South African Reserve Bank

Working Paper Series

WP/26/03

Socio-economic exposure to nature-related risks in the Southern African Development Community

Antoine Godin, Julie Maurin and Julien Calas

Authorised for publication by Konstantin Makrelov

4 February 2026

SOUTH AFRICAN RESERVE BANK

South African Reserve Bank Working Papers are written by staff members of the South African Reserve Bank and, on occasion, by consultants under the auspices of the South African Reserve Bank. The papers deal with topical issues and describe preliminary research findings and develop new analytical or empirical approaches in their analyses. They are solely intended to elicit comments and stimulate debate.

South African Reserve Bank Working Papers are externally refereed.

Information on South African Reserve Bank Working Papers can be found at
https://www.resbank.co.za/en/home/publications/Papers/working-papers.

Enquiries relating to the Working Paper Series can be addressed to:
Head: Economic Research Department
South African Reserve Bank
P O Box 427
Pretoria 0001

Tel. +27 12 313 3911

Socio-economic exposure to nature-related risks in the Southern African Development Community

Antoine Godin,* Julie Maurin† and Julien Calas‡

Abstract

This paper presents the first comprehensive socio-economic assessment of Southern African countries' exposure to nature-related physical and transition risks. Results indicate high and heterogeneous exposure across the Southern African Development Community (SADC) region, reflecting differences in economic structures, dependence on ecosystem services and biodiversity impacts. Physical risks are particularly acute, driven by strong reliance on services such as water provision, climate regulation and flood control. Net exports are highly vulnerable, with average exposure reaching 67% directly and 88% when indirect effects are included. Angola, Madagascar, Tanzania and Zimbabwe stand out for their pronounced dependence on ecosystem services.

Transition risks also vary widely: Madagascar, Mozambique and Zambia face substantial direct exposure, while Angola is chiefly affected through its petroleum supply chains. Madagascar emerges as the country most at risk overall, combining high biophysical dependence with extreme biodiversity sensitivity.

The assessment is subject to several data and methodological limitations, including reliance on static 2019 multi-regional input-output data, partial country coverage and constraints in environmental and ecosystem-service metrics. Despite these challenges, the paper highlights the urgent need for central banks and policymakers in Southern Africa to integrate nature-related risks into monitoring frameworks and to strengthen data and modelling capacities to guide effective and resilient transition strategies.

JEL classification

Q01, Q56, Q57

Keywords

Nature-related risk, biodiversity, ecosystem service, physical risk, transition risk, Global Biodiversity Framework Target 15, Taskforce on Nature-related Financial Disclosures, SADC

---

* Agence Française de Développement.

† Agence Française de Développement.

‡ Agence Française de Développement.

1. Introduction[1]

1.1 Humanity, nature and the economy: a relationship on the brink

Human activity is exacerbating the erosion of biodiversity on a global scale at a rate unprecedented in human history, leading to what is sometimes referred to as the "sixth mass extinction" (Ceballos et al. 2015). According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES),[2] biodiversity refers to the variety of living organisms present in each terrestrial and aquatic ecosystem and their ecological complexes. It includes genetic diversity, diversity between species, diversity of ecosystems and the interactions within and between each of these dimensions. The latest Global Assessment Report by IPBES (2019) warned that 1 million species and a third of terrestrial ecosystems are at risk of extinction, while 66% of marine ecosystems have been significantly altered by human activities. We have now reached a point where human demands exceed nature's capacity to regenerate, as evidenced by the transgression of six out of nine planetary boundaries (Borucke et al. 2013; Richardson et al. 2023).

This rapid decline of biodiversity is the result of a combination of direct and indirect drivers. According to IPBES (2019), the main direct anthropogenic pressures on biodiversity are, in decreasing order of importance at the global level: changes in land use, the extraction of natural resources, climate change, pollution and the introduction of invasive species. Indirect drivers include macro socio-economic trends, encompassing factors such as demographics, sociocultural characteristics, economic and technological developments, institutional and governance systems and issues like conflicts and epidemics. These direct and indirect drivers are reinforced by global trade structures and regimes of accumulation that deepen existing inequalities. The labour

[1] We wish to thank Jüha Siikamäki and Antonin Vergez from the International Union for Conservation of Nature (IUCN) for their help with the Red List of Threatened Species. Thank you to Serafin Jaramillo, Etienne Espagne, Katie Kedward, Mathilde Salin, Romain Svartzman, Morgane Gonon, Guilherme Magacho, Luca Tausch and Jhan Andrade for their comments on this paper and the methodology behind it. We also thank Matthieu Trichet and Paul Hadji-Lazaro for more general discussions that informed our reflections on this methodology.

[2] IPBES is an independent intergovernmental body established by member states in 2012. It provides decision-makers with objective scientific assessments of the state of knowledge about the planet's biodiversity, ecosystems and their benefits to people, as well as tools and methods to protect and sustainably use these vital natural resources. It can be seen as the biodiversity equivalent of the Intergovernmental Panel on Climate Change (IPCC).

and natural resources of regions rich in biodiversity are often extracted at low cost through unequal exchange, undermining their capacity to invest in sustainable development and to protect ecosystems that are crucial for global environmental balance (Hickel, Hanbury Lemos and Barbour 2024; Tausch and Althouse 2025).

This degradation can lead to sudden and sometimes irreversible shifts in ecosystems, known as tipping points, which occur when critical thresholds are crossed. These changes can severely reduce an ecosystem's capacity to recover, adapt and continue delivering key functions. As a result, essential ecosystem services – such as clean water, fertile soil and climate regulation – may be disrupted, directly affecting human survival and quality of life (Folke et al. 2004). Ecosystem services represent the contributions of ecosystems to human survival and quality of life. According to Ecosystem Accounting within the System of Environmental-Economic Accounting, three types of ecosystem services exist: provisioning services (e.g. water, food, medicine), regulating services (e.g. flood control, climate regulation) and cultural services (e.g. recreation, aesthetic) (United Nations 2021). Our economies are intrinsically dependent on ecosystem services either directly, as inputs, or indirectly, by facilitating production processes. The World Economic Forum (2020) estimates that nearly half of the world's GDP – some US$44 000 billion – relies moderately or highly on the health of ecosystems.

Among these ecosystem services, water and climate regulation are particularly necessary for sustaining and supporting key productive sectors. Ecosystems regulate the flow and quality of water through processes such as water purification, flow regulation and flood control. Vegetation and soil absorb, store and gradually release water, ensuring a stable supply during dry periods and reducing flood risks during heavy rains. Ecosystems also filter pollutants, maintaining clean water for human use and aquatic life, and help regulate climate, both globally and locally. Globally, they regulate atmospheric gases by storing carbon and other greenhouse gases, helping to mitigate climate change. Locally, vegetation influences microclimates by cooling the air through evapotranspiration and moderating temperature extremes, which supports human well-being and economic activities. Forests and other vegetation also play a key role in maintaining rainfall patterns by recycling moisture, which sustains precipitation far inland.

1.2 The economic and financial risks of nature's collapse

Biodiversity loss presents profound risks to economic and financial stability. The Dasgupta Review (2021) underscores the catastrophic consequences biodiversity decline could have for global economic and financial systems, and calls for an urgent and systemic valuation of nature. Central banks, financial supervisors and ministries of finance increasingly acknowledge the financial sector's exposure to nature-related risks. This growing awareness is reflected in initiatives such as the Network for Greening the Financial System (NGFS),[3] the INSPIRE network, the Coalition of Finance Ministers for Climate Action and the Coalition for Capacity on Climate Action.[4] These initiatives notably reveal that biodiversity loss could create significant risks, including reduced asset productivity and regulatory misalignments, which may destabilise financial markets (NGFS 2023, 2024).

National-level analyses further illustrate the potential scale of nature-related financial shocks. In the Netherlands, for instance, van Toor et al. (2020) found that 36% of financial portfolios are heavily reliant on ecosystem services, with biodiversity footprints comparable to significant losses of pristine nature. Similarly, Calice, Diaz Kalan and Miguel (2021) applied this methodology to Brazil and discovered that 45% of the corporate loan portfolio of Brazilian banks is exposed to sectors highly dependent on ecosystem services. In France, Hadji-Lazaro et al. (2024) revealed that 42% of the value of securities held by French financial institutions is tied to companies that are highly dependent on one or more ecosystem services, with the cumulative terrestrial biodiversity footprint of these securities equating to the loss of 130 000 km² of pristine nature. Moreover, Kedward, Ryan-Collins and Buller (2021) found that 40% of the bonds held by the European Central Bank are highly or very highly dependent on ecosystem services, with particular financial exposure to water-related services amounting to €38.6 billion.

---

[3] The NGFS is a voluntary initiative created on the occasion of the "One Planet Summit" launched in 2017 by French President Emmanuel Macron, the United Nations and the World Bank to identify and accelerate transformational initiatives and financing for climate, biodiversity and ocean solutions. The NGFS regroups 144 central banks and regulators worldwide.

[4] https://www.climatecapacitycoalition.org/

In short, although climate change has captured most of the attention with regard to human-environmental interactions, biodiversity loss consequences could be at least as high as those generated by climate change, in addition to interacting with them (IPBES and IPCC 2021). The World Economic Forum (2024) ranks biodiversity loss and ecosystem collapse as the third most significant long-term threat over the next decade. Furthermore, Kedward, Ryan-Collins and Chenet (2023) argue that nature-related financial risks may materialise more rapidly than climate risks, suggesting that systemic financial risks are underestimated when these domains are considered in isolation.

1.3 The risk of international agreements on nature conservation

The Earth Summit in Rio de Janeiro in 1992 marked a pivotal moment in international biodiversity governance, with the adoption of the United Nations Convention on Biological Diversity (CBD).[5] The agreement was composed of a series of non-binding targets, which each signatory country was encouraged to implement at the national level. In 2010, the Nagoya Conference further strengthened these commitments, leading to the creation of the Aichi targets – 20 specific objectives organised around five strategic goals to address and mitigate biodiversity loss across the globe. Despite these efforts, however, the majority of the Aichi targets have not been achieved, highlighting the ongoing challenges in global biodiversity conservation.

In December 2022, the 15th Conference of the Parties (COP15) led to the adoption of the Kunming-Montreal Global Biodiversity Framework by 196 parties (CBD 2022). As such, signatory countries will have to draw up new national trajectories for sustainable development (the so-called National Biodiversity Strategies and Action Plans) and for the protection of living organisms by applying sectoral policies to reduce pressures on biodiversity. In particular, the framework sets out 23 targets to halt biodiversity loss by 2030 and recover a net positive increase in biodiversity by 2050. Governments, as well as economic and financial stakeholders, are being urged to rethink their models in

[5] The CBD is a legally binding international treaty that was opened for signature on 5 June 1992 at the United Nations Conference on Environment and Development (also known as the “Earth Summit”). The 196 signatories commit to three main objectives: to conserve biological diversity, to use biological diversity sustainably and to share the benefits arising from the use of genetic resources fairly and equitably.

order to systematically integrate biodiversity-related issues. Indeed, the financial sector is directly targeted by the goals of the Global Biodiversity Framework, particularly through Target 15, which “calls for the assessment and disclosure of nature-related risks, impacts and dependencies by large companies, including financial institutions”, and Target 19, which “calls for a substantial increase in public and private financial resources – by at least US$200 billion annually – towards addressing the nature-related funding gap”. Moreover, several targets related to pollution reduction and the management of agriculture, forestry and aquaculture, as well as transparency regarding their impacts on biodiversity (Targets 6, 10), address the sectors with the most significant impact on biodiversity. States have also committed to integrating biodiversity into public policies across sectors (Target 14).

1.4 Assessing nature-related risks: methods and approaches

As in the case of climate, we can distinguish between two types of nature-related risks: physical risks and transition risks (NGFS 2024; Taskforce on Nature-related Financial Disclosures (TNFD) 2023).

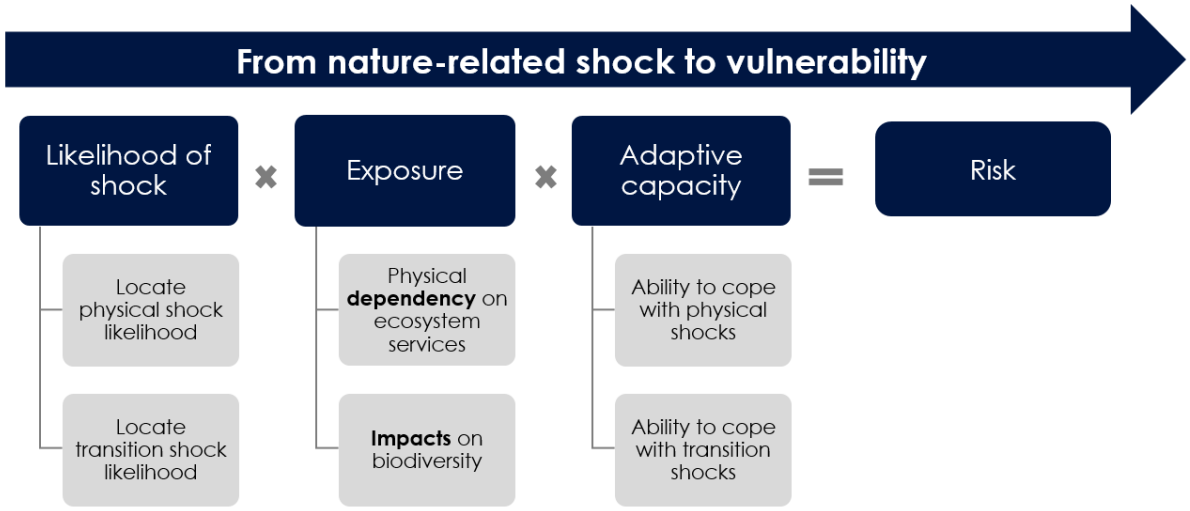
Physical risks arise when the degradation of nature and consequential loss of ecosystem services affect human capital and economic activity. Industries whose production processes are highly dependent on those ecosystem services – directly or indirectly through their value chain – will be the most exposed to physical shocks. These risks may have a **chronic nature**, such as the prolonged use of pesticides causing a gradual decline in pollinator populations, reduced soil fertility and decreased agricultural yields. Alternatively, they may be **acute**, like forest fires or pests affecting a harvest. These physical shocks can occur on a local scale, such as a drop in agricultural production due to water scarcity in a specific region, or on a global scale, exemplified by supply chain disruptions or an unprecedented decline in aggregate demand caused by a pandemic.

Transition risks relate to changes in policies, consumer preferences or behaviours, and technologies aiming to mitigate human activity’s impact on biodiversity and the effect of these changes on economic activity and asset value. Firms with a significant direct or indirect negative impact on biodiversity are more exposed to nature-related transition risk than businesses with a low impact (i.e. firms with less impact in the same

or different sectors). Transition shocks can also manifest on a very **local scale**, such as changes in agricultural subsidies affecting farmers within a specific region. Alternatively, they may occur on a more **global scale**, such as adjustments to trade agreements aimed at addressing issues like imported deforestation or species extinctions, which could result in revenue losses for certain countries (Irwin et al. 2022).

The theoretical framework of nature-related risks presented in Figure 1 is in line with that of the NGFS (2024) and the LEAP (Locate, Evaluate, Assess, Prepare) approach of the TNFD (2023). It consists of three phases. The first phase is to determine the probability of a shock occurring (e.g. the probability that an ecosystem will no longer be able to provide ecosystem services and the probability that companies will be forced by regulations to reduce their pressures on nature). The second phase is to measure the exposure of agents through their dependencies on ecosystem services (in the case of physical risk) or their impact on biodiversity (in the case of transition risk). The third phase involves assessing the ability of agents to adapt to physical or transition shocks.

Figure 1: Steps to assess nature-related risks



Industries may be indirectly exposed to a physical shock or to an ecological transition[6] through their supply and distribution chains. Indeed, if an industry buys from or sells goods and services to exposed industries, it may itself face a transition or physical risk. For example, the manufacturing of agricultural products relies heavily on the upstream

[6] We define an ecological transition as all the changes in technology, policies or behaviour that lead to a reduction of pressures exerted on ecosystems.

agricultural sector, which is exposed to a double vulnerability. On the one hand, it can be exposed to major physical risks, notably linked to its consumption of water and its need for nutrient-rich land. On the other hand, it may be faced with significant transition risks due to its major impact on biodiversity, notably through its use of land and pesticides. Thus, manufacturers of agricultural products may be indirectly exposed to physical and transitional shocks that affect their upstream inputs.

This assessment is complex, because sectors may be indirectly exposed to multiple shocks – both physical and transitional – and the interactions between these shocks are not fully understood. It is also difficult to assess the materiality of these risks, as we cannot predict exactly which industries will be negatively affected. Unlike climate scenarios, which often assume a shift from fossil fuels to renewable energy, sectors that heavily affect biodiversity – like agriculture – are unlikely to disappear. Instead, they will likely need to adapt, though the possibilities for adaptation vary across sectors and regions and remain uncertain.

1.5 The urgency of protecting Africa's ecosystems

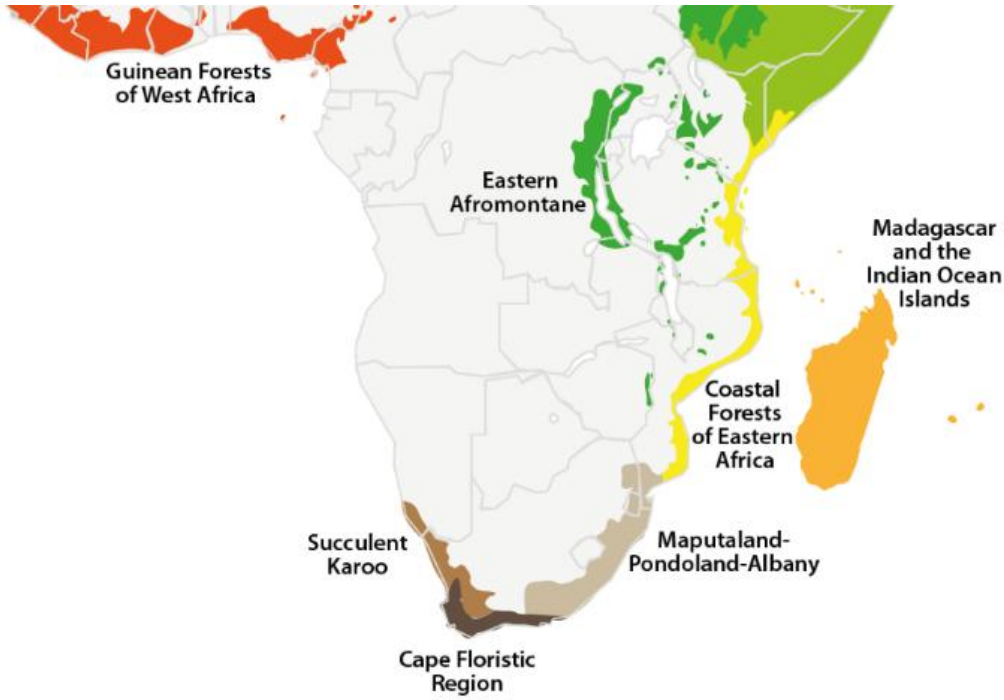
The African continent possesses an exceptionally rich biodiversity, hosting about a quarter of the world's mammal species. It has the most intact assemblages of large mammals on Earth, with 1 160 megafauna species acting as ecological engineers and playing vital roles in maintaining ecosystems (Malhi et al. 2016). Africa is also home to more than 2 500 bird species, accounting for one quarter of the world's total. The continent hosts eight of the world's 36 recognised biodiversity hotspots (IPBES 2018). Six of these regions – containing a significant proportion of endemic vascular plants and having lost at least 70% of their original native vegetation – are located in Southern Africa (Figure 2).

Among Africa's biodiversity hotspots, the Cape Floristic Region and Madagascar are particularly noteworthy for their unique levels of endemism.[7] For instance, more than 90% of Madagascar's species are endemic (Antonelli et al. 2022). Africa also hosts

[7] Endemism refers to the ecological condition of a species being native and restricted to a particular geographic area, such as a specific region, country or ecosystem, and not occurring naturally anywhere else.

about one-sixth of the world's remaining forests, including the vast Congo Basin. This 240-million-hectare rainforest spans eight African countries and supports the livelihoods of 80 million people in the region (White et al. 2021). These landscapes are not untouched wildernesses but have been deeply shaped by centuries of human presence and land management. Local communities have long interacted with these ecosystems, drawing on traditional knowledge and practices to sustain both livelihoods and biodiversity. Today, the continent's protected area network covers 4.4 million km² (14.6% of its land area), with the largest share found in Southern Africa (Barnes 2015; UNEP-WCMC and IUCN 2024). And yet only the Central and Southern African regions have achieved Aichi Biodiversity Target 11 for terrestrial protected areas.

Figure 2: Biodiversity hotspots in SADC (adapted from IPBES 2018)



Currently, over 62% of Africa's rural population directly depends on ecosystem services for sustenance, including food, water, energy and health (IPBES 2018). However, biodiversity is under severe threat. Since 1970, wildlife populations in Africa have declined by 76%, a rate faster than the global average (WWF 2024). A third of Africa's flora is at risk of extinction (Stévart et al. 2019) and 20% of the continent's land area (6.6 million km^2) has become degraded, with a high severity in Central Angola, Central Botswana, Madagascar and South Africa (IPBES 2018).

Africa's population is projected to double by 2050 and quadruple by 2100 (Gerland et al. 2014), resulting in rapid economic growth and urbanisation that will significantly transform land-use patterns across the continent. This demographic shift will place considerable pressure on biodiversity, leading to increased soil erosion and habitat fragmentation and a decline in vital ecosystem services. As urbanisation expands, the strain on natural resources, particularly water, is likely to intensify.

In addition to these challenges, climate change is expected to worsen the environmental impacts, with more frequent and severe droughts, greater rainfall variability and extreme flooding events already observed in many regions (Cai et al. 2021; IPCC 2023). These climate extremes, which have been intensifying since the 1970s, will disrupt both ecosystems and agricultural systems, particularly those dependent on rainfall. As a result, millions of Africans, particularly in drought-prone areas, will face increased food insecurity, with an estimated 200 million people at risk of hunger by 2050 (Adom 2024).

In response, the Southern African Development Community (SADC) member states have ratified a number of conventions that aim to facilitate the management of biodiversity. These include the CBD, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Bonn Convention on the Conservation of Migratory Species of Wild Animals. At a regional scale, in 2008 SADC set up a framework – the Regional Biodiversity Strategy – to increase cooperation on biodiversity issues and in 2010 set up a Regional Action Plan. Both documents are currently being revised with the support of the Food and Agriculture Organization of the United Nations and will be aligned with the Kunming-Montreal Global Biodiversity Framework.

2. Context and scope of this study

The current paper builds on previous research on the risks and opportunities related to nature in South Africa. This work was conducted by the French Development Agency in partnership with the South African National Biodiversity Institute, the Department of Environment, Forestry and Fisheries, the South African Reserve Bank, WWF South Africa and the National Treasury (Hadji-Lazaro et al. 2025). The study highlights that ecosystem services related to water represent the country's primary physical threat.

Notably, 80% of net exports originate from activities highly dependent on surface water – particularly in the manufacturing and mining sectors. Additionally, about 59% of corporate loans are issued to water-dependent sectors, underscoring the potential financial instability posed by water shortages. A key strength of this study is its spatially explicit approach, revealing municipalities where exposure is most critical by considering both the location of sectors and the water stress levels in these regions. For instance, we found that 23% of net exports are generated by sectors dependent on surface water and located in water-sensitive municipalities. Regarding transition risks, the study shows that 51% of mining-related exports come from municipalities where ecosystems are at risk due to mining activities. This suggests that if the country implements policies to protect ecosystems threatened by mining, half of these exports could be destabilised.

In this paper, we replicate parts of the Hadji-Lazaro et al. (2025) methodology to analyse the socio-economic exposure of Southern African countries to nature-related risks. We identify the sectors most exposed to physical and transition risks and assess how much they contribute to key socio-economic indicators – such as net exports, production, wages and net taxes – to evaluate the overall exposure of countries to these risks.

This is done by first assessing the dependence of sectors on ecosystem services using the ENCORE tool,[8] their pressure on biodiversity using the Environmentally Extended Multi-Regional Input-Output (EE-MRIO) GLORIA database (Lenzen et al. 2017, 2022) and their contribution to species extinction risk using an indicator specifically developed for this purpose (the Species Threat Abatement and Restoration (STAR) metric).

- We characterised **physical risks** by identifying both direct and indirect exposures. We considered a sector directly exposed if it showed high or very high dependence on ecosystem services based on the ENCORE tool. We classified a sector as indirectly exposed when the sectors in the first tier of its

[8] ENCORE Partners (Global Canopy, UNEP FI and UNEP-WCMC). 2025. ENCORE: Exploring natural capital opportunities, risks and exposure. Cambridge, UK. https://encorenature.org.

value chain – upstream or downstream – on average also demonstrated high or very high dependence on these services.

- We assessed **transition risks** in terms of both direct and indirect exposure. We classified a sector as directly exposed if it generated significant biodiversity pressures or impacts at the national level – specifically, if it accounted for at least 10% of a national-level pressure (e.g. land use, emissions and resource extraction) or at least 5% of the national STAR score. We considered a sector indirectly exposed when the first-tier sectors in its value chain generated significant biodiversity pressures – defined as contributing at least 10% of upstream or downstream pressures within a country, or at least 5% of the corresponding STAR score relative to national totals.

In the second step, we use GLORIA to examine the contribution of these sectors to key national socio-economic aggregates (such as net exports, net taxes, production and wages) and to evaluate countries' socio-economic exposure to nature-related risks. For example, a country is considered exposed via its net exports if the sectors driving those exports are either highly dependent on nature (exposed to physical risk) or exert significant pressure/impact on biodiversity (exposed to transition risk). For more details on the calculations, see the methodology (Maurin, Calas and Godin 2025). Figure A0.1 in Annex A0 presents the breakdown of socio-economic indicators by sector and country in SADC.

This paper provides crucial insights for central banks and governments by identifying the sectors most exposed to nature-related risks. Central banks and ministries of finance can use these insights to develop quantitative tools to assess the economic stability of their country in light of biodiversity degradation. As financial supervisors, central banks can also use this knowledge to monitor the exposure of commercial banks, helping to prevent defaults, asset losses and financial turmoil.

Nature-related shocks can also lead to price fluctuations in goods and services, such as food price increases from natural disasters or rising production costs in affected sectors, which can lead to inflation. Understanding vulnerable sectors allows central banks and ministries of finance to monitor and adjust their fiscal policies to manage potential sources of inflationary pressure. Furthermore, recognising these

vulnerabilities could enable central banks and financial regulators to guide or discourage investments, directing them to more resilient sectors, fostering a sustainable economy and reducing systemic risks.

This study provides an initial framework for analysing nature-related risks in line with the NGFS guidelines, of which all SADC countries are members. It offers central banks the opportunity to rethink their policies by incorporating quantitative tools that account for nature-related shocks.

The assessment focuses on 10 countries within SADC (Figure 3). Six countries – Comoros, Eswatini, Lesotho, Malawi, Mauritius and Seychelles – were excluded due to a lack of economic data. A general assessment of the region's exposure to nature-related risks, along with its main challenges and characteristics, is presented in the following sections, with country-specific results provided in Annexes A1 to A10.

Figure 3: Map of the 10 SADC countries covered by the study

3. Results

3.1 Socio-economic exposure to physical risks

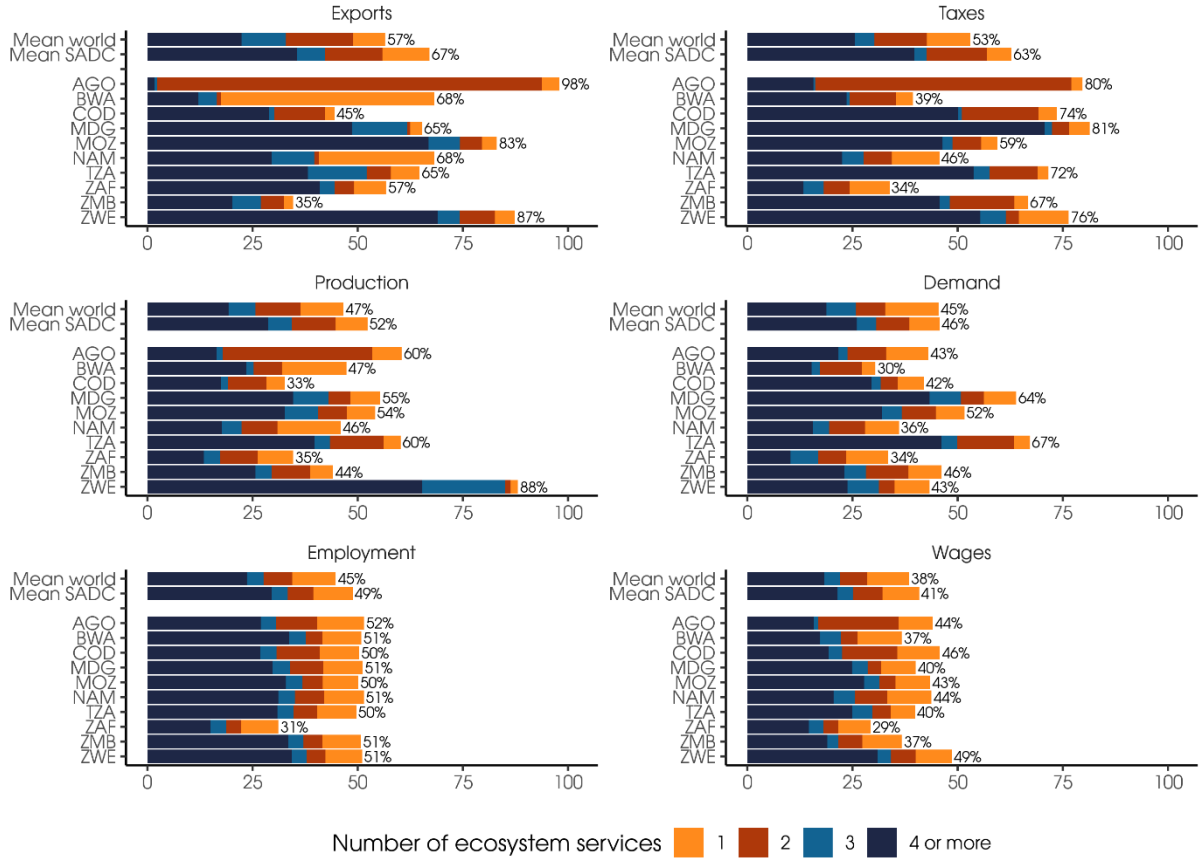
A country's exposure to nature-related physical risks is strongly linked to its dependence on ecosystem services that support economic production. As biodiversity declines and these services become increasingly unstable or degraded, countries face growing vulnerability to physical risks – such as disruptions in water supply, reduced soil fertility and decreased climate regulation – that can severely impact key economic sectors. However, reducing exposure does not mean severing ties with nature; rather, the challenge is to strengthen the resilience of ecosystems and anticipate the potential economic disruption associated with their degradation. This means there is an urgent need to protect and restore ecosystem functions, notably through nature-based solutions that preserve essential services and support long-term economic resilience.

This section evaluates the dependence of economic sectors on ecosystem services by combining data from the ENCORE tool with input-output tables from the GLORIA database. Across SADC, direct exposure to nature-related shocks remains consistently high across all socio-economic dimensions. On average, sectors that strongly depend on at least one ecosystem service generate 67% of net exports and 63% of net taxes. This pattern highlights the broad and systemic reliance of these economies on various aspects of nature (Figure 4). Notably, no country in the region falls below a 29% exposure threshold, reflecting a shared structural vulnerability. Despite this regional pattern, country-level exposure reveals substantial heterogeneity – especially in production, net exports, fiscal exposure and regarding final demand with a coefficient of variation higher than 27% (Table A0.1 in Annex A0). Production-based exposure ranges from a minimum of 33% in the Democratic Republic of the Congo (DRC) to a maximum of 88% in Zimbabwe. In contrast, exposure through employment and wages tends to be more evenly distributed across countries.

Some SADC members appear to share similar types and intensities of direct exposure (Figure 5 and Annexes A1 to A10). For example, Madagascar, Tanzania and Zimbabwe show consistently high levels of exposure, largely because their agricultural sectors – which underpin multiple socio-economic indicators – depend heavily on a wide range of ecosystem services. In contrast, other countries in the region, such as the DRC and Zambia, face exposure primarily through their mining sectors. These

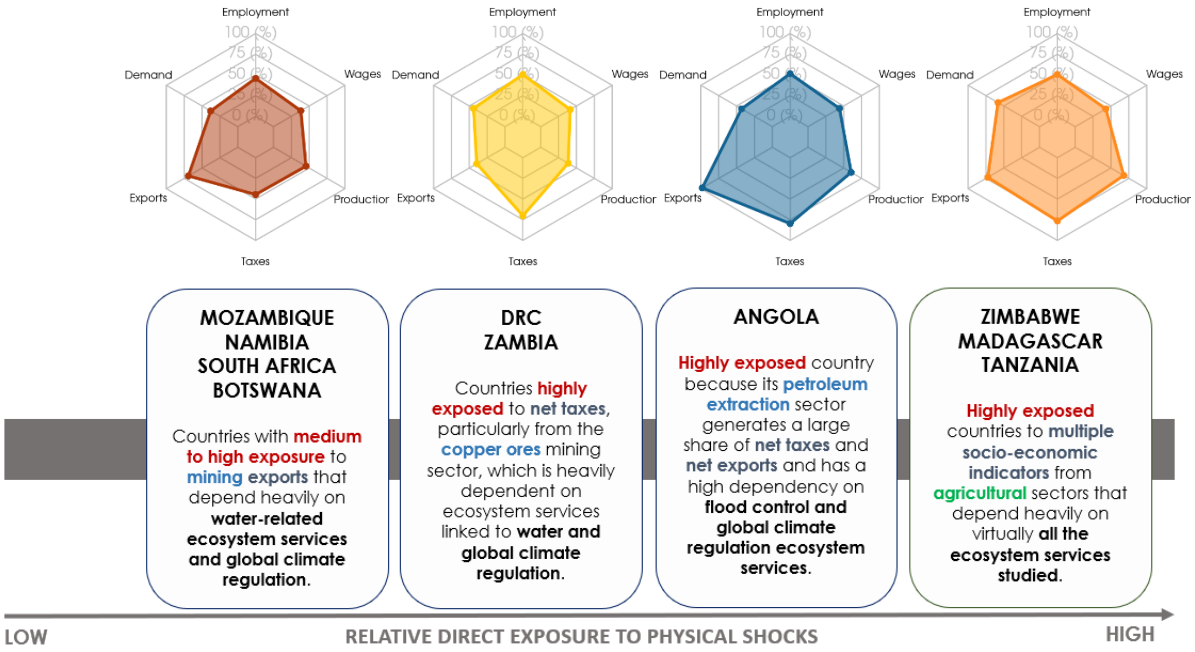
sectors, particularly copper ore extraction, rely extensively on ecosystem services related to water availability and global climate regulation. Angola is a distinct case of extreme exposure: its petroleum extraction sector – highly dependent on flood control and climate regulation – generates 90% of the country's net exports and 56% of its net tax revenues.

Figure 4: Share of socio-economic indicators generated by exposed sectors



Note: A sector is considered exposed if it is highly and directly dependent on at least one ecosystem service.

Figure 5: Direct physical exposure to biodiversity loss: the four patterns in SADC



Note: For groups composed of multiple countries, the radar plots show the average share of socio-economic indicators generated by sectors that are highly dependent on at least one ecosystem service. For Angola, the values represent its own data (not an average).

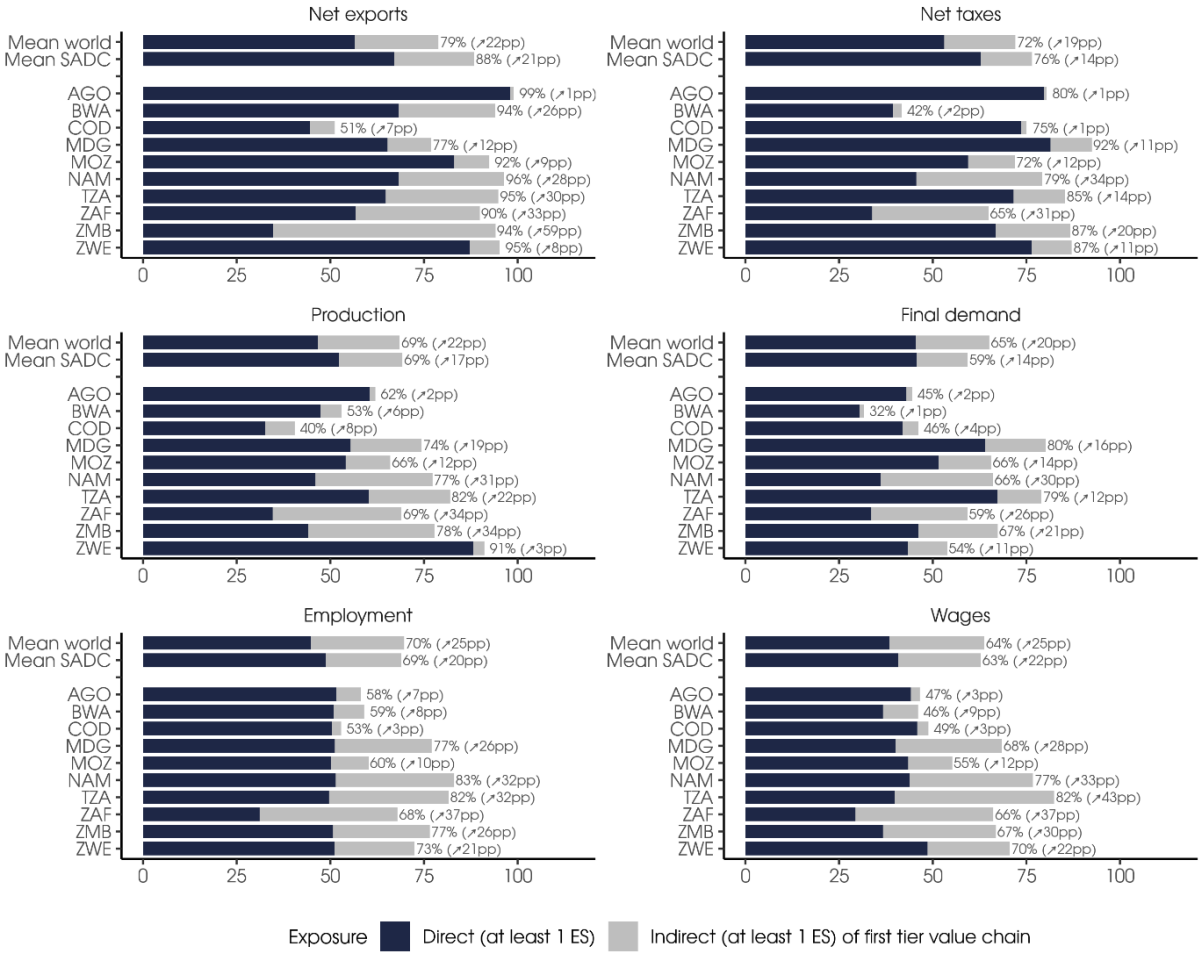
When considering indirect effects – those embedded in the first tier of upstream and downstream value chains – exposure levels rise significantly (Figure 6). On average, SADC is slightly more exposed than the rest of the world, especially for net exports. When including indirect effects, SADC shows an average export-related exposure of 88%, an increase of 22 percentage points. Its combined direct and indirect exposure through net taxes stands at 76%.

In Zambia, for instance, net exports exposure increased by 59 percentage points when accounting for dependencies within the first-tier value chains of its sectors. These rises are driven by numerous economic sectors that are not directly impacted by physical shocks but are nonetheless indirectly exposed. For example, the basic copper sector is highly and indirectly dependent on five ecosystem services through its upstream value chain, while contributing significantly to the country's net export volume. This is largely because it sources half of its inputs from the copper ores sector, which itself is highly dependent on these ecosystem services.

Similarly, wage-related exposure in Tanzania increased by about 43 percentage points under the indirect analysis. This rise is mainly driven by the wholesale and retail trade

sector, which supplies inputs to animal-based manufacturing sectors. The same sector also contributes to increased exposure in South Africa across all socio-economic indicators (Annexes A1–A10).

Figure 6: Share of socio-economic indicators generated by exposed sectors



Note: A sector is considered exposed if it is dependent directly (or indirectly) on at least one ecosystem service. The values at the end of the bars represent the increase in exposure when indirect exposures are included in the analysis (in percentage points, pp).

