Study on Nature-Related Financial Risks in Zambia

2025

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Photo credits:
Victoria falls aerial view

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Abbreviations

Abbrev.	Meaning
AIM	Asia-Pacific Integrated Modelling model
AuM	Assets under Management
BOZ	Bank of Zambia
BRF	Biodiversity Risk Filter
CGE	Computable General Equilibrium
CIS	Collective investment schemes
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure
GCAM	Global Change Assessment Model
GDP	Gross Domestic Product
GFMWG	BIOFIN Zambia's Green Finance Mainstreaming Working Group
GHG	Greenhouse Gas
GLORIA	Global Resource Input Output Assessment
GVA	Gross Value Added
IAMs	Integrated Assessment Models
IAMC	Integrated Assessment Modelling Consortium
IFRS	International Financial Reporting Standards Foundation
INSPIRE	International Network for Sustainable Financial Policy Insights, Research, and Exchange
IMAGE	Integrated Model to Assess the Global Environment model
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs module
IO	Input-Output tables
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ISIC	International Standard Industrial Classification of All Economic Activities
ISSB	International Sustainability Standards Board
LEAP	Locate, Evaluate, Assess and Prepare
MAGNET	Modular Applied GeNeral Equilibrium Tool
MAgPIE	Model of Agricultural Production and its Impacts on the Environment
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact

Abbrev.	Meaning
MOFNP	Ministry of Finance and National Planning
MRIO	Multi-Region Input-Output
NAPSA	National Pensions Scheme Authority
NbS	Nature-based Solutions
NGFS	The Network of Central Banks and Supervisors for Greening the Financial System
PIA	Pensions and Insurance Authority
PSPF	Public Service Pension Fund
REMIND	Regional Model of Investments and Development
SBTi	Science Based Targets initiative
SBTN	Science Based Targets Network
SEC	Securities and Exchange Commission
SUT	Supply-Use Table
TFND	Taskforce on Nature-related Financial Disclosure
UNDP	United Nations Development Programme
USD	US Dollar
WRF	Water Risk Filter
ZAMSTATS	Zambia Statistics Agency
ZMW	Zambia currency (Kwacha)

Executive Summary

The objective of this study was to understand the financial sector - specifically banking, insurance, pensions and capital markets - exposure to nature related risks, and the impact of these financial activities on nature. In this report, we present the results of the analysis across the study, which is split into 4 components:

1. The dependencies and impacts of economic activity in Zambia on nature.
2. The nature risks faced in Zambia (i.e. the need for quality functioning nature-related services).
3. The implications of 1. and 2. for financial portfolios, across the banking, insurance, capital markets, and pensions sectors.
4. Models that Zambian stakeholders could use to assess nature risks.

The financial portfolios that are used for the analysis in this study are drawn from engagements with stakeholders in the four financial sectors.[1] The portfolios rely heavily on information provided by the respective sector's regulatory body, namely the Bank of Zambia (BoZ) for banking, the Securities and Exchange Commission (SEC) for capital markets, the Pensions and Insurance Authority (PIA) for insurance and private pensions. Finally, for public pensions, information was provided by the National Pension Scheme Authority (NAPSA) and the Public Sector Pension Fund (PSPF).

Findings reveal that the economy relies heavily on nature-related services, showing direct dependencies on regulation, maintenance, and provisioning services, specifically storm and flood mitigation and water flow regulation, in primary[2] and secondary[3] sectors. Risks cascade from primary sectors to secondary and service sectors while impacts, particularly from crop and animal production and mining, also affect various sectors, with manufacturing notably impacting through toxic pollutants. This observation underscores the importance of understanding these relationships for integrated financial management.

Zambia's financial portfolios demonstrated varying levels of direct and indirect dependencies on nature-related services. Particularly, commercial loan portfolios in banking, capital holdings in capital markets, and underwritten insurance portfolios displayed dependencies on regulation, maintenance, and provisioning services, with implications for the sector's operations and stability. Overall, we find a significant breadth of dependencies on nature, as all sub-sectors have more than 90% of their portfolio dependent on nature. The depth of these dependencies is significant as well. In the banking sector, 75% of the portfolio (ZMW 437.25 billion | USD 21.64 billion) was found to be moderately dependent on 5 or more ecosystem services. Finally, the severity of the reliance on nature is significant for parts of the financial sector. Insurance exposure equivalent to ~ ZMW 300 billion (USD 14.84 billion) is very highly dependent on ecosystem services. The study also revealed how impact drivers such as freshwater-use changes, climate change, pollution, and resource exploitation influence nature-related risks within the financial sector, emphasizing the need for targeted risk management strategies.

Zambia faces moderate ecosystem service risks, particularly flooding. Water risks are projected to increase significantly by 2030 and 2050, with Southern, Lusaka, and Eastern provinces most

[1] Across the report, we use the following exchange rate, which represents the average ZMW-USD rate in 2023: **1 USD = 20.21 ZMW.**
[2] extracting and harvesting natural resources e.g., agriculture and mining
[3] transformation of natural resources to manufactured products e.g., food and beverage

vulnerable. Soil and air quality risks are also high, driven by ecosystem and soil conditions. Drought risk is high, particularly in Copperbelt, Lusaka, and Central provinces, and is expected to increase most in Western and North-Western provinces by 2050. These observations further heighten the need to understand risks associated with ecosystem services.

Overall, the recommendations for the financial sector and relevant stakeholders in Zambia is enhancing regulatory frameworks by **adopting nature-related risk assessments** and using relevant tools and models, such as Integrated Assessment Models (IAMs). These will help integrate these risks within financial risk management frameworks. **Financial institutions should integrate nature-related risks into their strategic and operational frameworks,** using frameworks like TNFD's LEAP to evaluate environmental risk factors in investment and lending decisions. Sector-specific recommendations and opportunities include:

- **Banking Sector:** Focus on enhancing due diligence processes to evaluate the environmental impact of funded projects, especially in high-impact industries such as agriculture and mining.
- **Capital Markets:** Promote investment in sustainable projects and companies that demonstrate effective management of ecological impacts, leveraging green bonds and other sustainable financial instruments.
- **Insurance Sector:** Develop insurance products that incentivize biodiversity conservation and sustainable practices among policyholders, particularly in sectors like agriculture and construction that are prone to environmental risks.
- **Pensions Sector:** Encourage pension funds to invest in environmentally sustainable projects, assessing the long-term sustainability of their investments with respect to ecological concerns.

- **Banking Sector:** Financing nature-related activities for nature-dependent companies in high-risk areas, including raising funds for biodiversity through green bonds. Banks can tailor approaches based on clients' awareness and risk management capability, developing risk perspectives and collaborating with insurers for clients with varying levels of risk awareness.
- **Capital Markets:** Green and thematic bonds that cover activities with economic co-benefits need credible nature-related baselines, targets and plans. Security issuers can also explore biodiversity credits and provide equity and securitized project finance into distressed projects targeting carbon removal credits.
- **Insurance Sector:** Understanding and incorporating nature risk into insurance offerings allow insurers to competitively price premiums and offer innovative products, such as natural assets and biodiversity credits coverage.
- **Pensions Sector:** Nature-linked green bonds and KPI-linked structured finance with a nature focus offers new investment opportunities and bolsters the country's sovereign fiscal position.

Adopting these outlined recommendations will not only protect Zambia's financial sectors from ecological risks but also position them to support broader biodiversity conservation and sustainable development goals. Continued adaptation to global best practices and ongoing research is vital for refining Zambia's approach to integrating financial and environmental health, ensuring the economy progresses in tandem with its natural environment.

1.1 Background

While climate change has gained prominence over recent years as an area of concern for the financial sector, nature-related risks have been less understood and discussed. The degradation of nature is happening at rates beyond what has been seen in recent history, and the consequences are serious for societies and economies. Climate change and nature are closely related. Climate change is often a driver of degraded natural resources. Meanwhile, poorly functioning natural systems can exacerbate the impacts of climate hazards. However, other human activities can contribute further, for example, through air pollution or deforestation. Nature risks are recognized as the third gravest global risk over the next ten years by the World Economic Forum, and addressing these risks is necessary for ensuring resilient and prosperous economies.[4]

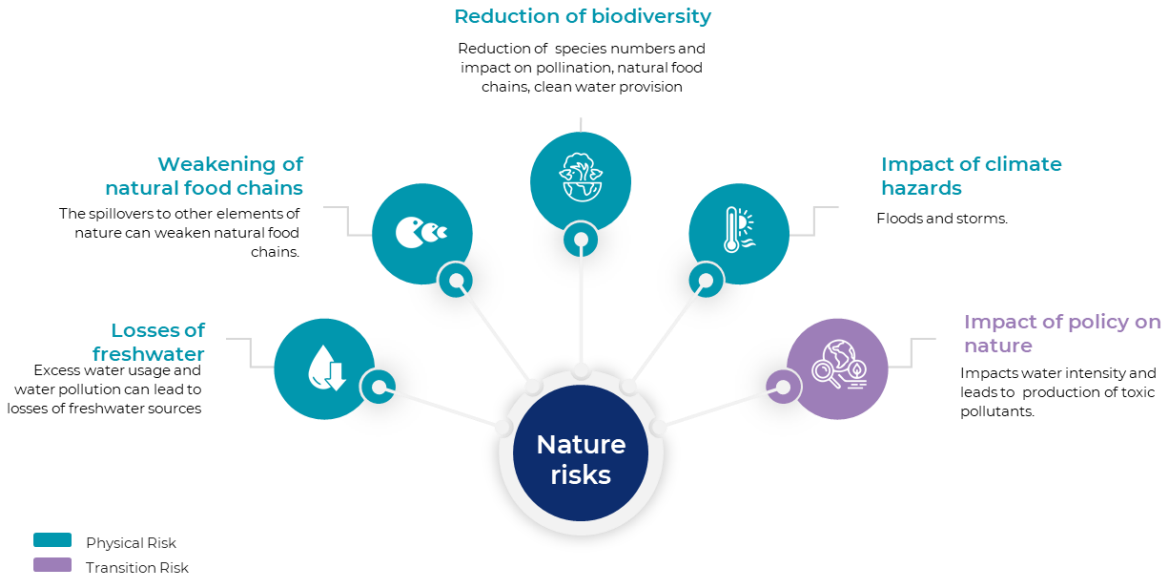
Zambia is exposed to disaster risks, through prolonged droughts, increased flood events, and unpredictable variations in precipitation patterns threatening livelihoods and the economy. The United Nations Office for Disaster Risk Reduction (UNDRR) Index Management for Risk (INFORM) rates Zambia with a score of 4.2, positioning it as the 66th most at-risk country out of 191[5]. The country ranks 102nd in terms of hazard and exposure, 48th in vulnerability, and 46th in lack of coping capacity.[6]

The interaction of these climatic changes with other human behaviors that affect nature can exacerbate nature risks. Excess water usage and water pollution can lead to losses of freshwater sources, rushing industry and populations elsewhere. The spillovers to other elements of nature can weaken natural food chains. Crop production, through soil overuse and degradation, and deforestation, can reduce biodiversity, reduce species numbers and impact pollination, natural food chains, clean water provision, while having some yet unknown longer-term consequences. The deterioration of nature alongside climatic change can have pronounced effects given nature's role in climate mitigation and adaptation, such as through acting as a storer of carbon and through limiting the impact of climate hazards such as floods and storms.

The final dimension of the interaction between climate change and nature is the impact of policy on nature. Implemented alone, industrial climate change mitigation policies are expected to use significant areas of land, and the mining of critical minerals will have varied impacts from its water intensity and the production of toxic pollutants. Zambia faces challenges in understanding these nature-related risks due to limited access to accurate and timely information, exacerbating these vulnerabilities.

[4] World Economic Forum (2024). The Global Risks Report 2024.
[5] INFORM. (2025) Country Risk Profiles.
[6] Ibid

Figure 1: Key Nature-Related Risks



Source: Author

Within the domain of finance, one of the critical challenges lies in the insufficient engagement of the private sector in funding initiatives aimed at bolstering resilience against climate and nature-related risks. Notably, biodiversity and ecosystem preservation initiatives lack adequate financing from the private sector, emphasizing economic activities that inadvertently harm vital ecosystems.[7] This oversight stems from a limited recognition of the importance of nature and ecosystems in mitigating nature-related threats, which can disrupt supply chains and present risks to companies, sectors, and supply chains, thereby affecting the financial sector through credit, underwriting, and strategic risks.

The United Nations Development Programme (UNDP)'s Biodiversity Finance Initiative (BIOFIN) - Zambia has undertaken a crucial initiative to enhance the efforts of the Green Finance Mainstreaming Working Group (GFMWG) in Zambia through research, economic modelling, and report development. This assignment is timely and essential given the multitude of risks facing the country, highlighting the pivotal role of the financial sector in mitigating these risks and providing sustainable solutions.

Box 1: BIOFIN work in Zambia

BIOFIN Zambia is part of the global Biodiversity Finance Initiative (BIOFIN) managed by UNDP and implemented in partnership with the Ministry of Green Economy and Environment. Launched in 2015, BIOFIN Zambia has focused on identifying and implementing sustainable financing solutions to close the biodiversity finance gap in Zambia. It has played a central role in catalyzing green finance reforms within the financial sector, including supporting the development of green bond guidelines, engaging financial sector regulators, and leading policy advocacy for biodiversity- inclusive finance.

[7] OECD (2024)

Currently, BIOFIN Zambia is implementing three strategic finance solutions. The first is the development of a Green Finance Taxonomy and Tagging and Reporting System, which will classify and help track financial flows into green sectors and enhance the financial sector's ability to report on climate, biodiversity, and land degradation-related investments. Second is the formulation of a Green Finance Strategy and Implementation Plan, designed to embed green finance principles across Zambia's financial sector. The third solution focuses on Green Bond Market Development, through which BIOFIN is supporting the creation of a Green Bond Investment Portal and providing technical assistance to potential issuers—helping to unlock long-term capital for nature-positive and climate-resilient investments. These solutions collectively aim to mainstream nature into financial decision-making and drive increased investment toward sustainability in Zambia.

1.2 Nature Risks

Human development, our economies and societies, are dependent on the natural resources around us. The natural world is essential for human life and well-being in a multitude of ways, from agriculture and food provision to the provision of medicines, from water for consumption to natural flood defenses. The full extent to which these ecosystems and their services will support society in the future is still unknown.[8] The rich variety and diversity of nature could facilitate human well-being in a wide range of yet undiscovered and undeveloped areas.

The world's resources, however, are limited, and have been impacted by human activity over centuries, and most particularly since the industrial revolution. Overusing or misusing of resources is already having consequences, and the impacts will be further felt in years to come.

Natural capital - defined as the stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people[9] - is the value of the natural world, including all natural assets such as soil, air, water, geology, and living things. Humans derive a wide range of services from these assets (stocks), known as ecosystem services. Broadly defined, ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity.[10] These services can be further classified into three groups:[11]

[8] As defined by the Convention on Biological Diversity (1992), ecosystems are a dynamic complex of plant, animal and microorganism communities and the non-living environment, interacting as a functional unit.
[9] Capitals Coalition (2016)
[10] United Nations et al. (2021)
[11] Reference made from United Nations. *et al.* (2021) System of Environmental-Economic Accounting – Ecosystem Accounting

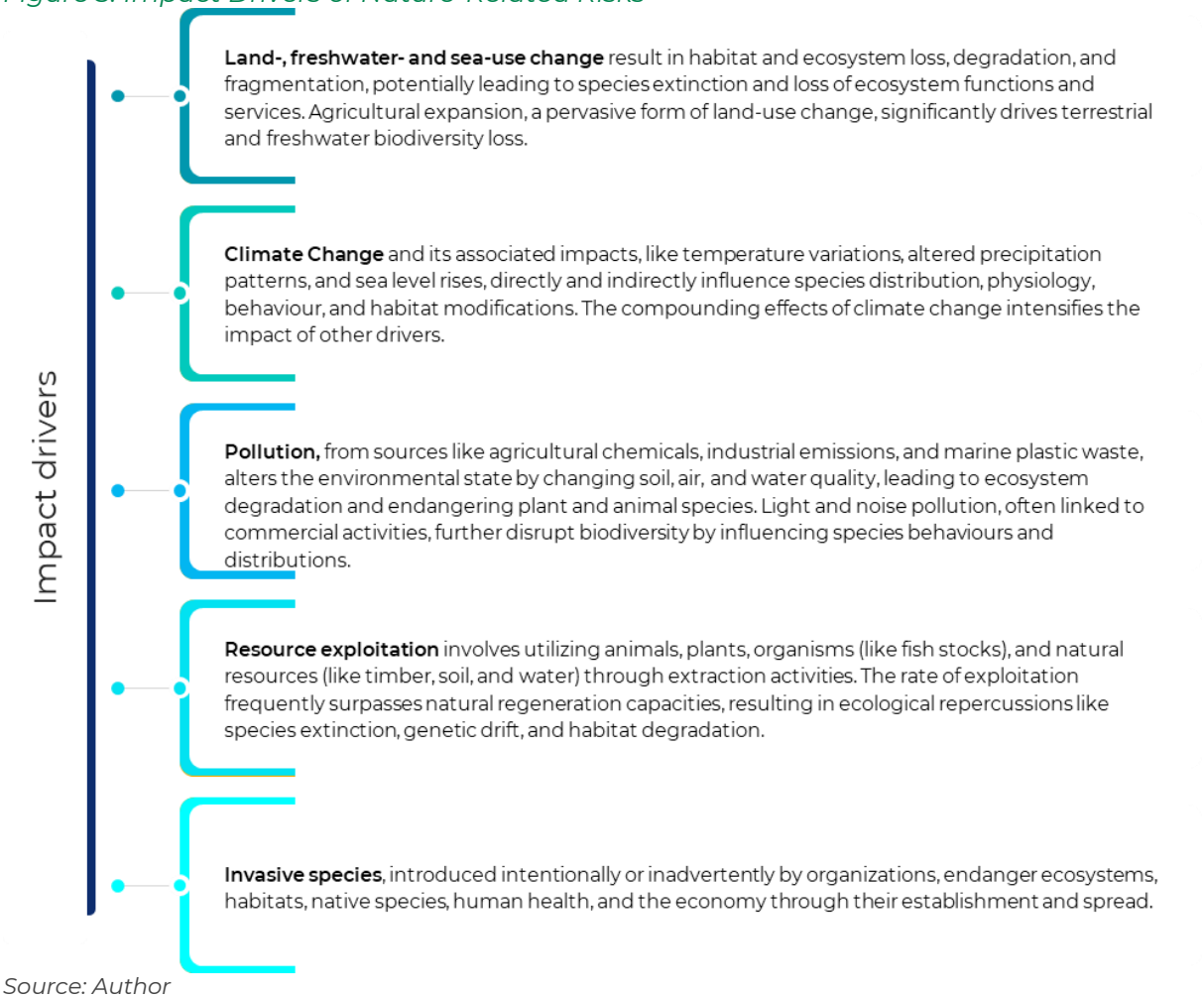
Figure 2: Ecosystem Services Provided by Nature

Source: Author

Naturally, natural capital provides these essential ecosystem services. Their loss triggers nature-related risks, leading to ecosystem vulnerabilities and degradation. By identifying impact drivers, we can pinpoint the causes of ecosystem instability. Impact drivers are pressures—from inputs, activities, and outputs—that induce changes in nature's state. These pressures, intentional or unintentional from economies and societies, contribute to altering the ecosystem. There are five impact drivers[12] generally considered:

[12] Climate Disclosure Standards Board. (2021)

Figure 3: Impact Drivers of Nature-Related Risks



Source: Author

While climate change has been brought to the forefront of discussions and agreements within and across peoples, businesses, and countries, the progress on protecting nature is more limited. However, the extent of nature risks is substantial, and the importance of their impact is not underestimated. Furthermore, climate change and nature interact; for example, risks to freshwater systems occur both because of climate change (droughts, flooding, salination) and direct human activities on water flows and management (overusing boreholes, water pollution, building of impermeable services, etc.).

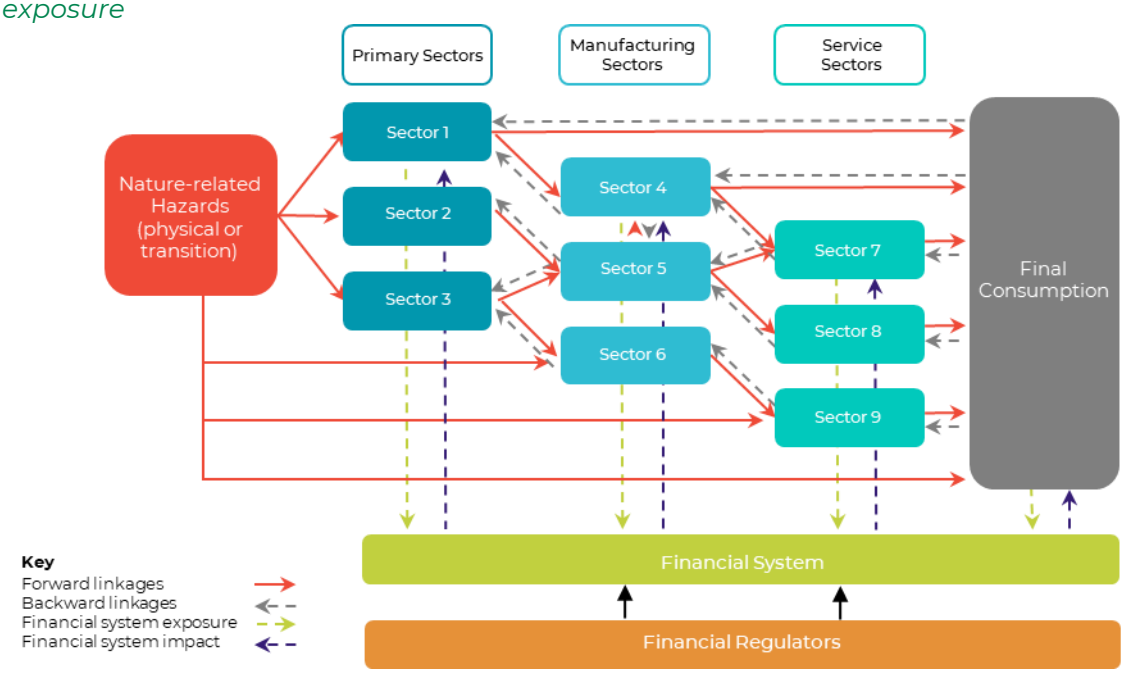
As set out in the 2021 Dasgupta Review on the Economics of Biodiversity,[13] nature plays a crucial role in economies while its loss poses significant risks. With biodiversity declining rapidly, there's a need to quantify and assign monetary value to natural assets to integrate nature's importance into economic and policy decisions.[14] Failure to do so may result in overlooking negative impacts on natural resources, leading to severe consequences in the short, medium and long term. Nature risks

[13] HM Treasury. (2021, June 14).
[14] Biodiversity is commonly defined according to Article 2 of the Convention on Biology Diversity (1992) as the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

affect the economy directly through primary resources like agriculture and mining, impacting industries, construction, services, and end consumers in a cascading flow of influence.

Throughout the entire process, the financial system engages with primary, secondary, and tertiary sectors, facilitating investments and providing goods and services. This involvement exposes the financial system to risks like those faced by individual sectors, acting as both a supporter and a potential enabler of activities that harm the environment. Direct interactions with consumers and households, such as through personal banking services, also expose the sector to nature-related risks, like financing properties in flood-prone areas. Individual financial institutions' vulnerability to risks depends on portfolio diversification, sector exposure, and risk management strategies. **Systemic risks increase when considering the interconnected nature of the financial system, potentially amplifying pressures through feedback loops and interactions across various economic sectors.** This is shown in Figure 1[15].

Figure 4: How sectors' exposure to nature-related risks translates into financial sector exposure



Source: Adapted from NGFS (2023a). Recommendations toward the development of scenarios for assessing nature-related economic and financial risks.

The dependencies and impact results shown in Section 3 depict how the economic sectors in Zambia are exposed to nature-related risks, both directly and indirectly, which in turn could impact Zambia's financial system.

1.3 Scope of Financial Portfolios

In this section, we outline the data received from financial sector stakeholders to conduct the analysis. The section shows that each sector has its own metric for financial allocation. As such, it is

[15] For another representation of the transmission channels of nature risk to the financial sector, see Figure 2 of NGFS (2023b)

not possible to aggregate the financial sector data into a single whole representation. We also outline any transformations made to the data, and what informed/motivated them.

1.3.1 Banking Sector

The data shared by the banking sector consisted of the annual commercial loan portfolio from 2009-2024 (as of June 2024) independently by sector and by province. In 2022, the level of sectoral detail was expanded from 22 to 100 sub-sectors which covers and exceeds the level of granularity that is used for the analysis. For the general analysis, the report used data from the most recent complete year - 2023. In total, the value of gross loans made by commercial banks over this period was **ZMW 583 billion (USD 28.8 billion).**

Without the existence of sector-province information, the report assumed the geographic distribution of sector loans using GVA data received from the Zambia Statistics Agency (ZAMSTATS). To do this, we first estimated sector-province lending based on each province's relative contribution to GVA in each sector. After which, an adjustment factor, based on the relative difference between estimated and actual provincial lending, was applied to each province (and therefore each sector-province pair) to arrive at a final estimate that matched both the sectoral and provincial totals.

1.3.2 Capital Markets Sector

In the capital markets sector, the data used for the analysis comes from the Securities and Exchange Commission (SEC). The capital markets portfolio is composed from three sources[16]:

- Securities on the Lusaka Securities Exchange - including information on market capitalization and general locations of securities.
- Collective investment schemes (CIS) - information on all individual investments[17]
- Corporate bonds - information on the value of issuances

Securities and investments were then tagged to economic sectors and locations (where missing). In many cases for CIS and Corporate Bonds, investments or issuances came from loan-making institutions. Therefore, these investments and issuances were allocated to sectors and regions in the same way as the banking sector.

Most of the ZMW 155 billion (USD 7.67 billion) capital markets portfolio emerged from the market caps of listed securities on LuSE (ZMW 101 billion | USD 5 billion).

1.3.3 Insurance Sector

In the insurance sector, data was provided for 672 high risk general insurance policies taken out in 2023. Included in the data were the insurance provider, policy holder, the total and maximum exposure, and the risk location, among other information. In total, the exposure of these policies amounted to **ZMW 976 billion (USD 48.29 billion).**

From this, the policies were tagged into economic sectors based on information gathered on the policyholder. This information was aggregated up at the provider level. To match the sector, an adjustment factor was applied to each provider based on the relative difference in their holding of

[16] Unlisted securities were not used for the analysis owing to a lack of information on their respective values.
[17] Some of the CIS investments are in listed equities. To avoid double counting, they are not included in the capital markets portfolio. However, where pension funds have invested in CIS, these equities are included.

high-risk policies and their market share as stated by the Pensions and Insurance Authority (PIA) Annual Report 2022.[18]

1.3.4 Pensions Sector

Data on public pensions holdings came from the information on assets under management (AuM) for 14 Zambian private pensions funds. The total AuM for these funds is equivalent to **~ZMW 10 billion (USD 0.49 billion),** with the largest of these being the Saturnia Regna Pensions Trust Fund, with a total of ZMW 5.04 billion (USD 0.25 billion) in AuM. However, given the inability to tag government bonds and treasury bills to sectors, the total AuM that the analysis considers is ZMW 4.84 billion (USD 0.24 billion). This is spread across property, equities, CIS, corporate bonds, and term deposits.

Public pensions investments are obtained from 2023 annual reports from the National Pensions Scheme Authority (NAPSA) and the Public Service Pension Fund (PSPF). In total, the two funds have over ZMW 70 billion (USD 3.46 billion) in AuM. Excluding investments in government securities (ZMW 35 billion | USD 1.73 billion) and other investments could not be tagged, the public pensions portfolio considered for the analysis totals ZMW 30 billion (USD 1.48 billion), across equities, fixed term deposits, property, and other investments.

1.4 Previous Studies of Nature Risk in Zambia

Nature stress test on banking systems. An examination of nature stress tests on banking systems in Ghana, Mauritius, Morocco, Rwanda, and Zambia revealed how different nature transition scenarios could impact business profits, considering risks like deforestation and water scarcity across sectors at high nature-related risk (McKinsey Sustainability and FSD Africa, 2022). The findings were crucial for African financial regulators and institutions facing similar risk exposure, indicating potential effects on business profits, commercial lending, job creation, and economic growth. The report evaluated an orderly nature transition versus a disorderly approach or no transition, providing insights to enhance stakeholder responses and navigate potential impacts on job creation and community empowerment. The stress test outcomes, encompassing unweighted profit losses by sector, weighted profit losses for the banking system, and credit losses, offer strategic metrics to measure the financial implications of nature-transition scenarios across various sectors and the banking system in these selected African countries.

