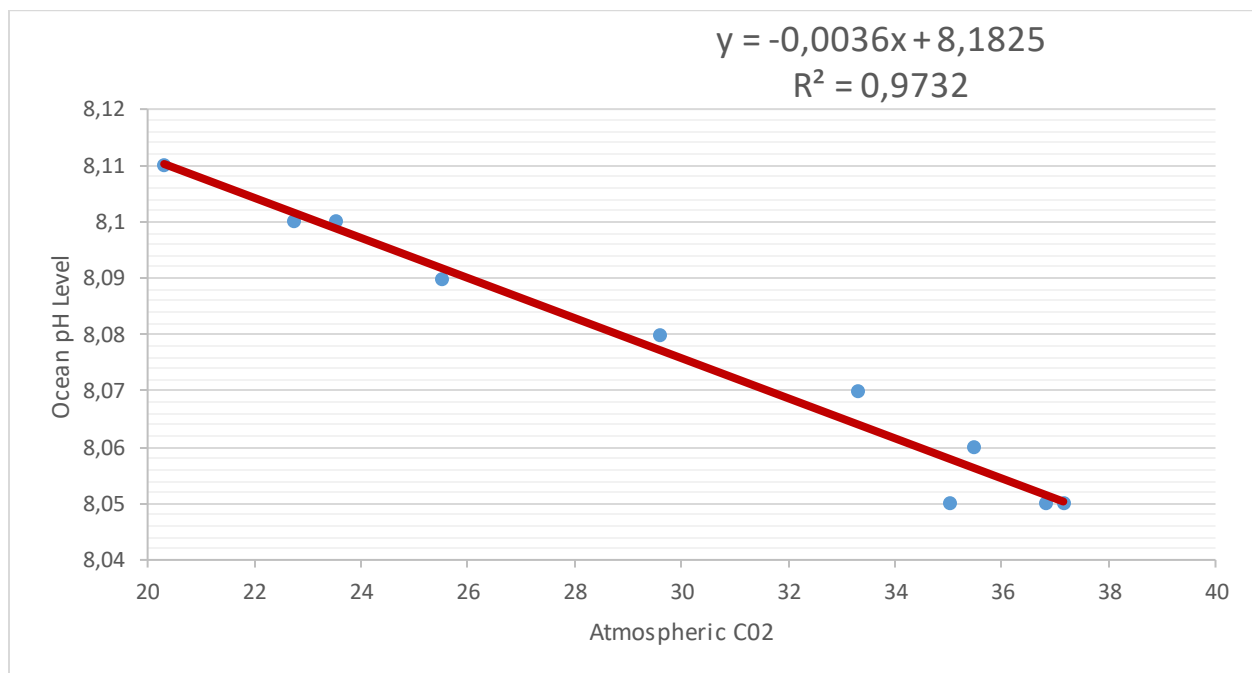


Figure 2: Relationship between Atmospheric CO2 and Ocean pH levels.

Source: Researchers work, 2024

Correlation coefficient $r = -0.98651$ shows a strong inverse relationship between Atmospheric CO_2 and Change in Ocean pH levels, an increase in CO_2 levels will bring about a downward trend in pH levels of the ocean (the lower the pH level, the more acidic the ocean)

Slope of the graph is $= -0.0036$, this shows that for every unit change in Atmospheric CO_2 , there will be a corresponding drop in Ocean pH level by 0.0036, the lower the ocean pH level. (0.1 change in pH level of the ocean is equivalent to 26 per cent increase in Acidity levels.

The intercept of the graph is 8.1823, approximately 8.2 which is the standard pH level for the ocean when the excess CO_2 level in the atmosphere is zero. For intercepts it says that if the value of CO_2 in atmosphere were normal, the Ocean pH will be 8.18

The coefficient of determination R^2 , shows the goodness of fit of the model, in other words indicates how well this model predicts the relationship between the variables. It shows a value of 0.9732, indicating that variability observed in pH level and by implication, Ocean Acidification, can be predicted with up to 90 per cent accuracy using this model.

Descriptive Statistics

Table 2: Descriptive statistics of relationship between Atmospheric CO_2 and Ocean pH levels 1985-2022.

STATISTIC	ATMOSPHERIC CO_2 (ppm)	OCEAN pH LEVEL
MEAN	29.4	8.08
MEDIAN	31.45	8.05
STANDARD DEVIATION	6.43	0.02
MINIMUM	20.31	8.05
MAXIMUM	37.15	8.11
KURTOSIS	-1.79	-1.72
SKEWNESS	-0.30	0.14

Source: researcher's work, 2024

Table 2 shows measures such as- mean, median, mode, standard deviation, skewness, kurtosis, and extremes—they offer valuable insights into the trends and variability in the dataset, the analysis provides a clearer understanding of the data trends and variability, which supports the hypotheses and lays a foundation for further analysis and discussion (Nick, 2007)

Mean:

The mean atmospheric CO₂ level was 29.94 ppm, representing the average concentration of CO₂ over the study period. This value reflects the steady increase in CO₂ emissions driven by things like industrialization, deforestation, and fossil fuel use. Similarly, the mean ocean pH was 8.08, indicating the average acidity of the ocean during the same timeframe.

Median:

The median atmospheric CO₂ level was 31.45 ppm, closely aligning with the mean, suggesting a relatively symmetric distribution of CO₂ values over the years. For ocean pH, the median was 8.05, indicating that most pH values were clustered around this level, with no significant outliers. This consistency in the median and mean further supports the gradual but steady progression of acidification over time.

Standard Deviation:

The standard deviation for atmospheric CO₂ levels was 6.43 ppm, reflecting a moderate degree of variability in emissions across the study period. This variability corresponds to fluctuations in global industrial activity, energy consumption patterns, and mitigation efforts. For ocean pH, the standard deviation was 0.02, signifying a much smaller variation in pH values. This stability underscores the gradual yet persistent decline in pH as CO₂ concentrations increased.

Minimum and Maximum Values:

The maximum CO₂ level of 37.15 ppm was recorded in 2022, representing the peak of industrial emissions and the culmination of decades of fossil fuel use and deforestation. The minimum CO₂ level of 20.31 ppm in 1985 reflects the lower baseline conditions at the start of the study period. For ocean pH, the maximum value was 8.11 in 1985, closely approximating pre-industrial ocean alkalinity.

The minimum value of atmospheric CO₂ was 20.31, while the maximum value was 37.15, a change of 16.84 units in 37 years study period (1985–2022), an average increase of 0.46 units annually. This is very significant given the serious implication of increase of Atmospheric CO₂ in driving Ocean acidification, a unit Increase in Atmospheric CO₂ is equivalent to 0.00036 drop in

Ocean pH level while a unit change in Ocean pH level represents a tenfold increase in the acidic level of the Ocean.

Skewness and Kurtosis:

Skewness measures the asymmetry of a dataset's distribution and tells us whether the data leans more to the left or right of the mean (Kim & White, 2004). In the context of atmospheric CO₂ and ocean pH, skewness helps assess whether changes in these variables have been gradual and symmetric over time or if they have been influenced by extreme events or outliers.

The skewness of the atmospheric CO₂ data was -0.30, indicating a slight negative skew, with a longer tail on the lower end of the distribution. This suggests that while most CO₂ values are concentrated on the higher side of the mean, there are a few lower values pulling the distribution slightly to the left, likely reflecting periods of lower emissions earlier in the study period. For ocean pH, the skewness was 0.14, reflecting a slight positive skew over the years. This indicates that pH values are fairly symmetric but with a minor tendency for more values on the lower side, aligning with the gradual and persistent decrease in pH due to increasing ocean acidification. The kurtosis values for atmospheric CO₂ (-1.79) and ocean pH (-1.72) were both negative, suggesting relatively flat distributions with fewer extreme values or sharp peaks.

Effects of Ocean Acidification on Ocean Ecosystems

Organisms have been known to be very sensitive to changes in pH levels in fluids surrounding them or within them, in humans for example, blood in the arteries can drop in pH, a fall from 7.35 -7.45, which is a change of just 0.1 pH unit can result in very dire health consequences, such as seizures, heart arrhythmia, or coma (acidosis). Similarly, Ocean acidification has also been termed “Osteoporosis of the ocean” the reduction in the mineral composition of bone or its mass. Several marine organisms react negatively to the change in the acidity (H⁺ concentration) levels in the marine environment.

Biological processes in the ocean such as respiration, reproduction calcification (shell and skeleton building), photosynthesis are critically influenced by the pH levels in the ocean. According to Byrne, (2011) There is a link between acidification and the reduced ability of species like mollusks and certain plankton to maintain their calcium carbonate shells, this weakening leads

to higher mortality rates, especially among the young. Acidification is also known to disrupt neural processing in fish, altering their behavior and diminishing their ability to detect predators.

Lacoue-Labarthe *et al.*, (2016) has listed the implications of ocean acidification on the aquatic ecosystem in the Mediterranean. They highlighted the reduction in growth of phytoplankton, drop in population of certain fish species, migration of fish species away from their natural habitat and coral bleaching. Coral reefs which serve as nurseries and breeding ground for diverse aquatic organisms is under threat, also the global oyster population is affected. The economic value derivable from the ocean is estimated to drop by up to 300 billion United States dollars annually as a direct consequence of ocean acidification.

Global Initiatives and Acceptable Best Practices

The United Nations creates awareness and fund researches that provide undeniable proofs to naysayers. In the United States, The National Oceanic Atmospheric Administration has developed an action plan, that stipulates steps to mitigate the impacts of Ocean Acidification.

In the European Union, a review of about 90 legislative documents from seventeen countries and the United Kingdom show that the policies are not properly coordinated (Galdies, *et al.*, 2020). In Africa, the knowledge and impact of Ocean Acidification is still very elementary, however, the Global Ocean Acidification Observing Network (GOA-ON), which is supported by multiple organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), International Atomic Energy Agency (IAEA) and International Ocean Carbon Coordination Project (IOCCP) as well as The Ocean Foundation in Washington D.C, has started the process of establishing the technical and human capacity for ocean acidification measurement in Africa.

In the African continent to date, only one platform located in the Eastern African region is recognized for measuring ocean acidification and delivering relevant data. Because of the devastating effect of Ocean Acidification on developing countries and the paucity of resources to drive emergency responses, developed nations should develop an all-encompassing global strategy to fight it. To date, there is yet to be a well-coordinated global initiative focused on managing the challenges of Ocean Acidification. The reduction in carbon emissions through diversion from use of fossil fuels to renewable energies is a foremost strategy in reducing atmospheric CO₂ and Ocean Acidification, the world must look towards more energy efficient systems to stop the high reliance

on hydrocarbon based fuels. Because the already obvious impacts of Ocean Acidification on living organisms cannot be reversed immediately, efforts should be made to make legislations and enforce them with the aim of controlling fishing and other exploiting activities in the Oceans by setting limits and increasing monitoring as well as funding conservation practices.

