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Nature's safecrackers: Decoding substitutability and protecting natural capital in innovation ecosystems SSA and MENA regions

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ABSTRACT

The innovation ecosystems in economies dependent on natural resources use these assets as fundamental capital to promote development and economic growth. Ensuring the lasting sustainability of these economies represents a difficult challenge, especially in a context of limited and irreplaceable natural capital. This study explores indicators of natural capital protection (environmental quality, reduction of greenhouse gas emissions, protection of biodiversity and ecosystems, and cultural and social values) in Sub-Saharan Africa (SSA), the Middle East, and North Africa (MENA), two regions dependent on natural resources. A new panel quantile estimation technique is applied to panel data covering 59 countries from 2019 to 2023. The results indicate that, in SSA economies, lower levels of these indicators contribute positively to higher levels of natural capital protection. In the MENA economies, only higher levels of environmental quality and cultural and social values contribute positively to higher levels of natural capital protection. The critical implications arising from this study emphasize the urgent need to implement strategies aimed at safeguarding natural capital in economies heavily dependent on it. These strategies include resilient urban development, investment in climate resilient infrastructure, The strategies include resilient urban development, investment in climate-resilient infrastructure, recognition and valorization of environmental services, attention to modern renewable energy technologies, environmental education, greater consideration of the balance between environmental sustainability and human well-being by governments, and recognition of the impacts of globalization on environmental sustainability and human development. The uniqueness of this study lies in its pioneering approach to the pressing issues of protecting natural capital in natural resource-dependent economies. It is a pioneer in analyzing several countries in two regions regarding synergies between protecting natural capital and its indicators in economies dependent on natural resources.

1. Introduction

The innovation ecosystems in resource-dependent economies in Sub-Saharan Africa (SSA) and the Middle East and North Africa (MENA) regions heavily rely on natural resources such as oil, gas, and minerals for economic growth and development. Natural resource dependence plays a crucial role in shaping these regions' industrial structure and economic landscape (Nkemgha et al., 2022; Woertz, 2014). An innovation ecosystem comprises a network of actors, institutions, policies, and resources that foster, promote, and sustain innovation within a particular geography or sector (Cavallo et al., 2019; Lopes & Franco, 2019). These ecosystems are crucial for stimulating economic growth, enhancing competitiveness, and addressing societal challenges. In the context of SSA and MENA, where economies often rely heavily on natural resources, innovation ecosystems can provide pathways for diversification and sustainable development (Gómez Martín et al., 2020; Spigel & Harrison, 2018). The relevance of these ecosystems in such regions is underscored by the need to overcome economic challenges posed by resource

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dependency and to harness innovation for economic transformation. This approach aligns with efforts to move away from traditional economic development models towards more knowledge-based economies where innovation plays a central role (Lopes & Franco, 2019).

The relationship between innovation ecosystems, natural wealth and economic growth is a topic of significant interest, highlighting the intricate link between resource abundance and economic performance (Olcay, 2019; Tiba & Frikha, 2020). Capital substitutability is a critical concept in the context of resource-dependent economies, as it pertains to the ability to replace one form of capital with another in production processes (Figge, 2005). In SSA and MENA, exploring of capital substitutability can offer insights into the resilience and adaptability of these economies in the face of changing resource availability and environmental challenges. Understanding the dynamics of capital substitutability is essential for optimizing resource use, enhancing productivity, and promoting sustainable development (Driskill & McCafferty, 1987; Williamson et al., 2012). As these regions navigate the challenges and opportunities presented by the Fourth Industrial Revolution, the concept of capital substitutability becomes increasingly relevant in shaping their economic strategies and policies (Njifen & Anemann, 2023).

Natural capital protection is a fundamental component of sustainable development in SSA and MENA, given the rich biodiversity and environmental resources present in these regions. Preserving natural capital, including indigenous plant and animal species, is essential for maintaining ecosystem services, biodiversity, and environment's overall health (Addicott & Fenichel, 2019; Ouyang et al., 2016; Smith et al., 2017). By implementing nature-based solutions for climate and environmental challenges, countries in these regions can enhance their resilience to shocks, promote ecological sustainability, and support long-term development goals (Acosta et al., 2020). Emphasizing the protection of natural capital can also contribute to achieving the Sustainable Development Goals (SDGs) related to environmental conservation and climate action, underscoring the importance of integrating natural capital considerations into policy frameworks and decision-making processes (Acosta et al., 2020).

The critical role of natural capital within the economies of SSA and MENA cannot be overstated. SSA, for instance, has a significant portion of its population living in extreme poverty, estimated at 35% in 2019. This contrasts sharply with other regions like South Asia, which had a lower percentage of the population living in extreme poverty (ISMPI, 2023). Furthermore in most African countries, natural capital represents a substantial portion of the total wealth, ranging between 30% and 50% (UNEP, 2024). This significant proportion underscores the reliance of these economies on natural resources for both livelihoods and economic development. Over 70% of SSA's population depends on agriculture and natural resources for their livelihoods, emphasizing the direct link between natural capital and population's well-being (UNEP, 2024). Comparatively, MENA countries have shown a proactive approach towards sustainability, particularly in the pursuit of carbon neutrality, indicating a strategic shift towards the valuation and conservation of natural capital amidst global environmental concerns (Kong et al., 2022). The importance of natural capital in these regions highlights its role as a cornerstone for sustainable economic growth and development, necessitating focused efforts towards its preservation and sustainable management.

A comparative analysis of natural capital depletion rates in SSA and MENA reveals a complex interplay of factors influencing these trends. In SSA, the depletion of natural capital is exacerbated by factors such as high population growth rates and biased capital investments, which strain the available natural resources (Managi et al., 2024). This scenario is further complicated by governance challenges that hinder effective management and conservation of natural resources (Ferreira et al., 2023). On the other hand, despite being notable emitters, MENA countries have embarked on significant investments to achieve carbon neutrality (Osei-Kusi et al., 2024). These investments reflect a strategic approach towards mitigating the depletion of natural capital by balancing economic development with environmental sustainability (Kong et al., 2022). The contrast in depletion rates and management strategies between SSA and MENA underscores the varying challenges and priorities these regions faced in their quest to sustainably manage their natural capital.

The sustainable management of natural capital in SSA and MENA presents a mix of challenges and opportunities in innovation ecosystems. For SSA, the challenges are manifold, ranging from the need to improve governance and accountability (Ferreira et al., 2023) to harnessing the benefits of the Fourth Industrial Revolution for sustainable economic development. These challenges are compounded by the pressing need to address high population growth rates and skewed investment patterns that favor short-term gains over long-term sustainability (Managi et al., 2024). Conversely, with its significant investments in renewable energy and commitment to carbon neutrality, the MENA region showcases the potential for leveraging innovative technologies and policies for sustainable natural capital management (Kong et al., 2022). The opportunities in both regions are anchored on the strategic integration of sustainable practices into the economic development framework, aiming to preserve natural capital and enhance its contribution to economic resilience and growth (Managi et al., 2024).