Water-related ecosystem services – such as purification, rainfall pattern regulation and flow regulation – and global climate regulation are central to the region's economic stability. On average, more than 34% of both net taxes and net exports originate from sectors heavily dependent on at least one of these services. While some ecosystem services appear more robustly supplied in SADC compared to global averages, others – such as flood control – remain insufficiently supported (average provision capacity score: 2/5) despite their critical role in sustaining sectors that contribute nearly half of regional net taxes and exports (Figure 7). These regional averages, however, mask

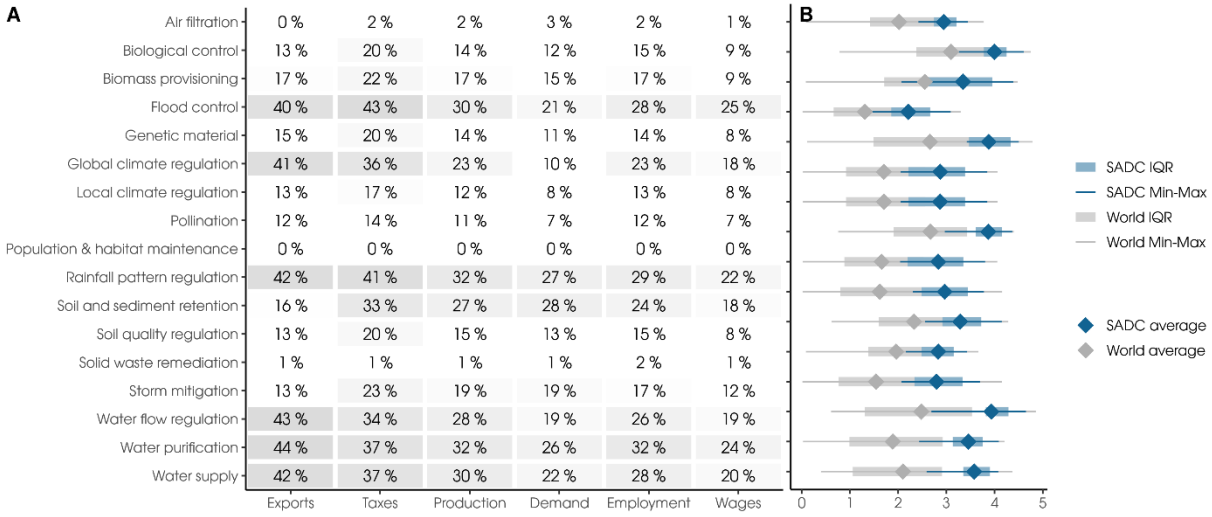
significant intra-regional disparities and should be interpreted cautiously. Ultimately, more granular, country-specific assessments are needed to evaluate the true state of ecosystem service provision and its implications for socio-economic stability. Indeed, to assess a country's vulnerability to physical risks it will be necessary to conduct local assessments on the current state and trend of ecosystem services provision and the presence or absence of industries dependent on these services.

Sectoral analysis confirms that the agriculture, forestry and fishing sector is among the most directly exposed to nature-related shocks, owing both to its intrinsic dependence on nature and its socio-economic significance in Southern Africa (Figure 8). Mining also plays a major role in shaping exposure, particularly through its reliance on water-related services and the regulation of flood and climate. While manufacturing sectors are diverse, they similarly depend on these services due to operational needs such as stable water quantity and quality, protection from extreme weather and uninterrupted processes like cooling, effluent treatment and dust suppression. In SADC, this reliance translates into significant economic exposure, as a large share of national exports and fiscal revenues is tied to these sectors. On average, 40% of net exports are generated by sectors that depend heavily on flood control services (Figure 7), and, notably, 80% of these exports come from the mining sector alone (Figure 8). Meanwhile, the construction sector increases the region's vulnerability through its dependence on soil retention, rainfall pattern stability and flood control – services already under pressure in several SADC ecosystems.

Figure 7:

(A) Average share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in SADC

(B) Average capacity of countries to provide ecosystem services



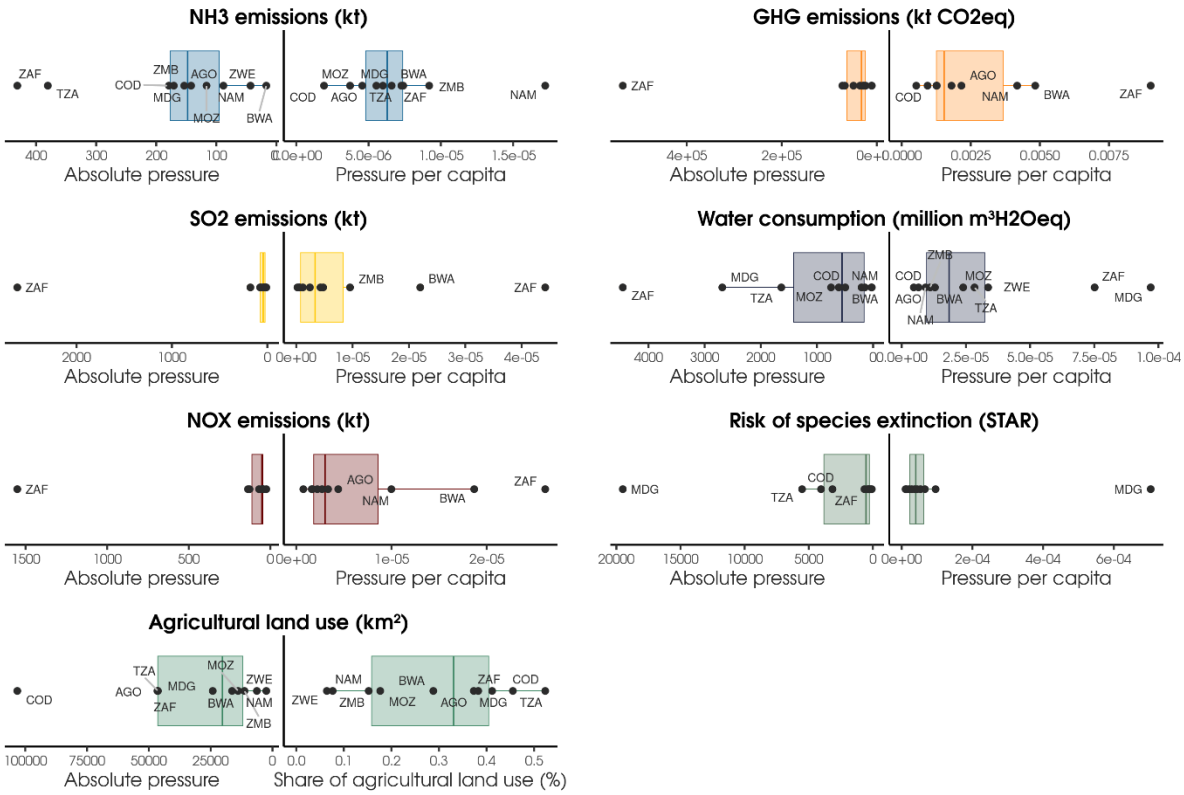
Note: In Figure 7A, gradients of grey correspond to magnitude of exposure. In Figure 7B, 0 = low capacity, 5 = high capacity. The IQR refers to the interquartile range, while Min-Max indicates the minimum and maximum values observed in the dataset for the region under consideration. The provision capacity score was developed based on ENCORE's ecosystem services by the Agence Française de Développement with support from ecologists. For more details on its calculation, please refer to the methodology.

Figure 8: Weighted average of socio-economic indicators generated by sectors highly dependent on ecosystem services using SADC countries' total exposure as weights. On average, for example, 80% of SADC net exports' exposure related to flood control is generated by mining and quarrying sectors.

3.2 Socio-economic exposure to transition risks

The pressures analysed in this section contribute to four of the five main drivers of biodiversity loss identified by IPBES – land use, resource extraction, greenhouse gas (GHG) emissions and air pollutants. However, this overview is not exhaustive. In particular, we were not able to assess any pressure relative to the driver invasive alien species. Our assessment focuses on pressures that can be quantified at the sectoral level using the MRIO-EE GLORIA database. In addition, we included a biodiversity impact metric – the STAR metric – that is widely used to assess species extinction risk. All pressures and the impact metric are presented in Figure 9.

Figure 9: Pressures and risk of species extinction (i.e. STAR) generated by country in SADC



Note: The STAR metric is an impact indicator of endangered species extinction risk in a given country.

Land-use change is the most significant driver of biodiversity degradation, as it leads to habitat loss and fragmentation. This driver is assessed by analysing the share of national territory dedicated to agriculture and forestry – two major land-consuming sectors. It is therefore a static picture of agricultural land extent rather than a dynamic measure of land-use change between two time periods. In absolute terms, the DRC

leads the region, with over 1 million km² under cultivation and forestry – unsurprising given its large size. However, when considering the proportion of land used for these purposes relative to total territory, Tanzania stands out, with over 50% of its land dedicated to agriculture and forestry, narrowly surpassing the DRC, where 46% of the territory is used for these activities. At the other end of the spectrum, Namibia and Zimbabwe allocate the least amount of their land (less than 8%) to agriculture and forestry.

Blue water consumption – freshwater taken from rivers, lakes or groundwater – is a key pressure associated with resource extraction. Overuse of blue water disrupts hydrological cycles, degrades aquatic habitats and threatens freshwater species. Because this water is lost through evaporation or product integration, it does not return to the ecosystem, making high consumption levels a marker of unsustainable use. The two countries with the highest water consumption in the region are South Africa and Madagascar, with respective usage of 4 457 m^3 and 2 685 million m^3 of water equivalent.

GHG emissions are the primary driver of climate change, which significantly threatens biodiversity worldwide. Rising temperatures, altered rainfall patterns and more frequent extreme weather events are disrupting species' life cycles, shifting habitats and forcing species to adapt, migrate or risk extinction. South Africa emerges as the region's dominant emitter of GHGs, with annual emissions of 534 million tons of CO_2 equivalent – or 9 tons per capita. It is followed by Botswana and Namibia, both with 4.8 tons per capita.

Air pollution from ammonia (NH_3), nitrogen oxides (NO_X) and sulphur dioxide (SO_2) is another major threat to biodiversity. These pollutants contribute to eutrophication, acidification and toxicity in ecosystems. NH_3 is mainly linked to agricultural practices, especially livestock farming. NO_X and SO_2 are primarily produced by the industrial combustion of fossil fuels and metal processing. South Africa and Tanzania are the leading emitters of NH_3 in the region, each emitting over 380 kilotons annually. However, when adjusted for population, Namibia tops the list, with 0.02 tons of NH_3 per capita. South Africa is the primary contributor of NO_X and SO_2, emitting 1 550 tons

and 2 620 tons annually, respectively. Botswana is another significant emitter of these pollutants.

To assess the potential risk of species extinction, we use the STAR metric, which quantifies the contribution of sectors to extinction risk based on the IUCN Red List. Madagascar faces the highest risk of species extinction in the region – unsurprising, as the entire country is a biodiversity hotspot that hosts a large number of endemic species and is experiencing a high rate of species loss.

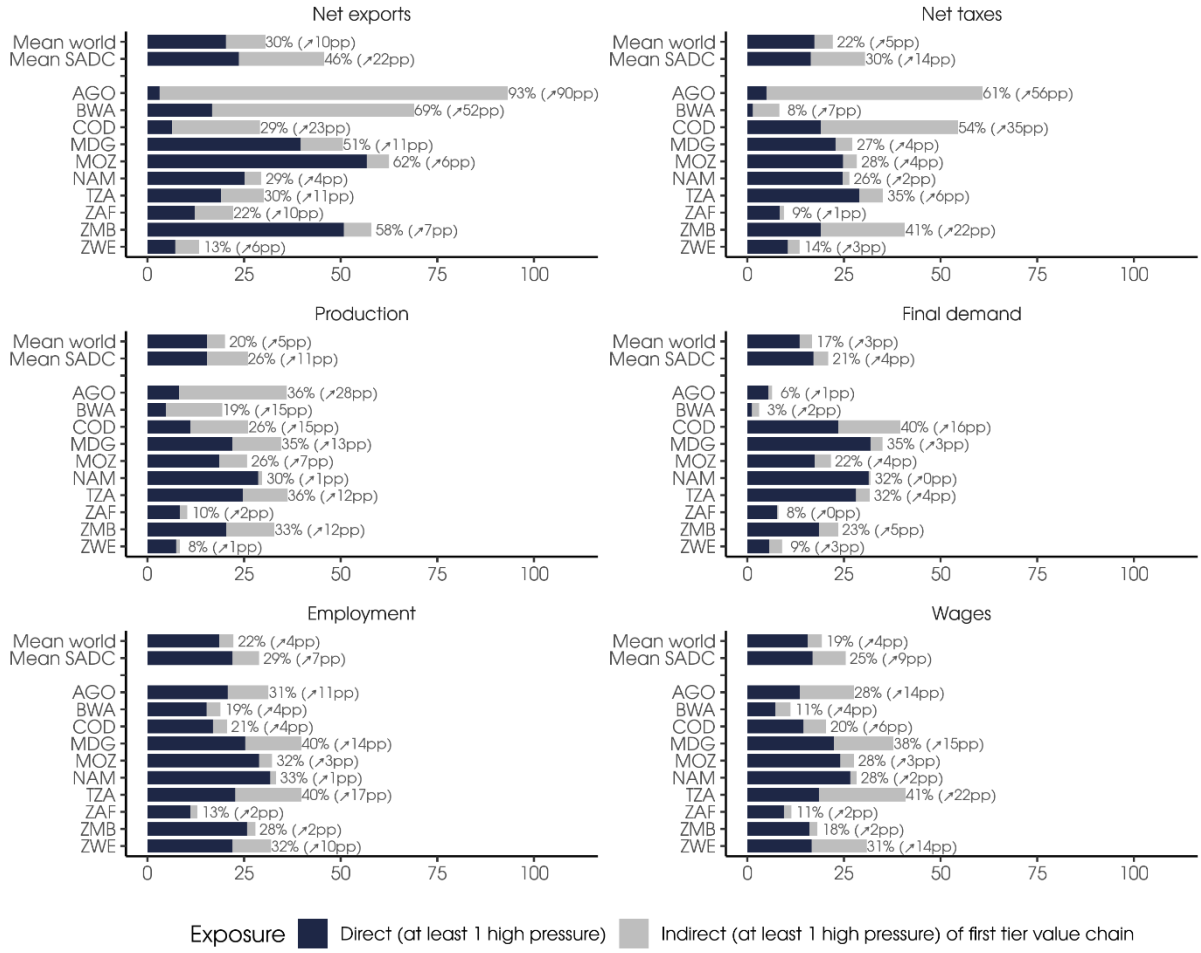
Transition risk exposure is determined by the extent to which national sectors exert pressure on biodiversity. Unlike physical risk, the best way to mitigate transition risk – characterised by political, behavioural and technological changes in favour of the environment – is to act directly on exposure and reduce the impact of industries on biodiversity. It is highly likely that ecological transitions will take different forms in different countries, with some pressures being more relevant than others for local biodiversity protection. A more detailed analysis of the probability of a transition shock in a given country would therefore provide a better understanding of countries' actual exposure.

In this assessment, sectors are considered directly exposed to a national ecological transition if they generate at least 10% of the country's total environmental pressure (e.g. land use, water consumption) or at least 5% of its species extinction risk (e.g. STAR). Sectors directly exposed to ecological transition were found to have the greatest impact on SADC stability in terms of net exports and employment, accounting on average for more than 20% of these socio-economic indicators (Figure 10). Nevertheless, there are wide variations in degree of exposure between countries. The greatest variations appear in terms of countries' external stability,[9] as the coefficient of variation is 81% and the share of net exports generated by exposed sectors ranges from 3% to 57% in the region (Table A0.2 in Annex A0).

[9] External stability is defined as the impact on net exports – that is, exports net of the import they contain.

Countries are not exposed to the same extent and, above all, do not face the same challenges in terms of ecological transition and economic consequences. Globally, Mozambique, Zambia and Madagascar are the most directly exposed countries in the region, mainly through their net exports, although they also have a high exposure to other relevant socio-economic indicators. Mozambique is highly exposed through its hard coal sector, which directly generates 40% of NH_3 emissions and 18% of GHG emissions while contributing 35% of the country's exports. In Madagascar, it is the "growing of spices, aromatic, drug and pharmaceutical crops" sector that exposes the country most in terms of its external stability (it generates 37% of the country's exports), as it makes a major contribution to the risk of species extinction (it generates 14% of the country's risk of species extinction). Finally, in Zambia, the basic copper sector accounts for 42% of the country's net exports and 42% of direct emissions of SO_2 (Annexes A1–A10).

Figure 10: Share of socio-economic indicators generated by sectors exposed to a transition (in per cent)



Note: Exposed sectors are those that generate at least 10% of a pressure on biodiversity or at least 5% of the country's total STAR pressure. The values at the end of the bars represent the increase in exposure when indirect exposures are included in the analysis.

Including indirect upstream and downstream effects – even when limited to first-tier suppliers and distributors – significantly increases countries' overall exposure (Figure 11). In terms of indirect exposure, SADC countries appear more exposed than the global average. Their average combined direct and indirect export-related exposure reaches 46%, with a widening disparity across countries, as indicated by a coefficient of variation of 63%. Angola's net export exposure increased by 90 percentage points when considering the pressures exerted by sectors in the first round[10] of its value chain, while the net taxes generated by exposed sectors rose by

10 We define rounds along the value chain as an impact to the direct suppliers or clients of the sector analysed who would not be able to sell or produce their own goods. Theoretically, the shock could propagate throughout the production chain (and hence have many more rounds) but we decided to limit our analysis to the first round.

56 percentage points. These increases are largely driven by the petroleum extraction sector, which – despite not being directly exposed to transition risks – is indirectly affected through its downstream value chain. In particular, the sector exports 3% of its output to China's refined petroleum products sector, a major emitter of GHGs, NO_X and SO_2. Similar patterns are observed in Botswana, where net export-related exposure rises by 52 percentage points due to the indirect water intensity of its "mining and quarrying n.e.c.; services to mining" sector. This sector exports 10% of its output to the United Arab Emirates' crustaceans and molluscs sector – a highly water-intensive sector – and accounts for 50% of Botswana's total exports. In the DRC, indirect effects also explain a 35 percentage point increase in exposure related to net taxes, largely due to the copper ores sector. While not directly exposed to transition risks, this sector contributes 26% of national tax revenues and sources inputs from sectors associated with high species extinction risks (Annexes A1–A10).

On average, SADC's exposure mainly stems from the direct or indirect pressures generated by sectors on the risk of species extinction (Figure 11). This means that if, for instance, countries implement strong policies to reduce this impact, on average 14% of employment and 12% of final demand could be at risk. When also accounting for the impact such reforms could have on the first round of suppliers and distributors, the share of affected net exports and employment rises to 17%. On average, countries' exports are also exposed to other types of transition risk, such as the reduction of SO_2, NO_X and GHGs.

Regarding the sectors most responsible for these exposures at the national level, the agriculture, forestry and fishing sector stands out as a major contributor to direct environmental pressures – particularly in terms of water consumption, land use, GHG emissions and STAR (Figure 12). However, when indirect pressures are also taken into account, other sectors emerge as significant contributors to environmental exposure. For instance, the mining and quarrying sector is a major source of SO_2, NO_X and GHG emissions. The manufacturing sector also plays a substantial role through net exports, especially due to its heavy reliance on agricultural inputs that consume a lot of land surface.

Figure 11: Share of socio-economic indicators generated by sectors exposed to an ecological transition, either directly (left) or indirectly (right) – that is, sectors generating at least 10% of one of the six environmental pressures analysed or at least 5% of the country's STAR score, whether through their own impact or via their value chains

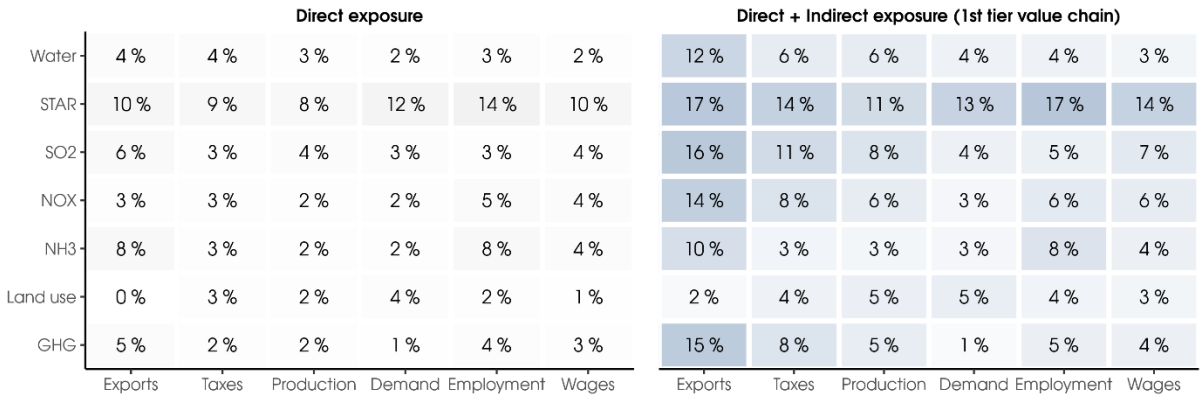
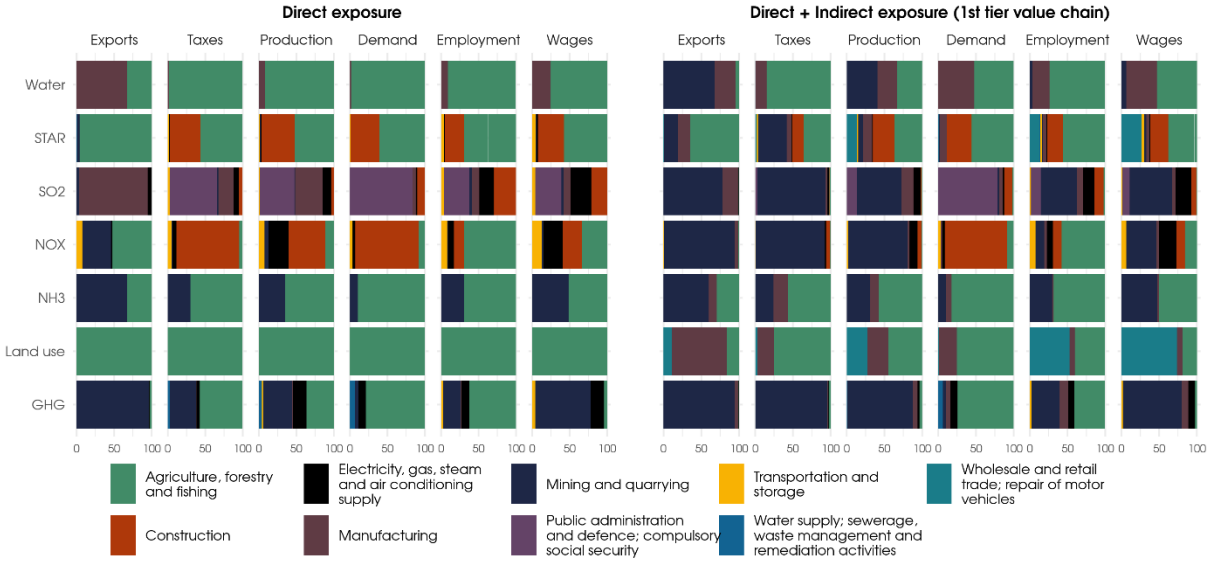


Figure 12: Weighted average of socio-economic indicators generated by sectors that contribute most to pressures on biodiversity, using SADC countries' total exposure as weights. On average, for example, 72% of SADC net exports' direct and indirect exposure through land use is generated by manufacturing sectors.



4. Conclusion

This paper provides a first-of-its-kind socio-economic assessment of Southern African countries' exposure to nature-related physical and transition risks. The assessment reveals significant economic exposure across SADC, although the nature and intensity of these risks vary widely. All countries in the region are exposed to at least one form of risk, but the magnitude and pathways of exposure differ based on the country's economic structures, its reliance on ecosystem services and the pressure it exerts on biodiversity.

In terms of physical risks, the region is highly exposed on average, especially through its dependence on ecosystem services essential for agriculture and mining – such as water supply and purification, climate regulation and flood control. Net exports are particularly at risk, with an average direct exposure of 67%, rising to 88% when indirect effects (first-tier suppliers and distributors) are considered. Angola, Madagascar, Tanzania, and Zimbabwe stand out for their high exposure, largely due to the essential role of ecosystem services in agricultural and petroleum extraction production processes.

In terms of transition risk, the analysis shows that countries are likely to face different consequences from an ecological transition – either directly or through their supply chains. While Madagascar, Mozambique, and Zambia are among the countries most directly exposed to transition risks – particularly through net exports and employment – Angola faces significant indirect exposure due to its reliance on the petroleum extraction value chain. On average, if national strategies are implemented to target the risk of species extinction caused by economic sectors, economic consequences could be significant.

Crucially, Madagascar emerges as the country most at risk in the region, with high exposure to both physical and transition risks. This is especially concerning given its status as a global biodiversity hotspot, home to numerous endemic species under threat.

Despite its contributions, this paper is subject to a number of methodological and data-related limitations. The assessment is based on static input-output data from 2019, which does not reflect structural shifts, recent technological and policy developments or potential responses to shocks. Only 10 out of 16 SADC countries could be included due to data constraints, and the sectoral resolution, though relatively detailed, remains too aggregated to capture intra-sectoral variability in production processes and environmental impacts. For example, diverse agricultural activities are often grouped under broad labels that obscure distinct ecological footprints and dependencies on ecosystem services.

Moreover, while the MRIO-EE GLORIA database harmonises national statistics, underlying differences in data quality, reporting standards and estimation methods may introduce biases across countries. It is also worth noting that the database may not fully capture the exposure of informal sectors to nature-related risks, which could lead to underestimates in the exposure of some countries – particularly where smallholder agricultural activities play a major role. In addition, some environmental pressures in GLORIA are based on generalised estimates rather than measured emissions, and key drivers of biodiversity loss – such as invasive species or biomass over-extraction – are not covered. Biodiversity impacts themselves are not directly measured; proxies such as the STAR metric, while useful, only partially reflect biodiversity impacts and exclude important dimensions such as genetic diversity, marine ecosystems or lesser-known taxa.

In terms of ecosystem service dependencies, the ENCORE framework is the only available tool with cross-sectoral coverage, but it lacks geographic specificity and scientific peer review. The analysis also excludes eight of the 25 ecosystem services listed in ENCORE, further limiting coverage. Moreover, the assessment of ecosystem capacity to provide services is static and aggregated at the national level, which limits its usefulness for identifying localised vulnerabilities. Nevertheless, it remains the only existing assessment to date.

Modelling assumptions also affect the robustness of transition exposure results. Thresholds used to identify high-impact sectors are not grounded in consensus guidelines and involve arbitrary cutoff values. Here, sectors are considered ‘exposed’ if they account for at least 10% of a given environmental pressure or 5% of the STAR index – an approach that may inflate exposure estimates for countries with otherwise low absolute impacts. Moreover, while some pressure-intensive sectors may appear highly exposed, they could be exempt from stringent regulation due to their essential role (e.g. food systems and clean energy materials) or could even receive support during the transition. Furthermore, the analysis only accounts for first-round indirect effects in supply chains, though shocks and policy responses can propagate through multiple tiers, affecting seemingly unrelated sectors.

Looking ahead, several avenues could be explored to further enrich the study's findings and enhance its policy relevance. These include:

- geolocating economic activities to better understand their interaction with degraded ecosystems;
- exploring the transition shocks most likely to affect the region;
- assessing the adaptive capacity of sectors to cope with nature-related shocks;
- expanding environmental coverage to encompass additional pressures and more comprehensively capture marine, genetic and ecosystem diversity; and
- connect portfolio-level information to assess financial exposure to nature-related risks.

This paper underscores the importance of integrating nature-related risks into central banks' monitoring frameworks in Southern Africa to assess potential sources of risk and exposed financial institutions, inform the design of policy tools to manage risks and increase system-wide resilience. As governments move to implement biodiversity targets and environmental policies, better data and robust quantitative tools will be essential for guiding their strategies.

Annexures

A0 General statistics

Figure A0.1: Sectoral decomposition of socio-economic indicators to assess the contribution of sectors to national economic output in 10 SADC countries

Table A0.1: Statistics on the socio-economic exposure of SADC countries to physical shocks

	Net exports	Net taxes	Production	Final demand	Employment	Wages
Mean	67% (88%)	63% (76%)	52% (69%)	46% (59%)	49% (69%)	41% (63%)
Min.	35% (51%)	34% (42%)	33% (40%)	30% (32%)	31% (53%)	29% (46%)
Max.	98% (99%)	81% (92%)	88% (91%)	67% (80%)	52% (83%)	49% (82%)
Median	67% (94%)	69% (80%)	51% (72%)	43% (62%)	51% (70%)	42% (67%)
Coefficient of variation	29% (16%)	28% (19%)	30% (21%)	27% (26%)	13% (16%)	14% (21%)

Note: These statistics have been computed from the share of socio-economic indicators generated by sectors highly dependent on at least one ecosystem service in each country. Indirect exposure is shown in brackets.

Table A0.2: Statistics on the socio-economic exposure of SADC countries to an ecological transition

	Net exports	Net taxes	Production	Final demand	Employment	Wages
Mean	24% (46%)	16% (30%)	15% (26%)	17% (21%)	22% (29%)	17% (25%)
Min.	3% (13%)	1% (8%)	5% (8%)	1% (3%)	11% (13%)	7% (11%)
Max.	57% (93%)	29% (61%)	29% (36%)	32% (40%)	32% (40%)	27% (41%)
Median	18% (40%)	19% (28%)	15% (28%)	18% (23%)	22% (32%)	16% (28%)
Coefficient of variation	81% (55%)	58% (59%)	55% (40%)	68% (64%)	29% (31%)	37% (40%)

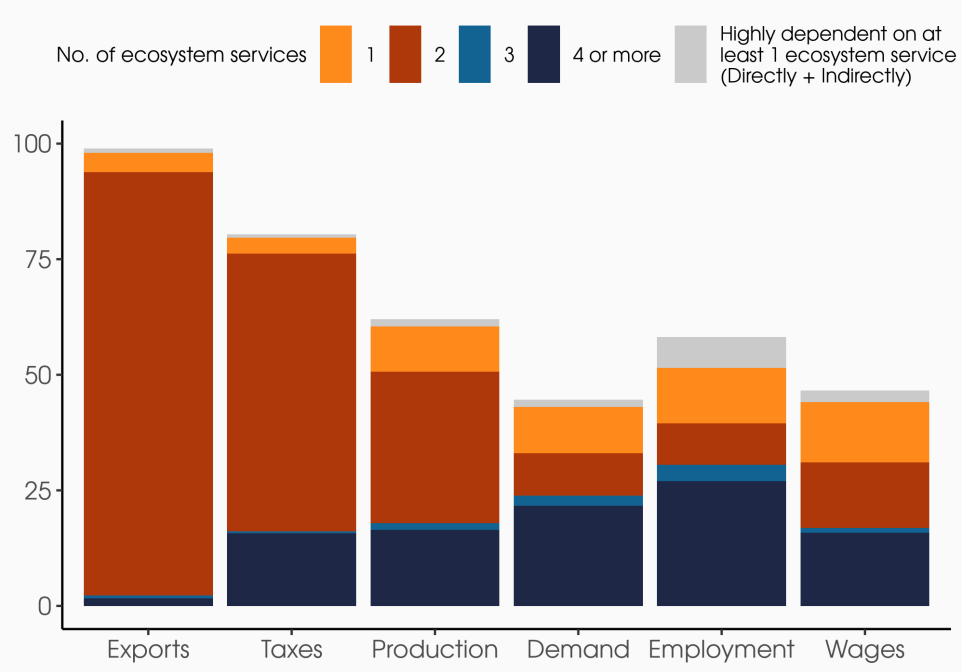
Note: Statistics computed from the share of socio-economic indicators generated by sectors exposed to a transition. Indirect exposure is shown in brackets.

A1 Angola

Physical exposure

Angola's economy is highly exposed to nature-related physical shocks. Indeed, 98% of the country's net exports and 80% of its net taxes come from sectors relying directly and heavily on at least one ecosystem service, with most of these sectors dependent on at least two services. Furthermore, these sectors generate 60% of production, 52% of employment, 44% of wages and 43% of the country's final demand. The indirect effects are not significant; the only notable variation comes from employment-related exposure, which increases by 7 percentage points when taken into account (Figure A1.1).

Figure A1.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Angola



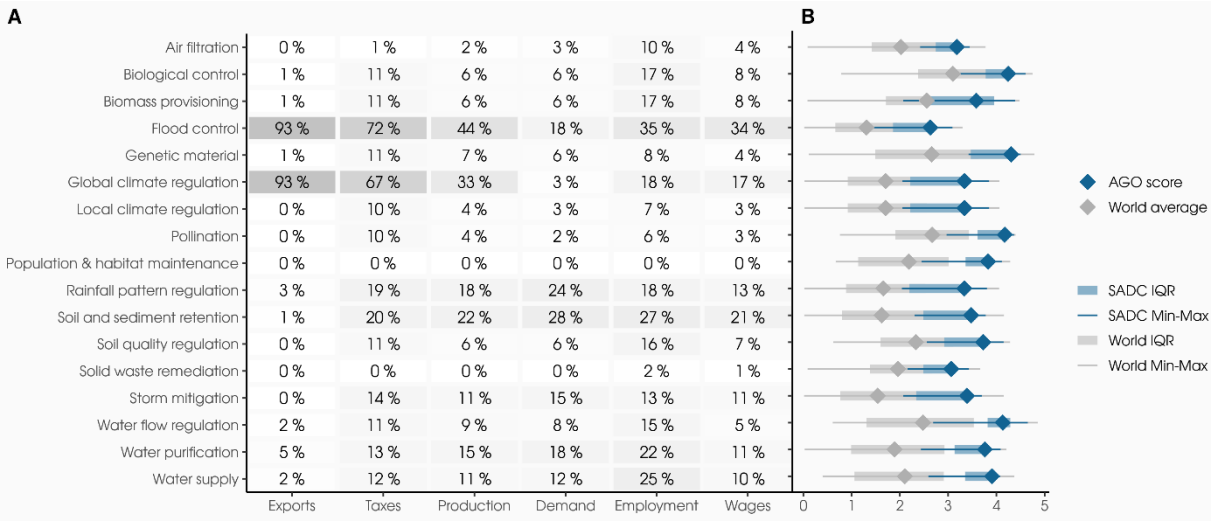
Angola is particularly sensitive to global climate regulation and flood control physical shocks, as sectors depending on these services account for 93% of exports, around 70% of tax revenue and 40% of production. If not properly sustained, the provision of these ecosystem services could expose Angola to considerable fiscal and external vulnerabilities. Fortunately, national-level indicators suggest that these services are currently being delivered at adequate levels, which could help buffer the country against such risks. However, this statement needs to be confirmed by localised

analyses of the current state of ecosystem service provision and the effective dependence of industries on these services (Figure A1.2).

Figure A1.2:

(A) Share of socio-economic indicators generated by economic sectors directly and highly dependent on a given ecosystem service in Angola

(B) Capacity of Angola to provide ecosystem services

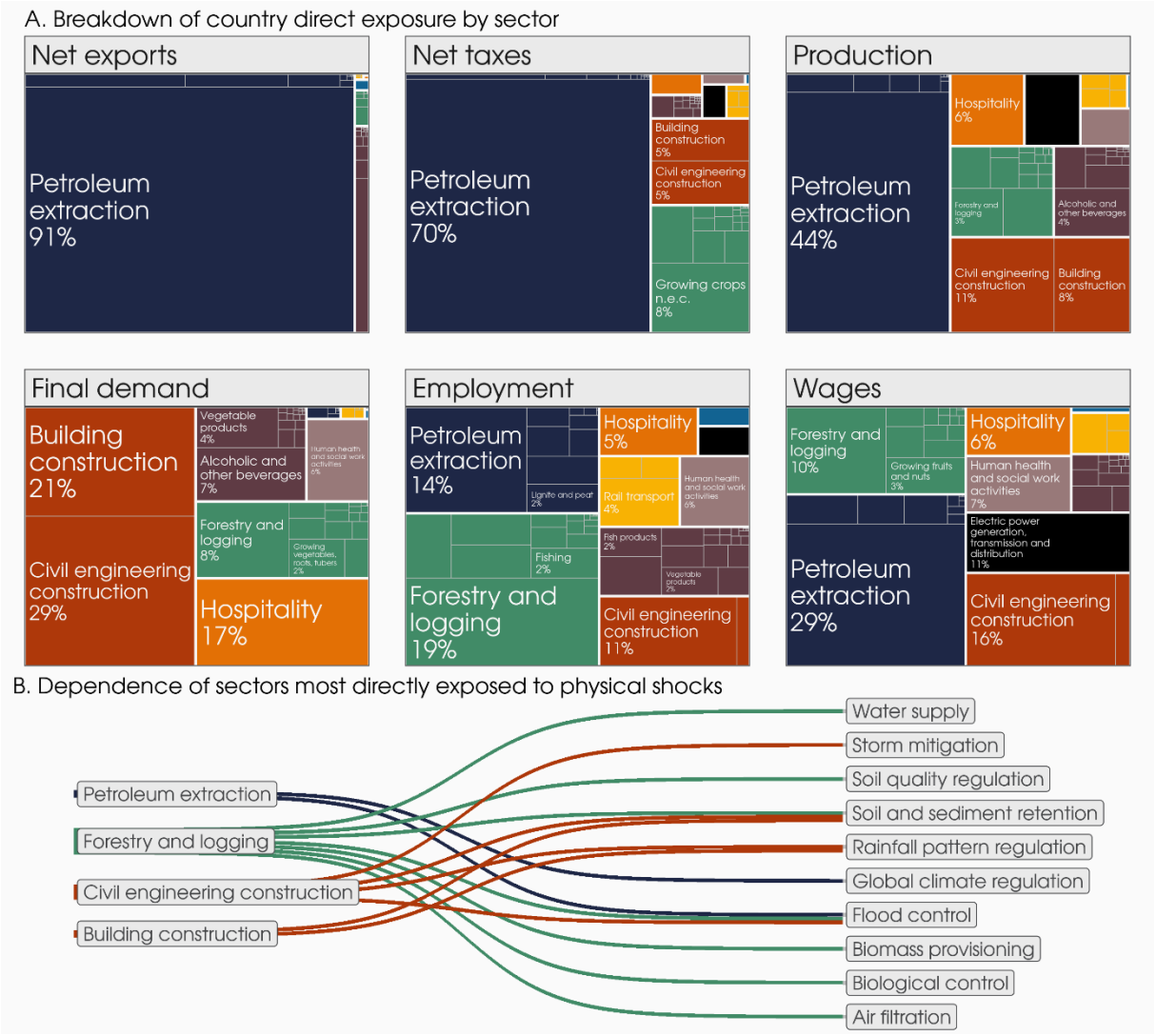


Petroleum extraction is the sector by far the most exposed to nature-related shocks, accounting for 91% of Angola's exposure related to net exports, 70% to net taxes, 44% to production, 29% to wages and 14% to employment. This sector is highly dependent on two ecosystem services: global climate regulation and flood control. Flood regulation, provided by natural vegetation, is essential for protecting extraction infrastructure and maintaining access to sites, particularly in flood-prone areas. Global climate regulation helps limit the occurrence and severity of extreme weather events – such as storms or heatwaves – that could disrupt operations, damage infrastructure and increase operational and maintenance costs. Other significant sectors could destabilise the country's economy if a shock were to occur. For instance, the forestry and logging sector contributes to 19% of total employment exposure, 10% of wages and 8% of final demand. Moreover, the civil engineering and building construction sectors pose substantial risks, accounting for 50% of demand exposure, 19% of production and over 16% of wages. As a result, Angola's economic exposure to nature-related risks is concentrated in a few key sectors (Figure A1.3).

Figure A1.3:

(A) Distribution of exposure across Angola's economic sectors

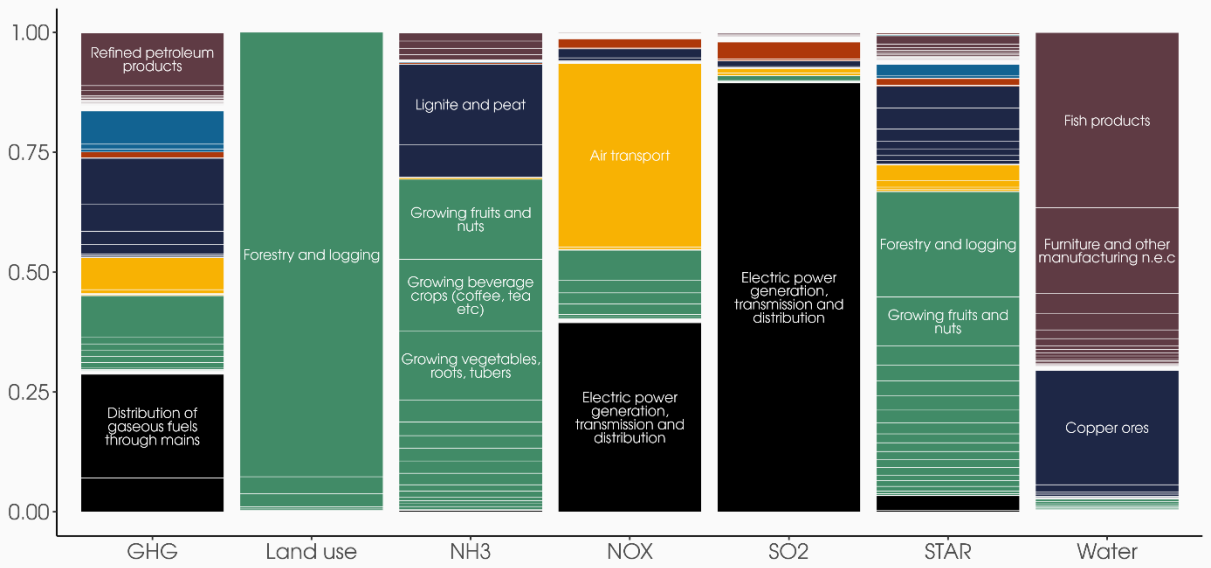
(B) Dependence of the country's key exposed sectors on ecosystem services



Transition exposure

The forestry and logging sector accounts for 93% of land-use pressure and 22% of the risk of species extinction in Angola (i.e. STAR). The electric power generation, transmission and distribution sector generates almost all the country's SO_2 emissions (90%) and a large proportion of NO_X emissions (40%). The fish products sector is responsible for 37% of water consumption, and air transport for 38% of the country's NO_X emissions. A large number of sectors emit GHGs; only two of the 120 sectors each produces at least 10% of these emissions: the distribution of gaseous fuels through mains and the refined petroleum products sectors, which cause 22% and 11% respectively of the country's CO_2eq emissions (Figure A1.4).