The United Nations Climate Summit (COP 26) Holding in Azerbaijan presently must consider asking the developed nations and major industries to make provision for mitigating the impact of sea level rise, sea temperature rise, flooding, and other Climate change driven adverse weather conditions. Coral reefs management and restoration is very fundamental because of the huge marine life diversities that make the coral reefs home.

Conclusion and Recommendations

Ocean Acidification has a direct relationship with CO₂ absorption by the Ocean beyond the natural limits, the change in Ocean pH level is determined by how much CO₂ is dissolved in the Ocean water, the more CO₂ absorbed, the lower the pH level and the higher the acidity level in the Ocean. The implications of this trend is far reaching and has devastating consequences on the aquatic ecosystem. The chain effect on marine life and how it affects food chain and the livelihood of those that rely on the ocean for sustenance is too fundamental to be left to chance.

The occasioned changes pose very profound social economic effects on world population, especially in areas of food sufficiency and loss of ocean biomass. The global fish reserve in the ocean supports a huge food production industry, when ocean acidification threatens this, then, the world will be in Danger of hunger. The ocean also has critical impacts on the heat and cold regimes on the globe, regulation of weather conditions, Polar ice reserve and maintenance of global sea levels as well as provide reliable transport that supports the global trade. Global efforts to protect the Ocean are at best uncoordinated. The effects of Ocean Acidification which are driven by excess CO₂ absorption are profound, yet not clearly identified as such especially in the third world economies. While a global coordinated effort is required to control Ocean Acidification, there is already a fallout of events and adverse weather conditions with prolonged impact on the global aquatic eco system.

In view of the observed relationship between Atmospheric CO₂ and Ocean Acidification, there is need to urgently regulate the quantity of CO₂ pushed into the atmosphere, through legislation and embracing technologies that advance nature and ecosystem based solutions, Data

pool should be made more readily available to enhance research and study of causal relationships between these climate elements and human activities.

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EVE

7. Raising Awareness: Europe's Commitment to Aerosol Control Has Just Begun. What About Africa?

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EVE Fall School 2024



Raising Awareness: Europe's Commitment to Aerosol Control Has Just Begun. What About Africa?

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Introduction

In March 2020, the onset of the COVID-19 pandemic prompted the implementation of significant restrictive measures that profoundly altered the daily lives of millions worldwide (Miyah et al., 2022). This led to a notable reduction in aerosol emissions, raising awareness about the potential for living in environments with improved air quality. Specifically, in Italy, the national lockdown from March 10 to May 18, 2020, provided a unique opportunity for researchers and policymakers to investigate the effects of air pollution, raised attention on the aerosol phenomena and so encouraged the adoption of new containment approaches to improve the air quality (Donzelli et al., 2021).

Despite this, aerosol loading is still not fully understood by scientists, a safe boundary value has not yet been determined (French & Kotze, 2020) and different parties of the world still experience different levels of consciousness concerning risks related to aerosol emissions. Thanks to data from Europe, particularly Italy, this compilation-based study draws attention to whether populations are adequately aware of the health risks and climate change associations linked to aerosol emissions, with a focus on sub-Saharan Africa, particularly Ghana. Onyeuwaoma et al. (2018) explored the impact of increasing industrialization and high population density on aerosol loading in urban and suburban areas in West Africa. His study emphasized that urban centers, driven by industrial activities and dense populations, are hotspots for aerosol emissions, primarily from combustion processes such as vehicle exhaust, industrial outputs, and domestic energy use. These aerosols contribute significantly to atmospheric extinction, reducing visibility and impacting regional air quality and climate. The suburban areas, though less densely populated, are also affected by aerosol transport from urban centers, highlighting the regional scale of the issue. Our thesis highlights the fact that aerosols are under-studied in sub-Saharan countries such as Ghana, even though Western African countries also have high risks for the future from aerosols due to both increasing industrialization and a high population rate.

Although the vocabulary used may at times be related to a technical terminology of a chemical-biological nature, this is a multidisciplinary study, which intends to draw attention not so much to the number of aerosols present in Ghana per se, but rather to the need to study the phenomenon and activate a common political consciousness on the subject. In the first paragraph it is first of all our intention to explain what the aerosol are; moreover, the health and climate risks are going to be exposed. Additionally, the following paragraphs of the

research will delineate where aerosol comes from, comparing several sources, distinguishing them in Ghana, or generally in West Africa, and Italy, or generally South Europe.

1. Problems Related to Aerosols Emissions

1.1 What Aerosols Are?

Collections of airborne solid or liquid particles ranging in size from 0.01 to 10 micrometers are known as atmospheric aerosols. Because of their effects on climate change and human health, their loading is now considered to be one of the nine planetary boundaries. Due in major part to industrial development, their main sources are secondary particles generated from gaseous precursors and direct emissions of particulate matter (PM). These particles can stay in the atmosphere for hours or longer and have an impact on both local and global environments (French & Kotze, 2020).

The aerosol's concentration has more than doubled since pre-modern times but it differs deeply from country to country. The derived measurement useful to investigate the aerosol load and its distribution at different spatiotemporal scales is called Aerosol Optical Depth (AOD). Considering Europe, where aerosol scientific studies seem to be recurrent, at the continental level AOD indicates peak values during the summer months (June, July, August) and minimal values during the winter months (December, January, February). Furthermore, elevated AOD levels are observed in regions such as the Po Valley which include Piedmont, Lombardy, Emilia Romagna, and Veneto, which are characterized by strong industrialization and intensive agriculture (Di Antonio et al., 2023).

1.2 Health Effects of Aerosols

Exposure to air pollution has many substantial adverse effects on human health, to the extent that the World Health Organization identifies ambient air pollution as a leading cause of global disease and death. High concentrations of aerosols, particularly near-surface fine particles, are associated with increased morbidity and mortality from cardiopulmonary diseases, especially among vulnerable populations such as children and the elderly (Lepeule et al., 2012). Some studies attribute seven million deaths to the emission of aerosols globally (Jiang XQ et al., 2016).

Short-term exposure exacerbates respiratory issues like asthma, while long-term exposure elevates mortality rates from cardiovascular and respiratory diseases (WHO, 2018). Airborne

fine particulate matter can penetrate deep into the respiratory tract, reaching the alveoli where clearance is slow, leading to prolonged pulmonary and systemic inflammation. Furthermore, these particles often carry toxic chemicals with carcinogenic potential, increasing the risk of respiratory diseases, including lung cancer (Laden et al., 2000; Pinkerton et al., 1995). For all these reasons, in low- and middle-income countries, over half of deaths from acute lower respiratory infections in children under five are linked to air pollution (WHO, 2018).

Eventually, air pollution has been recently hypothesized to enhance the clinical severity of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection, acting through adverse effects on immunity, and induction of respiratory and other chronic diseases. After the appearance of the virus, Italy was the first European country to be severely affected by the outbreak, particularly in the North of the country. The so-called ‘Padan Plain’ or Po basin, known as one of the most polluted regions in Europe, was particularly affected, and some studies have been investigating the association between air pollution and COVID-19 mortality (Filippini et al., 2021).

1.3 Aerosols’ Effect on the Climate Variation

Different locations’ climates are influenced by both natural and man-made aerosols, such as dust and sea salt, ammonium nitrate, and ammonium sulfate. Sulfur oxides released by volcanic eruptions, for example, cause the atmosphere to temporarily cool, especially in the Northern Hemisphere. However, the effects of aerosols on the climate are far from easily identifiable. Aerosols have both a direct and indirect impact on the climate. They change the atmospheric energy balance directly by scattering and absorbing solar radiation, and they have an indirect impact on cloud durations and properties by serving as nuclei for cloud condensation. Complex climatic consequences are the result of these processes (Myhre et al., 2013).

For instance, we can affirm that while some aerosols, such as sulfate, generate a cooling impact by reflecting sunlight, black carbon has a warming effect. Because of these cooling effects that partially counteract their warming impacts, the overall influence of aerosols on the climate is complex, leading to uncertainty in climate projections and increasing the need for more accurate aerosol impact research (French & Kotze, 2020).

2. Aerosol Sources

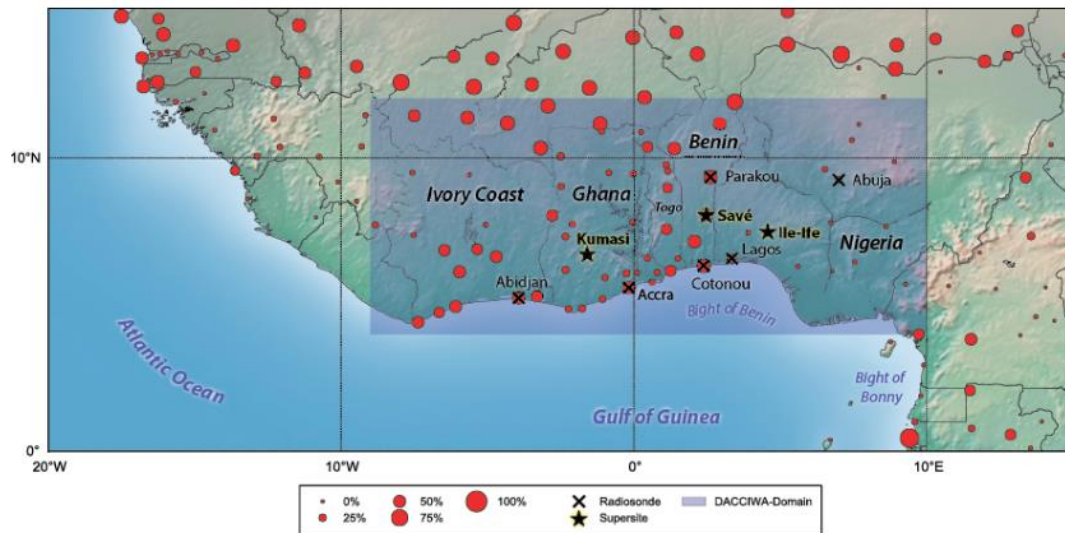
2.1 Anthropogenic Factors in Italy

The transport sector is certainly one of the most polluting sectors. In 2018, according to the International Energy Agency, the road transport sector was responsible for 25% of total carbon dioxide emissions in Europe, making it the primary source of air pollutant emissions, and a significant contributor to particulate matter (International Energy Agency, 2018).

Shipping emissions are specifically a significant contributor to air pollution on both local and global scales, and this impact is expected to intensify in the future due to anticipated increases in global maritime transport volumes. The Mediterranean Sea, for example, serves as a critical corridor for short-sea shipping within Europe and between Europe and East Asia. Consequently, there has been a growing concern regarding maritime emissions from Mediterranean ports, which has also fostered discussions surrounding the potential establishment of a Mediterranean Emission Control Area (MedECA) (Toscano, 2023).

2.2 Anthropogenic and Non-Anthropogenic Factors in Ghana

In Ghana and other West African countries, aerosol loading is influenced by both anthropogenic and non-anthropogenic factors. Vehicular emissions are significant contributors, with many over-aged and poorly maintained imported vehicles emitting high levels of black carbon, nitrogen oxides, and particulate matter, particularly in urban areas (Abokyi et al., 2019). Additionally, the widespread use of charcoal and biomass for energy releases black carbon and particulate matter, which further increases aerosol concentrations and contributes to global warming. Natural factors like the Harmattan season also play a major role, as dust from the Sahara significantly raises particulate levels, impacting air quality and respiratory health, especially in the northern and central regions. Together, these factors highlight the complex interplay of human activities and natural events in shaping aerosol burdens in Ghana (Abokyi et al., 2019).