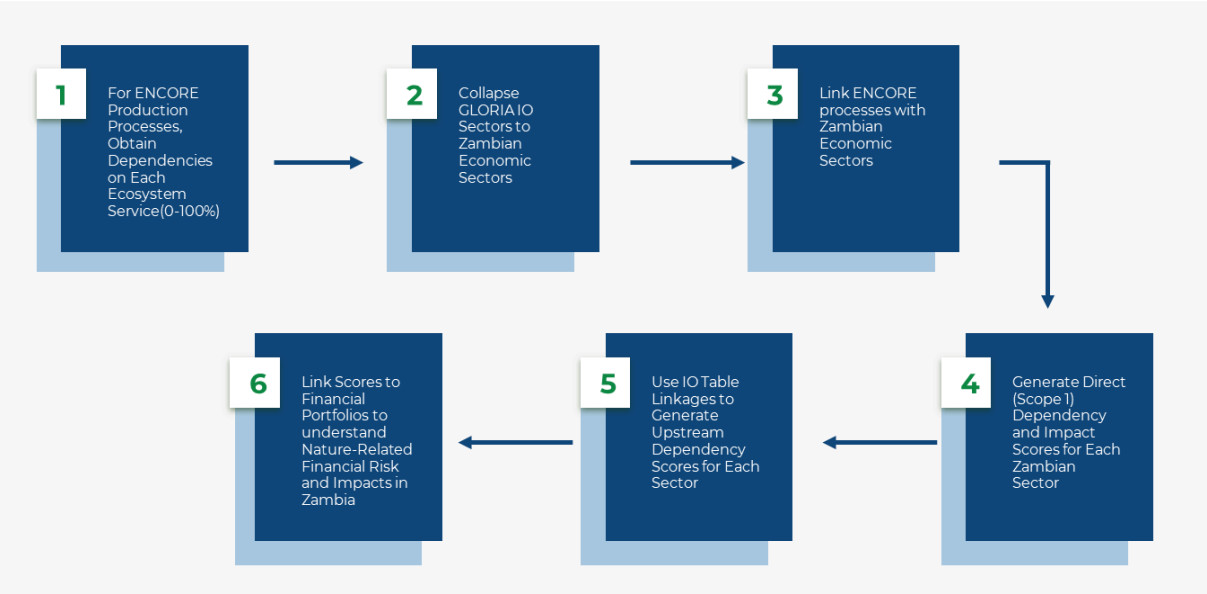
We build on this key study in the following ways. Firstly, the existing work is focused heavily on the banking sector. This study widens coverage to consider impacts and risks for the broader financial system, including capital markets, insurance, and pension sectors. Secondly, we make use of input-output methodologies to extend the analysis to other sectors in the supply chain. Thirdly, we incorporate a wide array of ecosystem services through ENCORE and finally, through linking ecosystem services to WWF Risk Filters, we can look at both place- and activity-based dependencies, risks, and impacts related to nature.

[18] Pensions and Insurance Authority (PIA), 2023

2.1 Financial Sector Dependence and Impact on Nature

Our approach to linking financial sector portfolios to direct and indirect nature-related risks (dependences and impacts) is outlined in the figure below, and can be characterized by 6 stages as presented in Figure 2:

Figure 5: Our methodological approach



Source: Author

Step 1: Obtaining Dependencies and Impacts on Each Ecosystem Service | The first step follows the methodology presented by Svartzman et al. (2021) to generate percentage scores, ranging from 0-100%, for each of the 271 Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) production processes connected to 13 drivers of biodiversity loss (impacts) and the 25 ecosystem/nature-related services they depend upon (dependencies). For consistency with the literature, the percentage scores shown in Table 1 are attributed in the same way.

Table 1: Percentage scores used

Level of Dependency	Percentage Score
N/A	0%
VL - Very Low	20%
L - Low	40%
M - Moderate	60%
H - High	80%
VH - Very High	100%

Source: Svartzman et al. (2021)

Step 2: Collapsing GLORIA IO Sectors to Zambian Economic Sectors | Global Resource Input Output Assessment (GLORIA), a Multi-Region Input Output (MRIO) table that measures the interlinkages between 121 economic sectors in and across 164 countries/regions was used for the analysis. Firstly, to focus the analysis to Zambia only, the table is collapsed to highlight the production interlinkages between Zambia's economic sectors.

While GLORIA presents 121 economic sectors to be considered, these were significantly high for the following reasons:

1. Possibility of increased risk of errors due to challenges in tagging financial sector portfolios to granular economic sectors. Recipients of financial investments often span multiple similar sectors, posing alignment difficulties. The collected data also lacks the necessary specificity to accurately identify the sectors in which recipients operate.
2. Possibility of a lack of informative outcomes on nature-based dependencies and impacts. This stems from having numerous sectors that may prove challenging and fail to leave a lasting impression on readers of this report. Additionally, the 121 GLORIA sectors may not align directly with those utilized in the current Gross Domestic Product (GDP) framework of Zambia.

Consequently, the sectors used for the analysis of dependencies and impacts are the 29[19] sectors used by the Ministry of Finance and National Planning (MOFNP) to measure national and regional GDP and Gross Value Added (GVA) (see Annex 4). Both the Zambian and the GLORIA sectors were able to be linked to a common classification of economic activity, the International Standard Industrial Classification of All Economic Activities (ISIC), which resulted in a straightforward aggregation. At this point, the GLORIA table collapses again according to this classification, giving us the production interlinkages between these 29 sectors.[20]

Step 3: Linking ENCORE Processes with Zambian Economic Sectors | ENCORE processes are linked with the 29 identified economic sectors to understand sectoral dependencies and impacts on nature.[21] Thereafter, we aggregate the 271 production process scores from Step 1 to the 29 Zambian economic sectors. Once more, we follow the literature and calculate the dependency scores by taking the mean dependency score from all of the production processes that fall under each economic sector.

It is worth noting, as in Svartzman et al. (2021),[22] that this approach is arbitrary and could be done by using the maximum/minimum scores (which would raise/lower the overall dependencies and impacts of the economy on nature), or any other method of calculation. Our analysis uses the mean approach because it (a) facilitates comparison with the Svartzman and other related studies, and (b) mitigates against the possibility that a maximum/minimum score is awarded to a sector by a production process that would not even occur in Zambia.

Step 4: Generate Direct Dependency and Impact Scores for Each Zambian Sector | Once ENCORE scores are linked to economic sectors, we calculate the dependency of an economic sector on a certain nature-related service, as well as that sector's impacts on nature. A heat map of these

[19] Zambia uses 30 sectors for the measurement of GDP and GVA. In order to avoid mistagging data, all financial services including pensions and insurance are combined into a single sector - financial services, giving 29 in total.
[20] To verify the GLORIA data, we compare GVA estimates generated by the IO model and the GVA estimates provided by MOFNP to identify if there are any outliers. We found that GLORIA was a good approximation of government GDP data and proceeded with using it as a representative account of production within the country.
[21] We were able to achieve this as ENCORE processes can also be linked to ISIC as they are classified at the ISIC Class or Group level.
[22] See Page 29 - Footnote 39 of Svartzman et al (2021) A "Silent Spring" for the Financial System? Exploring Biodiversity-Related Financial Risks in France. Banque de France Working Paper #826.

dependencies and impacts, with darker blue boxes representing a greater dependency/impact, is shown in Figure 3 and Figure 5 in Section 3.

Step 5: Using IO Table Linkages to Generate Upstream Dependency and Impact Scores for Each Sector | Whilst informative to an extent, the attribution of nature-related dependencies and impacts independent of a sector's economic dependence on other areas of the economy can be misleading. This is because it generates a picture that services and even manufacturing are unaffected by the non-provision of an ecosystem service and equally are not responsible for the deterioration of the provisioning of such services.

To represent how economic sectors are indirectly affected, and responsible for, the deterioration of nature, the analysis makes use of the GLORIA IO table, and the methodology laid out in Svartzman et al. (2021) and similar reports. Specifically, the Leontief inverse matrix,[23] which represents the intermediate inputs from all sectors $i = 1, 2, \ldots, 29$ to produce a unit of final demand in sector i, is subtracted by the identity matrix (to remove the final demand element). After this, the relative importance (weight) of sector j as an intermediate input in the production of sector i is calculated as the proportion of total inputs that come from this sector. For example, if 1 total unit of production is required to produce in sector i, and sector j accounts for 0.1 units of this, its relative weight w is 0.1 or 10%, such that total weights sum to 1[24]. The upstream dependence of sector i on ecosystem service x, UDS_i^x was therefore calculated as:

$$UDS_i^x = \sum_j w_j^x \, DS_j^x$$

where DS_j^x represents sector j's direct dependence on ecosystem service x[25]. Upstream or indirect heat maps for a sector's dependence or impact on nature are calculated and shown in Figure 4 and Figure 6 in Section 3.

Step 6: Linking Scores to Financial Portfolios | In order to understand nature-related financial risk and impacts in Zambia, we link financial sector portfolios from the banking, capital market, insurance, and pension sectors to these findings (See Section 3 for the elaboration of this step). Across all four financial sectors, except for the banking sector, an extensive tagging exercise was needed to link their portfolios to economic sectors and geographical locations (provinces).

Limitations to the methodology

Extensive efforts are made to access data from the four financial regulatory sectors, as well as from ENCORE and GLORIA. However, challenges which lead to some data constraints persist, namely:

1. **Financial portfolios are not commonly tagged to both economic activity and location:** This means that in several cases, a simplifying calculation must be applied to locations (as in banking and capital markets) or even to sectors (for financial portfolios that could be operating across multiple sectors).
2. **Data provided on financial portfolios was often not complete:** While this may be assumed as a norm for the financial sector, it was not always the case. Here, we mention these instances:

[23] An economic analysis tool that helps us understand the interdependence between different sectors of an economy by calculating the impact of changes in final demand on the production of goods and services across different sectors of the economy.
[24] The mathematical notation that has been described in words can be located in Annex 2.C. in Svartzman et al. (2021).
[25] The same method applies when calculating impact scores.

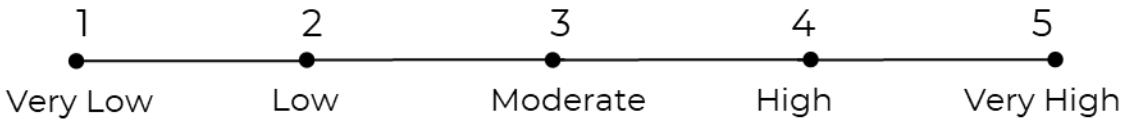
a. In insurance, the analysis uses risky insurance policies as a proxy for the entire insurance financial portfolio. This is due to the level of detail captured, both in the economic sector and location.
b. Financial portfolios holding government securities, which were considerable under the pensions sector, were not usable since they could not be tagged into specific economic activities. This limits the ability to understand how these investments impact and depend upon nature.

2.2 Scenario Water and Biodiversity Risks

In this section, we discuss the methodology used to identify the quality of two high-level natural services in Zambia, and the consequences of this in terms of nature risk. In Section 3, this methodology is used for a combined analysis which identifies where the financial sector in Zambia is both dependent on nature and where the quality of services provided by nature are lower or have been degraded.

2.2.1 WWF Water Risk Filter (WRF) and Biodiversity Risk Filter (BRF)

For the analysis, we use the WRF and BRF that come from the Worldwide Fund for Nature (WWF). These filters, which have updated scores for 2024, classify risks from 1-5, with the following classification:



Risks are measured across a broad spectrum of variables, including regulatory and reputational risks. However, as part of this analysis, the focus is on physical risks, and more specifically the physical risks that impact water and supporting services. For both ecosystem services, the analysis uses an index of risk that is founded on the indices constructed by WWF, with some slight adaptation to allow for integration with the financial sector analysis, and to minimize overlap between the two indices.

The water-related ecosystem services originate from WRF. The index is constructed using the following indicators[26], with the contents in brackets representing the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) ecosystem services that have been linked to each:

- Water Availability (Water Flow Regulation)
- Flooding (Flood Mitigation)
- Water Quality (Water Purification)
- Ecosystem Services Status: referring to river connectivity, forest loss, and wetland degradation (Rainfall Pattern Regulation)

[26] Drought risk is excluded due to its lack of coverage in future water risk scenarios in the WRF. In Annex 1, we include an analysis of drought risk over time in Zambia, based on the World Bank's Climate Change Knowledge Portal (CCKP). The CCKP uses the SPEI index, similarly to the WWF. However, due to a lack of comparability of results over time, it remains excluded from the general analysis.

To generate the index, we use the data for each of the indicators from the WRF[27], which is aggregated at the provincial (sub-national) and national level in Zambia. In alignment with the 2024 scores, equal weight is given to each of the indicators.

The supporting services index is constructed from the BRF. The following indicators are used[28] . Once more the brackets represent the linked ENCORE services:

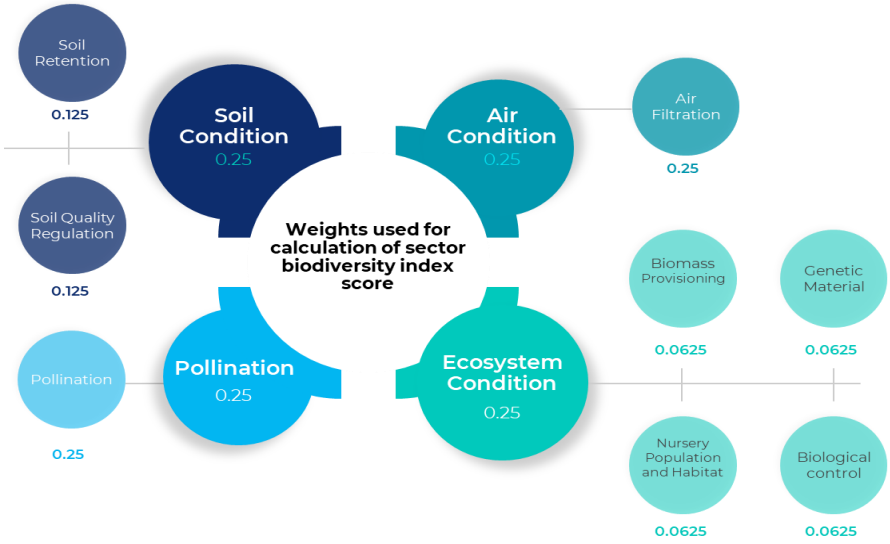
- Soil Condition (Soil Retention and Quality Regulation)
- Pollination (Pollination)
- Air Condition (Air Filtration)
- Ecosystem Condition (Biomass Provisioning, Genetic Material, Biological Control, and Nursery Population and Habitat Maintenance)

As with the water index, scores are aggregated by the WWF at the provincial level. To build the index, we likewise assign equal weight to each of the indicators.

2.2.2 Financial Portfolios and ENCORE Dependencies

As mentioned, each of the WRF and BRF indicators are linked to one or multiple ecosystem services from ENCORE, which was used to understand financial portfolio dependencies in the cascade analysis. To understand the risk to financial portfolios, sectoral water and biodiversity risk indices are constructed based on these linked dependencies. Where a WWF indicator is linked to multiple indicators, equal weights are given to each dependency score, such that the weight of each associated risk is equal, matching the approach to WRF and BRF scores. Given that ENCORE dependency ranges from 0-1, the water and biodiversity scores are likewise bounded by 0 and 1, with a higher score representing a higher 'index risk'. The BRF-linked dependency weights are provided as an example in Figure 6 below.

Figure 6: Weights used for calculation of sector biodiversity index score



Source: Author

[27] WWF Water Risk Filter - Country profiles.
[28] All indicators in the BRF (SRC2) are used apart from water condition, which is excluded to limit overlap between the indices as the indicator is a replica of the Water Quality measure from the WRF.

The water and biodiversity risk scores are aggregated to financial sector portfolios based on the relative economic sector weights in each portfolio in each province. The portfolio index risk, PIR, for a dependency x and province j is given by the weight w of each sector, i, in the portfolio for that province. This is then multiplied by the respective sector index risk, SIR, and summed across all sectors. This calculation is shown formally below:

$$PIR_{x,j} = \sum_{i} w_j^i SIR_x^i$$

Limitations to the methodology

The methodology aims to provide insight into the quality of ecosystem services in Zambia and the implication this has for nature-related risk. Nonetheless, there are some caveats:

1. **The calculation of the index weights by using a means is inherently arbitrary.** It is likely that some indicators will have a greater impact on risk. However, in the absence of sufficient knowledge on this, we choose to follow the WWF approach to calculate 2024 scores.
2. **The scenarios are driven by well-established Shared Socioeconomic Pathways (SSPs).** This enables the integration of this work into other analysis given this common background. These pathways are projections based on present knowledge but may not represent the realities in 2030 and 2050 as the implications of climate and natural change are realized.

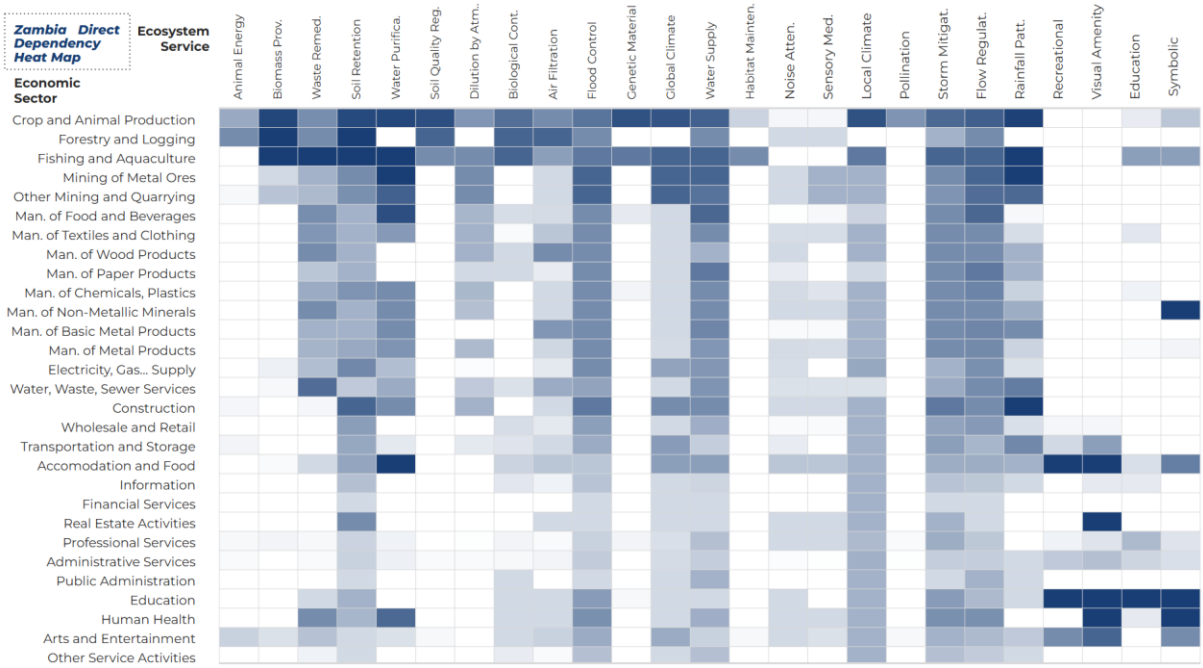
3.1 Zambia's Dependence and Impact on Nature

In this section, we present the result of stages 1-5 of the methodology in Section 2.1. These results show the extent and severity of the dependencies and impacts that the Zambian economy has on nature (ecosystem services).

3.1.1 Dependencies

Within the Zambian economy, 'primary' resource extraction sectors can be seen to be more reliant on the services provided by nature. This appears to be quite an intuitive result due to the proximity of such production processes to nature and natural resources. However, most of the economic sectors categorized by this analysis depend on nature either directly or indirectly. This resulted in common ecosystem dependencies that are pervasive throughout the economy, in particular storm and flood mitigation, and water flow regulation. This again is an intuitive result regarding the damage that is presented by such climate-related hazards.

Figure 7: Heat map of direct dependencies of economic sectors on natural services



Source: Author based on ENCORE processes

Where nature-related risks are concentrated at the top of heat maps for direct dependencies, given the interdependencies of the economy, risks cascaded down to manufacturing and service sectors. For dependencies, some risks are pressing across the entire economy, as presented below, categorized by the ecosystem services they provide):

Figure 8: Heat Map of Indirect Dependencies of Economic Sectors on Natural Services

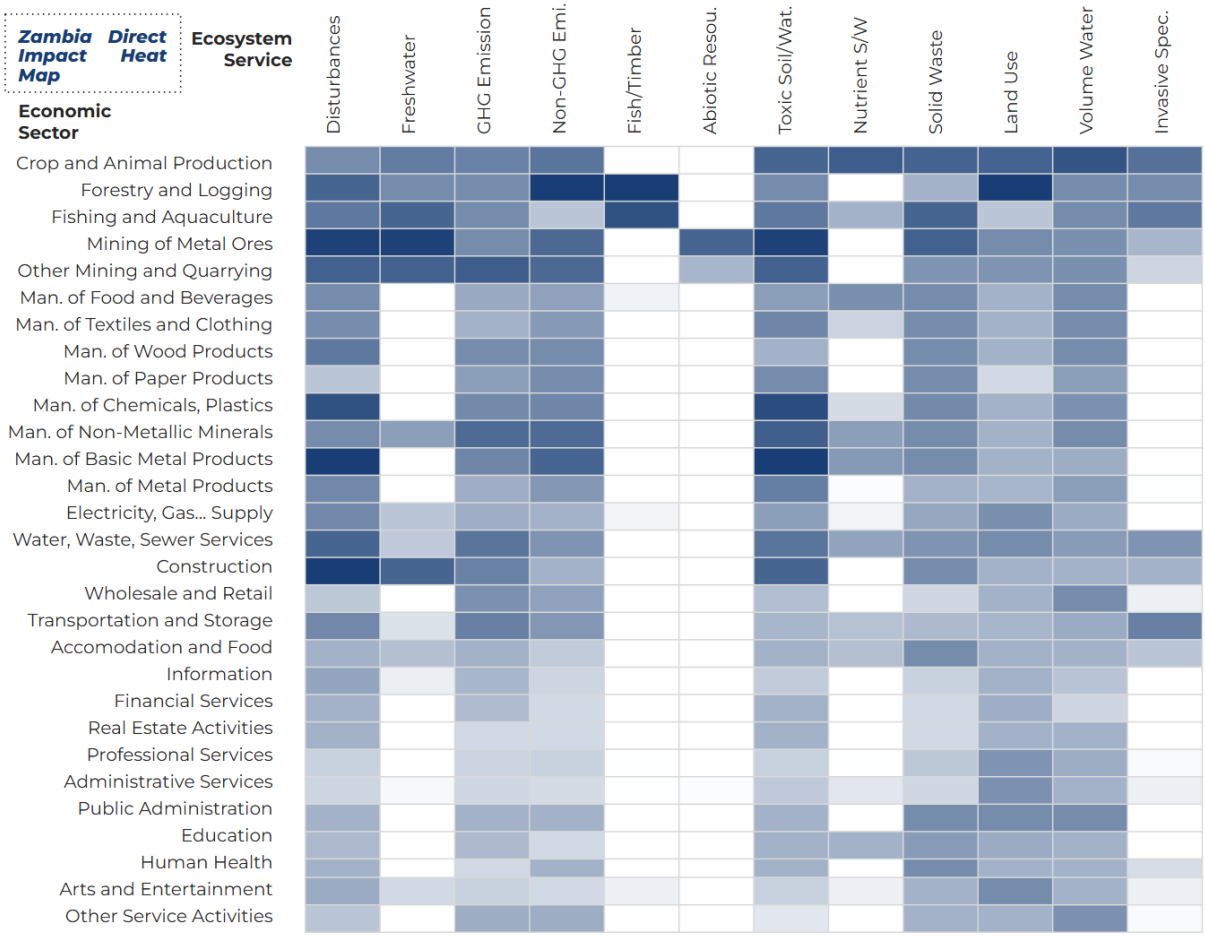
Source: Author based on IO table calculations

Provisioning	Regulating and maintenance	Cultural
Water supply	Soil and sediment retention Flood control Storm mitigation Water flow regulation Rainfall pattern regulation Global climate regulation Local climate regulation	N/A

3.1.2 Impacts

As for impacts on nature, there is a similar story to dependencies and impacts are concentrated on primary industries. Crop and animal production, and various mining activities are particularly impactful on nature. This creates a notable result where sectors that directly depend the most on nature are simultaneously more impactful on it. However, once again, impacts are spread across the economy and severe impacts are not exclusive to the primary sectors, as manufacturing is notably very impactful with regards to its emission of toxic soil and water pollutants.

Figure 9: Heat map of direct impacts of sectors on natural services



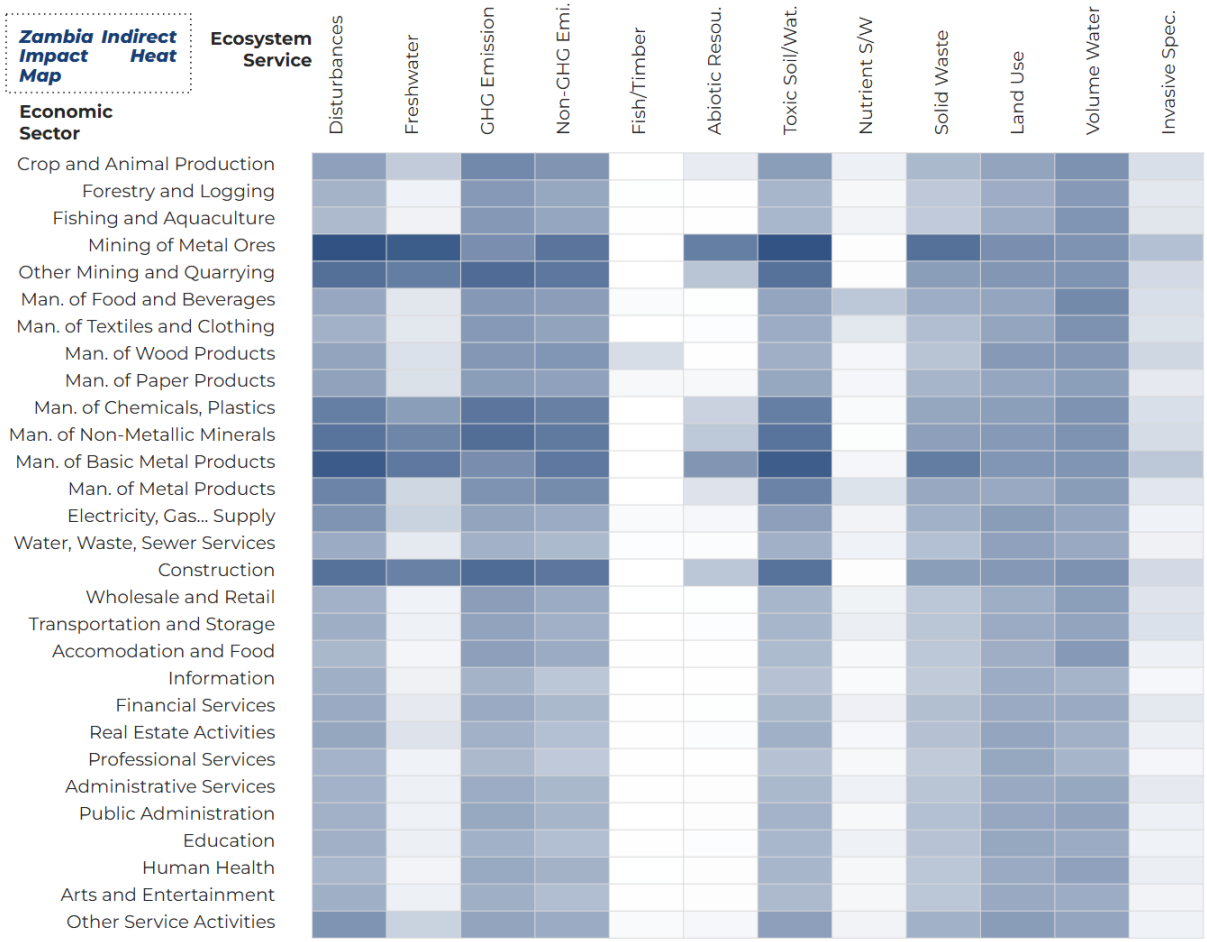
Source: Author based on ENCORE processes

Concerning indirect impacts, the analysis found that risks have cascaded across the entire economy as well. However, very high impacts have remained in some sectors, such as mining of metal ores. Common impacts across the entire economy, categorized by impact drivers,[29] include:

Climate change	Resource exploitation	Pollution	Invasive species	Land-, freshwater- and sea-use change
GHG emission Non-GHG emission	Solid waste generation	Disturbances (noise, light) Toxic soil and water pollution		Land use Volume of water used

[29] Defined by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the TNFD, there are **five impact drivers** that cause nature-related risks through loss of ecosystem services. These impact drivers are used to identify ecosystem vulnerabilities and degradation.

Figure 10: Heat Map of Indirect Impacts of Sectors on Natural Services



Source: Author based on IO table calculations

3.2 Nature Risks (Water and Supporting Services)

In this section, we turn to the risks posed by the current state of nature, making use of the methodology presented in Section 2.2. Firstly, nature risks in Zambia are compared internationally, with a focus on its closest neighbors. Next, water and biodiversity risks are broken down in turn at the provincial level. For water risks, this includes estimates of how they will change over time, based on various climate scenarios.

3.2.1 Cross-Country Comparison of Risks

Findings show that Zambia can be of moderate risk concerning the provision of ecosystem services to other countries within its vicinity and globally. Regarding the Water Risk Index, this is driven particularly by low relative risks for water availability (1.63 - 52nd)[30] and for water quality (1.83 - 31st), and higher relative risks of flooding (2.29 - 145th) and a lower current ecosystem services status (2.77 - 136th). This implies that business in Zambia, and as a result, the financial sector, need to be particularly concerned by the risks of flooded assets and operations, considering these within risk assessments, and seeking ways to reduce these risks, including via nature.

However, the Water Risk Index for Zambia and the rest of the region in 2030 and 2050 shows a significant absolute and relative increase in risk. From 2024 to 2030, Zambia's score increases by 0.49, lower than the regional average (0.52) but greater than the global average increase (0.41). This projected increase in risk means that Zambia's global rank in 2030 is 23 places lower than in 2024. At the indicator level, there is a general increase in risk, for water availability (↑0.44 - 68th), flooding (↑0.63 - 125th), water quality (↑0.93 - 40th), but not for ecosystem service status (↓0.04 - 151st). In 2050, the risk index sees a smaller increase, leading to a higher rank of 81st.

As for Supporting Services, Zambia's relative ranking in 2024 is much lower, the 3rd most at risk country in the region, behind only Zimbabwe and Malawi. This higher level of risk is driven especially by high risks concerning soil condition (4.13 - 175th), air quality (2.58 - 116th), and less so by ecosystem condition (2.61 - 77th) and pollination (1.59 - 69th). The score for soil condition is most alarming and indicates that the ecosystem services pertaining to it - that of soil retention and quality regulation - are not currently being well provided.

