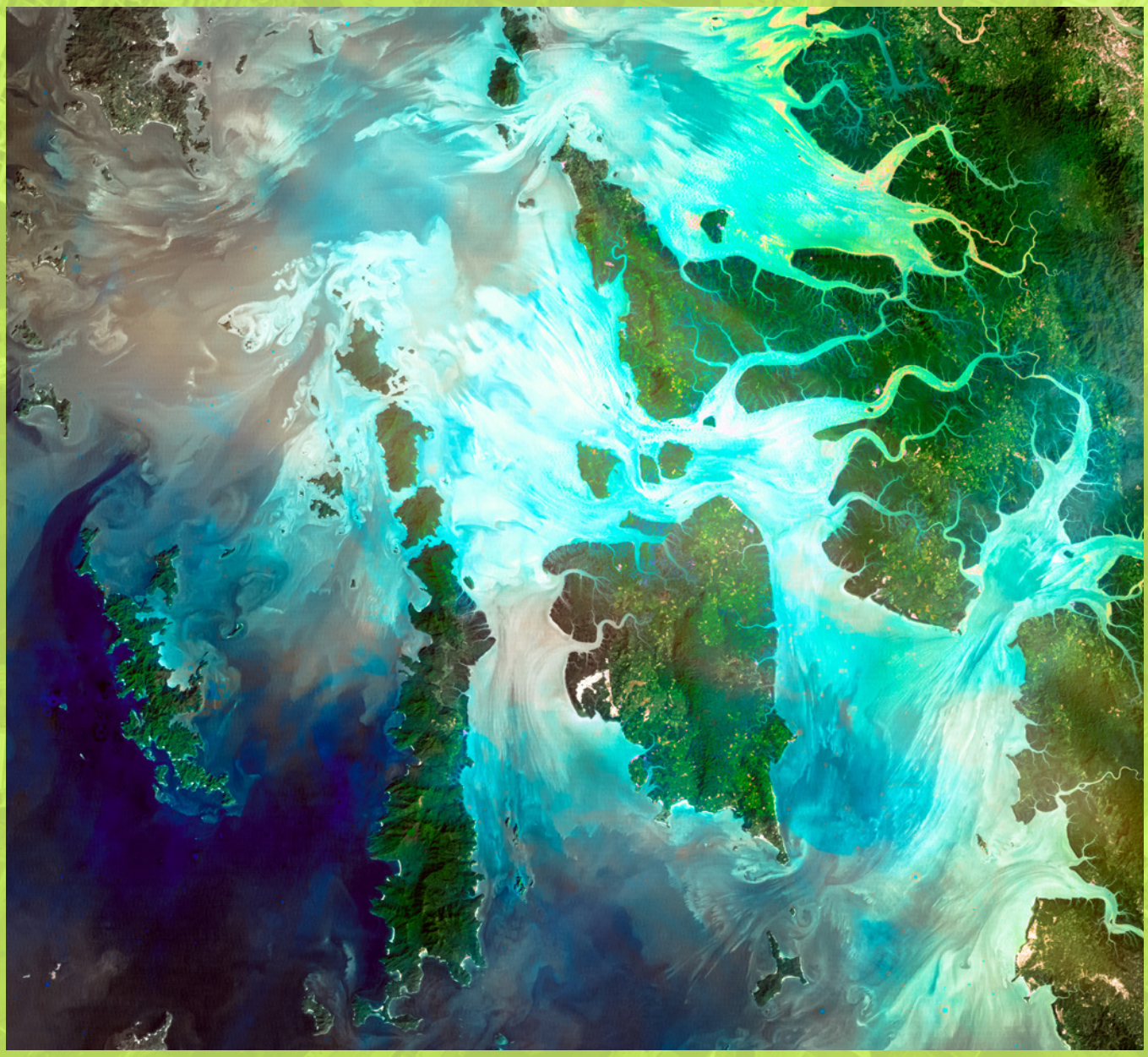

Guidance on biomes

Version 1.0 September 2023

tnfd.global

Taskforce on Nature-related Financial Disclosures

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Introduction to biomes

What you will find in this guidance

- An introduction to each biome
- A mapping of sectors and business activities to biomes and the ecosystem services they provide
- Specific additional guidance on biomes for each phase of LEAP, where relevant
- Illustrative examples of biome-specific impacts, dependencies, risks and opportunities
- Assessment indicators and metrics for each biome
- Reference to industry standards and other tools, frameworks and data sources that may assist with your assessment

The TNFD has developed this guidance on biomes to support the identification, assessment and disclosure of nature-related dependencies, impacts, risks and opportunities. These issues are location-specific and depend on the type of ecosystem (biome) and current and expected future state of nature in the relevant location.

This guidance aims to support organisations whose operations involve nature-related issues associated with the biomes covered. It is a supplement to TNFD's Guidance on identification and assessment of nature-related issues – the LEAP approach and should be read in conjunction with that guidance.

The guidance will be periodically reviewed and updated by the Taskforce, based on scientific and technical updates related to biomes and market feedback, in order to enhance its relevance and usability. Guidance on additional biomes will be added over time.

What are biomes?

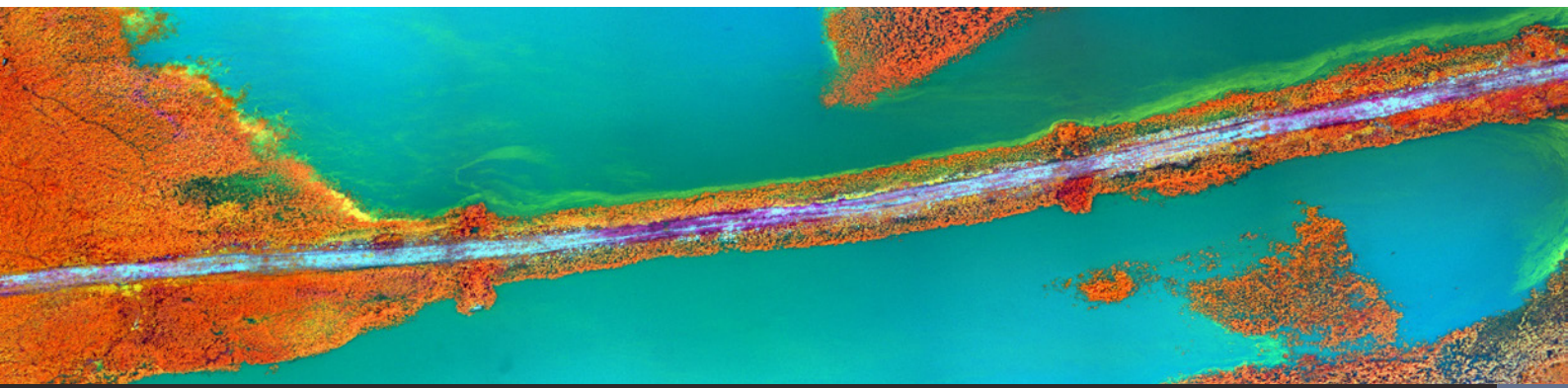
In simple terms, biomes are types of ecosystem (such as tropical rainforests) that exist in different locations around the world. They are generally defined by the type of plant life that they support in response to average rainfall and temperature patterns.[1]

The International Union for the Conservation of Nature (IUCN) provides a taxonomy of biomes known as the Global Ecosystem Typology (GET). Figure 1 shows the full list of biomes grouped by the four realms of nature. Many biomes span more than one realm.

1 Based on Keith, D. et al. (2020) IUCN global ecosystem typology (GET) 2.0.

Figure 1: Overview of fundamental concepts for understanding nature

Adapted from: United Nations et al. (2021) System of Environmental-Economic Accounting and IUCN (2020) Global Ecosystem Typology (GET) 2.0 The numbers in brackets for each biome refer to the alphanumerical code from the GET. In some cases, the terms used here for biomes have been simplified from the GET to aid understanding.



Why is consideration of biomes important to a LEAP assessment?

Biomes in different locations (e.g. a tropical rainforest in Guinea and a tropical rainforest in Brazil) are likely to provide similar types of ecosystem services as a flow of benefits to business and society and are also likely to be affected by similar impact drivers. Identifying and understanding the biome where your organisation's business model and value chain interface with nature can therefore provide insight into the types of nature-related dependencies, impacts, risks and opportunities relevant to your organisation.

Table 1 summarises the principal ecosystem services provided by each biome covered in this guidance.

Table 1: Principal ecosystem services by biome

Biome or sub-biome	Principal ecosystem services		Example
Tropical and sub-tropical forests (T1)	Provisioning services	Water supply	Sustained supply of clean water.
		Biomass provisioning	Timber, fibre, fuelwood, medicinal plants, food.
	Cultural services	Recreation-related services	Forest recreation and tourism.
		Spiritual, artistic and symbolic services	Sacred groves and trees, emblematic animals.

Biome or sub-biome	Principal ecosystem services		Example
	Regulating and maintenance services	Pollination	Pollination by forest animals such as bees, bats and birds.
		Biological control	Natural pest and disease control.
		Soil and sediment retention	Soil stabilisation, protection against erosion.
		Flood mitigation	Flood protection by riparian vegetation.
		Water flow regulation	Absorption and storage of water to regulate flows.
		Rainfall pattern regulation	Regional climate regulation.
		Local climate regulation	Local climate regulation through evapotranspiration and shading.
		Global climate regulation	Carbon sequestration and mitigation of greenhouse gas (GHG) fluxes.
		Soil quality regulation	Improvement of soil fertility and structure.
		Water purification	Water purification.
		Air filtration	Filtering and removing airborne pollutants.