Despite the comprehensive framework provided by the literature on natural capital protection indicators (Acosta et al., 2020), significant gaps prevent a more integrated understanding and application in natural resource-dependent economies. One of the main gaps is the lack of a unified methodology for quantifying and assessing natural capital, which makes it difficult to compare data across different regions and sectors (Aminetzah et al., 2022). In addition, there is a critical need for indicators that can capture the socio-economic impacts of natural capital degradation on vulnerable communities, which is often overlooked in current frameworks (SOER, 2020). These gaps point to the need for enhanced interdisciplinary research and the development of more holistic indicators that can bridge the gap between economic development and environmental sustainability. For economies heavily dependent on natural resources, ensuring future sustainability is a complex challenge, especially when faced with limited natural capital that is difficult to replace. The literature suggests that incorporating natural capital into economic models is essential to achieving environmental sustainability (Brandon et al., 2021; Fenichel & Hashida, 2019; Helm, 2019). This implies recognizing natural resources as critical economic assets that support development and growth, as indicated by their contribution to GDP per capita (Bagstad et al., 2021). However, empirical data supports the resource curse hypothesis, suggesting that an increase in the endowment of natural resources can lead to a decrease in economic growth (Shao & Yang, 2014), which can harm innovative ecosystems. In innovative ecosystems in economies dependent on natural resources, there is currently limited natural capital that is difficult to replace, so how can the future sustainability of these economies be guaranteed? This requires a more in-depth understanding of the indicators of natural capital protection in resource-dependent economies. Therefore, in this context, the following research question is formulated, which the study aims to answer: How do the main indicators of natural capital protection behave in resource-dependent economies such as the SSA and MENA regions? Thus, this study aims to explore the indicators of natural capital protection in resource-dependent economies.

This study makes important contributions. In general, we can infer six important implications. Firstly, this study develops and deepens the literature on innovation ecosystems, natural capital substitutability, natural capital protection, environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection, and cultural and social values. The valorization of natural capital and greater knowledge of its indicators can allow the adoption of policies and practices that conserve and improve it. At the same time, societies can achieve their green growth and sustainability goals (Acosta et al., 2020). Secondly, the study underscores the practical significance of protecting natural capital to provide essential resources and systemic ecosystem services, which are

pivotal for economic development and environmental sustainability. By valuing natural capital and implementing conservation and improvement policies, societies can achieve green growth and sustainability. Thirdly, the study underscores the urgent need for resilient urban development. Constructing cities that can withstand and prosper amidst environmental challenges is imperative for ensuring sustainability. This necessitates investments in infrastructure and policies that enhance resilience to climate change impacts such as floods, droughts, and extreme weather events. Fourthly, the study highlights the importance of recognizing and valuing environmental services to avoid economic hardship resulting from their loss. By identifying the importance of systemic ecosystem services, such as clean air, water, and fertile soils, policymakers can prioritize conservation and ensure the sustainable use of natural resources (Acosta et al., 2020). Fifthly, the study reinforces the importance of prioritizing environmental education, creating a common language among entities within innovative ecosystems, and facilitating relationships between them for effective Environmental engagement (Reverte et al., 2024). Sixthly, the study emphasizes that governments must balance environmental sustainability and human well-being in their ecosystems. It is crucial to create policies that integrate both. Addressing environmental protection alongside economic development requires innovations that promote sustainable land management, food security, and the preservation of natural capital (Kassouri & Altıntaş, 2020). Finally, this study also allows us to infer specific implications for protecting natural capital in the MENA and SSA regions, resource-dependent regions. In the economies of the SSA region, low levels of environmental quality, reduction of greenhouse gas emissions, protection of biodiversity and ecosystems, and cultural and social values also contribute positively to the protection of natural capital. However, in the economies of the MENA region, only higher levels of environmental quality and cultural and social values contribute positively to higher levels of natural capital protection. These results demonstrate that, although MENA and SSA are two regions dependent on natural resources, efforts to protect natural capital in the MENA region must be much higher and more urgent than those in the SSA region.

2. Literature review

2.1. Resource-dependent economies

Resource-dependent economies are characterized by their reliance on natural resources for economic development and growth (Quaas et al., 2013; Shahbaz et al., 2019). These economies, prevalent in regions such as Sub-Saharan Africa (SSA) and the Middle East and North Africa (MENA), bank on their abundant reserves of minerals, hydrocarbons, oil, and gas as the mainstay for their economic activities. Sub-Saharan Africa, for instance, is richly endowed with natural resources, hosting significant reserves that have historically underpinned its economic framework (Nwani et al., 2023). Similarly, the MENA region boasts not only a wealth of human resources but also a significant portion of the world's petroleum production and exports (Matallah, 2024; Qian, 2013). While beneficial in the short term, this heavy reliance on natural resources posits challenges for sustainable economic growth and development, as it exposes these economies to the vicissitudes of global commodity markets and the risk of resource depletion. These challenges underscore the urgent need for transformation in these regions, shifting from reliance on natural resources to more diversified and resilient economic models.

The importance of innovation ecosystems in the economic diversification efforts of SSA and MENA cannot be overstated. Innovation ecosystems, which include economic incentives, innovation, education, and information infrastructure, play a pivotal role in developing new industries and enhancing productivity across existing sectors (Asongu & Andrés, 2020). These ecosystems provide a supportive environment for entrepreneurs and businesses to innovate, create jobs, and contribute to sustainable economic growth. Furthermore, the framework for building innovation ecosystems highlights the necessity of integrating various elements such as policy, finance, culture, and infrastructure to support innovation and entrepreneurial activities (Lopes & Franco, 2019; Rinkinen & Harmaakorpi, 2019). In resource-dependent economies, developing robust innovation ecosystems can help mitigate the effects of commodity price volatility and reduce economic vulnerabilities by encouraging diversification into knowledge-based sectors.

The vulnerability of resource-dependent economies to fluctuations in commodity prices presents a formidable challenge in diversifying the economy and promoting sustainable growth (Albassam, 2015; Shrestha et al., 2021). Price volatility can severely impact national income, especially in countries where the economy heavily relies on a single or a few commodities for export earnings and fiscal revenues (Guan et al., 2021; Mahmud & Basher, 2014). This dependency creates a precarious economic situation, where sudden drops in commodity prices can lead to budget deficits and economic instability. Furthermore, the challenge of diversifying these economies away from natural resources is compounded by weak institutions and governance structures, which can inhibit the development of other sectors and the efficient management of resource revenues (Henry, 2019). The absence of a diversified economic base makes it difficult for these countries to cushion the impact of commodity price shocks, impeding their path toward sustainable economic development (Albassam, 2015). The future sustainability of resource-dependent economies, particularly in SSA and MENA, hinges on addressing the limitations posed by their limited natural capital. Given the non-renewable nature of many of these resources, there is a pressing need to explore strategies that guarantee economic sustainability beyond their depletion.

2.2. Innovation ecosystems in green growth

Effective innovation ecosystems are crucial for driving sustainable development and environmental preservation in Sub-Saharan Africa (SSA) and the Middle East and North Africa (MENA) regions. By fostering the development and adoption of green technologies, these ecosystems, play a pivotal role in mitigating environmental impacts and promoting sustainability (Chowdhary & Bharagava, 2020). Integrating innovative solutions within these ecosystems helps address the complex challenges of climate change, resource scarcity, and biodiversity loss. By implementation of green growth strategies, innovation ecosystems contribute to achieving a balance between economic growth and environmental sustainability (Fan et al., 2022). The importance of these ecosystems lies in their ability to provide a structured framework for collaboration among stakeholders, including governments, private sector entities, research institutions, and civil society, facilitating the seamless exchange of knowledge, resources, and best practices (Lopes & Franco, 2019).