Table 2: Country-Level Comparison of Water and Supporting Services Risk

Country	Water Risk Index						Supporting Services Risk Index	
	2024[31]		2030		2050		2024	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Zambia	**2.13**	**69th**	**2.62**	**92nd**	**2.66**	**81st**	**2.73**	**111th**
Angola	1.96	50th	2.35	56th	2.46	59th	2.67	105th
Botswana	2.27	99th	2.75	111th	2.78	105th	2.65	102nd
Congo DRC	1.86	43rd	2.20	47th	2.30	51st	2.63	97th
Mozambique	2.24	94th	2.79	118th	2.81	110th	2.50	77th
Malawi	2.49	150th	2.95	140th	3.14	153rd	2.89	133rd
Namibia	2.25	97th	2.72	108th	2.73	88th	2.69	106th
Tanzania	2.06	60th	2.63	94th	2.78	104th	2.64	99th
Zimbabwe	2.36	124th	3.26	186th	3.27	174th	3.20	165th

[30] Lower scores constitute a better rank.
[31] 2024 country ranks are of 230. 2030 and 2050 ranks are of 229.

3.2.2 Provincial Water and Supporting Services Risk

At the province level, there is a lot of heterogeneity in the Water Risk Index score and of its contributory components. As of 2024, the most at-risk provinces - Southern, Lusaka, and Eastern (in order of risk) - can be found along the southern edge of the country. In general, each of these provinces have amongst the highest risk scores for Water Quality and Ecosystem Services Status. However, Southern and Lusaka have high relative scores for Flooding risk, with Eastern suffering from greater risks to Water Availability, implying greater baseline water stress.

When compared to country scores, Southern province would be tied-119th most at risk region. On the other hand, the Northern province - the least at-risk region - would be tied-44th.

Table 3: Present day provincial water risks

Province	Water Risk Index	Water Availability	Flooding	Water Quality	Ecosystem Services Status
Central	**2.12**	1.6	2.19	1.79	2.88
Copperbelt	**2.11**	1.8	1.79	1.79	3.06
Eastern	**2.27**	1.88	2.24	2.03	2.94
Luapula	**1.96**	1.13	2.58	1.74	2.4
Lusaka	**2.32**	1.51	2.54	2.17	3.05
Muchinga	**2.03**	1.48	2.23	1.82	2.6
North-Western	**2.08**	1.81	2.19	1.63	2.7
Northern	**1.88**	1.14	2.17	1.79	2.42
Southern	**2.35**	1.64	2.65	2	3.09
Western	**2.23**	1.92	2.33	1.87	2.81

Source: Author

Beyond 2024, all of Zambia's provinces see significant increases in risk to 2030, regardless of the scenario, and by 2030 even the least at-risk province has a higher score than the riskiest province in 2024. Relatively high-risk provinces from 2024 remain riskier, however, Lusaka becomes by far the most at-risk province when it comes to water - its score increasing by 0.75. In 2030, compared to other countries, this would make the province tied-156th most at risk. This score would mean that, in the present day, Lusaka would be the 222nd most at-risk region (and the highest in Africa), suffering from equivalent water-related risks as the Dominican Republic, and greater than countries like Pakistan and Sri Lanka. This substantial increase is driven by the respective score changes at the indicator level: Water Availability - ↑0.61 to 2.12; Flooding - ↑0.29 to 2.83, Water Quality - ↑0.98 to 3.15; Ecosystem Services Status - ↑1.13 to 4.18. The result is that the financial sector must be increasingly wary of the implications that ecosystem and water quality degradation will have on economic activity, and therefore their returns, particularly when investments depend strongly on these services.

In 2050, provinces are not expected to suffer from a further increase in risk. Under the central projected scenario, three provinces - North-Western, Southern, and Western - are estimated to have lower risks than in 2030, although in Southern province the overall risk remains high. Nonetheless, Lusaka and Eastern provinces continue to face greater risks to water-related ecosystem services.

Table 4: Current and future water risks under different scenarios

Province	Water Risk Index	2030 Water Risk Index			2050 Water Risk Index		
		Optimistic	Central	Pessimistic	Optimistic	Central	Pessimistic
Central	**2.12**	2.67	**2.66**	2.66	2.69	**2.76**	2.82
Copperbelt	**2.11**	2.54	**2.52**	2.48	2.47	**2.65**	2.64
Eastern	**2.27**	2.92	**2.87**	2.99	2.99	**2.98**	3.08
Luapula	**1.96**	2.32	**2.43**	2.42	2.40	**2.52**	2.48
Lusaka	**2.32**	3.04	**3.07**	3.08	3.11	**3.18**	3.22
Muchinga	**2.03**	2.55	**2.63**	2.70	2.67	**2.71**	2.74
North-Western	**2.08**	2.50	**2.40**	2.40	2.38	**2.39**	2.39
Northern	**1.88**	2.32	**2.46**	2.46	2.44	**2.56**	2.53
Southern	**2.35**	2.92	**2.84**	2.93	2.84	**2.83**	3.02
Western	**2.23**	2.71	**2.69**	2.65	2.72	**2.61**	2.64

Source: Author

Regarding Supporting Services, the at-risk provinces remain consistent as - identical to the Water Risk Index - Lusaka, Eastern, and Southern provinces see the highest scores. This appears to be driven by one indicator in particular - Ecosystem Condition - which is linked with biodiversity intactness. Equally important for biodiversity risks in the country is the pervasiveness of high scores related to soil condition, and the implications that this may have for economic activity, especially agriculture.

Table 5: Present day provincial supporting services risks

Province	Supporting Services Risk Index	Soil Condition	Air Condition	Ecosystem Condition	Pollination
Central	**2.78**	4	2.27	2.91	1.95
Copperbelt	**2.84**	4	2.99	2.85	1.53
Eastern	**2.93**	4	2.37	3.15	2.18
Luapula	**2.64**	4	3	1.65	1.89
Lusaka	**3.01**	4	2	4.06	1.97
Muchinga	**2.66**	4	2.62	2.42	1.6
North-Western	**2.60**	4	3	2.33	1.06
Northern	**2.64**	4	2.95	1.67	1.93
Southern	**2.88**	4.28	2	3.36	1.89
Western	**2.68**	4.57	2.43	2.71	1.01

Source: Author

The WRF provides 2024 scores for drought risk in Zambia. The results reveal the severity of the risk faced by businesses and the financial sector to drought even in the current day. Globally, Zambia is one of the highest risk countries in the world. Provincially, this translates to consistently high risks across the country, with Copperbelt, Lusaka, and Central provinces particularly exposed to drought risk.

As stated, the WRF does not provide future scenario scores for drought risk. Instead, we therefore make use of the World Bank's climate change knowledge portal. The World Bank's data portal makes for a reasonable comparison with the WRF as both make use of the SPEI (Standardised Precipitation Evapotranspiration Index), which is commonly used as a proxy for drought risk. To maintain comparability, we use the projection from SSP2 (Shared Socioeconomic Pathway 2), which is also used for the centrally projected scenario in the WRF. At the national level, SPEI scores are taken from the specific year, whilst at the provincial level, average scores across time ranges are used (2020-2039 and 2040-2059). Finally, for SPEI, we use the anomaly, or the change in the index from its historical baseline (1990-2014).

The results show that Western and North-Western provinces are going to see the highest increase in drought risk under SSP2 until 2050. This could pose an issue for business and the financial sector as, given current risks are quite low, economic activity in the region may have low levels of resilience to drought. However, importantly, the next most affected provinces are Copperbelt, Central, and Lusaka, which we noted previously have the highest level of present-day drought risk, suggesting financial sector actors need to be incredibly wary of this threat both now and in the future.

Table 6: Current and Future Provincial Drought Risk in Zambia

Region	2024 Drought Risk	2030 SPEI Anomaly	2050 SPEI Anomaly
Zambia	3.61 (166th)	-0.09	-0.29
Central	3.96	-0.17	-0.27
Copperbelt	4.32	-0.09	-0.33
Eastern	3.47	-0.12	-0.16
Luapula	3.83	-0.03	-0.16
Lusaka	4.05	-0.2	-0.25
Muchinga	2.99	-0.13	-0.1
Northern	3.81	-0.1	-0.08
North-Western	3.3	-0.19	-0.42
Southern	3.69	-0.15	-0.3
Western	3.44	-0.22	-0.4

Source: Author

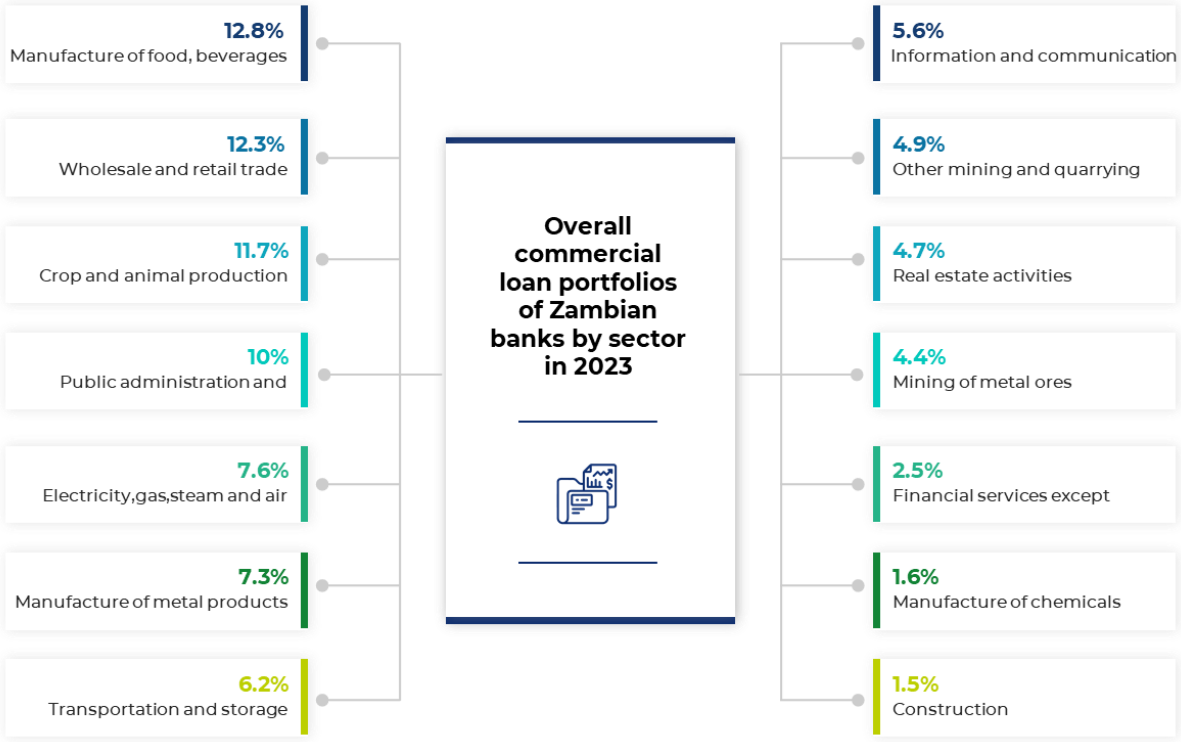
4.1 Banking Sector

4.1.1 Portfolio Breakdown

At a sectoral level, commercial portfolios were not heavily concentrated. However, sectors that individually received greater than 10% of loans from the banking institutions were (see Figure 11):

- Manufacture of food and beverages - 12.8%
- Wholesale and retail - 12.3%
- Crop and animal production - 11.7%
- Public administration - 10.0%

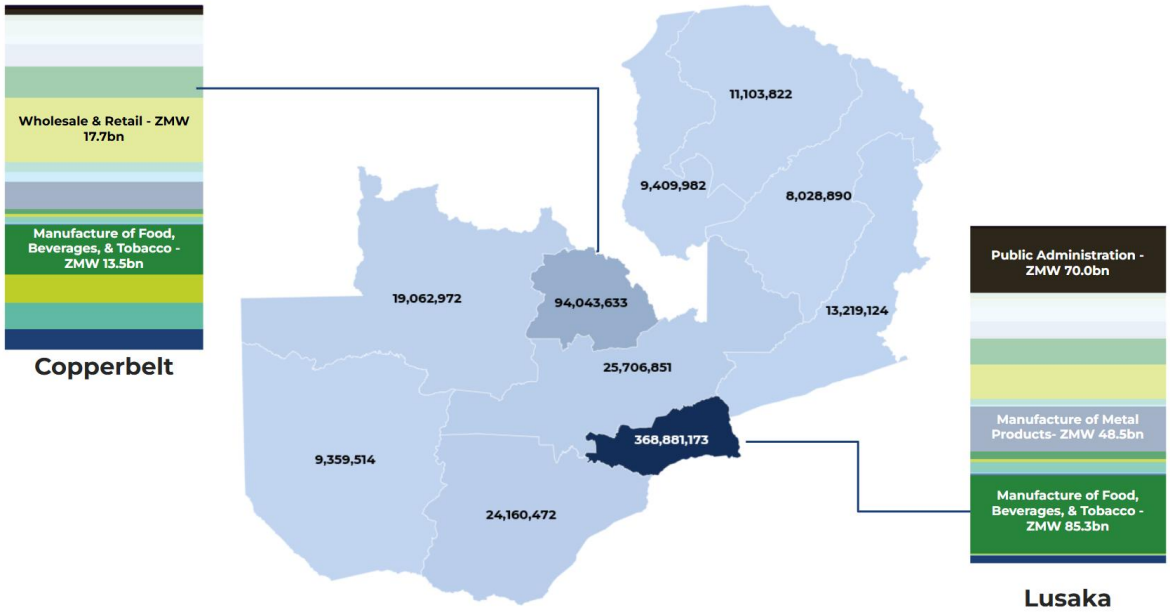
Figure 11: Overall commercial loan portfolios of Zambian banks by sector in 2023



Source: Author

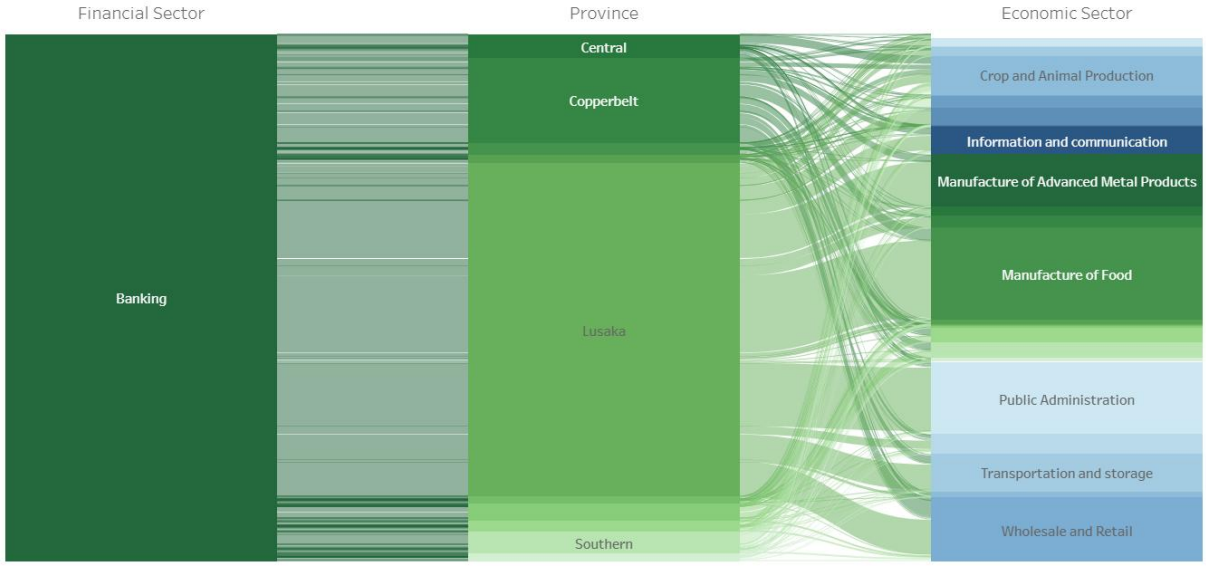
Geographically, the portfolio was highly concentrated, with almost 80% of total lending going to two provinces - Lusaka (63.28%) and Copperbelt (16.13%). Within Lusaka, the sectoral composition was unique. The province is estimated to be responsible for most loans to public administration and the manufacture of metal products. 3 provinces: Western, Luapula, and Muchinga were individually recipient to less than 2% of the total commercial loan portfolio.

Figures 12: Commercial loan portfolios by Zambian banks by province in 2023 (ZMW thousands)



Source: Author

Figure 13: Financial exposure of Zambia's commercial loan portfolios and associated economic sectors



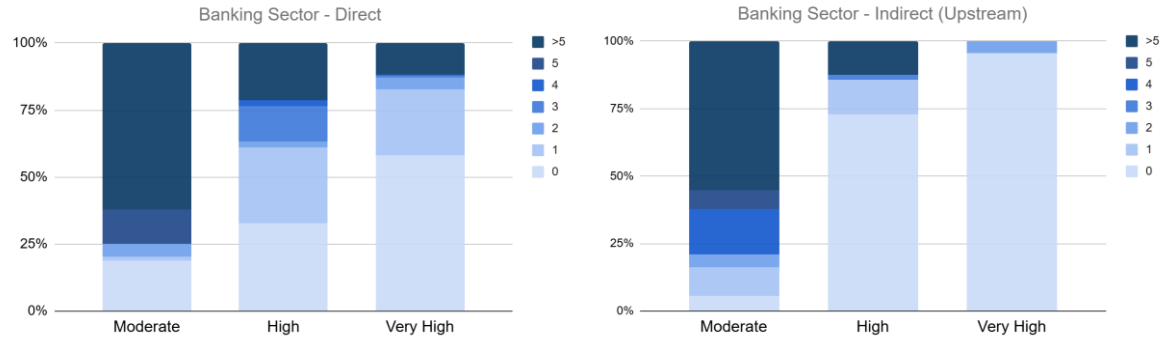
Source: Author

4.1.2 Direct and Indirect Dependencies

The banking sector portfolio is one of the most affected by nature risks of all the financial sectors in Zambia. In terms of direct impacts, 75% of the banking sector portfolio (ZMW 437.25 billion | USD 21.64 billion) was found to be moderately dependent on 5 or more ecosystem services. Looking at more critical dependencies, almost 70% of the portfolio was highly dependent on at least 1 ecosystem services and 21% was highly dependent on more than 5 services. Concerning very severe dependencies, 42% of the sector were very highly dependent on an ecosystem service, with 12% very highly dependent on more than 5.

80% of the portfolio was indirectly moderately dependent on at least 3 services, with 55% reliant on more than 5. Only 27% were highly dependent on a nature-related service However, 4% of the portfolio was still indirectly very highly dependent via investments in the mining sector.

Figure 14: Share of commercial loan portfolio directly (through own activities) and indirectly (through upstream activities) dependent on n ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)

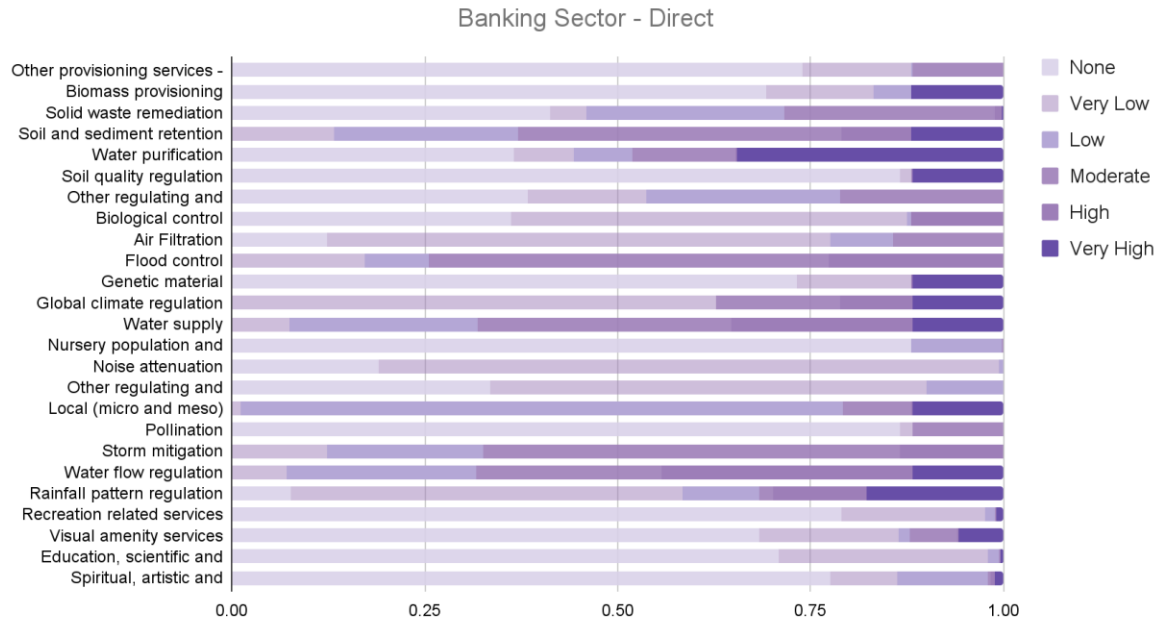


Source: Author

Compared to other financial sectors, analysis found that banking had a disproportionately greater relative investment in crop and animal production. In the results, this led to a particular dependency on many of the services that this sector relies on. The key dependencies of the banking portfolio are found in the table below. The brackets alongside each service represent the percentage of the portfolio that is directly and indirectly at least moderately dependent on this respective service.

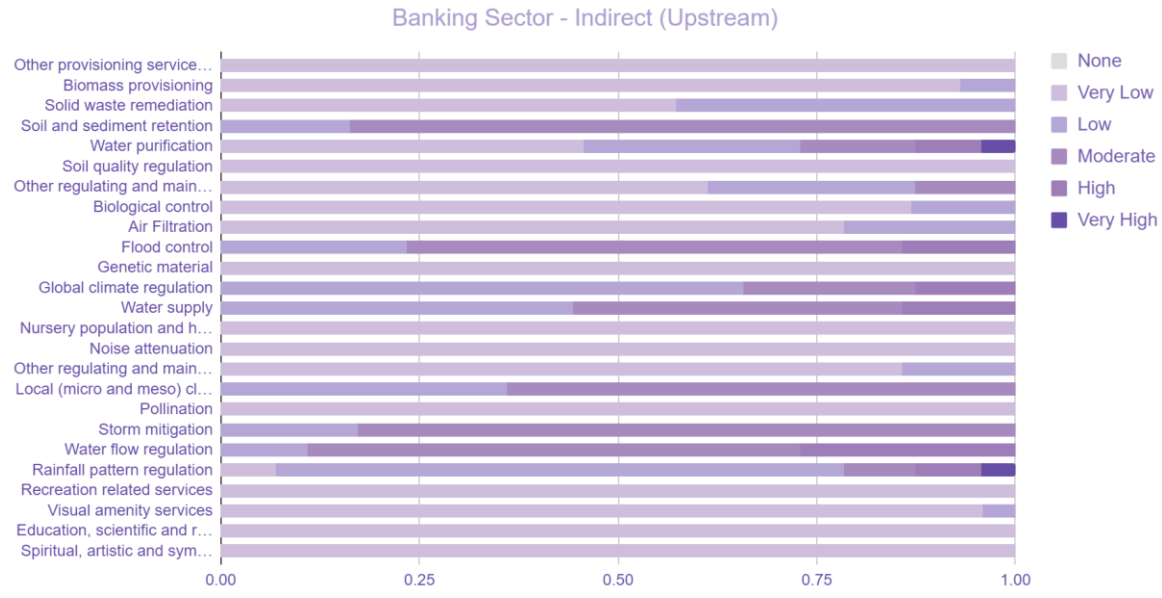
Provisioning	Regulating and maintenance	Cultural
Water supply (68/56)	Soil and sediment retention (63/84) Water purification (48/27) Local climate regulation (21/64) Storm mitigation (67/83) Water flow regulation (68/89)	N/A

Figure 15: Direct dependencies of commercial loan portfolio on individual ecosystem services



Source: Author

Figure 16: Indirect dependencies of commercial loan portfolio on individual ecosystem services



Source: Author

4.1.3 Nature Risks to the Portfolio

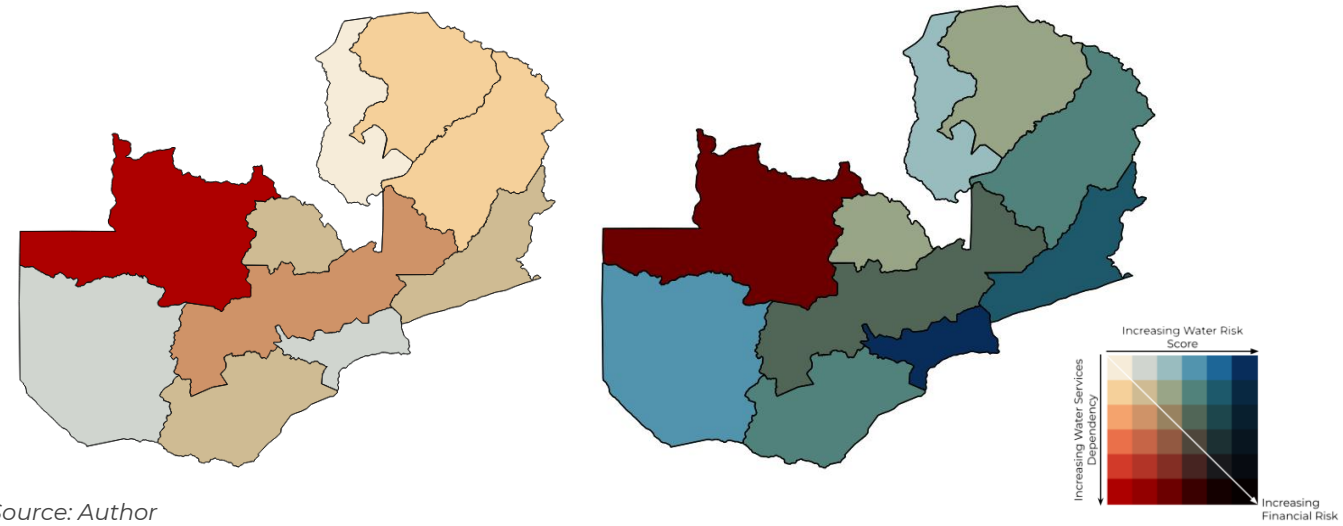
Water-related risks and dependencies are combined in Figure 17. The results show that, if portfolios remain the same, commercial loans will be far more vulnerable to water-related risks. North-western and Central provinces are likely to be particularly vulnerable due to a combination of high risks and dependencies. Equally, future commercial loans in Lusaka and Eastern provinces will need to be wary of their dependence on water-linked ecosystem services, as both are estimated to have much greater risks from now until the mid-century.

Table 7: Banking portfolio dependency on water and supporting services

Province	Portfolio Water Dependency	Portfolio Support Services Dependency
Central	0.54	0.31
Copperbelt	0.49	0.15
Eastern	0.50	0.33
Luapula	0.42	0.21
Lusaka	0.41	0.11
Muchinga	0.48	0.29
Northern	0.49	0.32
North-Western	0.70	0.17
Southern	0.46	0.18
Western	0.41	0.24

Source: Author

Figure 17: Bivariate graph - provincial water service dependency and 2024 (left) and 2050 (right) water risk scores for the banking sector

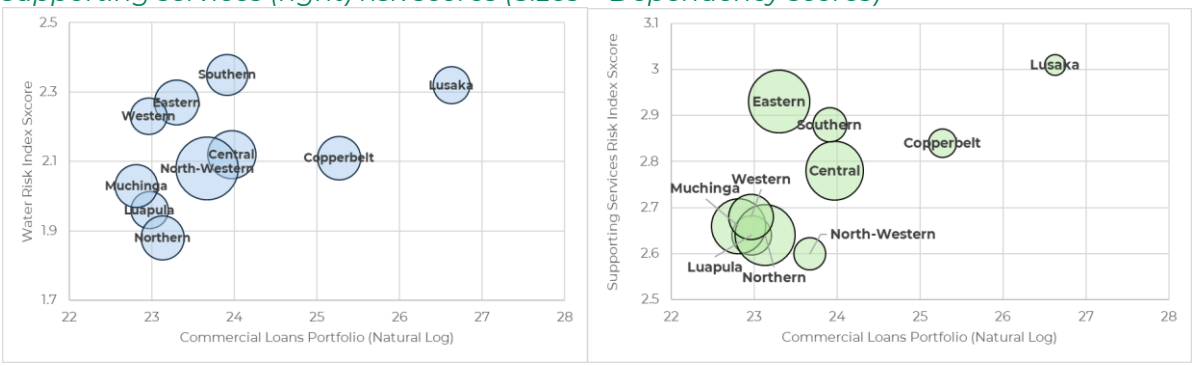


Source: Author

Commercial loan analysis - banking sector

Provincial differences in the level of financing must also be considered. In figure 18, provincial water and supporting services risk scores are plotted against dependencies and the size of the respective commercial loan portfolio (natural logarithms are taken for graph visibility). The results show an interesting pattern: provinces with higher nature-related risks - at least for water and supporting services - also appear to receive greater financing from the banking sector.

Figure 18: Provincial commercial loans portfolios against provincial water (left) and supporting services (right) risk scores (Sizes = Dependency scores)



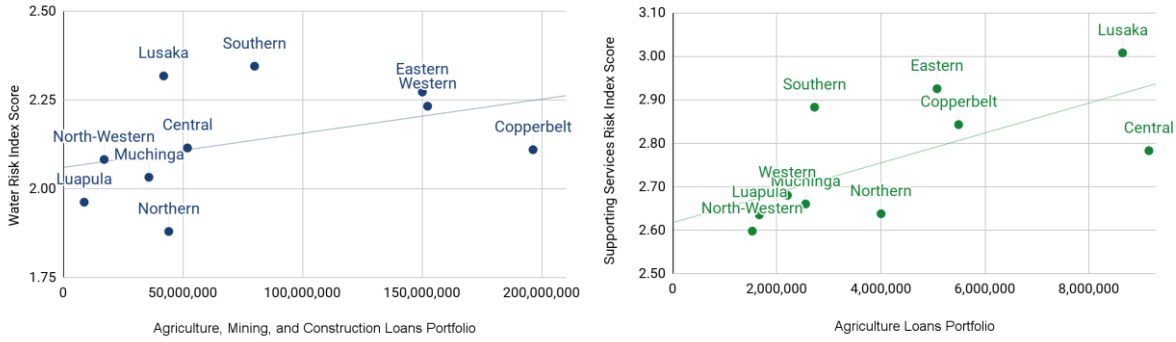
Source: Author

Whilst there may be a positive association between ecosystem risks and financial sub-sector portfolio size, this does appear to be mitigated by low relative dependencies in these provinces. For instance, Lusaka has the lowest dependency on water and supporting services of all of the provinces. This is due to the lower relative investment in sectors that are more reliant on functioning water ecosystems. The association between provincial nature risks and high dependency investments in the banking sector is displayed in Figure 19.