The image depicts the air pollution situation in West Africa. The larger the dots, the higher the density of aerosols in the area. Image Source: [European Centre for Medium-Range Weather Forecasts](#).

2.3 Geographical Factors

Geographical factors also influence the persistence of aerosols. In Italy, an analysis of the seven most populous countries within the European Union revealed that from 2005 to 2019 Italy achieved the second-highest average reduction in emissions at 39% (Robotto et al., 2022). Despite this effort to mitigate emissions across the EU, it continued to surpass the EU's established limit values.

Studies indicate that during winter, stable weather conditions can lead to high aerosol concentrations, making this period critical for air quality, especially in the cities, while other causes can be found in the efficiency of wind speed, in the planetary boundary layer (PBL) height, and in the atmospheric pressure in the Po basin, which is three to five times lower in terms of pollutant dilution and dispersion compared to regions situated north of the Alps (Robotto et al., 2022).

Moreover, it is well known that the geographical conformation of the Po Valley, closed on three sides by the Alps and the Apennines, contributes to maintaining high pollutant concentrations for long periods, especially during the cold season. The phenomenon is further aggravated by stagnant weather conditions that limit the dispersion of pollutants (Robotto et al., 2022).

3. Community Involvement and Public Awareness

3.1 Covid-19 Awareness Raising in Italy

For the first time with the lockdown, the European population, especially the Italian population, realized the health risks of air pollution and, the poor quality of the air they breathed. The lockdown measures implemented in 2020 in response to the COVID-19 pandemic resulted worldwide in significant alterations to atmospheric pollutant and greenhouse gas emissions, igniting attention to the effects of a prolonged and significant decrease in air quality.

In Italy, aerosols have been extensively documented as prevalent in the region, with a marked reduction observed during the COVID-19 pandemic. Specifically, urban road traffic experienced the most substantial impact, with an average reduction of 48% to 60% considering the distant situation of cities such as Milan, Bologna, Florence, Rome, Naples, and Palermo (Gualtieri et al., 2020).

Albeit lower than the reduction in traffic volume, scientists revealed a decrease in Nitrogen dioxide (NO₂) levels across all urban areas, ranging from a reduction of 24.9% in Milan to 59.1% in Naples. In contrast, ozone (O₃) concentrations either remained stable or increased, with rises of up to 13.7% in Palermo and 14.7% in Rome. Particulate matter (PM₁₀) exhibited reductions of up to 31.5% in Palermo, while increases were observed in Naples, reaching 7.3%. For PM_{2.5}, reductions of approximately 13% to 17% were counterbalanced by increases of up to 9%. The heightened use of household heating (an increase of 16% to 19% in March), driven by colder weather conditions compared to 2019 (a decrease of 0.2 to 0.8 °C), may partially explain the rise in primary PM emissions. Additionally, increased agricultural activities may account for the rise in ammonia (NH₃) emissions, contributing to secondary aerosol formation (Gualtieri et al., 2020).

3.2 What's in the World?

All the variations observed in Italy during the COVID-19 lockdown era underscored the intricate nature of atmospheric pollution, highlighting the necessity for sustained decarbonization efforts across all emission sectors to effectively enhance air quality and public health. The popular raising of awareness that occurred during the lockdown, however, does not seem to have resulted in substantial changes in public policy that would drastically reduce air pollution. Reducing the health dangers associated with aerosols requires increasing public knowledge of air quality issues. Programs for community participation can raise awareness of

the risks posed by aerosol pollution, motivate people to take precautions and support cleaner energy sources.

Making the switch to renewable energy is essential to cutting back on the use of fossil fuels and the resulting aerosol emissions. Campaigns such as the Clean Cooking Alliance promote healthier cooking practices that reduce indoor air pollution and support the Sustainable Development Goals (SDGs) concerning energy and health (WHO, 2018). Reducing man-made aerosols requires focusing on industrial emissions and trash burning. Existing climate treaties indirectly promote aerosol reduction by supporting cleaner energy sources, even though no international treaty specifically addresses aerosol emissions.

Moreover, the COVID-19 aerosols raising awareness was not uniform throughout the world. The South of the world seems to be completely unaware of the risk of growing aerosols linked to industrialization. Studies highlighting geographical factors that encourage the persistence of air pollution seem to be a rarity even for places, such as Italy, where aerosol pollution is well known. The complete absence of studies on West African countries could be concerning, given that aerosols are commonly found in densely populated regions, such as those in West Africa.

Conclusion

The absence of extensive literature on the presence of aerosols in West Africa symbolizes the local population's lack of awareness of the issue. However, it is crucial to comprehend aerosol loading in sub-Saharan countries and enhance public engagement. While awareness of the environmental risks associated with improper waste disposal is common, the same level of attention has not been given to aerosols. Both natural and human-caused factors, like industrialization, vehicle emissions, and seasonal dust from the Sahara, contribute to the fluctuating aerosol concentrations in major cities like Accra, Kumasi, Takoradi, and Tamale in Ghana. Moderate to high Aerosol Optical Depth (AOD) values are highlighted in recent studies, particularly in pre-monsoon seasons. For example, both marine and terrestrial sources contribute to the higher AOD values (~ 0.80) in Kumasi and Takoradi than in Accra and Tamale (Fosu-Amankwah et al., 2021). These results highlight the necessity of thorough aerosol monitoring to comprehend the distinctions between urban and rural areas, noting that urban regions typically experience higher levels of aerosol pollution and demonstrate greater awareness of associated health risks. In contrast, rural areas, which are less industrialized, often exhibit lower levels of public understanding regarding these critical issues.

The ongoing industrialization in sub-Saharan Africa, coupled with findings indicating a significant knowledge gap among populations concerning aerosols-related problems underscores a pressing concern for future public health. This study seeks to inform policy interventions that could mitigate health risks associated with aerosol exposure while promoting greater community engagement in climate adaptation strategies connected with aerosols. By addressing these dimensions, the research aspires to contribute to a more comprehensive understanding of the interplay between environmental health and public awareness in developing regions. Enhanced awareness is crucial for fostering informed communities that can effectively engage with and respond to the challenges posed by aerosol emissions and their health implications.

Eventually, comparative logics such as those in this research can enhance investigative analysis, allowing countries in sub-Saharan Africa, where the presence of aerosols is not yet widely known, to learn from lessons learned elsewhere and establish a pattern model to study the topic.

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EVE

8. Delving into the Montreal Protocol Negotiations: Perspectives from Global North to Global South

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Delving into the Montreal Protocol Negotiations: Perspectives from Global North to Global South

Abstract

The stratospheric ozone layer surrounds the Earth, protecting it from harmful ultraviolet radiation. However, ozone-depleting substances, such as chlorofluorocarbons, have significantly damaged this shield. This paper explores how the international community gathered efforts to overcome this issue by reaching and successfully implementing the Montreal Protocol. The research analyses the combination of these by reviewing the literature on the subject and underlining the missing factors among those commonly recognised by scholars as crucial. In this context, the paper assesses the factors and stakeholders facilitating international cooperation by including previously neglected elements. Additionally, the study shows how Ghana, as a case study from the Global South, acted to address the risks of ozone depletion. Developing countries have indeed shown a trajectory of success in ensuring the phasing out of Ozone Depleting Substances (ODS). The research concludes with a Global North perspective by evaluating whether the European Community has effectively led international efforts to reduce stratospheric ozone depletion. A comparison between supranational and intergovernmental institutions' roles will help determine if the European Union's environmental legislation on this issue has been among the most ambitious globally.

This holistic approach allowed the treaty to address the complexities of ozone depletion in a way that made it more effective than agreements like the Kyoto Protocol or the Paris Agreement, which lacked similar mechanisms for broad participation and sustained commitment.

Keywords

Stratospheric ozone depletion, EU, Ghana, Montreal Protocol, UN negotiations.

Introduction

In 1974, scientists Mario Molina and F. S. Rowland first sounded the alarm on stratospheric ozone depletion, signalling that the increased chlorofluorocarbons (CFCs) and other ozone-depleting substances (ODS) were harming the environment and human health. Although governments were initially reluctant to phase out these chemicals, further studies confirmed these concerns in the following years. By August 1987, an "enormous ozone loss" was recorded above Antarctica, marking its lowest levels ever (Du Toit, 2021, p. 265). Multiple factors, further explored in this paper, finally led governments to cooperate and address this challenge on a multilateral level. Negotiations conducted within the United Nations framework resulted in the 1987 adoption of the Montreal Protocol on Substances that Deplete the Ozone Layer.

Widely regarded as a successful model for addressing global environmental threats, the Protocol and its amendments led governments to almost entirely phase down ozone-depleting substances. As a result, current ozone levels remain well within the Planetary Boundary threshold outlined in Rockström et al.'s framework (Rockström et al., 2009). Furthermore, scientists project a full recovery to 1980s conditions by mid-century (UNEP, n.d.).

This paper explores how the international community has dealt with stratospheric ozone depletion, examining what has worked during multilateral negotiations and the factors at the origin of the successful implementation of the Montreal Protocol. With this purpose, the analysis will begin with the 1985 adoption of the Vienna Convention for the Protection of the Ozone Layer, which paved the way for further negotiations. It will then trace developments to the present day, considering and comparing perspectives from the Global South and the Global North.

This paper will be structured as follows. The first section will examine the negotiation process that led to the signing of the MP. It will investigate the multifaceted factors that contributed to its success and those that differentiate it from less effective instruments, such as the Kyoto Protocol and the Paris Agreement. In this context, we will assess the factors and stakeholders facilitating international cooperation by including previously neglected elements. A better understanding of these processes could help governments address interconnected environmental crises, as demonstrated by the recent Kigali Amendment to the Protocol.

The second part of this study will glance at developing countries by examining Ghana's case study and its role in implementing the objectives of the Montreal Protocol locally. This section will enquire how the risks and vulnerabilities associated with stratospheric ozone depletion have varied between industrialised and developing nations. Hence, it will scrutinise the different solutions implemented in light of the financial assistance mechanisms outlined in the Protocol.

Finally, the last paragraph will build on the sources gathered from the Historical Archives of the European Union and the Luxembourg Historical Archives of the European Parliament. It will explore the perspective of the Global North, emphasising the evolution of the leading position of the European Community / European Union in tackling ozone depletion. By comparing the positions of supranational and intergovernmental institutions, we will assess if the European

Union's environmental legislation on ozone depletion has consistently been among the world's most ambitious.

1. The success of the Montreal Protocol: Analysing the factors behind its universal ratification

Scholars and scientists extensively debated and analysed the Montreal Protocol's (MP) success. When, in the 1970s, scientists first sounded the alarm on ODS, no action ensued. Some States remained suspicious; others considered themselves unconcerned or could not see a benefit in binding to an agreement that reduced their sovereignty or negatively influenced their economy. Despite these divergences, we still managed to reach a protocol of universal ratification. This raises the question: How did the negotiation process unfold, and how did it contribute to our current Protocol?