Green growth in Sub-Saharan Africa (SSA) and the Middle East and North Africa (MENA) regions represents a transformative approach to sustainable development. This concept is built upon the foundation of integrating economic growth with environmental stewardship to ensure long-term prosperity and health of the planet (Jänicke, 2012; Jouvet & de Perthuis, 2013; Smulders et al., 2015). Green growth is characterized by four main pillars: 1) efficient and sustainable use of resources; 2) protection of natural capital; 3) creation of green economic opportunities; and 4) promotion of social inclusion. These elements work together to enable countries in SSA and MENA to address climate change challenges while fostering economic development and reducing poverty (Hassan, 2010; Kithiia, 2011). By prioritizing green growth, these regions can build resilience against environmental risks, enhance energy security, and create new job opportunities in green industries, thereby contributing to global efforts to combat climate change and promote sustainable development (Chirambo, 2018; Clay & Zimmerer, 2020).

In the context of SSA and MENA, efficient and sustainable use of resources, protection of natural capital, creation of green economic opportunities, and promotion of social inclusion are crucial for green growth. Efficient use of resources means optimizing the consumption of water, energy, and raw materials to minimize environmental impact

while maximizing economic output (Abu Hanieh et al., 2014). This can be achieved through the adoption of innovative technologies and practices that reduce waste and increase productivity. For example, the implementation of renewable energy projects in these regions can significantly reduce reliance on fossil fuels, decrease greenhouse gas emissions, and ensure a sustainable energy supply (Neto et al., 2018; Talan et al., 2021). On the other hand, protecting natural capital involves conserving ecosystems, biodiversity, and natural resources that are vital for human well-being and economic activities (Hails & Ormerod, 2013; Stafford-Smith et al., 2012). Initiatives such as reforestation, sustainable agriculture, and conservation of water bodies are essential in preserving the natural assets upon which future generations will depend. These strategies not only contribute to environmental sustainability but also support economic growth by securing the resources necessary for various industries and livelihoods (Tawiah et al., 2021).

Green economic opportunities refer to the creation of jobs and industries that contribute to a low-carbon, resource-efficient economy. This includes sectors such as renewable energy, sustainable agriculture, green construction, and environmental services (Annandale et al., 2004; Chu & Majumdar, 2012). By investing in these areas, countries can diversify their economies, reduce their carbon footprint, and improve the quality of life for their citizens. Social inclusion, on the other hand, ensures that the benefits of green growth are equitably shared among all segments of society, including the most vulnerable (Arthurson & Baum, 2015; Mirzoev et al., 2022). This involves implementing policies that support fair access to green jobs, education, and healthcare, as well as ensuring community participation in environmental decision-making processes (Belle-Isle et al., 2014; Cheung, 2013). Through these efforts, SSA and MENA can foster a more resilient and equitable economic system that benefits everyone, while addressing the pressing challenges of climate change and environmental degradation (Chirambo, 2018; Takian et al., 2022).

2.3. Natural capital substitutability and natural capital protection

The concept of natural capital substitutability encompasses the idea that human-made capital can, in some cases, replace natural capital, a principle that has become increasingly pivotal in discussions of sustainability (Gollier, 2019; Reijnders, 2021). This notion posits that through technological advancement and innovation, societies can generate alternatives to the goods and services provided by nature (Clow, 1998). However, the substitutability of natural capital is not without limits. It hinges on the type and function of the natural capital in question, with some forms being irreplaceable by human-made alternatives (Reijnders, 2021). This understanding underscores the importance of critically evaluating which aspects of natural capital can be substituted without compromising ecological integrity and human well-being.

Linking the concepts of natural capital substitutability and natural capital protection is essential for a balanced approach to sustainable development. Natural capital protection involves safeguarding the Earth's biodiversity and ecosystems to ensure they continue to provide the essential goods and services upon which human life depends (Acosta et al., 2020). While substitution might provide temporary relief or alternatives for certain natural resources, it cannot be the sole strategy for addressing environmental challenges. Effective protection strategies must consider the limits of substitutability by focusing on conserving irreplaceable natural assets and enhancing the resilience of ecosystems (Carroll & Ray, 2021; Millar et al., 2007). This dual approach helps maintain the balance between utilizing and conserving natural resources, aiming for a sustainable future where human and natural capital coexist harmoniously.

The framework for protecting natural capital encompasses several key dimensions, each critical for maintaining and enhancing the planet's ecological health. These include (Acosta et al. (2022): 1) Environmental quality - ensuring clean air, water, and soil is fundamental for the health of all living beings and for the overall functioning of ecosystems; 2) Reduction of GHG emissions - Mitigating climate change by reducing greenhouse gas emissions is crucial for stabilizing global temperatures and minimizing climate-related disruptions; 3) Biodiversity and protection of ecosystems - preserving the variety of life on Earth and safeguarding natural habitats are essential for ecological resilience and the provision of ecosystem services; and 4)Cultural and social value -recognizing and preserving the cultural, spiritual, and recreational values of natural landscapes and features contribute to human well-being and social cohesion. These dimensions highlight the multifaceted nature of natural capital protection, underscoring the need for integrated and comprehensive strategies to safeguard our planet's life-support systems (Dewulf et al., 2015; Miteva, 2019).

2.3.1. Environmental quality

The impact of climate change on environmental degradation in both SSA and the MENA regions has been profound and multifaceted. In the MENA region, the adverse effects of climate change are particularly pronounced, with the area experiencing extreme temperatures, significant desertification, and an overall increase in the vulnerability of its ecosystems (Kong et al., 2022). MENA is experiencing economic repercussions from environmental degradation quality (e.g., water, air), and this degradation is a pressing concern (Goel et al., 2013; Sowers et al., 2011). Similarly, SSA faces its own challenges, with climate change exacerbating weather-related natural disasters such as droughts and floods (Andriamahery et al., 2022). Both regions grapple with the consequences of climate-induced changes, albeit with varying manifestations and degrees of impact.

When examining pollution levels and their repercussions on public health in SSA and MENA, a stark contrast emerges, particularly regarding air quality and its implications. In SSA, a significant portion of the population lives in areas where air pollution exceeds safe levels, posing severe health risks (Rentschler & Leonova, 2023). Industrial pollution, along with overgrazing, deforestation, and a shortage of water, contributes to the region's environmental and public health crises (Beyene & Kotosz, 2021). On the other hand, despite facing serious pollution issues, the MENA region often links its environmental problems to energy consumption patterns, particularly in oil-producing countries where carbon emissions are a major concern (Onifade & Alola, 2023). This divergence in the sources and impacts of pollution underscores the different challenges and priorities facing SSA and MENA in addressing environmental health risks.

Measuring and improving environmental quality present considerable challenges, stemming from the complexity of environmental systems and the interplay of various anthropogenic and natural factors. Traditional measures of environmental quality, such as air quality indicators based on ozone and particulate matter levels, provide valuable insights but may not fully capture the multifaceted nature of environmental degradation (Hendryx et al., 2013). Furthermore, developing and implementing effective strategies for environmental improvement requires a thorough understanding of general environmental attitudes and the factors that influence them. White and Hunter (2009) and Cruz and Manata (2020) state that education and political engagement play crucial roles in fostering greater environmental awareness and concern, which are essential for driving positive change.