For the highly dependent sectors, the analysis uses any sector with a dependency score of 0.7 or greater. For water, this constitutes agriculture, mining, and construction and, for supporting services, solely agriculture. Overall, provinces with higher ecosystem service risks also tend to receive greater levels of investments in sectors that are dependent on them.

Figure 19: Provincial water (left) and supporting services (right) risk scores against commercial loans portfolios in highly dependent sectors[32]

[32] Trend lines have been added to aid the visualization of data patterns. They are not to be interpreted as implying a relationship between the variables.



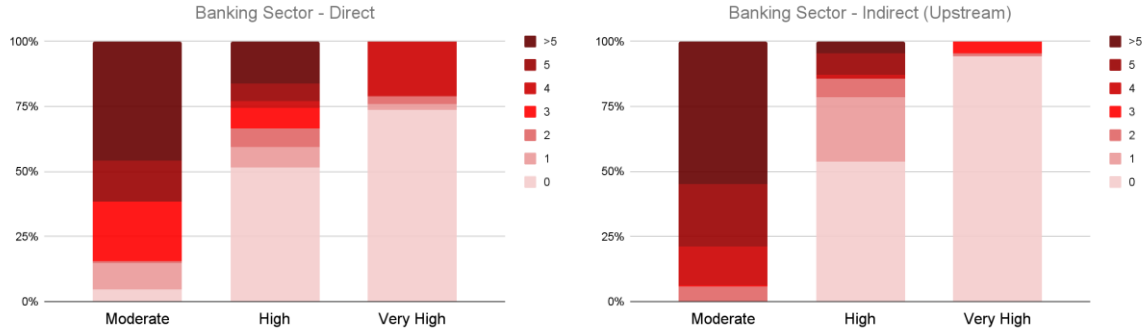
Source: Author

4.1.4 Direct and Indirect Impacts

The banking sector's activity has significant impacts on nature. More than 60% of the commercial loans' portfolio exerts at least five direct moderate pressures on nature. Roughly 25% of the portfolio directly impacts nature very highly in at least one way.

Similar proportions of the banking portfolio impact on nature indirectly. The entire portfolio moderately impacts on nature (vs. 95% for direct impacts), whilst 46% of the portfolio is highly indirectly impactful on nature (vs. 48% directly). However, for very high impacts, there is a greater disparity (6% vs. 26%).

Figure 20: Share of commercial loan portfolio directly (through own activities) and indirectly (through upstream activities) dependent on n ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)

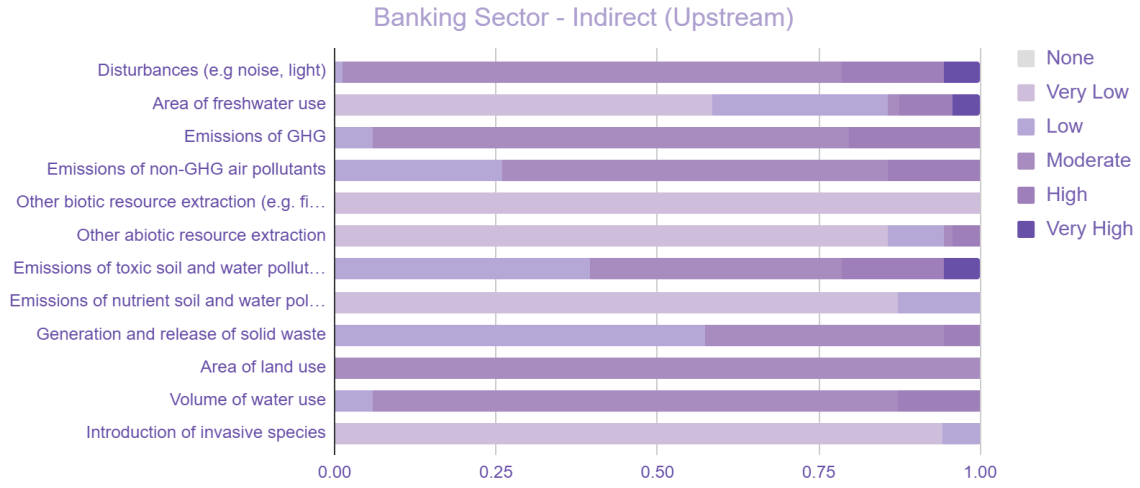


Source: Author

The banking sector impacts nature in several ways. In particular, the volume of freshwater use, driven by loans to agriculture and food and beverage manufacturing, serves as a key impact. Alongside this, the sector also impacts nature via the emission of toxic pollutants and the generation of solid waste. The key impacts of the banking portfolio are found in the table below. The brackets alongside each service represent the percentage of the portfolio that is directly and indirectly at least moderately impacting on nature in the specified way.

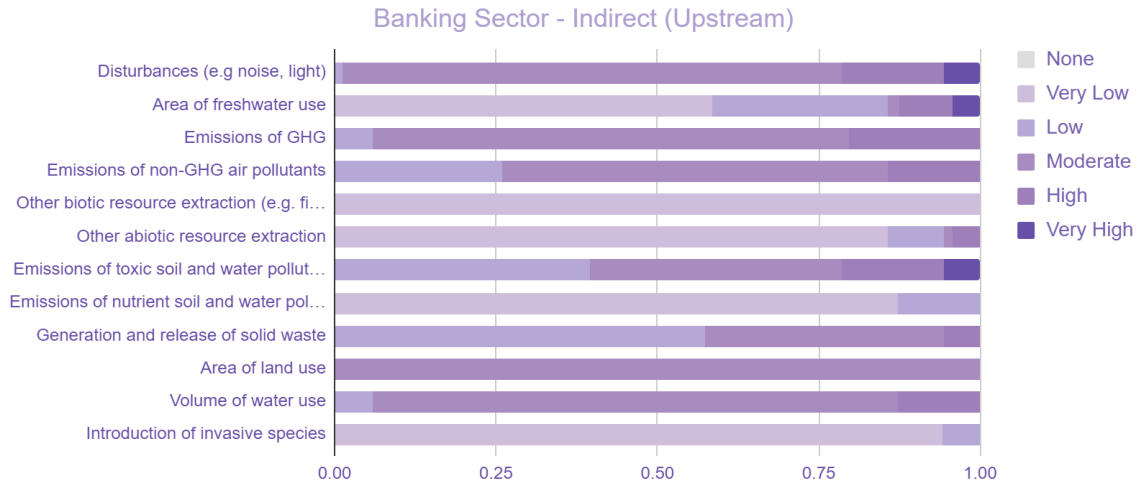
Climate change	Resource exploitation	Pollution	Invasive species	Land-, freshwater- and sea-use change
GHG emission (74/94) Non-GHG emission (65/74)	Solid waste generation (59/43)	Disturbances (noise, light) (67/99) Toxic soil and water pollution (55/60)	N/A	Land use (44/100) Volume of water used (83/94)

Figure 21: Relative direct commercial loan portfolio exposure with high or very high impacts (physical risk)



Source: Author

Figure 22: Relative indirect commercial loan portfolio exposure with high or very high impacts (physical risk)



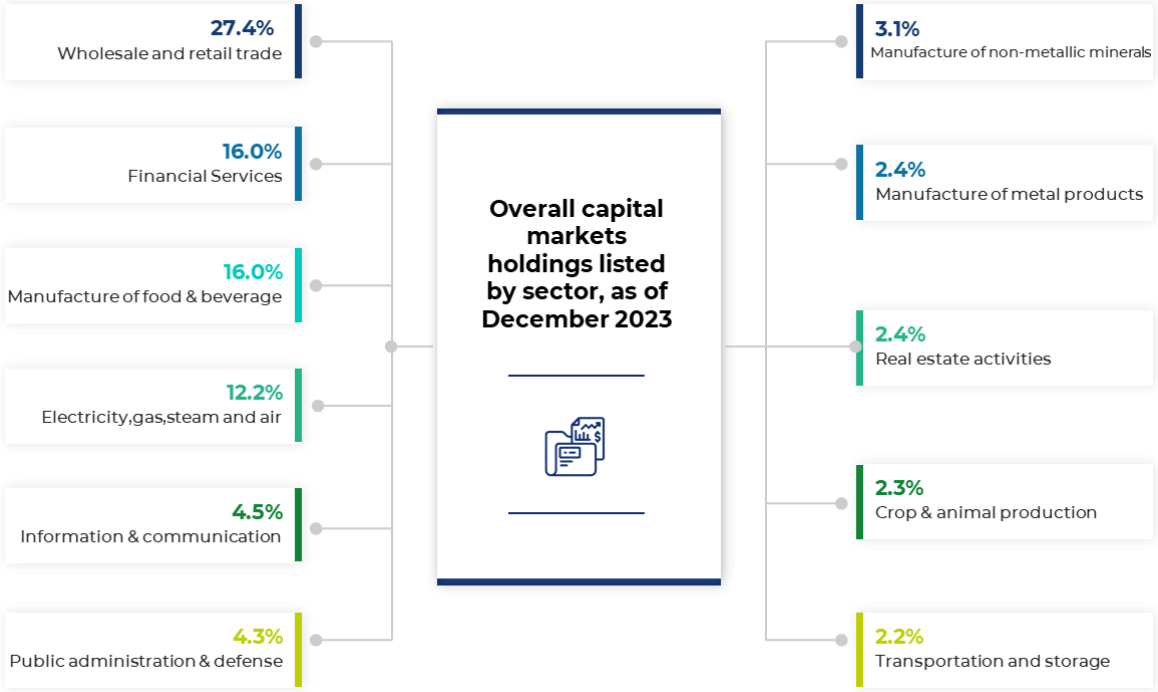
Source: Author

4.2 Capital Markets Sector

4.2.1 Portfolio Breakdown

Key sectors for the capital markets portfolio are wholesale and retail (27.4%), financial services (16.0%), and the manufacture of food and beverage (16.0%). This is driven by the value of Shoprite Holdings Plc in the wholesale and retail sector, Zambia National Commercial Bank Plc and Standard Chartered Bank Zambia Plc in the financial services sector, and Zambia Sugar Plc and National Breweries Plc in the food and beverages sector.

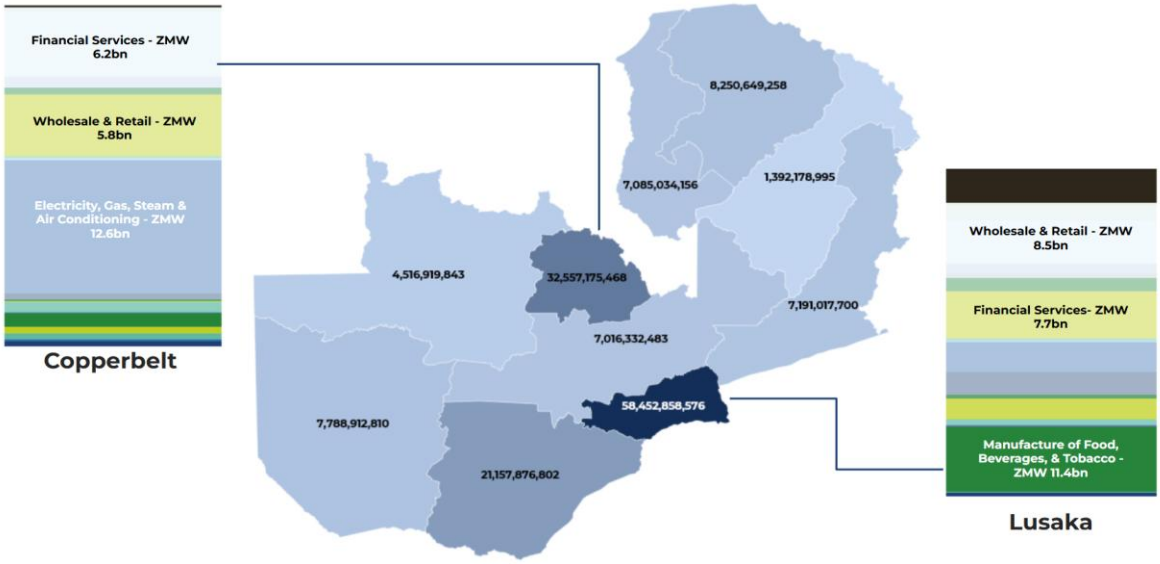
Figure 23: Overall capital markets holdings listed by sector, as of December 2023



Source: Author

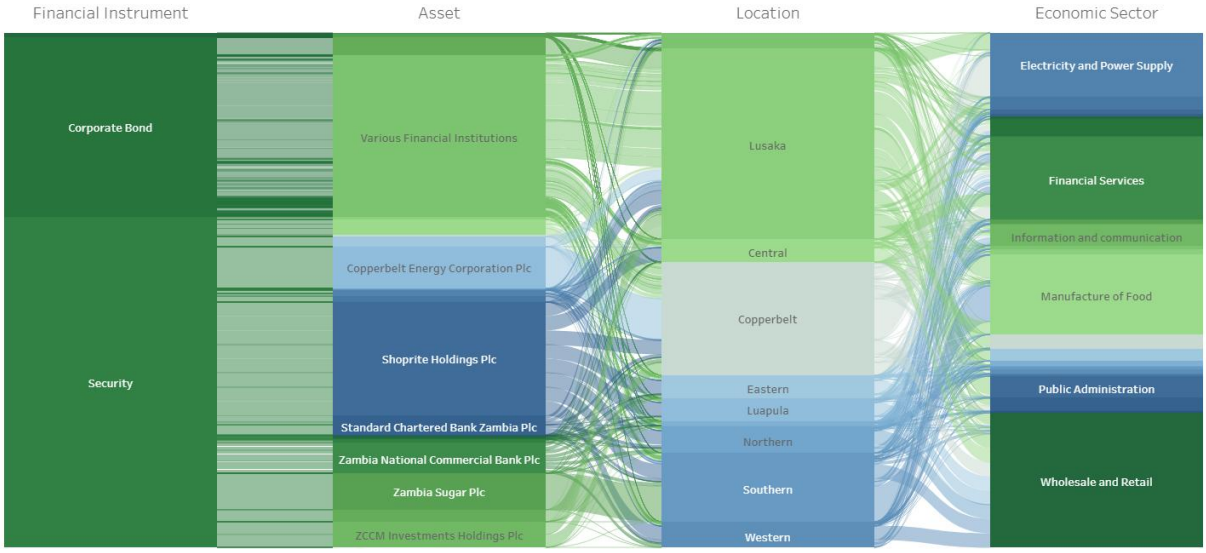
Geographically, the securities portfolio is spread across the country. However, the provinces that contribute most to the capital markets portfolio are Lusaka, Copperbelt, and Southern provinces. In Lusaka, the key sectors in the portfolio match those at the national level. On the other hand, in Copperbelt, the dominant sector is power provision.

Figure 24: Capital markets holdings by province, as of December 2023



Source: Author

Figure 25: Financial exposure of Zambia's capital markets holdings and associated economic sectors



Source: Author

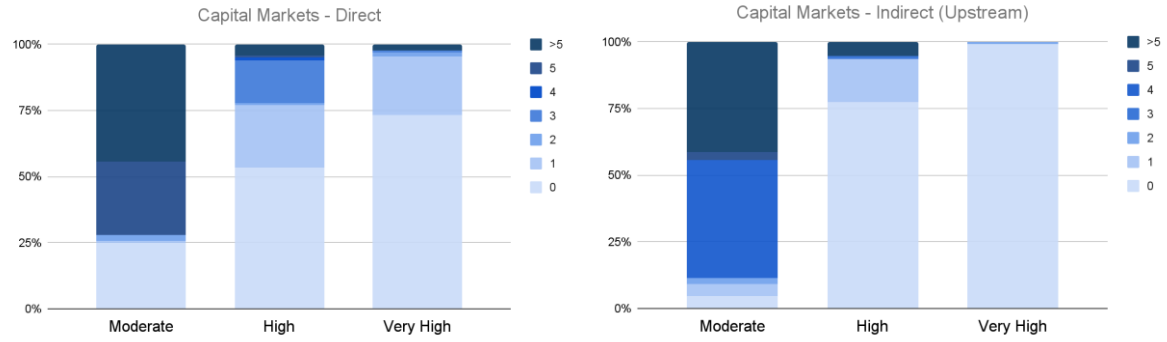
4.2.2 Direct and Indirect Dependencies

In the capital markets sector, nature-related risks are lower than banking. However, direct risks remain widespread. 70% of the capital markets portfolio is moderately dependent on 5 or more

ecosystem services. Almost half of the portfolio is highly dependent on at least 1 ecosystem services and 22% is highly dependent on at least 3 services. 27% of total portfolio value is critically dependent on an ecosystem service.

For indirect risks, the analysis tells a similar story: moderate risks are more pervasive but severe risks are diminished. 90% are indirectly moderately dependent on at least 2 services and 40% was found to be reliant on more than 5. Despite a lower indirect high dependence on nature (23% vs 47%), more (5.3% vs. 4.1%) are highly dependent on >5. Only 0.8% of the portfolio is indirectly very highly dependent on two ecosystem services.

Figures 26: Share of capital markets holdings directly (through own activities) and indirectly (through upstream activities) dependent on n ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)

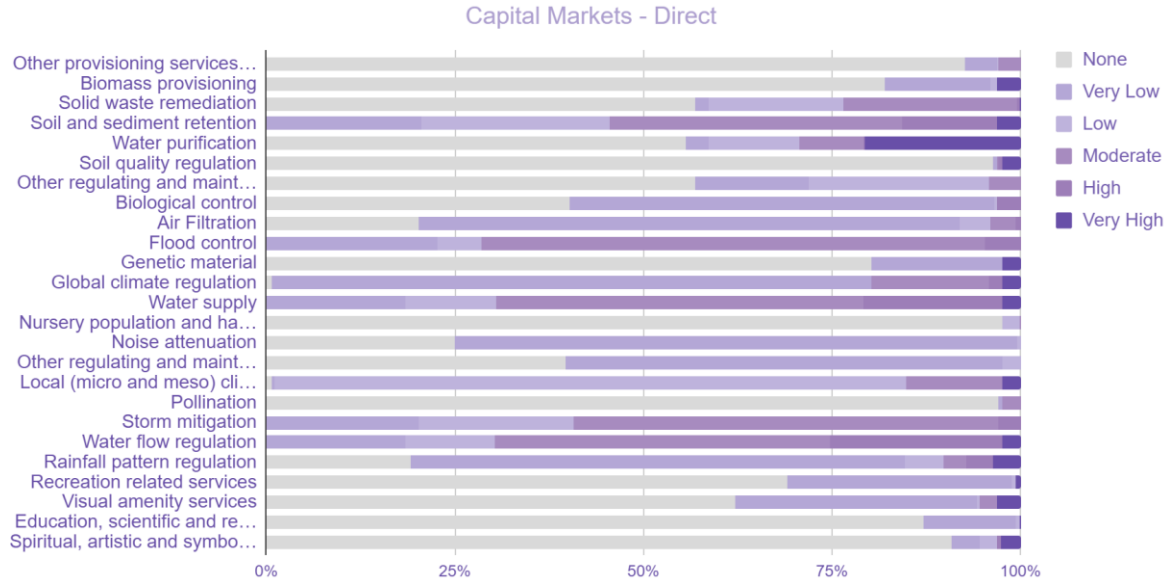


Source: Author

The capital markets portfolio, through listed securities, has a disproportionate composition of financial services and information and communication sectors. These sectors have no direct dependencies on nature and very few indirect dependencies, and this is therefore a key reason for the lower relative exposure of the sector compared to banking and insurance. Nonetheless, the portfolio was still found to have a number of key dependencies:

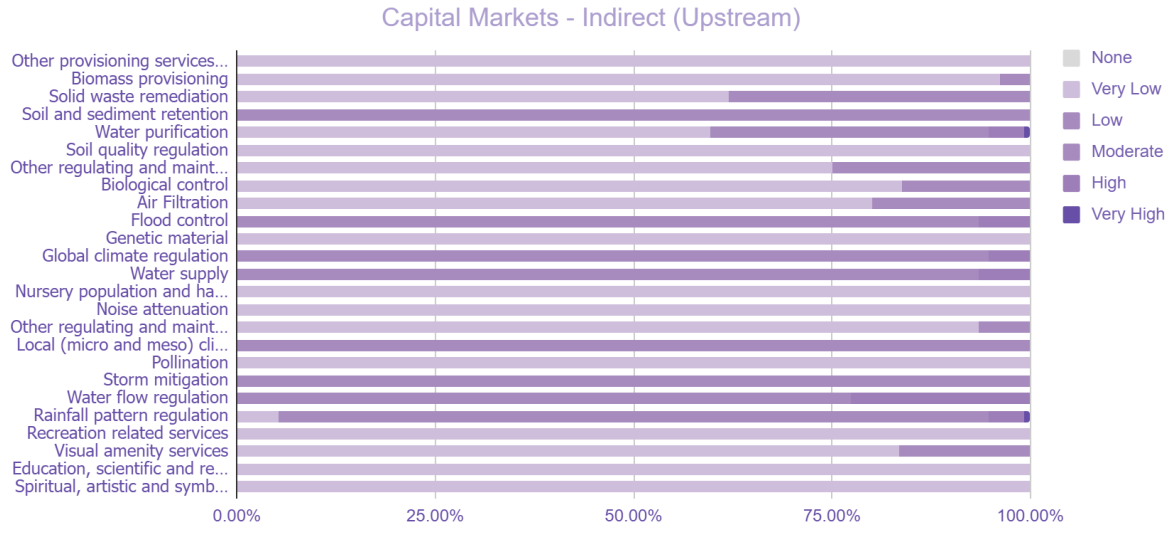
Provisioning	Regulating and maintenance	Cultural
Water supply (70/42)	Soil and sediment retention (54/91) Flood control (72/73) Storm mitigation (59/91) Water flow regulation (70/93)	N/A

Figure 27: Direct dependencies of capital markets holdings on ecosystem services



Source: Author

Figure 28: Indirect dependencies of capital markets holdings on ecosystem services



Source: Author

4.2.3 Nature Risks to the Portfolio

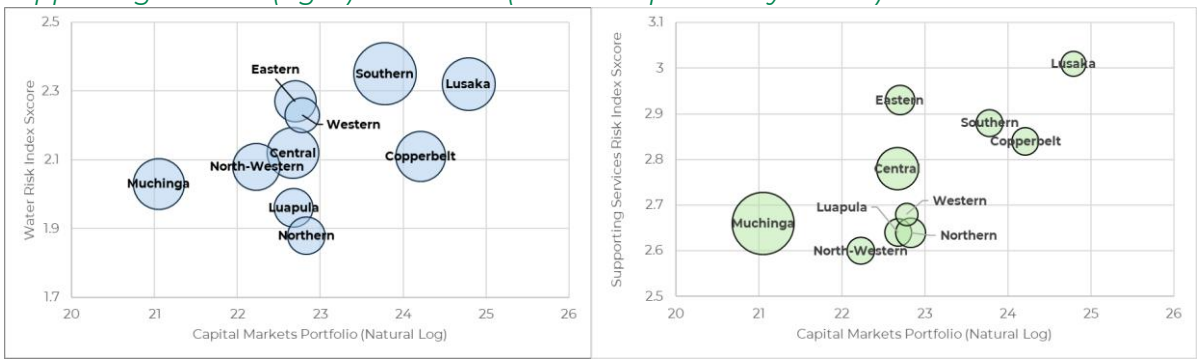
Actors in capital markets should be incredibly wary of water risks in their portfolios. The three provinces with the greatest activity in the portfolio (Lusaka, Copperbelt, Southern) have a dual issue of relatively high dependencies and water risks. On the dependency side, this is driven by agri-food investments in Lusaka and Southern provinces, and mining investments in the Copperbelt. The results for supporting services are a little more reassuring. While there is a persistent positive association between investment and natural risk, the only province where the portfolio is dependent on these services is Muchinga, which overall sees low investments and has a relatively lower risk.

Table 8: Capital Markets portfolio dependency on water and supporting services

Province	Portfolio Water Dependency	Portfolio Support Services Dependency
Central	0.37	0.17
Copperbelt	0.36	0.11
Eastern	0.30	0.12
Luapula	0.28	0.11
Lusaka	0.38	0.10
Muchinga	0.37	0.25
Northern	0.27	0.12
North-Western	0.34	0.11
Southern	0.45	0.11
Western	0.25	0.09

Source: Author

Figure 29: Provincial capital markets portfolios against provincial water (left) and supporting services (right) risk scores (Sizes = Dependency scores)



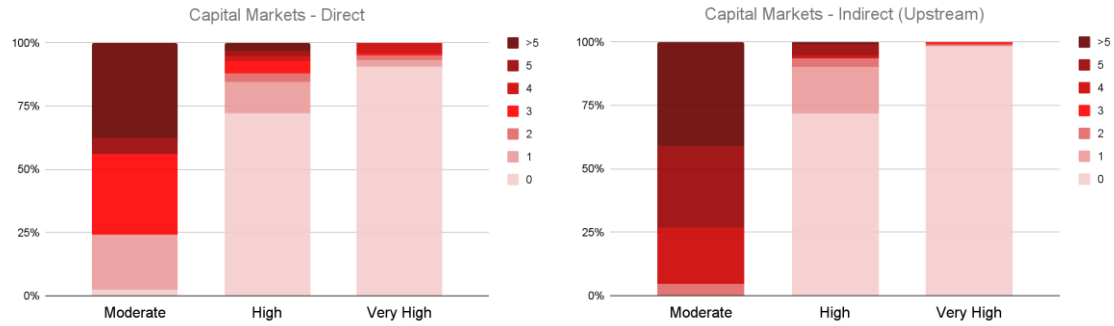
Source: Author

4.2.4 Direct and Indirect Impacts

In capital markets, the general story is like the banking sector. Both directly and indirectly, the sector's portfolio almost universally impacts on nature in at least a moderate way (98% and 100%). However, overall, the sector is less impactful on nature than banking and insurance due to lower levels of high and very high impacts driven by the greater representation of the wholesale and retail, and the financial services sector.

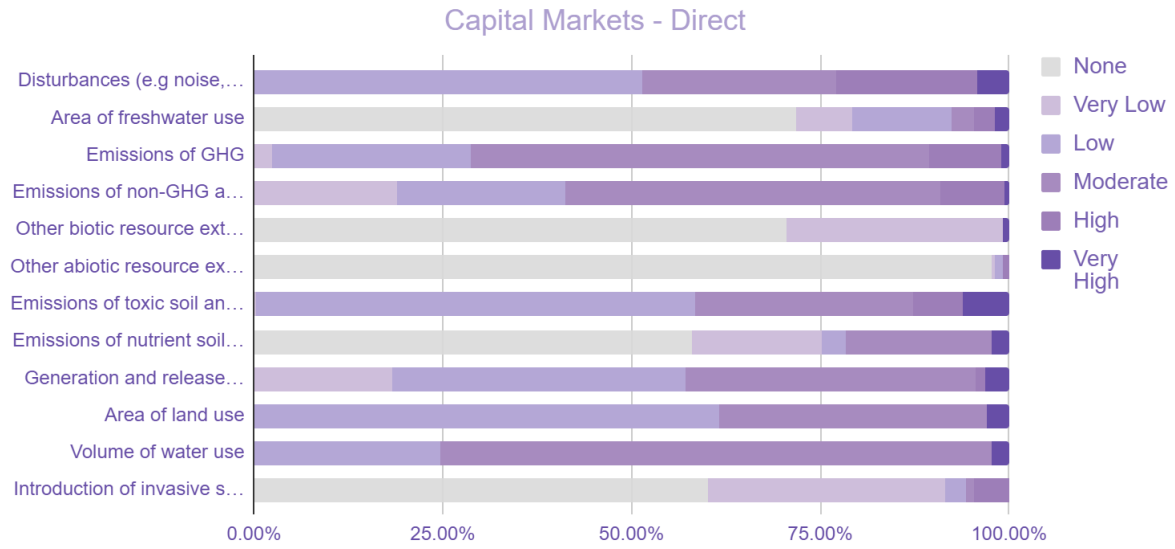
Climate change	Resource exploitation	Pollution	Invasive species	Land-, freshwater- and sea-use change
GHG emission (48/99)	N/A	Disturbances (noise, light) (71/95)	N/A	Land use (38/100) Volume of water used (75/95)

Figure 30: Capital market holdings and ecosystem services dependencies per Zambia kwacha invested (in million ZMW)



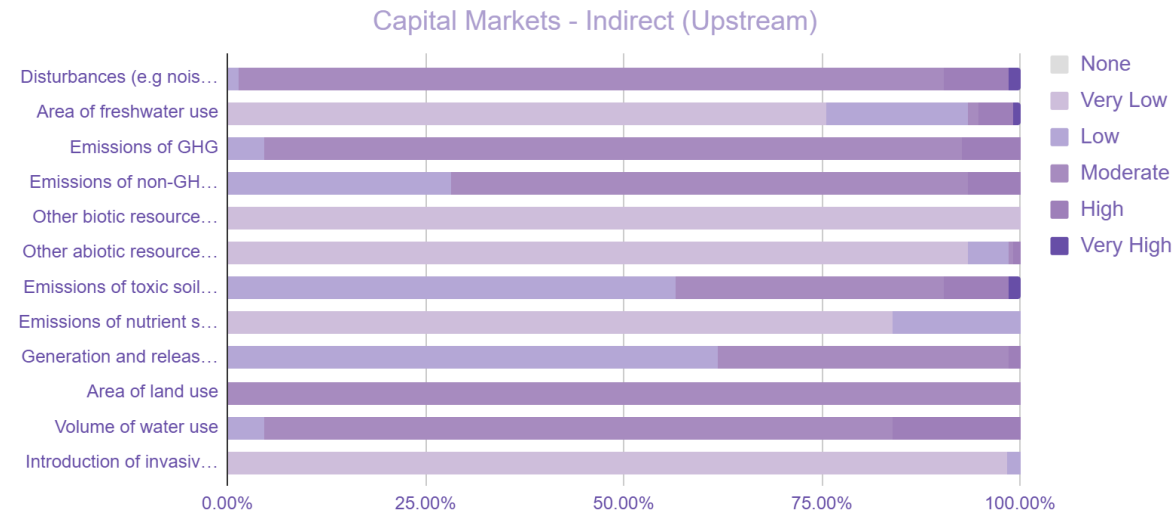
Source: Author

Figure 31: Relative direct capital markets holdings exposure with high or very high impacts (physical risk)



Source: Author

Figure 32: Relative direct capital markets holdings exposure with high or very high impacts (physical risk)



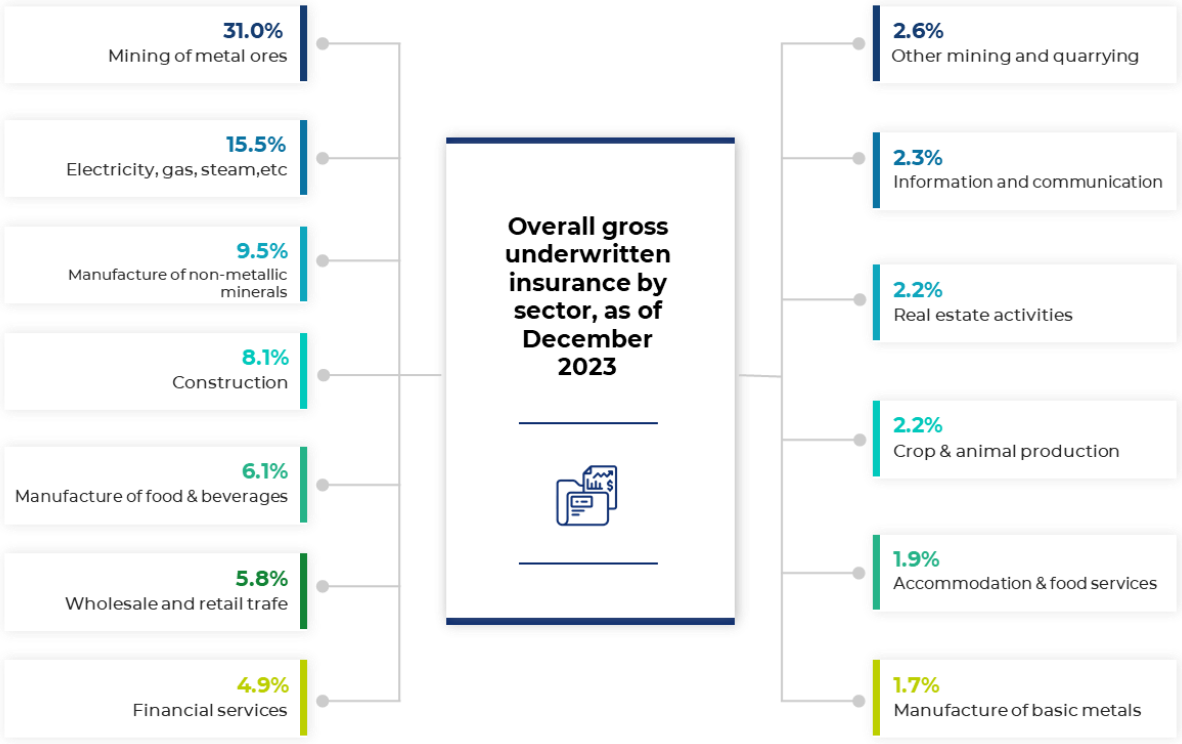
Source: Author

4.3 Insurance Sector

4.3.1 Portfolio Breakdown

The exposure of the insurance sector is more concentrated than the baking sector. Almost half of the portfolio analyzed is directed to the mining of metal ores (31.0%), and the supply of electricity, gas, steam, and air conditioning (15.5%).