In this section, we will try to answer these questions. By analysing the literature on the subject, we will add to the typical five factors referred to in the literature - scientific evidence, flexibility, technology transfer, technological substitutes, and the role of NGOs and activists – others additional elements: incentives, compliance, and the leading role of the United States, which makes the understanding of the Protocol's achievement more complete.

1.1. The Vienna Convention for the Protection of the Ozone Layer (1985)

The battle against the thinning of the ozone layer started with the Vienna Convention, which concluded in 1985 and laid down the definitions, principles, and general obligations of the parties involved. Scholars like Gonzalez et al. (2015) and Talbot (1991) widely recognise that, despite its limited scopes, goals, and the lack of specific obligations, the Convention proved the willingness of the international community to cooperate. Cumberlege (2009, p. 311) argues that the Convention served as a preliminary phase that raised awareness and provided us with a frame of the issue but was then going to leave the floor to a more substantive protocol. Indeed, when analysing how most critical international treaties were adopted, it becomes clear that small, incremental obligations are needed to achieve general acceptance. However, although States need to be accommodated, the planet has its own pressing needs.

In 1987, scientific evidence revealed the urgent environmental situation, compelling States to return to the negotiating table they had just left. This time, the protocol was better detailed, and several factors were put in place to grant its effectiveness, namely the scientific evidence, the flexibility of the treaty, the role of the United States, the incentives for participation of the developing countries, the involvement of the different stakeholders, the technological transfer and substitutes.

1.2. The role of science

Science played a significant role in the negotiations, providing evidence of the damages the Ozone Depleting Substances (ODS) were causing and, this way, overcoming the initial scepticism and uncertainty within the international community. While the literature agrees that science played a vital role in the process, extensively praising its centrality and attributing it to almost all of the merits (Abdel-Khalik, 2001; p. 509, 513), Whitesides (2020; p. 3) firmly believes that scholars and the media tend to overstate it. He argues that science's function role was complementary and supported by ulterior factors, particularly the policy response. In his analysis, he continues debunking this general belief, arguing that the United States ratified the Protocol despite scientific uncertainty (Whitesides 2020; p. 3).

In this paper, we agree that science made an essential contribution as a force that guided the negotiations, showing the political urgency of the issue. However, attributing the Protocol's achievement solely to a few factors, such as science, overlooks the complexity of the process. In addition, scholars who emphasise the necessity of the Protocol's flexibility to accommodate evolving scientific knowledge inadvertently acknowledge the limitations of science at the time.

1.3. Flexibility

The concept of flexibility is another widely discussed characteristic of the agreement. Scholars such as Cumberlege (2009) and Gonzalez et al. (2015) argue that initially and intentionally, the Montreal Protocol was not designed as a rigid treaty to secure global participation. Epstein et al. (2014; p.16) state that adopting the incremental approach contributed to convincing the parties to abide by a document that would not reduce their liberty nor jeopardise their economy. Indeed, the Protocol was later enforced by other instruments. Flexibility was desired, even given the eventual evolution of science and economic needs.

We discover the same approach in the Kyoto Protocol, which adopted a similar scheme as Cumberlege (2009) notes. Still, the latter did not prove effective because of a lack of balance between flexibility and enforceability as the MP did.

1. 4. The Role of the United States

Moved by the seriousness of the problem, among the major players on the international scene, the United States has first taken the lead on the issue and undertaken initiatives to combat ozone depletion. Scholars agree that for the treaty to be effective, its adoption and support by the more powerful States is an essential prerequisite. Their influence and diplomatic capacities not only add credibility to the treaty but also tend to pressure smaller States into emulating their actions to contribute to its success. As discussed in the following sections of this paper, the European

Community / European Union will adopt a proactive role only in the latest stages of the negotiations, thereby giving way to US leadership.

Milewicz and Snidal (2016) bring forth the role of the United States in shaping treaties. By contrast, the Kyoto Protocol's effectiveness suffered from the missing US ratification. As Cumberlege (2009) argues, despite the significant participation of no less than 174 countries, it was reported as ineffective and empty of substance as the parties did not fulfil their obligations. Similarly, in January 2020, US President Joe Biden signed the instrument to rejoin the more recent Paris Agreement on climate change. However, President Trump's previous decision to withdraw from this agreement highlighted an apparent inconsistency in the United States' support for climate initiatives and their subsequent negative consequences on the treaties' effectiveness. During the US's absence from the Paris Agreement, other countries and climate research were impacted by the withdrawal of the US's funds (Zhang et al., 2017) and by placing an important burden on other nations to compensate by further reducing their carbon emissions (Dai, Zhang, & Wang, 2017).

The government's inability to tackle climate change globally shows us the importance of the presence of great powers in international treaties. However, their participation is necessary but not enough. Hence, unilateral action proved insufficient within the Montreal Protocol negotiation framework, requiring international cooperation efforts. Therefore, the United States started seeking broader participation (2014).

1.5. Bargaining power of developing nations and incentives for participation

The participation of developing nations was essential for the Protocol. Developing countries formed coalitions to increase their bargaining power. Under the representation of the United Nations Environment Programme (UNEP), they demanded financial assistance and technological transfer as a condition of their participation (Sprinz & Vaahtoranta, 1994).

The principle of common but differentiated responsibilities (CBDR), which recognises that States have different capabilities, was necessary for a fairer share of the burden and for addressing the imbalances between developed and developing countries (Gonzalez et al., 2015). It ensured a more equitable distribution of commitments (Milewicz & Snidal, 2016). For example, China and India agreed to join the treaty after introducing provisions that allowed them to increase their production of ozone-depleting substances for some time while receiving assistance from developed countries.

Scholars analyse these incentives using many different lenses, but they commonly refer to the Prisoner's Dilemma in the case of the cost-benefit of the parties. For example, Sean Cumberlege (2009, p. 324) considers that, by using the incentives, the parties to the Montreal Protocol ensured that payoffs for participation and compliance increased. Payoffs for non-cooperation diminished, and this way, they could counter the Prisoner's Dilemma. The "game theory" also

helps explain unilateral action's feasibility in eliminating ODS. When the ozone hole was discovered, most CFC emissions were concentrated in the US and the EC, making unilateral phases-out effective in addressing the issue. Conversely, because greenhouse gas emissions are globally diffused, no State is willing to take pervasive measures against global warming while other countries emit tons of CO₂. Specifically, Peloso refers to a global "game of the chicken" (2010, p. 315).

Scholars such as Abdel-Khalik (2001) argue that the Montreal Protocol's financial and technological mechanisms created unique incentives for compliance, which other agreements have struggled to replicate. Indeed, the Kyoto Protocol lacked similar strategies, resulting in broad participation. However, that was not followed by the incentivisation of commitment, which led to a lack of concrete action, particularly from developing countries (Cumberlege, 2017; p. 325). These measures underscore the importance of incentives and how they can balance global equity and effectiveness in international environmental agreements.

1.6. Actors' participations

One of the strengths of the Montreal Protocol was its ability to incentivise participation through stakeholder engagement. By contrast, despite its ambitious goals, the Kyoto Protocol failed to create incentives for long-term commitment. Scholars such as Cook (2005; P. 336) argue that the Montreal Protocol integrated stakeholders into its mechanisms, giving them political space to advance their claims. The literature highlights that the broad participation of NGOs, industry, and other stakeholders in the Montreal Protocol was unprecedented compared to other environmental treaties. These actors not only helped shape the treaty but also played a central role in ensuring its implementation. For example, in the case of the European Union, pressure was among the factors that prompted the Council to align with the US's stance. In addition to these actors, as we will explore further in the final section of our paper, the European Parliament is another actor whose action served as a catalyst force for change. Often overlooked by scholars, the EP pushed for more action within the EC, going against the willingness of other institutions to proceed cautiously.

However, while this multi-stakeholder approach has been widely praised, some scholars have noted that the model is not easily applicable in other contexts, such as climate change, where the scale and scope of action required is significantly greater (Cumberlege, 2017).

1.7. Technological substitutes

The claim that the Montreal Protocol succeeded because there were affordable, adequate substitutes for ozone-depleting substances (ODS) is another idea widely advanced by scholars (Abdel-Khalik, 2001). The ability of industries to start using inexpensive alternatives did

facilitate compliance. Still, as for science, it could not make a difference without the combination of all the factors we have seen. The literature typically underlines five key factors that contributed to the Protocol's success: science, flexibility, technology transfer, technological substitutes, and the role of NGOs and activists. These factors played a key role in many aspects, especially in the European context. Still, while they are put forward and considered as the only factors for the success of the Protocol negotiations, a smaller group of scholars also highlight additional elements: incentives, compliance, and the leading role of the United States, which makes the understanding of the Protocol's achievement more complete.

2. Ghana as a case study

UNEP (2023) asserts that developed countries have been the most advanced in implementing regulations on environmental protection due to their enhanced energy efficiency standards. Nonetheless, developing countries have also shown a trajectory of success in ensuring the phasing out of ODS (Okley, 2004). Among these is Ghana's success story, which recorded an early achievement in phasing out ODS to align accurately with the objectives of the Montreal Protocol.

UNEP (1997) indicates factors that led to Ghana's early achievements. Firstly, the most significant contributors to ODS were identified in the economy. These were refrigerators and foam factories. As part of the strategies, steps to reduce the production of ODS from these factories were initiated: to impose taxes on refrigerators that emit CFC, to give tax-free duty for refrigerators that do not emit CFC and assemble technologies to be used in foam factories that do not emit ODS. Secondly, policy development and awareness campaigns were issued. Policies included regulatory frameworks for the release of ODS. These laws include: Export and Import Act, 1995 (Act 503), Customs Act (As Amended) 2015 (ACT 891), Environmental Protection Agency Act, 1994 (Act 490): Management of Ozone Depleting Substances and Products Regulations, 2005 (LI 1812) and Energy Commission - Energy Efficiency Regulation, 2008 (LI 1932).

More importantly, there was an office called the National Ozone Office to effectively implement the strategies adopted by the Environmental Protection Agency (UNDP, 2014). The awareness campaigns included the media, students and lecturers from tertiary institutions and representatives from the factories trained to resonate the depleting status of the ozone. Aside from the 1990 meeting of member states to improve the Montreal Protocol, Ghana was involved in other meetings to support the phase out of ODS.

2.1. The interconnected relationship between the EU and Ghana regarding the Montreal Protocol

The economic dimension of the EU is a strong component of the outfit serving as a regional economic integration body; its role in the Montreal Protocol significantly hangs on its capacity as an integrative body rather than a signatory of the Montreal Protocol (Ojonugwa & Arthur-Jolasinmi, 2024; Scott, 2004).