Figure A1.4: Share of pressures generated by sectors in Angola



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR. N.e.c.: not elsewhere classified.

Angola is primarily indirectly exposed to transition shocks related to biodiversity. Indeed, 93% of its net exports, 61% of tax revenues, 36% of production, 31% of employment and 27% of wages are generated by sectors that exert the highest pressures on biodiversity in the country – either directly or indirectly. However, when considering only direct exposures, just 3% of net exports are generated by sectors considered exposed (Figure A1.5).

The country is particularly vulnerable to a transition shock related to GHG, NO_X and SO_2 emissions. Sectors responsible for the highest levels of these emissions contribute at least 89% of the country's net exports and at least 56% of net tax revenues (Figure A1.6). Among these, the petroleum extraction sector is by far the largest contributor to this exposure. It is indirectly affected by transition shocks through its downstream value chain, linked to reductions in GHG, NO_X and SO_2 emissions. Specifically, this sector alone accounts for 89% of net exports and 56% of net tax revenues while generating at least 10% of the country's indirect environmental pressures or at least 5% of its indirect STAR pressure (Figure A1.7).

Moreover, the petroleum extraction sector exports 3% of its output to China's refined petroleum products sector – a highly emissive sector in terms of GHG, NO_X and SO_2. By supplying goods and services to this Chinese sector, Angola's petroleum extraction sector indirectly contributes to over 20% of all downstream SO_2 emissions across Angola's first-tier value chains, 10% of GHG emissions and 8% of NO_X emissions. If

Angola aims to limit the impact of its sectors on biodiversity through the export of inputs, the petroleum sector could be a key target for such measures (Figure A1.8).

Figure A1.5: Share of socio-economic indicators generated by exposed sectors in Angola

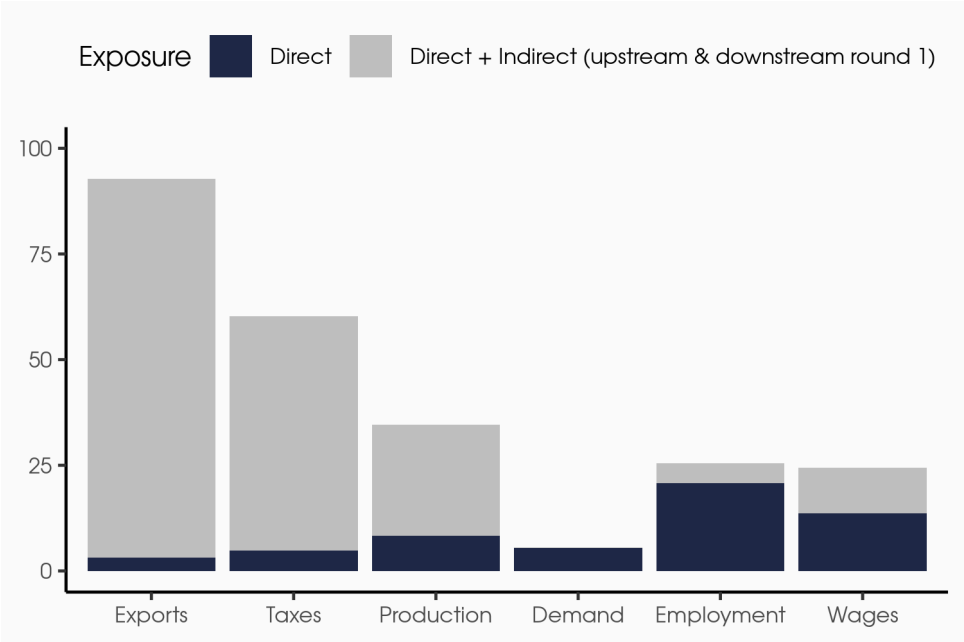


Figure A1.6: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Angola

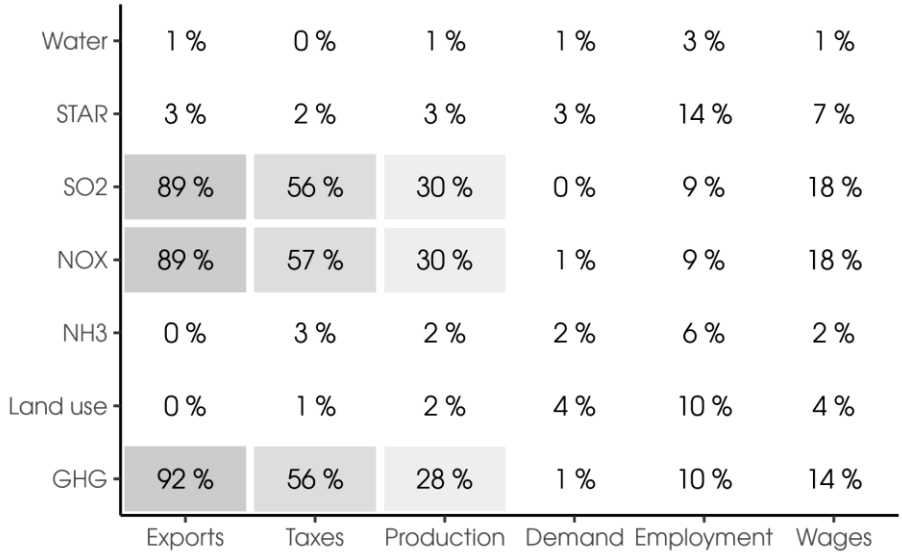


Figure A1.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Angola

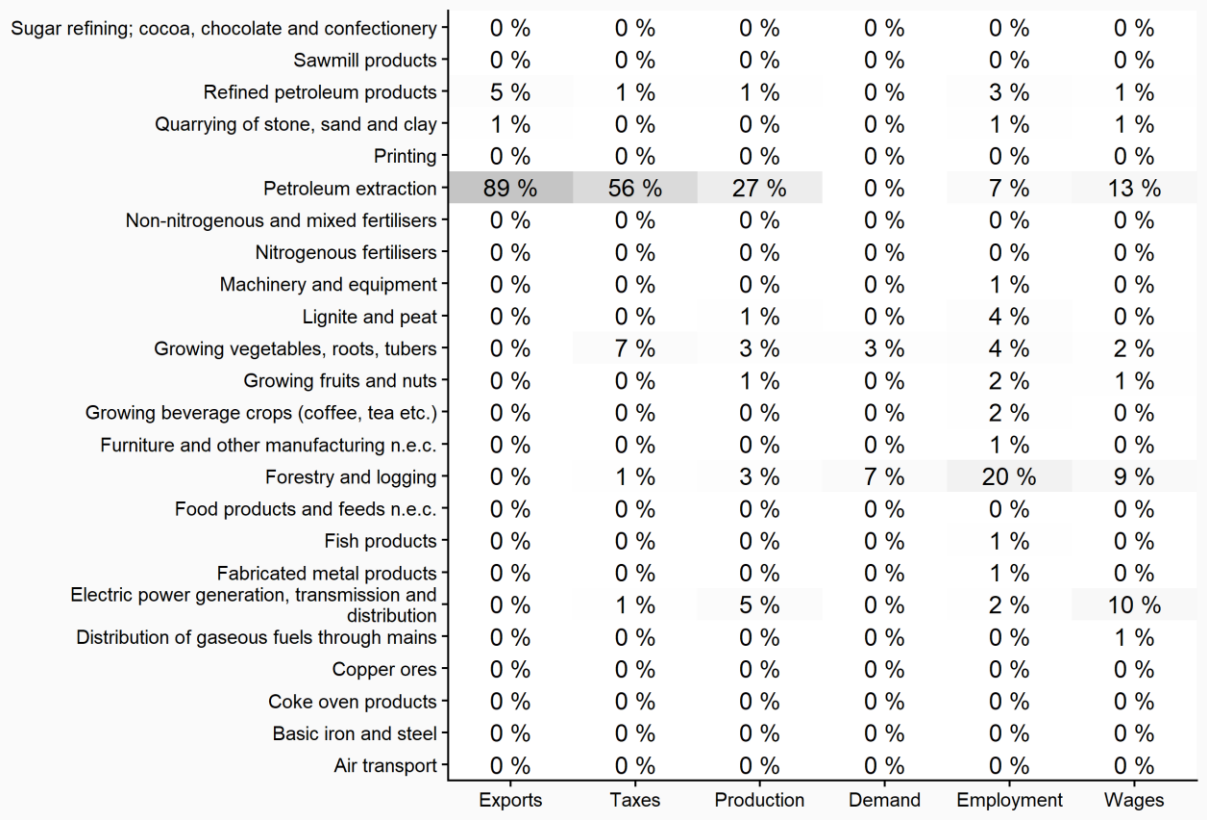
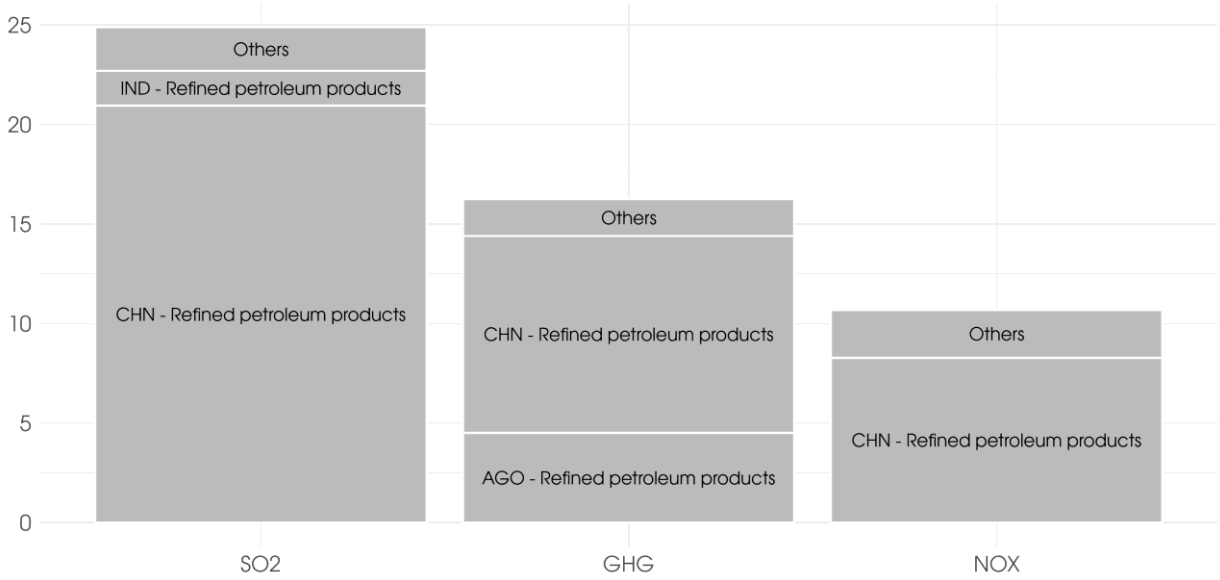


Figure A1.8: Share of indirect pressures generated by the petroleum extraction sector in Angola through the first tier downstream of its value chain as a function of indirect emissions downstream of all value chains in Angola (in %)

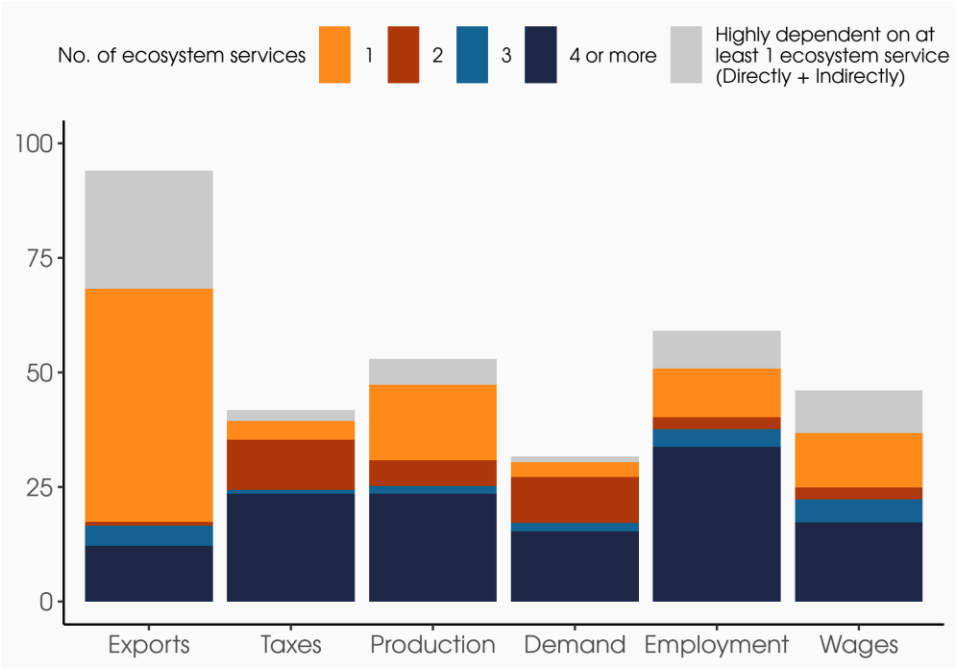


A2 Botswana

Physical exposure

Botswana's trade balance is highly exposed to physical shocks, as 94% of its exports are generated by sectors that depend – directly or indirectly – on at least one ecosystem service. However, when considering only direct exposure, this share drops significantly to 68%, highlighting the importance of indirect linkages, which account for an additional 26 percentage points. Moreover, these shock-sensitive sectors also contribute to 59% of employment, 53% of production and 46% of wages (Figure A2.1).

Figure A2.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Botswana

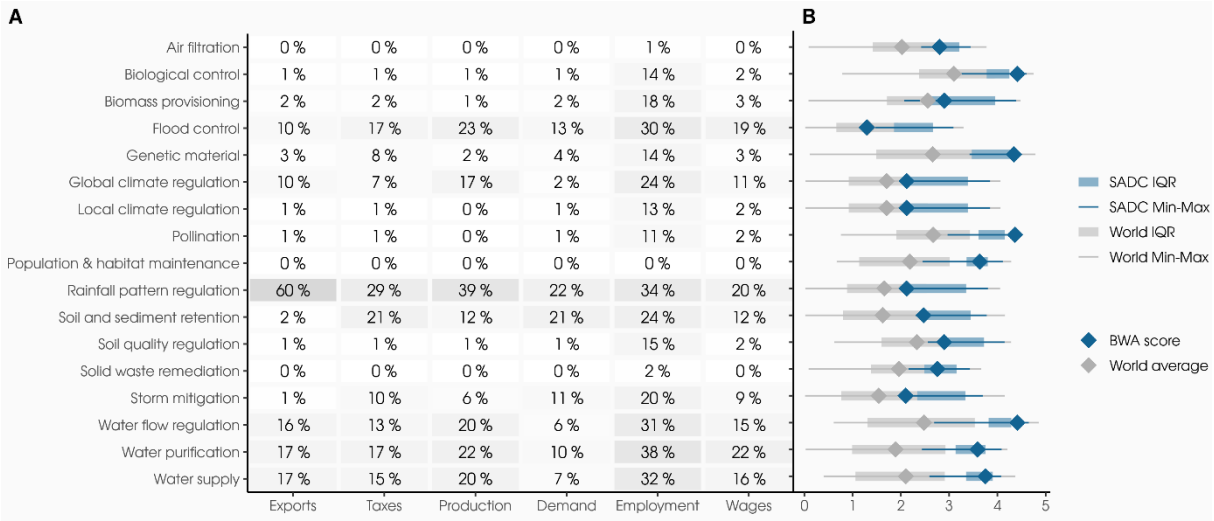


Botswana is particularly vulnerable to a physical shock related to the ecosystem service of rainfall pattern regulation. In fact, 60% of the country's net exports – as well as 39% of total production and 34% of employment – are generated by economic sectors that are highly and directly dependent on this service. Moreover, this ecosystem service appears to be poorly provided within the country: Botswana has the lowest score in the SADC region for rainfall pattern regulation. More detailed assessments of the integrity and resilience of this service are needed to better understand and qualify the country's vulnerability to such physical shocks (Figure A2.2).

Figure A2.2:

(A) Share of socio-economic indicators generated by economic sectors directly and highly dependent on a given ecosystem service in Botswana

(B) Capacity of Botswana to provide ecosystem services

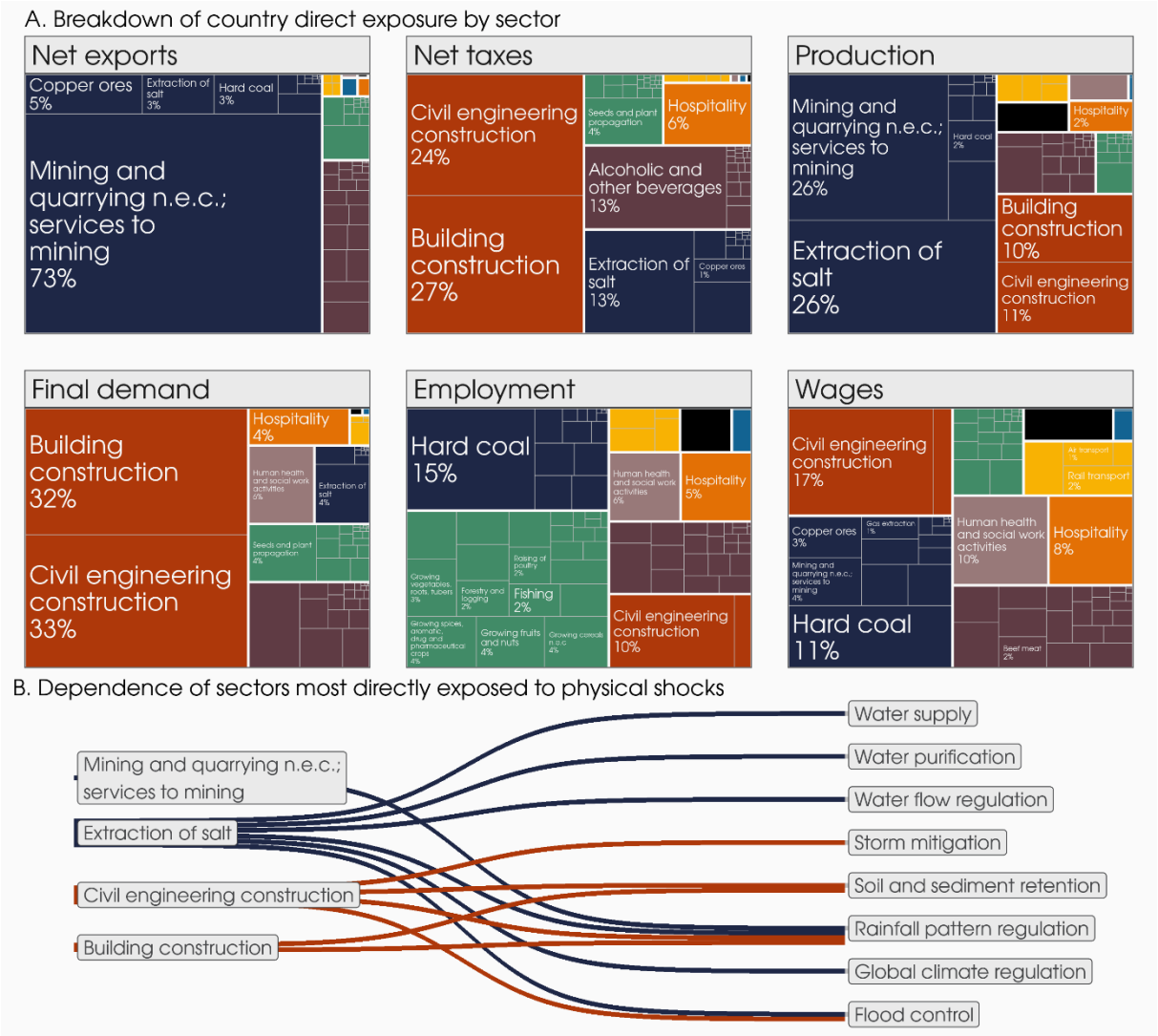


The economic sector most responsible for Botswana's direct external exposure is the "mining and quarrying n.e.c.; services to mining" sector, which accounts for 73% of the country's export exposure (Figure A2.3). This exposure stems exclusively from the sector's heavy reliance on rainfall pattern regulation to mitigate the risk of floods and damages at manufacturing sites and to secure water supply from rivers and other water sources. It would therefore be beneficial for Botswana to evaluate the capacity of its mining and quarrying sector to mitigate the effects of declining rainfall pattern regulation. This could include strategies such as optimising water resource management, investing in climate-resilient infrastructure, adopting water-efficient technologies and implementing measures to preserve and restore local ecosystems. The construction sector – including both building construction and civil engineering – also plays a significant role in the country's ecological exposure. It accounts for 65% of the exposure related to final demand, 51% of fiscal revenue-related exposure and 22% of exposure linked to domestic production. This sector is highly dependent on multiple ecosystem services, including climate regulation, flood control, rainfall pattern regulation, soil and sediment retention and storm mitigation (Figure A2.3).

Figure A2.3:

(A) Distribution of exposure across Botswana's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services



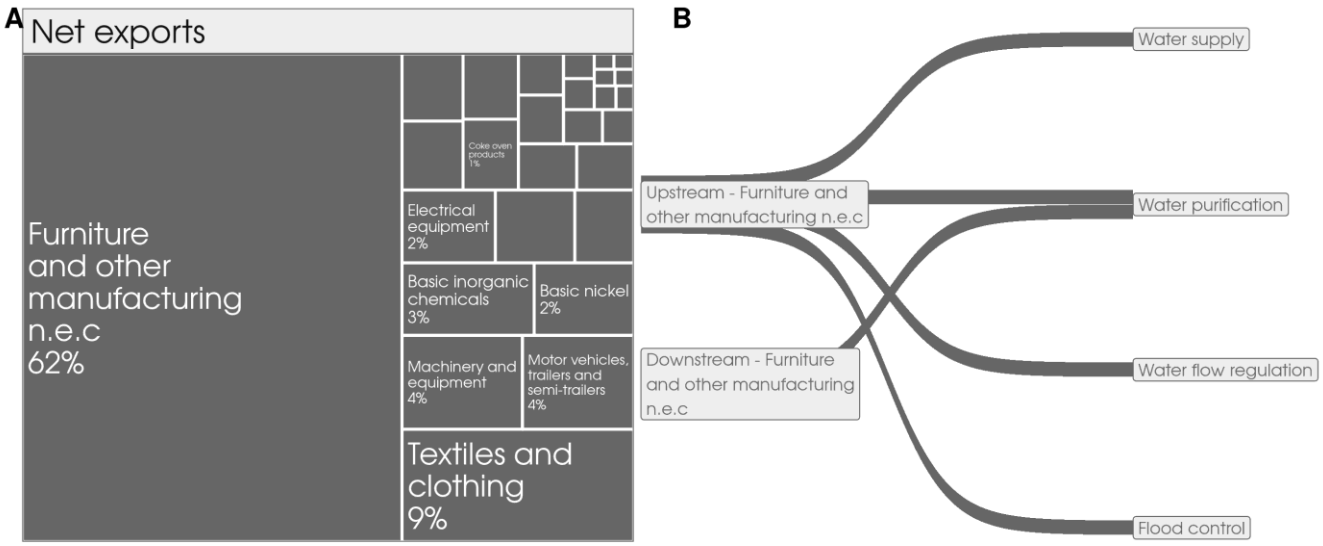
In terms of indirect exposure, the share of exports exposed increases by 26 percentage points between the direct and indirect analysis (Figure A2.1). This is mainly because the "furniture and other manufacturing n.e.c." sector accounts for 16% of the country's net exports – representing 62% of all indirect exposures – and is exposed exclusively through its upstream and downstream value chains (Figure A2.4). It is heavily dependent downstream on the water purification service, as it sells its products to multiple sectors that are themselves highly reliant on this service – such as the "growing rice" sector in Hong Kong. Moreover, the "furniture and other manufacturing n.e.c." sector is also indirectly dependent upstream on flood control, water flow regulation, water purification and water supply. This is primarily because it sources

40% of its inputs from the nickel ore sector in Zimbabwe, which is itself highly dependent on these four ecosystem services (Figure A2.4).

Figure A2.4:

(A) Breakdown of Botswana's net exports' indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A2.1.

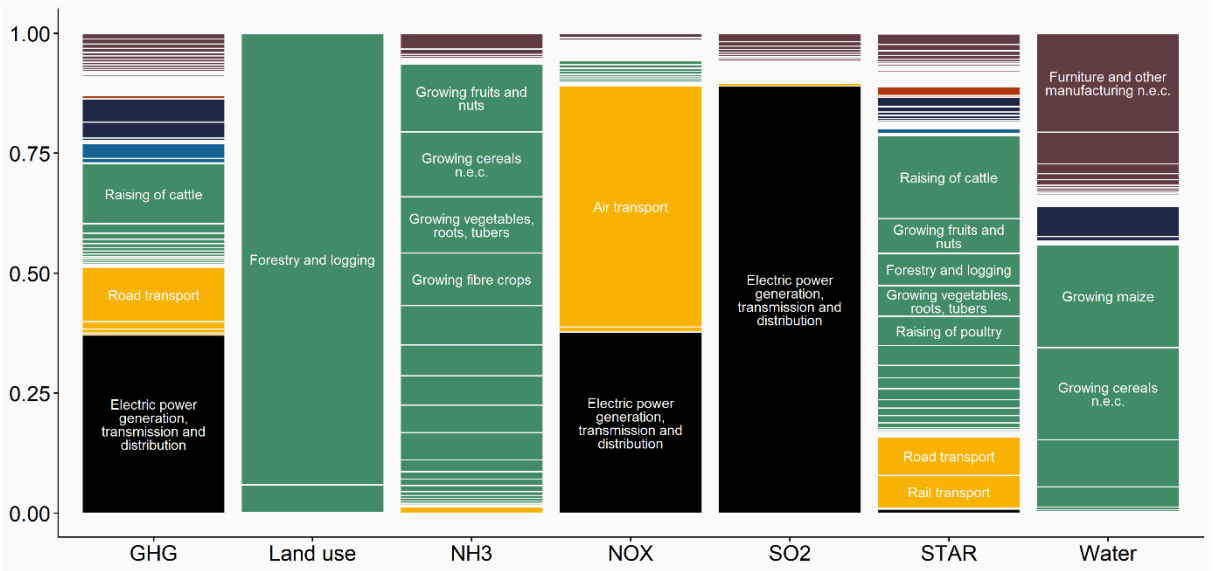
(B) Dependence of the country's key indirectly exposed sectors on ecosystem services



Transition exposure

The forestry and logging sector is responsible for 94% of the land-use pressure and 6% of the STAR in Botswana. Emissions of SO_2, NO_X and GHGs are largely attributable to the electric power generation, transmission and distribution sector (89% for SO_2, 38% for NO_X and 37% for GHGs). The air transport sector alone accounts for 50% of NO_X emissions. The risk of species extinction (measured by the STAR metric) can be attributed to several sectors, including agriculture, livestock and transport. Agriculture is also a major contributor of NH_3 emissions and water consumption, particularly the production of cereals and maize (Figure A2.5).

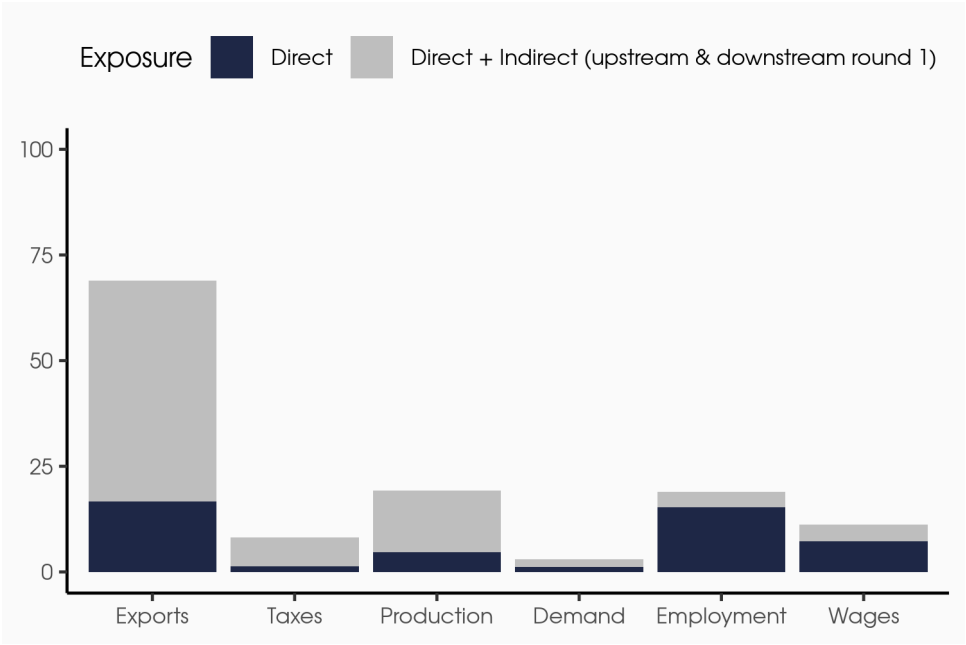
Figure A2.5: Share of pressures generated by sectors in Botswana



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

Botswana faces significant exposure to transition risks through its net exports. Indeed, 69% of its net exports are generated by sectors that contribute at least 10% of environmental pressures or 5% of the STAR indicator, either directly or indirectly. The country is more exposed indirectly than directly, as only 17% of net exports come from sectors that are directly exposed. Other socio-economic indicators show much lower levels of exposure, none exceeding 20% (Figure A2.6).

Figure A2.6: Share of socio-economic indicators generated by exposed sectors in Botswana



Botswana is also vulnerable to transition risks aimed at reducing water consumption across industries. Sectors with the highest levels of water use (both direct and indirect) account for 66% of the country's net exports (Figure A2.7). Two sectors appear to be largely responsible for this exposure: "mining and quarrying n.e.c.; services to mining" and "furniture and other manufacturing", which generate 50% and 16% of the country's net exports respectively (Figure A2.8).

The "furniture and other manufacturing" sector directly consumes 21% of the country's water and indirectly accounts for 23% of downstream water use. In contrast, the "mining and quarrying n.e.c.; services to mining" sector is only indirectly exposed to blue water consumption pressures, solely through its downstream value chain – representing 11% of the country's downstream indirect water consumption. This sector exports 10% of its output to the crustaceans and molluscs sector in the United Arab Emirates, a highly water-intensive sector. As a result, this single trade link is responsible for nearly all the downstream water-related emissions associated with the "mining and quarrying n.e.c.; services to mining" sector (Figure A2.8).

Figure A2.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Botswana

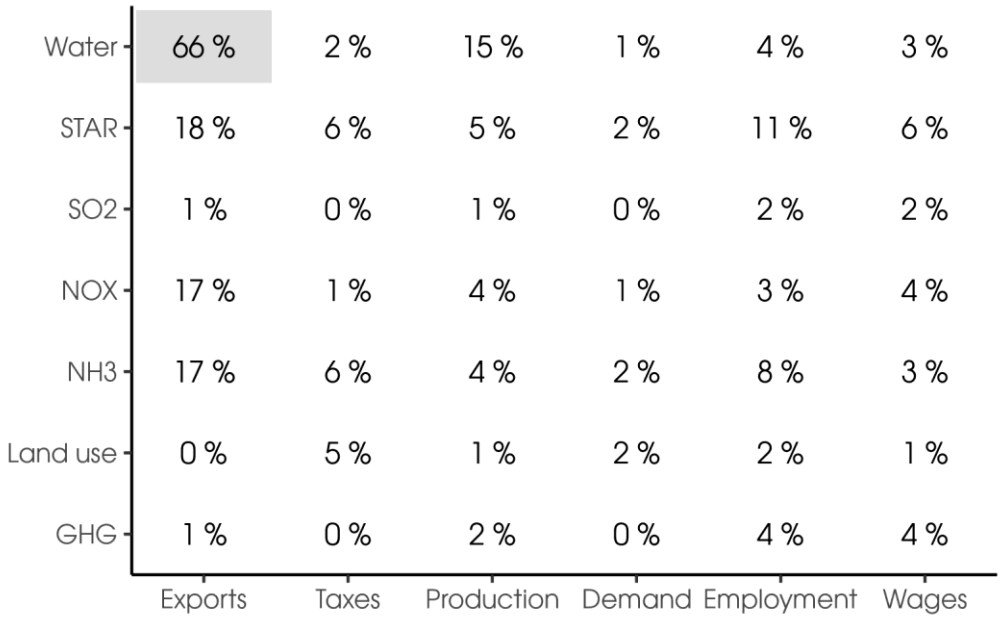
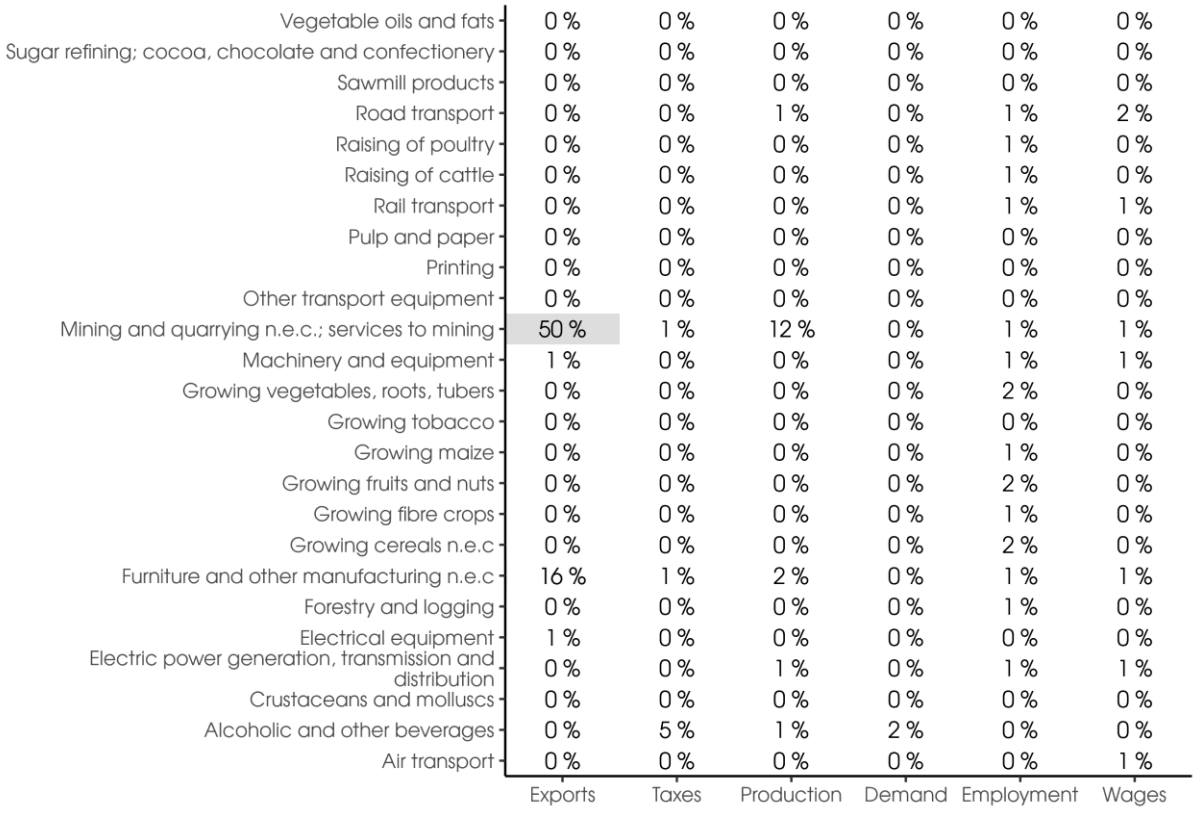


Figure A2.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Botswana

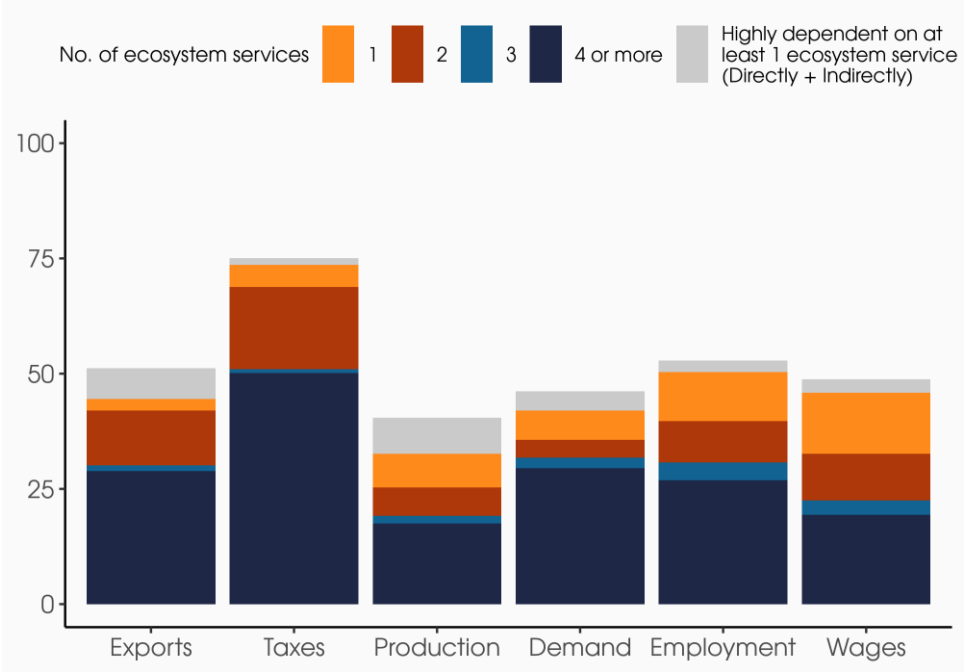


A3 Democratic Republic of the Congo

Physical exposure

The Democratic Republic of the Congo (DRC) is highly exposed to nature-related physical risks through its tax revenues. Sectors that depend directly on at least one ecosystem service account for 74% of net tax revenues, while those relying on four or more ecosystem services contribute up to 50%. These sectors also represent 50% of employment, 46% of wages, 45% of net exports, 42% of final demand and 33% of total production. Including indirect dependencies from the first tier of the value chain does not significantly alter these results. The largest increase in exposure is only 8 percentage points for production and 7 percentage points for net exports (Figure A3.1).

Figure A3.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in the DRC



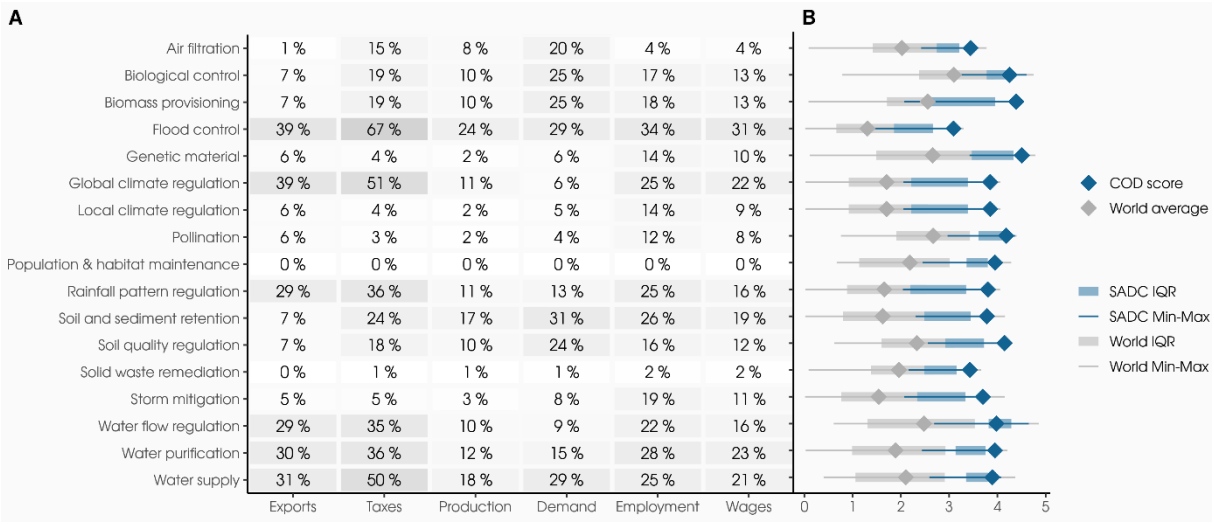
The DRC is exposed to nearly all types of physical shocks. Sectors that are highly dependent on flood control generate 67% of the country's net tax revenues, 39% of net exports and around 30% of the other socio-economic indicators. The country is also vulnerable to shocks related to global climate regulation, with 51% of net tax revenues and 39% of net exports coming from sectors heavily reliant on this service. Moreover, water-related ecosystem services – including water flow regulation, water purification, water supply and rainfall pattern regulation – are also critical to national

main economic aggregates (Figure A3.2, panel A). Nevertheless, the DRC currently benefits from relatively well-provided ecosystem services, ranking among the top countries in SADC. However, intra-national analyses are still required to validate this observation at a more local scale, particularly by considering the geographic location of industries most dependent on these services (Figure A3.2, panel B).