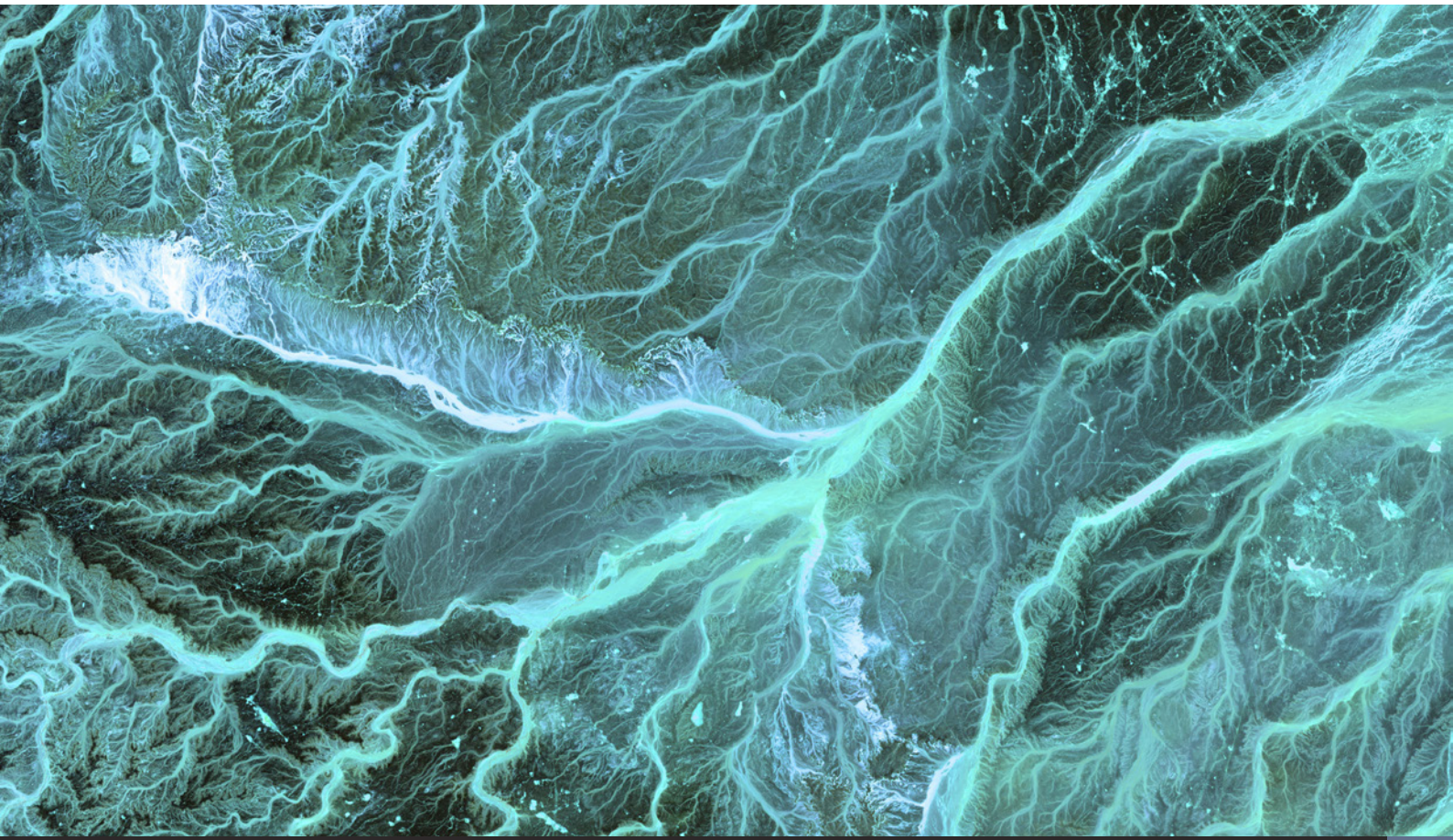
Biome or sub-biome	Principal ecosystem services		Example
Savannas and grasslands (T4)	Provisioning services	Biomass provisioning	Forage/fodder in low intensity grazing systems, food (edible plants, and hunted animals), fuel, medicine.
	Cultural services	Recreation-related services	Recreational hunting, other recreation, tourism.
		Visual amenity services	Aesthetic value.
		Spiritual, artistic and symbolic services	Cultural heritage.
	Regulating and maintenance services	Pollination	Pollination by animals living in the grasslands and surrounding habitats.
		Soil and sediment retention	Erosion control.
		Water flow regulation	Absorption and storage of water to regulate flows.
		Global climate regulation	Carbon sequestration and mitigation of GHG fluxes.
		Soil quality regulation	Soil fertility maintenance.
		Water purification	Water purification.
		Other regulating and maintenance service	Protection against desertification.

Biome or sub-biome	Principal ecosystem services		Example
Intensive land-use systems (T7) – Excluding urban and industrial ecosystems	Provisioning services	Genetic material services	Genetic materials from animal and plant breeds.
		Biomass provisioning	Food, animal fodder, materials, fibre and biomass from cultivated annual or perennial crops; and meat, milk and materials from livestock.
	Cultural services	Recreation-related services	Outdoor recreation, walking, hunting.
		Visual amenity services	Appearance of traditionally managed landscapes.
		Spiritual, artistic and symbolic services	Sense of place, cultural identity.
	Regulating and maintenance services	Pollination	Pollination by wild species (according to management practices).
		Biological control	Pest control by wild species (according to management practices).
		Soil quality regulation	Maintenance of soil fertility (according to management practices).

Biome or sub-biome	Principal ecosystem services		Example
Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4)	Provisioning services	Water supply	The sub-biome can include local water sources.
		Biomass provisioning	Food from urban and peri-urban agriculture.
	Cultural services	Recreation-related services	Urban greenspaces provide opportunities for physical exercise, and urban biodiversity can boost the psychological wellbeing of urban dwellers. They also provide tourism opportunities.
		Education, scientific and research services	Supporting education around nature.
		Spiritual, artistic and symbolic services	Urban biodiversity is part of the intangible fabric of sense of place to urban dwellers.
	Regulating and maintenance services	Pollination	Urban greenery can provide habitat for pollinators, supporting urban and peri-urban agriculture.
		Soil and sediment retention	Trees can reduce the risk of landslides.
		Air filtration	Urban greenery can help to purify air in the area.
		Flood mitigation	Trees can slow the flow of excess water, and mangroves can reduce the risk of coastal flooding.
		Water flow regulation	
		Local (micro and meso) climate regulation	Urban greenery can reduce local temperatures by providing shade.
		Noise attenuation	Urban greenery can support dampening of noise.

Biome or sub-biome	Principal ecosystem services		Example
Rivers and streams (F1)	Provisioning services	Water supply	Supply of water for industry, irrigation, human and animal consumption.
		Biomass provisioning	Harvested fish, shellfish and plants; aquaculture.
		Other provisioning services	Hydro-electric energy; water surface for navigation.
	Cultural services	Recreation-related services	Tourism; outdoor recreation such as sailing, swimming, fishing, waterfowl hunting.
		Visual amenity services	Scenic beauty.
	Regulating and maintenance services	Soil and sediment retention	Erosion control, regulation of sediment flow, augmentation of fertile land in floodplains, maintenance of productive deltas.
		Flood mitigation	Mitigation of flood events by river floodplains.
		Nursery population and habitat maintenance	Maintenance of nurseries and migratory connections for fish species.
		Water purification	Pollutant control by fringing or wetland vegetation; dilution of pollutants.

Biome or sub-biome	Principal ecosystem services		Example
Marine shelf (M1)	Provisioning services	Biomass provisioning	Wild and farmed fish, shellfish and seaweed.
		Other provisioning services	Water surface for navigation.
	Cultural services	Recreation-related services	Recreational fishing, diving, whale watching.
	Regulating and maintenance services	Flood mitigation	Reefs or sandbanks protecting coasts.
		Global climate regulation	Carbon sequestration and mitigation of GHG fluxes; heat sink.
		Nursery population and habitat maintenance	Nursery provision for marine species.
		Water purification	Removal of nutrients and other pollutants.



Biomes of likely relevance to different sectors

Your organisation is likely to interface with multiple biomes across its value chain. Table 2 sets out the most common interfaces of a selection of sectors with the biomes covered in this guidance, but you should consider the possibility of interfaces with all biomes in the GET.

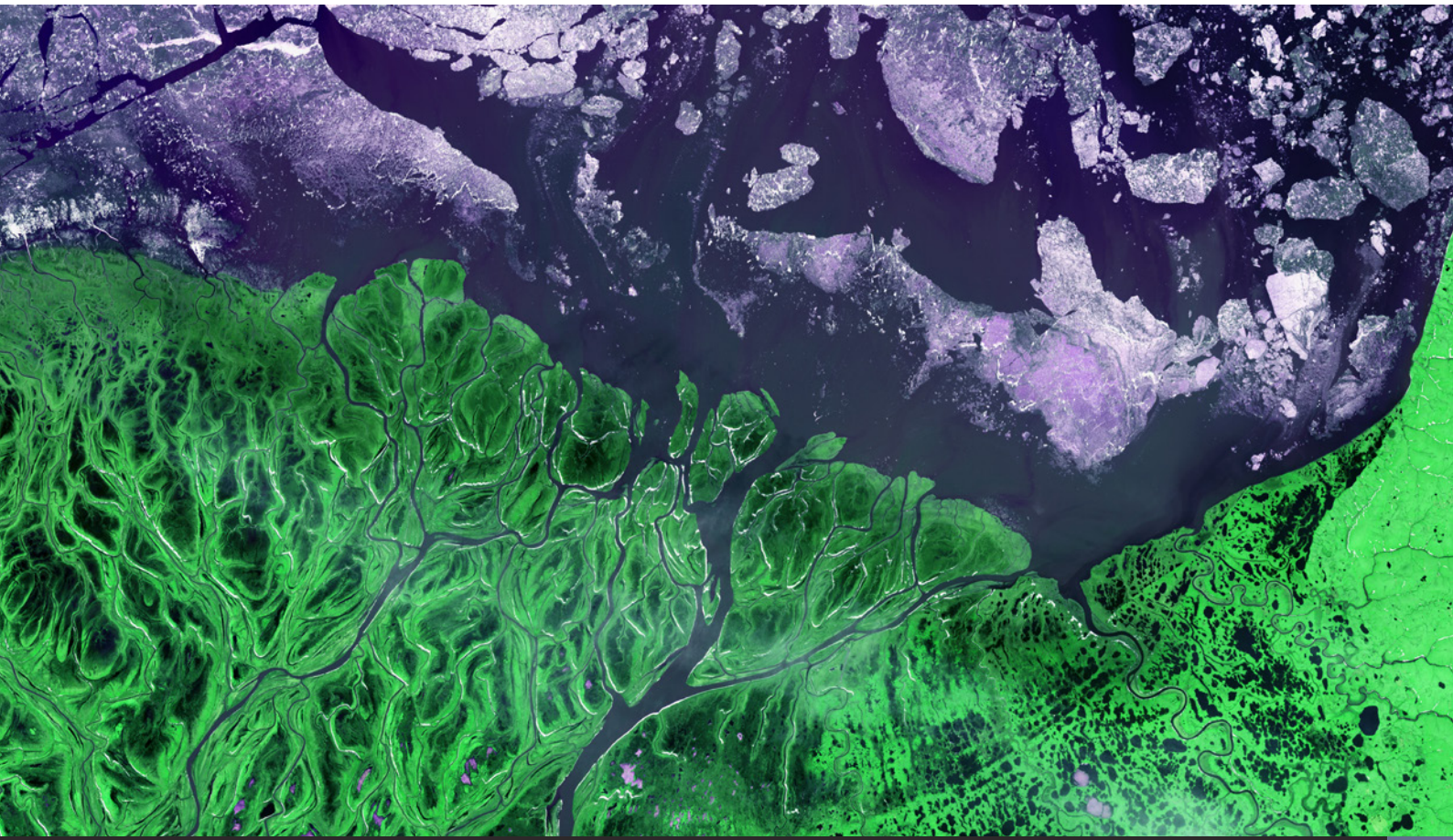
This sector-to-biome mapping is only a starting point based on common business models within a sector. All organisations should consider their own particular business model and value chain and how their business processes and activities have impacts and dependencies on nature in order to determine the relevant biomes. The relevant biome may not be in the same location as business operations or value-chain activities.