2.3.2. GHG emissions reductions

The current status of GHG emissions in SSA is significantly influenced by various socio-economic factors, including investment in education, employment opportunities, and adopting renewable energy sources (Lin & Agyeman, 2021; Mabogunje, 1995). These factors play a crucial role in determining the region's carbon footprint, with renewable energy adoption showing a particularly complex relationship with CO2 emissions. While renewable energy sources are expected to contribute to emissions reductions, their impact has been relatively insignificant compared to the increase in emissions caused by non-renewable energy sources (Elom et al., 2024; Nathaniel & Iheonu, 2019). This suggests that

while SSA is making efforts towards sustainable development, the effectiveness of these initiatives in significantly reducing GHG emissions is yet to be seen fully.

In contrast, the MENA region presents a different scenario regarding GHG emissions. Justice et al. (2024) and Kong et al. (2022) indicate that economic globalization and government effectiveness towards renewable energy adoption play significant roles in the region's carbon emissions. Furthermore, the MENA region has been identified as a notable emitter of GHGs, with certain studies investigating the determinants of CO2 emissions across 18 countries within this region (Jalil, 2014; Osei-Kusi et al., 2024). Jalil (2014) and Osei-Kusi et al. (2024) have highlighted the complex interplay between economic activities, energy consumption, and GHG emissions, suggesting that while there are efforts towards renewable energy adoption, the overall impact on reducing emissions in the MENA region is varied and requires further investigation.

Comparative analysis of GHG emissions trends between SSA and MENA reveals distinct differences in the factors influencing emissions and the effectiveness of reduction strategies. The SSA region, with its focus on investment in education, employment, and renewable energy, faces challenges in significantly reducing emissions due to the limited impact of renewable energy on CO2 emissions. On the other hand, the MENA region's approach, characterized by economic globalization and targeted renewable energy policies, suggests a complex relationship between economic growth and emissions reduction. Despite these efforts, both regions demonstrate varying levels of success in GHG emissions reduction, indicating the need for tailored strategies that consider the unique socio-economic and environmental contexts of each region (Osei-Kusi et al., 2024). This analysis underscores the importance of a nuanced understanding of regional differences in GHG emissions trends and the factors that influence these patterns.

2.3.3. Biodiversity and ecosystem protection

The biodiversity of SSA and the MENA regions is under considerable threat, with key species playing crucial roles in maintaining the ecological balance being increasingly endangered. In SSA, for example, the highest-ranked threats include hunting and the expansion of annual and perennial non-timber crops, which have significant impacts on wildlife habitats and species survival (Leisher et al., 2022). The MENA region faces its own challenges, notably habitat loss due to land use changes, which poses a severe threat to the indigenous species and their ecosystems (Bruder et al., 2022; Usman et al., 2021). These species are integral to ecosystem functions such as pollination, seed dispersal, and maintaining the food web, underscoring the importance of addressing these threats to ensure the sustainability of these biodiverse regions.

Conservation efforts across SSA and MENA vary in effectiveness, with various strategies employed to mitigate the threats to biodiversity. In SSA, large investments in biodiversity conservation have been made, though there is a notable lack of prioritization among the direct threats, which diminishes the potential impact of these efforts (Leisher et al., 2022). Meanwhile, in the MENA region, the impacts of climate change on biodiversity have prompted calls for increased research and targeted conservation measures (Waha et al., 2017). Despite these efforts, the effectiveness of conservation strategies is often hampered by insufficient funding, lack of local community engagement, and inadequate enforcement of existing environmental laws and regulations (El-Khalil & El-Kassar, 2018; Sowers et al., 2011).

The challenges to biodiversity protection in SSA and MENA are complex and multifaceted, involving environmental and socio-economic factors. In SSA, climate change and related hydro-meteorological risks are identified as the most significant threats to biodiversity, exacerbating the vulnerability of the region's ecosystems (Enu et al., 2023). Similarly, in the MENA region, biodiversity loss is being accelerated by climate change, highlighting the urgent need for comprehensive strategies that address the root causes of ecosystem degradation (Al-Mulali & Ozturk, 2015; Sowers et al., 2011). Furthermore, both regions suffer from low levels of knowledge exchange dynamics and catching-up processes, which hinder the implementation of effective biodiversity policies and conservation practices (Asongu & Andrés, 2020).

2.3.4. Cultural and social value

The traditional practices in SSA and the MENA regions play a pivotal role in shaping environmental stewardship, reflecting a deep-rooted connection between cultural heritage and natural capital. In SSA, communal land management and age-old agricultural practices have been vital in promoting biodiversity and sustainable use of resources, demonstrating an intrinsic understanding of environmental conservation before modern environmentalism (Rjoub et al., 2021). Similarly, in the MENA region, traditional practices such as falaj or qanat systems for water management illustrate an ingenious adaptation to arid conditions, showcasing how ancient wisdom can guide contemporary efforts to combat climate change (Serdeczny et al., 2017). These practices underscore the importance of preserving traditional knowledge as a key component of natural capital, which is crucial for addressing environmental challenges in both regions.

Religious beliefs profoundly influence natural resource management and conservation efforts in both the SSA and MENA regions, guiding environmental ethics and behaviors. In the MENA region, Islamic teachings on stewardship of the earth encourage the sustainable use of natural resources, which is evident in the religiously motivated initiatives for water conservation and the protection of biodiversity (Bakir, 2001; Mardani et al., 2014). Similarly, in SSA, religious and spiritual beliefs often intertwine with traditional conservation practices, where sacred groves and species are protected due to their spiritual significance, demonstrating a unique blend of faith and environmentalism (Murray & Agyare, 2018). These examples highlight how religious beliefs are intertwined with cultural values, significantly impacting conservation efforts and the sustainable management of natural resources, further emphasizing the necessity of integrating religious perspectives into environmental policies and practices.

Community engagement emerges as a cornerstone for sustainable development initiatives in the SSA and MENA regions, embodying social and cultural capital synthesis in driving forward community-based environmental management. In SSA, participatory approaches in environmental conservation have led to successful community-driven reforestation projects and wildlife management, which are founded on the principles of equity, transparency, and local empowerment (Bergh, 2014; Hishan et al., 2019). The MENA region, despite facing significant environmental challenges, has seen a rise in community-led initiatives aimed at addressing water scarcity and promoting sustainable agricultural practices, supported by a growing awareness of the importance of collective action in environmental stewardship (Hejazi et al., 2023; Nouri et al., 2019). These examples underscore the critical role of community engagement in fostering sustainable development, where the integration of local knowledge, cultural values, and social capital is essential for effectively managing natural resources and achieving long-term environmental sustainability.

3. Data and variables

The present study aims to explore natural capital protection indicators in natural-resources-dependent economies, such as countries belonging to the SSA and MENA regions. The sample comprises 59 countries, 43 of which belong to the SSA region and 16 to the MENA region (more details in Appendix). These two regions were selected because they have high levels of natural capital and income from natural resources (Ferreira et al., 2023). Data was collected for five years, from 2019 to 2023, in the Green Growth Index Report. The choice of this time period is justified by the availability of data since the first Green Growth Index report is from 2019 and a new one has been published annually. Thus, in relation to SSA economies, the sample consists of 211 observations and in relation to MENA economies, the sample consists of 80 observations.

Table 1 contains the definition of natural capital protection indicators used in this study (Acosta et al., 2022).

Since natural capital protection is measured by the four indicators presented in Table 1, Table 2 contains the items that measure these indicators as presented in the report of environmental and sustainability indicators (Acosta et al., 2022).

All indicators are measured in scores (0–100), where: 80–100 are very high scores, having reached or almost reached the target; 60–80 are high scores, taking a strategic position to reach the target completely; 40–60 are moderate scores, finding the right balance to move closer to the target; 20–40 are low scores, identifying the right policies to align development toward achieving the target; 1–20 are very low scores, requiring significant actions to improve position relative to the target.