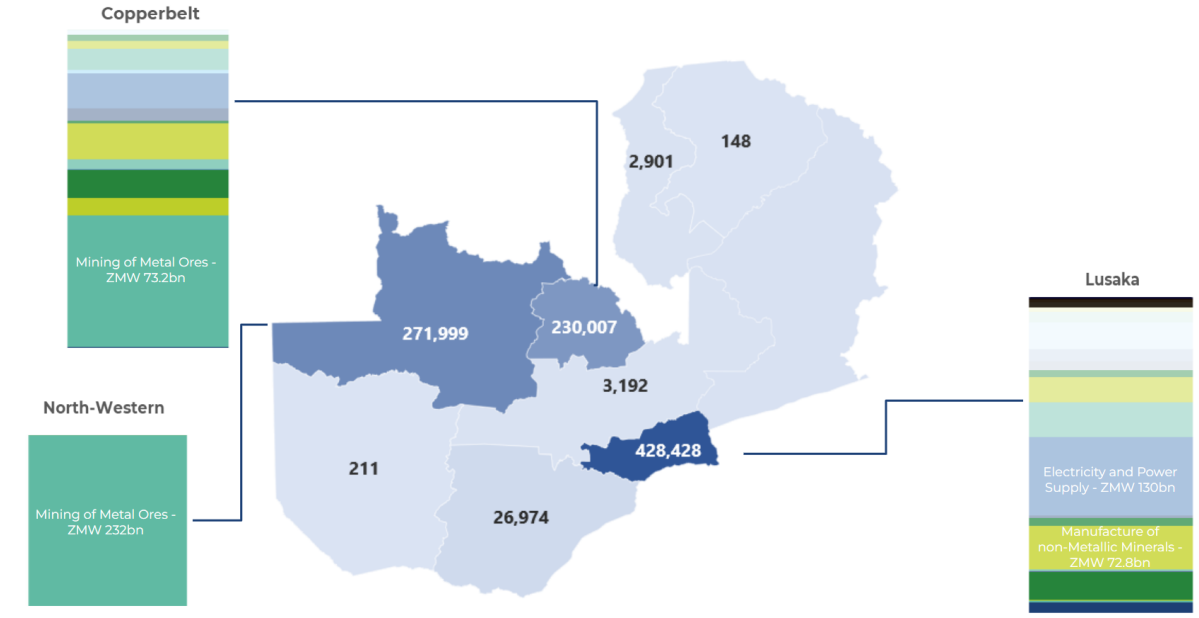
Figure 33: Overall gross underwritten insurance by sector, as of December 2023



Source: Author

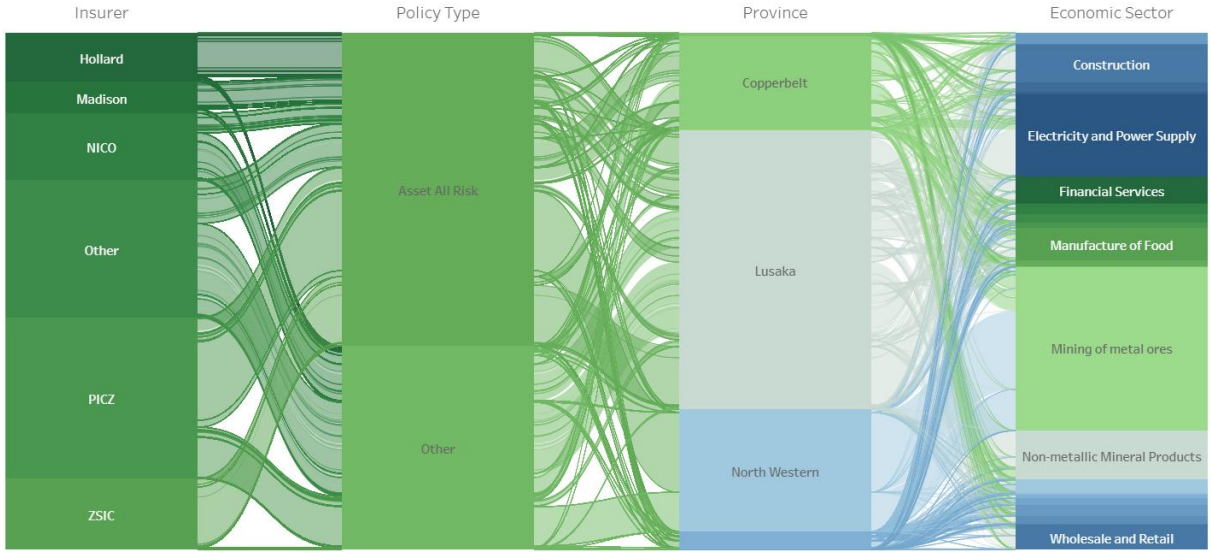
Compared to other financial sector portfolios, Lusaka constitutes a smaller portion of the insurance portfolio, nonetheless, ~95% of total exposure is spread across Lusaka, Copperbelt, and North-Western provinces. Within provinces, sector coverage is also highly concentrated. In North-Western province, insurance is mainly provided to the mining of metal ores. Similarly, in the Copperbelt, mining dominates. In Lusaka, power provision is the main sector, representing nearly half of the provincial exposure.

Figure 34: Gross underwritten insurance by province in 2023 (ZMW millions)



Source: Author

Figure 35: Financial Exposure of Zambia's gross underwritten insurance and associated economic sectors



Source: Author

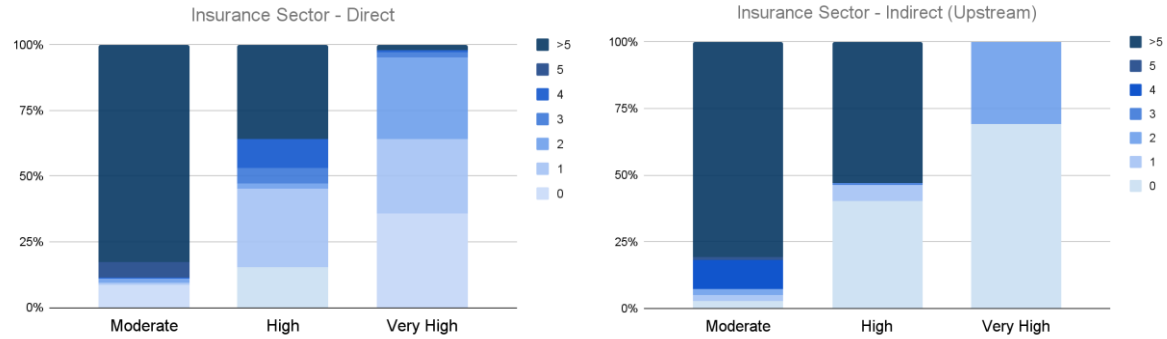
4.3.2 Direct and Indirect Dependencies

The insurance sector in Zambia is the most exposed to nature-related risk. 80% of insurance exposure is moderately reliant on more than 5 services and 36% of the portfolio is directly highly dependent on more than 5 services. Insurance was the only financial sector in which more of the

portfolio is directly very highly dependent on nature than not. Only 36% of exposure is not heavily dependent on a single service.

Indirectly, insurance remains the most at-risk sector. 97% of exposure is at least moderately reliant on an ecosystem service. Through the substantial exposure to the mining sector, 30% of insurance exposure is very heavily dependent on water purification and rainfall pattern regulation.

Figure 36: Share of gross underwritten insurance directly (through own activities) and indirectly (through upstream activities) dependent on n ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)

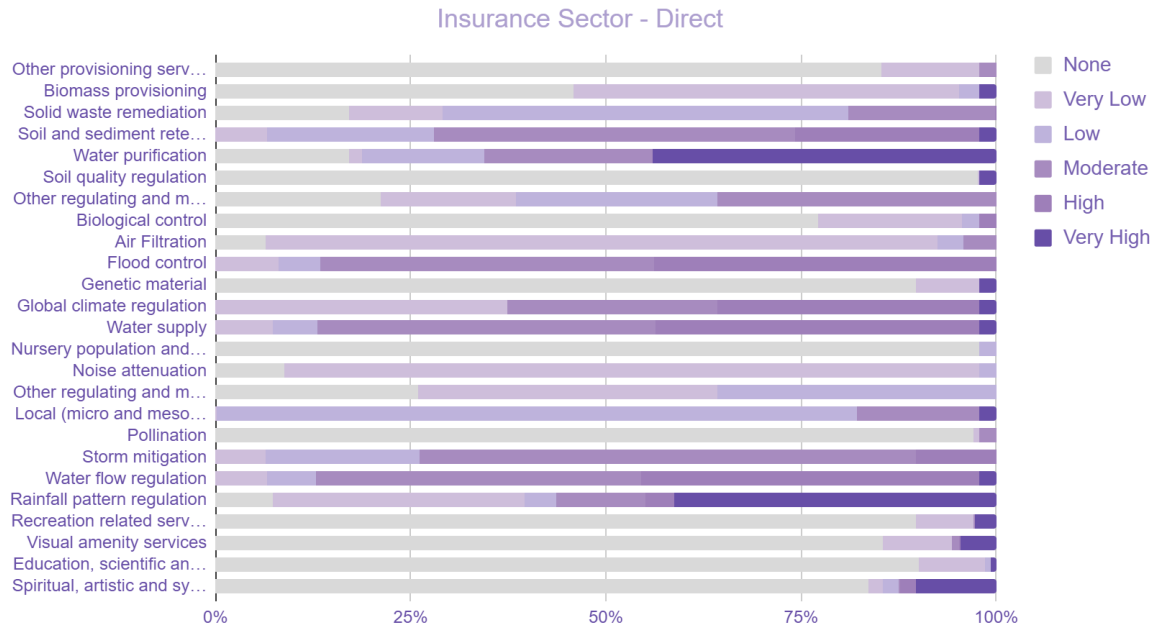


Source: Author

As aforementioned, the insurance portfolio in 2023 was far more exposed to the ore mining sector than other financial institutions. The ore mining sector is the only sector with a very high indirect dependency on nature. As such, the specific ecosystem services through which the insurance sector was reliant upon followed closely the dependencies of the mining sector.

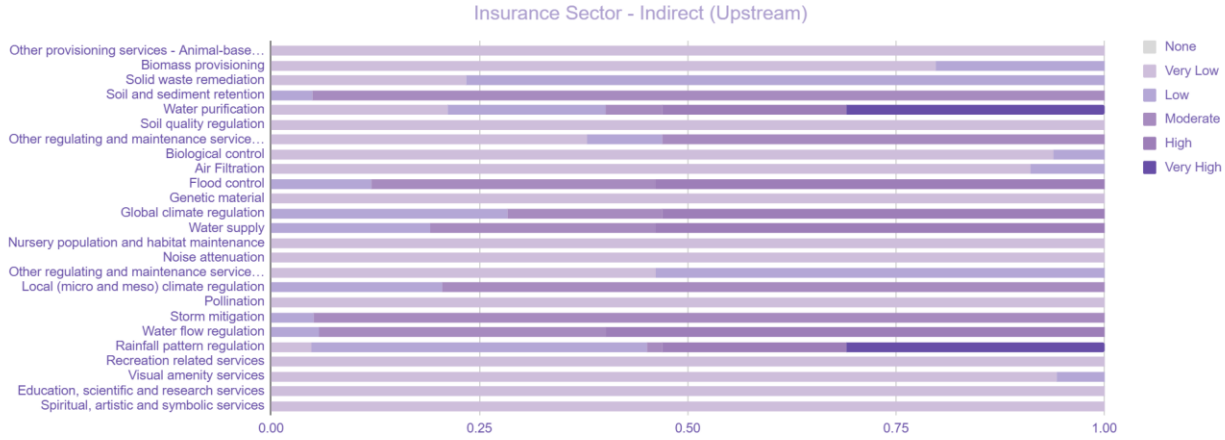
Provisioning	Regulating and maintenance	Cultural
Water supply (87/81)	Soil and sediment retention (72/95) Flood control (87/88) Storm mitigation (74/95) Water flow regulation (87/94) Water purification (66/60) Rainfall pattern regulation (56/55)	N/A

Figure 37: Direct dependencies of gross underwritten insurance on individual ecosystem services



Source: Author

Figure 38: Indirect dependencies of gross underwritten insurance on individual ecosystem services



Source: Author

4.3.3 Nature Risks to the Portfolio

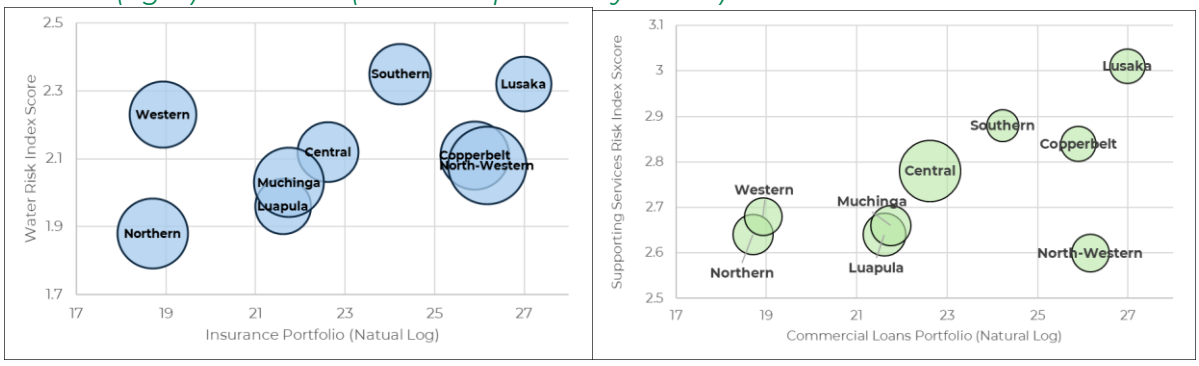
Within the insurance sector, the association between water risk and exposure also appears to exist. As identified, North-Western and Copperbelt provinces have high financial exposures and ecosystem dependency because of activities in the mining sector. For supporting services, this positive association is also observed, albeit dependencies on supporting services are much lower than for water. Nonetheless, this suggests that insurance institutions - who already offer substantive coverage in Lusaka, Southern, and Copperbelt provinces - should be vigilant when it comes to these risks.

Table 9: Insurance portfolio dependency on water and supporting services

Province	Portfolio Water Dependency	Portfolio Support Services Dependency
Central	0.54	0.23
Copperbelt	0.69	0.13
Eastern	N/A	N/A
Luapula	0.46	0.16
Lusaka	0.45	0.13
Muchinga	0.72	0.15
Northern	0.73	0.15
North-Western	0.90	0.14
Southern	0.55	0.12
Western	0.65	0.14

Source: Author

Figure 39: Provincial insurance portfolios against provincial water (left) and supporting services (right) risk scores (Sizes = Dependency scores)



Source: Author

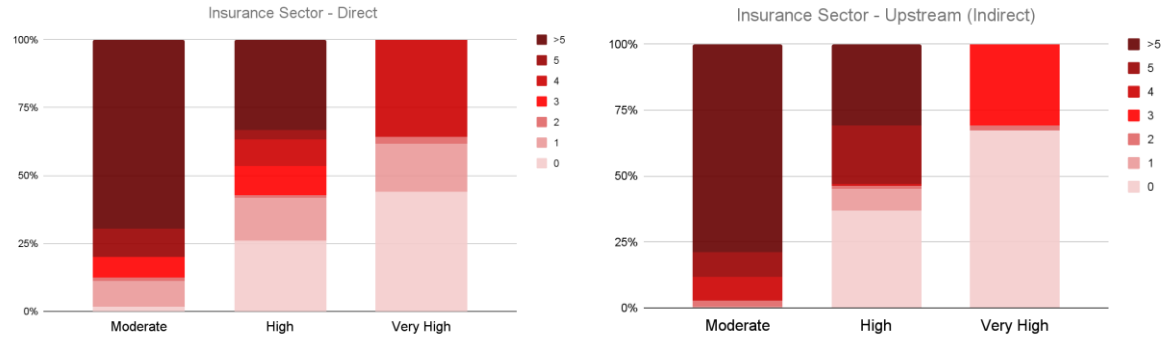
4.3.4 Direct and Indirect Impacts

Policyholders in the insurance sector are also more relatively impactful on nature. This is again driven by the relatively high exposure to the activities of the metal mining sector. Insurance is the sole financial sector in which most of the portfolio has a very high direct impact on nature in some ways. Like in capital markets, all general insurance policyholders analyzed were indirectly impactful on nature through at least two channels.

The mining sector, among other impacts, has a pronounced impact on nature through the disturbances that it produces, as well as the sector's emission of toxic soil and water pollutants. This last impact is notable given the sector's simultaneous dependence on nature to purify water.

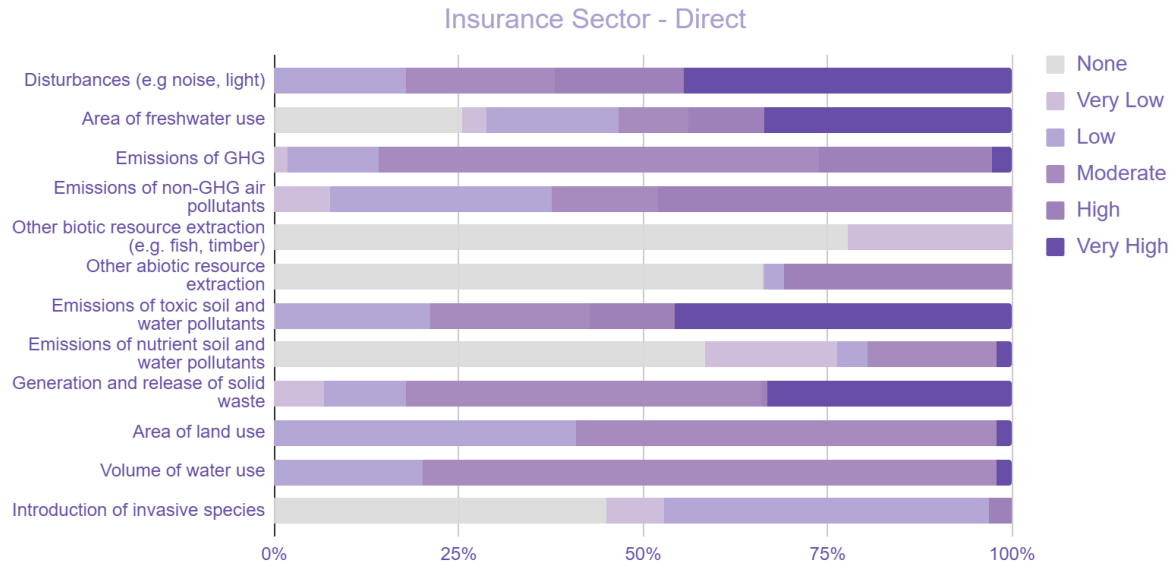
Climate change	Resource exploitation	Pollution	Invasive species	Land-, freshwater- and sea-use change
GHG emission (86/97) Non-GHG emission (62/88)	Solid waste generation (82/77)	Disturbances (noise, light) (82/97) Toxic soil and water pollution (55/60)	N/A	Land use (59/100) Volume of water used (80/97)

Figure 40: Share of gross underwritten insurance directly (through own activities) and indirectly (through upstream activities) dependent on n ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)



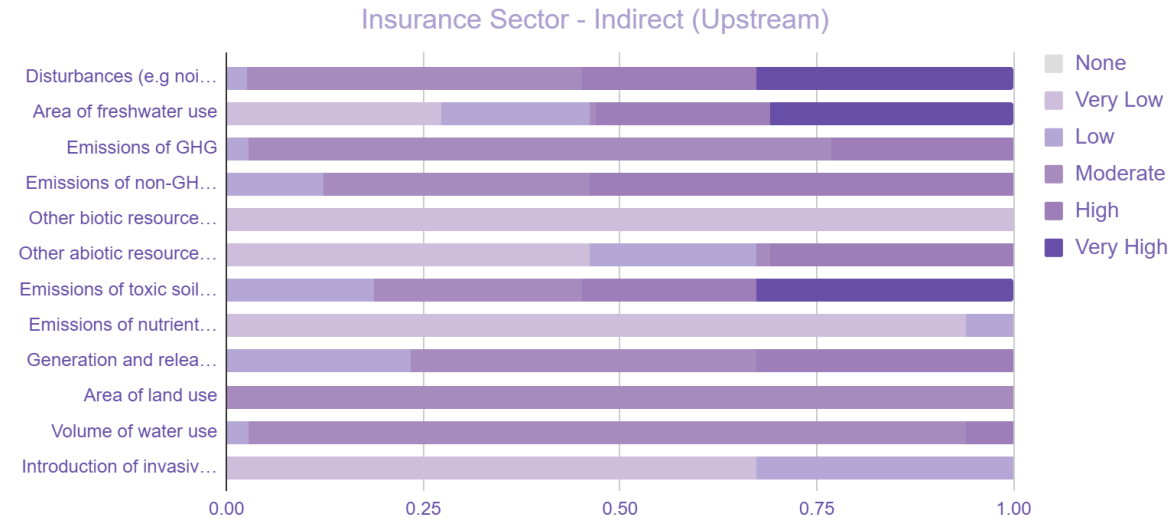
Source: Author

Figure 41: Relative direct gross underwritten insurance exposure with high or very high impacts (physical risk)



Source: Author

Figure 42: Relative indirect gross underwritten insurance exposure with high or very high impacts (physical risk)



Source: Author

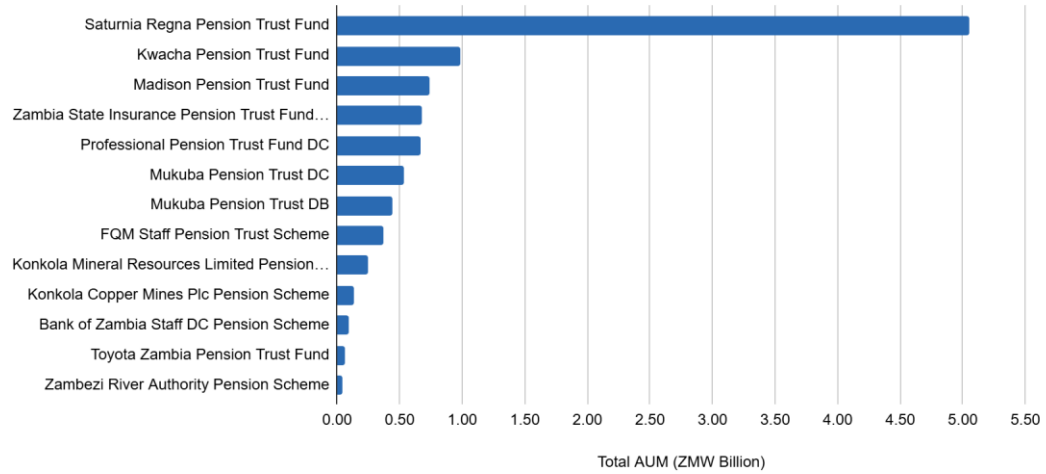
4.4 Pensions Sector

4.4.1 Portfolio Breakdown

Private Pensions

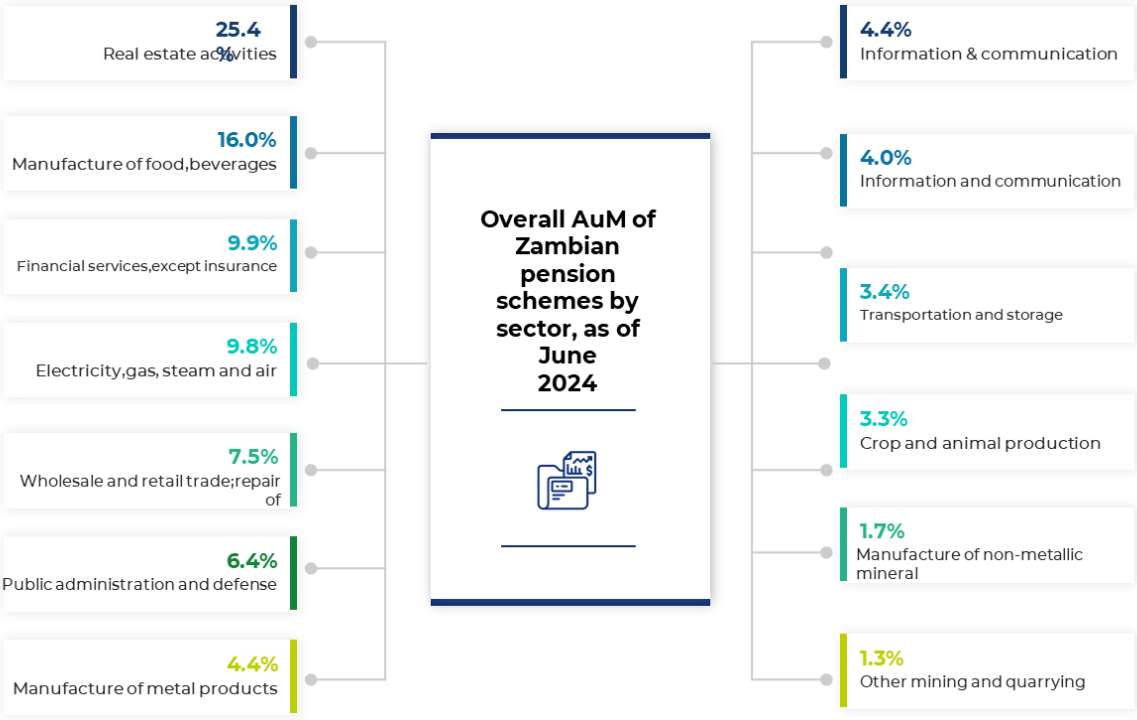
The total AuM for private pensions is equivalent to ~ZMW 10 billion (USD 0.49 billion), with the largest of these being the Saturnia Regna Pensions Trust Fund, with a total of ZMW 5.04 billion (USD 0.25 billion) in AuM.