Table 2: Principal sectors interfacing with each biome

Sectors	Likely relevant biomes in this guidance
Consumer goods	Tropical and sub-tropical forests (T1) Intensive land-use systems (T7) – Excluding urban and industrial ecosystems Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4) Rivers and streams (F1)
Electric utilities and power generation	Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4) Rivers and streams (F1) Marine shelf (M1)
Energy (oil, natural gas and renewable energy)	Tropical and sub-tropical forests (T1) Savannas and grasslands (T4) Intensive land-use systems (T7) – Excluding urban and industrial ecosystems Marine shelf (M1)

Sectors	Likely relevant biomes in this guidance
Food and beverage	Tropical and sub-tropical forests (T1) Savannas and grasslands (T4) Intensive land-use systems (T7) – Excluding urban and industrial ecosystems Rivers and streams (F1) Marine shelf (M1)
Food and beverage (aquaculture and fishing)	Intensive land-use systems (T7) – excluding urban and industrial ecosystems Rivers and streams (F1) Marine shelf (M1)
Forestry management Pulp and paper products Other forest-based enterprises and users of formerly forested land	Tropical and sub-tropical forests (T1) Savannas and grasslands (T4) Intensive land-use systems (T7) – Excluding urban and industrial ecosystems Marine shelf (M1)
Hospitality and recreation (tourism)	Tropical and sub-tropical forests (T1) Savannas and grasslands (T4) Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4) Rivers and streams (F1) Marine shelf (M1)
Infrastructure	Tropical and sub-tropical forests (T1) Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4) Savannas and grasslands (T4) Rivers and streams (F1)

Sectors	Likely relevant biomes in this guidance
Metals and mining	Tropical and sub-tropical forests (T1) Savannas and grasslands (T4) Intensive land-use systems (T7) – including urban and industrial ecosystems Rivers and streams (F1) Marine shelf (M1)
Resource transformation	Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4) Rivers and streams (F1)
Transportation	Intensive land-use systems (T7) – Urban and industrial ecosystems (T7.4)

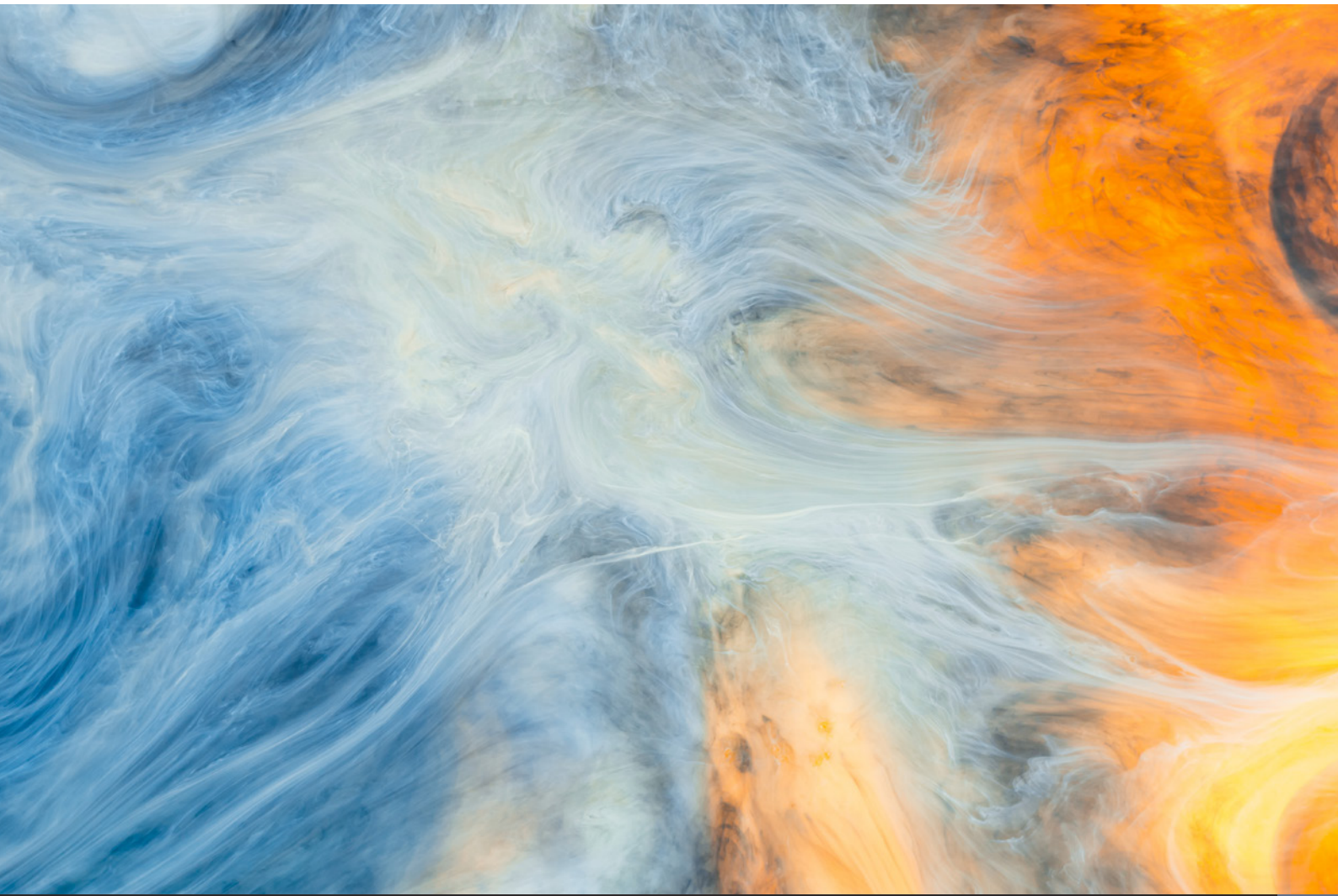


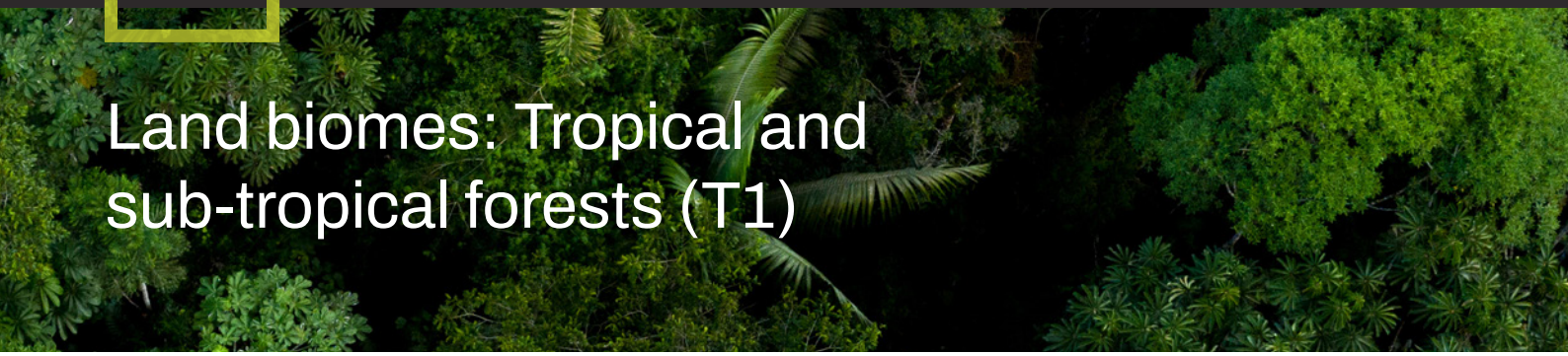
Additional guidance to support LEAP assessments

This document only provides additional guidance for specific biomes in each phase of the LEAP approach where additional insights are relevant. Where there is no additional guidance provided below, the Guidance on identification and assessment of nature-related issues – the LEAP approach should be applied.

For each biome, the scientific classification from the GET is shown (e.g. T1 for tropical and sub-tropical forests) and the additional guidance is arranged in the following sections, which follow the four phases of the LEAP approach:

- Introduction;
- Concepts and definitions;
- Scoping a LEAP assessment;
- L – Locating the organisation's interface with nature;
- E – Evaluating nature-related dependencies and impacts;
- A – Assessing nature-related risks and opportunities;
- P – Preparing to respond and report; and
- Assessment metrics.





Land biomes: Tropical and sub-tropical forests (T1)

Introduction

Tropical forests are found at low latitudes. They are shaped by high rainfall and stable year-round temperatures. Tropical forests are structurally complex and exceptionally diverse.