Figure A3.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in the DRC

(B) Capacity of the DRC to provide ecosystem services

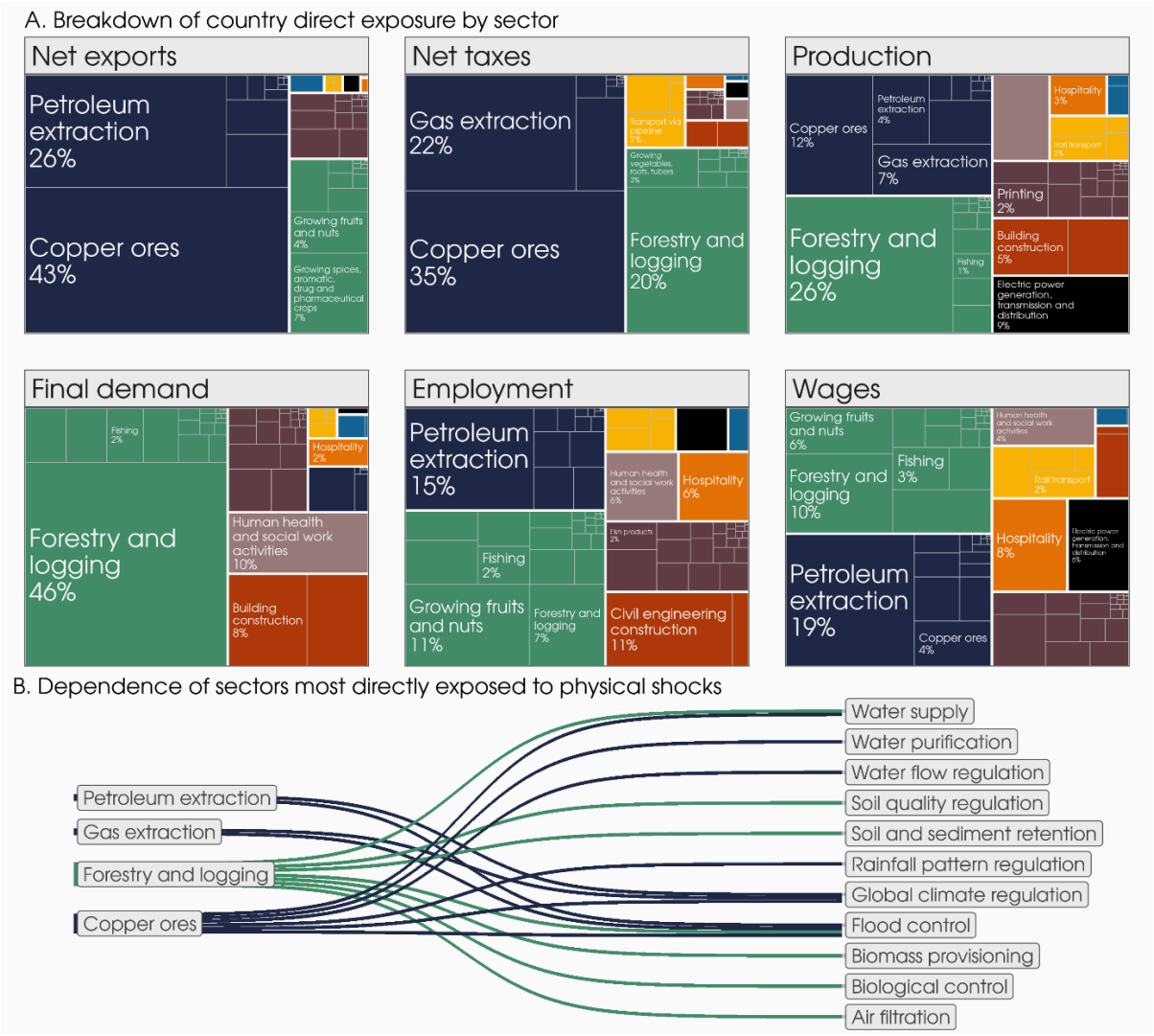


The sectors contributing most to the country's exposure through tax revenues are copper ores (35% of exposure) and gas extraction (22%). Both sectors are highly dependent on flood control and global climate regulation to operate effectively. In addition, copper ores is also strongly reliant on rainfall pattern regulation, water flow regulation, water purification and water supply. Other sectors account for a significant share of the country's overall exposure. Notably, the forestry and logging sector is responsible for 46% of the exposure related to final demand, 26% of that related to production and 20% of the tax-related exposure while being heavily dependent on multiple ecosystem services. The petroleum extraction sector also contributes to the country's vulnerability, accounting for over 15% of the exposure related to net exports, wages and employment. These four sectors should be closely monitored to prevent undesirable economic consequences stemming from disruptions to key ecosystem services (Figure A3.3).

Figure A3.3:

(A) Distribution of exposure across the DRC's economic sectors

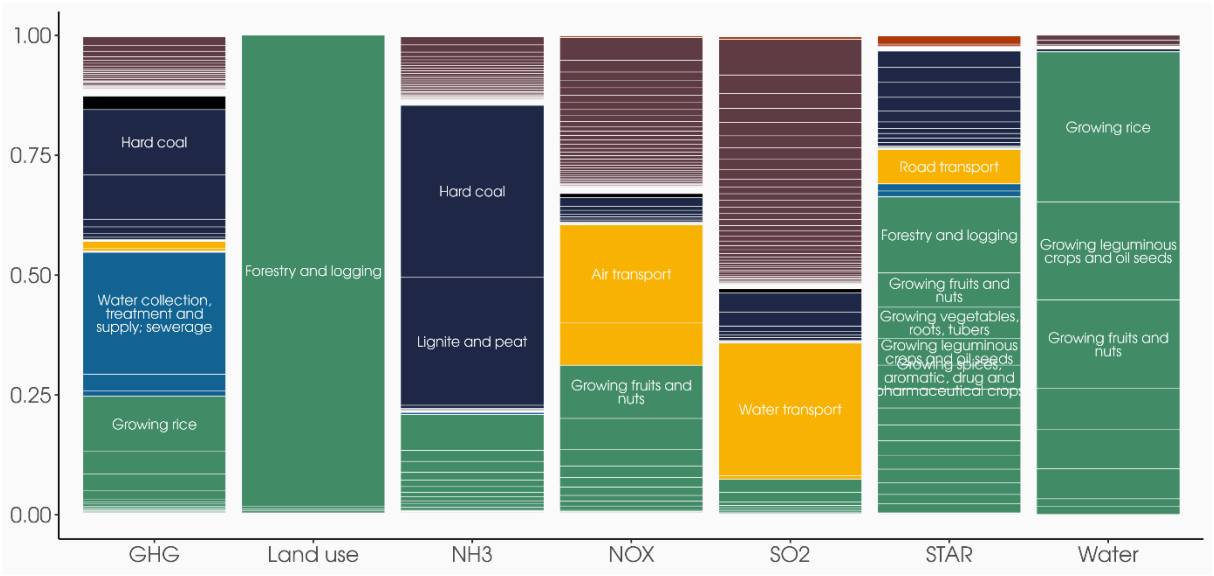
(B) Dependence of the DRC's key exposed sectors on ecosystem services



Transition exposure

The forestry and logging sector accounts for 98% of the DRC's land-use pressure and 16% of its risk of species extinction (i.e. STAR). The water transport sector is responsible for 28% of the country's SO_2 emissions. Agricultural sectors are the main drivers of national water consumption pressure – most notably the growing rice sector, which accounts for 32% of this pressure. The "water collection, treatment and supply; sewerage" sector is the largest contributor to GHG emissions, generating 25% of the country's GHG pressure. Meanwhile, the hard coal and lignite and peat sectors are responsible for significant shares of NH_3 emissions, contributing 36% and 27% respectively (Figure A3.4).

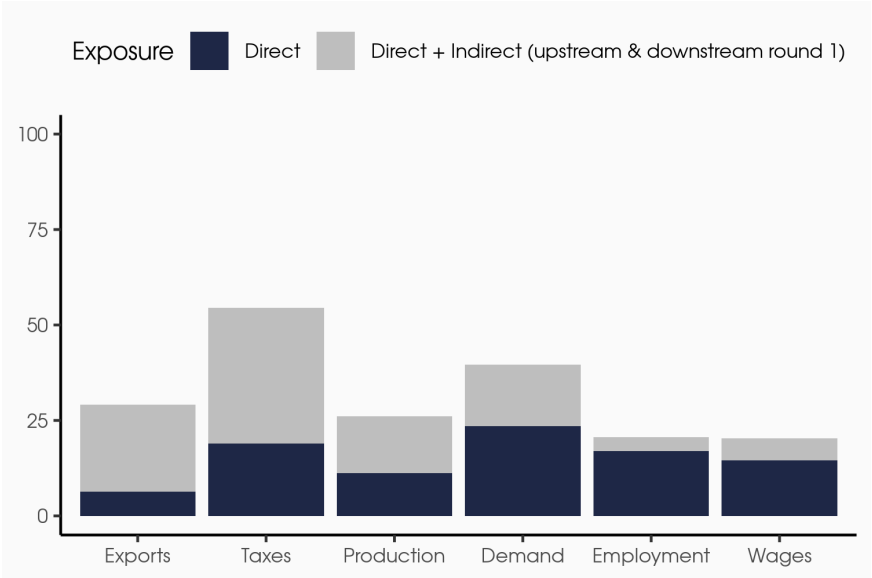
Figure A3.4: Share of pressures generated by sectors in the DRC



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

The country's tax revenues are significantly exposed to an ecological transition, particularly when considering indirect dependencies. Sectors that directly exert the greatest pressures on biodiversity contribute 19% of national tax revenues directly and 55% when factoring in the first tier of their upstream and downstream value chains. When considering both direct and indirect exposure, an ecological transition could also affect 40% of final demand, 30% of net exports, 26% of production and around 20% of both employment and wages (Figure A3.5).

Figure A3.5: Share of socio-economic indicators generated by exposed sectors in the DRC



The DRC is particularly exposed to an ecological transition aimed at reducing the risk of species extinction and land-use pressure, especially in terms of net taxes and domestic demand. Sectors that significantly contribute to species extinction risk account for roughly 50% of tax revenues and 30% of final demand. Moreover, those accounting for more than 10% of country land use generate 26% of final demand and 18% of net taxes (Figure A3.6).

The forestry and logging sector uses 98% of the country's land, accounts for 16% of the national STAR score and contributes over 10% to both upstream and downstream emissions related to land use. This sector also generates 20% of final demand and 15% of net taxes. The copper ores sector is a major driver of the country's transition exposure, accounting for 26% of net taxes and 18% of net exports (Figure A3.7). While not directly exposed to ecological transition risks, it is indirectly affected through its purchase of inputs that contribute to species extinction risk. Given this context, it is essential for the country to evaluate the adaptive capacity of these key economic sectors in response to a nature-positive transition. This includes assessing whether production practices can be altered to reduce impacts on biodiversity and whether alternative tax revenue sources can be developed to offset potential fiscal losses.

Figure A3.6: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in the DRC

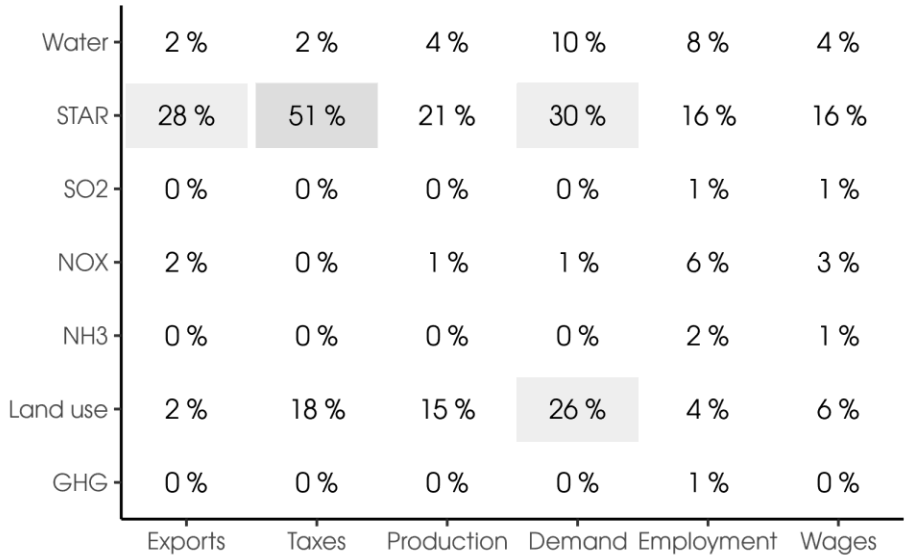
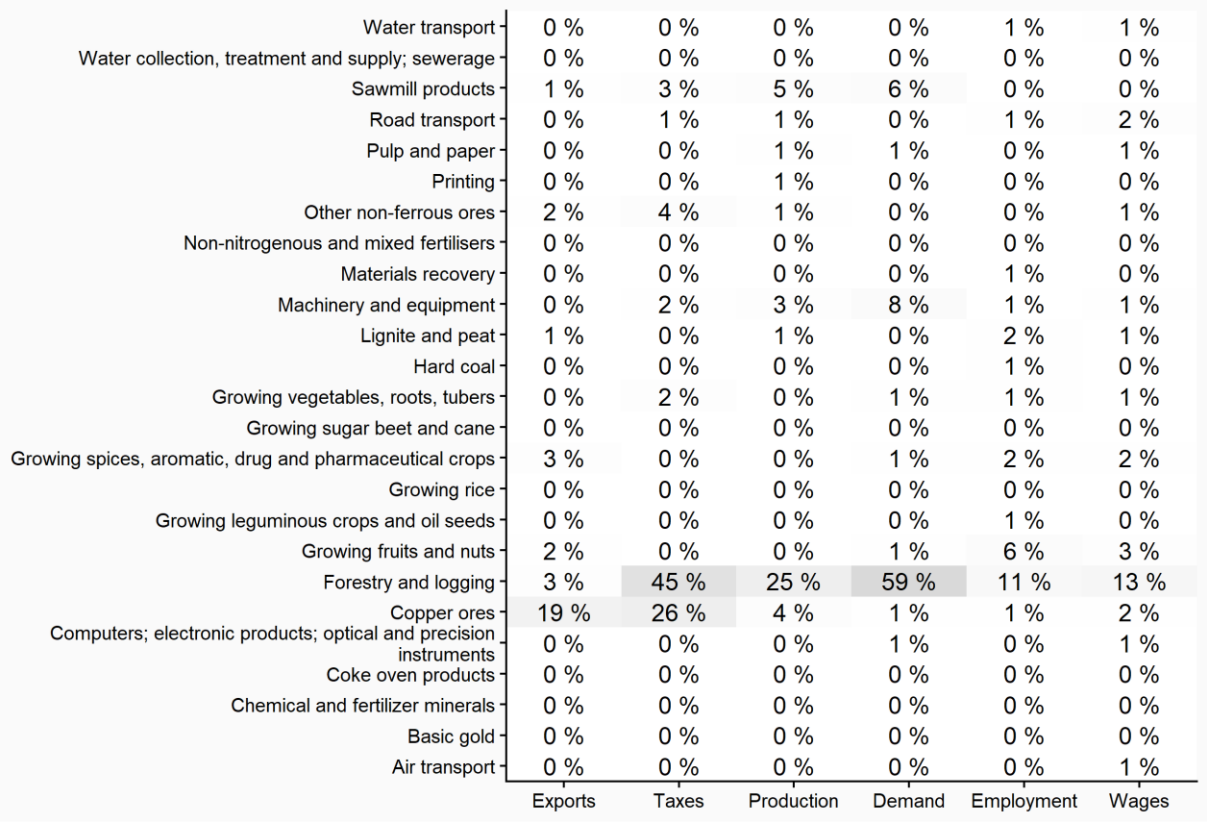


Figure A3.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in the DRC

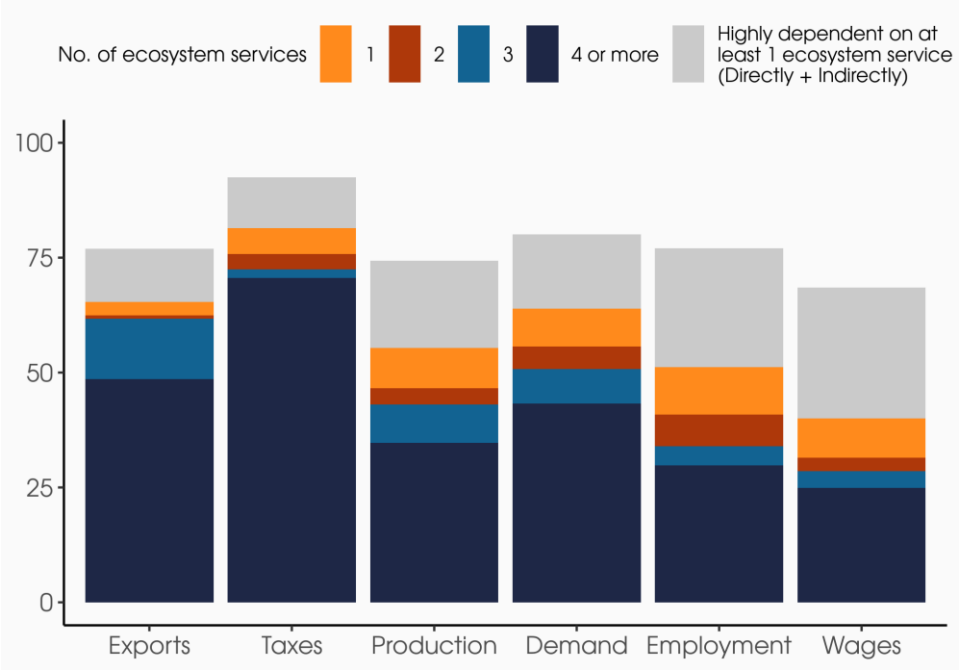


A4 Madagascar

Physical exposure

Madagascar is highly exposed to physical shocks, particularly through its tax revenues, with 81% of taxes coming from sectors directly reliant on at least one ecosystem service and 71% dependent on at least four. This figure rises to 92% when including strong dependencies within the first tier of upstream suppliers and downstream distributors. Moreover, sectors exposed to at least one physical shock – considering direct and indirect exposure – account for 80% of final demand, 77% of employment and net exports, 74% of total production and 68% of wages (Figure A4.1).

Figure A4.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Madagascar



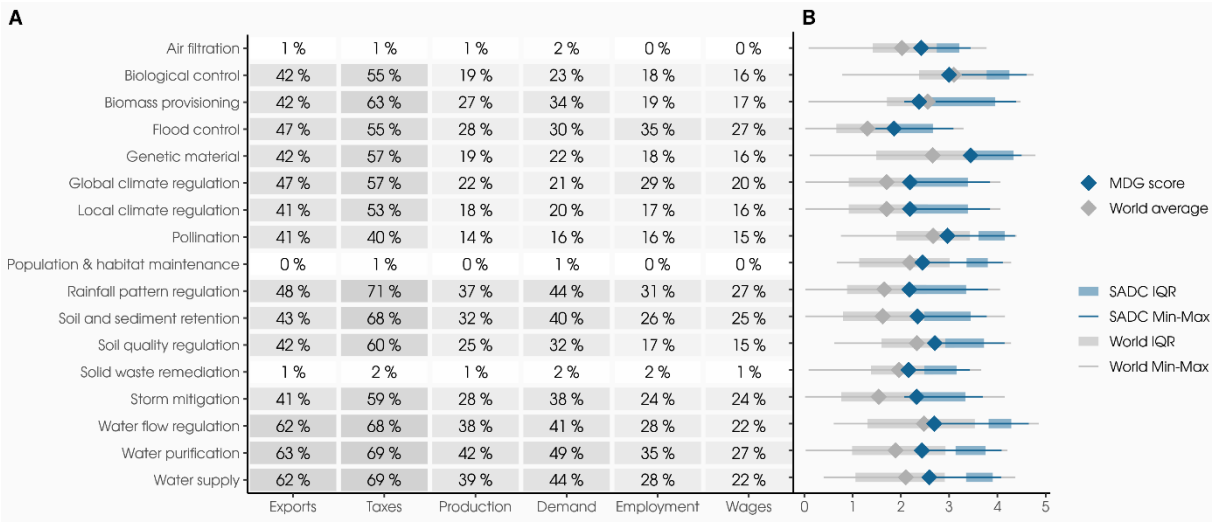
Madagascar is exposed to nearly all analysed ecosystem services at relatively equivalent levels, which is quite rare in the region. Between 40% and 71% of the country's tax revenues are generated by sectors that are highly dependent on at least one ecosystem service (e.g. biological control, flood control, pollination, storm mitigation), with the exception of three services that appear less critical (air filtration, population and habitat maintenance and solid waste remediation). A similar pattern is observed for net exports, with 41% to 62% of them generated by sectors highly dependent on these same ecosystem services. The country's highest exposure is to rainfall pattern regulation, which plays a key role in the production processes of many

national sectors. Moreover, the supply of ecosystem services appears to be weaker in Madagascar than in the rest of the region (the supply of all ecosystem services is strictly below or equal to the third SADC quantile), particularly for rainfall pattern regulation. While this requires further analysis to confirm, it already raises concerns about the potential consequences of shocks related to this service (Figure A4.2).

Figure A4.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in Madagascar

(B) Capacity of Madagascar to provide ecosystem services



A breakdown of exposures by sector reveals that agriculture is the primary driver of the country's multi-sectoral exposure. Specifically, the sector "growing spices, aromatic, drug and pharmaceutical crops" accounts for 56% of exposed net exports, 33% of exposed wages, 28% of exposure related to employment and at least 10% of exposure across other socio-economic indicators. This sector depends heavily on 14 ecosystem services, underscoring its deep reliance on healthy ecosystems. Tax revenues – which are significantly exposed in Madagascar – are also largely generated by various agricultural sectors (e.g. rice, vegetables, cereals, sugar beet and cane) (Figure A4.3).

Figure A4.3:

(A) Distribution of exposure across Madagascar's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services

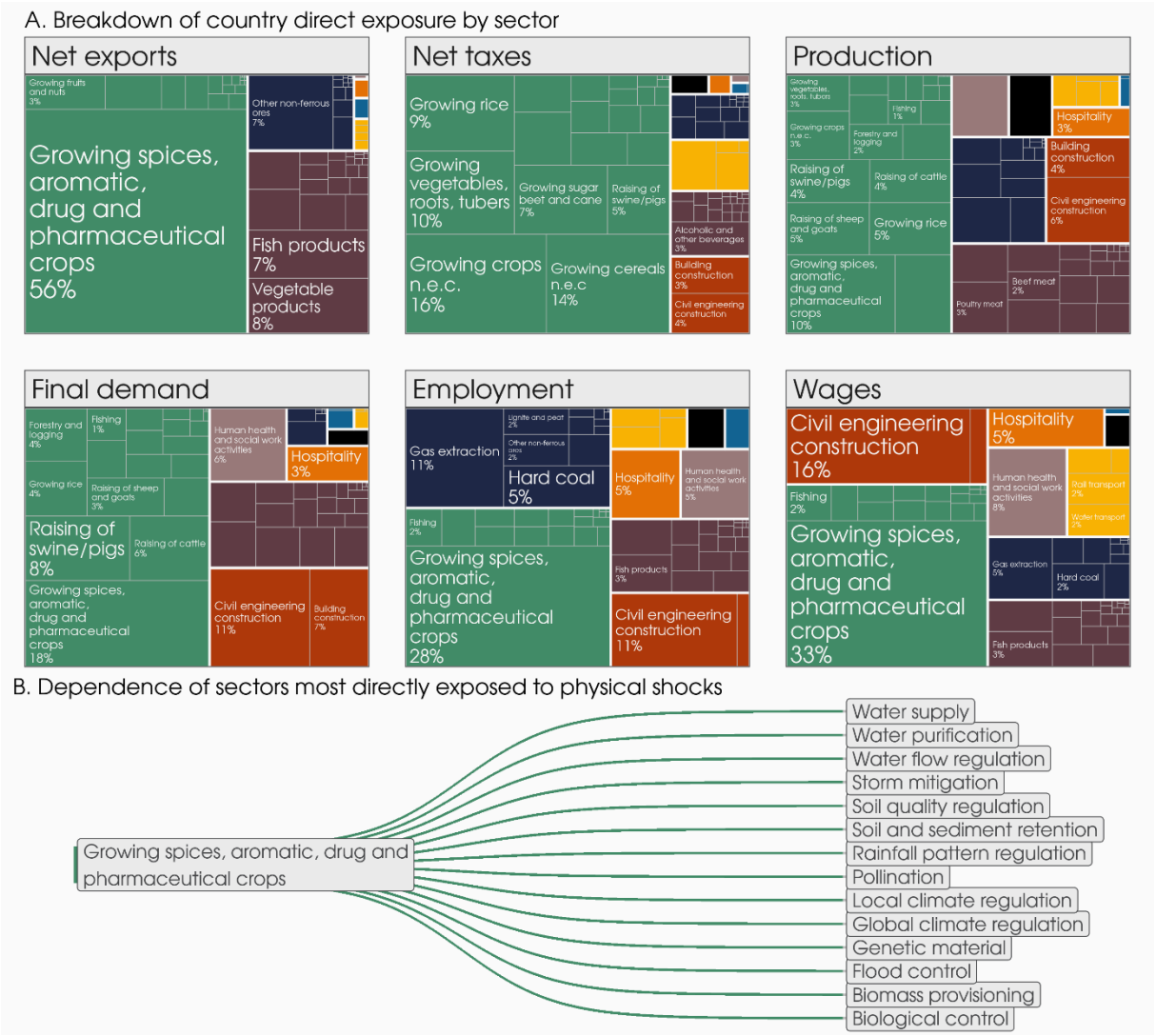


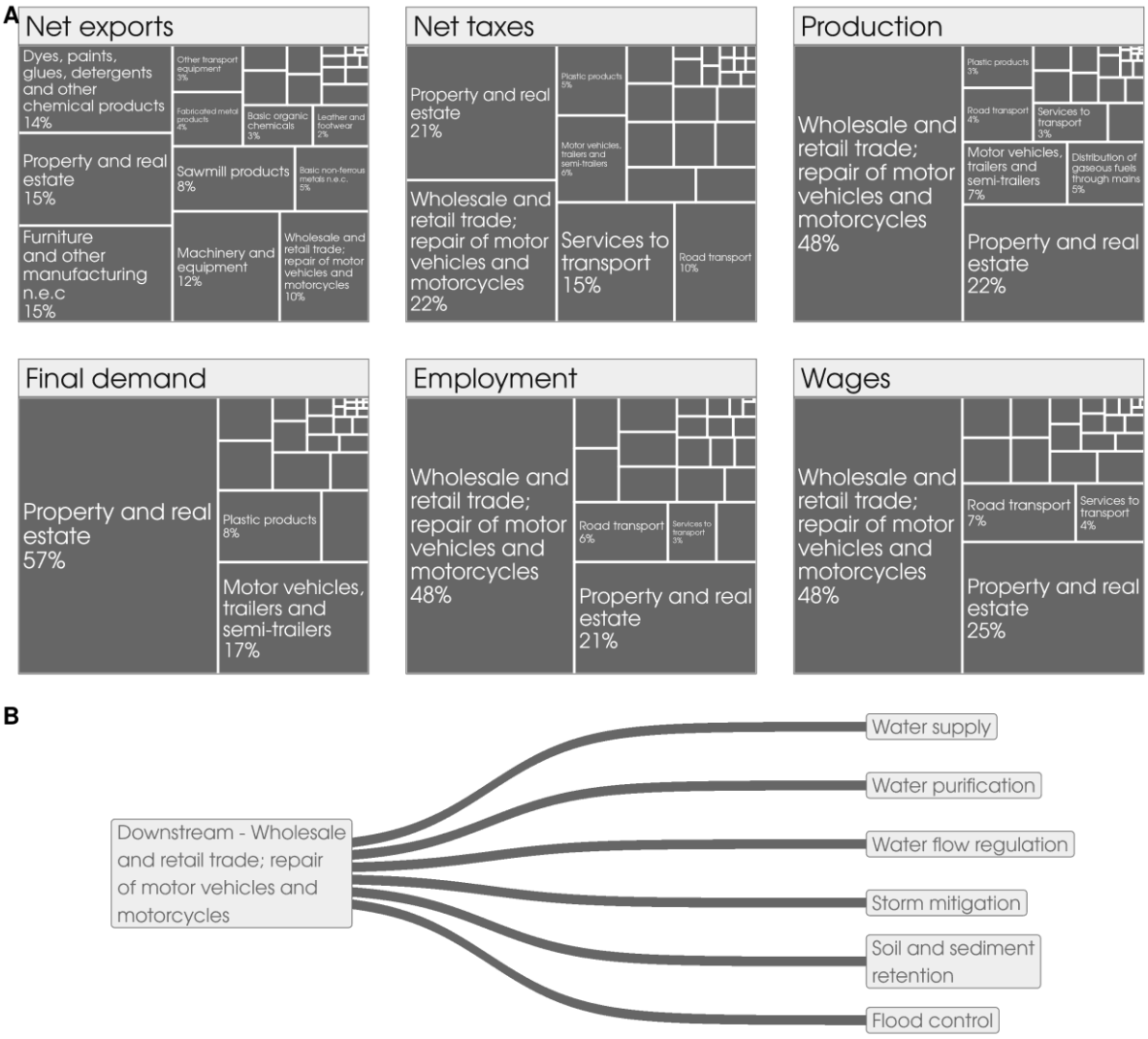
Figure A4.1 shows that all socio-economic indicators increase when strong dependencies from the first tier of sectors' value chains – both upstream and downstream – are included in the analysis. The sector that best explains these increases is "wholesale and retail trade; repair of motor vehicles and motorcycles", as it is not directly exposed to physical risks but is indirectly exposed (Figure A4.4). It is the primary contributor to the observed rise in exposure, while the remaining contribution is spread across a wide range of other sectors. Indeed, this sector alone accounts for 48% of the indirect exposure related to employment, wages and production, corresponding respectively to 12% of national employment, 14% of wages and 9% of production. Its exposure is entirely through its downstream value chain, specifically to water supply, purification, flow regulation, storm mitigation, soil and

sediment retention and flood control. This is because it supplies products to many sectors – primarily located in Madagascar – such as forestry and logging, growing fruits and nuts, and beverage crops, which are highly dependent on these ecosystem services.

Figure A4.4:

(A) Breakdown of Madagascar's socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A4.1.

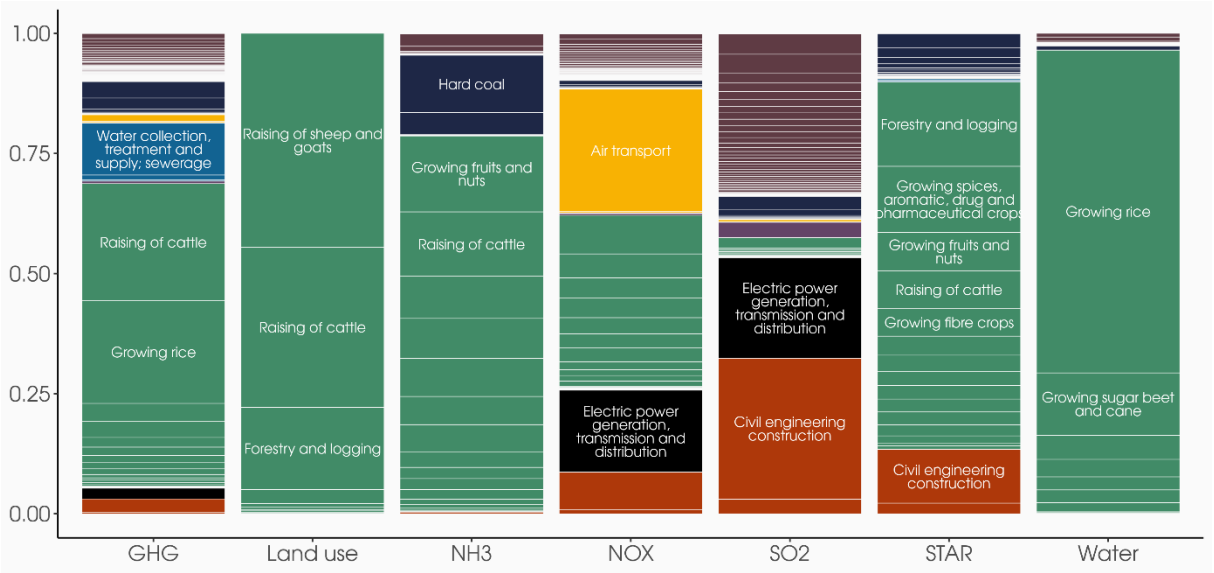
(B) Dependence of the country's key indirectly exposed sectors on ecosystem services



Transition exposure

In Madagascar, the raising sheep and goats sector alone uses 44% of the country's available agricultural land, while the raising of cattle sector uses 33%. The growing rice sector consumes 67% of available water. The sectors contributing most to the risk of species extinction are numerous, including agriculture, forestry and civil engineering construction. The electric power generation, transmission and distribution sector generates 20% of SO_2 emissions and 17% of NO_X emissions (Figure A4.5).

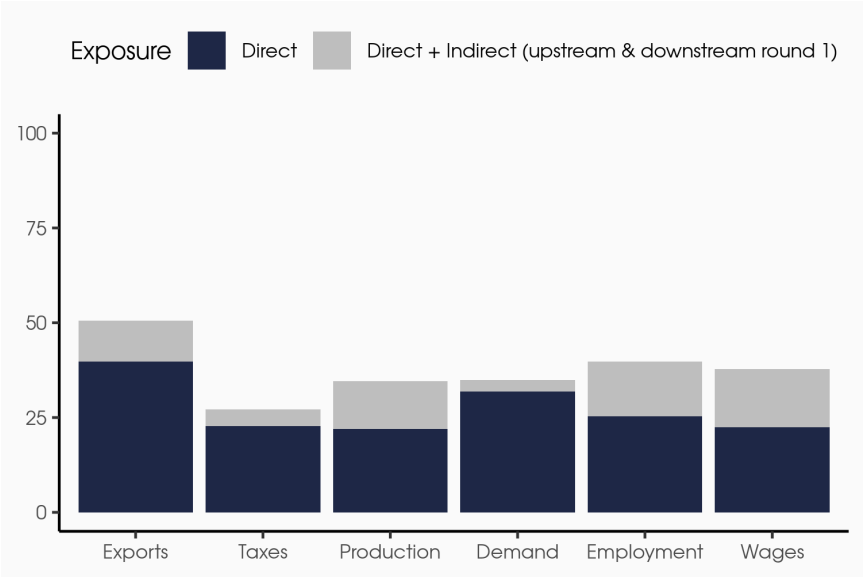
Figure A4.5: Share of pressures generated by sectors in Madagascar



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

Madagascar is primarily exposed to ecological transition risks through its net exports. Sectors that exert the highest direct pressures on biodiversity account for 40% of the country's net exports. These same sectors also contribute 32% to final demand and between 22% and 25% to other key socio-economic indicators. When indirect pressures – those linked to upstream and downstream value chains – are considered, the country's overall exposure increases moderately. The most notable rises are observed in employment and wages, each increasing by approximately 15 percentage points. In total, 51% of net exports are generated by sectors that directly or indirectly exert significant pressure on biodiversity (Figure A4.6).

Figure A4.6: Share of socio-economic indicators generated by exposed sectors in Madagascar



The transition shocks most likely to destabilise Madagascar are those related to species extinction. Indeed, 41% of the country's net exports are generated by sectors that are directly and indirectly exposed to this risk. These sectors also account for 26% of final demand, 21% of employment and wages and 14% of national production. Furthermore, 14% of net tax revenues come from sectors with high direct or indirect water consumption, while 17% of production is driven by sectors with intensive land use. This highlights the country's multi-dimensional exposure to various transition shocks (Figure A4.7).

The most exposed sector by far is the cultivation of spices, aromatic, drug and pharmaceutical crops. This sector contributes 37% of Madagascar's net exports, 14% of total employment and 13% of national wages while accounting for 14% of the country's total STAR score – making it one of the primary drivers of extinction risk. The wholesale and retail trade sector also merits close attention, as it represents 14% of national wages and 12% of employment. Though not directly exposed, it is indirectly affected by the ecological transition through land-use pressures embedded in its upstream supply chain. It sources 25% of its inputs from the raising of sheep and goats sector, which is a significant land user (Figure A4.8).

Figure A4.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Madagascar

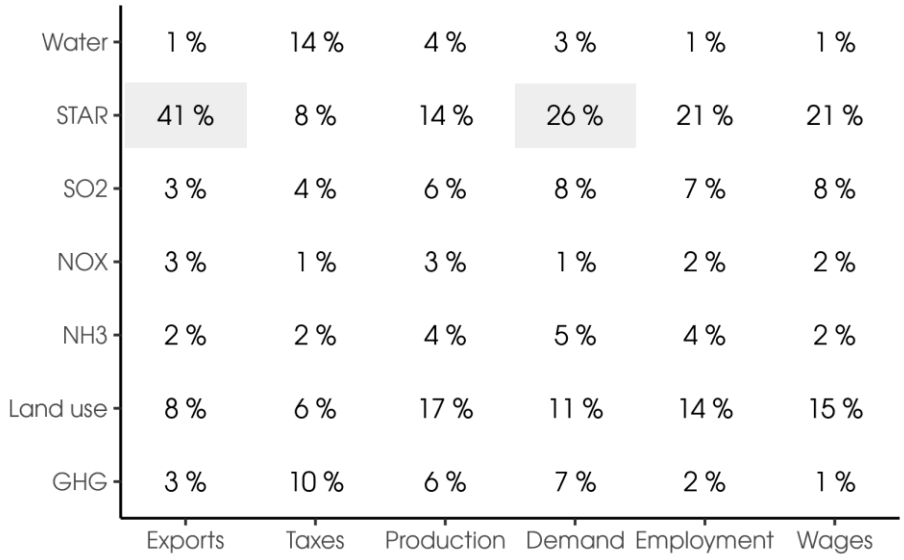
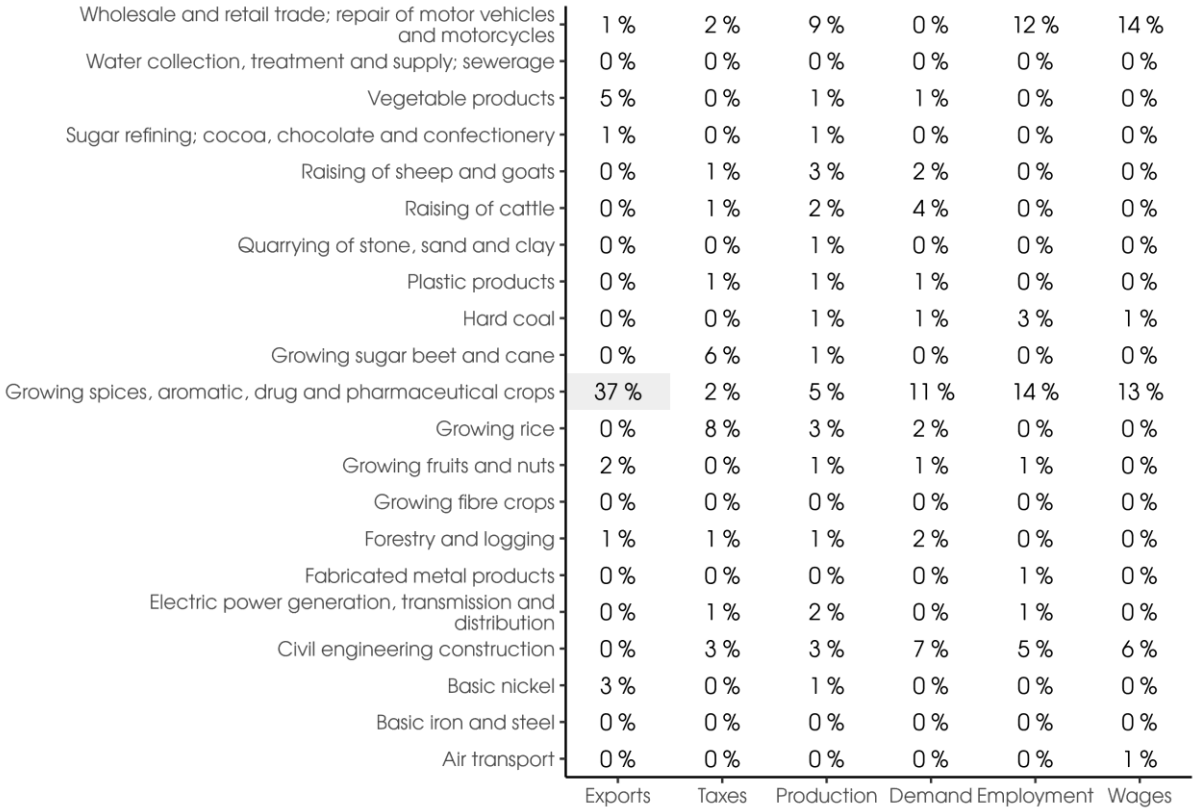


Figure A4.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Madagascar

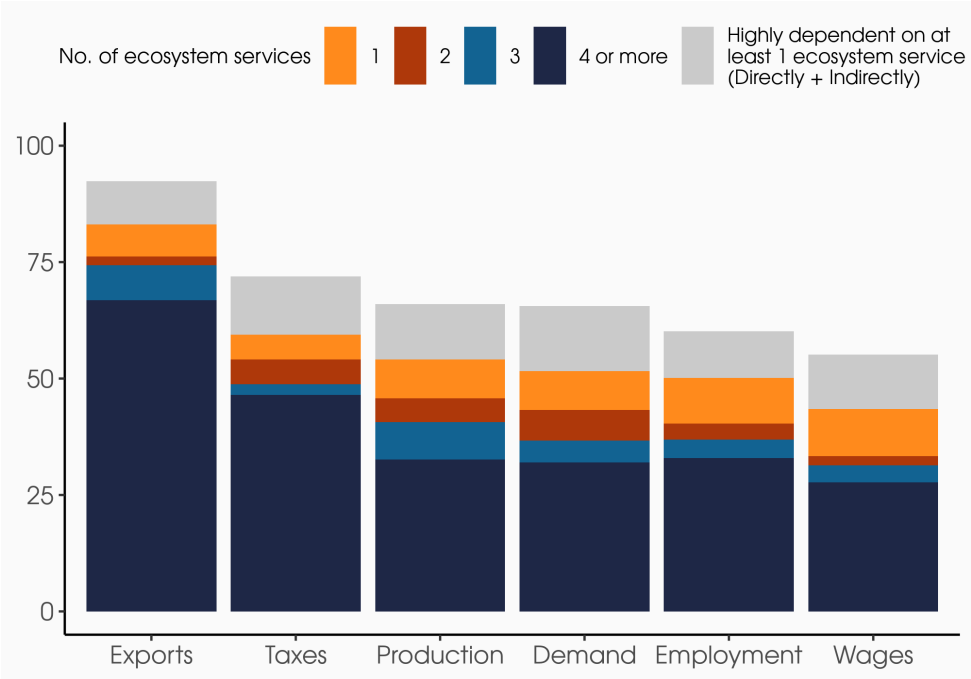


A5 Mozambique

Physical exposure

Mozambique is highly exposed to physical risks through its exports, with 83% of them generated by sectors that are highly dependent on at least one ecosystem service and 67% on at least four ecosystem services. In addition, 59% of net tax revenues, 54% of production, 52% of final demand, 50% of employment and 43% of wages are exposed to physical shocks. When accounting for exposure through the first tier of sectors' upstream and downstream value chains, these figures can increase by 9 to 14 percentage points (Figure A5.1).