Figure 43: Overall AuM per pension scheme (ZMW Billion)



Source: Author

Figure 44: Overall AuM of Zambian private pension schemes by sector, as of June 2024

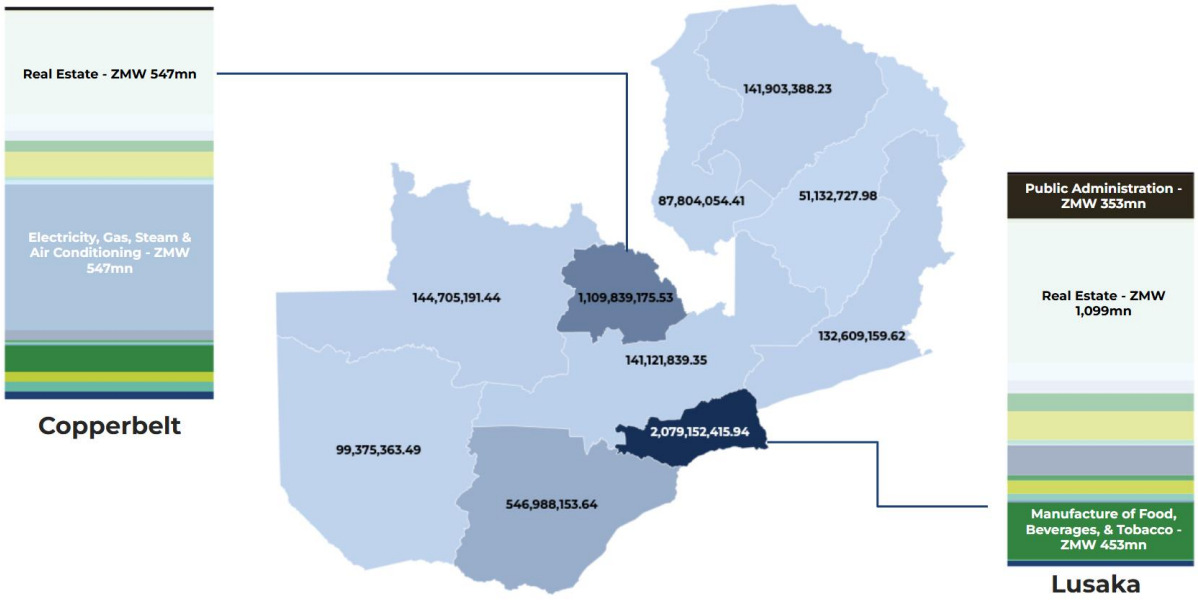


Source: Author

The main sectors to receive investments from private pensions, either directly or indirectly, are real estate activities (25.4%), manufacture of food and beverages (16.0%), and financial services (9.9%).

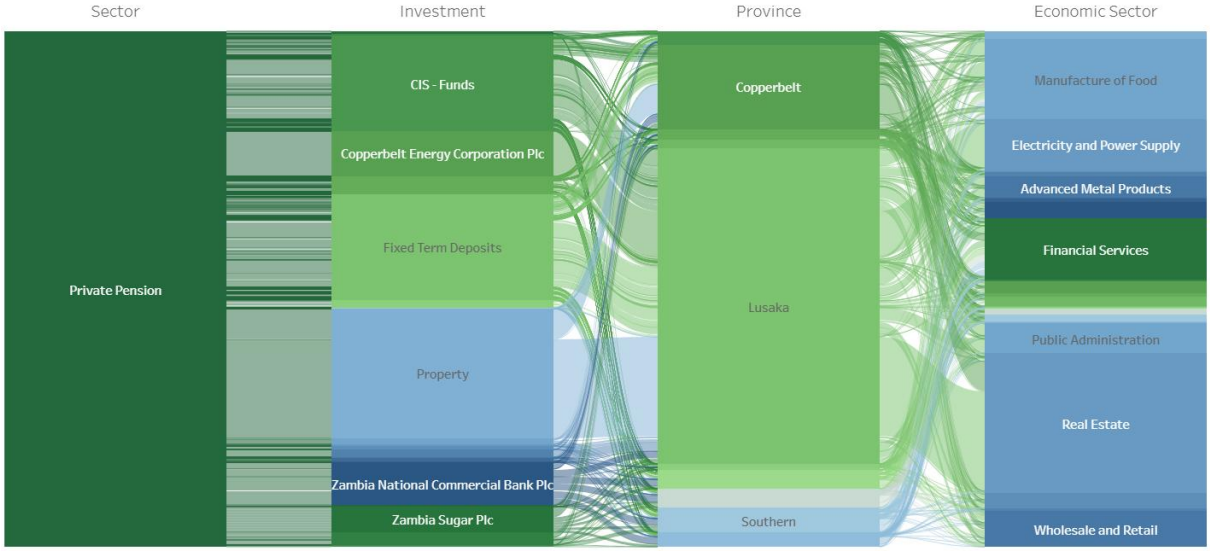
At the provincial level, there is a consistent story with other financial institutions. Most investments are concentrated in Lusaka and Copperbelt, with the region seeing the next greatest level of investment being Southern Province.

Figure 45: AuM of private pension schemes by province, as of June 2024



Source: Author

Figure 46: Financial Exposures of private pensions AuM and associated economic sectors

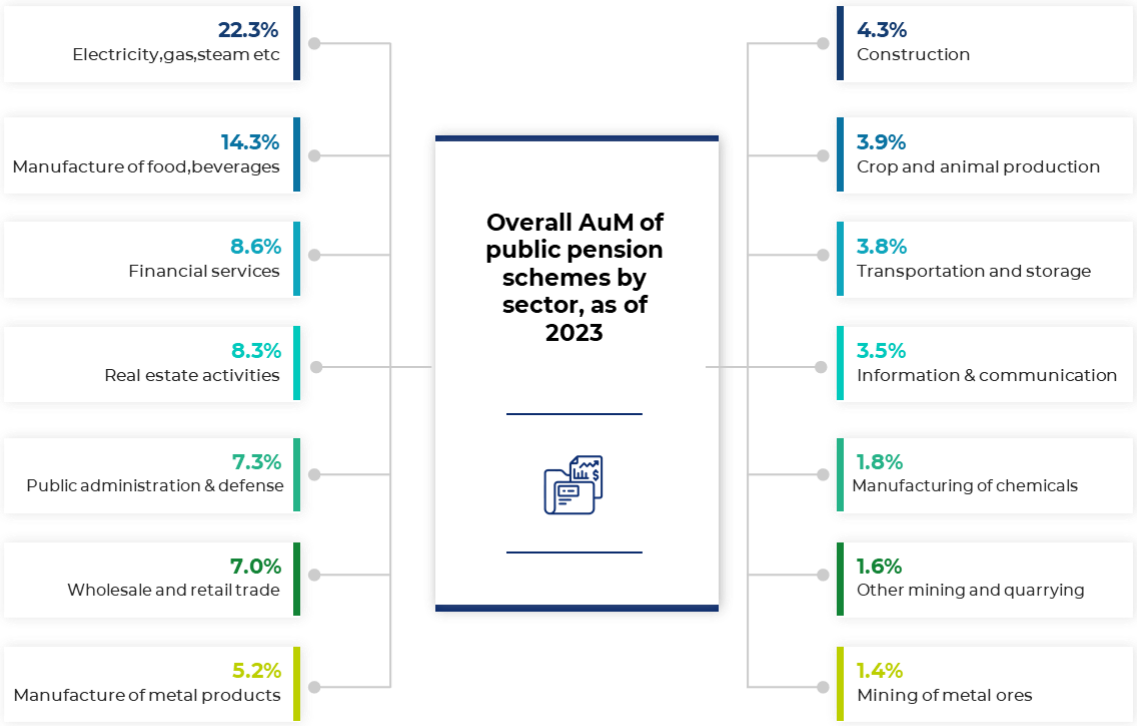


Source: Author

Public Pensions

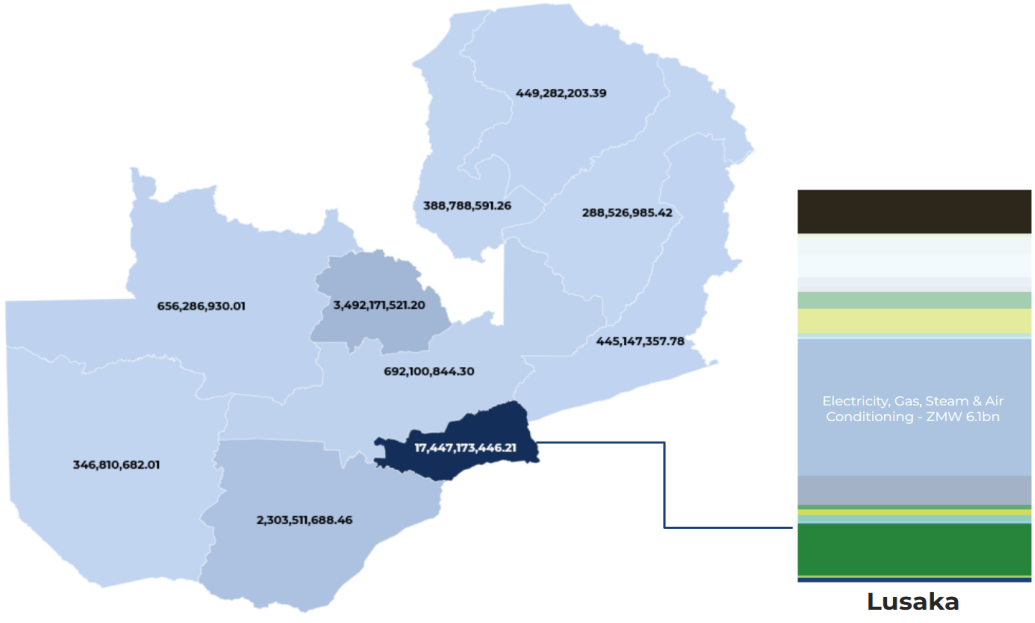
There are only two sectors that have received more than 10% of the total investments from the public pensions portfolio: power provision (22.3%) and the manufacture of food and beverages (14.3%). Geographically, most total investments by public pensions are located in Lusaka (58.9%). Within that, power provision is the largest sector in the portfolio, owing to NAPSA's ZMW 6 billion (USD 0.30 billion) investments in the Kafue Gorge Lower Power Plant project.

Figure 47: Overall AuM of public pension schemes by sector, as of 2023



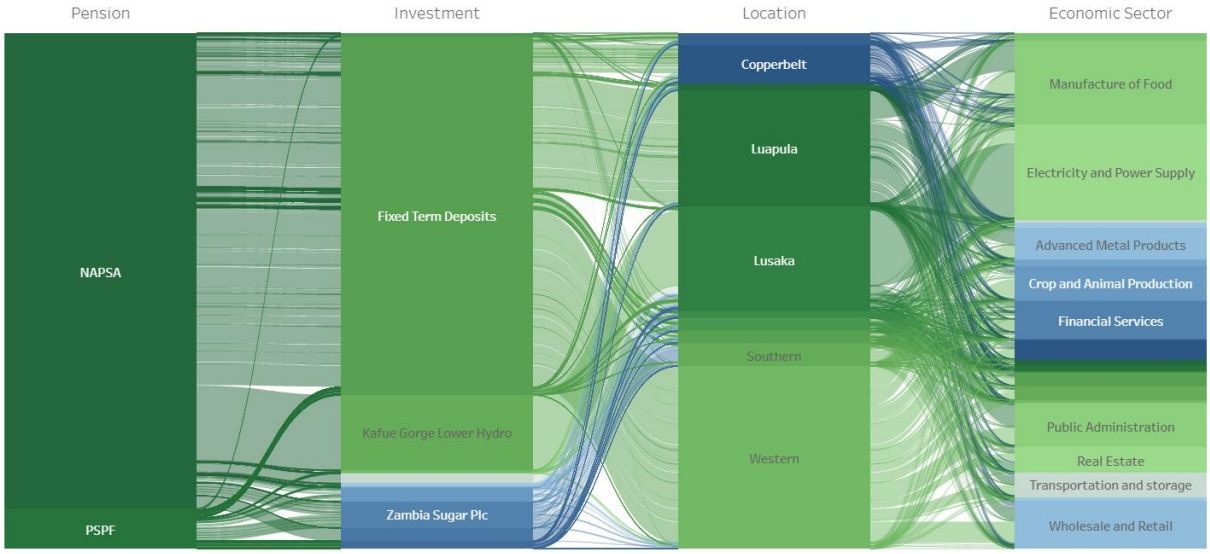
Source: Author

Figure 48: AuM of public pension schemes by province as of 2023



Source: Author

Figure 49: Financial exposures of Zambia's public pension AuM and associated economic sectors



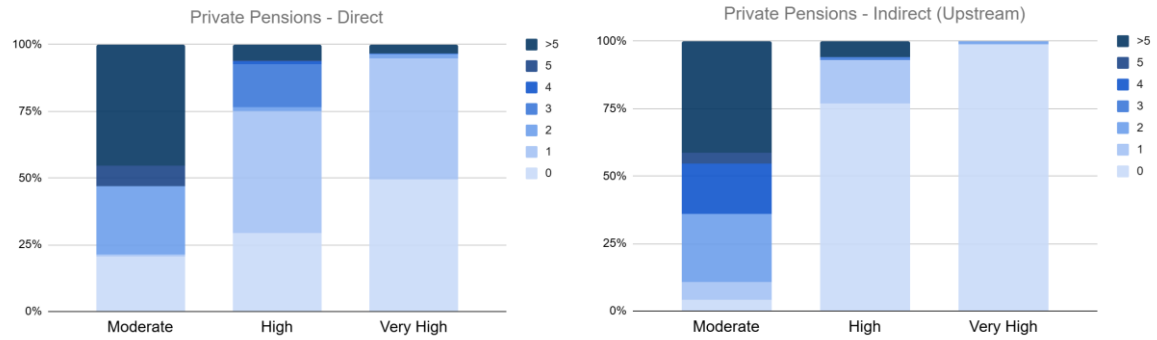
Source: Author

4.4.2 Direct and Indirect Dependencies

Private Pensions

For private pensions, dependencies are lower than in other financial sub-sectors. 44% of portfolio values are moderately directly dependent on >5 nature-related services. Nonetheless, 51% of the portfolio is very heavily directly dependent on an ecosystem service, with much of this being the visual amenity provided by nature for real estate activities. Indirectly, a vast majority of the portfolio is moderately dependent on a nature service (96%), however, only 1.2% has a very high dependence.

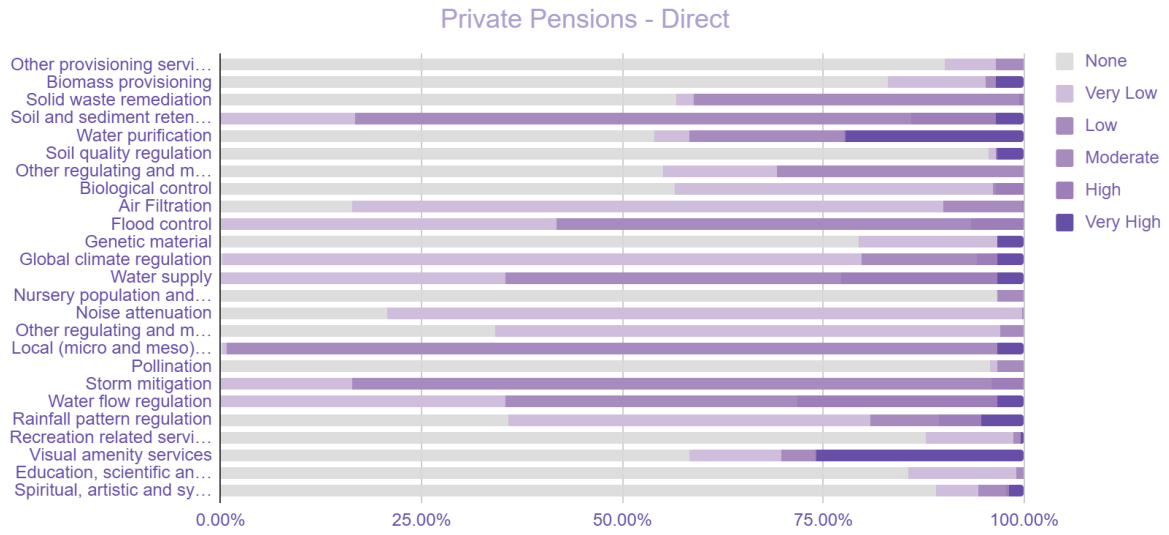
Figure 50: Share of private AuM directly (through own activities) and indirectly (through upstream activities) dependent on n ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)



Source: Author

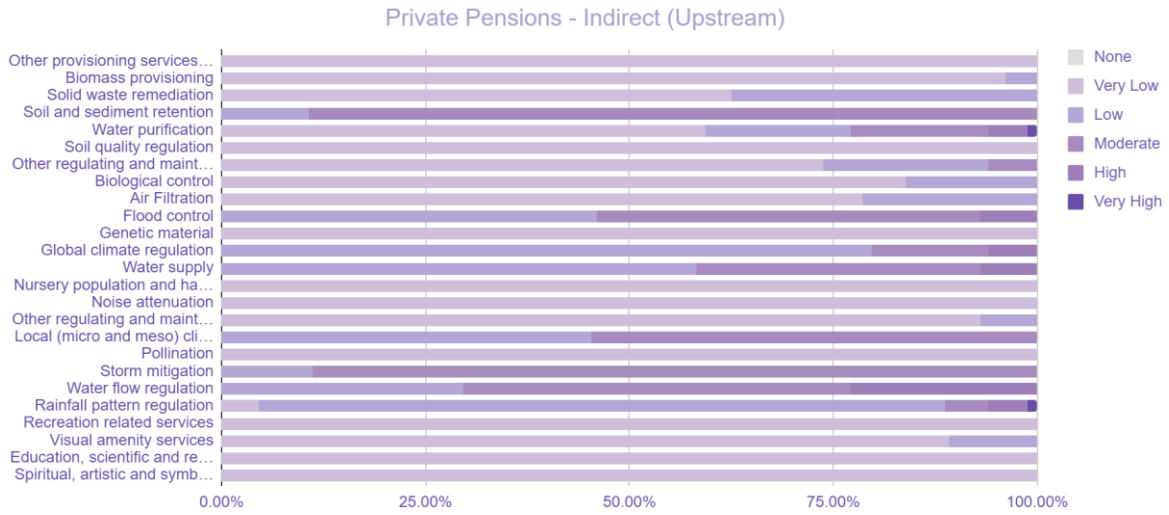
Provisioning	Regulating and maintenance	Cultural
Water supply (49/42)	Soil and sediment retention (59/89) Flood control (53/54) Storm mitigation (43/89) Local climate regulation (14/55) Water flow regulation (50/70)	N/A

Figure 51: Direct dependencies of private AuM on individual ecosystem services



Source: Author

Figure 52: Indirect dependencies of private AuM on individual ecosystem services

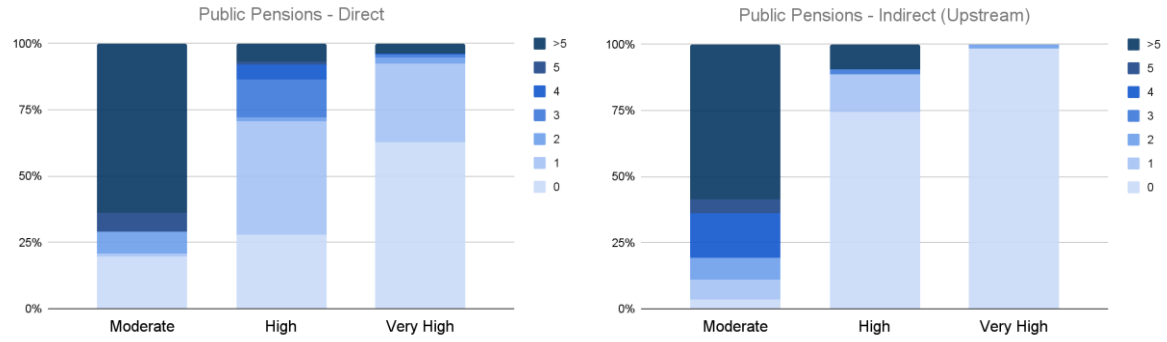


Source: Author

Public Pensions

Direct nature dependencies are very similar to private pension portfolios. 64% of portfolio values are moderately dependent on >5 nature-related services. Almost 75% of the portfolio value is heavily dependent on at least one service. Indirectly, the entirety of the portfolio is moderately dependent on 2 or more services. However, this dependence is not very severe, as 98% of the portfolio is not heavily indirectly dependent on nature.

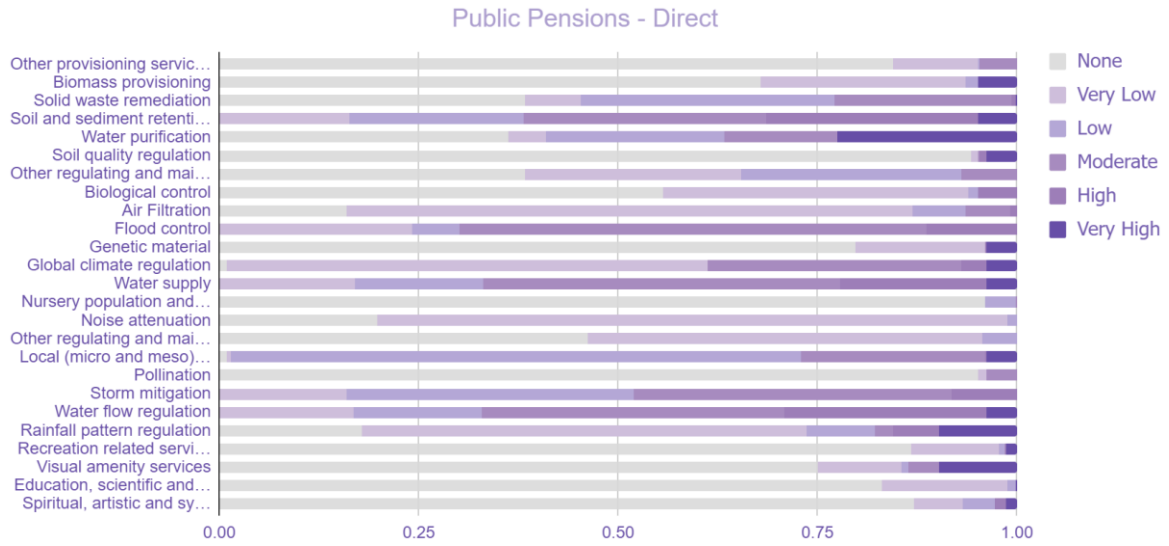
Figure 53: Share of public AuM directly (through own activities) and indirectly (through upstream activities) dependent on 𝑛 ecosystem services at least Moderately (DS >0.4), Highly (>0.6) and Very Highly (>0.8)



Source: Author

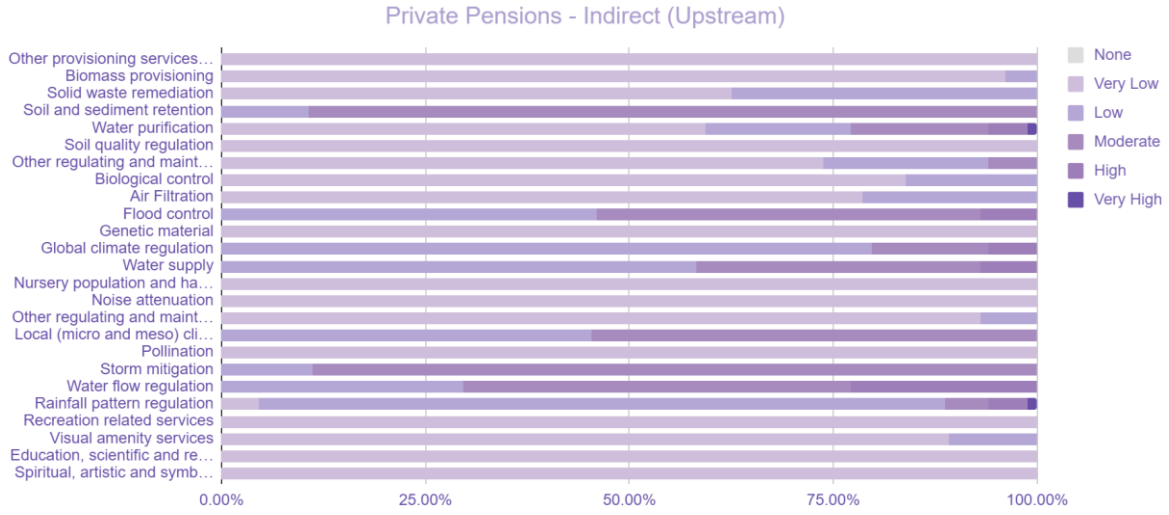
Provisioning	Regulating and maintenance	Cultural
Water supply (67/60)	Soil and sediment retention (62/89) Flood control (70/72) Water flow regulation (67/88)	N/A

Figure 54: Direct dependencies of public AuM on individual ecosystem services



Source: Author

Figure 55: Indirect dependencies of public AuM on individual ecosystem services



Source: Author

4.4.3 Nature Risks to the Portfolio

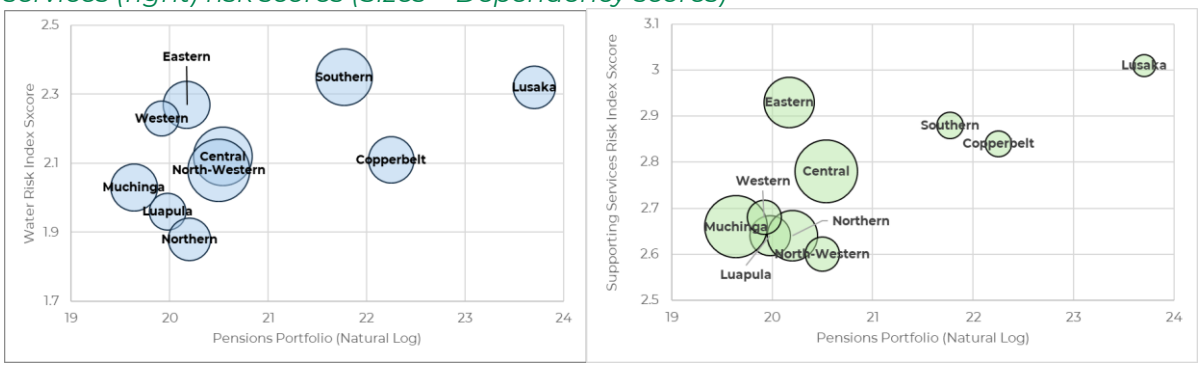
Finally, within the pensions sector, the risks posed by the portfolio's geographical concentration are clear. Assets under management in Lusaka are more than four times greater than in any other province. This is particularly alarming due to the high risks faced by the province to water and to

supporting services. Investors should be aware of this and consider them when considering how to invest and maintain diversity within portfolios.

Table 10: Pensions portfolio dependency on water and supporting services

Province	Portfolio Water Dependency	Portfolio Support Services Dependency
Central	0.54	0.31
Copperbelt	0.42	0.13
Eastern	0.43	0.25
Luapula	0.34	0.20
Lusaka	0.39	0.11
Muchinga	0.43	0.31
Northern	0.39	0.25
North-Western	0.57	0.17
Southern	0.52	0.13
Western	0.32	0.17

Figure 56: Provincial pensions portfolios against provincial water (left) and supporting services (right) risk scores (Sizes = Dependency scores)



Source: Author

4.4.4 Direct and Indirect Impacts

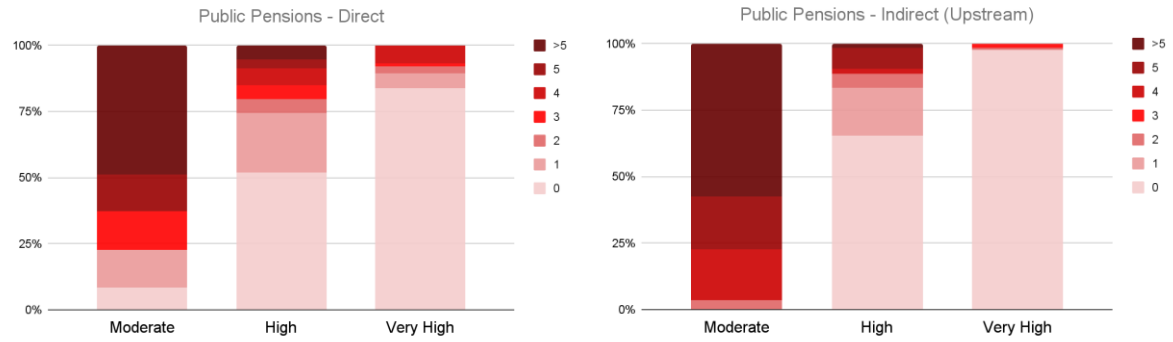
Compared to other industries in the financial sector, pension portfolios have lower levels of high or very high materiality in terms of impact on nature. Even considering direct impacts - which tend to be more severe than their upstream equivalent - the analysis showed that only 16% of the public pensions' portfolio and 13% of the private portfolio very severely affected nature in some way.

The key pressures on the environment are also consistent with other areas of the financial sector. Water and land use remains a key pressure, as do light and noise disturbances, solid waste generation, and the emission of soil, water, and air pollutants.