Concerning regulations and frameworks, the EU has more stringent measures to phase out ODS (Næs, 2004). The EU implemented a more robust framework that is beyond the Montreal Protocol and includes five additional substances that were not included in the Montreal Protocol (EEA, 2016). Owing to this, Ghana also adopted regulations and frameworks with the Management of ODS and Products Regulations, 2005 (LI 1812) directly addressing the management of ODS, detailing prohibitions on their production, import, export, and use.

The EU functions as an independent financial entity and possesses significant financial power. As such, it contributes to the Multilateral Fund for the implementation of the Montreal Protocol, which provides financial assistance to countries in the phasing out of ODS. Conversely, Ghana is a beneficiary of the Multilateral Fund and heavily relies on funding to implement strategies to phase out ODS (Abor et al., 2024).

The EU organises training programs and workshops to enhance the technical capacity of member countries, such as Ghanaian officials, to enable them to implement ozone layer protection strategies adequately (Palmer, 2007).

The European Union's multifaceted support for developing countries like Ghana underlines its commitment to global environmental governance through the Montreal Protocol. By providing financial resources, technical expertise, and policy guidance, the EU is crucial in enabling Ghana to phase out ozone-depleting substances while pursuing sustainable development goals effectively. This collaborative approach not only aids compliance but also fosters long-term environmental sustainability in Ghana.

3. From Precaution to Leadership: The European Union's Role in Ozone Layer Protection

The European Union's environmental legislation is currently among the most ambitious in the world. Internally, EU regulations have addressed the challenges covered within the Planetary Boundaries framework, thus also covering stratospheric ozone depletion. By 2007, EU Member States had already phased out hydrofluorocarbons (European Communities, 2007). This remarkable result was also possible because EU institutions have constantly updated their normative acts according to the newest scientific evidence. At the same time, by setting pioneering environmental goals, the European Union has positioned itself as a model in the international arena and a reliable partner for developing countries, as Ghana's case study shows. However, although the limits established by the current ozone depletion regulation surpass those of the Montreal Protocol, the EU's role in protecting the ozone layer has evolved significantly, shifting from a precautionary approach to a proactive leadership position over time.

This section aims to explore this transition in detail, analysing the role of the different European Community (EC) institutions in shaping the ozone depletion framework both on an internal and external level. Existing studies on the precautionary position of the EC during the early stages of the Montreal Protocol negotiations neglect the distinction between supranational and intergovernmental institutions. In this research, we expect to demonstrate how their opposite behaviours led to an initially incoherent approach. Moreover, in highlighting the current active role of the EU in protecting the ozone layer, we will discuss how the EU leveraged the structure and effectiveness of the Montreal Protocol to mitigate climate change, anticipating the Kigali Amendment.

After Mario J. Molina and Sherwood Rowland first warned that increased emissions of CFCs were harming the ozone layer in 1974, the media coverage on the issue was more robust in the United States than in Europe. By the following year, a notable shift in consumer behaviour caused the aerosol spray demand to halve in the U.S., whereas European public opinion continued to disregard the issue (Peloso, 2010, p. 311). At the same time, U.S. administrations began banning chlorofluorocarbons at both local and federal levels. Hence, as argued in the previous paragraphs, the U.S. found itself at the forefront of the fight against ozone-depleting substances when multilateral negotiations started within the UN framework. According to most scholars, their advocacy for strict regulation harshly contrasted with the reluctant and incoherent approach adopted by the European Community. These divisions first emerged within the Working Group that UNEP launched after the committee of experts provided the executive summary of the state of the ozone layer in 1981, as established by the UNEP Governing Council. Some EU Member States argued the need to gather more data on this phenomenon and better reflect upon its possible alternative causes before setting CFC limits. The costs of phasing down ozone-depleting substances were considered extremely high since the European Community accounted for 43% to 45% of the world's CFC emissions in 1986 while being at the same time the most significant exporter of CFCs to the developing world (Barret-Brown, 1991, p. 523).

Nevertheless, when analysing the position of the European Community during the early stages of multilateral ozone depletion negotiations, it is appropriate to distinguish between intergovernmental and supranational institutions. Within the Council, the diverse views among the then twelve Member States sharply contrasted with the EC's proclaimed will to speak with one voice, resulting in sharp criticism on the U.S. side. While countries such as West Germany supported a CFC phase-out, others bent to the pressure of the lobbying activities carried out by the chemical sector, most notably Britain's Imperial Chemical Industries (ICI) and France's Atochem (Barrett-Brown, 1991, p. 524). However, although the Council defined the negotiating mandate for the Commission, other bodies influenced the switch in the E.C.'s stance. In particular, the European Parliament (EP) consistently called for a rapid phase-out of ozone-depleting substances. The Luxembourg Historical Archives of the European Parliament offer multiple examples in this sense. On 17 November 1976, Deputy Nielsen Brondlung addressed the first ozone-related interrogation to the then Vice-president of the Commission. In his response, attempting to mediate between the E.P. and the Council, Carlo Scarascia Mugnozza

recognised the legitimacy of the new scientific studies' concerns on human health. Regardless, given the existence of divergent findings, he upheld the need to proceed cautiously, financing more research first (Historical Archives of the European Parliament, 1976). Thenceforth, particularly after the first direct elections held in 1979, individual deputies and groups presented several resolution proposals asserting the need for a more incisive approach by E.C. institutions. Besides, many of them submitted several oral and written interrogations to the Commission, whose position gradually aligned with the Parliament's (See, for example, Historical Archives of the European Parliament, 1986). On 19 September 1980, for instance, the new Vice-President, Lorenzo Natali, agreed with Ms Weber's apprehension on the newest alarming findings on ozone depletion (Historical Archives of the European Parliament, 1980). Ultimately, within the UNEP framework, the Commission vainly recommended halving aerosols by 50% by 1983. (Barret-Brown, 1991, p. 524).

Over time, more studies were published demonstrating the connection between CFCs and ozone layer depletion. Moreover, the activism of supranational institutions, along with the efforts of NGOs such as Greenpeace and Friends of the Earth, prompted the Council to adopt a unified stance that aligned with the position of the United States. A key turning point in this sense was Bonn's announcement to phase down CFCs by 95% (Barret Brown, 1990, p. 529). As a result, in 1987, the European Economic Community formally joined the Montreal Protocol following the ratification by all twelve of its Member States.

Thenceforth, the European Community/European Union has played a pivotal role in securing the effective implementation of the Protocol and its successive Amendments. According to the Maastricht Treaty, in December 1994, following the advisory opinion of the European Parliament, the Council adopted the first Regulation on ozone-depleting substances. The 3093/94 Regulation set limits on the production, trade, supply, use and recovery of ozone-depleting substances. Specifically, it addressed chlorofluorocarbons, halons, carbon tetrachloride, trichloroethane, methyl bromide, hydrobromofluorocarbons and hydrochlorofluorocarbons (Council of the European Union, 1994. Article 1). To ensure compliance, the Regulation (E.C.) No 3093/94 also envisaged a monitoring scheme consisting of the periodic submission of MS government reports and eventual inspections (Article 18). However, Commission investigations would have taken place only with the agreement of the Member State's designed authorities, who were also in charge of defining the applicable infringement sanctions (Article 19).

After subsequent amendments, the current Regulation entered into force on 11 March 2024, after the European Parliament's position and the decision of the Council. MSs maintain the prerogative to set penalties in case of violation of the Regulation (European Union, 2024, Article 27). Exceptions to the total phase-out of ozone-depleting substances are guaranteed for limited industrial processes, such as firefighting and scientific uses (European Environment Agency, 2024).

Transcending the Montreal Protocol requirements regarding phasing out time schedules and the number of substances involved, these regulations demonstrate the switch in the EU's position on the topic. Moreover, their continuous amendments show the will to keep the process updated

according to new scientific findings. The results of this commitment are tangible, as already under the previous Regulation (E.C.) No 1005/2009, the production and trade of ozone-depleting substances had almost been phased out (European Union, 2024, recital 9).

Additionally, the European Union is now at the forefront of leveraging the Montreal Protocol of the Vienna Convention for the protection of the ozone layer to mitigate climate change. On 14 September 2011, the European Parliament adopted a resolution asserting the need for a more comprehensive climate policy (European Parliament, 2011).

On the one hand, the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) only included some greenhouse gas emissions, leaving aside other global warming halocarbons covered by the Montreal Protocol¹. Besides, some chemicals, such as carbon monoxide (CO), nitrogen oxides (NO_x), methane, and volatile organic compounds (VOCs), led to the formation of an ozone type which remained trapped in the troposphere instead of reaching the upper stratosphere, thus contributing to global warming (European Parliament, 2011, Recital E). Following this need for a comprehensive strategy in facing environmental threats, the European institutions adopted Regulation (EU) No. 517/2014. This act aimed at mitigating climate change while protecting the ozone layer by regulating fluorinated greenhouse gases (F-gases), whose usage had increased after banning ODSs. The Regulation focused on hydrofluorocarbons, establishing rules for the containment, usage, recovery, and destruction of F-gases (Regulation|EU 517/2014).

The EU thus anticipated the UNEP adoption of the Kigali Amendment to the Montreal Protocol on a multilateral scale. Nonetheless, when the Amendment entered into force in 2019, various environmental NGOs strongly advocated for a revised and stricter EU Regulation. In light of the European Climate Law, the new Regulation/EU No. 2024/573 on F-gases entered into force on 11 March 2024, marking the world's first HFCs phase-out mandate, expected by 2050 (Environmental Investigation Agency, 2024). To ensure compliance with the Kigali Amendment, the EU revised its quota system, including additional F-gas-related products and more stringent trade limits. Moreover, digitalised and automatised instruments will be introduced to facilitate monitoring activities. Additionally, the regulation recognises the importance of international cooperation when addressing transnational threats. Ultimately, the EU is currently the leader in eliminating hydrofluorocarbons (European Commission, n.d. -a). This achievement underscores the EU's full commitment to its environmental objectives.

In conclusion, these latest evolutions emphasise the need for a global approach when dealing with intertwined transnational environmental challenges.

Conclusion

The Montreal Protocol has been recognised as a successful agreement for several reasons. Firstly, because of its apparent results, i.e. not only has depletion stopped increasing, but the

¹ The Kyoto Protocol (1997) under the UNFCCC primarily focused on reducing six greenhouse gases, including CO₂, CH₄ (methane), N₂O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), and SF₆ (sulfur hexafluoride).

stratospheric ozone layer is recovering, and it is hoped that efforts will continue for full restoration. Secondly, the MP has been able to engage the whole international community in addressing the issue. It has succeeded in bringing the planetary urgency to the fore and in reconciling politics and science. The instruments adopted, such as incentives for developing countries, the possibility of participation by different actors such as NGOs, activists, and industries, the flexibility of the Protocol in the face of evolving science and States' skepticism, the availability of affordable chemical substitutes, as well as the critical role of the United States, led to the result we know today. We could observe these instruments in function in our case study of Ghana. Ghana, like other developing countries, with the help of the UNDP, could take advantage of the Multilateral Fund and create a plan to involve local partners in combating the presence of ozone-depleting substances. Ghana has effectively tackled the problem. Starting with the taxation of manufacturers that emitted CFCs and later using awareness campaigns, the approach has evolved to include a list of legal and policy instruments that seek to protect the ozone layer.