The tropical and sub-tropical forests biome can be sub-divided into:

- **Tropical and sub-tropical lowland rainforests (T1.1)** – Shaped by relatively high temperatures and stable year-round rainfall patterns, these forests can reach exceptional heights and levels of structural complexity and diversity;
- **Tropical and sub-tropical dry forests (T1.2)** – Experiencing particularly dry seasons during which some trees shed leaves, such forests are globally more threatened than lowland rainforests;
- **Tropical and sub-tropical montane rainforests (T1.3)** – These mountain rainforests are characterised by a single-layered tree canopy. Grasses are rare or absent. At high altitudes forest structure becomes less complex, with dwarf tree forms. Montane rainforests are typically shorter and less structurally complex; and
- **Tropical heath forests (T1.4)** – Tropical forests which grow on acidic soils, characterised by high densities of low, slender trees and unusual plant communities, including insectivorous plants.

Concepts and definitions

Forest: Land spanning more than 0.5 hectares with trees higher than five metres and a canopy cover of more than 10% or trees able to reach those thresholds in situ. It does not include land that is predominantly under agricultural or other land use. Forest includes natural forests and tree plantations. For the purpose of implementing zero deforestation supply chain commitments, the focus is on preventing the conversion of natural forests.[2]

Deforestation: The conversion of forest to other land use independently whether human-induced or not.[3]

Forest degradation: Entails a reduction or loss of the biological or economic productivity and complexity of forest ecosystems resulting in the long-term reduction of the overall supply of benefits from forest, which includes wood, biodiversity and other products or services, provided that the canopy cover stays above 10%.[4]

Tree cover loss: Conversion of a tree-dominated land use type to a non-tree-dominated land use type. Note that deforestation is included in this, but that not all tree cover loss is deforestation, as it could also include tree cover loss within commercial forest plantations.

Scoping a LEAP assessment

In considering activities, assets, sectors and value chains in scope, your organisation should consider the diverse ways in which it may interact with this biome through its value chain (Table 3).

2 Accountability Framework.

3 FAO (2020) Forest Resources Assessment - Terms and Definitions; FAO (2000) Forest Resources Assessment – Definitions of Forest Change Processes.

4 FAO and UNEP (2020) The State of the World's Forests 2020: Forests, biodiversity and people. Rome; FAO (2000) Forest Resources Assessment - Definitions of Forest Change Processes.

Table 3: Connections to the tropical and sub-tropical forests biome

Degree of connection	Examples and implications
A. Business owns or manages land, or has significant operational control over supply chain, in tropical and sub-tropical forest biome	Examples: • Agricultural business sourcing from leased land or from contracted smallholders. • Mining company with operations in tropical forests. Implications: • Companies with a direct connection to tropical forest should have (or be able to develop) precise location information on their activities. • Activities are directly linked to impacts and dependencies, but with considerable potential for effective management of risks and uptake of opportunities.
B. Business supply chain is linked to tropical and sub-tropical forest biome, but with limited operational control over suppliers	Examples: • Food retailer sourcing from consolidating commodity trader. • Manufacturer sourcing minerals from first-tier suppliers. Implications: • Traceability remains a challenge for many supply chains. Companies at the downstream end of supply chains may have limited information, at best, on source locations. • With societal and regulatory expectations of increased transparency, companies are more exposed to risks, which creates impetus for better traceability. At present, however, companies may only be able to access relatively imprecise sourcing information – at the level of country or sub-national administrative unit, for example.

C. Business has an indirect connection to tropical and sub-tropical forest biome	Companies with no obvious connection to tropical forests may nevertheless have indirect linkages, creating impacts, dependencies and potential risks and opportunities. Examples: • A company with an office or other operations in a tropical forest country may depend on water supply, hydroelectric power, flood control or erosion prevention that are underpinned by intact forest. • The company's employees or procurement could be impacting tropical forests through use of food, fuel, wood or timber sourced from forests, or links to forest conversion. • The ecosystem services provided by forests can affect distant company activities. For example, downstream fisheries or coral reef tourism could depend on erosion control and water flow regulation from forests many hundreds of kilometres away. Implications: • Indirect connections may be challenging to infer from location information alone. The relevant information may be whether activities are located in a tropical forest country or region, rather than in the tropical forest biome. • Companies with indirect connections to tropical forests may have limited scope to address forest-related dependencies, impacts, risks and opportunities directly. The Evaluate and Assess phases of LEAP nevertheless remain important, especially to understand the scale of risk and to consider what policy or management actions may be appropriate.

Locating the organisation's interface with nature

Organisations interfacing with this biome can do so with different degrees of connection and control, and with portions of the biome with different levels of integrity (Table 4). When analysing locations and identifying which biomes your organisation is interfacing with, it should also consider whether the land was forested in the recent past. Tools include:

- Nature Map Explorer for identification of whether the land cover is classed as a tropical forest;[5]
- Recent, fine-scale maps can help to identify whether tree cover is present or was present in the recent past.

Locations in this biome are highly likely to meet the criteria for sensitive locations. All tropical forest ecosystems can be considered of high importance for biodiversity and provision of ecosystem services through their absorption and storage of carbon from the atmosphere. Many tropical forest ecosystems are also seeing rapid decline in integrity.

5 Nature Map Initiative (2023) Nature Map Explorer

Table 4: Different types of interfaces with the tropical and sub-tropical forests biome

Interface with the biome	Degree of connection and control		
	A. Land manager or supply chain with significant operational control	**B. Supply chain with limited operational control**	**C. Indirect connection**
Forest-based enterprises	Logging company.	Retailer of hardwood furniture.	Telecommunications company with regional office in capital of tropical forest country.
	Tourist lodge in forest.		Manufacturer using hydroelectric power from reservoirs maintained by forest water regulation.
	Large sawmill with long-term contracts with suppliers.		
Use of formerly forested land	Plantation owner/operator.	Supermarket selling chocolate.	
	Chocolate manufacturer sourcing from specific cacao farmers.		
Site-specific activities – temporary or permanent impacts	Industrial copper mine.	Manufacturer of electrical wiring.	
	Railway company.		
	Real estate developer.		
	Hydropower energy generator.		

Evaluating nature-related dependencies and impacts

Table 5 and Table 6 provide the principal impact drivers and ecosystem services present in the tropical and sub-tropical forests biome. This can assist LEAP project teams to identify the impact drivers and ecosystem services most relevant to their assessment.

Companies should consider the synergies between the impact drivers identified. For example:

- Timber extraction increases the accessibility of forest areas, which increases the risk of deforestation;
- Mining developments can lead to an influx of people which can increase hunting pressure in surrounding tropical forests;
- Climate change and deforestation are a particularly important synergy; and
- Road construction is typically a catalyst for all other pressures.

Metrics and responses are likely to be impact driver-specific and sector-specific, but it is important to be aware of the interconnections among drivers to ensure your organisation's assessment is comprehensive and its identified response options are effective.

Table 5: Drivers of nature change and impact drivers associated with common business activities in the tropical and sub-tropical forest biome

Business activity	Driver of nature change	Impact driver
Agricultural expansion, energy, minerals and infrastructure development Over 80% of tropical deforestation between 2000 and 2010 was driven by agricultural expansion, of which around 50% was for beef pasture and around 20% for either oil palm or soy. Other commodities produced on deforested land include rubber, cocoa, coffee, rice, maize and cassava. Smaller contributions came from energy, minerals and infrastructure development. This conversion leads to reduced extent and condition of the ecosystems in the biome, including through increased fragmentation. Land conversion is also often associated with forest fires as a way to clear the land.	Land/freshwater/ ocean use change	Land ecosystem use
	Climate change	GHG emissions
	Pollutants/pollution removal	Non-GHG air pollutants
Infrastructure development The development of new infrastructure such as roads, railways and ports fragments forests and increases activities such as logging, deforestation for agriculture and other land uses, as well as hunting and trapping.	Land/freshwater/ ocean use change	Land ecosystem use
	Resource use/ replenishment	Other resource use

Business activity	Driver of nature change	Impact driver
Logging Timber extraction causes degradation through the creation of canopy gaps, which increase susceptibility to drought and fire. The extent of long-term impacts depends on the level of canopy damage and on subsequent management. Impacts can be low if reduced-impact logging methods are used and forests are subsequently allowed to regenerate, but most logging operations cause higher level of damage. Logged areas are also at higher risk of subsequent deforestation for other purposes such as agriculture. The development of new roads and other transport infrastructure is a catalyst for other impact drivers such as logging, deforestation for mining and agriculture, and a major driver of tropical forest fragmentation in general.	Land/freshwater/ ocean use change	Land ecosystem use
	Resource use/ replenishment	Other resource use
Mining and fossil fuel extraction Mining, fossil fuel extraction and renewable energy developments all contribute to further deforestation, although on more localised scales than agriculture. Mining and fossil fuels may also cause local pollution issues, though these can be potentially diffuse if the pollution enters freshwater ecosystems and food chains. These sectors also cause indirect impacts that can be much larger than their direct footprint, for example by creating roads that open up new areas to deforestation, or by driving population increases as workers and their families move to developments, which increases food demand and hunting.	Land/freshwater/ ocean use change	Land ecosystem use
	Pollutants/pollution removal	Water pollutants
Miscellaneous commercial operations Many commercial operations in the biome are associated with carbon dioxide emissions. Climate change causes increasing temperatures and changes in rainfall patterns, leading to water stress and tree mortality as well as increased fire risk in this biome.	Climate change	GHG emissions
Operations from food and agriculture activities, including cattle farming Biological alterations, such as the introduction of Brachiaria grass species as forage for cattle and compete with native vegetation, can change fire regimes leading to further forest degradation.	Invasive alien species introduction/removal	Introduction of alien invasive species

Table 6: Principal ecosystem services present in the tropical and sub-tropical forest biome

Principal ecosystem services		Example
Provisioning services	Water supply	Sustained supply of clean water.
	Biomass provisioning	Timber, fibre, fuelwood, medicinal plants, food.
Cultural services	Recreation-related services	Forest recreation and tourism.
	Spiritual, artistic and symbolic services	Sacred groves and trees, emblematic animals.
Regulating and maintenance services	Pollination	Pollination by forest animals such as bees, bats and birds.
	Biological control	Natural pest and disease control.
	Soil and sediment retention	Soil stabilisation; protection against erosion.
	Flood mitigation	Flood protection by riparian vegetation.
	Water flow regulation	Absorption and storage of water to regulate flows.
	Rainfall pattern regulation	Regional climate regulation.
	Local climate regulation	Local climate regulation through evapotranspiration and shading.
	Global climate regulation	Carbon sequestration and mitigation of GHG fluxes.
	Nursery population and habitat-maintenance services	This biome maintains a large proportion of global terrestrial species diversity.
	Soil quality regulation	Improvement of soil fertility and structure.
	Water purification	Water purification.
	Air filtration	Filtering and removing airborne pollutants.