Figure A5.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Mozambique



Water-related ecosystem services and global climate regulation services account for most of the country's exposure. Indeed, over 60% of exports are generated by sectors highly dependent on at least one water-related service or on the global climate regulation ecosystem service. For example, 76% of the country's net exports are generated by sectors highly dependent on the ecosystem service of water purification. Nevertheless, the country's ecosystem services seem to be better provided than in the rest of SADC, which somewhat mitigates the overall picture. However, this indicator is only an approximation of reality: it is static and national, so it is necessary to continue

investigations into the integrity of water resources in Mozambique and beyond its borders, particularly those used by the national industries (Figure A5.2).

Mozambique's export-related exposure is largely driven by the hard coal sector, which alone contributes 43% of exports, 24% of wages, 13% of employment and 11% of net tax revenues. This sector's strong dependence on ecosystem services related to water and global climate regulation largely explains these figures. Mining operations rely on ecosystem-provided water supply services to ensure adequate quantity and quality of water – for purposes such as haul road dust suppression, washdown facilities and the replenishment of groundwater in backfilled pit voids as mining progresses. Agricultural sectors also play a significant role in the country's exposure to physical shocks. More than half of the exposure of fiscal revenues originates from agriculture – particularly from sectors such as forestry and logging and the production of vegetables, roots and tubers. Overall, agricultural sectors are highly reliant on a wide range of ecosystem services (Figure A5.2).

Figure A5.2:

(A) Share of socio-economic indicators generated by sectors highly and directly dependent on a given ecosystem service in Mozambique

(B) Capacity of Mozambique to provide ecosystem services

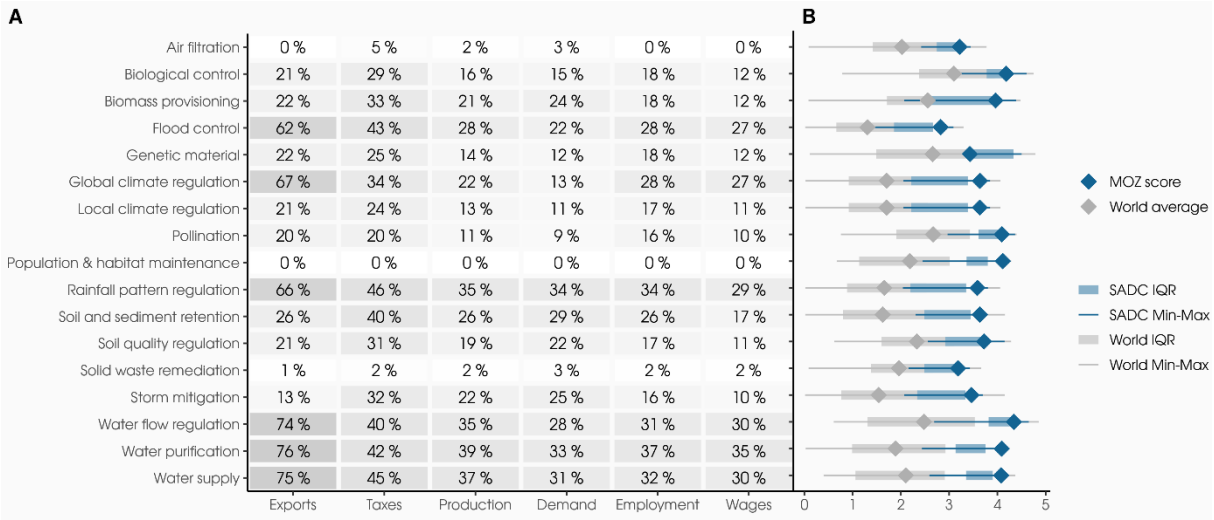


Figure A5.3:

(A) Distribution of exposure across Mozambique's economic sectors. Only sectors generating at least 5% of the socio-economic indicators are shown in the graph.

(B) Dependence of the country's key sectors on ecosystem services

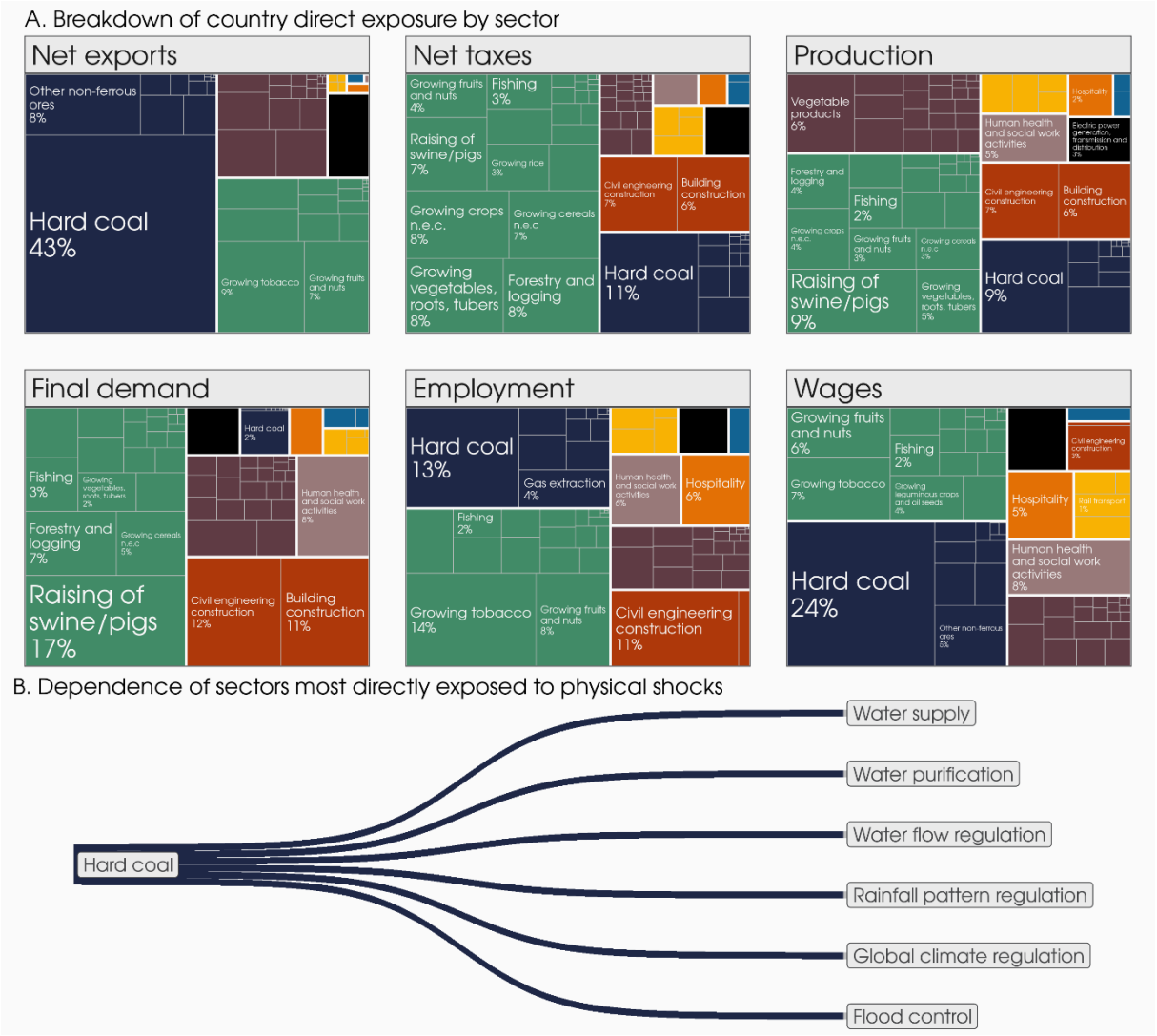


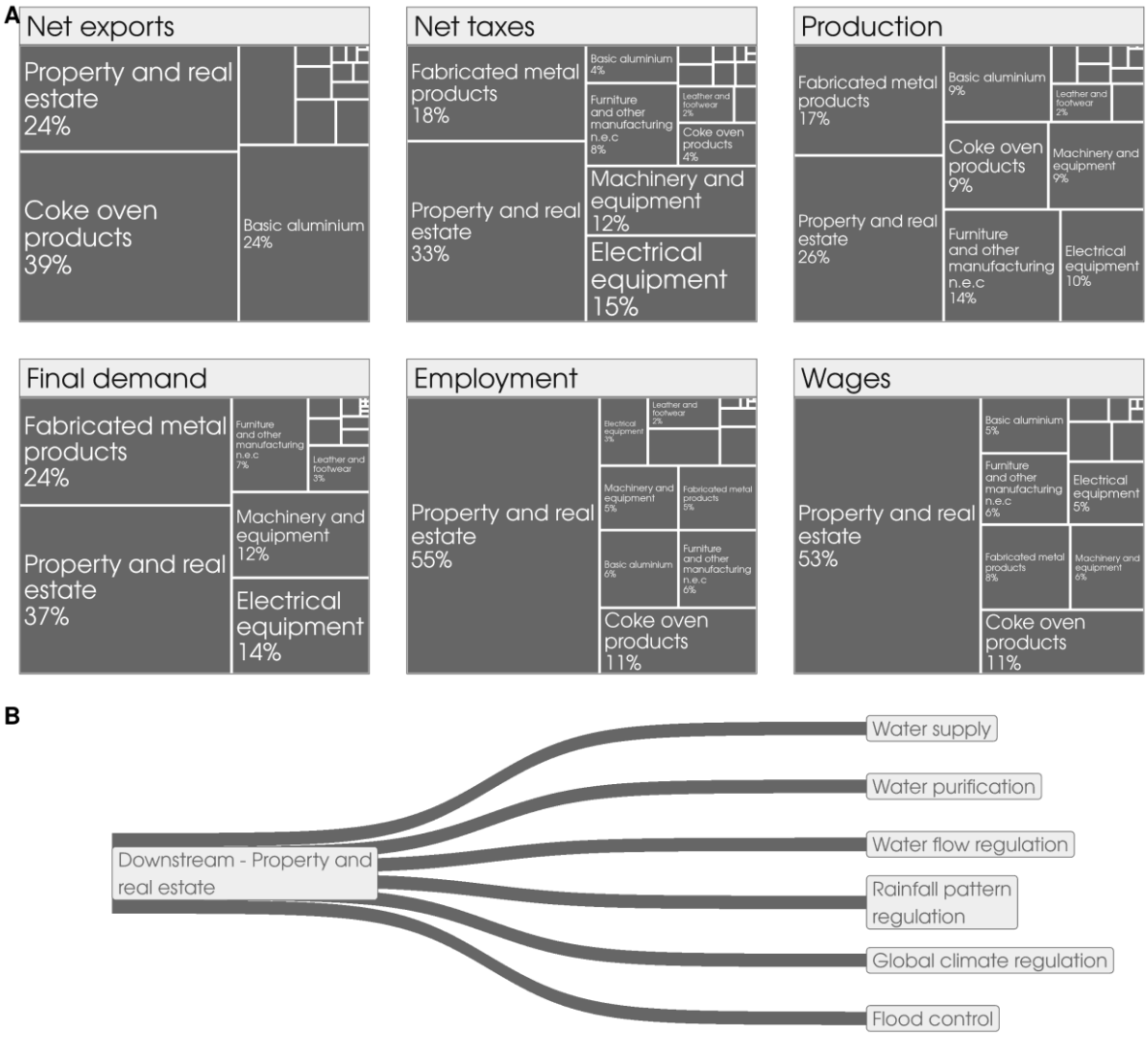
Figure A5.1 reveals that Mozambique's overall exposure increases significantly (from 9 to 14 percentage points) when strong indirect dependencies – both upstream and downstream – from the first tier of sectors' value chains are taken into account. This rise in exposure is primarily driven by the property and real estate sector, which was not previously identified as being exposed to physical risks (Figure A5.4). However, it now emerges as a key contributor to the country's exposure due to its downstream dependence on several critical ecosystem services – namely flood control, water flow regulation, water purification, water supply, global climate regulation and rainfall pattern regulation. These ecosystem services are essential to the sectors supplied by

real estate activities, thus making the latter highly dependent on ecosystems on which they do not appear to be directly dependent at first glance.

Figure A5.4:

(A) Breakdown of Mozambique's socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A5.1.

(B) Dependence of the country's key indirectly exposed sectors on ecosystem services

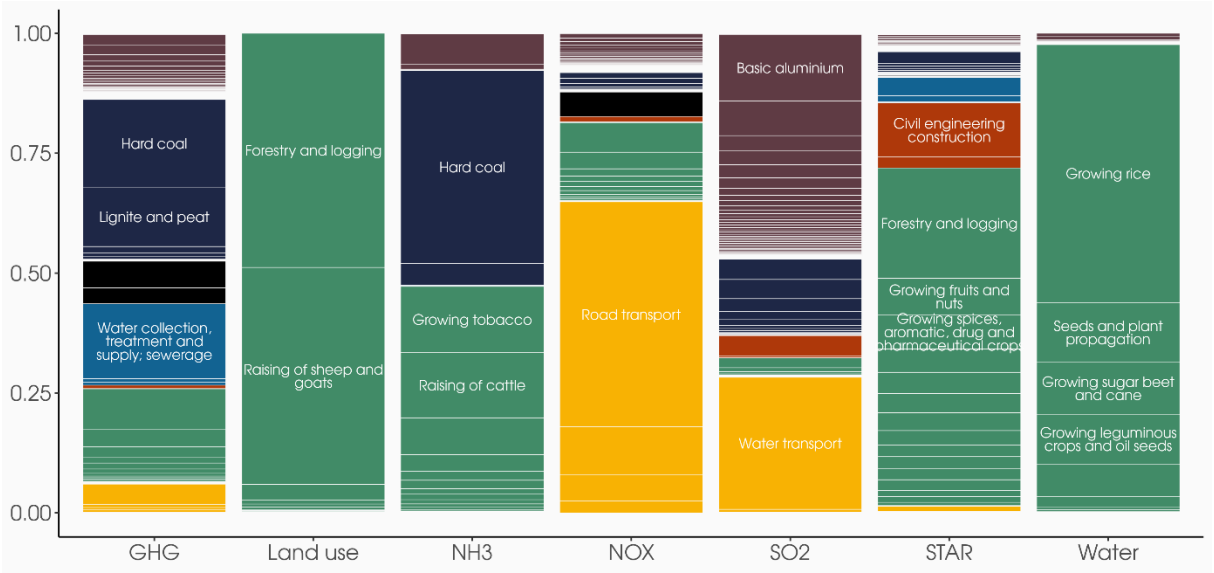


Transition exposure

Mozambique's transport sector is a major source of pressure on biodiversity. The road transport sector alone generates 47% of NO_X emissions and the water transport sector 28% of SO_2 emissions. Agricultural land use is distributed as follows: 49% is used by the forestry and logging sector, 45% is used for raising sheep and goats, and the remainder is used by sectors not exposed to a transition linked to this pressure. The hard coal mining sector also exerts significant pressure on biodiversity, as it is

responsible for 40% of NH_3 emissions and 18% of GHG emissions. Meanwhile, the growing rice sector is the country's largest water consumer, accounting for 54% of total water consumption (Figure A5.5).

Figure A5.5: Share of pressures generated by sectors in Mozambique



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

Mozambique appears to be highly exposed to nature-related transition risks, particularly through its net export structure. Indeed, 63% of these risks are generated by sectors that exert the most significant pressures on biodiversity – either directly or through their first-tier value chain connections. These same sectors also contribute 32% of national employment and over 22% of other key socio-economic indicators, including final demand, wages and net tax revenues. Nevertheless, the exposure stems primarily from sectors that directly contribute to biodiversity pressures (Figure A5.6).

The country's vulnerability is particularly pronounced in the case of a transition that would aim to reduce NH_3 and GHG emissions. Indeed, 43% of net exports are generated by sectors highly exposed to NH_3-related pressures and 39% are linked to GHG-intensive sectors. Moreover, sectors responsible for the majority of NH_3 emissions also account for 13% of employment and 14% of total wages, indicating the strong social and economic interdependence between Mozambique's labour market and environmentally sensitive sectors (Figure A5.7).

Two sectors stand out as key contributors to this exposure. First, the hard coal sector, which generates 35% of the country's net exports, 10% of wages and 7% of net taxes. This sector is directly responsible for 18% of national GHG emissions and 40% of NH_3 emissions, placing it at the heart of Mozambique's exposure to an ambitious ecological transition. Second, the growing tobacco sector, which produces 7% of net exports and employment while being both directly and indirectly exposed to NH_3-related pressures through its upstream and downstream activities (Figure A5.8).

Figure A5.6: Share of socio-economic indicators generated by exposed sectors in Mozambique

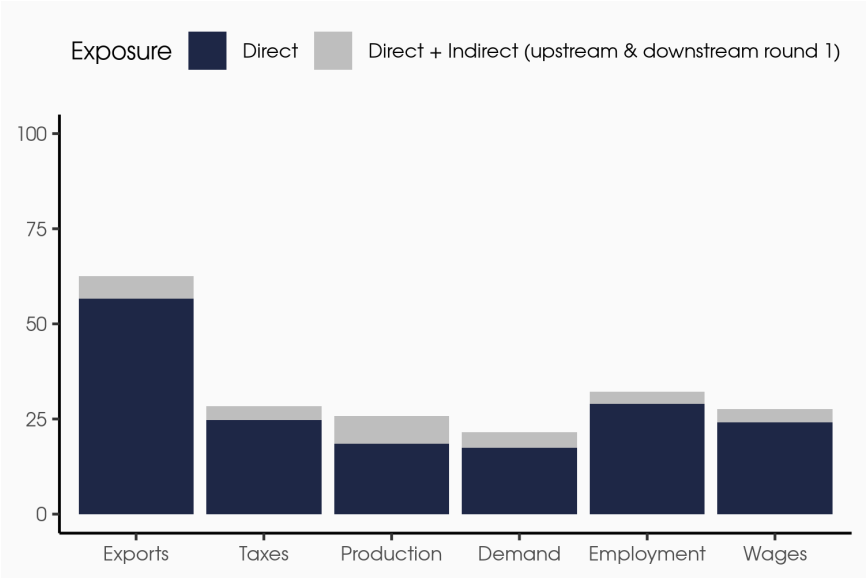


Figure A5.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Mozambique

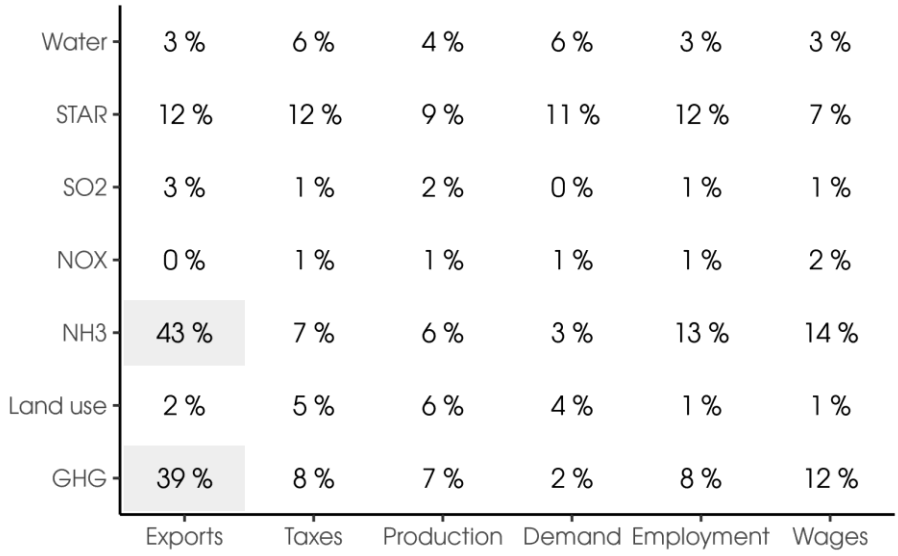
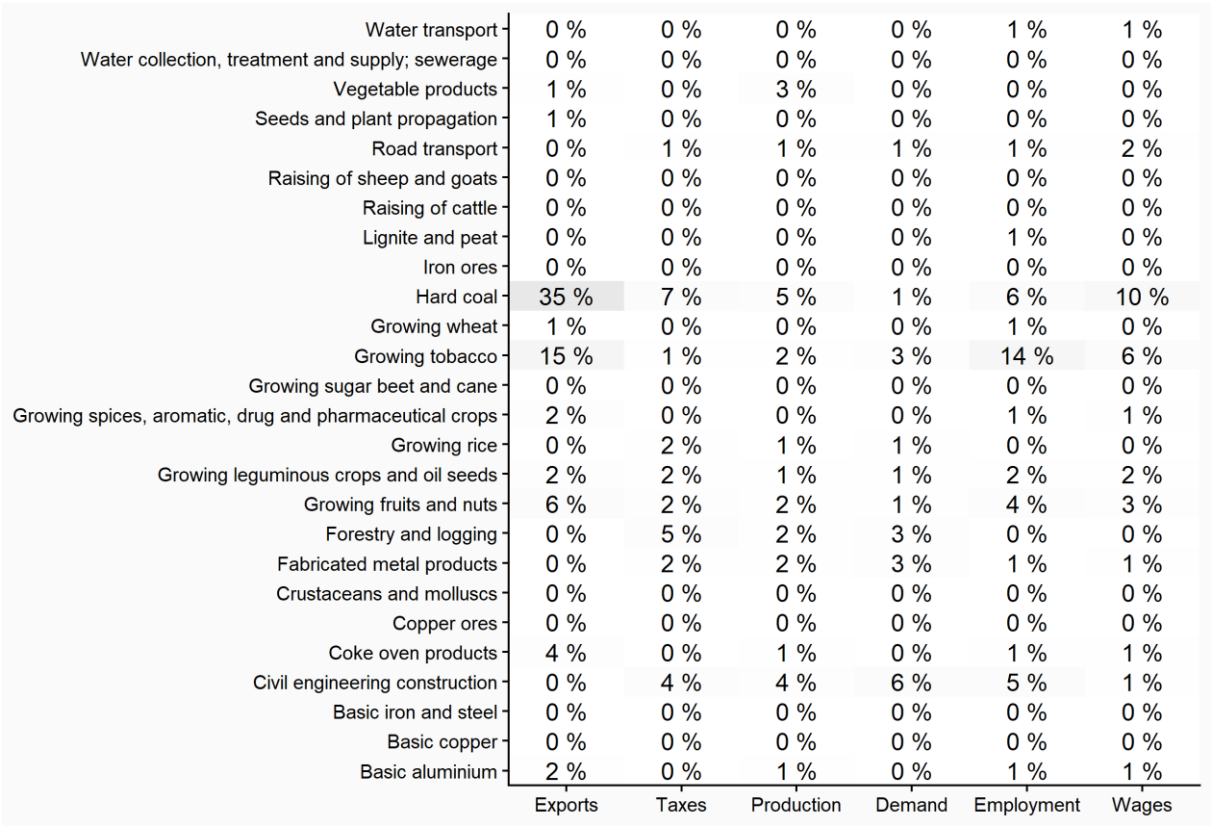


Figure A5.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Mozambique

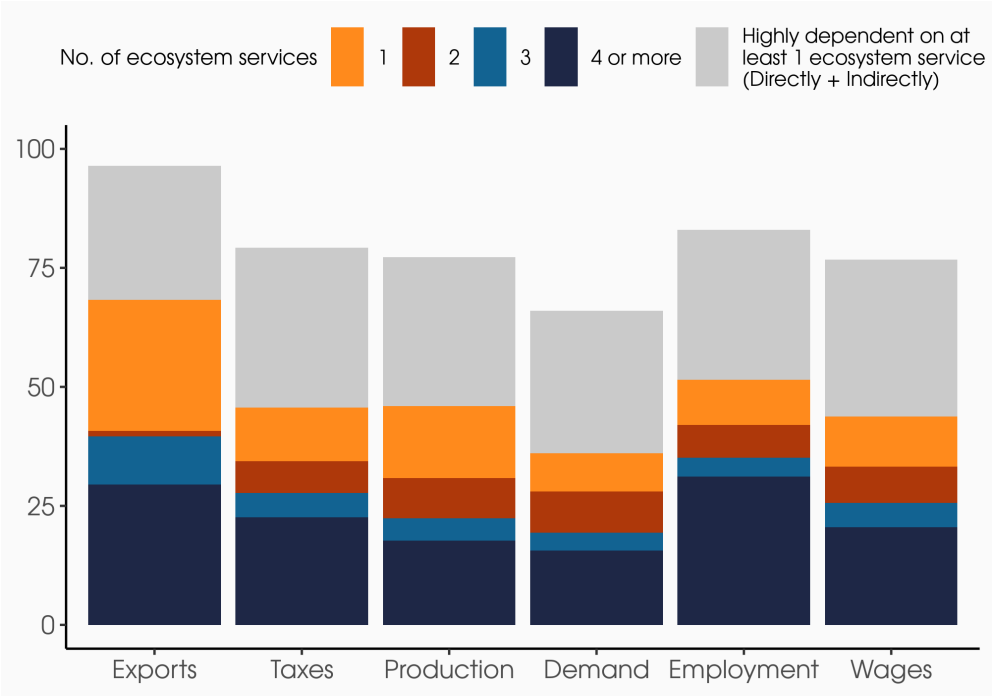


A6 Namibia

Physical exposure

Namibia is highly and directly exposed to physical risks through its exports, with sectors highly dependent on at least one ecosystem service generating 68% of net exports and those relying on four or more accounting for 30%. These sectors also support 51% of national employment. When accounting for indirect dependencies – through the first tier of suppliers and distributors of sectors – the country's exposure increases significantly, with net export-related exposure rising by 28 percentage points and other socio-economic indicators by at least 30 percentage points (Figure A6.1).

Figure A6.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Namibia

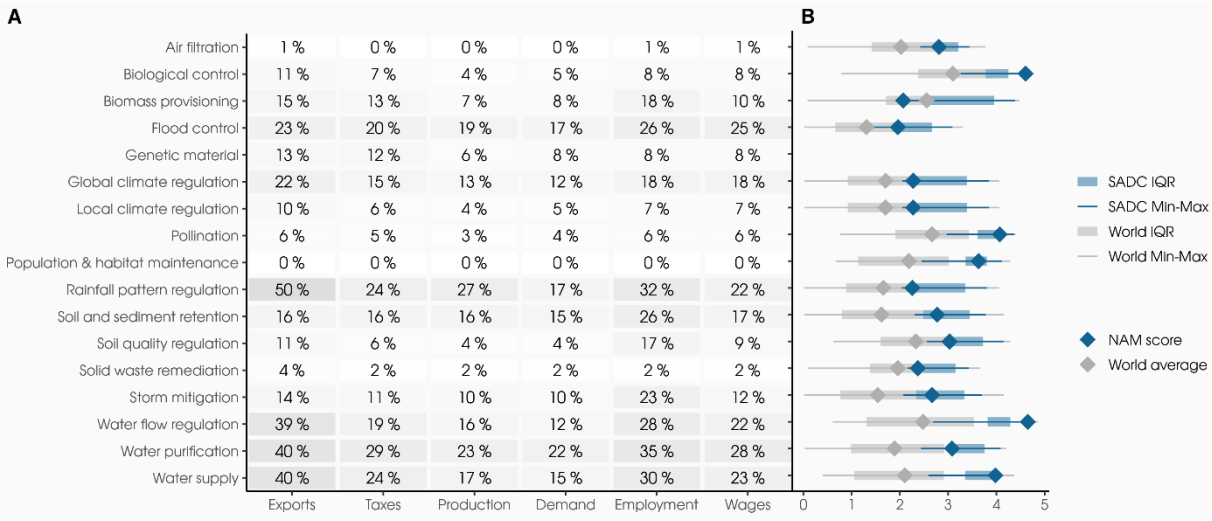


Fifty per cent of Namibia's net exports are generated by sectors that are highly dependent on the ecosystem service of rainfall pattern regulation, while about 40% rely on services such as water flow regulation, water purification and water supply. Furthermore, at least 17% of key socio-economic indicators are linked to sectors that are heavily reliant on the flood control service. Notably, both flood control and rainfall regulation appear to be inadequately provided by the country's ecosystems. It is therefore essential to assess whether these ecosystem services are locally available in the regions where the dependent industries operate (Figure A6.2).

Figure A6.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in Namibia

(B) Capacity of Namibia to provide ecosystem services



Overall, the mining sector is a major contributor to the country's exposure. Specifically, 35% of Namibia's net exports' exposure originates from the "mining and quarrying n.e.c.; services to mining" sector, and an additional 10% from the uranium ores sector. The "mining and quarrying n.e.c.; services to mining" sector is particularly dependent on ecosystem services that mitigate flood risks and ensure reliable water supply from rivers and other sources. Given Namibia's high export-related exposure, there is a pressing need to investigate the mining sector's capacity to adapt to nature-related physical shocks. Protecting local biodiversity should also be a strategic priority to effectively reduce this vulnerability.

In terms of employment – which is highly exposed to physical shocks – 16% is generated by the raising of cattle sector. This sector relies heavily on eight ecosystem services, including water supply, purification and flow, soil quality and sediment retention, storm mitigation, biomass provisioning and rainfall pattern regulation. The remaining employment exposure is distributed across a wide range of sectors, including construction, mining, manufacturing and hospitality (Figure A6.3).

Figure A6.3:

(A) Distribution of exposure across Namibia's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services

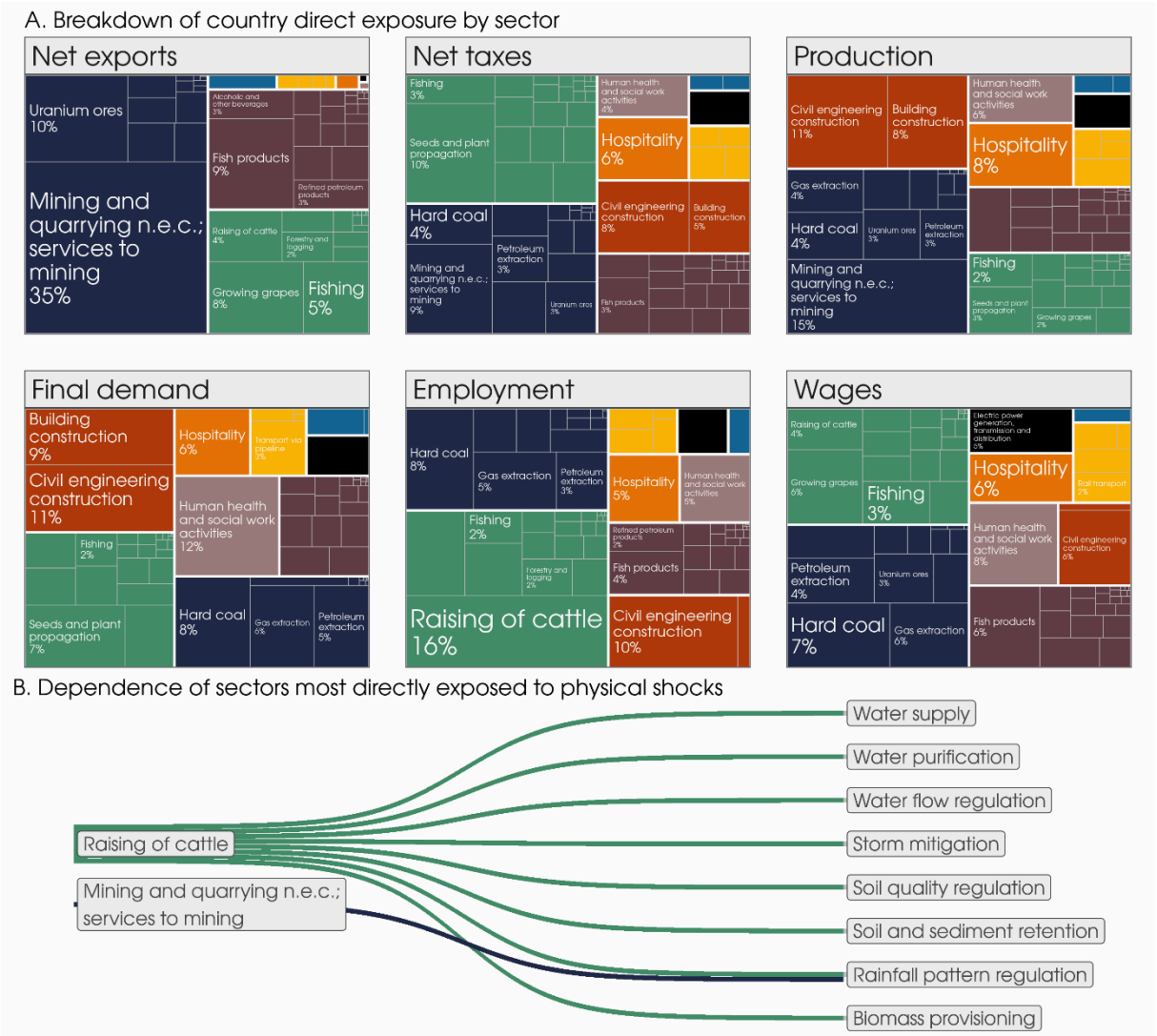


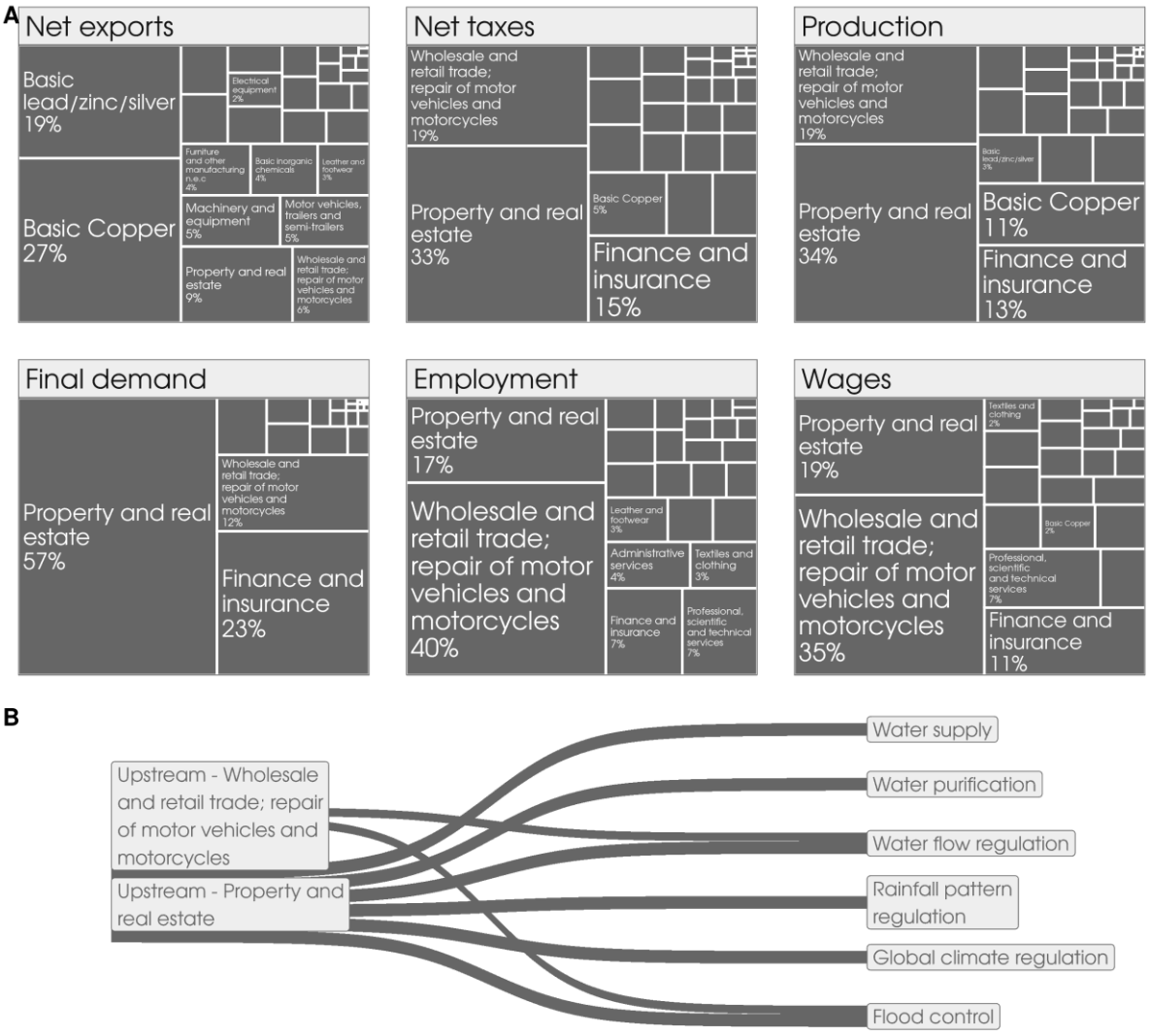
Figure A6.1 shows that Mozambique's exposure increases considerably when indirect dependencies are included through the first round of upstream and downstream value chain linkages. Two sectors in particular stand out as major contributors to this increase (Figure A6.4). The first is the "wholesale and retail trade; repair of motor vehicles and motorcycles" sector, which is indirectly dependent on water flow regulation and flood control. This dependency arises from its input structure: while most inputs are sourced within the sector itself, a notable share comes from the copper ores sector in the DRC. This connection amplifies the sector's reliance on key ecosystem services. The sector plays an important role in the national economy, especially in terms of employment and wages, being responsible for 40% of the country's indirect exposure related to employment and 35% of that related to wages.