Choosing Ghana as a case study and observing its response to the problem gives us a general picture of other developing countries and the tools available to help them close the gap with the developed world.

Through the framework and the holistic view we have set up in this paper, we have been able to answer the question: What factors led to this outcome?

On the other hand, as regards the role of the European Union, we have found that, contrary to our expectations, the European Community has not always played a proactive role in mitigating stratospheric ozone depletion. With internal cacophony, it has not been possible to address ozone depletion coherently, let alone lead the international community. In the beginning, there were disagreements between the Member States and at different institutional levels, particularly counterposing intergovernmental and supranational bodies. Specifically, the European Parliament always called for an ambitious phase-out of ozone-depleting substances. Hence, this research not only explains how the opposite behaviours of different institutions led to an initially incoherent approach, but it also argues that supranational bodies played a significant role in changing the EC position. The EC eventually acceded to the Protocol also thanks to the growing body of scientific evidence and pressure from NGOs and other actors on governments, but the role of the EP should not be overlooked. Initially, the community played a timid role by slowly adopting regulations and later amendments, ending up adopting more and more of them or updating them according to science, changing its position and making evident its proactive role. This is also evident in the efforts to comply with the regulations of the Kigali Amendment. By analysing the archives, primary sources, and the various regulations mentioned, we can see how the EC/ EU has gone from being a heterogeneous entity unable to tackle the issue to having some of the most ambitious environmental legislation in the world and now leading the way in the phase-out of CFCs. However, the tools we have today and the efforts we have made so far should not lead us to rest on our laurels. On the contrary, we must continue our efforts because, let us not forget, the problem persists and legal and political instruments are only as effective as the

actions behind them.

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IEVE

9. The crude oil paradox: navigating the legal challenges of novel entities in nigeria's niger delta region

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THE CRUDE OIL PARADOX: NAVIGATING THE LEGAL CHALLENGES OF NOVEL ENTITIES
IN NIGERIA'S NIGER DELTA REGION

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Abstract.

This paper assesses the far-reaching impacts of oil pollution in the Niger Delta, focusing on the increasing wave of ecological and climate litigation in response to these threats. Specifically, the paper examines the landmark *Centre for Oil Pollution Watch (COPW) v. Nigerian National Petroleum Corporation (NNPC)* case within the framework of novel entities and environmental law. In a significant 2018 ruling, the Nigerian Supreme Court granted COPW *locus standi* to sue NNPC over extensive contamination caused by oil spills in the Ineh and Aku streams. This decision is pivotal, as it broadens locus standi for NGOs in environmental public interest cases, especially where pollutants—such as hydrocarbons, oil pollutants heavy metals, and other industrial byproducts—qualify as novel entities.

KEYWORDS: Novel Entities, Niger delta, Litigation

I. INTRODUCTION

The *Centre for Oil Pollution Watch (COPW) vs. Nigerian National Petroleum Corporation (NNPC)*¹ cases have become a watershed in the climate and environmental litigation in Nigeria, especially in the Niger Delta Region (NDR) where oil spill has caused serious environmental challenges. In past 60 years, NDR served as the country's economic powerhouse contributing over 45 percent of its GDP and accounting for 95 percent of foreign earnings through crude oil production.² Nigeria ranks as the 11th largest producer of crude oil globally, with potential for further production having a proven reserve of approximately 37 billion barrels.³

Crude oil remains Nigeria's primary source of revenue, particularly as the agricultural sector faces severe challenges. Despite the country's heavy reliance on oil and gas, both the government and international oil corporations operating in the region have largely failed to address the numerous adverse effects of oil spill. This negligence has led to severe environmental degradation, deforestation, loss of biodiversity, and the disruption of local ecosystems resulting to various environmental litigations cases.⁴ This study highlights how novel entities creates potential for litigations and reputational risks against government institutions, international corporations and stakeholders. It examined the landmark cases between the *Centre for Oil Pollution Watch (COPW) a non-governmental organization (NGO) vs. Nigerian National*

¹ Mbadugha JN 'Environmental Public Interest Litigation in Nigeria: A Case Comment on *Centre for Oil Pollution Watch v Nigerian National Petroleum Corporation*' (2021) 11 *Nnamdi Azikiwe University, Awka Journal of Public and Private Law*.

² Omojimite BU 'The Economic Dimensions of the Niger Delta Ethnic Conflicts' *International Association of African Researchers and Reviewers* (2011) 5(5) 46–55 DOI: 10.4314/afrev.v5i5.5.; Nwaoburu LE 'Economy of the Niger Delta, Militancy and Class Struggle' *International Journal of Political Science and Governance* (2023) 5(2) 88–93.; World Bank. *Taxation and State Participation in Nigeria's Oil and Gas Sector* (Energy Sector Management Assistance Programme Technical Paper No. ESM 057 2004) available at <http://hdl.handle.net/10986/18078>.

³ OPEC *Annual Statistical Bulletin 2023* (OPEC, 2023); Sasu DD 'Contribution of Oil and Natural Gas Sector to GDP in Nigeria 2010–2023' *Statista* (August 2024) available at <https://www.statista.com/statistics/1165865/contribution-of-oil-sector-to-gdp-in-nigeria/> (accessed 10 November 2024).

⁴ *Centre for Oil Pollution Watch v Nigerian National Petroleum Corporation* (2018) SC/150/2014 (Supreme Court of Nigeria).; *Bowoto v Chevron Corp*, 557 F. Supp. 2d 1080 (N.D. Cal. 2008).; *Wiwa v Royal Dutch Petroleum Co*, 226 F.3d 88 (2d Cir. 2000).; *Kiobel v Royal Dutch Petroleum Co*, 569 U.S. 108 (2013). For discussion on this cases see Ochei NV, Ezeani EC & Anderson C 'Mechanisms Used by Multinational Oil Companies to Derail Human Rights and Environmental Litigations Arising from the Niger Delta' (2023) *African Journal of Legal Studies* 15(2) 185–214 available at <https://doi.org/10.1163/17087384-bja10075>; CETIM *Cases of Environmental Human Rights Violations by Shell in Nigeria's Niger Delta* (2014) available at <https://www.cetim.ch/cases-of-environmental-human-rights-violations-by-shell-in-nigeria%E2%80%99s-niger-delta/> (accessed 10 November 2024); Sabin Center for Climate Change Law 'Climate Litigation in Nigeria' (2024) available at <https://climatecasechart.com/non-us-principle-law/nigeria/> accessed 19 November 2024.

Petroleum Corporation (NNPC) case within the framework of novel entities and environmental law.

II. CONCEPTUAL CLARIFICATION

Novel entities are broadly recognized within the framework of the nine planetary boundaries, which are thresholds to which the Earth system can be critically impacted by human activities.⁵ Among these boundaries, land system changes, such as deforestation is viewed as a control variable and any activity contributing to it reductions, including crude oil spills can thus be evaluated within this framework. This paper thus identifies crude oil spill as a novel entity although Richardson et al. (2023) argues that novel entities are primarily synthetic chemicals,⁶ this paper submit that such a definition is too narrow. Crude oil spills, though originates from natural deposits, introduce chemicals that can significantly disrupt the environments into which they are introduced.⁷

In regions like the Niger Delta, where synthetic chemicals such as nuclear materials are less likely to occur, the environmental impact of oil spills must still be addressed. Hence, by restricting the definition of novel entities to synthetic chemicals, critical pollutants like crude oil would be omitted from planetary boundary considerations. Historical evidence supports this inclusion, as previous studies in the NDR reveal that the environmental degradation and biodiversity loss observed were absent prior to crude oil exploration in the region.⁸

Thus, this paper defines novel entities as: *“things or chemicals created or introduced into the environment by human activities that disrupt the earth system”* These may include synthetic chemicals, organic pollutants, carbon, radioactive materials, genetically modified organisms, nano-materials, and microplastics. Under this definition, crude oil spills which is a complex

⁵Rockström J et al 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity' Ecology and Society (2009) 14(2) 32 available at <http://www.ecologyandsociety.org/vol14/iss2/art32/> (accessed 10 November 2024).; Steffen W et al "Planetary Boundaries: Guiding Human Development on a Changing Planet" Science (2015) 347 DOI:10.1126/science.1259855.; Richardson K et al 'Novel Entities and Planetary Boundaries' Science Advances (2023) 9eadh2458.

⁶Ibid

⁷Novakovskiy A et al 'Long-Term Dynamics of Plant Communities After Biological Remediation of Oil-Contaminated Soils in Far North' Scientific Reports (2021) 11 4888 DOI: 10.1038/s41598-021-84226-5; Jacobson RS, Korte AR, Vertes A, and Miller JH 'The Molecular Composition of Soot' Angewandte Chemie International Edition (2020) 59 4484–4490;

⁸Nwaoburu LE cite note 1

pollutant comprising hydrocarbons, organic compounds, and trace of other elements, qualify as novel entity since it can interfere with biophysical and biochemical processes that regulate planetary stability.⁹

As of today, crude oil remains the most relied-upon source of energy globally and the dependence on it has led to persistent oil spillages, which need to be managed within a safe threshold to mitigate its adverse impacts on human health, and the environment. Unfortunately, in the NDR, these safe thresholds have been largely absent. Unchecked oil spills, driven by the negligent actions of international oil corporations, illegal crude oil refining, and acts of sabotage, have surpassed the region's ecological carrying capacity, crossing its planetary boundaries.¹⁰ The resulting consequences are profound, including water contamination, loss of biodiversity, deteriorating public health, and severe socio-economic challenges.¹¹

Crude oil as a novel entity poses unique challenges. The processes of extraction, refining, and storing it releases greenhouse gas, cause air and water pollution disrupting environmental systems at the sub-global level pushing the NDR ecology to it collapse.¹²

III. AN OVERVIEW OF THE NIGER DELTA REGION

The NDR is located in the southern part of Nigeria, serving as the discharge point for numerous rivers flowing from the north part of the country into the Atlantic Ocean. The region is characterized by vast stretches of mangrove forests, tropical rainforests, meandering rivers,

⁹Novakovskiy A et al cite note 6

¹⁰Baker JM 'The Effects of Oils on Plants' *Environmental Pollution* (1970) 1(1) 27–44 DOI: 10.1016/0013-932(70)90004-2; Jacob OJ et al 'Oil Spillage in Nigeria's Coastal Waters: Review of Causes, Effects and Mitigation' *IIARD International Journal of Geography & Environmental Management* (2024) 10(3) 370–412 DOI:10.56201/ijgem.v10.no3.2024.pg370.412; Balogun TF 'Mapping Impacts of Crude Oil Theft and Illegal Refineries on Mangrove of Nigeria's Niger Delta with Remote Sensing Technology' *Mediterranean Journal of Social Sciences* (2015) 6 150–153.