Assessing nature-related risks and opportunities

A number of nature-related risks and opportunities are relevant for tropical forests:

- **Evolving deforestation regulation:** Stopping deforestation is highly relevant for addressing both climate and nature loss. Societal expectations of zero tropical deforestation are growing, with a quickly evolving regulatory landscape;
- **The impact of non-deforestation activities:** Nature-related risks such as zoonotic diseases can emerge from the exploitation of species from tropical forests – through hunting, trapping and collecting species, for example; and
- **Social equity and land tenure:** Indigenous Peoples and Local Communities have an important role in stewardship of tropical forests and depend on these ecosystems. Their land tenure and nature resource-use rights may not be formally mapped or enshrined in laws and regulations. These considerations are often challenging and important and need to be carefully considered.

Further examples of risks and opportunities for organisations interfacing with this biome are set out in Table 7 and Table 8.

Table 7: Examples of nature-related risks in the tropical and sub-tropical forest biome

Category	Nature-related risk	Tropical and sub-tropical forest examples
Physical risks	Changes to the supply of natural inputs (provisioning services)	Declining timber and Non-Timber Forest Product (NTFP) yields through unsustainable management.
	Changes to protection from natural hazards due to change in hazard mitigation services	Increased susceptibility to hazards such as floods and fires.
	Changes in other regulating and maintenance ecosystem services	Deforestation and forest degradation exacerbates climate change. Air pollution from forest fires is hazardous to health.
	Changes in recreational value of area	Loss of aesthetic and cultural values due to loss of tropical forests.
	Effects on species, including ones that an organisation depends upon	Direct threat to approximately half of the world's terrestrial biodiversity.

Category	Nature-related risk	Tropical and sub-tropical forest examples
Transition risks	Policy and legal: Changes to legislation/ regulations	Strong societal expectations around zero tropical deforestation, increasingly reflected in regulations (e.g. EU Deforestation Law).
	Policy and legal: More stringent nature-related reporting obligations	Strong societal expectations around zero tropical deforestation, increasingly reflected in reporting frameworks (e.g. CDP Forests).[6]
	Market: Shifting customer/investor values or preferences	Reputational risk for association with deforestation and biodiversity.
	Market and reputation: Decline in brand and value proposition/changes in sentiment towards the organisation/brand due to impacts on nature	Reputational risk for association with deforestation and biodiversity. Reputational risk for negative impacts on forest-dependent communities, including Indigenous Peoples.
	Market: Volatility/changes to costs of materials	Volatility in prices of tropical forest commodities.
	Technological: New monitoring technologies used by regulators and other stakeholder	Remote sensing improving detection of patterns of deforestation and logging.
Systemic risks	Ecosystem collapse and mass extinction	Beyond a certain threshold of deforestation, risk of ecosystem collapse (e.g. transition from forest-dominated biome to savannah-dominated biome) with profound consequences for natural ecosystems and human activities that can be supported by the biome. Runaway climate change would be exacerbated by widespread tropical forest dieback.
	Financial contagion	Ecosystem collapse within the tropical forest biome would threaten the many sectors that depend on it, including forestry and agriculture, which could lead to financial contagion.

6 CDP (2023) Forests.

Table 8: Examples of nature-related opportunities in the tropical and sub-tropical forest biome

Category	Nature-related opportunity	Tropical and sub-tropical forest examples
Resource efficiency	Transition to efficient and circular production systems and value chains.	Sustainable timber and NTFP yields through increased extraction efficiency and sustainable management.
		Transition to circular sourcing practices.
Capital allocation/ investments	Use of public-sector incentives (e.g. biodiversity credits, payments for ecosystem services).	Reducing Emissions from Deforestation and Forest Degradation (REDD+) programmes and financing.
		Biodiversity credits.
Products and services	New business model/activities with positive impacts on nature/ reduced negative impacts on nature.	Well-managed ecotourism.
		Premiums for deforestation-free products.
Markets	Access to new and emerging markets.	Access to markets with strong no-deforestation legislation.
Reputational capital	Collaborative engagement with stakeholders and rightsholders, at local, national and international levels.	Free, Prior and Informed Consent (FPIC) and careful engagement with Indigenous Peoples and Local Communities that have rights to live in and depend on tropical forests.
Ecosystem protection, restoration and regeneration	Supporting conservation or restoration projects.	Restoration of degraded forests.
		Conservation, e.g. through Protected Areas and Other Effective Area-based Conservation Measures (OECMs).
	Integrated multi-stakeholder action at land/seascape/river basin/jurisdictional/sector scale.	Participation in sector-wide initiatives such as the Roundtable on Sustainable Palm Oil.
	Transition to processes with lower negative impacts on nature/ increased positive impacts on nature.	Improved selective logging practices.

Preparing to respond and report

Responses particularly relevant to this biome can include actions to:

- Engage with Indigenous Peoples and Local Communities to gain a deeper understanding of a particular ecosystem, its current state and changes over time;
- Engage with local communities and smallholders to reduce barriers to access to Zero Deforestation commitments; and
- Seek third-party certification (% and/or value of production, consumption and sourcing of raw materials).

A number of supporting international standards, regulations and frameworks can be useful when preparing to report on nature-related issues in this biome, including:

- CDP Forests;
- Science Based Target Initiative (SBTi) Forest, Land and Agriculture (FLAG) guidance;
- SBTN: Science Based Targets Network;
- Greenhouse Gas Protocol Land Sectors and Removals Guidance;
- The Accountability Framework Initiative (AFi); and
- EU Law to fight global deforestation and forest degradation driven by EU production and consumption.[7]

Note that there are many sector-specific, national and regional standards that should also be consulted where relevant.

Assessment indicators and metrics for the tropical and sub-tropical forests biome

To support the identification of priority locations and evaluation of dependencies and impacts in this biome, a LEAP assessment team may wish to consider the assessment metrics in Table 9 and Table 10. These are not part of the TNFD's core global or sector disclosure metrics.

7 CDP (2023) Forests; Science Based Targets (2022) Forest, Land and Agriculture Science Based Target-Setting Guidance; Science Based Targets Network (2023) Step 3: Measure, Set, Disclose: Land (Version 0.3); Greenhouse Gas Protocol (2023) Land Sector and Removals Guidance Draft for Pilot Testing and Review, Parts 1 and 2; Accountability Framework Initiative (2023) Accountability Framework; Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010 (2023).

Location prioritisation indicators and metrics

Table 9: Illustrative location prioritisation assessment indicators and metrics for the tropical and sub-tropical forests biome, by type of interaction with the biome

Type of interaction	Indicator or metric
Direct operational control	**Forest-based enterprises** Geographic location of each operational site in tropical forest. Area of operational site. Type of activity (sectoral classification codes and additional relevant detail). Location of associated facilities.
	Use of formerly forested land Geographic location for each production site (owned, leased, managed) in tropical forest biome. Distance to nearest forest. Production area – deforestation risk commodities. Production area – other commodities. Location and supply shed of associated facilities.
	Site-specific activities Geographic location for each operational site (owned, leased, managed) in tropical forest biome. Size of operational site or infrastructure footprint. Area of footprint overlap with tropical forest. Length of roads/rail overlapping with tropical forest. Location of associated facilities.

Type of interaction	Indicator or metric
Indirect operational control (i.e., diffuse control via supply chain)[8]	**Forest-based enterprises** *If specific locations and areas not known:* Inferred locations based on processing sites and buffer. Inferred area footprint based on quantities and yield. Inferred location and supply shed of associated facilities.
	Use of formerly forested land *If specific locations and areas not known:* Inferred locations based on processing sites and buffer. Inferred area footprint based on quantities and yield. Area of forest within buffer or distance to nearest forest. Inferred location and supply shed of associated facilities.
	Site-specific activities *If specific locations and areas not known:* Inferred locations based on mining/processing sites and buffer. Inferred area footprint based on quantities and yield. Inferred location of associated facilities.
Indirect interaction	**For business sites in the tropical and sub-tropical forest biome, or with potential dependencies on the tropical and sub-tropical forest biome** Geographic location. Size and activity (number of staff/budget).

8 If specific information is known from suppliers, refer to direct operational control.

Dependency and impact assessment indicators and metrics

Table 10: Illustrative dependency and impact assessment indicators and metrics for the tropical and sub-tropical forest biome

Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
Dependencies and impacts: Impact drivers	Land/freshwater/ocean use change	Natural forest cover loss within areas of direction operational control.
		Landscape-level or country – ecoregion-level natural forest cover loss within areas of indirect operational control (i.e. sourcing locations).
		Description of methods and tools used to assess natural forest cover loss.
		Spatial overlap (ha) of business activities with Protected Areas.
		Spatial overlap (ha) of business activities with Key Biodiversity Areas.
		Spatial overlap (ha) of business activities with deforestation hotspots.
Dependencies and impacts: State of nature	Ecosystem condition and extent	Ecosystem condition as measured by Mean Species Abundance (MSA), adjusted for management in case of forest-based activities such as logging.
		Forest Landscape Integrity Index (FLII) in sourcing locations or areas under direct operational control for forest-based enterprises such as logging.
	Species	Maximum STAR-t (Species Threat Abatement and Restoration metric).

Land biomes: Savannas and grasslands (T4)

Introduction

The savannas and grasslands biome (T4) is an important type of ecosystem covering about 33 million km^2 worldwide (around a quarter of the world's land area).[9] Savannas and grasslands ecosystems are dominated by grasses and grass-like plant families with varying degree of shrub and/or tree cover, but never closed canopy. Many of the issues covered are also relevant to some of the sub-biomes listed under the intensive land-use guidance (T7), particularly sown pastures and fields (T7.2).

Many grasslands and savannas are highly diverse,[10] often as diverse as forest ecosystems, with high levels of plants that are unique to the biome and can have a high level of underground mass and carbon storage.[11] They are maintained by disturbance, which in different places may include:

- frequent surface fires;
- the consumption of plants by large native animals or low-intensity grazing by domestic livestock that are adapted to the specific environment;
- soil disturbance by digging animals;
- shallow and nutrient-poor soils; and
- seasonal water deficits and flooding.