Based on the definition of Natural Capital Protection presented in the Acosta et al. (2022) report, this study proposes to evaluate the individual impact of the indicators of environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection and cultural and social values on Natural Capital Protection. In this way, the empirical model (1) will be tested:

$$NCP_{it} = \beta_0 + \beta_1 EQ_{it} + \beta_2 GHGE_{it} + \beta_3 BEP_{it} + \beta_4 CSV_{it} + \mu_{it} \quad (1)$$

Where, μit – It is error term for country i between times t.

4. Methods

First, we characterize the country sample used in this study based on the variables used by the SSA and MENA regions. Then, a multivariate analysis was carried out for the data series to avoid estimating spurious regressions. To this end, we assessed heteroscedasticity by implementing the Breusch-Pagan test (Breusch & Pagan, 1979) and the White test (White, 1980). The possible cross-sectional dependence between the countries in the sample was assessed by carrying out Pesaran's Cross-Sectional Correlation Test (Pesaran, 2021).

Using Westerlund (2005) cointegration test, we determined the long-term relationships of the variables, considering the possibility of cross-sectional dependence and heterogeneity between the countries in the sample. As the data in this study involves a time series from 2019 to 2023, the variables may present imbalances in short periods. Still, the variables tend to be balanced in the long term, moving to approximately satisfy a relationship. Therefore, if the time series are cointegrated, their behavior will follow the established long-term relationship, obeying a systematic relationship. It is unnecessary to provide precise information about how the data was generated, and it is possible to estimate cumbersome parameters.

In the last step, we estimated the long-term relationships defined in the proposed empirical model using Powell's Quantile Panel Data Estimator (QRPD). This method allows analyzing variation within groups of quartiles, assuming that fixed effects are not additive and disturbance terms cannot be separated from the estimated quartile. In this way, we can analyze the effects of natural capital protection in different ranges (quartiles) of the independent variables of environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection, and cultural and social values. Furthermore, it accommodates individual heterogeneity of variables by estimating quantile treatment effects to generate the data. This method is more suitable for estimating multiple linear regressions than the Ordinary Least Square method when there are outliers and non-normal distribution of the dependent variable, as is the case with the natural variable capital protection. Consequently, it allows the impact of the covariate to be observed across the entire data and not just the average, even when there is data transformation (Sinha & Sengupta, 2019). Also, in this study, non-additive fixed effects were used as used in Ferreira et al. (2023) so as not to separate the error terms from the quartile estimate, specified as follows:

$$Yi,t = D'_{i,t}\beta Z^*_{i,t}\ Z^*_{i,t} \sim U(0,1) \quad (2)$$

$D'_{i,t}\beta(\tau)$ increases only in t quantiles, and $Z^*_{i,t}$ is a function of the disturbance terms and orientation for the outcome. The quantile regression specified for this study aims to analyze the impact of the four dimensions of natural capital protection on income from natural resources. Thus, we specify the following equation (3):

$$(NCP_{it}\ (\tau/\propto i, \gamma_t, X_{it} = \propto_i + \gamma_t + \partial_1 EQ_{it} + \partial_2 GHGE_{it} + \partial_3 BEP_{it} + \partial_4 CSV_{it} (3)$$

$\propto_i$ represent "the non-adaptive fixed effects", X_{it} is a "matrix of the independent variables at individual countries i and time t".

Table 1
Variables and definition.

Variables	Definition
Natural Capital Protection (NCP)	The indicator of biodiversity and ecosystem protection, environmental quality, GHG emissions reduction, and cultural and social value.
Environmental Quality (EQ)	The indicator of properties and characteristics of the environment may affect the health of human beings and other organisms, including air, water and noise pollution, access to open space, and visual impacts of buildings.
Greenhouse Gas Emissions Reductions (GHGE)	The indicator of reduction and removal of CO2 non-CO2 emissions from the atmosphere to address climate change.
Biodiversity and Ecosystem Protection (BEP)	The indicator of protection of species, habitats, and ecosystems as well as the services they provide, with protected areas as an important measure to achieve biodiversity conservation.
Cultural and Social Value (CSV)	The indicator of societal value given to natural capital is due to its importance to communities and their local culture, which encourages sustainable use and protection of natural resources.

Table 2
Natural capital protection indicator items.

Variables	Items
Environmental Quality (EQ)	PM2.5 air pollution, mean annual population-weighted exposure (Micrograms per m3) DALY rate due to unsafe water sources (DALY lost per 100,000 persons) Municipal solid waste (MSW) generation per capita (Tons per year per capita)
Greenhouse Gas Emissions Reductions (GHGE)	Ratio of CO2 emissions to population, including AFOLU (Tons per capita) Ratio non-CO2 emissions (CH4, N2O and F-gas) excluding AFOLU to population (CO2eq tons per capita) Ratio non-CO2 emissions (CH4, N2O and F-gas) in Agriculture and LUCF to population (CO2eq tons per capita)
Biodiversity and Ecosystem Protection (BEP)	Average proportion of Key Biodiversity Areas covered by protected areas (Percent) Share forest area to total land area (Percent) Above-ground biomass stock in forest (Tons per hectare)
Cultural and Social Value (CSV)	Red list index (Score) Tourism and recreation in coastal and marine areas (Score) Share of terrestrial and marine protected areas to total territorial areas (Percent)

5. Results

Table 3 contains the statistical description of the variables included in the empirical model. The standard deviation of the variables is lower than the average value of all variables, meaning they do not present high disparities in the MENA and SSA regions. However, the statistical results of the independent variables (environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection and cultural and social values) are heterogeneous and lead to substantial heterogeneity in the dependent variable, natural capital protection. In this way, the estimation of quantile regression is based.

Table 3
Statistical description of the variables.

	NCP	EQ	GHGE	BEP	CSV
SSA REGION					
Mean	64,03	67,20	82,38	55,16	61,79
Std. Deviation	8,95	12,08	13,19	16,81	19,27
Minimum	35.88	30.77	25.26	8.48	23.00
Maximum	84.55	91.32	97.09	93.09	99.15
Percentiles					
25	35,88	30,77	25,26	8,48	23
50	35,92	30,77	25,52	8,54	23,03
75	36,30	30,77	27,86	9,17	23,29
Obs.	211	211	211	211	211
MENA REGION					
Mean	44,18	73,21	68,44	19,01	49,36
Std. Deviation	12,28	9,28	22,15	12,97	15,21
Minimum	22,97	54,68	29,9	2,51	26,46
Maximum	74,82	89,62	96,43	48,92	82,29
Percentiles					
25	22,97	54,68	29,9	2,51	26,46
50	22,97	54,68	29,9	2,51	26,46
75	22,97	54,68	29,9	2,51	26,46
Obs.	80	80	80	80	80

Note: EQ - environmental quality, GHGE - greenhouse gas emissions reductions, BEP - biodiversity and ecosystem protection and CSV - cultural and social values.

The SSA region presents higher average scores for the natural capital protection variable than the MENA region (64.03 and 44.18, respectively). Regarding the classification used by the Green Growth Index, the natural capital protection variable presents, on average, high scores in the SSA region and moderate scores in the MENA region. The independent variables greenhouse gas emissions reductions, biodiversity and ecosystem protection and cultural and social values also present higher scores, on average, in the SSA region than in the MENA region. It should also be noted that, in the MENA region, biodiversity and ecosystem protection presents, on average, a very low score (19.01).