The second sector is property and real estate, which contributes 57% of the country's indirect exposure linked to final demand and 34% of that related to production. This sector sources about 70% of its inputs from the copper ores sector in the DRC, making it highly dependent on six essential ecosystem services: flood control, water flow regulation, water purification, water supply, global climate regulation and rainfall pattern regulation.

Figure A6.4:

(A) Breakdown of Namibia's socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A6.1.

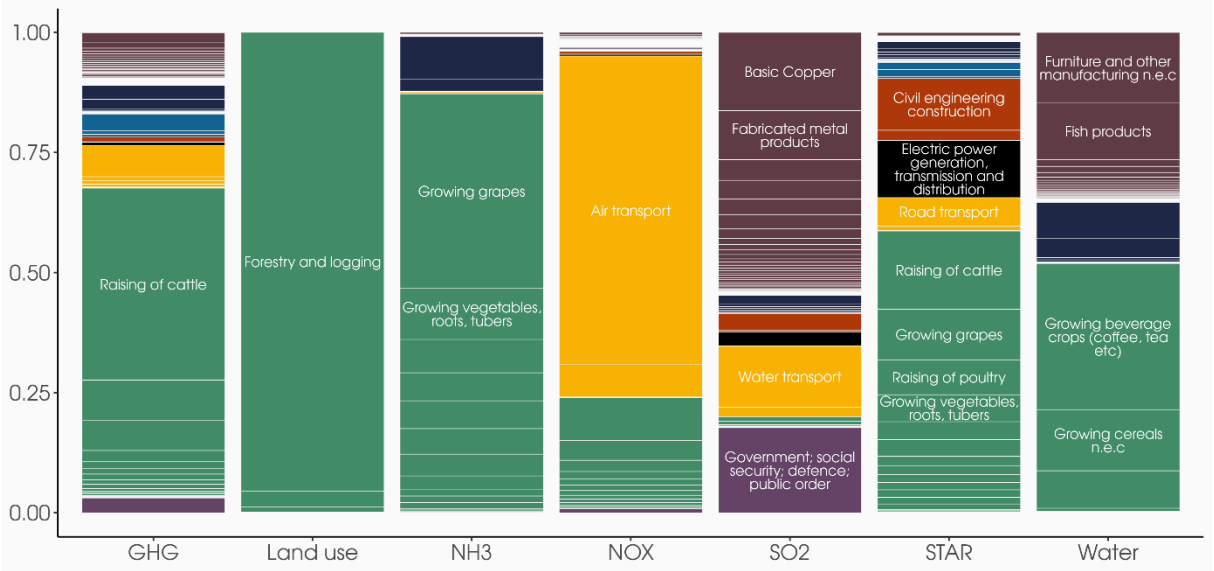
(B) Dependence of the country's key indirectly exposed sectors on ecosystem services



Transition exposure

In Namibia, the forestry and logging sector is responsible for 95% of the country's land-use pressure. Agricultural sectors also generate a great deal of pressure in the country – in fact, the growing grapes sector generates 41% of NH_3 emissions, and only the raising of cattle sector is exposed to a transition linked to the reduction of GHG emissions (exerting 40% of the pressure). The air transport sector generates 64% of NO_X pressure and is the only sector exposed to this pressure. Seven sectors are responsible for most of the country's risk of species extinction, including agriculture, road transport, electricity and construction (Figure A6.5).

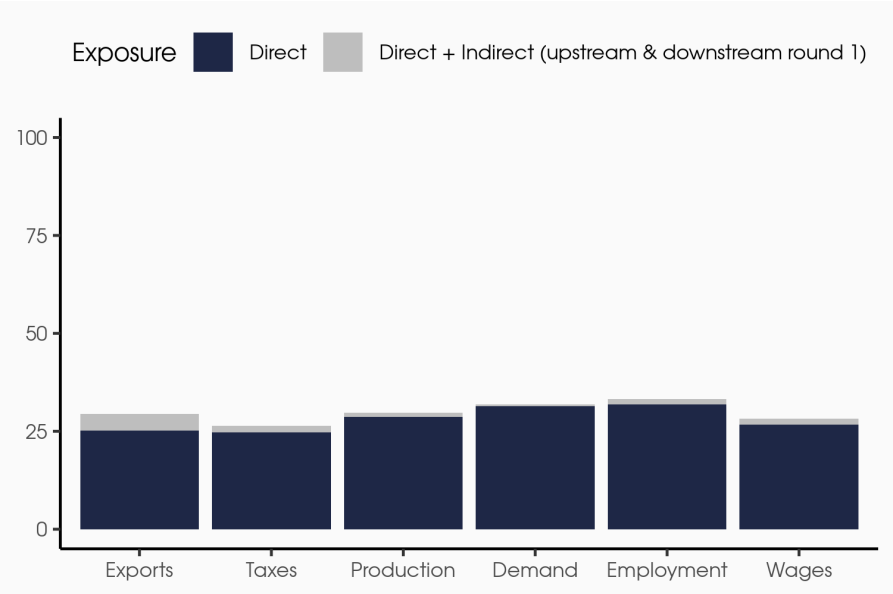
Figure A6.5: Share of pressures generated by sectors in Namibia



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

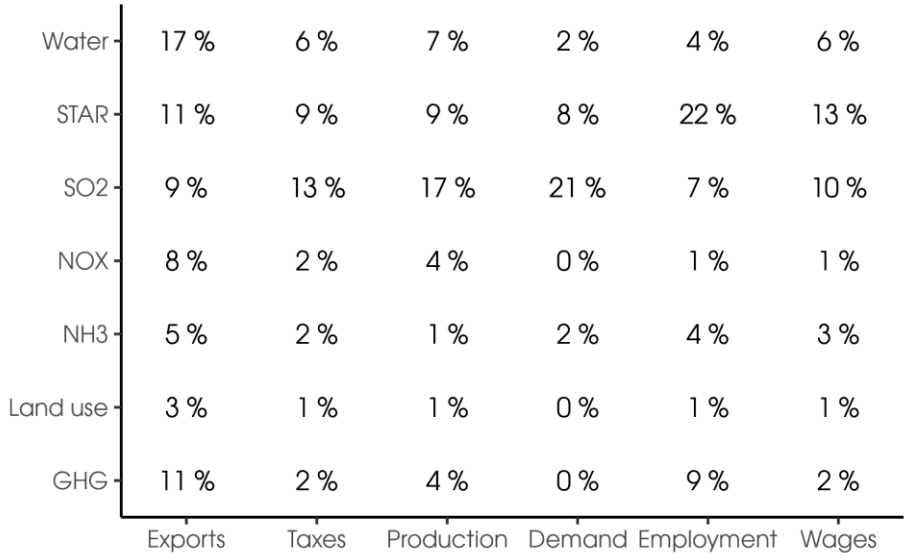
Namibia is primarily directly exposed to transition risks, with 25% to 32% of key socio-economic indicators associated with sectors that exert the highest direct pressures on biodiversity – that is, sectors responsible for at least 10% of a given pressure or 5% of the national STAR score. An analysis of indirect impacts – through first-tier upstream and downstream value chain connections – shows that the overall picture remains largely unchanged. The only notable difference concerns net exports, whose exposure increases by 4 percentage points. The highest direct exposures are observed in employment and final demand, although exposure across all socio-economic indicators remains relatively balanced (Figure A6.6).

Figure A6.6: Share of socio-economic indicators generated by exposed sectors in Namibia



The country's production and final demand may be significantly constrained by efforts to reduce industrial SO_2 emissions, as around 20% of both are generated by sectors highly exposed to this pressure. Furthermore, any transition aimed at reducing species extinction risk could affect employment, with 22% of jobs linked to sectors that contribute substantially to the country's STAR score. In addition, 17% of net exports are generated by sectors that would be exposed to a transition targeting reduced water consumption in national sectors (Figure A6.7).

Figure A6.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Namibia



Two economic sectors appear to drive Namibia's vulnerability to an ecological transition. First, the "government, social security, defence, public order" sector contributes 21% of final demand and 13% of production while being highly sensitive to SO_2 reductions, with a direct contribution of 18% to national SO_2 emissions. Second, the basic copper sector is a major driver of exposure, especially through its role in net exports and its large environmental footprint. It contributes not only to direct SO_2 emissions but also to downstream emissions of GHGs, SO_2 and NOx. These dependencies make the sector particularly vulnerable to a transition that involves stricter emission standards (Figure A6.8).

Figure A6.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Namibia

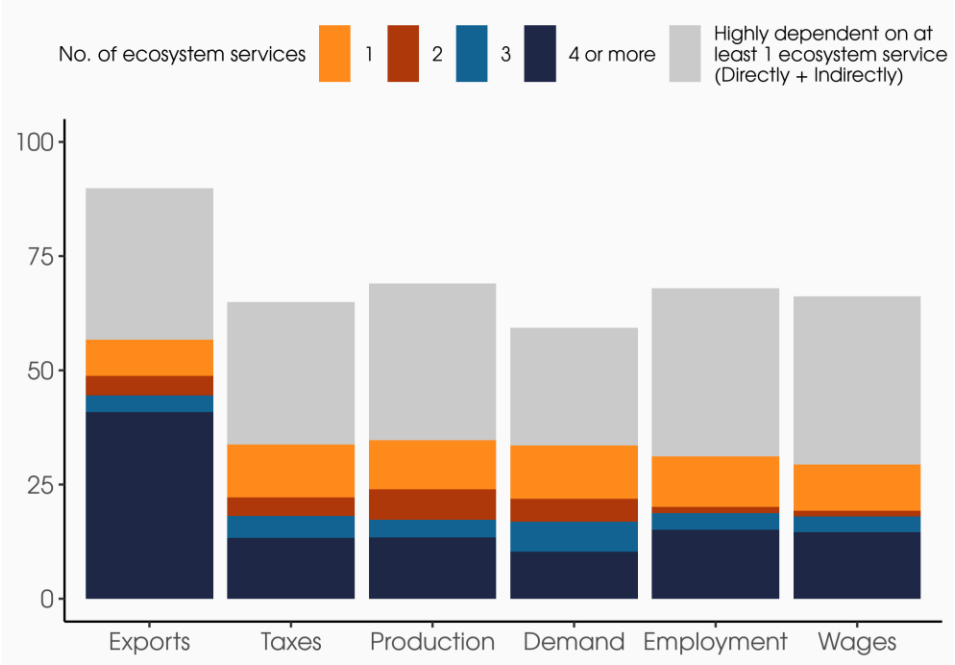
	Exports	Taxes	Production	Demand	Employment	Wages
Water transport	0 %	0 %	0 %	0 %	1 %	1 %
Road transport	0 %	1 %	1 %	1 %	1 %	2 %
Raising of poultry	0 %	0 %	0 %	0 %	0 %	0 %
Raising of cattle	3 %	1 %	0 %	0 %	8 %	2 %
Machinery and equipment	3 %	1 %	1 %	0 %	1 %	2 %
Growing wheat	0 %	0 %	0 %	0 %	0 %	0 %
Growing vegetables, roots, tubers	0 %	1 %	0 %	1 %	1 %	1 %
Growing maize	0 %	0 %	0 %	0 %	0 %	0 %
Growing grapes	5 %	1 %	1 %	1 %	3 %	3 %
Growing cereals n.e.c.	0 %	1 %	0 %	1 %	0 %	0 %
Growing beverage crops (coffee, tea etc.)	0 %	0 %	0 %	0 %	0 %	0 %
Government; social security; defence; public order	0 %	10 %	13 %	21 %	5 %	7 %
Furniture and other manufacturing n.e.c.	1 %	1 %	1 %	0 %	1 %	1 %
Forestry and logging	2 %	1 %	1 %	0 %	2 %	2 %
Fish products	6 %	1 %	1 %	0 %	2 %	3 %
Fabricated metal products	0 %	1 %	1 %	1 %	1 %	1 %
Electrical equipment	1 %	0 %	0 %	0 %	0 %	0 %
Electric power generation, transmission and distribution	0 %	1 %	1 %	1 %	1 %	2 %
Clay building materials	0 %	0 %	0 %	0 %	0 %	0 %
Civil engineering construction	0 %	3 %	5 %	4 %	5 %	3 %
Chemical and fertilizer minerals	0 %	0 %	0 %	0 %	0 %	0 %
Basic iron and steel	0 %	0 %	0 %	0 %	0 %	0 %
Basic copper	15 %	3 %	7 %	0 %	1 %	2 %
Alcoholic and other beverages	2 %	0 %	0 %	0 %	0 %	0 %
Air transport	0 %	0 %	0 %	0 %	0 %	1 %

A7 South Africa

Physical exposure

Overall, South Africa is less directly exposed to physical nature-related risks than other SADC countries. Although 57% of its exports are generated by sectors highly dependent on at least one ecosystem service, other socio-economic indicators remain below 35%. However, when accounting for indirect dependencies through the first tier of the country's value chains, analysis reveals that indirectly exposed sectors generate 90% of net exports, 69% of production and 68% of employment (Figure A7.1).

Figure A7.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in South Africa

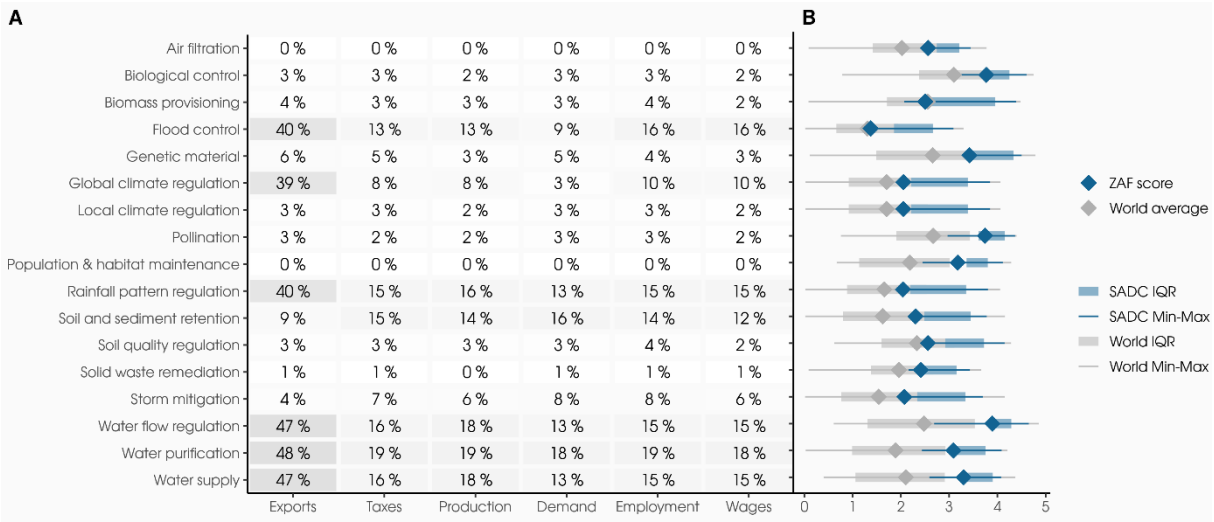


The country is particularly exposed to physical shocks related to the decline of water-related ecosystem services, global climate regulation and flood control. Indeed, between 39% and 48% of the country's exports and between 8% and 19% of its net tax revenues are generated by sectors heavily dependent on at least one of these ecosystem services. Among all ecosystem services, flood control is the least well provided (score = 1.37/5) relative to other SADC countries. Consequently, it is crucial for the country to closely monitor the sectors most reliant on this service, both to ensure that they have the capacity to mitigate associated risks and that the ecosystem services they depend on are sufficiently available locally (Figure A7.2).

Figure A7.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in South Africa

(B) Capacity of South Africa to provide ecosystem services

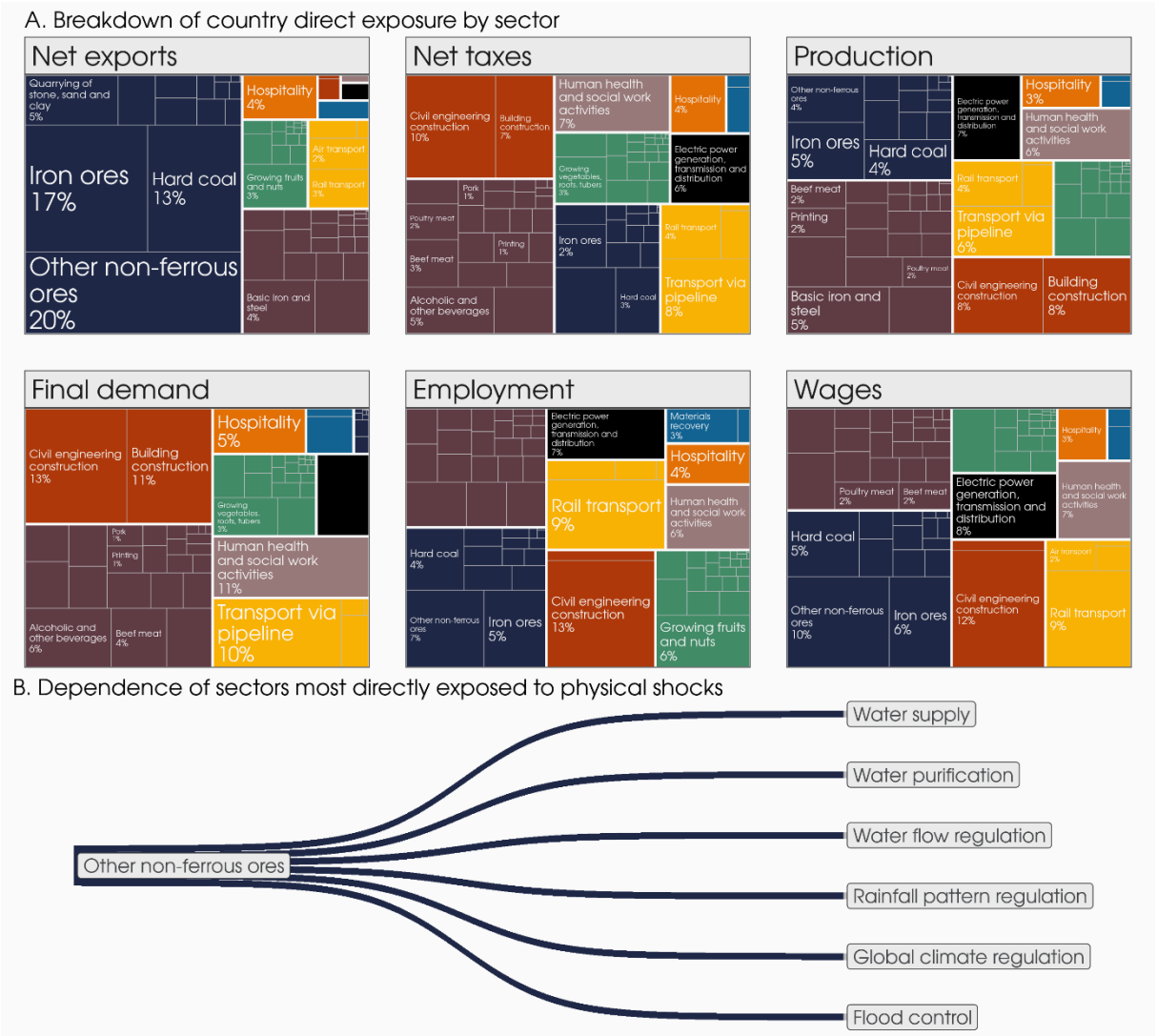


The economic sector that exposes the country the most is mining, which explains South Africa's high dependence on water-related services, flood control and global climate regulation. The mining sector, particularly for non-ferrous metal ores, depends on various ecosystem services, including water purification to maintain the chemical composition of water necessary for cooling, cracking and detoxifying effluents throughout production. It also relies on flood control, water flow maintenance and rainfall pattern regulation to protect infrastructure, ensure a stable water supply for dust suppression and pit refilling and to support essential operational processes. Mining accounts for 63% of the country's exposure related to net exports, with 17% coming from the iron ores sector, 13% from hard coal and 20% from other non-ferrous ores. Exposure related to other socio-economic indicators, which is much lower, stems from diverse sectors such as construction, agriculture, manufacturing, transport and electricity (Figure A7.3).

Figure A7.3:

(A) Distribution of exposure across South Africa's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services



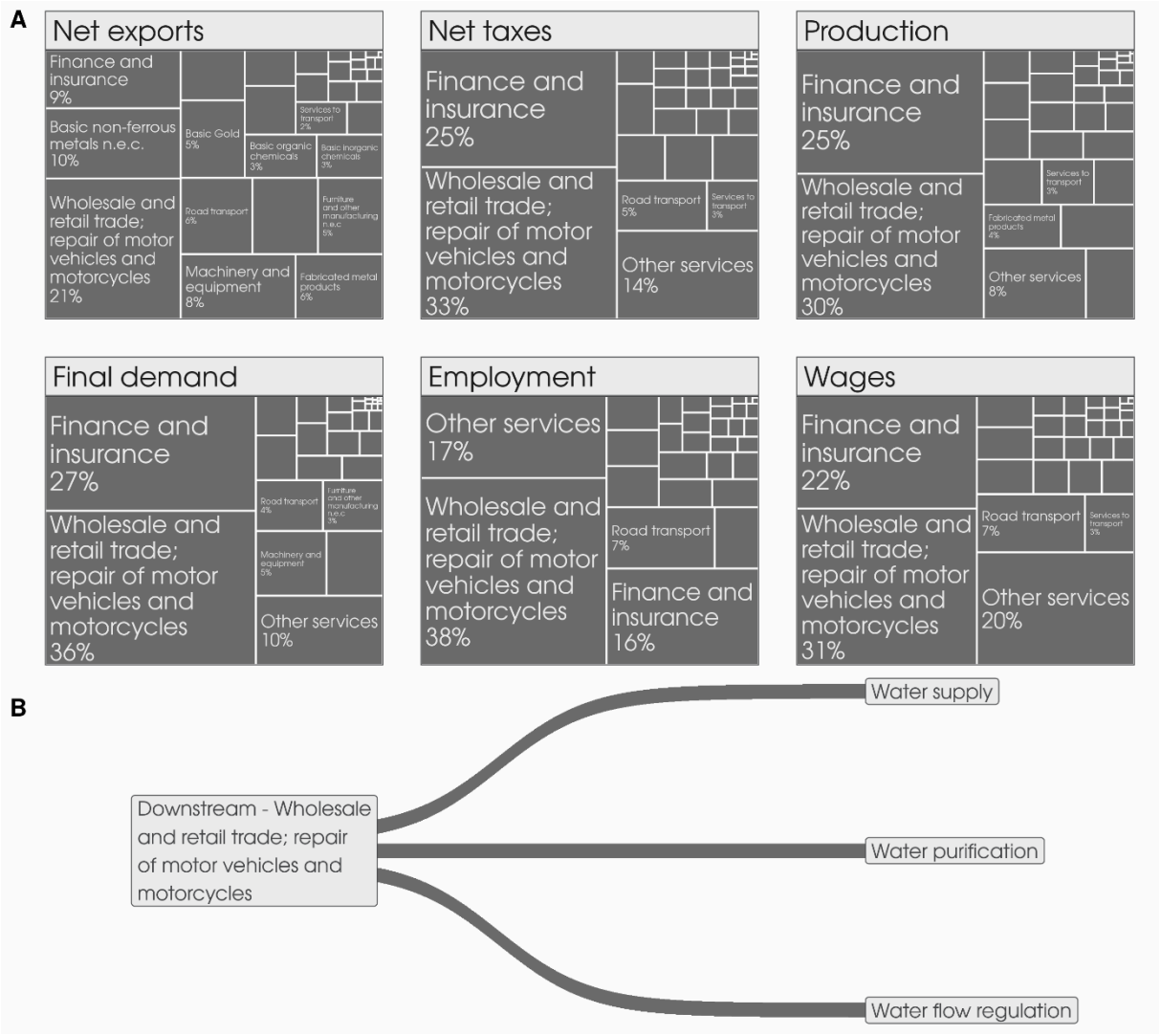
South Africa's direct exposure is significantly less than its indirect exposure, which includes first-round upstream and downstream value chain dependencies (Figure A7.1). This difference is largely due to the "wholesale and retail trade; repair of motor vehicles and motorcycles" sector, which drives a substantial share of the country's indirect socio-economic exposure (Figure A7.4). Specifically, this sector accounts for 38% of the exposure related to employment and at least 30% of the exposure linked to production, wages and final demand. Its exposure stems from downstream dependencies, as the sector sells its products to a wide range of other sectors highly dependent on ecosystem services. Its three largest downstream clients are meat products, beef meat and pork, all of which are highly dependent on key water-related

ecosystem services. This explains a significant portion of the sector's indirect exposure to these services. While exposure related to net exports also increases considerably in the indirect analysis, it is driven by such a large number of sectors that it is not possible to easily disentangle the underlying dynamics; nevertheless, the wholesale and retail trade sector remains responsible for 21% of this exposure.

Figure A7.4:

(A) Breakdown of South Africa's socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A7.1.

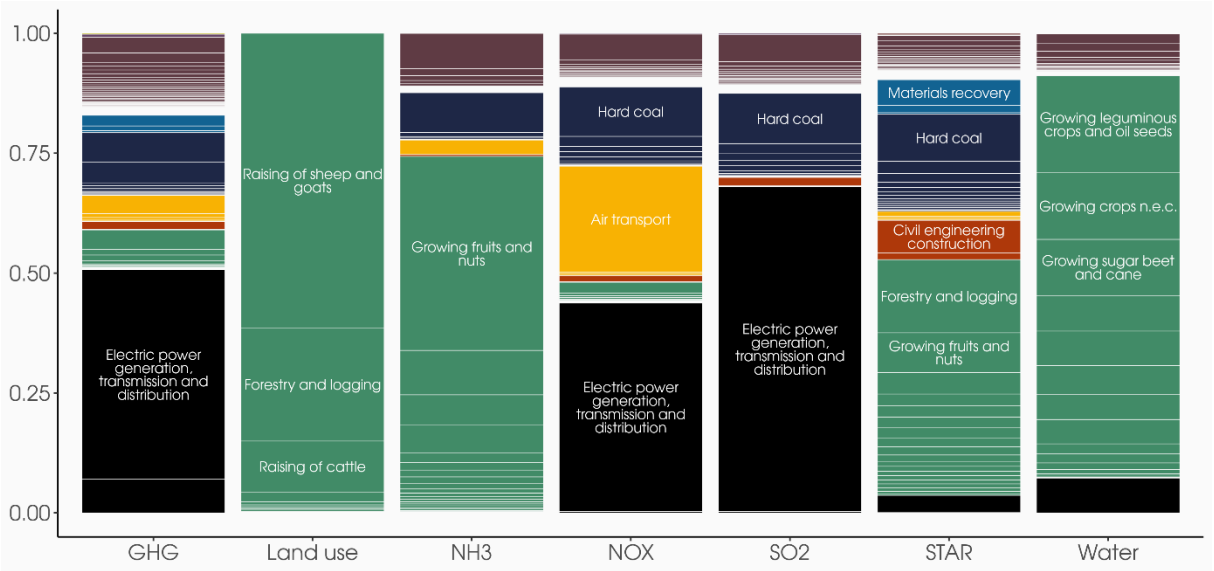
(B) Dependence of the country's key indirectly exposed sectors on ecosystem services



Transition exposure

In South Africa, the electric power generation, transmission and distribution sector is a major source of environmental emissions, accounting for 68% of SO_2 emissions, 44% of GHG emissions and 43% of NO_X emissions. Land-use pressure is primarily driven by three key sectors: raising of sheep and goats (61%), forestry and logging (24%) and raising of cattle (11%). The growing fruits and nuts sector is the sole contributor to NH_3 emissions, generating 40% of this pressure. Sectors with significant water consumption, such as those growing leguminous crops and oilseeds, collectively generate only 46% of the total water-related pressure (Figure A7.5).

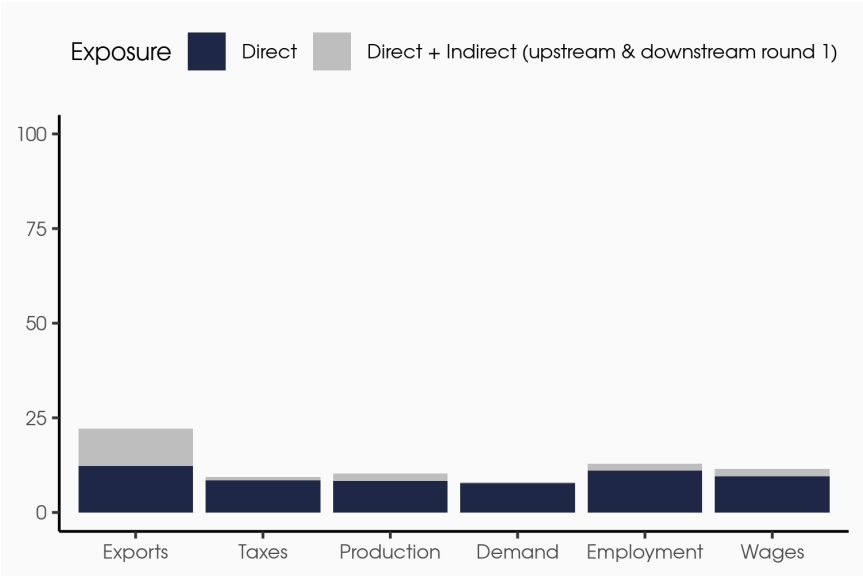
Figure A7.5: Share of pressures generated by sectors in South Africa



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

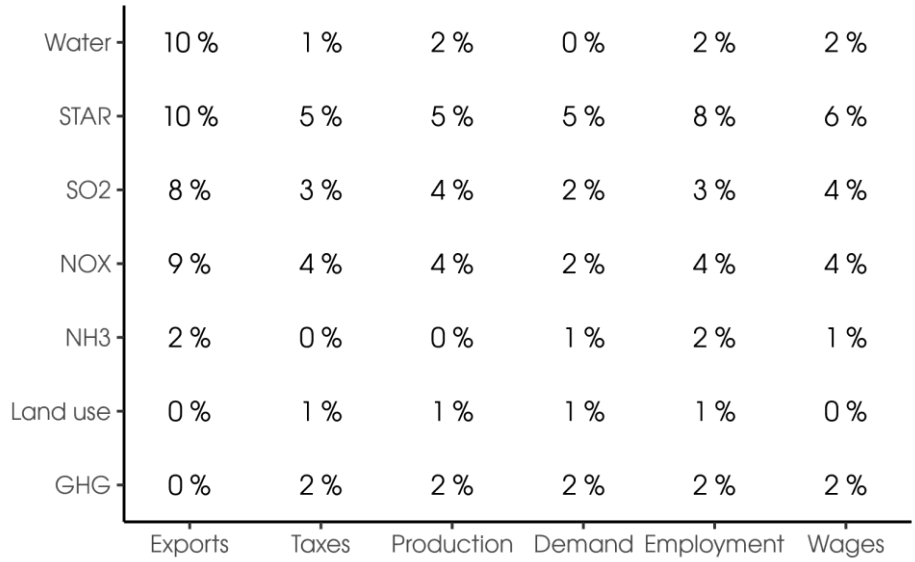
South Africa appears to be only marginally exposed to nature-related transition risks. The only socio-economic indicator that could be significantly affected is net exports, with 22% generated by sectors exerting the highest pressures on biodiversity, whether directly or indirectly. Indirect effects play a notable role in this case, as including first-tier upstream and downstream impacts increases the exposure by 10 percentage points. In contrast, exposure levels for all other socio-economic indicators remain below 13% (Figure A7.6).

Figure A7.6: Share of socio-economic indicators generated by exposed sectors in South Africa



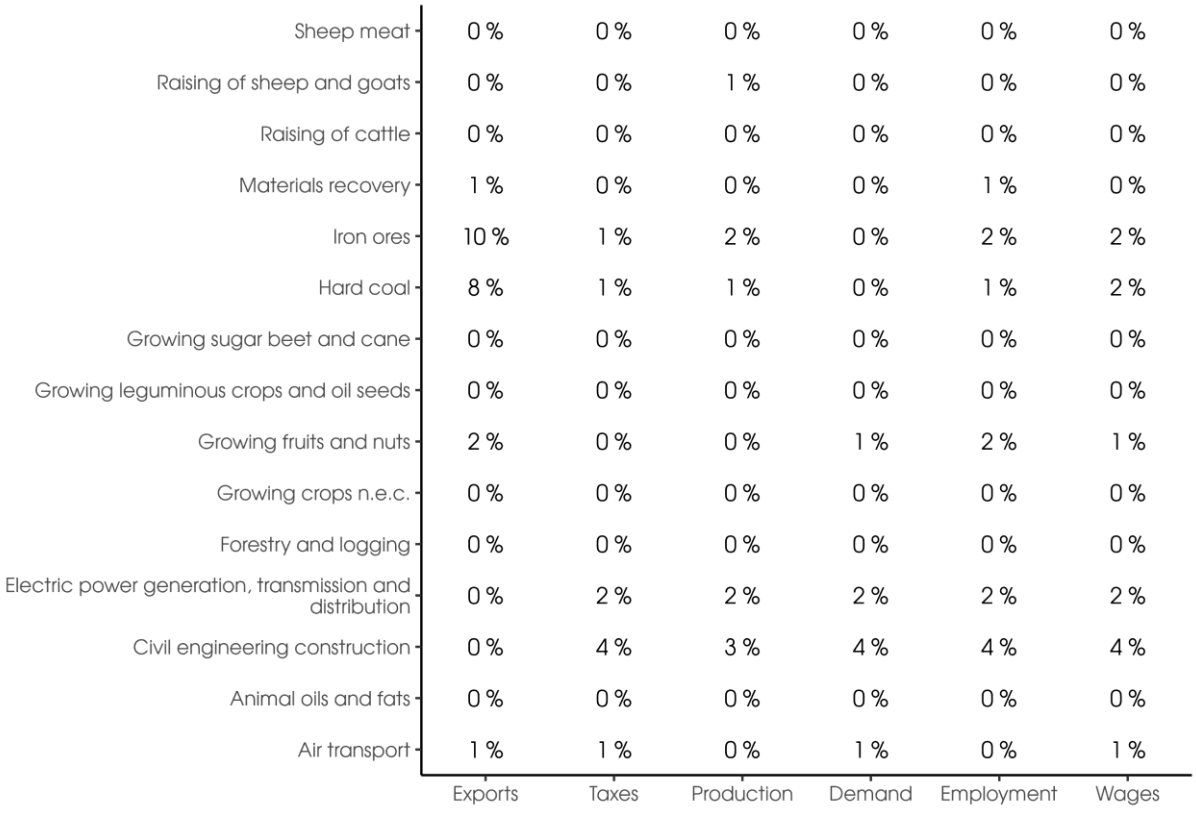
A transition targeting SO_2, NO_X emissions, water consumption and species extinction risks would pose the greatest challenges for South Africa's economy. Roughly 10% of the country's net exports come from sectors directly or indirectly exposed to these environmental pressures (Figure A7.7).

Figure A7.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in South Africa



Among the most exposed sectors, the iron ore sector accounts for 10% of net exports and is indirectly exposed through downstream water consumption, which represents 17% of national downstream use. It is indirectly exposed because it sells 1.5% of its output to the Chinese basic iron and steel sector. Similarly, the hard coal sector generates 8% of net exports and is directly exposed to NO_X and SO_2 emissions (around 10% of national totals for each) and contributes significantly to biodiversity loss, accounting for 10% of the country's total STAR score. It would therefore be valuable to evaluate whether these key sectors have the capacity to adapt their production models in response to a transition focused on reducing ecological pressures (Figure A7.8).

Figure A7.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in South Africa

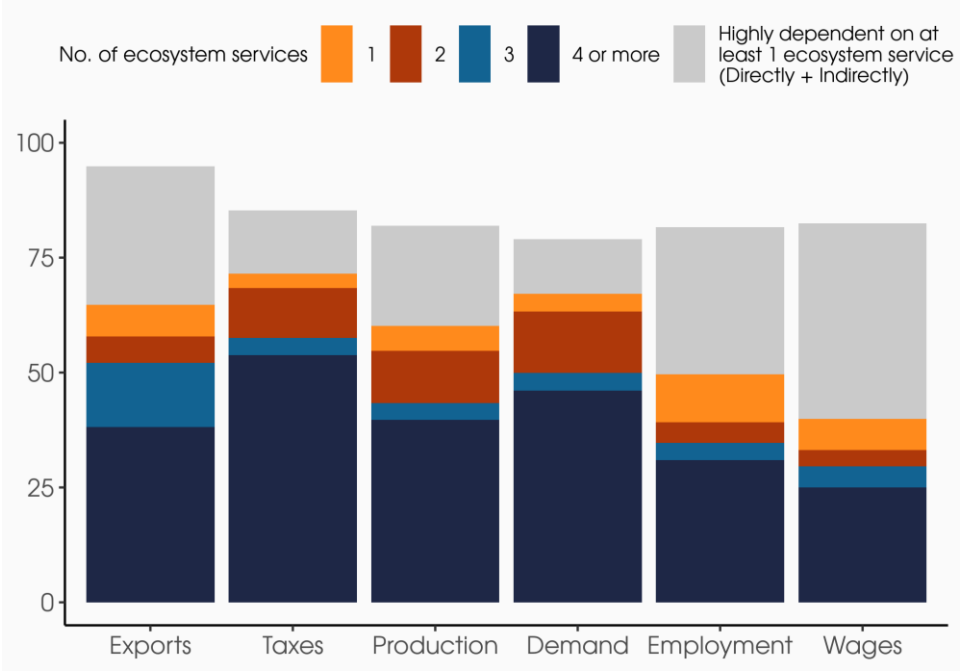


A8 Tanzania

Physical exposure

Tanzania is highly exposed to physical risks, both directly and indirectly, across all socio-economic indicators. In terms of direct exposure, 72% of net tax revenues, 67% of final demand, 65% of net exports and 60% of total production are generated by sectors that are highly dependent on ecosystem services. When including indirect exposure – through the first tier of upstream suppliers and downstream distributors – the country's exposure increases significantly. Export-related exposure reaches 95%, representing a 30 percentage point increase, while wage-related exposure rises by 43 percentage points, reaching 82% (Figure A8.1).

Figure A8.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Tanzania



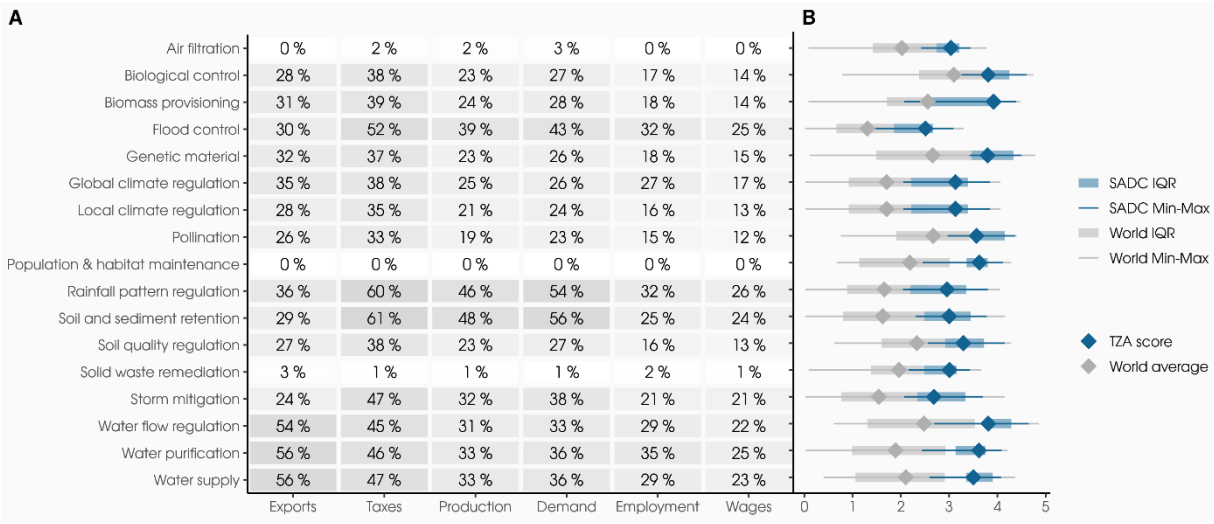
Tanzania is highly dependent on a wide range of ecosystem services; the only physical shocks that do not significantly expose the country are those related to population and habitat maintenance, air filtration and solid waste remediation. All other ecosystem service-related shocks are likely to destabilise the national economy. Sectors dependent on at least one of these services generate between 33% and 60% of the country's net tax revenues, depending on the specific service. Additionally, between 54% and 56% of net exports come from sectors heavily reliant on water flow regulation, water purification and water supply ecosystem services. Furthermore, 54% of final

demand is driven by sectors highly dependent on rainfall pattern regulation. For now, these ecosystem services appear to be relatively well supplied by Tanzania's ecosystems compared to other SADC countries. However, they should be closely monitored through detailed, localised assessments to ensure long-term resilience (Figure A8.2).