Public Pensions

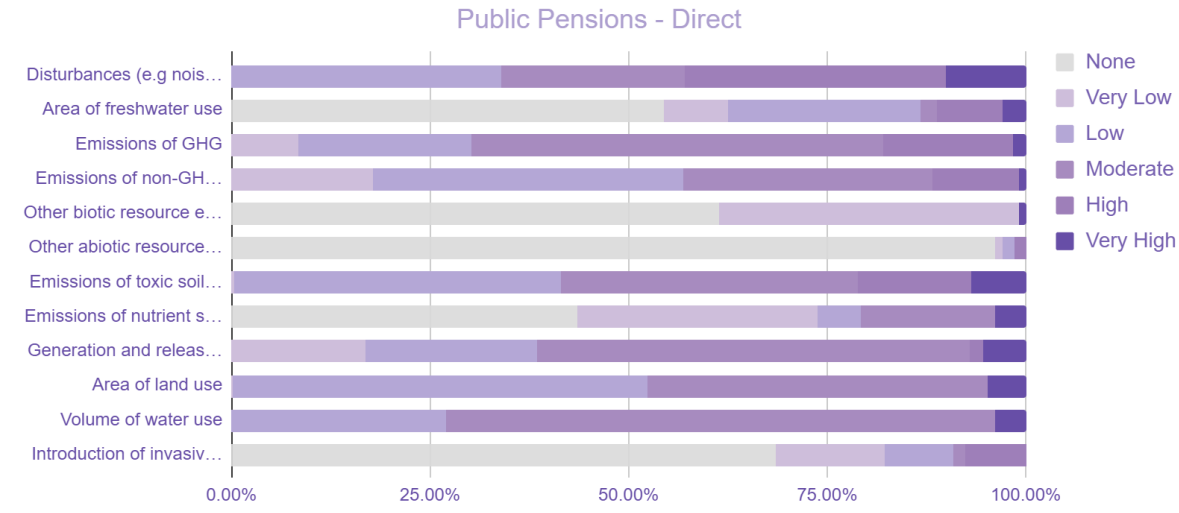
Climate change	Resource exploitation	Pollution	Invasive species	Land-, freshwater- and sea-use change
GHG emission (70/98) Non-GHG emission (43/71)	Solid waste generation (61/53)	Disturbances (noise, light) (66/98) Toxic soil and water pollution (59/66)	N/A	Land use (48/100) Volume of water used (73/96)

Figure 57: Public AuM and ecosystem services dependencies per Zambia kwacha invested (in million ZMW)



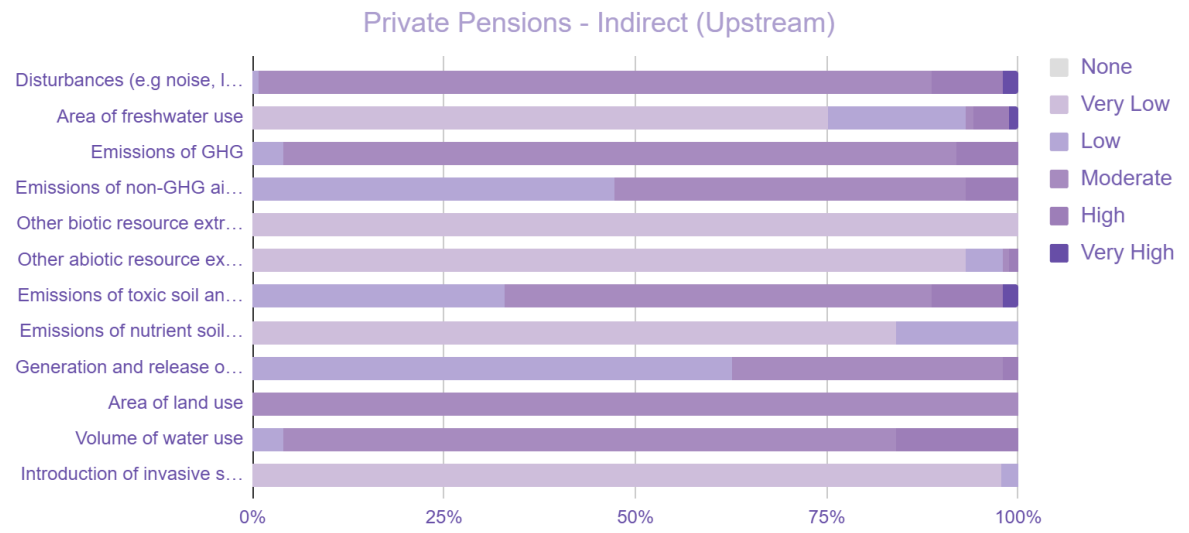
Source: Author

Figure 58: Relative direct public AuM exposure with high or very high impacts (physical risk)



Source: Author

Figure 59: Relative indirect public AuM exposure with high or very high impacts (physical risk)

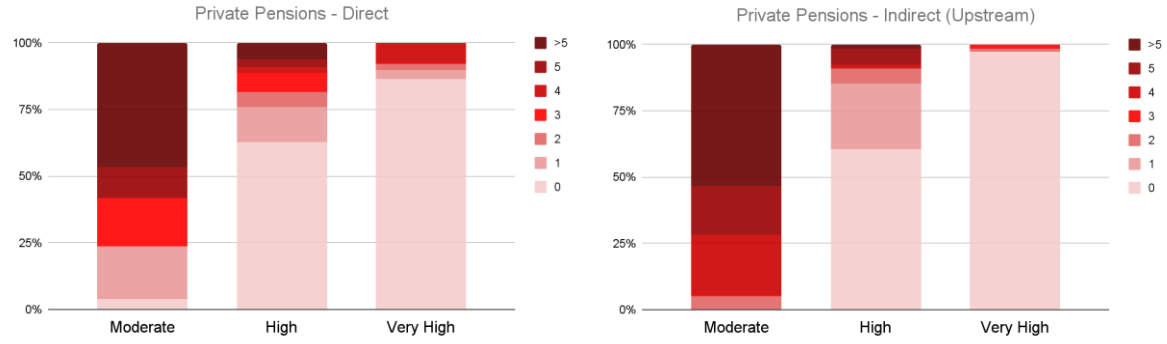


Source: Author

Private Pensions

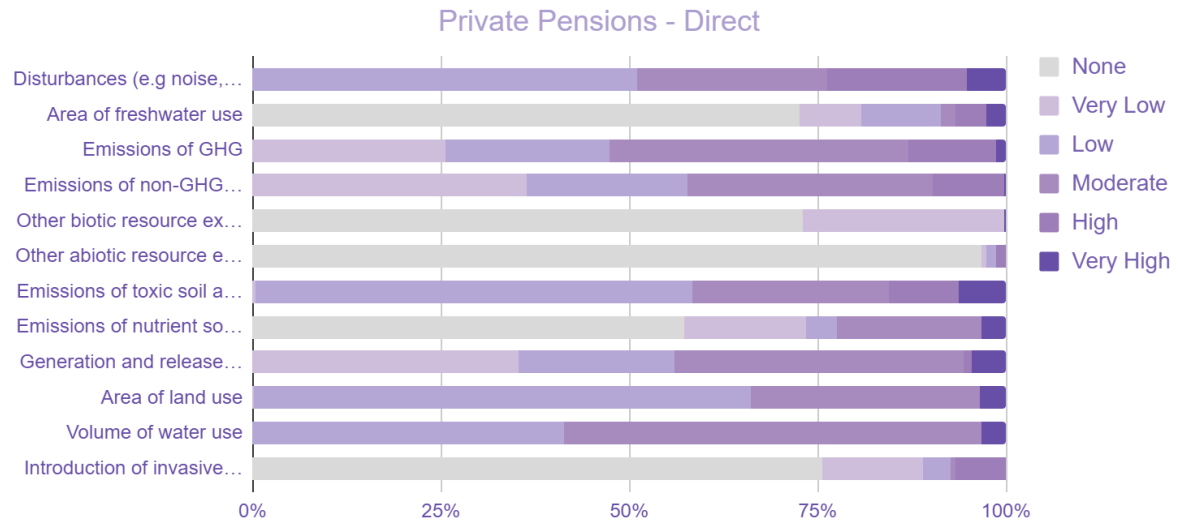
Climate change	Resource exploitation	Pollution	Invasive species	Land-, freshwater- and sea-use change
GHG emission (68/95) Non-GHG emission (54/68)	Solid waste generation (57/48)	Disturbances (noise, light) (63/99) Toxic soil and water pollution (54/58)	N/A	Land use (43/100) Volume of water used (75/95)

Figure 60: Private AuM and ecosystem services dependencies per Zambia kwacha invested (in million ZMW)



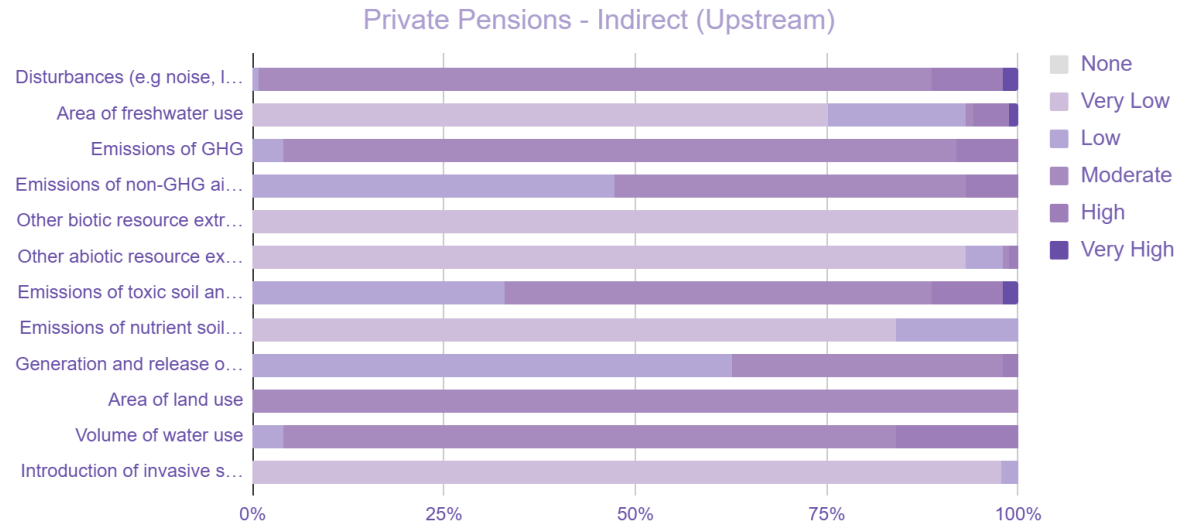
Source: Author

Figure 61: Relative direct private AuM exposure with high or very high impacts (physical risk)



Source: Author

Figure 62: Relative indirect private AuM exposure with high or very high impacts (physical risk)



Source: Author

4.5 Asset Level Case Studies

The focus of this study is on the nature of dependencies, impacts, and risks linked to the financial sector, aggregated at the portfolio level. However, it is also possible to understand and evaluate asset-level linkages to nature through the ENCORE and WWF Risk Filter frameworks. To show this, we apply the analysis to two major assets relevant to the financial sector in Zambia - the Kariba Dam and the Maamba Coal Plant. We also consider two hypothetical assets: a large flour mill near Mpongwe in Central Province and a large copper mine near Solwezi in North-Western province. We discuss each other in turn.

Box 2: Nature Risks and Dependencies for the Kariba Dam

The Kariba Dam is a double curvature concrete arch dam on the Zambezi River, bordering Zambia's Southern Province and the Zimbabwean region of North-West Mashonaland. The capacity of the dam regarding electricity generation for Zambia is 1,080 MW, roughly a third of total capacity across the country.

The dam has suffered significantly from climate change, the key factor influencing the power production of the Kariba dam. In 2024, low water levels in the upstream reservoir led to power shortages across the country. Whilst the evolution of physical climate risks will be the major component as to the financial viability of the dam, nature will also be contributory to this issue.

According to ENCORE, the production of hydropower energy has four 'very high' nature dependencies. Hydropower benefits significantly from a well-functioning water cycle, and as such the dependencies are closely linked to this:

- Water supply
- Water flow regulation
- Flood mitigation
- Soil and sediment retention

A consistent supply of water is essential, and nature is paramount in providing this service. Additionally, poor soil retention transports sediment downstream to reservoirs. This reduces reservoir capacity - which is crucial to maintain power production during dry periods.

Looking at the WWF Risk Filters, the current and future risks posed by water scarcity are low-to–medium and are not expected to worsen from now until 2050 under the current trends. Even under pessimistic scenarios, flooding risk will only slightly increase.

However, the current risks from drought are high. Furthermore, risks related to soil condition in the Kariba hydro basin, and in other water basins along the Zambezi River, are very high.

These two risks - water scarcity and drought - could have potentially large impacts on the operability of the power plant over the next decades. Investors, insurers, and other financial sector actors with exposure to such an asset should therefore consider the nature risks in their assessment of their portfolios and may decide to include additional investments on their balance sheets to diversify this risk, or to demand complimentary investments to support the nature dependencies and their continued availability.

The dam is dependent on ecosystem services that are not currently well provided, albeit this will not significantly worsen in the future. Biodiversity and nature-based solutions could be used to improve the profitability of the dam and lower the nature risks. For example, forest and wetland ecosystems act as water stores in wet seasons, before releasing this water downstream in dry seasons.[33] Furthermore, forests help to retain soil, reducing sedimentation affecting reservoir capacity and dam lifespans.

Box 3: Nature Risks and Dependencies for the Maamba Coal Plant

The Maamba coal plant is in Maamba Township, in the Southern Province of Zambia. The plant has a current operational capacity of 300 MW. However, a second 300 MW unit is under construction, which will bring the total capacity to 600 MW. It is the largest thermal power plant in the country.

The climate transition is likely to impact on the operation of the plant. Even in the present day, there is an increasing pressure to move away from coal power production. However, at present Maamba acts as a climate adaptation measure, given the volatility of production from major hydropower assets.

Whilst the risks to alternative power production remain, it will also be important to safeguard the plant against nature risk. Results from ENCORE indicate that coal power production has no 'very high' nature dependencies, however the sector is highly dependent on two water-related ecosystem services for cooling, fire control, and other operations:

- Water supply
- Water flow regulation

For cooling, the use of clean water is often vital for the longevity of the plant's equipment. This is relevant due to the high impacts of coal power plants on water and soil pollution. Not only does this pollution impact upon future clean water supply, but it also deteriorates natural capital that is vital for natural water purification.

Information from the WWF Risk Filters shows that issues of water scarcity are currently low. This is expected to remain true in the future. Therefore, the analysis does not suggest any major nature risk concerns for the power plant at present. This could be continually tracked over time; in case the situation evolves.

From the available information, it appears that the main risk currently to the Maamba plant is the net-zero transition. Nonetheless, the proposed expansion of the plant does have implications for nature. Risk assessments should consider the continued provision of clean water to the plant, the impacts of operations on nature, and nature-based interventions that could help to address both issues simultaneously.

Box 4: Nature Risks and Dependencies for the a Flour Milling Plant in Central Province

The manufacture of food and beverages - a major sector in banking and capital market portfolios - will be highly sensitive to the quality of ecosystem services over time. However,

[33] Peña-Arincibia et al. (2019).

this will mainly be driven by supply chain factors, particularly the upstream production of crops.

This holds true for the manufacture of grain mill products. According to ENCORE, the sector has only one 'very high' dependency on nature. Like with many other major sectors in Zambia, the production process is dependent on a water-related service:

- Water purification

Specifically, the purification of water by nature is deemed essential for effluent detoxification.

Evidence from the WWF Water Risk Filter mitigates the severity of this risk. Risks to water quality in the region are currently low and are not expected to significantly worsen in the future, even by 2050.

However, assume for supply chain efficiencies that wheat crop production is located nearby. This is likely given that the province is a major producer, according to the IFC and USDA. The growing of cereals has significantly higher dependencies:

- Biomass provisioning
- Genetic material
- Global climate regulation
- Local climate regulation
- Rainfall pattern regulation
- Soil quality regulation
- Soil and sediment retention
- Water purification

Alongside several high dependencies.

The degradation of water catchments - which are incredibly important for the regulation of local rainfall patterns - is high risk. Additionally, this high risk is expected to continue in the future under all climate scenarios. Equally, all regions of Zambia suffer from poor soil condition, adding to the risk associated with the dependencies of wheat on both soil retention and quality.

Overall, these supply chain risks underscore the need for financial actors to consider indirect asset-level nature risks as well. Investors could seek to promote geographically diversified supply chains as an investment criterion to insure against these risks. However, given that some risks, such as those to soil, are systemic, pro-nature practices will also be key.

Box 5: Nature Risks and Dependencies for a Copper Mine in North-Western Province

As identified in the main analysis, the Zambian financial sector - especially insurance - is exposed to the mining sector and the nature-related risks that it faces. Within the mining sector, copper is the primary commodity - making up more than 60% of the country's exports according to the OEC.

Looking specifically at the nature dependencies for the mining of non-ferrous metal ores, ENCORE identifies two very high dependencies:

- Rainfall pattern regulation

- Water purification

Specifically, rainfall pattern regulation is needed to mitigate flooding and damage at mining sites, as well as to maintain a consistent supply of water for cooling. Naturally purified water is also critical for cooling purposes, as well as for cracking and for the detoxification of effluents.

There is a close relationship between the impacts and dependencies of copper mining. Very high impacts include:

- Disturbances (Noise, Light, etc.)
- **Area of freshwater use**
- **Emissions of toxic pollutants into water and soil**

In particular, the leaching of toxic chemicals and heavy metals into soil and water have significant impacts on the maintenance of vegetation, forests, and wetlands, all of which are important in regulating rainfall patterns.

Looking at the WWF Risk filter, ecosystem services in the area, such as those used for the regulation of rainfall, are at medium-high risk. This pattern is estimated to continue, unless action is taken.

Copper mine assets cannot be relocated. As such it will be essential from a financial risk perspective that actors continue to quantify risks for mining assets and establish pro-nature criteria to mitigate risks and improve the outlook of investments in the sector.

5.1 Financial Sector Recommendations

While financial regulatory and supervisory approaches to nature-related financial risks in Zambia are at an early stage, our analysis can be used as the foundation for further work to improve their understanding of those risks and address the challenges identified above. Our analysis provides a working hypothesis of where financial institution activities are likely to have a material nature-related dependency and impact, as well as the risk and opportunities they face. We propose potential actions based on Taskforce on Nature-related Financial Disclosures (TNFD)'s LEAP (Locate, Evaluate, Assess and Prepare) approach[34] as presented in table 11.

Table 11: Proposed actions based on TFNDs LEAP approach

TFND Framework	**Locate |** Interface with nature	**Evaluate |** Dependencies & impacts	**Assess |** Risks & opportunities	**Prepare |** Respond & report
Report findings	• Provincial level spatial distribution of financial portfolios • Economic activity that financial portfolios contribute	• Identification of dependencies and impacts • Dependency and impact measurement • Impact materiality assessment	• Risk and opportunity identification, and prioritisation	/A
Potential action	• Disaggregate to district and community level to sharpen results • Understand where direct operations are occurring	• Environmental assets, ecosystem services and impact drivers are associated business processes	• Adjustment of existing risk mitigation and risk and opportunity management • Risk and opportunity materiality assessment	• Risk management, strategy and resource allocation decisions from the analysis • Disclosures in line with the TNFD • Format and frequency of sharing of nature-related disclosures

Source: Author based on TFND (2023b).

We acknowledge that these approaches are faced with challenges, including limited availability of data, development of analytical approaches and quantitative assessments, lack of resources, and competing priorities. **However, ongoing work on nature related risks will further enhance the understanding and application of these approaches.** Some of these ongoing works include:

- UNDP-BIOFIN are performing national assessment of readiness for nature-related financial disclosure across 18 developing countries,
- TFND published general requirements for nature-related disclosures, [35]
- IFRS ISSB will be commencing work on nature-related issues following the release of its IFRS S1 and IFRS S2 sustainability reporting standards in 2023,[36]
- Global Reporting Initiative (GRI) has recently published its revised biodiversity standard, GRI 101: Biodiversity 2024, that replaces GRI 304: Biodiversity 2016,[37]

[34] TFND (2023b)
[35] TFND (2023a)
[36] *TNFD welcomes the ISSB's decision to commence work on nature-related issues* (April 24, 2024).
[37] *GRI publishes an update to its biodiversity standard.* (Jan 25, 2024)

- Science Based Target Network (SBTN) recently released it released its guidance on setting science-based targets for nature (the "Guidance"),[38] and
- other ongoing works by NGFS study group and other central banks.

Nature related risks assessment toolkits

It is crucial to acknowledge Zambia-specific thresholds and tipping points in nature-related risks, as biodiversity and ecosystem-services can undergo rapid changes with substantial social and economic consequences on a local and global scale. Therefore, financial risk assessment scenarios concerning nature must be tailored to Zambia's context, reflecting the unique conditions of natural assets and their interconnectedness with communities and the economy at varying scales. To the extent that financial sectors are exposed to international assets/capital/risks etc., there is also a role to be aware of the dependency on nature (and other) risks beyond Zambia's borders. Such risks are beyond the scope of this report but should be considered in the assessment of any individual institution's portfolio.

It is important for BOZ, PIA and SEC to develop their own locally relevant scenarios using the outputs of these studies that have highlighted where the most financially material risks may emerge. This will help in prioritizing the development of specific scenarios based on existing toolkits, that feature the interconnectedness of climate and nature. A good starting point is the NGFS' Integrating Nature Climate Scenarios and Analytics for Financial Decision-making (INCAF) project.

In Annex 5, we review the potential use of Integrated Assessment Models (IAMs) to analyze the impacts of nature risk. These models - which are very complex - seek to model the dynamic impacts within the nature-economy-climate nexus. In our assessment, we find GTAP-InVEST to be the best option given its relevance for nature-related policymaking, specifically for the financial sector.

Finally, the collection and tracking of data on nature-related risks will be crucial to protect and support the financial sector. Tracking these risks beyond this project will enable information to remain relevant and up to date, enhancing decision making. BoZ, PIA, and SEC may wish to develop guidelines for the voluntary measurement and reporting of nature risks - building capacities alongside this - to enable better and easier tracking over time. Where possible, this could be integrated into the measurement of climate risks to create an aligned process. Data tracked should include both the size of exposures in the balance sheet, by sector and location. Location-level data will be a particularly major step to measure risk. With this information, the type and scale of nature risks can be tracked.

5.1.1 Banking Sector

Our findings have highlighted a high moderate dependency on nature, and its impacts, mainly from 60% of the banking portfolio. This is driven mainly by gross loan disbursements in the manufacture of food and beverages, as well as copper and other metal ores, wholesale and retail and crop and animal production economic activities. Zambia is experiencing its worst drought in 40 years that has brought systemic shocks on water and agriculture supply that are further amplified with cascading feedback across markets leading to significant impacts on the banking system.

[38] Science Based Targets Network (2024)

Provinces with higher water and supporting services and nature-related risks also receive greater financing from the banking sector. While there may be a positive association between ecosystem risks and financial sub-sector portfolio size, this is mitigated by low relative dependencies in these provinces. For example, Lusaka has the lowest dependency on water and supporting services due to lower relative investment in sectors reliant on functioning water ecosystems. Overall, provinces with higher ecosystem service risks tend to receive greater levels of investments in sectors that are dependent on them.

Financial institutions in Africa can adopt nature-related risk assessment practices by following these steps:

- Increasing the **adoption of UN's Principles for Responsible Banking (PRB) Nature Target Setting Guidance into banking practices** with focus on sector-specific guidance for closely linked nature industries like agriculture, forestry, and mining;[39]
    - As capacities continue to be strengthened, future steps could be to consider the adoption of **TNFD or GRI Financial Services Sector Standards frameworks.**
- **Setting targets for engagement with customers and counterparties in the three high-impact economic activities** based on their lending exposures across manufacturing, wholesale and retail and crop and animal production. This engagement will be targeted at enhancing understanding of their impacts and dependencies on nature;[40]
- **Promote negative or positive screening policies to industry** e.g., no new financing to clients involved in high degradation of ecosystems. This can also cover customers and counterparties by encouraging them to put in place non-ecosystem conversion commitments and policies and work

Opportunities will also present for the banking sector:

- Globally, the required investment in nature is significant.[41] Equally, the assets under management held in biodiversity funds have grown by 50% from September 2023-2024.[42] Banks could **engage with companies with high dependence, high impact, or those located in high-risk areas, to provide financing for nature-enhancing activities.** In some areas, economic co-benefits are also significant.[43] This provides a 'double dividend' for banking actors, reducing counterparty risk through reduced nature risks *and* improved production for the borrower.
- The banking sector can build on the overlap between activities covered in the Green Bond Principles and in the Kunming-Montreal Global Biodiversity Framework. **By taking advantage of the standardized and established green bond, the banking sector can raise more money for biodiversity.**[44]
- Banks can adopt **a differentiating approach given the awareness and capability levels of their clients.**[45]
    - For clients with moderate to high awareness of risks and mitigation actions, **banks can develop an external perspective on risk concentration.** This can be achieved by analyzing asset data and physical

[39] UNEP FI. (n.d.).
[40] ANZ, & UNEP FI. (2021).
[41] BCG (2024).
[42] MSCI (2024).
[43] IFC (2023).
[44] UNEP FI (2023).
[45] Castoldi, A., Lucini, G., Micale, B., Benayad, A., & Coppola, M. (2024).

towards full traceability in their supply chains.

- **National regulators can adapt and contextualize nature-related guidelines**, including means and metrics for the industry to disclose their efforts towards integrating nature-related risks.
- Initiate pilot projects through **nature-related sandboxes - aimed at gathering data and expertise in developing risk assessment models - to refine nature-related processes** before scaling up their efforts across the industry.
    - This exercise can be supported by partnerships with institutions such as environmental NGOs, local governments, and academic institutions.

features of client assets to identify financing needs and fine-tune data.

    - Banks can **partner with insurance companies and solution providers to assist medium and small clients with limited or no capability to quantify physical risk impacts**. These partnerships can help to mitigate risk and introduce adaptation and resilience measures by providing easy-to-use tools for a first assessment. As the client's needs evolve, the bank can continue to support them by introducing additional solutions.

5.1.2 Capital Markets Sector

While we found that direct dependency for listed securities stood out in capital holdings, less than 10% of the holdings had a high impact on nature, driven by high investments in wholesale and retail. Despite this apparent moderate impact on nature, the capital markets sector is exposed to hidden dependencies and impacts through supply chains. These hidden dependencies are because of either direct extraction of resources from forests and freshwater or the provision of ecosystem services such as healthy soils, clean water, pollination and a stable climate.

For example, in Zambia, the most retail-traded commodity is maize. Maize is threatened by the outbreaks of invasive pests, particularly the fall armyworm, and diseases, which already suffer annual losses of up to 25.4% of total production (valued at USD 198 million).[46] This leads to significant destabilization of retail trade in maize, affecting the livelihoods of many smallholder farmers.

Capital markets actors should be wary of water-related risks. Lusaka, Copperbelt, and Southern provinces have high dependencies and water risks due to agri-food and mining investments. Supporting services in Muchinga province show low investment and relatively low risk.

Some actions that SEC can take in such a case include:

- Introducing **a duty-of-care law that requires listed companies to include environmental assessments** in their

In the capital markets sector, there will also be significant opportunities:

- The SEC and LuSE can build on learnings from the Copperbelt Energy Corporation's green bond issuance to support listed companies and other corporations to **use the results of their nature related**

[46] De Groote, H., Gitonga, Z. M., & Sonder, K. (2023).

supply chains (currently being done in France[47]).

- **Redirecting investments to production of net-biodiversity loss commodities** to avoid holding stranded assets (assets facing premature write-offs, downward revaluations or conversions to liabilities due to increasing awareness of exposure to nature-related services).
- Developing guidelines to help listed companies **publicly disclose their policies that "demonstrate commitment to integrating nature-related risks"** (similar approach was adopted by investors with assets totaling USD 6.3 million in soy trading companies.[48])

assessments to issue green, and other thematic bonds that cover activities with economic co-benefits. Issuing securities that preserve nature, and biodiversity can be supported by the to be developed green finance taxonomy framework - there has been an increase in the share of green and sustainability bonds featuring terrestrial and aquatic biodiversity, 16% of bonds issued in 2023 from 5% in 2020;[49]
    - This will require establishment of credible nature-related baselines, targets and plans to improve their impact.

- Security issuers will also have activities that do not offer direct economic benefits but may nonetheless reduce the risks that they face.[50] Depending on the level of risk, green bonds may still prove a viable option. However, **issuers can also explore the opportunities from biodiversity credits,[51] which would offer an economic reward to go alongside risk reduction.**
- Security issuers could find opportunities by **providing equity and securitized project finance into post-validation distressed projects targeting carbon removal credits.** They may consider investing in distressed nature assets with considerable carbon and biodiversity potential, with a particular focus on post-validation distressed projects.

5.1.3 Insurance Sector

Our findings have highlighted a significant impact on nature by the sector due to its high reliance on nature, over 80% of its portfolio, in the mining and construction sectors. Mining, especially copper that is a global mainstay export for Zambia, is critical for growth forecasts of Zambia and many other developing countries. This creates high risk in wetland areas, where these activities are in proximity as is the case in the North-Western province. Furthermore, reputational

[47] Cossart, S., Chaplier, J., & De Lomenie, T. B. (2017).
[48] Belmaker, G. (2019, July 18).
[49] Sustainable Fitch (2023, September)
[50] IFC (2023).
[51] Under different scenarios, global demand for biodiversity credits is estimated to be US$1-2 billion in 2030 and US$6-69 billion by 2050. *See Nature-Based Offtake Deals: Something is stirring in voluntary carbon markets. (2024, Nov).*

risk is evident given the high artisanal and small-scale mining (ASM) in the country, which may result in collective moral damage penalties when disasters strike.

The insurance sector is exposed to financial risk due to water risk. This is particularly relevant in the North-Western and Copperbelt provinces, where mining activities have resulted in high financial exposure and ecosystem dependency. Insurance companies with significant business in Lusaka, Southern, and Copperbelt provinces should be aware of these risks. This is due to the positive association between supporting services and water risk, even though the dependency on these services is lower.

Some actions that PIA - Insurance can take in such a case include:

- **Negative insurance screening** by refusing coverage to economic activities that significantly degrade nature or demand for higher capital requirements from policyholders in areas that are disruptive to biodiversity[52];
- Requiring a **coverage contingent on binding commitments** not to degrade wetlands.
- Minding the insurance protection gap (Zambia currently has an estimated protection gap between 39%-82%[53]), in partnership with public authorities, by **introducing nature climate solutions (NCS) pricing** while considering insurance affordability and availability.
- **Increasing policyholders' awareness about their dependency and impact on nature** as a way of influencing the demand for corresponding insurance products - this can be targeted by incorporating granular information on the policyholders' exposure to nature-related risks e.g., the possible increase in epidemics following loss of biodiversity; and
- Adopting innovative insurance models such as the Restoration Insurance Service Company (RISCO), based on **incorporating**

The incorporation of nature and nature risk into insurance offerings will present several opportunities and benefits:

- **Understanding nature risks will improve the profitability of insurance companies.** Currently, nature risk is uncertain, and as a result the pricing of premiums is imperfect. As the impact of nature risks are modelled, insurers can offer more competitive pricing where risks are minimal, thereby securing further business, and where risks are high, insurers can avoid unexpected losses where pricing previously did not take nature into account.
- **Driven by greater consideration to nature risk and finance, insurance companies will also be able to provide a wider product offering:**[56]
  - Insurance companies will be able to offer coverage for natural assets, such that they can be rebuilt quickly after disasters, like what has been done as part of the Mesoamerican reef insurance program.[57]
  - Much like the growth of carbon credit insurance, which can offer coverage against counterparty risk, fraud and negligence in carbon transactions, insurers can also offer similar products for biodiversity and nature credits.