¹¹Jacob OJ et al cite note 10; Ordinioha B & Brisibe S 'The human health implications of crude oil spills in the Niger Delta, Nigeria: An interpretation of published studies' (2013) *Nigerian Medical Journal* 54(1) 10–16 available at <https://doi.org/10.4103/0300-1652.108887>; Kalagbor IA et al 'Exposure to Heavy Metals in Soot Samples and Cancer Assessment in Port Harcourt, Nigeria' *Journal of Health and Pollution* (2019) 9(24).

¹²'Nigeria: Cancer-Causing Black Soot Assails Port Harcourt, Residents Panic' *Sweet Crude Reports* (11 February 2017) available at <http://sweetcrudereports.com/2017/02/11/nigeria-cancer-causing-black-soot-assailport-harcourtresidents-panic/> (accessed 10 November 2024).

creeks, and estuaries. These unique ecosystems are rich in crude oil and hydrocarbon deposits, making the NDR a critical hub for Nigeria's oil and gas industry.¹³

Historically, the region has been a hub for commerce and economic activities. Between the 15th and early 19th century, the Niger Delta was a major region for Portuguese-led European explorers who engaged in the transatlantic slave trade. By the 19th century, as the global demand shifted from human labor to commodities like palm oil, rubber, and other cash crops became the region's principal exports, with the British controlling trade activities.¹⁴ The discovery of crude oil in the 20th century marked another transformative era for the region, altering its economic and environmental landscape making it the epicenter of Nigeria's oil and gas industry.

IV. CRUDE OIL AS A NOVEL ENTITY

Novel entities in the Niger Delta region of Nigeria are intrinsically linked to crude oil and hydrocarbon exploration, with oil spills forming one of the ways it interacts with the environmental. This argument is supported by numerous scholarly works which have examined the impact of crude oil operations in the region, highlighting that sustained oil spills threaten to push the planetary boundaries beyond thresholds manageable by the environment.

Oil spills in the NDR, have led to critical environmental degradation with immediate and long-term ecological and economic consequences,¹⁵ disrupting food chains. Oil droplets continue to sink to the seabed long after a spill, altering sedimentation rates.¹⁶ On land, oil spills cause severe long-term damage to vegetation, interfering with photosynthesis leading to morphological and anatomical changes in plants.¹⁷ Additionally, oil spills seeps into the soil, contaminating surface and groundwater rendering it unsuitable for irrigation. Works of J.M. Baker, Nothers et

¹³Balogun TF cite note 9

¹⁴Francis CO, Agomuo KO, and Chukwulet CO 'The Niger Delta in Historical Perspective, 1800–1960' *IMPACT: International Journal of Research in Humanities, Arts and Literature* (2021) 9(4) 75–86.

¹⁵ Ukhurebor KE, et al 'Petroleum spills and the communicative response from petroleum agencies and companies: Impact assessment from the Niger Delta Region of Nigeria' (2023) *The Extractive Industries and Society* 15 101331 available at <https://doi.org/10.1016/j.exis.2023.101331>.

¹⁶Larson RA et al 'High-Resolution Investigation of Event-Driven Sedimentation: Northeastern Gulf of Mexico' *Anthropocene* (2018) 24 40–50 DOI:10.1016/j.ancene.2018.11.002.

¹⁷Abosede EE 'Effects of Crude Oil Pollution on Some Soil Physical Properties' *Journal of Agriculture and Veterinary Science* (2013) 6(3) 14–17.

al, and Novakovskiy et al have documented these impacts, emphasizing the urgent need for effective prevention and remediation measures.¹⁸

The discovery of oil in Oloibiri, Bayelsa State, in 1956 transformed Nigeria's economy but led to severe environmental degradation in the Niger Delta Region (NDR) due to oil spills. Nigeria ranks among the top 10 countries globally for oil spills, with over 12 million barrels of crude oil spilled since 1958, averaging approximately 240,000 barrels annually. Data from the Nigerian Oil Spill Monitor, based on records from the National Oil Spill Detection and Response Agency (NOSDRA), reveals 13,800 oil spill incidents between January 2010 and November 2024, resulting in 630,525.37 barrels of crude oil spilled.¹⁹ These spills have had devastating impacts on biodiversity, as well as the socio-economic lives of affected communities.²⁰

In the 1990s, widespread environmental degradation in the NDR, gave rise to protests across the region as groups advocates for environmental justice. Ken-Saro Wiwa led Movement for the Survival of the Ogoni People (MOSOP), launched a peaceful campaign in 1990 aimed at halting Shell's activities, which were causing extensive damage to their natural environment. The protest gained significant international attention, with a global demand for shell to provide environmental cleanup, pay a fair compensation and equitable royalties to the affected oil-producing communities.²¹

Decades of oil spills have affected lives in the NDR, leaving communities who rely on marine and forest resources for their livelihoods impoverished. In year 2000 and 2001, Shell Petroleum Development Company (SPDC) pipeline spilled over 120,000 barrels of crude oil in Ogbodo-Isiokpo community of Rivers State devastating marine life, contaminating soil and water, and causing long-term environmental damage.

Between 2004 to 2007, oil spills from Shell severely impacted the fish ponds and agricultural lands in the Bodo and Goi communities. A major spill occurred in 2004 from the

¹⁸See Baker JM cite note 10; Novakovskiy A et al note 6; Nothers M et al 'Desert Vegetation Forty Years After an Oil Spill' *Journal of Environmental Quality* (2017) 46(3) 568–575 DOI: 10.2134/jeq2016.03.0078.

¹⁹ *Nigerian Oil Spill Monitor* (2024) available at <https://oilspillmonitor.ng/> accessed on 15 November 2024.

²⁰ Obuah EE & Keke RC 'Mitigating the Negative Externalities of Oil Drilling Activities in the Niger Delta, Nigeria' (2022) *Open Access Library Journal* 9 1–21 available at <https://doi.org/10.4236/oalib.1108629>.

²¹ Osha S *Ken Saro-Wiwa's Shadow: Politics, Nationalism and the Ogoni Protest Movement* 3rd ed (2021) Cambridge Scholars Publishing.

Trans-Niger pipeline, which traverses Ogoniland to the Bonny Export Terminal. In 2005, the Oruma community in Bayelsa State experienced oil spill from Shell's facility, resulting in the destruction of fish ponds, farms, and trees. Similarly, the 2007 Ikot Ada oil spill led to pollution of farmlands, ponds in the affected communities. Oil spills in the region has also been exacerbated by oil theft and pipeline vandalism. These incidents promoted litigation efforts, both within and beyond Nigeria, calling attention to corporate accountability and environmental justice.

The cumulative environmental, economic, and social costs of oil spills underscore the urgent need for robust climate litigation legal frameworks and the expansion of the *locus standi* on environmental issues. Beyond litigation, achieving effective environmental and address the far-reaching impacts of oil spills management in the Niger Delta will require stronger enforcement mechanisms, corporate accountability, and international cooperation.

V. COPW V. NNPC: A CASE OF PERSISTENT POLLUTION AND LOCUS STANDI

In the light of above, the Nigerian Supreme Court employed climate litigation as a tool for environmental management in the notable case of *Centre for Oil Pollution Watch (COPW) v. Nigerian National Petroleum Corporation (NNPC)*. In this case, the appellant (COPW) a Nigerian non-governmental organization focused on, *inter alia*, environmental advocacy, specifically in the restoration and remediation of environments impaired by oil spills and pollution.

The respondent in the suit is NNPC, Nigeria national oil company and the largest in Africa, established by an Act of Parliament. That engages extensively in prospecting, exploration, production, and storage of hydrocarbons, including crude oil. NNPC's operations span across Nigeria, with installations of oil pipelines, rigs, and other infrastructures.

The Supreme Court judgment on this matter as regards climate litigation in Nigeria is relevant to this paper not only because it addresses the challenge of oil pollution in the NDR, but it sets a precedent for other cases involving novel entities and environmental degradation through the expansion of the *locus standi in judicio* to private citizens and NGOs. Previously, litigations on environmental related matter have always been considered public nuisance and courts have

thrown out cases on lack of merit or that the plaintiff has not suffered any injury above the general public.²²

The *locus standi* doctrine refers to the legal right of an individual to stand a sue in a court. Traditionally, its rule postulates that to possess the title to sue, “a person must show interest that is sufficient in the subject matter of the intended suit to enable him to sue.”²³ In Nigeria legal context the restrictive definition of *locus standi* adopted by the courts a quo in this litigation is in accordance with other non-environmental rules of the Supreme Court. It implies that “only the person who has suffered a specific legal injury by reason of an actual or threatened violation of his legal right or legally protected interest can bring an action for judicial readdress”.²⁴ However, in this case, the Court adopted a more complex decision, amplifying the possibilities of the mitigation of novel entities, as enlightened above.

The claims:

- i. The appellant, an NGO, filed suit at the Federal High Court, Lagos, seeking reinstatement, restoration, and remediation of the oil-contaminated environment in the Acha community, specifically Ineh and Aku streams, which were allegedly damaged by NNPC's negligent oil spill.
- ii. In 2003, the appellant observed crude oil in Ineh and Aku streams, overflowing into surrounding lands and waterways. The rivers were the only source of water supply in the region. An investigation revealed the rupture of NNPC's oil pipeline, leading to extensive pollution
- iii. According to the appellant, the respondent only stopped the spillage, without cleaning the rivers. The appellant claimed that the spill, resulting from NNPC's negligence in maintenance, adversely affected marine life, human health, and the usability of water from the local streams. Also, a reduction in amenities and economic activities was noticed.

²² *Amos v Shell B-P Petroleum Company Nig Ltd* [1977]LPELR – 74892 (SC) pages 7-8 para E-B.

²³ Achikeh, C., & Akpunonu, A. C. (2015). Standing to sue: A review of the doctrine of locus standi in Nigerian jurisprudence. *Madonna University Law Journal of Commercial, Private and Industrial Law-COPIL*, 1(1), 61-71.

²⁴ Centre for Oil Pollution Watch (COPW) v. Nigerian National Petroleum Corporation (NNPC) (2018) SC. 319/2013, Supreme Court of Nigeria.

- iv. NNPC denied responsibility, attributing the spill to sabotage by individuals in the community. NNPC also contested the appellant's *locus standi*, requesting dismissal on this legal ground.
- v. The trial court ruled in favor of NNPC, dismissing the case for lack of *locus standi*. The Court of Appeal upheld this decision, prompting the appellant to seek final recourse with the Supreme Court.

COPW argues that previous decisions did not consider that the action was devoid of any private interest while the plaintiff has a “*genuine concern for the environment, particularly the unowned environment, and maintained the suit for the interest of the public*”.²⁵ In addition, it argues that in view of Section 6 of the Constitution²⁶, every Nigerian citizen has the *locus standi* to present an action on any issue regarding their civil rights; and allowing this action would also mean vindicating the rule of law, in specific the provisions of the Federal Environmental Protection Agency Act.²⁷

Finally, the NGO contested that if the appeal is denied the right to stand, it is unlikely that any other person would sue NNPC for the environmental damages, letting it without remediation. Therefore, the cited circumstances would justify an exceptional approach of the court regarding the *locus standi*. Especially because, according to the council's appellant, the principle of the “*sufficient interest in a subject matter of having suffered any injury above other members of the society as a determinant of locus standi*”²⁸ is typical of the common law legal system, which Nigeria inherited from the United Kingdom – a country who already expanded its meaning of *locus standi* in similar cases.