Figure A8.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in Tanzania

(B) Capacity of Tanzania to provide ecosystem services



A significant share of Tanzania's exposure originates from the agricultural sectors: they account for 54% of exposure to tax revenues, 42% to final demand, 48% to exports and 40% to production. In particular, the "growing cereals n.e.c." sector is responsible for 24% of the exposure related to the country's net tax revenues. Agricultural sectors are inherently highly dependent on multiple ecosystem services, especially those related to soil quality and water supply. The construction sector is also a major source of exposure, generating 40% of the country's exposure in terms of final demand, 34% in terms of wages and 28% of net tax-related exposure. This sector depends on ecosystem services such as soil and sediment retention for stable foundations and erosion control, flood regulation to protect infrastructure, storm mitigation to shield construction sites from wind and sand, and rainfall pattern regulation to reduce flood risks and infrastructure damage in civil engineering projects (Figure A8.3).

Figure A8.3:

(A) Distribution of exposure across Tanzania's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services

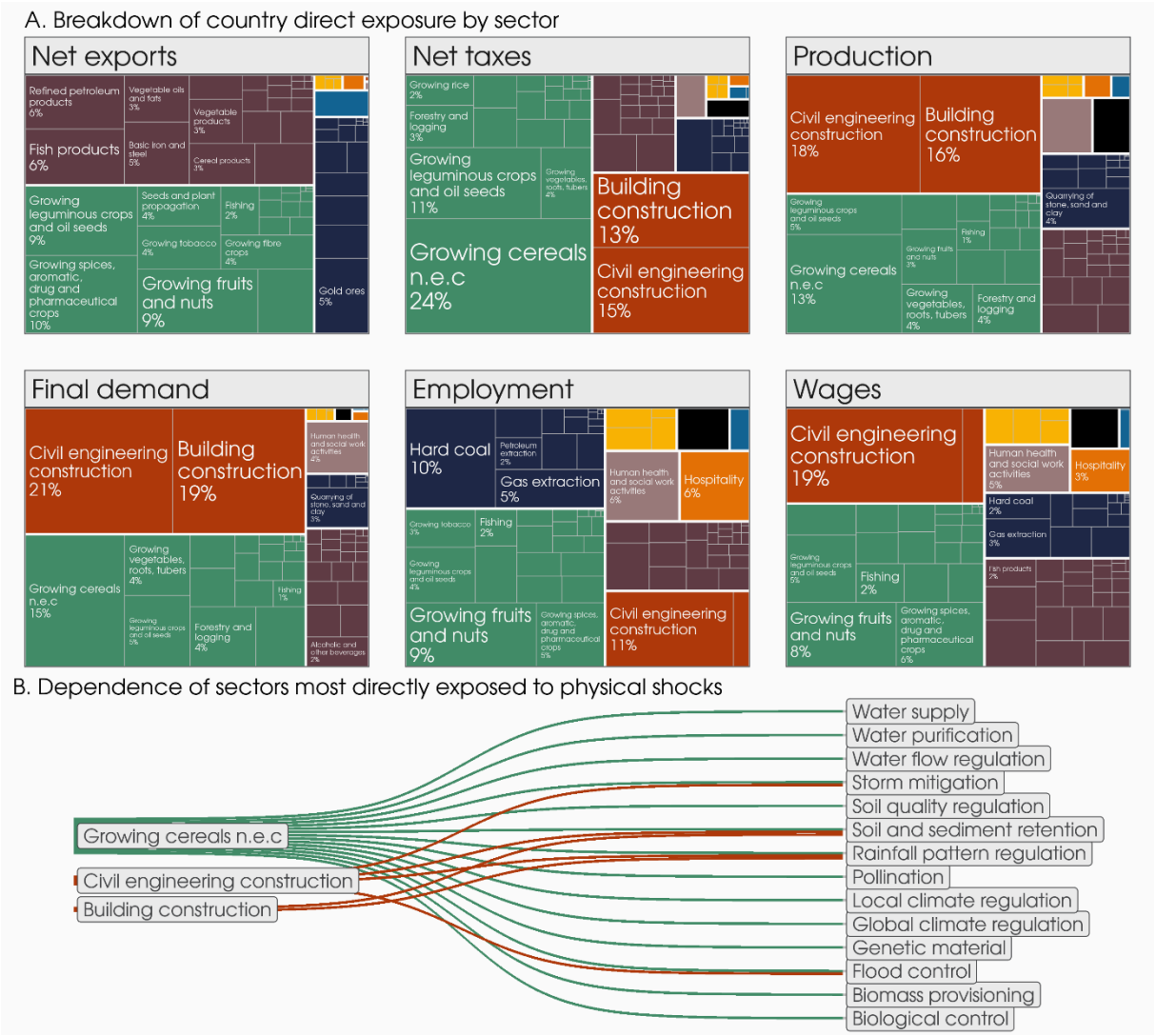
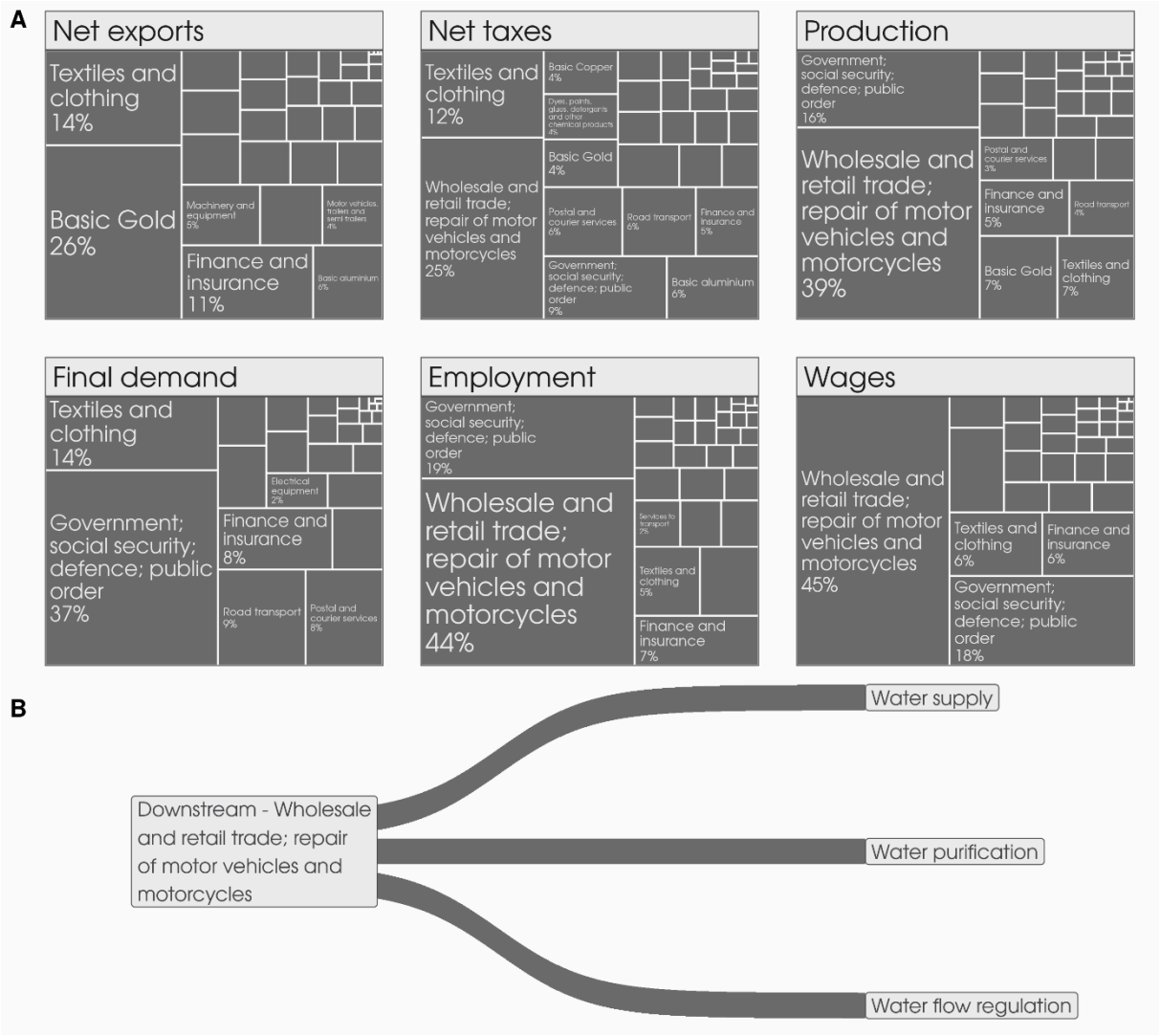


Figure A8.1 indicates that although all socio-economic indicators increase when indirect dependencies are considered, the most significant rise is observed in relation to wages. This increase is largely driven by the "wholesale and retail trade; repair of motor vehicles and motorcycles" sector, which alone accounts for 44% of the country's indirect exposure related to employment and 45% of that related to wages (Figure A8.4). This sector is indirectly exposed through its downstream value chain, particularly by selling its products to several sectors in Tanzania. Notably, 10% of its sales go to the animal oils and fats sector, 6% to fish products and 5% to other meat products – all of which are highly dependent on water-related ecosystem services (i.e. water supply, purification and flow regulation).

Figure A8.4:

(A) Breakdown of Tanzania's socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A8.1.

(B) Dependence of the country's key indirectly exposed sectors on ecosystem services

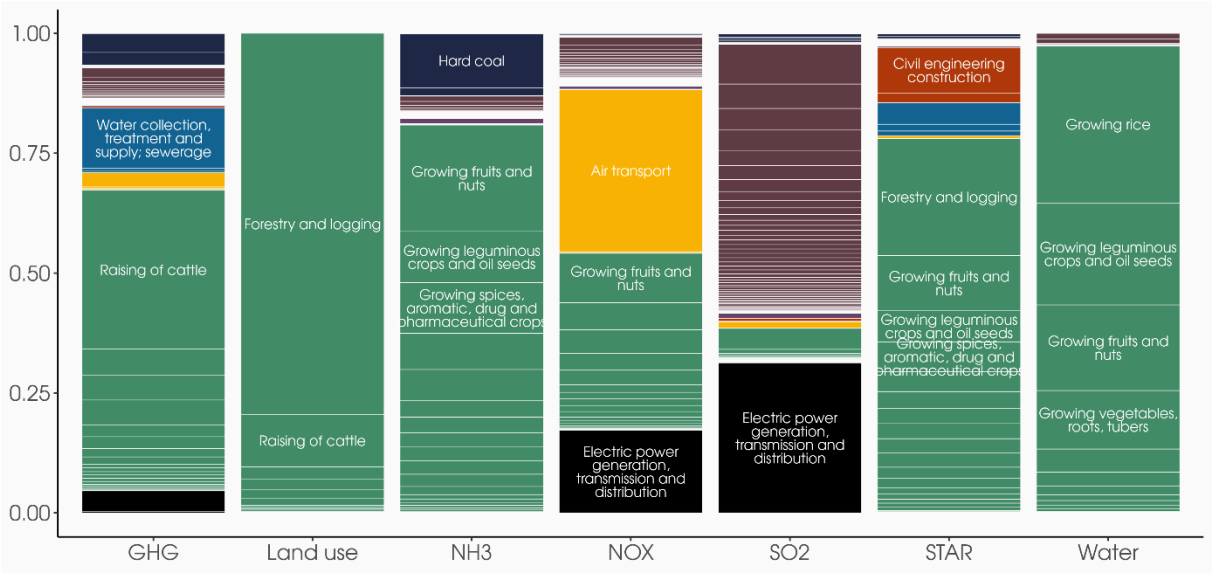


Transition exposure

The electric power generation, transmission and distribution sector generates all the SO_2 pressure in Tanzania captured by our methodology – that is, 31%. It is also responsible for 17% of the country's NO_X emissions – behind the air transport sector, which generates 34% of that pressure. The agricultural, forestry and livestock sectors exert the greatest pressure on biodiversity. In fact, the forestry and logging sector is responsible for 80% of the country's land-use pressure and 24% of STAR pressure. The rest of the STAR pressure analysed is reallocated between the growing fruits and nuts; leguminous and oil seeds; and spices, aromatic, drug and pharmaceutical crops

sectors, as well as the civil engineering construction sector. The cereals sector is responsible for 33% of the country's water consumption, with the remainder of the exposed resource divided between the country's other agricultural sectors (Figure A8.5).

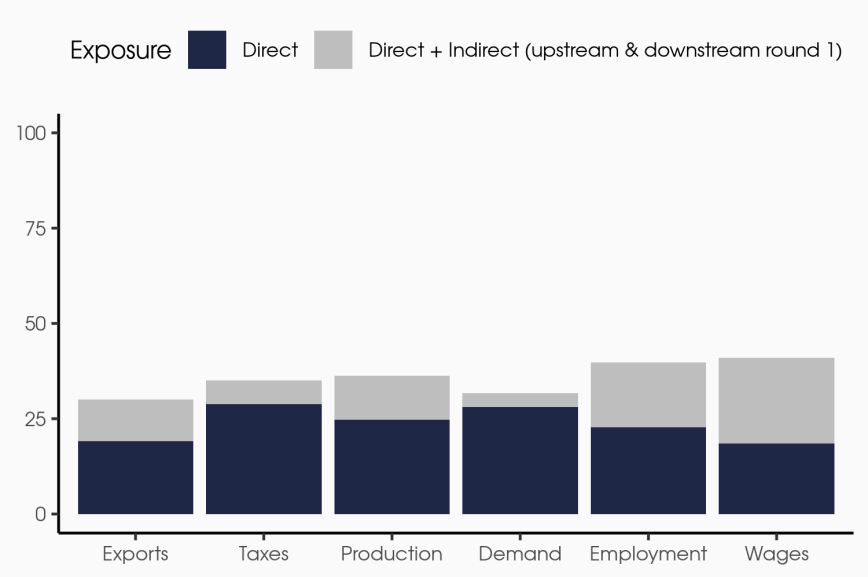
Figure A8.5: Share of pressures generated by sectors in Tanzania



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

In Tanzania, 29% of net tax revenues and 28% of final demand are generated by sectors directly exposed to nature-related transition risks. These sectors also account for between 18% and 25% of the remaining socio-economic indicators. When considering indirect pressures – that is, from the first tier of both upstream and downstream value chains – the exposure increases significantly: exposed sectors (directly and indirectly) generate 41% of wages, 40% of employment and between 30% and 36% of other socio-economic indicators. The largest shift is observed in wage-related exposure, which increases by 22 percentage points between the direct and indirect assessments (Figure A8.6).

Figure A8.6: Share of socio-economic indicators generated by exposed sectors in Tanzania



The most destabilising ecological transition risks for Tanzania are likely to be those involving a reduction in species extinction risks, followed by restrictions related to water consumption and NH_3 emissions. Between 25% and 36% of socio-economic indicators are linked to sectors contributing directly and indirectly to the country's STAR score. In addition, 18% of net exports come from sectors with high NH_3 emissions, and around 15% of both net exports and tax revenues are generated by water-intensive sectors (Figure A8.7).

Several sectors drive Tanzania's exposure to nature-related transition risks. The wholesale and retail trade sector, for instance, generates 19% of national wages and 14% of employment while being indirectly exposed to STAR-related transition risks via its downstream value chain (Figure A8.8). Indeed, this sector generates 5.5% of the total downstream STAR across all value chains in the country, with 2.5% stemming from its sales to the forestry and logging sector and 1.5% from sales to the civil engineering construction sector (Figure A8.9). Moreover, the growing of leguminous crops and oil seeds sector generates 8% of the country's net tax revenues while being directly exposed to multiple environmental pressures: NH_3 emissions, contribution to species extinction risk and high water consumption. It is also indirectly exposed to downstream SO_2 emissions. Lastly, the civil engineering construction sector accounts for 14% of final demand and contributes 10% to the country's STAR score (Figure A8.8)

Figure A8.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Tanzania

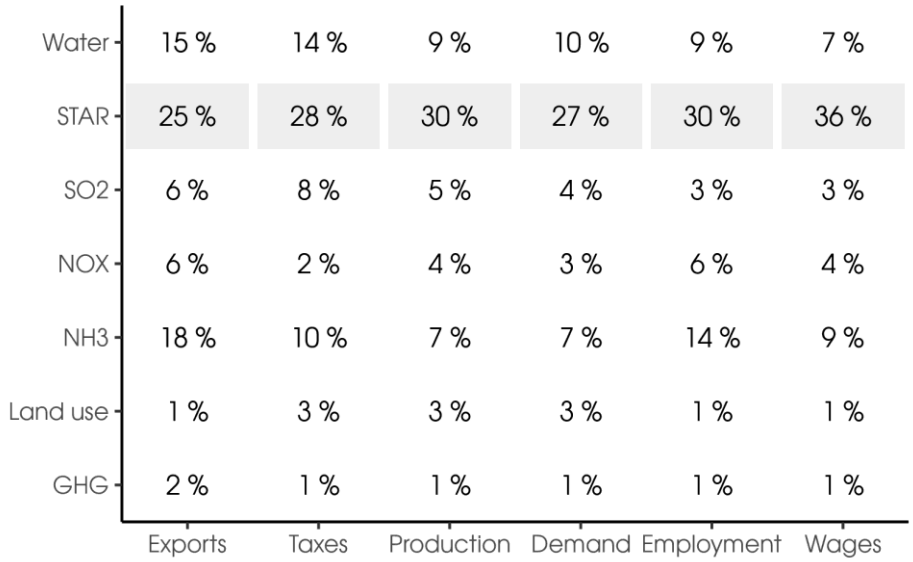


Figure A8.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Tanzania

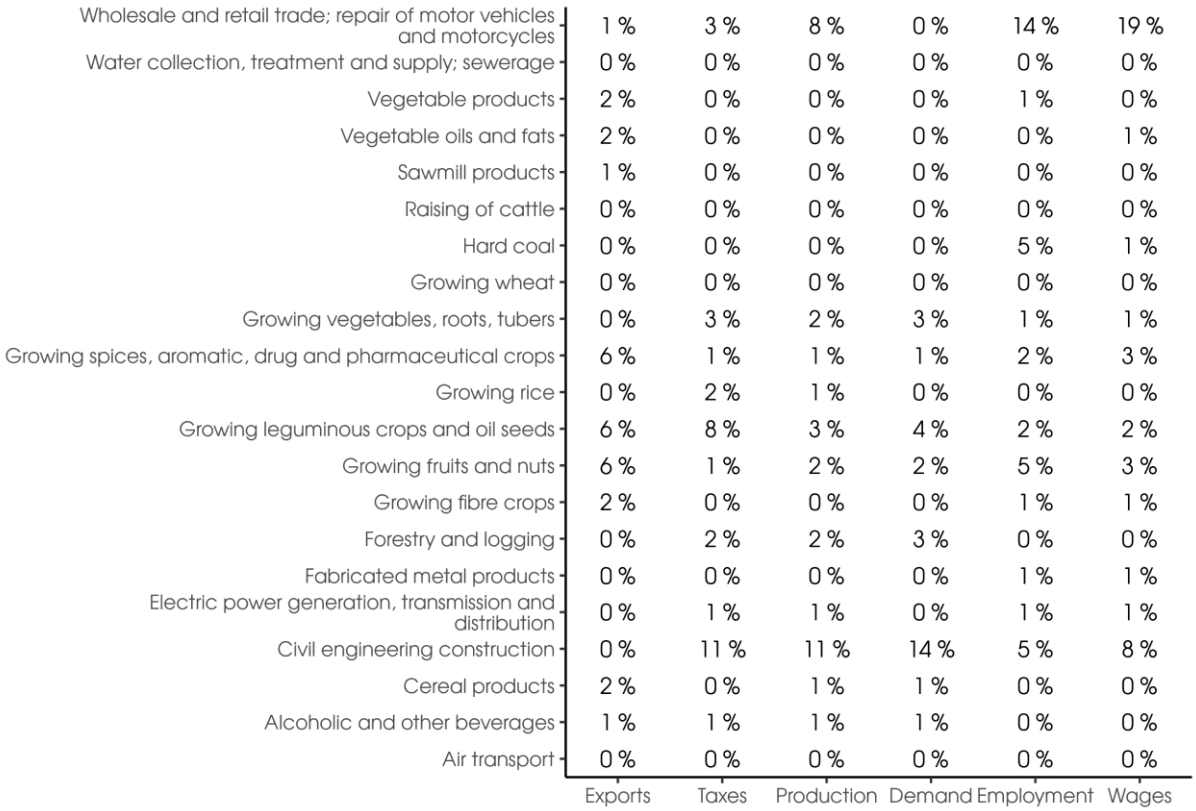
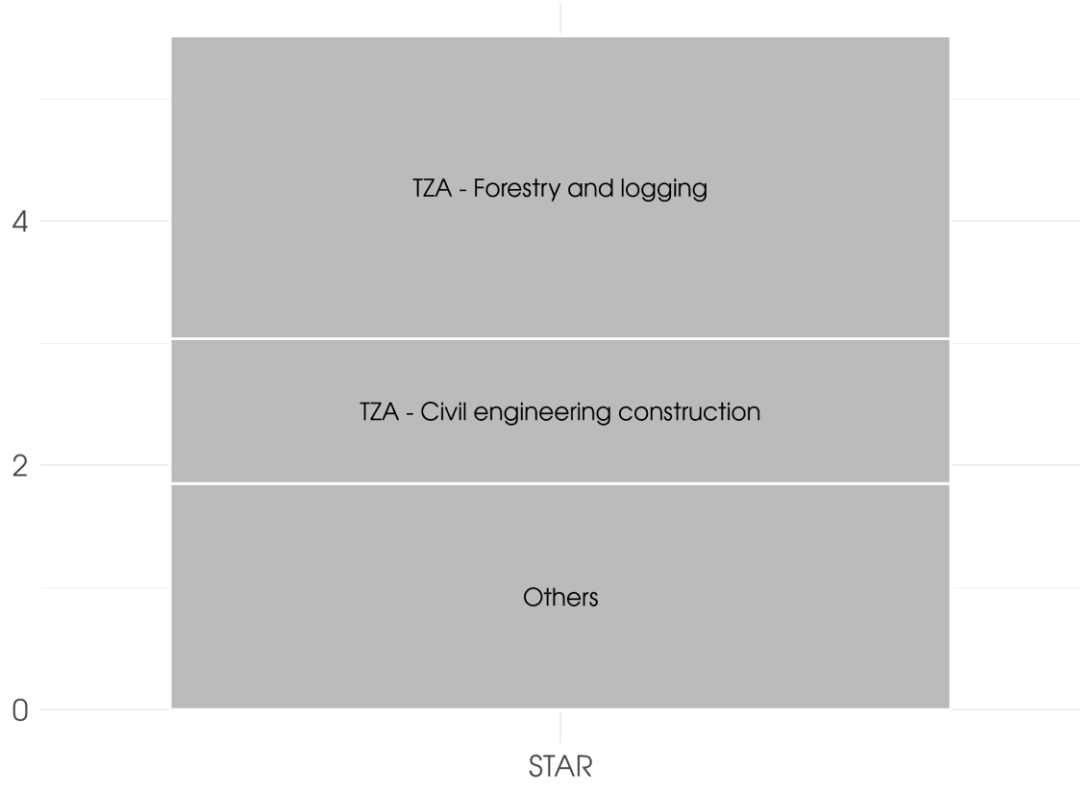


Figure A8.9: Share of indirect pressures generated by the wholesale and retail trade sector through the first tier downstream of its value chain as a function of indirect emissions downstream of all value chains in Tanzania (in %)

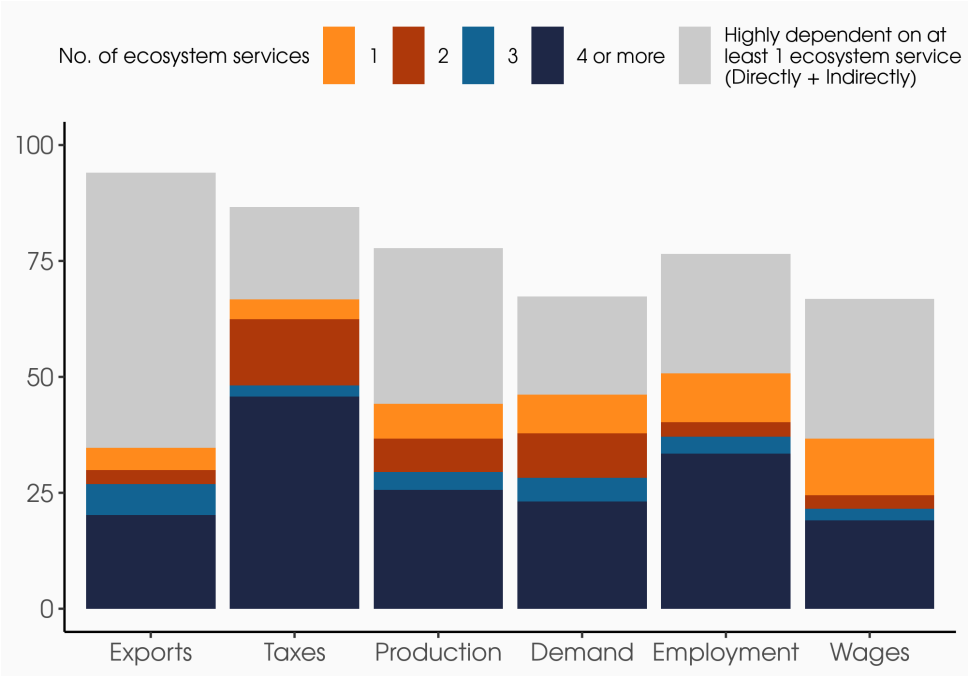


A9 Zambia

Physical exposure

Zambia is highly and directly exposed to physical shocks through its tax revenues. Indeed, 67% of net taxes are generated by economic sectors highly dependent on at least one ecosystem service and 46% by those dependent on four or more ecosystem services. Sectors heavily reliant on at least one ecosystem service generate 51% of employment, around 45% of production and final demand, and 35% of wages and exports. Moreover, the country shows a very high indirect exposure to physical shocks: 94% of its net exports are generated by sectors highly dependent directly or indirectly on at least one physical shock, and these sectors contribute up to 87% of net taxes (Figure A9.1).

Figure A9.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Zambia



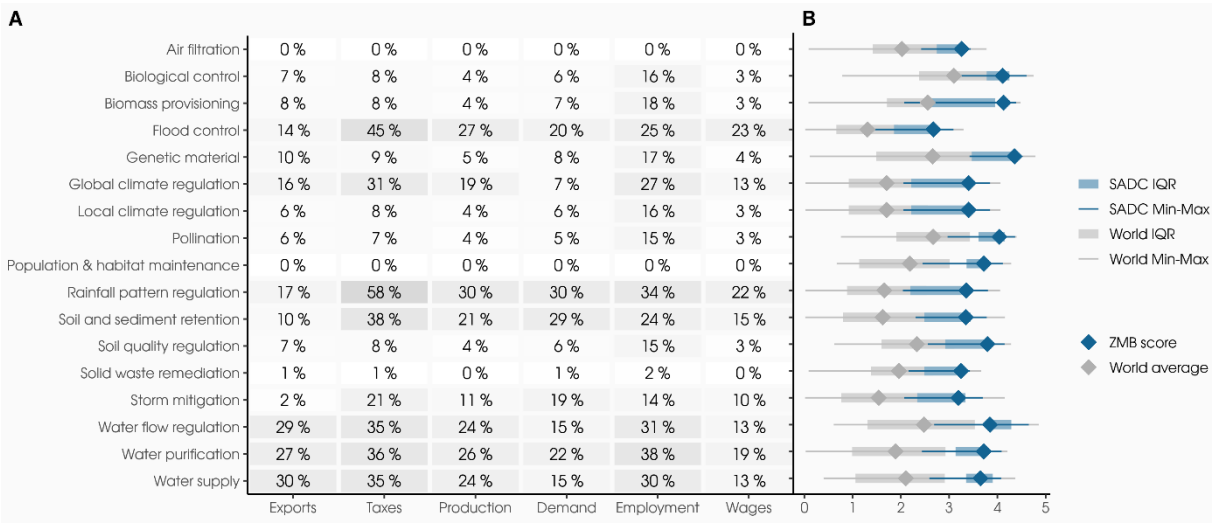
Zambia is mainly exposed to physical shocks through water-related ecosystem services and global climate regulation, as well as those linked to flood control and soil and sediment retention. Over 31% of net tax revenues are generated by sectors highly dependent on at least one of these ecosystem services, rising to 58% when considering only the ecosystem service of rainfall pattern regulation. This indicates that if this particular service were to deteriorate, the country's socio-economic indicators could be at risk should the sectors generating this exposure fail to adapt their

production methods and mitigate the risk. The provision indicator suggests that ecosystem services in Zambia are currently well supplied, but it remains essential to conduct localised investigations to verify whether these services are effectively available in sufficient quantities for the sectors relying on them (Figure A9.2).

Figure A9.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in Zambia

(B) Capacity of Zambia to provide ecosystem services

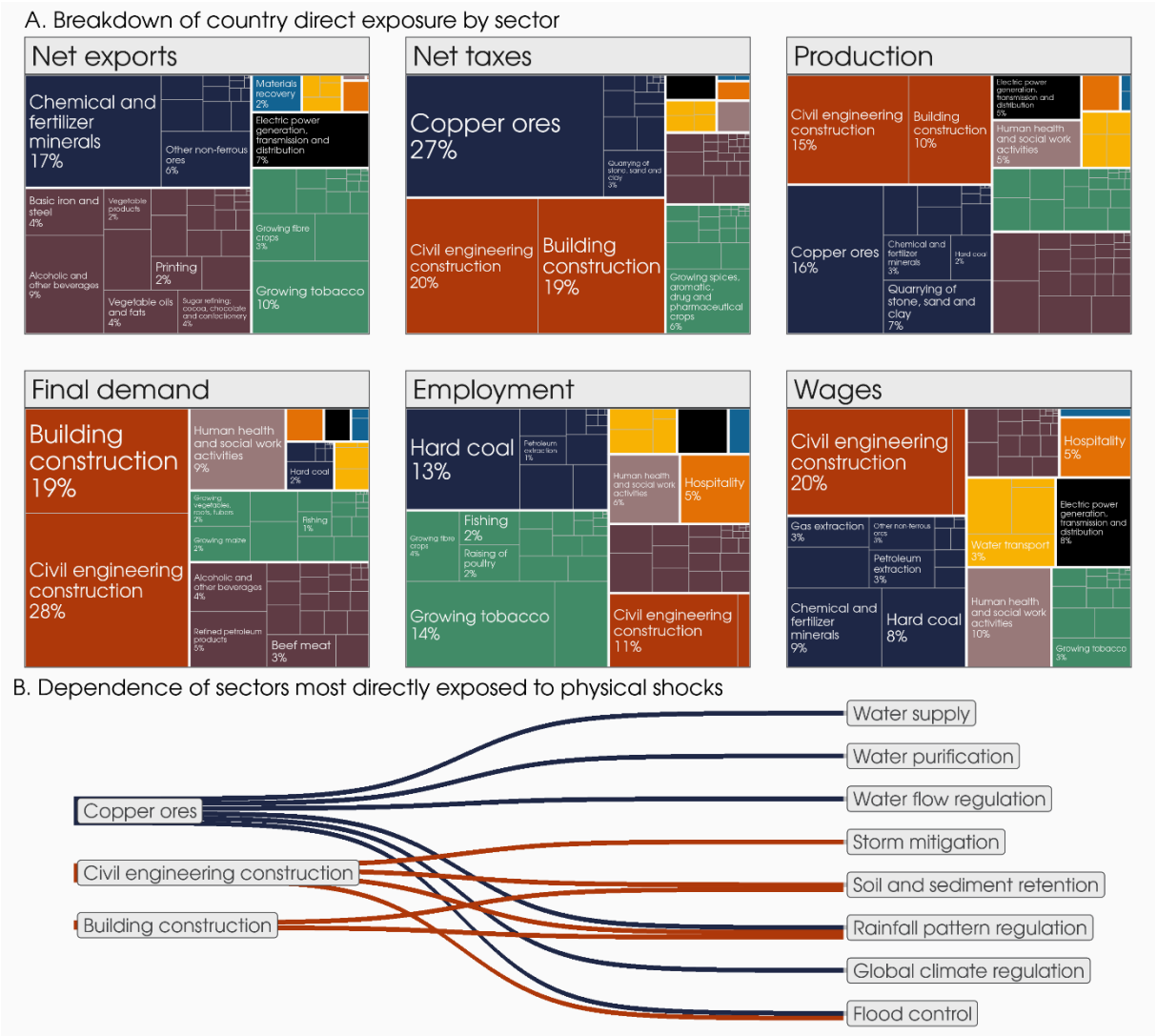


In Zambia, the mining sector accounts for a large share of the country's exposure to nature-related physical risks. The copper ores sector alone is responsible for 27% of the country's exposure in tax revenues and 16% in production. Water-related ecosystem services and global climate regulation are critically important for the mining sectors and could destabilise mining operations if they are poorly supplied. Additionally, the civil engineering construction sector generates 20% of Zambia's exposure to net taxes and building construction accounts for 19%, both contributing significantly to exposure across other socio-economic indicators. The construction sector depends heavily on ecosystem services such as soil and sediment retention, rainfall pattern regulation, flood control and storm mitigation (Figure A9.3).

Figure A9.3:

(A) Distribution of exposure across Zambia's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services



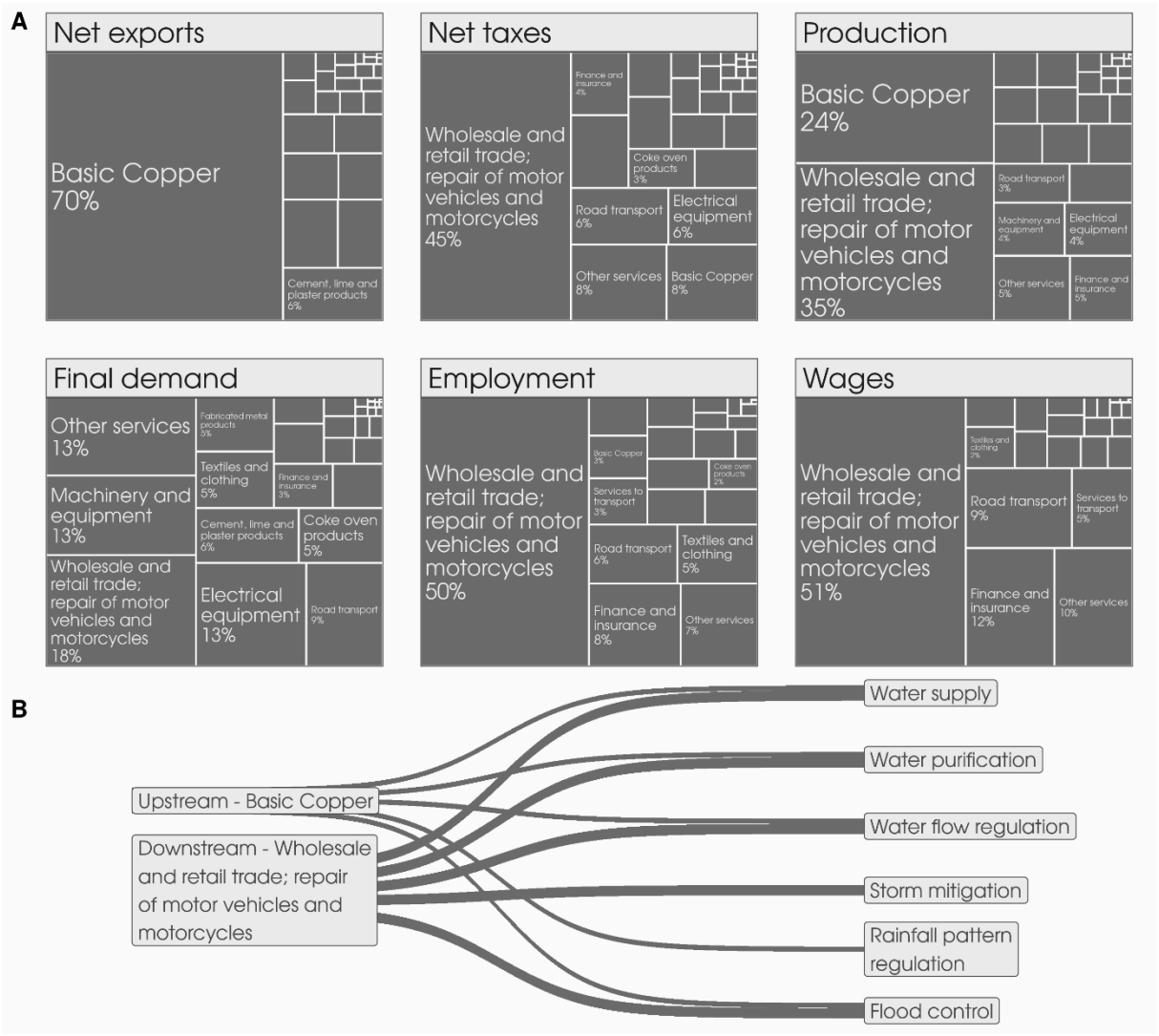
The country's exposure increases substantially when analysing indirect exposure, particularly for net exports (Figure A9.1). Notably, the basic copper sector accounts for 70% of the increase, largely because it sources 50% of its inputs from the copper ores sector in Zambia, which is highly dependent on five key water-related ecosystem services (Figure A9.4). Meanwhile, the "wholesale and retail trade; repair of motor vehicles and motorcycles" sector sells its products across a wide range of sectors, with no single sector accounting for more than 5% of its total sales. Among its clients are sectors such as animal oils and fats, growing rice and dairy products. This diversity makes it difficult to pinpoint which specific sectors drive its increased dependence on water-related services, including flood and storm regulation. Nevertheless, this sector

generates over 50% of the country's indirect exposure related to employment and wages.

Figure A9.4:

(A) Breakdown of Zambia's socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A9.1.

(B) Dependence of the country's key indirectly exposed sectors on ecosystem services

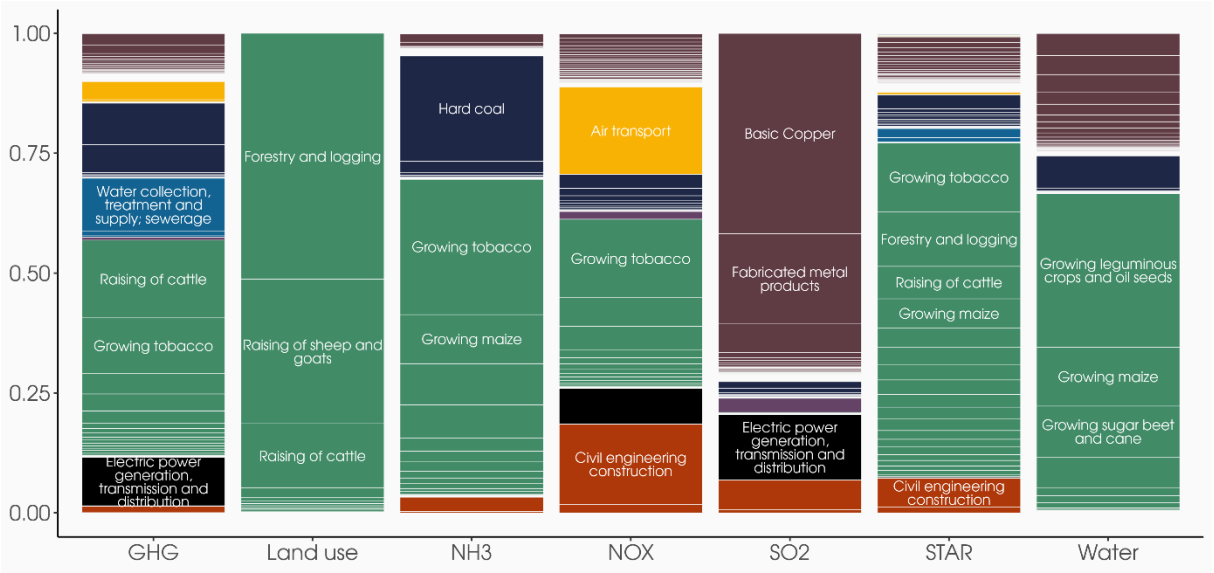


Transition exposure

In Zambia, the forestry and logging sector generates 51% of the land-use pressure and the raising of sheep and goats 30%. GHG emissions are attributable to a large number of sectors, including raising of cattle; water collection, treatment and supply and sewerage; and electric power generation, transmission and distribution. The basic copper and fabricated metal products sectors generate 42% and 19% of SO_2 emissions respectively. Meanwhile, the agricultural sectors of leguminous, sugar beet

and cane and maize consume 55% of the country's water. Finally, the growing tobacco sector is exposed to an ecological transition due to its GHG, NH_3 and NO_X emissions and its STAR metric, making it particularly important to monitor (Figure A9.5).