[52] World Economic Forum & Oliver Wyman. (2024).
[53] GIZ (2023)
[56] Pollination and Howden (2024).
[57] Mesoamerican Reef Fund, Willis Towers Watson, Ruiz, C., & Wharton, J. (2020).

- **wetlands risk reduction value into insurance pricing** and creating new revenue streams for conservation efforts, and added awareness and action on restoring biodiversity hotspots.[54]

These approaches can save the insurance sector as evidenced by an estimated USD 52 billion saving per year globally from protecting coastal wetlands.[55]

5.1.4 Pensions Sector

Public and private pensions portfolios had moderate dependency on nature, which also translated to moderate impact on nature, mainly from manufacture of food and beverages and power provision. These economic activities heavily rely on water supply and regulation, increasing their indirect dependencies and impacts on nature.

Furthermore, the geographical concentration of pension sector assets poses a risk. Lusaka's AuM are over four times that of any other province. This is due to the high water and support services risks Lusaka faces. Investors should consider these risks and portfolio diversification when making investment decisions, considering key environmental pressures including water and land use, light and noise disturbances, solid waste, soil, water, and air pollution.

Some actions that PIA - Pensions can take include:

- Increasing the **adoption of UN's Principles for Responsible Investment (PRI) by public and private pension companies** as a step towards demonstrating that they are not contributing to nature loss, which is likely to be increasingly demanded by their beneficiaries[58];
- Implementing **'net zero' nature loss policies** enforced through active engagement/ownership with asset managers to assess investments and supply chains for their impact on nature loss.
- **Develop forward-looking, return-based metrics**, such as a Biodiversity Value at Risk (BVaR), to support investors analyzing the financial materiality of nature and

Finally, nature-related finance will also offer opportunities to the pension sector:

- **Nature-linked green bonds will offer an additional source of investment for the pension sector.** Understanding nature risk and the importance of reducing them will also remove stigmas around investing in green bonds for pension schemes.
- Although rare at present, **pension schemes in Zambia could also issue green bonds to secure finance for attractive nature-improving infrastructure investments.** To date, only CPP Investments[59] and PSP Investments[60] based in Canada have issued green bonds, but other schemes in the country are making progress towards issuance.

[54] Global Innovation Lab for Climate Finance (2019)
[55] Barbier, E. B., Burgess, J. C., & Dean, T. J. (2018).
[58] Hudson, R. (2024).
[59] CPP Investments (2023)
[60] PSP Investments (2024).

biodiversity-related considerations that impact their portfolios.

- **Extending and applying the principles of the TFND framework**, as part of Enterprise Risk Management (ERM) and ESG practices.

- Nature can bolster Zambia's sovereign fiscal position through performance-based instruments and positive macroeconomic effects on key sovereign drivers. This can be **supported by pensions investing in straightforward, KPI-linked structured finance with a nature focus**.[61]

[61] Nature as a Shock Absorber: A Financial Materiality Assessment of Forestry-linked Sovereign Indicators in Ghana. (2025, February 26).

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Annex 2: Data Sources used

Data	Data Source
List of Economic Sectors	Zambia Statistics Agency
Banking Data	Bank of Zambia
Insurance Data	Pensions and Insurance Authority
Public Pensions Data	National Pension Scheme Authority, Public Services Pension Fund
Private Pensions Data	Pensions and Insurance Authority
SEC Data	Securities and Exchange Commission
Corporate Bonds	Securities and Exchange Commission
CIS Data	Securities and Exchange Commission
Nature Dependencies	ENCORE https://www.encorenature.org/en [July 2024]
Nature Impacts	ENCORE https://www.encorenature.org/en [July 2024]
Zambia Input-Output Table	GLORIA MRIO database https://ielab.info/labs/ielab-gloria [July 2024]

Annex 3: List of definitions used

Dependences (on nature)	Aspects of nature's contributions to people that a person or organization relies on to function, including water flow and quality regulation; regulation of hazards like fires and floods; pollination; carbon sequestration. Science Based Targets Network (2023) SBTN Glossary of Terms
Impacts (on nature)	These can be positive or negative contributions of a company or other actor toward the state of nature, including pollution of air, water, or soil; fragmentation or disruption of ecosystems and habitats for nonhuman species; and alteration of ecosystem processes. Science Based Targets Network (2023) SBTN Glossary of Terms
Biodiversity	The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Convention on Biological Diversity (1992) Article 2
Natural Capital	The stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people. Capitals Coalition (2016) Natural Capital Protocol
Ecosystem Services	The contributions of ecosystems to the benefits that are used in economic and other human activity. United Nations et al. (2021) System of Environmental-Economic Accounting - Ecosystem Accounting

Impact	Definition
Emissions of GHG	Activity emits GHG. Examples include volume of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), Sulphur hexafluoride (SF6), Hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs), etc.
Emissions of non-GHG air pollutants	Activity emits non GHG air pollutants. Examples include volume of fine particulate matter (PM2.5) and coarse particulate matter (PM10), Volatile Organic Compounds (VOCs), mono-nitrogen oxides (NO and NO2, commonly referred to as NOx), Sulphur dioxide (SO2), Carbon monoxide (CO), etc.
Introduction of invasive species	Activity directly introduces non-native invasive species into areas of operation.
Area of freshwater use	The freshwater area is used for the activity. Examples of metrics include area of wetland, ponds, lakes, streams, rivers or peatland necessary to provide ecosystem services such as water purification, fish spawning, areas of infrastructure necessary to use rivers and lakes such as bridges, dams, and flood barriers, etc. Impacts include hydrological changes, freshwater geomorphology and fluvial processes.
Area of land use	Activity uses land area. Example metrics include area of agriculture by type, area of forest plantation by type, area of open cast mine by type, etc.

Impact	Definition
Disturbances (e.g noise, light)	Activity produces noise or light pollution that has potential to harm organisms. Examples of metrics include decibels and duration of noise, lumens and duration of light, at site of impact.
Generation and release of solid waste	Activity generates and releases solid waste. Example metrics include volume of waste by classification (i.e., nonhazardous, hazardous, and radioactive), by specific material constituents (e.g., lead, plastic), or by disposal method (e.g., landfill, incineration, recycling, specialist processing).
Emissions of toxic pollutants to water and soil	Activity emits toxic pollutants that can directly harm organisms and the environment. Examples include volume discharged to the receiving water body of toxic substances (e.g., heavy metals and chemicals).
Emissions of nutrient pollutants to water and soil	Activity emits nutrient pollutants that can lead to eutrophication. Example metrics include volume discharged to the receiving water body of nutrients (e.g., nitrates and phosphates).
Other biotic resource extraction (e.g. fish, timber)	Activity extracts biotic resources including fish and timber. Examples of metrics include volume of wild-caught fish by species, number of wild-caught mammals by species, volume of timber by species, etc.
Other abiotic resource extraction	Activity extracts abiotic resources. Examples include volume of mineral extracted.
Volume of water use	Water is used for the activity. Example metrics include volume of groundwater consumed, volume of surface water consumed, etc.

Source: Natural Capital Coalition. (2016) Natural Capital Protocol. [Accessed Feb 2025]

Annex 4: List of Economic Sectors Used

Crop and animal production, hunting and related service activities
Forestry and logging
Fishing and aquaculture
Mining of metal ores
Other mining and quarrying
Manufacture of food, beverages and tobacco
Manufacture of textiles, clothing and leather products
Manufacture of wood and wood products
Manufacture of paper and paper products
Manufacture of chemicals, rubber and plastic products
Manufacture of non-metallic mineral products
Manufacture of basic metal products
Manufacture of metal products, computer, machinery, motor vehicles, furniture, and other
Electricity, gas, steam and air conditioning supply
Water supply; sewerage, waste management and remediation activities
Construction
Wholesale and retail trade; repair of motor vehicles and motorcycles
Transportation and storage
Accommodation and food service activities
Information and communication
Financial services, including insurance and pension funds
Real estate activities
Professional, scientific and technical activities
Administrative and support service activities
Public administration and defense; compulsory social security
Education
Human health and social work activities

Arts, entertainment and recreation
Other service activities

Annex 5: IAMs for the Analysis of Nature Risks

Another potential recommendation for financial sector actors is the adoption and use of economic models that can link risks to financial impacts. Therefore, we review the case for this action, using integrated assessment models (IAMs).

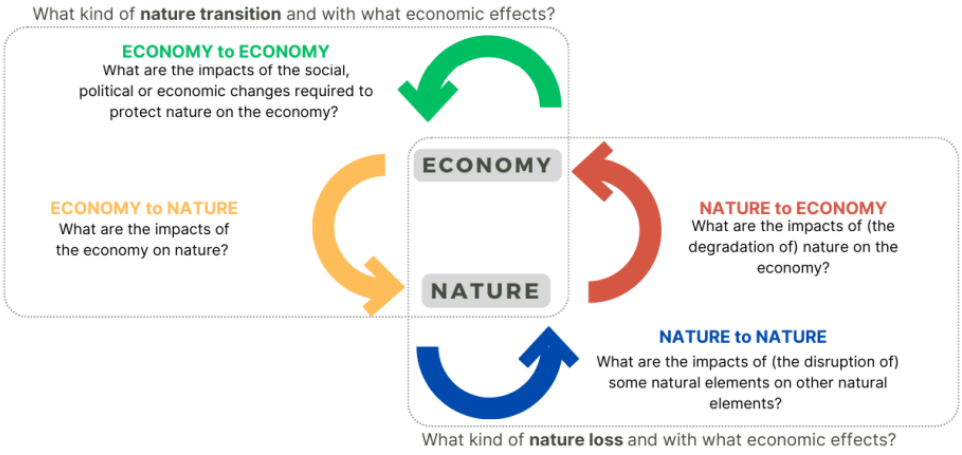
IAMs - according to the Integrated Assessment Modelling Consortium (IAMC) - "are simplified representations of complex physical and social systems, focusing on the interaction between economy, society and the environment". The models aim to provide policy-relevant insights into global environmental change and sustainable development issues by providing a quantitative description of key processes in the human and earth systems and their interactions.

Typically, the interaction has focused on climate change from the perspective of energy and greenhouse gas (GHG) emissions. As such, much of the use cases of IAMs to date has been to estimate social costs of carbon and to model the impacts of different climate change- and energy-related policies.

However, policymakers increasingly want to know the interaction between climate change, the economy, and finally, nature. Additionally, it has been proposed that IAMs can fill this gap in knowledge. Consequently, this document reviews the six most predominant IAMs to use if IAMs be used to evaluate the relationship between the economy and nature in Zambia and how the financial sector can be informed by its outputs.

Other reviews of IAMs and nature - such as that by Salin et al. (2024) - analyze the models in a four-part framework. This framework can be found in the figure below. We take that general framework and build on it, adding relevant details from model pages, user guides, and other reviews. Most relevantly, we also add in further criteria related to the applicability of these models to policymakers in Zambia, such sectoral and ecosystem coverage that has been revealed as important by the previous cascade analysis, the geographical detail, the feasibility of implementation (skill requirements and access), and the relevance to the financial sector.

Figure 63: Salin et al. (2024) framework for assessing the nature-economy relationship in IAMs



Source: Salin et al. (2024) [62]

[62] Salin, *et al* (August 22, 2024).

The assessment criteria for this review can be separated into 4 main categories:

- **Relevance** - referring to the ability of the model to capture the interactions between nature, ecosystem services, and the economy.
- **Applicability** - referring to the breadth in the economic model, in terms of sectors and the linkages between them, as well as the usefulness for the financial sector(s).
- **Feasibility** - referring to the ability of research bodies, practitioners, or private sector actors to install and use the model for scenario analysis.
- **Detail** - referring to spatial detail of the model from an economic and nature standpoint.

Within each of these categories, several sub-questions are used to assess the IAMs. These sub-questions are driven by the general use case of these models for nature-related macroeconomic scenario analysis, as well as the contextual questions related to the nature of the assignment, in terms of usefulness for the financial sector and the inclusion of economic and natural variables that are important for a comprehensive assessment of impacts on Zambia. The questions are shown in Table 12 below:

Table 12: IAM assessment criteria

Category	Question no.	Question
Relevance	1	Is the model able to incorporate dynamic feedback of ecosystem services on the social-economic system?
	2	Does the model cover both acute and chronic shocks to nature and biodiversity under different scenarios?
	3	Does the model incorporate the impacts of changes in nature on the quality of other ecosystem services?
	4	Is the model able to support policy decisions related to nature and biodiversity?
	5	Does the model cover the ecosystem services - water supply, storm and flood mitigation, soil retention - and impacts - soil and water pollution, water use, land use, GHG emissions - that are most relevant to Zambia?
Applicability	6	Does the model look at the interactions between sectors of the economy? Are upstream impacts effectively captured?
	7	What economic sectors are included as part of the model?
	8	Can the model be linked to the financial sector?
	9	If not, how would the results be helpful to them?
Feasibility	10	What programming skills are required to operate the model?
	11	What documentation/user guides are available?

	12	Who has used the model in the past (e.g. just the model creators, other academics, global institutions, or even private sector)
	13	Is the software open-source?
Detail	14	What is the macroeconomic geographical detail of the model?
	15	What region is Zambia considered a part of?
	16	What is the spatial granularity of land use data?

Based on the detailed comparison above, the models that seem most effective and relevant in detailing the impacts of economic change on nature and, to a certain extent, the recursive impact are GTAP-InVEST, followed by IMAGE-MAGNET (due to its lack of public availability).[63] Whilst the other models have advantages and specific use cases, these models are most relevant for nature-related policymaking, specifically for the financial sector, as looking at the impact of changes in nature on the economy can be used to evaluate investments, both in affected sectors and in adaptation and nature-improving projects. The relative advantages of specifically GTAP-InVEST compared to its counterparts are detailed below:

Advantages

1. GTAP-InVEST is crucially **able to model the impacts of nature on the economy in multiple ways** (although not fully) rather than considering changes to its state as being exogenous to economic prosperity.
2. The model includes **a wider variety of economic sectors**. Whilst it does not have as much of a detailed representation of the energy sector, this allows policymakers and the financial sector to have a holistic view of the impacts of policy changes. Additionally, the connection to the GTAP IO model considers sectoral interlinkages.
3. The model has amongst the **highest granularity of regional macroeconomic representation** of the evaluated models. This allows Zambian policymakers to also look at the spillovers of policies in other regions and for financial sector actors to evaluate external investments.
4. The **detail of the land use data from SEALS is incredibly detailed**. Therefore, land-related policy impacts - such as the valuable achievement of 30x30 biodiversity targets - are far more accurate.
5. **Model authors are committed to further improvements to the model** that add more valuable insights, such as dynamic feedback and the incorporation of more ecosystem services.
6. The **model is open-source** and has, for the adequately skilled practitioner, useful user guides to allow for personal implementation.

Disadvantages

1. Despite future commitments, it **does not currently model the impacts of many ecosystem services**. At the very least, linking the model to the GLOBIO framework would provide greater insight, even if it is unidirectional.
2. Like many of the IAM models, use of GTAP-InVEST does **require a strong knowledge of software programmes**.

[63] See Annex 5 for the full analysis

3. The model code is open source; however **contributory datasets are not freely available** and would require an investment on behalf of the implementing agency.

The GTAP-InVEST model is comparatively appealing, but there are a few general drawbacks that limit the usefulness of IAMs to national actors. Firstly, the underlying macroeconomic models do not uniquely identify Zambia. As a result, the economic composition and feedback of policy changes and nature shocks are not representative of the impact that Zambia would face. A key recommendation for the improved use of GTAP-InVEST in the Zambian context would be to isolate the country as its own geographical region within the model, to identify how domestic and international ecosystem shocks have unique implications for the economy and by extension the financial sector. Additionally, IAM models continue to not represent a full range of ecosystem services, especially those that are most relevant to Zambia. Finally, the direct transmission mechanism that translates nature-related shocks to economic impacts continues to come through the agricultural sector. Whilst the cascade analysis supports this to an extent, the exclusion of sectors such as mining and manufacturing continues to misrepresent - and potentially underestimate - the impact that changes in nature present. This is a key reason that we choose not to progress with one of these models for the scenario analysis component.

Moreover, future research in Zambia and beyond should strive towards bridging the gap between IAMs and the financial sector to foster a more integrated approach to nature-related impact assessments. By promoting interdisciplinary collaborations with local and global research institutions and harnessing the diverse strengths of IAMs, evidence-based decision-making frameworks that harmonize transmission mechanisms across all sectors with environmental preservation in Zambia can be enhanced.

Annex 5: Detailed IAMs assessment

Question	Model					
	GTAP-InVEST	REMIND-MAgPIE	AIM-Hub	IMAGE-MAGNET	GCAM	MESSAGE-GLOBIOM
Relevance						
Is the model able to incorporate dynamic feedback of ecosystem services on the social-economic system? Is the model able to incorporate dynamic feedback of ecosystem services on the social-economic system?	**Yes.** The model is run in two stages. First, the impacts of economic changes or policy on ecosystem services are modelled through changes in the structure and demand of land use. From there, the impacts on the modelled ecosystem services are inputted back into the economic model to look at recursive impacts. Additionally, model authors state that one of the next steps in its evolution is to develop a fully iterative model that	**No.** MAgPIE affects REMIND macro modules through changes in relative prices of bioenergy and expenditures for abatement of land use emissions Further, changes in water supply can impact agricultural yields in MAgPIE, affecting output in REMIND. However, other ecosystem services do not impact on yields.	**No.** There is no feedback from loss of nature on the economy. Crop yields are not impacted by future climate damage or from nature-related changes. To include these types of feedback effects, it would have to be manually included in a model scenario.	**Yes**. Ecosystem services can impact back on the economy in the following ways. On the supply side: negative shocks to ecosystem services affect the sector's productivity. On the demand side: for some sectors that must be consumed (e.g., food), higher prices will lower demand for other sectors, impacting aggregate demand. Equally, changes to the economy can have their own impacts on nature through an extension of the model to GLOBIO.	**No.** The impacts of biodiversity changes back on the macroeconomy are not currently linked.	**No.** Energy is the only channel through which shocks are transmitted back into macroeconomic outcomes.

	dynamically quantifies the impacts on both nature and the economy.[64]					
Does the model cover both acute and chronic shocks to nature and biodiversity under different scenarios?	**Yes.** The model can look at both chronic (classical climate change) and acute (climate tipping or breaking point) impacts. Chronic shocks to nature are modelled through projected changes to population, land use, temperature, and precipitation under SSPs (Shared Socioeconomic Pathways) and RCPs (Representative Concentration Pathways) until 2030. Acute shocks are modelled through collapses of 3 ecosystem services: 1) wild pollinators; 2)	**Partially.** MAgPIE can link the changes in climate from the REMIND model to look at the impacts on biodiversity. Chronic impacts are yet to be modelled but land degradation and pollinator loss is being developed.	**Partially.** The model can look at some chronic impacts that come through climate change/economic scenarios, however acute scenarios are not included.	**Yes.** The model can look at both chronic and acute impacts on biodiversity. However, the only transmission mechanism through which ecosystem services affect the macro-economy is through its impact on agricultural yields.	**Partially.** Like IMAGE-MAGNET, ad-hoc shocks can be integrated through shocks to agricultural yields, however there is not a predefined relationship that comes from a certain nature-related shock on economic output.	**No.** The model is not linked to either chronic or acute shock to biodiversity.

[64].Thakrar, *et al* (2023).

	forests, and 3) marine fisheries.					
Does the model incorporate the impacts of changes in nature on the quality of other ecosystem services?	**Not yet.** These interactions are not considered. Only economic impact on nature which is linked back to the economy. However, the ambition to create a dynamic model will mean that in an iterative sense a nature shock can impact on other ecosystem services, but only with the macro-economy as the transmission mechanism.	**No.** There are no feedback effects between different ecosystem services.	**No.** There are no feedback effects between different ecosystem services.	**No.** The impacts of scenarios of biodiversity are not dynamic, as they are calculated separately to the model in the GLOBIO extension.	**No.** There are no feedback effects between different ecosystem services	There are no feedback effects between different ecosystem services.
Is the model able to support policy decisions related to nature and biodiversity?	**Yes.** The main nature-related policy is that relating to 30x30 biodiversity targets,[65] However, a few additional policies relating to 1) farmer subsidies, 2) domestic forest carbon	**Partially.** It is possible to model the effects of water scarcity on agricultural yields. The medium-term research agenda aims to refine the link between MAgPIE and the SEALS model as	**Partially.** The model is mainly useful for climate transition scenarios, but it can also be used to model land use changes and increase efforts in conservation.	**Yes.** The model can support a vast number of potential scenarios, including REDD based afforestation and carbon sequestration, as well as declines in pollinators, and improvements to water systems	**Yes.** GCAM has biodiversity policies consistent with other IAM models: Protected areas (7 different options depending on suitability intactness, and protection level), Shadow carbon price of land, Land use	GLOBIOM has been used to assess: · the effect of biodiversity policies on land use, biodiversity and food prices (Leclère et al. 2020) · the consequences of nitrogen mitigation

[65] Johnson, *et al*. (2021).

	payments, 3) global forest carbon payments, 4) public spending on Agri R&D can all be modelled in any combination.	well as to link to INVEST ecosystem service models. Increased conservation efforts and water scarcity can also be modelled.		management.	constraints, and varying systems of agricultural management (irrigated vs rainfed, high versus low fertilizer use),	policies on food production and security (Chang et al. 2021) · the implications of achieving key SDGs (including water and biodiversity) on land-based climate mitigation potential (Frank et al. 2021). Biodiversity policies explored include increasing share of protected areas, avoiding conversion of biodiversity hotspots, and respecting water flow requirements for freshwater ecosystem protection
Does the model cover the ecosystem services - water supply, storm and flood mitigation, soil retention - and impacts - soil and water pollution, water use, land use, GHG emissions - that are	**No.** Given that the ecosystem services that are currently covered by InVEST are Sediment retention, Climate regulation, Pollination of crops, Timber production, Coastal protection, and	**Yes.** The ecosystem services (dependences) and pressures are extensive in the MAgPIE model. Ecosystem services in MAgPIE are as follows: Provisioning food and	**No.** The model does not directly link to ecosystem services as typically defined. Instead, pressures from climate change and land use changes are more explicitly modelled. However, the model can be	**Yes.** The links to nature are extensive. Ecosystem services include: Water provision, quality, and flow maintenance, the provision of food, fish, timber, fibers, and bioenergy, pollination,	**No.** Ecosystem services are not explicitly modelled. However, there are biodiversity pressures included: Climate change, land use change, direct exploitation (of water only – withdrawals for energy & agriculture	**Not linked to traditionally defined ecosystem services, rather than pressures.** Climate change: GHG emissions from energy (MESSAGE – CO2, CH4, N2O, F-gases, other radiatively active gases, such as NOx, volatile

most relevant to Zambia?	Marine fisheries, many of the relevant ecosystem services are not included. However, this is another area of future expansion of the model.	fiber commodities including pollination, provisioning of water for secondary energy production. Yields also depend on physical properties of soil (fertility), climate conditions, terrain type, and water availability and quality. Additionally, biodiversity pressures modelled are: Land use and land use change and Climate change.	linked to biodiversity through model extensions, and link to assessments of ecosystem services, but not the impacts of changes thereof.	climate regulation, soil quality and retention, flood and storm mitigation, and pest control Biodiversity pressures include: Climate change, land use change, land-use intensity, fragmentation, infrastructure & encroachment, pollution flows, nitrogen Flow deviation (e.g. through dams, nutrient flows (N&P).	and consumption modelled, water supply modelled as a physical relationship between precipitation, evapotranspiration, recharge and runoff with river-routing)	organic compounds, CO, SO2, and BC/OC) and land-use (GLOBIOM), and resulting climate change (MAGICC). Land-use (from GLOBIOM) Air pollution (GAINS model) Water demand is associated to energy production (but water supply is not modeled)
Applicability						
Does the model look at the interactions between sectors of the economy? Are upstream impacts effectively captured?	**Yes.** The interaction between sectors is modelled due to the underlying GTAP I-O table included in the model. That means that the interactions between sectors and regions driven by decreases in output at the sectoral level are effectively captured.	**No.** There is no underlying input output table as part of the analysis. Furthermore, GDP impacts are only measured at a high-level.	**Yes.** There is an underlying SAM that links sectors to each other, so the interactions observed are sufficient. As an aside, biodiversity-relevant linkages are not modelled, however.	**Yes.** MAGNET, through the GTAP model that underlies it, is able to model these interaction effects.	**No.** There is no consideration of sectoral interlinkages.	**No.** Due to the sectoral make-up of the model, interactions are only considered within the agricultural sector, with relatively detailed inputs based on the different management techniques.

What economic sectors are included as part of the model?	**57.** The GTAP model has 57 total commodities (65 in the updated version). These commodities have significant overlap with those measured in GVA stats in Zambia. The sectors can be found here.	**Few.** REMIND only models' energy from a technological and end-use perspective. End-use sectors include sectors: electricity production, stationary non-electric, transport, buildings (all nested under energy). MAgPIE also only focuses on agriculture as a sector and the various processes in it, including forestry. However, mining, chemicals, fisheries and other sectors are not part of the model.	**44.** AIM has 44 sectors in total: they are distributed as follows: 10 in agriculture, 21 sectors in energy supply technology, and 13 other sectors, which mainly cover industrial processes and services are aggregated together.	**113.** The MAGNET macro model covers 113 sectors: 65 of which are from GTAP, and 49 are MAGNET extensions that provide additional details on sectors related to the bioeconomy or circular economy.	**Few.** The GCAM models only look at the energy sector and the agricultural sector (8 crop types)	**Few.** The MESSAGE model is based on energy demand, with end-use sectors defined as transport, residential/commercial (also referred to as the buildings sector) and industry. GLOBIOM focuses on agriculture, forestry, and livestock with various forms of management for them (e.g., irrigated, rainfed, subsistence)
Can the model be linked to the financial sector?	**No direct representation of the financial sector.**	**No direct representation of the financial sector.**	**No direct representation of the financial sector.**	**No direct representation of the financial sector.**	**No direct representation of the financial sector.**	**No direct representation of the financial sector.**
If not, how would the results be helpful to them?	The impacts on multiple economic sectors and the interlinkages between them can be used by the financial sector to observe stressors on their portfolio.	The ecosystem services in the model are very detailed, and can be used to look at impacts on and of agricultural investments	The interlinking pressures of investments on biodiversity can be modelled. However, due to the lack of modelling of impacts back on the economy, the use case is limited.	The model can be of use in a similar way to the GTAP-INVEST model	Like REMIND-MAgPIE, the model can be used to look at the biodiversity impacts of varying agricultural investments	MESSAGE-GLOBIOM has similar use cases to GCAM and REMIND-MAgPIE
Feasibility						

What programming skills are required to operate the model?	Running the model requires a considerable amount of technical skill and involves multiple different programming languages (Python, C, R, and GEMPACK). The model is 'glued together' in Python	Running the models requires a good knowledge of R	Given that the model is available in Excel, skills required are relatively lower	The model is not available for public use. Only the results of various projects can be accessed	The GCAM model is run using R	The model requires knowledge of either R or Python
What documentation /user guides are available?	User guides are available and are relatively helpful in explaining the purpose of the model, the set-up, and even the provision of some replication code as guidance for wider usage.	Significant GitHub repositories exist for the content, including the running of the model in a coupled format. Otherwise, tutorials are also available.	The model website does not have clear user guides or example cases that can be referred to by practitioners.	Documentation of how to use the IMAGE scenario viewer page is available on the website. The MAGNET manual is not available.	GCAM's GitHub repository has useful video guides for users who wish to make use of the model	User guides are available for the model's usage in Python and how it can also be implemented in R.
Who has used the model in the past (e.g. just the model creators, other academics, global institutions, or even private sector)	Given the recency of the founding paper, it is unlikely there has been wide usage of the model.	There does appear to be a wider academic use of Remind-Magpie beyond the model creators. Additionally, the usage of the model in NGFS scenarios indicates its ability to be understood by non-academic actors.	Applications exist beyond model creators, but there is no clearly available use case by private sector actors	There are a few academic uses of MAGNET, and of IMAGE, however IMAGE is also used by non-academic users like civil servants in the Netherlands PBL.	There are likewise a few studies using the GCAM but no clear evidence of private sector usage.	Wider academic use, private sector is unclear.
Is the software open source?	**No.** The model is open-source and can be accessed through a	**No.** REMIND: The model code is available open access however	**Yes.** Open access, one Excel version and one GAMS version	**No.** Open sourcing is currently under development, however	**Yes.** GCAM is available open access.	**Yes.** The scientific software underlying the global MESSAGE-

	GitHub page, however it requires access to the GTAP database (paid) and a GEMPACK license.	various data inputs are paid. MagPIE: Version 4 is open access. The coupling code is part of the REMIND and MAgPIE releases.		for MAGNET data licenses are required for a few datasets, including for GTAP and for software licenses, including GEMPACK.		GLOBIOM model (called the MESSAGEix framework) is open-source.
Detail						
What is the macroeconomic geographical detail of the model?	**37 regions**	**12 regions**	**17 regions**	**26 world regions**	**32 regions**	**11 regions**
What economic region is Zambia considered to be a part of?	**Rest of SSA** (less Angola, DRC, Ethiopia, Nigeria, South Africa, Madagascar)	**Sub-Saharan Africa**	**Rest of Africa (less North Africa)**	**Rest of Southern Africa** (Angola, Botswana, Lesotho, Mozambique, Malawi, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe)	**Africa Southern** (Angola, Botswana, Lesotho, Mozambique, Malawi, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe)	**Sub-Saharan Africa**
What is the spatial granularity of land use data?	10 arc seconds (~300mx300m)	30 arc minutes (~50kmx50km)	30 arc minutes (~50kmx50km)	5 arc minutes (~10kmx10km)	5 arc minutes (~10kmx10km)	30 arc minutes (~50kmx50km)

Source: Author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