The seasonality of the climate creates the conditions for the biome to exist, with fire in many grassland and savanna ecosystems typically occurring at regular intervals, with a varying return rate depending on the system, e.g. every 2 to 3 years in some tropical savannas.[12] The balance between the vegetation covers of grasses, bushes and trees is regulated by herbivores, fire, and climatic factors such as the quantity and timing of precipitation relative to temperature.

It can be challenging in practice to determine when natural savanna and grassland ecosystems have been converted to some intensive land-use (T7), particularly derived semi-natural pastures and old fields (T7.5). Levels of domestic livestock grazing, anthropogenic inputs (irrigation, seeding, and fertiliser application), mechanical treatment or removal of woody species, and human-caused fires can influence the conversion between natural savanna and grassland ecosystems to modified ecosystems. Low levels of domestic livestock grazing are compatible with a grassland classification,

9 Note that due to the difficulty in distinguishing modified grasslands (covered in the intensive land-use biome) and lightly modified and natural grasslands, some estimates of global grassland and savannah extent are higher – up to 52.5 million km^2, or 40.5% of the world's non-Antarctic land surface.
Ramankutty, N. and Foley, J. A. (1999) Estimating Historical Changes in Global Land Cover: Croplands from 1700 to 1992. Global Biogeochemical Cycles, 13, 997-1027; Bai, Y., Cotrufo, M.F. (2022) Grassland soil carbon sequestration: Current understanding, challenges, and solutions. Science 377, 603–608.

10 Kier, G., Mutke, J., Dinerstein, E., Ricketts, T.H., Küper, W., Kreft, H., Barthlott, W. (2005) Global patterns of plant diversity and floristic knowledge: Global plant diversity. Journal of Biogeography 32, 1107–1116; Wilson, J.B., Peet, R.K., Dengler, J., Pärtel, M. (2012) Plant species richness: the world records. Journal of Vegetation Science 23, 796–802.

11 Bai, Y., Cotrufo, M.F. (2022) Grassland soil carbon sequestration: Current understanding, challenges, and solutions. Science 377, 603–608.

12 Hoffmann, W.A., Schroeder, W. & Jackson, R.B. (2002) Positive feedbacks of fire, climate, and vegetation and the conversion of tropical savanna. Geophysical Research Letters 29, 9-1-9-4.

but an elevated density of livestock (particularly if non-native grass or woody species are introduced) can lead to conversion to intensive and semi-intensive pasture systems (intensive land-use biome).

Grassland and savanna ecosystems and the services they provide are also fundamental to many cultures and Indigenous Peoples. Organisations interfacing with such ecosystems should refer to the TNFD Guidance on engagement with Indigenous Peoples, Local Communities and affected stakeholders.

The T4 biome classification covers a broad range of sub-biomes:

- **Trophic savannas (T4.1)** – These are ecosystems characterised by bunch grasses and grasses with large root masses kept short by an abundance and diversity of large herbivores. These herbivores also limit the density of trees. There is significant vegetation growth in the rainy season and grasses are adapted to growing back quickly after being grazed by herbivores. Low intensity fires occur in these landscapes on 5–50-year intervals, but grazing is the predominant driver of vegetation control. This sub-biome is found largely in Africa and the Indian subcontinent;
- **Pyric tussock savannas (T4.2)** – This is similar to T4.1, but fire rather than herbivores is the main factor restricting tree growth, though large herbivores are present. Tussock grasses predominate in these grassland and grassy woodland landscapes. There is high growth in the rainy season, while dry winters promote fires. Flora has a high level of adaptation to fire. Large areas of this sub-biome feature in South America, eastern North America, Africa, northern Australia and South and South-East Asia;
- **Hummock savannas (T4.3)** – These savannas are dominated largely by hummock grasses, interspersed with trees strongly adapted to long periods of dryness and heat, and are found only in northern Australia. Temperature and rainfall vary with the seasons to some extent, but this variation is not as strong as in other grasslands;
- **Temperate woodlands (T4.4) –** These are woodland areas where trees are spaced well apart allowing light to reach the ground to a lower layer of shrubs and grasses. The ground layer is dominated by tussock grasses, herbaceous flowering plants (forbs) and, often, shrubs. The diversity of structure provides important micro-habitats for various species. This sub-biome is found throughout the temperate zone, including eastern North America, southern Europe, Central Asia, China and southern Australia. Note that biome-specific guidance relating to forested ecosystems may be more relevant to this sub-biome; and
- **Temperate subhumid grasslands (T4.5)** – These are large areas of grassland with marked seasons. Winter temperatures and snow limit growth in winter, and drought stress occurs in summers. Large herbivores are present and play a significant role in moving organic and inorganic nutrients from the physical environment to living organisms and back to the environment (nutrient cycling) and maintaining the composition of the plant community. These ecosystems are not as diverse as in other grassland types. Large areas occur over Central Asia, China, Argentina, eastern North America and southwestern Australia.

Concepts and definitions

Grassland: Grassland can be broadly defined as areas dominated by grasses and other similar plant families, where there is a limited amount of trees or shrubs.[13] This guidance focuses on natural grasslands that form due to biological and climatic conditions (e.g. native herbivore grazing pressure, fire regimes, seasonal precipitation) with minimal human interference. Other definitions also include semi-natural grasslands where a history of human activity and management drives the establishment of grasslands. This latter category would fall under the intensive land-use biome (T7).

13 Bardgett, R.D. et al. (2021) Combatting global grassland degradation. Nature Reviews Earth & Environment 2: 720–735.

Degraded grassland: Grassland where processes brought about by humans drive a persistent decline or loss in biodiversity, ecosystem functions or ecosystem service.[14]

Scoping a LEAP assessment

In considering the activities, assets, sectors and value chains in scope, your organisation should consider the diverse ways in which it may interact with this biome through its value chain:

A. **Does the company own or manage assets, or have significant operational control over value chain activities, in the savannas and grasslands biome?**
For example, a mining company may have direct operations in grassland or savanna areas. Similarly, an agricultural business may be sourcing directly from smallholders whose activities affect grassland ecosystems.

B. **Are the company's value chains linked to the savannas and grasslands biome, but with limited operational control over suppliers?**
For example, a company sourcing from commodity traders where there may be high degradation risks to grassland ecosystems.

C. **Does the company have an indirect connection to the savannas and grasslands biome?**
For example, a company may have an office or factory in a country with extensive grassland ecosystems, and depend on water supply, soil retention, or flood control provided by those grassland ecosystems.

Locating the organisation's interface with nature

Organisations interfacing with this biome can do so both with different degrees of connection and control, and with portions of the biome with different levels of integrity (Table 11).

Typical sectors operating in this biome include:

- **Food and agriculture (pastoral)** – Low-intensity domestic livestock grazing can be compatible with highly functional (high integrity) grassland systems, and indeed help to maintain them (e.g. where large native animals have been eradicated). However, higher intensities of grazing, especially if accompanied by fertiliser inputs, irrigation, soil disturbance, and/or the planting of non-native grasses, grazing can degrade or convert grasslands to intensive land uses;
- **Food and agriculture (arable)** – Conversion to cropland, especially accompanied by tillage, irrigation, and other forms of soil disturbance, is a major threat to the savanna and grassland biome and it can take centuries to restore old-growth grasslands;[15]
- **Tourism and recreation** – Many areas with iconic large native animals have high tourism value;
- **Construction and infrastructure** – Urban expansion and the expansion of infrastructure (e.g. roads) threaten many grassland areas. For example, extraction of oil, iron, uranium and precious metals threaten ecosystems in Australian and African savannas;[16] and
- **Forestry –** Conversion of grasslands to plantation forests, e.g. for timber, pulp and paper or carbon projects, is also a major threat. However, low-level sustainable extraction of timber, firewood and other non-timber-forest products from some grassland types (i.e. those more towards the open woodland end of the spectrum) can be compatible with high-integrity management, as can silvopasture if appropriately sited.

14 Bardgett, R.D. et al. (2021) Combatting global grassland degradation. Nature Reviews Earth & Environment 2, 720–735.

15 Williams, B.A. et al. (2022) Global drivers of change across tropical savanna ecosystems and insights into their management and conservation. Biological Conservation 276, 109786.

16 Williams, B.A. et al. (2022) Global drivers of change across tropical savanna ecosystems and insights into their management and conservation. Biological Conservation 276, 109786.

Table 11: Different types of interfaces with the savannas and grasslands biome

Interface with the biome	Degree of connection and control		
	A. Land manager or supply chain with significant operational control	**B. Value chain with limited operational control**	**C. Indirect connection**
Savanna and grassland-based enterprises	Low-intensity ranching in grassland ecosystems.	Retailer of fibre, meat, and leather sourced from grassland areas.	A financial organisation with offices based in a country with extensive natural grasslands and savannas. A manufacturer using water or hydropower energy that is reliant upon savanna and grassland ecosystems maintaining the water supply and quality.
Use of land formerly of savanna and grassland habitat	Plantation owner/ operator in areas of former grassland habitat. Agricultural company growing arable crops or sourcing from specific suppliers in areas of former grassland.	Supermarket selling products containing crops grown on former grassland areas (e.g. soy-based ingredients). A financial organisation investing in companies using products grown in areas of former grassland.	
Site-specific activities - temporary or permanent impacts	Tourist lodge in savanna and grassland ecosystems.	Tour operator.	

Companies can confirm the presence of savanna and grassland habitats in areas of influence using relevant global maps. Companies should ask:

- Is the location within the savanna and grassland biome?
- Is the land-cover type classed as savanna and grassland habitat?
- Is there historical evidence that the area was savanna and grassland habitat in the recent past?
- Is the activity located between savannah and grassland biome patches and potentially disrupting movement of species between patches?

Data sources that can be used to assess the distribution of ecosystem types, and areas of possible degradation include:

- Nature Map Explorer for identification of whether the land cover is classed as a savanna or grassland;[17] and
- Recent historical land cover maps, or historical satellite imagery (e.g. Landsat images go back to 1972).