To assess the robustness of the results, we assessed heteroscedasticity using two tests: (i) the Breusch-Pagan test and (ii) the White test. Their results are shown in Tables 4 and 5. The first Breusch-Pagan test contrasts the null hypothesis that the error variances are equal and homoscedastic with the alternative hypothesis that the error variances are a multiplicative function or heteroscedastic. White's test is similar but more suitable for cases where heteroscedasticity is not linear, and errors are not normally distributed.

The results shown in Tables 4 and 5 demonstrate that in the empirical model, all variables suffer from heteroscedasticity in both regions since the null hypothesis that the error variances are equal is rejected at a significance level of 1% in all cases.

Table 6 contains the results of Pesaran's Cross-Sectional Correlation Test, which was used to evaluate the cross-sectional dependence of the variables. The Pesaran Test demonstrates that the null hypothesis that observations are not cross-sectionally correlated was rejected at a significance level of 1%.

Given the heterogeneity and cross-sectional dependence, the long-term relationship between the variables was assessed using the

Table 4
Heteroskedasticity test - Breusch-Pagan Test.

	NCP	EQ	GHGE	BEP	CSV
SSA REGION					
Chi2	26.40	25.94	13.65	13.42	42.32
prob > Chi2	0,000	0,000	0.008	0.009	0,000
MENA REGION					
Chi2	3,38	10.70	5.89	2,37	9,33
prob > Chi2	0,006	0,000	0.002	0.001	0,002

Note: EQ - environmental quality, GHGE - greenhouse gas emissions reductions, BEP - biodiversity and ecosystem protection and CSV - cultural and social values.

Table 5
Heteroskedasticity test – White Test.

	NCP	EQ	GHGE	BEP	CSV
SSA REGION					
Chi2	143.53	160,00	100.99	31.69	177.72
prob > Chi2	0,000	0,000	0.000	0.003	0.000
MENA REGION					
Chi2	10,81	34,29	12,15	3,92	13,91
prob > Chi2	0,004	0,000	0.000	0.001	0,000

Note: EQ - environmental quality, GHGE - greenhouse gas emissions reductions, BEP - biodiversity and ecosystem protection and CSV - cultural and social values.

Table 6
Pesaran's cross-sectional correlation test.

	NCP	EQ	GHGE	BEP	CSV
SSA REGION					
Pesaran's test of cross-sectional independence	65.62	88.56	43.76	39.91	38.26
Pr	0,000	0,000	0,000	0,000	0,000
MENA REGION					
Pesaran's test of cross-sectional independence	55.12	49.01	38.93	32.94	28.54
Pr	0,000	0,000	0.000	0.000	0,000

Note: EQ - environmental quality, GHGE - greenhouse gas emissions reductions, BEP - biodiversity and ecosystem protection and CSV - cultural and social values.

Westerlund (2005) cointegration test. The results shown in Table 7 confirm the existence of a long-term relationship between the variables considered in the empirical model for a significance level of 1%.

The tests demonstrated that estimating the model would not result in spurious regressions, so we moved on to assessing the empirical model, having applied the quantile regression method. The results are shown in Table 8, Fig. 1, and Fig. 2. It is considered that quartiles 10t and 20t correspond to very low natural capital protection, quartiles 30t and 40t correspond to low, quartiles 50t and 60t correspond to moderate, quartiles 70t and 80t correspond to high, and the 90t quartile corresponds to very high.

The indicators of environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection and cultural and social values positively impact natural capital protection in both regions. However, the environmental quality indicator in the MENA region was not statistically significant in the first quartile.

About the economies of the SSA region, the highest impact of environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection and cultural and social values is observed when there are very low levels of natural capital protection, that is, in the first and second quartiles ($\beta = 0.313$; $\beta = 0.336$; $\beta = 0.346$ and $\beta = 0.313$, respectively). Furthermore, we found that biodiversity and ecosystem protection are the main predictors of natural capital protection in the economies of the SSA region. In the MENA region, the highest impact of environmental quality and cultural and social values is seen when there are very high levels of natural capital protection. On the other hand, the highest impact of greenhouse gas emissions reductions and biodiversity and ecosystem protection is seen when there are very low levels of natural capital protection.

The impact of environmental quality on natural capital protection in SSA regions is increasing in the first three quartiles, and from the fourth

Table 7
Cointegration test.

	Statistic	p-value
SSA REGION		
Variance Ratio	2.875	0.001
MENA REGION		
Variance Ratio	2.054	0.001

Table 8
Quantile regression results.

	VERY LOW NCP		LOW NCP		MODERATE NCP		HIGH NCP		VERY HIGH NCP
	q0,1	q0,2	q0,3	q0,4	q0,5	q0,6	q0,7	q0,8	q0,9
SSA									
Environmental Quality	0.313*	0.277*	0.273*	0.277*	0.276*	0.268*	0.267*	0.255*	0.253*
GHG Emissions Reductions	0.305*	0.336*	0.321*	0.297*	0.262*	0.250*	0.236*	0.227*	0.225*
Biodiversity and Ecosystem Protection	0.331*	0.346*	0.344*	0.330*	0.312*	0.310*	0.303*	0.307*	0.303*
Cultural and Social Value	0.313*	0.310*	0.301*	0.288*	0.284*	0.283*	0.266*	0.259	0.254*
MENA									
Environmental Quality	0.068	0.153*	0.155*	0.118*	0.141*	0.158*	0.198*	0.226*	0.258*
GHG Emissions Reductions	0.206*	0.188*	0.188*	0.185*	0.184*	0.170*	0.160*	0.156*	0.156*
Biodiversity and Ecosystem Protection	0.599*	0.601*	0.600*	0.599*	0.576*	0.588*	0.577*	0.553*	0.535*
Cultural and Social Value	0.230*	0.234*	0.240*	0.259*	0.276*	0.275*	0.284*	0.283*	0.290*

Note: * Sig. < 0.001; NCP – Natural Capital Protection.

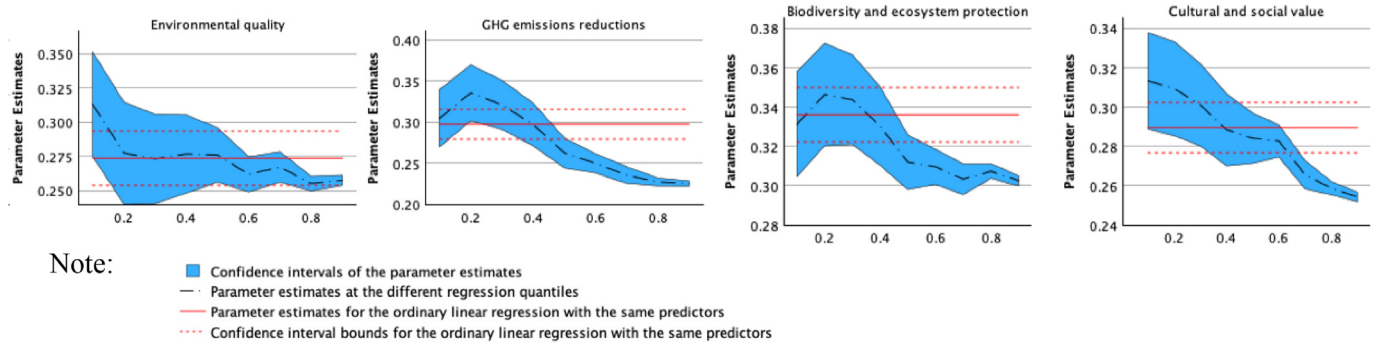


Fig. 1. Quantile regression results for SSA Region.