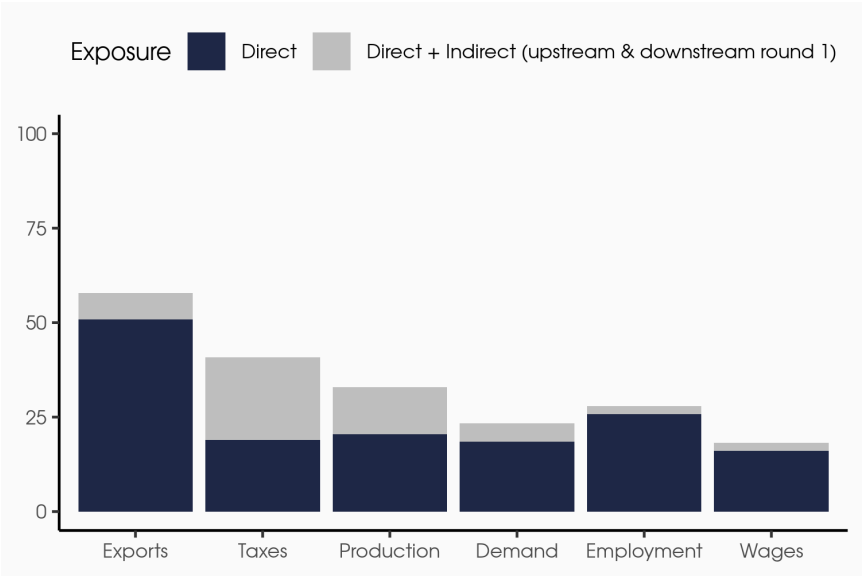
Figure A9.5: Share of pressures generated by sectors in Zambia



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

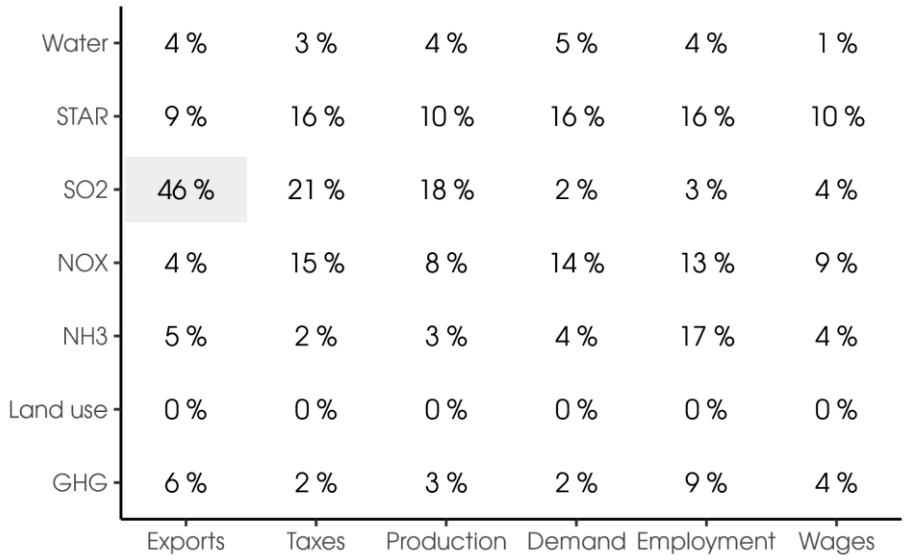
Zambia's net exports are highly exposed to ecological transition risks, with sectors exerting the most direct pressure on biodiversity accounting for 51% of total exports. This figure rises to 58% when including indirect pressures from upstream and downstream sectors within the first tier of the value chain. The country is also notably indirectly exposed in terms of tax revenues, with 41% of net taxes generated by sectors that are indirectly exposed, compared to only 20% from those directly exposed (Figure A9.6).

Figure A9.6: Share of socio-economic indicators generated by exposed sectors in Zambia



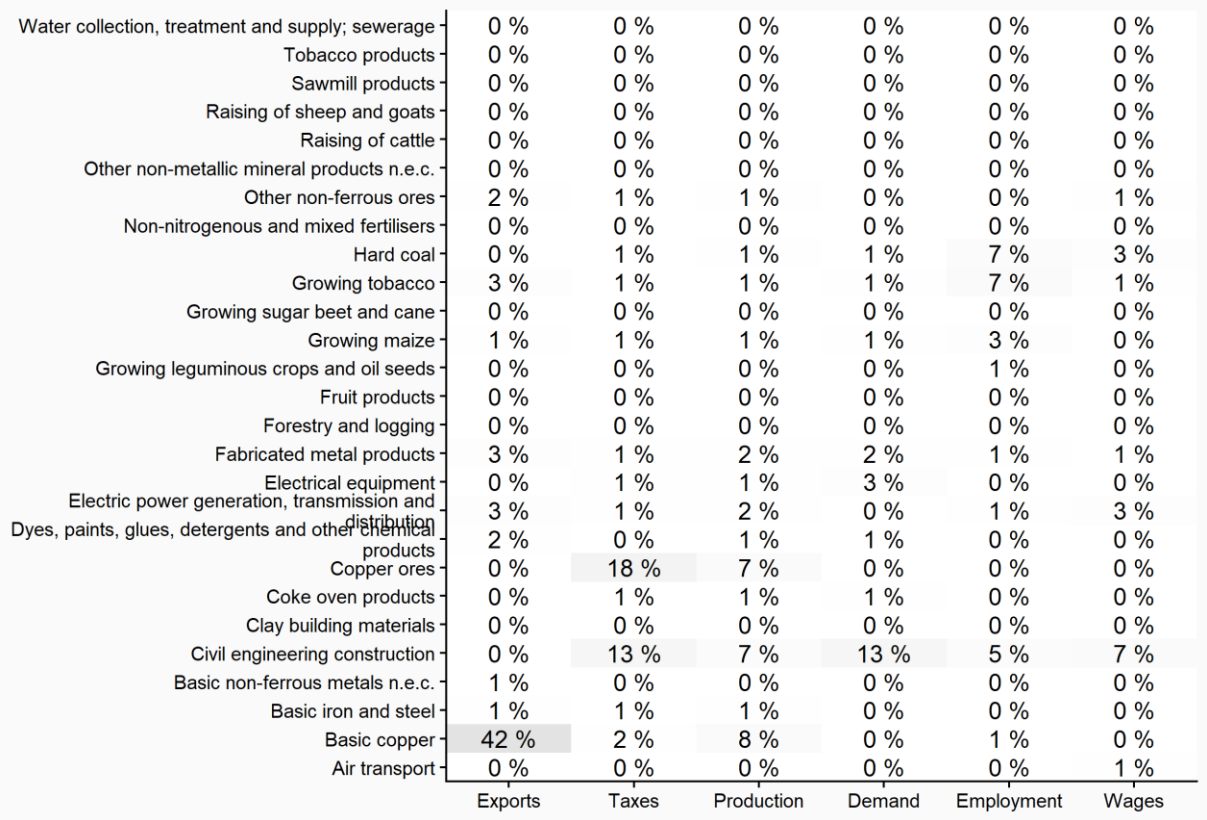
Sectors contributing at least 10% to Zambia's national SO_2 emissions account for 46% of net exports, 21% of net taxes and 18% of production. Additionally, 16% of employment, final demand and tax revenues come from sectors that significantly increase the risk of species extinction. If an ecological transition involved a reduction in NH_3 emissions, 17% of the country's employment could be at risk. It is therefore essential to determine whether these exposed sectors are capable of adapting their practices to reduce their environmental pressure. This will help assess their true vulnerability to a biodiversity-aligned ecological transition (Figure A9.7).

Figure A9.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Zambia



The most exposed sector by far is basic copper production, which alone generates 42% of the country's exports and 8% of production. It is directly exposed to SO_2 pressures, contributing 42% of Zambia's total SO_2 emissions. It is followed by the copper ores sector, which accounts for 18% of net tax revenues and shows indirect exposure to SO_2 through downstream emissions, which represent 21% of the country's total. This sector sells half of its output to the basic copper sector, which is responsible for over 40% of national SO_2 emissions. The civil engineering construction sector is also noteworthy, contributing 13% to both net taxes and final demand while being directly exposed to NO_X emissions and the country's STAR (Figure A9.8).

Figure A9.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Zambia

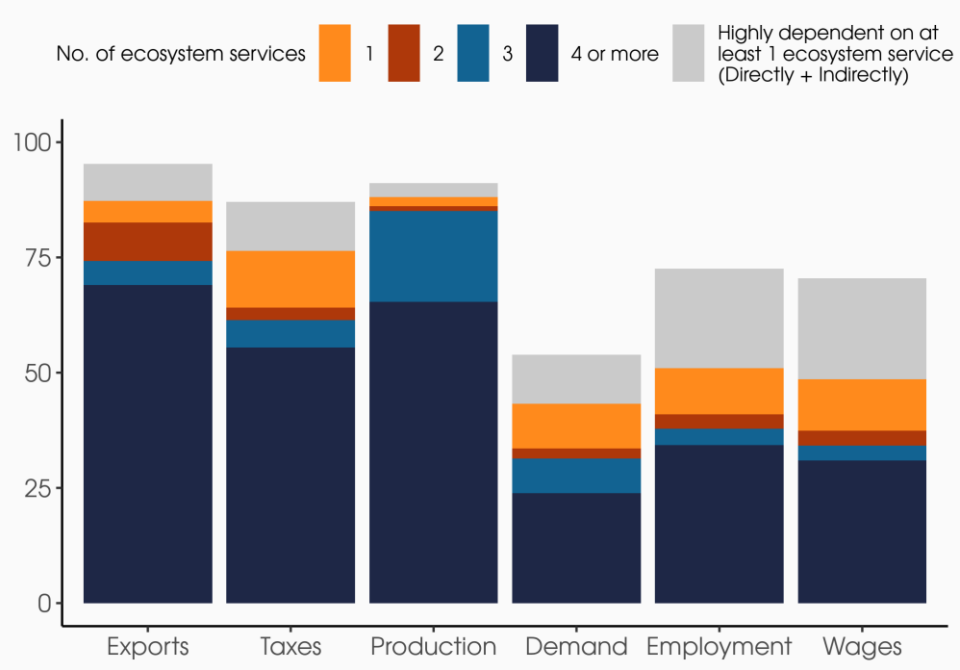


A10 Zimbabwe[11]

Physical exposure

In Zimbabwe, 88% of production is generated by sectors highly dependent on at least one ecosystem service, and 65% depend on at least four ecosystem services. The country is also highly exposed in terms of exports and net taxes, with 87% of exports and 76% of net taxes produced by sectors heavily reliant on at least one ecosystem service. Furthermore, when considering indirect exposure from only the first tier of upstream and downstream sectors within their value chains, the country's exposure increases significantly. In this case, 95% of exports strongly depend on ecosystem services, and exposure related to employment and wages rises by 22 percentage points (Figure A10.1).

Figure A10.1: Share of socio-economic indicators generated by sectors directly and indirectly exposed to physical shocks in Zimbabwe



Overall, Zimbabwe is exposed to all the physical shocks analysed, with the exception of those relating to the ecosystem services of population and habitat maintenance, solid waste remediation and air filtration. However, water-related ecosystem services (i.e. water supply, purification, flow regulation) seem the most likely to destabilise the

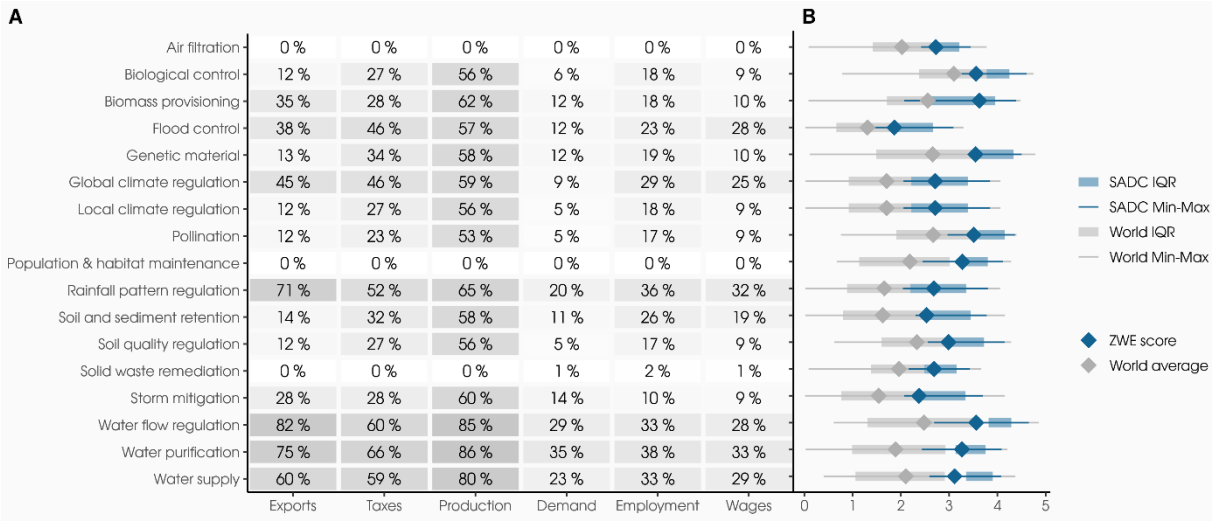
[11] The employment and wage data from Zimbabwe's input-output table in GLORIA have considerable limitations. The data come from different sources that sometimes do not provide consistent estimates.

country in the event of a decline in ecosystem services. Indeed, sectors heavily dependent on these ecosystem services generate between 80% and 86% of the country's production and between 60% and 82% of its net exports. All ecosystem services in Zimbabwe have a supply score slightly below the SADC average; it would be worth studying water-related services in greater detail to ascertain whether the sectors that depend most on them are located in areas that are more or less rich in the resource (Figure A10.2).

Figure A10.2:

(A) Share of socio-economic indicators generated by economic sectors highly and directly dependent on a given ecosystem service in Zimbabwe

(B) Capacity of Zimbabwe to provide ecosystem services

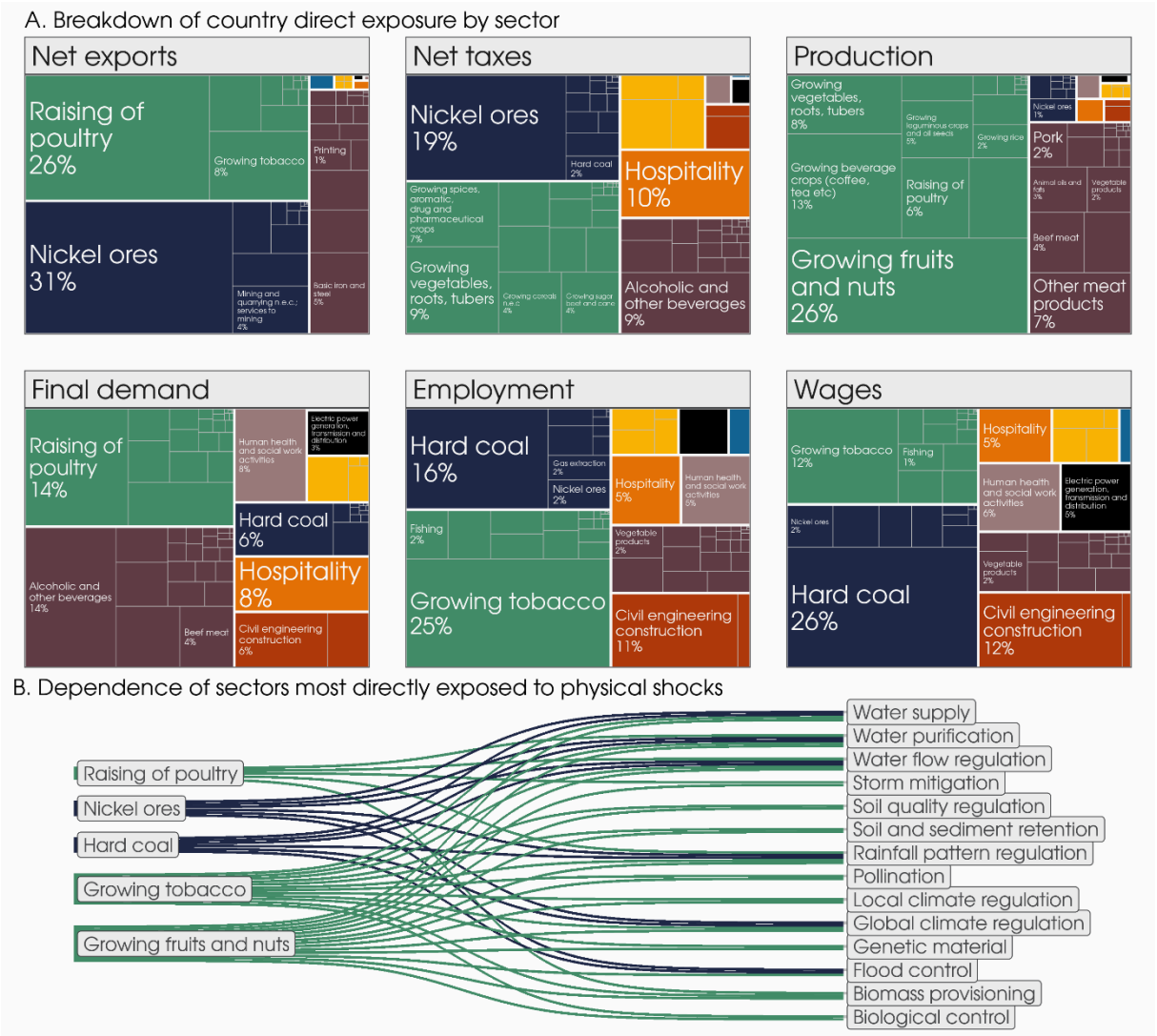


The country's production exposure cannot be attributed to just a few sectors, although agriculture is dominant: the growing fruits and nuts sector accounts for 26% of the exposure, while beverage crops contribute 13%. The country's high exposure in terms of net exports comes primarily from two sectors: the raising of poultry sector is responsible for 26% and nickel ores for 31%. Many mining sectors (e.g. hard coal accounts for 26% of exposure related to wages) and agricultural sectors (e.g. tobacco accounts for 25% of exposure related to employment) also contribute significantly to exposure across other socio-economic indicators. Agricultural sectors inherently have strong dependencies on ecosystem services, notably requiring nutrient-rich soils and adequate water quality and quantity. Mining sectors are heavily dependent on water-related services and climate regulation, which are crucial to prevent severe climatic hazards that could disrupt production (Figure A10.3).

Figure A10.3:

(A) Distribution of exposure across Zimbabwe's economic sectors

(B) Dependence of the country's key exposed sectors on ecosystem services



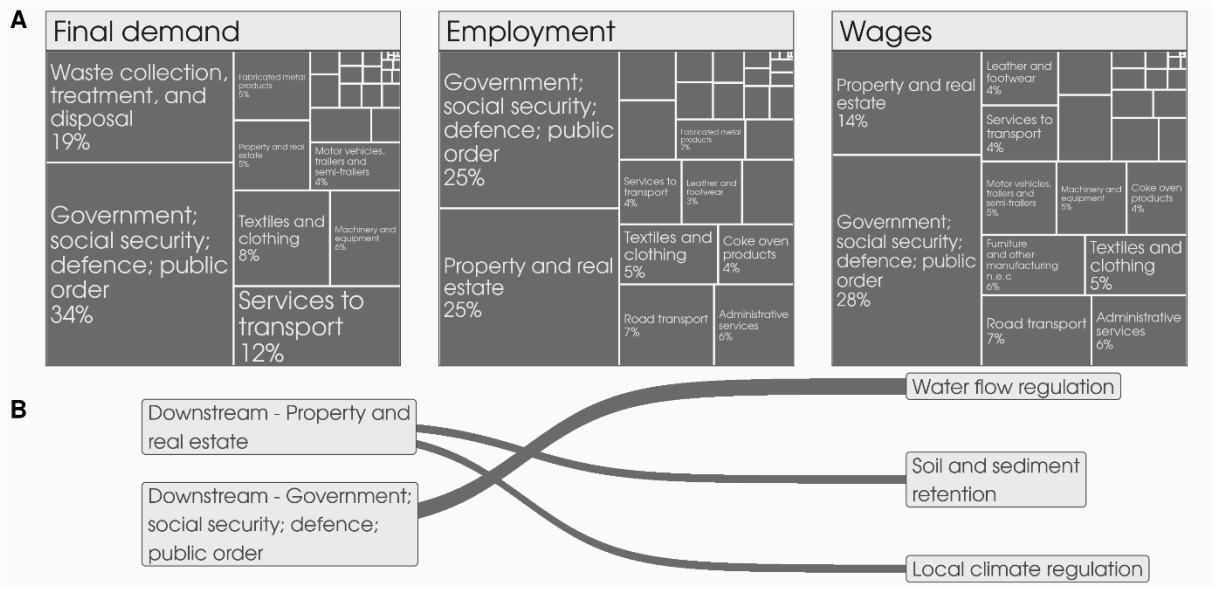
In Zimbabwe, the increase in exposure when accounting for the first tier of upstream and downstream value chains is particularly pronounced for employment, wages and final demand in the country's total exposure calculation (Figure A10.1). The "government; social security; defence; public order" sector is largely responsible for this rise, generating 34% of the country's indirect exposure linked to final demand, 25% related to employment and 28% associated with wages (Figure A10.4). This sector sells no more than 5% of its output to several domestic sectors – including printing, dairy products and growing fibre crops – all of which are highly dependent on the ecosystem service of water flow regulation. Additionally, property and real estate contributes significantly to the country's socio-economic exposure, accounting for 25% of exposure related to employment and 14% linked to wages. This sector sells 30% of

its products to the growing grapes sector in Zimbabwe, which is heavily dependent on local climate regulation.

Figure A10.4:

(A) Breakdown of Zimbabwe's main socio-economic indirect exposure by sector. The sectors shown are those that generate the grey exposure in Figure A10.1.

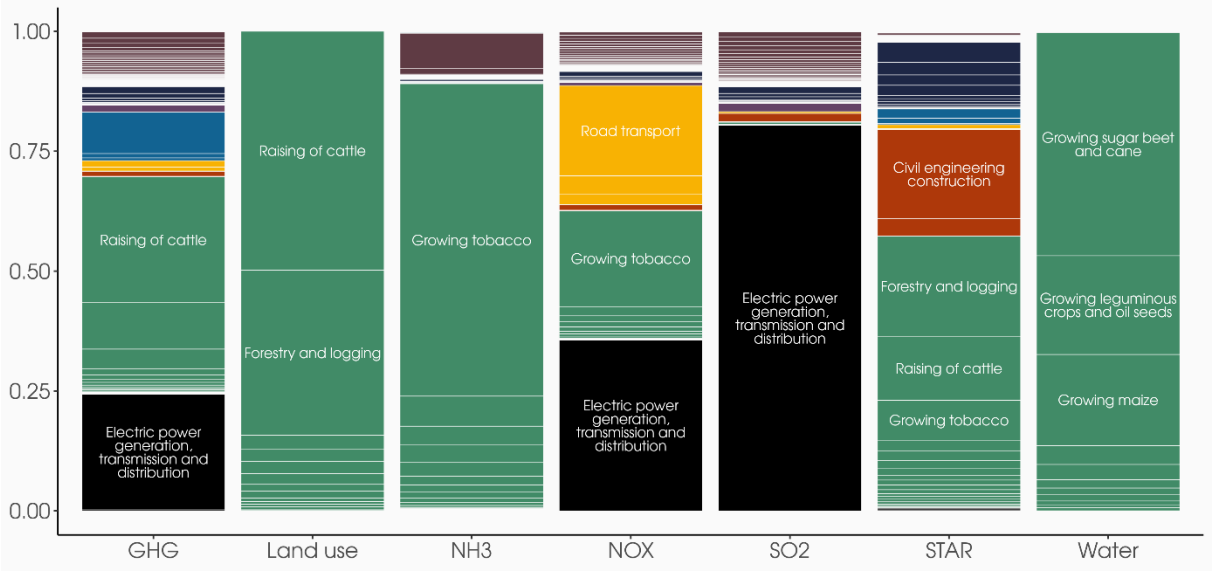
(B) Dependence of the country's key indirectly exposed sectors on ecosystem services



Transition exposure

In Zimbabwe, agriculture is responsible for the majority of the pressure on biodiversity. The growing tobacco sector alone generates 65% of the country's NH_3 emissions. The raising of cattle and the forestry and logging sectors generate 50% and 34% of the country's land-use pressure respectively, while the growing sugar beet and cane sector is responsible for 47% of water consumption. The electric power generation, transmission and distribution sector also stands out in terms of pressure on biodiversity, being responsible for 80% of the country's SO_2 emissions, 36% of NO_X emissions and 24% of GHG emissions (Figure A10.5).

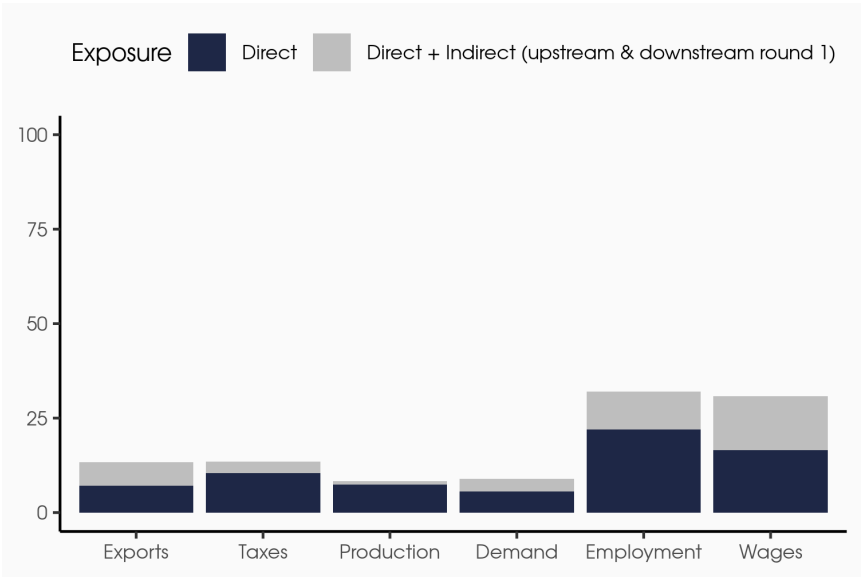
Figure A10.5: Share of pressures generated by sectors in Zimbabwe



Note: Only sectors with a label are considered exposed in the analysis, i.e. they generate at least 10% of a pressure or 5% of STAR.

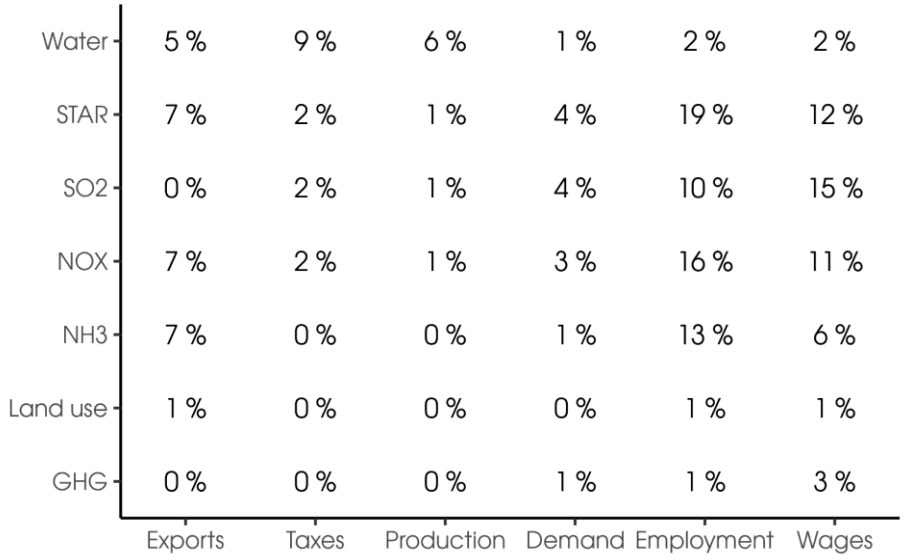
The country is primarily exposed through its social indicators, with sectors exerting the greatest direct pressure on biodiversity generating 22% of total employment and 17% of wages. When including indirect pressures – that is, sectors operating within the first tier of upstream and downstream value chains – this exposure increases significantly to 32% of employment and 31% of wages. In contrast, other socio-economic indicators remain far less exposed, not exceeding 13% (Figure A10.6).

Figure A10.6: Total share of socio-economic indicators generated by exposed sectors in Zimbabwe



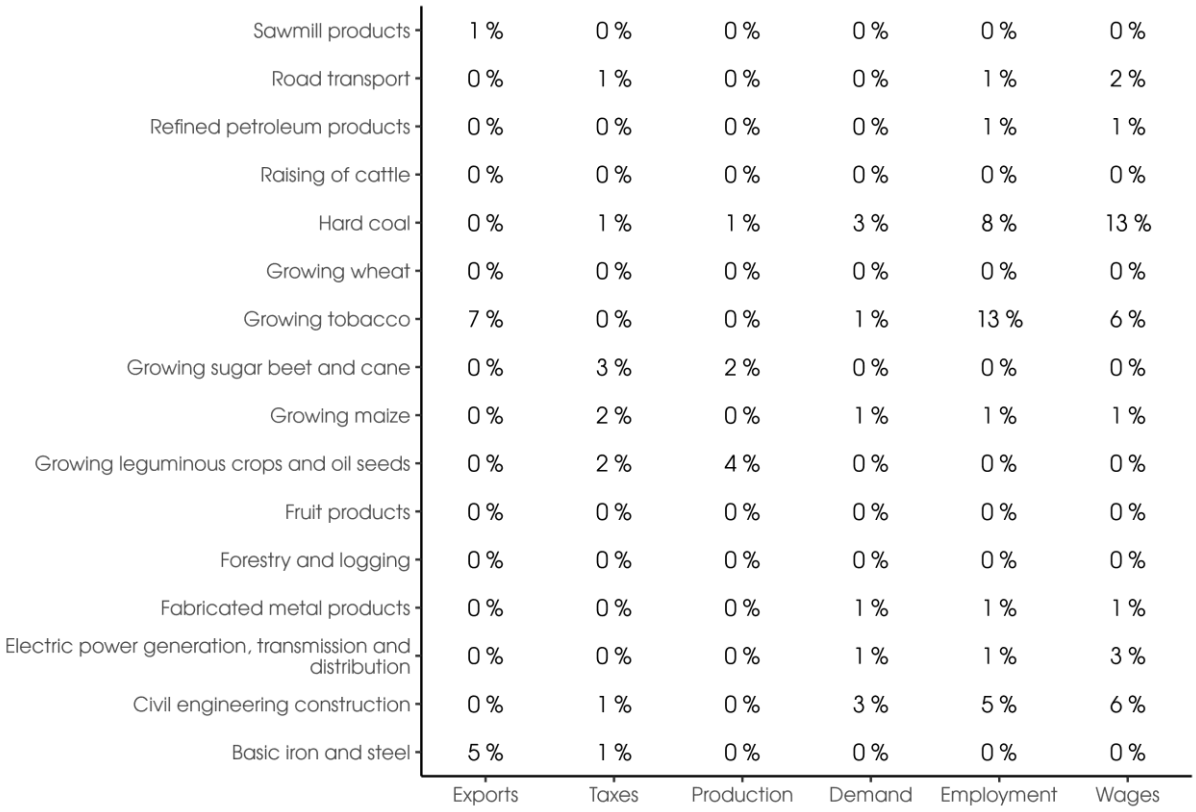
The main transition-related risks facing the country are those associated with efforts to reduce species extinction (STAR) and SO_2 and NO_X emissions. If ambitious biodiversity policies were implemented to reduce species extinction risks, up to 19% of employment could be affected. A transition targeting NO_X emissions would expose 16% of employment, while one focusing on SO_2 reduction would put 15% of wages at risk. This highlights the importance of evaluating whether the sectors responsible for these environmental pressures are capable of adapting their production processes to mitigate their impact on biodiversity (Figure A10.7).

Figure A10.7: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Zimbabwe



Among the most exposed sectors is tobacco cultivation, which accounts for 13% of national employment. It is directly exposed, primarily through its NH_3 emissions, which represent 65% of the country's total, and through its contributions to NO_X emissions and the risk of species extinction. The hard coal sector is indirectly exposed through its downstream SO_2 emissions, as it sells 35% of its output to the electric power generation, transmission and distribution sector. It also plays a significant socio-economic role, contributing 13% of the country's total wages (Figure A10.8).

Figure A10.8: Share of socio-economic indicators generated by sectors directly and indirectly exposed to an ecological transition in Zimbabwe



References

Adom, P K. 2024. 'The socioeconomic impact of climate change in developing countries'. Center for Global Development.

Antonelli, A, Smith, R J, Perrigo, A L, Crottini, A, Hackel, J, Testo, W, Farooq, H, Torres Jiménez, M F, Andela, N, Andermann, T, Andriamanohera, A M, Andriambololonera, S, Bachman, S P, Bacon, C D, Baker, W J, Belluardo, F, Birkinshaw, C, Borrell, J S, Cable, S, … Ralimanana, H. 2022. 'Madagascar's extraordinary biodiversity: evolution, distribution, and use'. *Science* 378(6623), eabf0869.

Barnes, M. 2015. 'Protect biodiversity, not just area'. *Nature* 526(195). https://www.nature.com/articles/526195e

Borucke, M, Moore, D, Cranston, G, Gracey, K, Iha, K, Larson, J, Lazarus, E, Morales, J C, Wackernagel, M and Galli, A. 2013. 'Accounting for demand and supply of the biosphere's regenerative capacity: the National Footprint Accounts' underlying methodology and framework'. *Ecological Indicators* 24: 518–533.

Cai, W, Yang, K, Wu, L, Huang, G, Santoso, A, Ng, B, Wang, G and Yamagata, T. 2021. 'Opposite response of strong and moderate positive Indian Ocean Dipole to global warming'. *Nature Climate Change* 11(1): 27–32.

Calice, P, Diaz Kalan, F and Miguel, F. 2021. 'Nature-related financial risks in Brazil'. Policy Research Working Paper, 9759. Finance, Competitiveness and Innovation Global Practice, World Bank Group.

Ceballos, G, Ehrlich, P R, Barnosky, A D, García, A, Pringle, R M and Palmer, T M. 2015. 'Accelerated modern human-induced species losses: entering the sixth mass extinction'. *Science Advances* 1(5), e1400253.

Convention on Biological Diversity (CBD). 2022. 'Kunming-Montreal Global Biodiversity Framework. Decision 15/4'. Secretariat of the Convention on Biological Diversity.

Dasgupta, P. 2021. ‘The economics of biodiversity: the Dasgupta review’. HM Treasury.

Folke, C, Carpenter, S, Walker, B, Scheffer, M, Elmqvist, T, Gunderson, L and Holling, C S. 2004. ‘Regime shifts, resilience, and biodiversity in ecosystem management’. *Annual Review of Ecology, Evolution, and Systematics* 35(1): 557–581.

Gerland, P, Raftery, A E, Ševčíková, H, Li, N, Gu, D, Spoorenberg, T, Alkema, L, Fosdick, B K, Chunn, J, Lalic, N, Bay, G, Buettner, T, Heilig, G K and Wilmoth, J. 2014. ‘World population stabilization unlikely this century’. *Science* 346(6206): 234–237.

Hadji-Lazaro, P, Calas, J, Godin, A, Skowno, A and Sekese, P. 2025. ‘A framework to assess socioeconomic and spatialized nature-related risks: an application to South Africa’. *Environmental and Sustainability Indicators* 26, 100605.

Hadji-Lazaro, P, Salin, M, Svartzman, R, Espagne, E, Gauthey, J, Berger, J, Calas, J, Godin, A and Vallier, A. 2024. ‘Biodiversity loss and financial stability as a new frontier for central banks: an exploration for France’. *Ecological Economics* 223, 108246.

Hickel, J, Hanbury Lemos, M and Barbour, F. 2024. ‘Unequal exchange of labour in the world economy’. *Nature Communications* 15(1), 6298.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2018. ‘The regional assessment report on biodiversity and ecosystem services for Africa’. https://www.ipbes.net/assessment-reports/africa.

IPBES. 2019. ‘Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services’. https://doi.org/10.5281/zenodo.6417333.

IPBES and Intergovernmental Panel on Climate Change (IPCC). 2021. ‘Scientific outcome of the IPBES-IPCC sponsored workshop on biodiversity and climate change’. https://files.ipbes.net/ipbes-web-prod-public-files/2021-06/20210609_scientific_outcome.pdf

IPCC. 2023. ‘AR6 synthesis report: climate change 2023’. Summary for policymakers. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the IPCC. Geneva, Switzerland.

Irwin, A, Geschke, A, Brooks, T M, Siikamaki, J, Mair, L and Strassburg, B B N. 2022. ‘Quantifying and categorising national extinction-risk footprints’. *Scientific Reports* 12(1), 5861.

Kedward, K, Ryan-Collins, J and Buller, A. 2021. ‘Quantitative easing and nature loss: exploring nature-related financial risks and impacts in the European Central Bank’s corporate bond portfolio’. *SSRN Electronic Journal*. https:doi.org/10.2139/ssrn.3922913.

Kedward, K, Ryan-Collins, J and Chenet, H. 2023. ‘Biodiversity loss and climate change interactions: financial stability implications for central banks and financial supervisors.’ *Climate Policy* 23(6): 763–781.

Lenzen, M, Geschke, A, Abd Rahman, MD, Xiao, Y, Fry, J, Reyes, R, Dietzenbacher, E, Inomata, S, Kanemoto, K, Los, B, Moran, D, Schulte in den Bäumen, H, Tukker, A, Walmsley, T, Wiedmann, T, Wood, R and Yamano, N. 2017. ‘The Global MRIO Lab – charting the world economy’. *Economic Systems Research* 29(2):158–186.

Lenzen, M, Geschke, A, West, J, Fry, J, Malik, A, Giljum, S, Milà i Canals, L, Piñero, P, Lutter, S, Wiedmann, T, Li, M, Sevenster, M, Potočnik, J, Teixeira, I, van Voore, M, Nansai, K and Schandl, H. 2022. ‘Implementing the material footprint to measure progress towards Sustainable Development Goals 8 and 12’. *Nature Sustainability* 5(2): 157–166.

Maurin, J, Calas, J and Godin, A. 2025. ‘Assessing economic exposure to nature-related risks.’ *AFD Research Papers n°360*. Paris. https://www.afd.fr/sites/default/files/2025-07/pr360_web_v1.pdf

Malhi, Y, Doughty, C E, Galetti, M, Smith, F A, Svenning, J-C and Terborgh, J W. 2016. 'Megafauna and ecosystem function from the Pleistocene to the Anthropocene'. *Proceedings of the National Academy of Sciences* 113(4): 838–846.

Network for Greening the Financial System (NGFS). 2023. 'Recommendations toward the development of scenarios for assessing nature-related economic and financial risks'. Technical document. https://www.ngfs.net/system/files/import/ngfs/medias/documents/ngfs_nature_scenarios_recommendations.pdf.

NGFS. 2024. 'Nature-related financial risks: a conceptual framework to guide action by central banks and supervisors'. Technical document. https://www.ngfs.net/system/files/import/ngfs/medias/documents/ngfs_conceptual-framework-on-nature-related-risks.pdf.

Richardson, K, Steffen, W, Lucht, W, Bendtsen, J, Cornell, S E, Donges, J F, Drüke, M, Fetzer, I, Bala, G, von Bloh, W, Feulner, G, Fiedler, S, Gerten, D, Gleeson, T, Hofmann, M, Huiskamp, W, Kummu, M, Mohan, C, Nogués-Bravo, D, … Rockström, J. 2023. 'Earth beyond six of nine planetary boundaries'. *Science Advances* 9(37).

Stévart, T, Dauby, G, Lowry, P P, Blach-Overgaard, A, Droissart, V, Harris, D J, Mackinder, B A, Schatz, G E, Sonké, B, Sosef, M S M, Svenning, J-C, Wieringa, J J and Couvreur, T L P. 2019. 'A third of the tropical African flora is potentially threatened with extinction'. *Science Advances* 5(11).

Taskforce on Nature-related Financial Disclosures (TNFD). 2023. 'The TNFD Nature-related Risk and Opportunity Management and Disclosure Framework: final draft – beta v0.4'.

Tausch, L and Althouse, J. 2025. 'Ecologically unequal exchange (EUE) as a multi-tiered hierarchy: investigating the interdependence of global and domestic environmental inequalities to explain China's rise'. *Ecological Economics* 235, 108644.

UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and International Union for Conservation of Nature (IUCN). 2024. 'The World Database on Protected Areas'. Dataset. https://www.protectedplanet.net/en.

United Nations. 2021. 'System of Environmental-Economic Accounting—Ecosystem Accounting'. https://seea.un.org/ecosystem-accounting

Van Toor, J, Piljic, D, Schellekens, G, van Oorschot, M and Kok, M. 2020. 'Indebted to nature: exploring biodiversity risks for the Dutch financial sector'.
De Nederlandsche Bank and Planbureau voor de Leefomgeving.

World Economic Forum. 2020. 'Nature risk rising: why the crisis engulfing nature matters for business and the economy'. 15th edition. Geneva, Switzerland. https://www.weforum.org/publications/nature-risk-rising-why-the-crisis-engulfing-nature-matters-for-business-and-the-economy/.

White, L J T, Masudi, E B, Ndongo, J D, Matondo, R, Soudan-Nonault, A, Ngomanda, A, Averti, I S, Ewango, C E N, Sonké, B and Lewis, S L. 2021. 'Congo Basin rainforest – invest US$150 million in science'. *Nature* 598(7881): 411–414.

WWF. 2024. 'Living planet report 2024 – a system in peril'. Gland, Switzerland. https://www.worldwildlife.org/publications/2024-living-planet-report/.