Many locations where a company's activities interact with natural savanna and grassland ecosystems are likely to be considered as sensitive, as these ecosystems are generally important for biodiversity and ecosystem services (e.g. carbon storage) and are experiencing rapid decline in integrity.[18]

Ecosystem degradation is a widespread and important problem for grassland ecosystems, but more difficult to identify than ecosystem conversion as the reference baselines vary depending on location and context. Threats will also vary depending on location and sub-biome type. For example, the suppression of fire regimes will have a larger impact on Pyric tussock savannas (where fire is a significant driver of the species in the community) than it will on temperate woodlands. The Brazilian Cerrado is highly threatened by conversion of land for agricultural use.[19]

Evaluating nature-related dependencies and impacts

Impact drivers

Actions like the conversion of grassland habitats, human-caused fires or water pollution are often associated with this biome. Table 12 sets out common impact drivers in this biome.

Table 12: Drivers of nature change and impact drivers associated with common business activities in the savannas and grasslands biome

Business activity	Driver of nature change	Impact driver
Livestock agriculture High-intensity grazing from domestic livestock, particularly if combined with fertiliser inputs, irrigation, soil disturbance, and planting of non-native species, can have a major impact on degrading and converting savanna and grassland ecosystems. However, in the right circumstances, intensifying livestock use can be used for conservation management (e.g. to manage weeds and woody species). Livestock density needs to be considered carefully with multiple outcomes in mind.	Land/freshwater/ocean use change	Land ecosystem use
	Invasive alien species introduction/removal	Introduction of invasive alien species

17 Nature Map Initiative (2023) Nature Map Explorer.

18 Bardgett, R.D. et al. (2021) Combatting global grassland degradation. Nature Reviews Earth & Environment 2, 720–735; Williams, B.A. et al. (2022) Global drivers of change across tropical savanna ecosystems and insights into their management and conservation. Biological Conservation 276, 109786.

19 Lopes dos Santos, G. et al. (2021) Degradation of the Brazilian Cerrado: Interactions with human disturbance and environmental variables. Forest Ecology and Management 482, 118875.

Business activity	Driver of nature change	Impact driver
Agricultural expansion, as well as smaller contributions from energy, minerals and infrastructure development causing habitat loss and degradation Several grassland areas are highly threatened due to land conversion for agriculture. This is exacerbated by tillage for agriculture and other soil disturbances caused by human activity. Vegetation removal leads to losses in soil biodiversity and soil erosion. Drainage or diversion of watercourses for use in intensive agriculture can also have negative effects. **Infrastructure (e.g. mining, fossil fuel extraction, roads, power lines)** can also have impacts on biodiversity in savanna and grassland biomes. These sectors can also cause indirect impacts much larger than direct footprints, for example by opening up areas of habitat to new agricultural activities. Future energy infrastructure is another source of potential impact on large areas of sub-Saharan savannas.[20] In some cases, this could also affect the access of local communities that maintain the ecosystem through low-intensity grazing.	Land/freshwater/ocean use change	Land ecosystem use
Suppression or modification of natural patterns of fire (referred to as fire regimes) and land conversion **Conversion of grasslands to forests by planting trees** leading to vegetation change and water stress. Many nature-based solution projects that are suitable for degraded lands in the forest biome may be highly inappropriate if applied in the grassland biome.[21]	Land/freshwater/ocean use change	Land ecosystem use

20 WWF Germany (2020) Grassland and savanna ecosystems: An urgent need for conservation and sustainable management.

21 Parr, C. L. et al. (2014) Tropical grassy biomes: misunderstood, neglected, and under threat. Trends in Ecology & Evolution 29, 205–213.

Business activity	Driver of nature change	Impact driver
Land clearance via fires While prescribed burning can be part of conservation management, fires for managing and preparing land for agricultural production in many cases can cause degradation of grassland habitat through vegetation and composition change, particularly when they alter the natural intensity and frequency of fires.[22]	Land/freshwater/ocean use change	Land ecosystem use
	Climate change	GHG emissions
Agricultural fertiliser and pesticide use Agricultural and industrial activities such as excess use of fertilisers and pesticides can pollute soil and water leading to ecotoxicity and eutrophication. Incineration of waste and waste collection are further sources of pollution. This can also damage adjacent ecosystems.	Pollution/pollution removal	Soil pollutants Water pollutants Non-GHG air pollutants
GHG from commercial operations (e.g. agricultural operations, industrial operations, transport) Climate change represents a key risk to some grassland areas due to changing climatic temperatures and rainfall patterns. This leads to increased risks of desertification in some areas, changes in fire regimes, and risks of woody vegetation encroachment in others. It may also lead to alteration of fire regimes, flooding and changes in vegetation composition.	Climate change	GHG emissions
Transport Transport can generate pollution including microplastics from tyre-wear and particulate air pollution, as well as GHG emissions.	Pollution/pollution removal	Water pollutants Non-GHG air pollutants
	Climate change	GHG emissions
Domestic and industrial water use Water use in human activities can lead to water stress in the biome.	Resource use/ replenishment	Water use

22 While fire is a regular component of many savanna and grassland ecosystems, changes in fire intensity and frequency can lead to degradation, e.g. as documented in the Cerrado biome in Brazil. Lopes dos Santos, G. et al. (2021) Degradation of the Brazilian Cerrado: Interactions with human disturbance and environmental variables. Forest Ecology and Management 482, 118875.

Business activity	Driver of nature change	Impact driver
Wastewater treatment Wastewater treatment can release pollution into soil and water, leading to ecotoxicity and eutrophication.	Pollution/pollution removal	Soil pollutants Water pollutants
Energy supply for commercial operations Fossil fuel-based energy supplies can contribute to climate change. Renewable energy will also require mineral extraction such as aluminium, copper, lithium and other metals.	Climate change	GHG emissions
	Resource use/ replenishment	Other resource use
Arable agriculture Tillage and removal of organic matter (context-dependent) leading to soil erosion and release of sequestered carbon.	Land/freshwater/ocean use change	Land ecosystem use
	Climate change	GHG emissions
Irrigation Poorly planned or excessive irrigation can lead to salinisation.	Land/freshwater/ocean use change	Land ecosystem use

Ecosystem services

A conservative estimate suggests that savannas and grassland store around one-fifth of total carbon contained in terrestrial vegetation and topsoil worldwide.[23] Table 13 sets out further ecosystem services that organisations and others may depend on that are provided by this biome. This can assist LEAP project teams to identify the ecosystem services most relevant to their assessment.

Table 13: Principal ecosystem services present in the savannas and grasslands biome

Principal ecosystem services		Example
Provisioning services	Biomass provisioning	Forage/fodder in low intensity grazing systems, food (edible plants and hunted animals), fuel, medicine.
Cultural services	Recreation-related services	Recreational hunting, other recreation, tourism.
	Visual amenity services	Aesthetic value.
	Spiritual, artistic and symbolic services	Cultural heritage: grassland and savanna ecosystems and the services they provide are fundamental to many cultures and Indigenous Peoples.
Regulating and maintenance services	Pollination	Pollination by animals living in the grasslands and surrounding habitats.
	Soil and sediment retention	Erosion control.
	Water flow regulation	Absorption and storage of water to regulate flows, both within the biome and for adjacent biomes (e.g. mitigating flood risks for adjoining areas by absorbing excess water).
	Global climate regulation	Carbon sequestration and mitigation of GHG fluxes.
	Soil quality regulation	Soil fertility maintenance.
	Water purification	Water purification.
	Other regulating and maintenance service	Protection against desertification.

Source: Bardgett, R.D. et al. (2021) Combatting global grassland degradation. Nature Reviews Earth & Environment 2, 720–735. Bengtsson, J. et al. (2019) Grasslands–more important for ecosystem services than you might think. Ecosphere 10, e02582.

23 Dudley, N. et al. (2020) Grasslands and savannas in the UN Decade on Ecosystem Restoration. Restoration Ecology 28, 1313–1317.

Changes to the state of nature

Considering changes to the state of nature in this biome resulting from your organisation's impact drivers and external factors, and determining appropriate responses, your organisation should consider:

- **Spatial location:** This plays a pivotal role as it influences the types of biodiversity and species that are likely to be affected by impact drivers and external factors. Some grassland ecosystems might be situated in water-stressed catchments and catchments susceptible to cumulative effects on water quality, connectivity, and hydrological balance. Availability of data can also vary depending on the location;
- **Proximity to designated areas:** Your organisation should consider any overlap or proximity to nationally or internationally designated areas and habitat types, as these factors can significantly impact your organisation's activities;
- **Climate change interactions:** Interactions with climate change can intensify the impacts of other impact drivers and external factors, increasing the likelihood of invasive alien species' introduction and ecosystem collapse;
- **Connectivity:** Fragmentation of habitats is an important element of land use change affecting ecosystem health and biodiversity in this biome;
- **Species habitat ranges:** Understanding species' habitat ranges, including grassland biodiversity and migratory species, is essential to understanding the potential impact on these species;
- **Operating practices:** If the organisation operates directly on sites, it should report on practices such as tillage methods and fertiliser inputs, which can pose significant threats to grassland ecosystems;
- **Below ground biomass indicators:** Indicators like carbon storage, a key indicator of old-growth grasslands, should be taken into account; and
- **Livestock impact:** Where applicable, the organisation can report on stocking densities of livestock, as high grazing pressure – beyond that to which the ecosystem is adapted – can pose a considerable threat to ecosystems.

Assessing nature-related risks and opportunities

Grassland ecosystems have historically been neglected in discussions of nature-related risks and opportunities in comparison to forest ecosystems, for example. However, there are a number of nature-related risks and opportunities emerging from interfacing with this biome, as illustrated in Table 14 and Table 15.

Table 14: Examples of nature-related risks in the savannas and grasslands biome

Category	Nature-related risk	Savannas and grasslands biome examples
Physical risks	Changes to the supply of natural inputs (provisioning services)	Loss of business value as a result of loss of biodiversity and ecosystem services attributed to business activities (e.g. loss of tourism value). Loss of business value as a result of water stress and water scarcity leading to lower agricultural yields and production.
	Changes to protection from natural hazards due to change in hazard mitigation services	Costs and revenue losses because of natural disasters such as fires.
	Changes in regulating and maintenance services.	Costs and revenue losses as a consequence of loss of other regulating and maintenance services, e.g. soil degradation and erosion.
	Changes in recreational value of an area	Changes in aesthetic value of a landscape. Reduced water quality leading to loss of recreational activity. Loss of recreational value as a result of ecosystem degradation and ecosystem service losses attributed to business activities.
	Effects on species, including ones that an organisation depends upon	Introduction and proliferation of invasive and non-native species.