²⁵*Ibidem*.

²⁶ Section 6(6) of the Nigerian Constitution defines the scope of judicial power vested in the courts. It empowers courts to decide on issues and enforce laws concerning any justiciable matter, meaning they can hear cases involving enforceable rights or legal obligations. However, this section is often interpreted to limit court cases to individuals or parties with a direct, personal interest in the matter, affecting *locus standi* (legal standing) by generally restricting who can bring a case.

²⁷The appellant cited Sections 5, 26, 27, and 41 of the Federal Environmental Protection Agency Act, emphasizing the duty of the Federal Environmental Agency to punish or persecute offenders or pollutions of the environment.

²⁸*Centre for Oil Pollution Watch (COPW) v. Nigerian National Petroleum Corporation (NNPC)* (2018) SC. 319/2013, Supreme Court of Nigeria.

On the other hand, the NNPC, who responded briefly, based its arguments on the narrow definition of *locus standi*, claiming the reference of Section 6 (6) of the 1999 constitution was inadequate due to the rule of the Supreme Court in *Adesanya*.²⁹

The decision:

To rule its decision, the Court recalled the roots of *locus standi* in common law jurisprudence through the sentence *Ex parte Sidebotham. Re Sidebotham*, inherited by Nigeria. According to the sentence, the right to stand a claim is reserved only to a “person aggrieved”, meaning a person “*who has suffered a legal grievance, a man against whom a decision has been pronounced which has wrongfully deprived him of something, or wrongfully refused him something, or wrongfully affected his title to something.*” In the Nigerian case, the application of *locus standi* depends on if the person has shown *sufficient interest* in the subject matter. The “*sufficient interest*” requirement is a broad term without clear legal meaning. Indeed, the vacuum in the description of the requirements to sue in Nigeria was an object of many sentences and debates. For instance, according to recent sentences:

*“What constitutes sufficient interest is one of mixed facts and law, that is, a question of fact and the degree of relationship between the applicant and the matter to which the application relates. The term interest should not be given a narrow construction but should be regarded as including any connection, association or inter-relation between the applicant and the matter to which the applicant relates.”*³⁰

To define the question of the *locus standi* to NGOs in environmental controversies, the Supreme Court invited five *amici curiae*³¹ to address the *locus standi* of NGOs concerning environmental degradation issues. Their position was divided into:

²⁹ In the rule of Senator Abraham Ade Adesanya v. President of the Federal Republic of Nigeria & Anor (1981), the Supreme Court ruled, “*It is of paramount importance and indeed most desirable to encourage citizens to come to court to have the Constitution interpreted. However, this is not to say, with respect, that meddlesome interlopers, professional litigants, or the like should be encouraged to sue in matters that do not directly concern them. In my view, to do that is to open the floodgate to frivolous and vexatious proceedings. I believe that such latitude can create undesirable state of affairs.*”

³⁰Mrabure, K. O. (n.d.). *Miscarriage of justice in the restrictive application of locus standi under Nigerian law*. *Ajayi Crowther University Law Journal*, p. 4

³¹The amici curiae invited by the Chief Justice of Nigeria was the Hon Attorney General of the Federation – represented by Dayo Apata – and four Senior Advocates of Nigeria.

- a. Against the extension of the *locus standi*'s doctrine to private citizens and NGOs in matters of environmental degradation, adopting a traditional interpretation of Section 6 (6) of the Nigerian 1999 Constitution,³² supported by previous case law, that limits access to the courts only for those directly affected by an issue.
- b. No need to expand *locus standi*'s doctrine because the appeal could be classified under the public nuisance, which can be prosecuted exclusively by the Attorney General of the Federation or of the State.
- c. In favor of the expansion of the *locus standi*'s doctrine in this case for seeing environmental rights as human rights under International Human Rights Law and the African Charter of Human Rights; for the immensurable environmental benefits the favorable rule would cause; and because the Oil Pipelines Act impose specific duties on pipeline license holders which should be enforceable by any party with an interest, however minor.

Section 6 (6) of the Nigerian 1999 Constitution letter (b) states that:

“The judicial powers vested in accordance with the foregoing provisions of this section shall extend, to all matters between persons, or between government or authority and to any persons in Nigeria, and to all actions and proceedings relating thereto, for the determination of any question as to the civil rights and obligations of that person.”

The section emphasizes that judicial power is empowered to handle disputes of all matters between individuals or individuals and the government or any authority. Conversely, it specifies that the judiciary's primary purpose is determining civil rights and obligations. Furthermore, the significant ruling of Bello JSC – as he was – in Adesanya issues that *“standing will only be accorded to a Plaintiff who shows that his civil rights and obligations have been or are in danger of being violated or adversely affected by the act complained of.”*³³. Indeed, in disputes involving the right to stand, Bello affirms that claimants must have a justiciable interest that was or will be affected by the action.³⁴

³²See above.

³³ Adesanya v. President of the Federal Republic of Nigeria & Anor, SC.1/1981 (Supreme Court of Nigeria 1981). Retrieved from <https://lite.judiciary.gov.ng/case/adesanya-v-president-of-the-fm-anor-supreme-1981>

³⁴Ibidem.

To clarify the controversies regarding Section 6 (6) (b), the JSC, Chima Centus Nweze, also calls for the judgment of Nnamani, JSC, who conceive the section as an extension of judicial powers, upon which courts can adjudicate justiciable issues under its parameters.³⁵ According to Nweze Section 6 (6) (b) is the basis for the separation of powers and extent of judicial powers. Indeed, he goes further citing Ayoola JCA in *N.N.P.C. v. Fawehinmi and Ors. (1998)*:

*“... The main objective of Section 6 of the Nigeria 1999 Constitution is to leave no doubt as to the definition and delimitation of the boundaries of the separation of powers between the judiciary on the one hand and the other organs of government on the other, in order to obviate any claim of the other organs of government, or even attempt by them, to share judicial powers with the courts.”*³⁶

Ayoola JCA perceives Section 6 as a delineation of the boundaries of judicial power, placing judicial authority firmly within the courts and excluding other branches. According to his point of view, the section does not explicitly provide a right to *locus standi*. Hence, the main objective of Section 6 is to safeguard the independence of the judiciary by ensuring its exclusive power to apply the law. However, Nigerian courts have generally taken a restrictive approach to *locus standi*, meaning they have set high thresholds for individuals or groups to establish their standing to sue, especially in cases involving public interest litigation.

Indeed, in *COPW v. NNPC*, the Court analysed previous cases of *locus standi* in the Nigerian courts, concluding that the traditional rule on *locus standi* in common law was restrictive, requiring plaintiffs to show a direct personal interest or specific legal injury from the defendant's actions. Nevertheless, this narrow traditional view needed to be relaxed in cases of environmental litigations due to the public interest nature of environmental protection.

Sections 20³⁷ and 17 (4)³⁸ of the 1999 Constitution were noted as supporting the state's obligation to protect the environment and uphold every person's right to life, which includes allowing standing for organizations representing the public's interests in environmental matters. Thus, the court acknowledged the significance of Article 24 of the African Charter on Human

³⁵ Ibidem.

³⁶ See Section 6 of the Nigeria 1999 Constitution

³⁷ Section 20 of the Constitution of the Federal Republic of Nigeria, 1999, states that “State shall protect and improve the environment and safeguard the water, air and land, forest and wildlife of the country”.

³⁸ Section 17 (4) of the Constitution of the Federal Republic of Nigeria, 1999.

and Peoples' Rights which asserts that *"All peoples shall have the right to a generally satisfactory environment conducive to their development."* The Charter was ratified by Nigeria, underscoring the right to a healthy environment as fundamental to human rights.

Also, as already stated, the Court referred to Nigeria's constitutional and statutory framework, which emphasizes ecological protection as a duty of the state and includes specific regulations under the Oil Pipelines Act 17(4) which established the essential legal framework for safeguarding public safety and addressing oil pollution:

*"Every license shall be subject to the provisions contained in this Act as in force at the date of its grant and to such regulations concerning public safety, the avoidance of interference with works of public utility in, over, and under the land included in the license and the prevention of pollution of such land or any waters as may from time to time be in force."*³⁹

In an exercise of Comparative Jurisdiction, the decision referenced cases from other common law jurisdictions—such as India, and the UK—where courts have broadened the scope of *locus standi* in environmental cases to include NGOs and other public interest groups:

*"English courts are not alone in this development. Other common law jurisdictions have followed that pattern. In India, the Supreme Court, without any statutory enactment, but rather for the overall need to do justice, generally, liberalized the traditional rule on locus standi with respect to environmental degradation, since, in the court's view, maintaining a clean environment is the responsibility of all persons in the country"*⁴⁰

Hence, JSC agreed that adopting this liberal approach would be in line with global trends and necessary for addressing the complexities of modern environmental issues. The court concluded that in environmental matters, the judiciary has a role in enforcing protections for public and ecological health. Justices emphasized that public interest litigation is vital for environmental justice, allowing the court to fulfill its responsibility to uphold the integrity of environmental laws.

Consequently, the Supreme Court allowed the appeal, holding that COPW have the necessary *locus standi* to bring environmental cases on behalf of affected communities. The

³⁹ Ibidem

⁴⁰Centre for Oil Pollution Watch (COPW) v. Nigerian National Petroleum Corporation (NNPC) (2018) SC. 319/2013, Supreme Court of Nigeria.

lower courts' rulings were set aside, and the case was remitted for further proceedings. This decision established a precedent in Nigeria, recognizing the role of civil society in environmental litigation and supporting the liberalization of standing in public interest cases. It is fair to affirm that the Supreme Court's judgment transcends the immediate parties. By softening the *locus standi* requirements for NGOs, the court has paved way for increased public interest litigation, aligning Nigeria more closely with global trends seen in India and other common law jurisdictions that recognize the *locus standi* of NGOs or groups to represent environmental interests. Therefore, this case sets a precedent that could significantly impact future climate litigation in Nigeria, especially in communities where environmental degradation threatens public health and ecosystems.

VI. CONCLUSION

The Centre for Oil Pollution Watch (COPW) v. Nigerian National Petroleum Corporation (NNPC) case has become a landmark in Nigeria's environmental and climate litigation history, establishing a significant precedent for addressing pollution and emission. The Supreme Court's judgment highlighted the important judiciary role in protecting public health and ecological well-being, affirming the importance of public interest litigation in achieving environmental and climate justice. This decision broadened avenues for holding polluters accountable and reinforced the legal framework for environmental protection.

However, as climate litigations starts to gains audience in Nigeria driven by expanding mining, oil exploration, and industrial activities, there is a pressing need for a more robust legal framework to hold polluters accountable. In the vein, the development of a transboundary climate litigation framework is becoming increasingly necessary in Africa to address cross-border pollution. Such a framework would ensure accountability for environmental harm that transcends national borders, promoting sustainable practices and ecological responsibility across the continent.

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