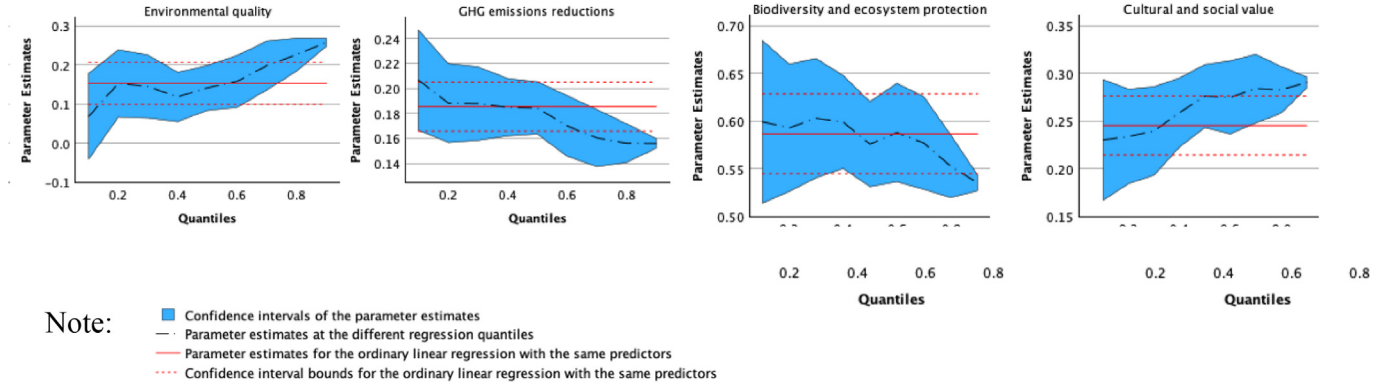


Fig. 2. Quantile regression results for MENA Region.

quartile onwards, it begins to decrease again. Therefore, in SSA economies, environmental quality decreases when natural capital protection is higher. On the contrary, in the MENA regions, the impact of environmental quality on natural capital protection increases, especially from the fourth quartile onwards. Thus, environmental quality increases when natural capital protection is higher.

The impact of GHG emissions reductions on natural capital protection is decreasing in the SSA and MENA regions. This means that, in the economies of these regions, higher levels of natural capital protection are associated with lower levels of GHG emissions.

The impact of biodiversity and ecosystem protection on natural capital protection in the SSA and MENA regions is increasing in the first two quartiles, decreasing from the third quartile onwards. Thus, in the economies of the SSA and MENA regions, higher levels of natural capital protection are associated with lower levels of biodiversity and ecosystem protection.

Finally, the impact of cultural and social values on natural capital protection differs between the SSA and MNA regions. While cultural and social values decrease when natural capital protection increases in the SSA region's economies, the opposite occurs in the economies of the MENA region. Thus, in the economies of the MENA region, cultural and social values are higher when there are higher levels of natural capital protection.

6. Discussion

Preserving natural resources is essential for the well-being of humanity (Costanza et al., 1997), as the depletion of natural capital by contemporary generations will hinder the capacity of future generations to satisfy their necessities (Bissoon, 2017). However, measuring the benefits of environmental preservation remains challenging due to its inherent complexities (Li et al., 2022). The results of this investigation

shed light on the urgent issues regarding natural capital protection in innovative ecosystems in economies reliant on natural resources, specifically in the SSA and MENA regions. They indicate that natural capital protection in innovative ecosystems in the SSA and MENA regions is positively impacted by environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection, and cultural and social values. The only exception is the environmental quality indicator in the MENA region's first quartile, which did not achieve statistical significance.

Regarding the economies of the SSA region, the examined indicators exert the greatest influence when natural capital protection levels are very low, specifically within the first and second quartiles. In SSA, there is a rapid depletion of natural capital resources, leading to accelerated environmental degradation in the region (Ulucak et al., 2020). In this context, it becomes clear that the indicators used in the analysis reflect of fundamental elements of sustainability. Consequently, when the level of protection for natural capital is diminished, these indicators hold greater sway. This is because lower levels of natural capital protection correspond to heightened environmental vulnerability and accelerated degradation, amplifying the influence of these indicators in assessing and addressing sustainability challenges.

Furthermore, biodiversity and ecosystem protection are key determinants of safeguarding natural capital. This is because habitat loss stemming from changes in land use presents a significant peril to native species and their respective ecosystems (Bruder et al., 2022; Usman et al., 2021). This reasoning can be applied to the observation that biodiversity and ecosystem protection are the primary predictors of natural capital protection in the MENA region. Climate change in this area is accelerating biodiversity loss, underscoring the urgent need for comprehensive strategies to address the root causes of ecosystem degradation (Al-Mulali & Ozturk, 2015; Sowers et al., 2011). For the MENA region, two indicators, environmental quality and cultural and social values, show the highest impact in very high levels of natural capital production. High environmental quality signifies effective management and conservation practices essential for sustaining natural capital long-term, while high levels of natural capital protection reflect a society's commitment to preserving culturally and historically significant landscapes, natural sites, and biodiversity. Conversely, the highest impact of greenhouse gas emissions reductions and biodiversity and ecosystem protection is observed when natural capital protection levels are very low because these measures become crucial for mitigating severe environmental degradation and restoring ecosystems.

Regarding the impact of environmental quality on natural capital protection, the results for SSA economies indicate a negative relation between environmental quality and natural capital protection, where environmental quality diminishes as levels of natural capital protection increase. The observed pattern aligns with findings indicating that in some circumstances (except for South Africa, where biomass is the predominant energy source), renewable energy fails to substantially contribute to environmental quality, as its use contributes to increased GHG emissions (Bisset, 2023). Furthermore, some protection efforts often address ongoing economic pressures that are not immediately alleviated by the protective measures. In the Mena regions, the influence of environmental quality on natural capital protection exhibits an upward trend. This indicates an increase in environmental quality and higher levels of natural capital protection. This means that for this region, the increase in renewable energy consumption will enable a reduction in CO2 emissions levels' (Charfeddine & Kahia, 2021), consequently contributing to the simultaneous maintenance of higher levels of natural capital protection and environmental quality. In a broader sense, it is crucial to consider the various intricacies related to energy consumption. For instance, promoting energy efficiency might not lead to energy savings or emission reductions, as it could encourage higher energy use if efficient technologies are employed (Herring & Roy, 2007).

The study results also show that higher levels of natural capital protection relate to lower GHG emissions in the SSA and MENA regions, indicating a diminishing impact of GHG emissions reductions on natural capital protection. The knowledge of various practices that support natural capital protection and reduce GHG emissions can rationalize this behavior, as several practices negatively impact both variables and mitigating them would be beneficial. Examples include deforestation for agricultural land enlargement and agricultural escalation (Kim et al., 2013; Wanyama et al., 2018). Moreover, this issue holds significant importance, as converting natural forests to croplands is acknowledged as the primary source of GHG emissions in SSA (Kim et al., 2021).

The results indicate that in the economies of the SSA and MENA regions, higher levels of natural capital protection are associated with lower levels of biodiversity and ecosystem conservation. This suggests a potential trade-off between efforts to safeguard natural capital and the effectiveness of measures to preserve biodiversity and ecosystem health in these regions. The feasibility of implementing environmental protection actions from international agreements is influenced by a country's stage of development (Arogundade et al., 2023); thus, less developed countries may face challenges such as limited financial resources and inadequate infrastructure, making implementation more difficult. Also, the population of SSA is anticipated to duplicate by 2050, complicating the sustainability of essential agricultural intensification efforts and further challenging the balance between ecosystem protection and food security (Duku et al., 2018; Okello et al., 2021). Additionally, MENA regions underscore the critical part played by economic institutions in mitigating trade-offs to concurrently fulfill both goals of security for the population and conservation of the ecosystems (Kassouri & Altıntaş, 2020).

Lastly, the findings indicate that the influence of cultural and social values on natural capital protection varies between the SSA and MENA regions. In SSA economies, there is a decrease in cultural and social values with increased natural capital protection. Currently, some agricultural techniques in SSA, such as managing manure, have transformed over time, leading to detrimental impacts on the environment (Ndambi et al., 2019). The cessation or abandonment of these agricultural practices plays a significant role in contributing to the protection and conservation of natural capital. While they were originally implemented to enhance agricultural productivity, advancements in understanding and technology have revealed their negative impacts on ecosystems, soil health, and overall environmental quality. On the other hand, in the economies of the MENA region, heightened emphasis on natural capital protection relates to increased cultural and social values. In this context, it is important to note that numerous historical practices support the preservation of natural capital. Especially the Fertile Crescent (stated to be the birthplace of human agricultural societies) has remains of antique agricultural methods still used today that optimize ecological conditions for the development of geophyte species (Stavi et al., 2024).

6.1. Theoretical implications

This research delves into the relationship between natural capital protection and the indicators: environmental quality, greenhouse gas emissions reductions, biodiversity and ecosystem protection, and cultural and social values. The results help in the knowledge regarding natural capital protection's role as the provider of essential resources and ecosystem services necessary for economic development while promoting environmental sustainability. By recognizing the value of natural capital and adopting policies and practices that conserve and enhance it, societies can achieve their green growth and sustainability targets (Acosta et al., 2020). In this context, it is crucial to continue pursuing of a better understanding of the synergies between natural capital protection in innovative ecosystems and the indicators. It is acknowledged that, in this study, akin to numerous other investigations into sustainability matters, enhanced knowledge repositories and authentically participatory networks are crucial for the success of the required transition, especially regarding innovative ecosystems. These networks mandate the convergence of collaborative entities, encompassing private enterprises,

financial institutions, non-governmental organizations, governmental bodies from local to national levels, and local communities and indigenous groups (Grilli et al., 2024).

6.2. Practical implications

Several valuable practical implications are identified for conserving natural capital in innovative ecosystems in economies reliant upon it. First, there is a need for resilient urban development to build cities capable of surviving and thriving amidst environmental challenges to ensure sustainable development. This involves investing in infrastructure and implementing policies that enhance resilience to climate change impacts such as flooding, droughts, and extreme weather events.

Second, recognizing and valuing environmental services is mandatory (Acosta et al., 2020). Thus, it's crucial to avoid economic hardship from their loss. By acknowledging the importance of ecosystem services like clean air, water, and fertile soil, policymakers can direct their strategies to prioritize conservation efforts and ensure the sustainable use of natural resources. This approach will enhance synergies between environmental education and can serve as an empowerment strategy to develop and implement technologies designed to mitigate environmental impacts.

Third, attention should be given to modern renewable energy technologies: Focusing on small, indigenous renewable energy technologies can help countries transition to cleaner energy sources and improve environmental quality (Bisset, 2023). Addressing infrastructural and regulatory barriers is essential to scale up renewable energy deployment and reduce reliance on fossil fuels.

Fourth, environmental education can serve as an empowerment strategy, creating a common language among entities within innovative ecosystems and facilitating relationships between them. Disseminating environmental information and actively engaging in conservation efforts can empower communities to adopt sustainable practices (Reverte et al., 2024). Enhancing green expertise through education and awareness campaigns can foster a culture of environmental stewardship and promote long-term sustainability. Particularly given that the nature of innovation ecosystems is dynamic, with actors, institutions and interactions continuously evolving both within and between multiple innovation ecosystems (Granstrand & Holgersson, 2020).

Fifth, the balance between environmental sustainability and Human well-being should be more present in government concerns, as developing policies that integrate environmental sustainability and social welfare are crucial. Addressing the trade-off between environmental protection and economic development requires innovative approaches that promote sustainable land management practices and ensure food security while preserving natural capital. And sixth, considering the impacts of globalization on environmental sustainability and human development is essential for policymakers. Designing policies that balance economic growth with environmental protection can help countries harness the benefits of globalization while mitigating its negative environmental impacts (Kassouri & Altıntaş, 2020).

7. Conclusion

Innovation ecosystems face a combination of challenges and opportunities in the sustainable management of natural capital. This study examined the preservation of natural capital in innovation ecosystems in economies dependent on natural resources, with particular attention to the SSA and MENA regions. It reveals that natural capital protection is positively influenced by environmental quality, reductions in greenhouse gas emissions, biodiversity and ecosystem protection, and cultural and social values. The indicators that most contribute to natural capital protection were identified, and measures were proposed to ensure that these regions continue to derive natural capital yields without placing them in a precarious situation. Additionally, it highlights trade-offs between safeguarding natural capital and biodiversity conservation, influenced by a country's development stage and population growth projections. Moreover, the study discusses how economic development stages and projected population growth further complicate the pursuit of environmental conservation and sustainable development goals within these regions.

While this study offers valuable insights into the conservation of natural capital in SSA and MENA regions, it is important to acknowledge its limitations. The study faced limitations due to the constrained sample size resulting from data availability for scrutinized variables. When extrapolating the findings, it's crucial to acknowledge the intrinsic characteristics of the studied regions within the specific time frame. Moreover, the analysis did not incorporate the variability in the commercial value of the different natural resources across regions and countries. Future research activities might extend the investigation by encompassing a more diverse array of regions and temporal periods to mitigate these constraints. Additionally, replicating the study across various types of natural resources with distinct characteristics could enhance understanding of the interplay between natural capital protection, related indicators, and economic development, thereby fostering more comprehensive insights and optimizing synergies within these domains.

CRediT authorship contribution statement

João J. Ferreira: Writing – review & editing, Writing – original draft, Funding acquisition, Formal analysis, Data curation. **João M. Lopes:** Methodology, Formal analysis. **Sofia Gomes:** Writing – original draft, Visualization, Validation. **Elisabete Nogueira:** Writing – original draft, Visualization, Validation. **Marina Dabić:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

I have nothing to declare.

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Glossary

SSA Countries

Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Comoros
Congo, Dem. Rep.
Congo, Rep.
Equatorial Guinea
Eritrea
Eswatini
Ethiopia
Gabon
Gambia, The
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Namibia
Nigeria
Rwanda
São Tomé and Principe
Senegal
Sierra Leone
South Africa
Sudan
Tanzania
Togo
Uganda
Zambia
Zimbabwe

MENA Countries

Algeria
Bahrain
Djibouti
Egypt, Arab Rep.
Iran, Islamic Rep.
Iraq
Israel
Jordan
Lebanon
Libya
Moroco
Oman
Qatar
Saudita Arabia
United Arab Emirates
Yemen