Category	Nature-related risk	Savannas and grasslands biome examples
Transition risks	Changes to legislation/ regulations	Changes to supply chain regulation (e.g. transparency requirements). Tourism restrictions in tourist areas (e.g. limited number of visitors to an area).
	More stringent nature-related reporting obligations	Required air and water quality monitoring. Required GHG emissions monitoring.
	Shifting customer/investor values or preferences	There are increasing risks associated with grassland habitat degradation in many supply chains (e.g. from soy production in the Cerrado).
	Stakeholder conflicts	Impacts on Indigenous Peoples and Local Communities who use and have rights relating to the biome. Land-tenure conflicts.
	Change in brand and value proposition/changes in sentiment towards the organisation/brand due to impacts on nature	Destruction of habitat of high biodiversity importance through conversion of grassland habitats (these habitats can hold many charismatic species including large mammals and birds). Impact on Indigenous Peoples and Local Communities. Accidents in industrial areas or along transport infrastructures (chemical spills, explosions, fires). Mismanaged waste, plastic pollution, noise pollution, light pollution.
	Volatility/changes to costs of materials	Reduction in water availability due to over-abstraction of water for consumption and processing. Changes in land value due to development.
	Requirements to transition to more efficient, resilient and less environmentally damaging technologies	Imposition of requirements for reduced water/air pollution, or greater efficiency of production. Environmental regulation of industrial machinery.
Systemic risks	Ecosystem collapse and biodiversity loss	Risk of ecosystem collapse due to climate change and over-exploitation.
	Financial contagion	Risk of financial contagion due to ecosystem collapse and loss of ecosystem services affecting dependencies.

Table 15: Examples of nature-related opportunities in the savannas and grasslands biome

Category	Nature-related opportunity	Savannas and grasslands biome examples
Systemic opportunities	Ecological	Supporting grassland biodiversity conservation efforts to increase connectivity of ecosystems and reduce risks of ecosystem collapse. Restore and maintain a diverse and abundant population of pollinator species.
Resource efficiency	Adoption of resource efficiency/circularity mechanisms that reduce dependencies and impacts on nature	Work with suppliers to develop efficiencies in agricultural production that can improve sustainability and reduce land requirements.
	Transition to efficient and circular production systems and value chains	Transition to circular sourcing practices for products sourced from savanna and grassland ecosystems, or areas of previous savanna and grassland ecosystems.
	Adoption of nature-based solutions within service and product lines	Invest in savanna and grassland restoration programs as nature-based solutions, tapping into their carbon sequestration potential.
Markets	Access to new and emerging markets	Growth in sustainable biomass production (e.g. sustainable charcoal); carbon credits.[24]
	Access to new assets and locations	Growth in ecotourism sector for some savanna and grassland ecosystems and protected areas.
Capital flow and financing	Access to nature-related green funds, bonds or loans	Access to sustainable finance via sustainability-linked loans and sustainability-linked bonds such as green bonds and green loans.
	Use of public-sector incentives (e.g. biodiversity credits, payments for ecosystem services)	Potential for payment for ecosystem services. Biodiversity credits where credits are generated in savanna and grassland ecosystems.

24 For example, IUCN (2021) Business case for nature: Savannah region in Ghana.

Category	Nature-related opportunity	Savannas and grasslands biome examples
Reputational capital	Actions that create positive changes in sentiment towards the organisation/brand due to impacts on environmental assets and ecosystem services that have impacts on society and local economic capabilities	Actioning and signalling departure from unsustainable resources usage in supply chain.
		Supporting conservation of grassland biodiversity.
Ecosystem protection, restoration and regeneration	Direct restoration, conservation or protection of ecosystems or habitats	Watershed management and rehabilitation in areas of watersheds in savanna and grassland habitats.
		Improvement or creation of degraded savanna and grassland areas.
		Conservation of Key Biodiversity Areas and Protected Areas in or adjacent to savanna and grassland ecosystems.
	Supporting conservation or restoration projects	Financially supporting nature-based solutions projects that target the restoration or sustainable use of savanna and grassland ecosystems.
	Communicating with the public on the importance of ecosystem protection	Supporting or facilitating educational campaigns to raise awareness on protection of savannas and grasslands.
Sustainable use of natural resources	Transition to processes with lower negative impacts on nature/increased positive impacts on nature	Establishment of sustainable grassland management practices.
		Improvements in remote monitoring of savanna and grassland ecosystems.
		Minimise impact of infrastructure through design and scheduling changes.
		Shift sourcing towards areas of lower habitat conversion risk, or avoid impact by shifting to alternative commodities.
		Engage with suppliers in the value chain to minimise impacts by moving towards sustainable agricultural production.
		Engage with sector-wide initiatives to ensure that zero-deforestation commitments and other initiatives do not lead to leakage of conversion to grasslands, as has occurred historically.[25]

25 Fleiss, S. et al. (2023) Implications of zero-deforestation palm oil for tropical grassy and dry forest biodiversity. Nature Ecology & Evolution 7, 250–263.

Preparing to respond and report

Responses in this biome can include actions to:

- **Avoid impacts on grassland ecosystems.** This includes avoiding certain species, ecosystems, areas and projects entirely;
- **Minimise and reduce impacts on grassland ecosystems from land degradation.** This could include moving to lower-impact approaches and using technology to facilitate this. It could also include reducing impacts from direct operations or reducing reliance on commodities from savanna and grassland ecosystems. Engaging with suppliers in the value chain can also be an approach to help minimise impacts (e.g. through agricultural production). This is particularly relevant for sectors like transportation, energy production, and mining;
- **Minimise impacts on water quantity, water quality and water regime,** which can have effects on grassland and savanna ecosystems;
- **Minimise impacts by helping suppliers move towards sustainable agricultural production** in areas of former savanna and grassland habitat;
- **Invest in restoration activities in areas of degraded savanna and grassland ecosystems.** This could be through habitat improvement works (e.g. to remove invasive species, or restore natural grazing and fire regimes, restore soil fertility[26]) or through the creation of habitat;
- **Invest in conserving remaining areas of highly diverse and intact grassland and savannah ecosystems, and in restoration activities for specific savanna and grassland species** affected by activities;
- **Invest in measures to conserve species threatened by over-exploitation** (e.g. protection from poaching); and
- **Contribute to sector-wide initiatives** to reduce pressures and increase positive impacts on savanna and grassland ecosystems.

Biome-specific standards and reporting frameworks include:

- Science Based Target Initiatives (SBTi) and Forest, Land and Agriculture Guidance (FLAG), which contains useful guidance on setting targets as well as a FLAG target-setting tool;
- SBTN Step 1 and Step 2 guidance, and SBTN Land Hub Step 3 guidance which includes targets for avoiding conversion of natural habitats, reducing land footprint and landscape engagement, all of which are highly relevant to companies operating in the grassland ecosystems sub-biome;
- Align project;
- EU Taxonomy;
- OP2B Framework for Restoration Actions;
- High Conservation Value (HCV) approach;
- IUCN Global Standard for Nature-based Solutions guidelines on engaging with stakeholder rights;
- GBF complementary indicator around Target 2: 'Percentage of cropped landscapes with at least 10% natural land', noting that some institutions may promote more ambitious targets; and
- UNCCD Land Degradation Neutrality (LDN).[27]

26 Neuenkamp, L., Prober, S.M., Price, J.N., Zobel, M., Standish, R.J. (2019) Benefits of mycorrhizal inoculation to ecological restoration depend on plant functional type, restoration context and time. Fungal Ecology, Ecology of Mycorrhizas in the Anthropocene 40, 140–149

27 Science Based Targets (2022) Forest, Land and Agriculture Science Based Target-Setting Guidance; Science Based Targets Network (2032) Step 1: Assess and Step 2: Interpret & Prioritize; Science Based Targets Network (2023) Step 3: Measure, Set, Disclose: Land (Version 0.3); Capitals Coalition (2023) Aligning Accounting Approaches for Nature; European Commission (2023) EU taxonomy for sustainable activities; WBCSD (2022) OP2B's Framework for Restoration Actions; HCV Network. HCV Approach; IUCN (2020) IUCN Global Standard for Nature-based Solutions: first edition; Convention on Biological Diversity (2022) Kunming-Montreal Global Biodiversity Framework: Target 2; United Nations Convention to Combat Desertification. Land Degradation Neutrality.

Assessment indicators and metrics for the savannas and grasslands biome

To support the identification of priority locations and assessment of nature-related issues relating to this biome, a LEAP assessment team may wish to consider the assessment metrics in Table 16 and 17. These are suggested by the TNFD to support assessment only and are not part of the TNFD's recommended core disclosure metrics.

Table 16: Illustrative location prioritisation assessment indicators and metrics for the savannas and grasslands biome, by type of interaction with the biome

Type of interaction	Indicator or metric
Land manager or supply chain with significant operational control	**Savanna and grassland-based enterprises** • Geographic location of each operational site in savanna and grassland ecosystems. • Area of operational site. • Type of activity (sectoral classification codes and additional relevant detail). • Location and supply shed of associated facilities. **Use of land formerly of savanna and grassland habitat** • Geographic location for each production site (owned, leased, managed) in the biome. • Distance to nearest area of native savanna and grassland habitat. • Production area for commodities associated with habitat degradation. • Other production area. • Location and supply shed of associated facilities. **Site-specific activities** • Geographic location for each operational site (owned, leased, managed) in the savanna and grassland biome. • Size of operational site or infrastructure footprint • Area of footprint overlap with grassland and savanna. • Length of roads/rail overlapping with savanna and grassland ecosystems. • Location of associated facilities.

Type of interaction	Indicator or metric
Value chain with limited operational control[28]	**Savanna and grassland-based enterprises** *If specific locations and areas not known:* • Inferred locations based on processing sites and buffer. • Inferred area footprint based on quantities and yield. • Inferred location and supply shed of associated facilities. **Use of land formerly of savanna and grassland habitat** *If specific locations and areas not known:* • Inferred locations based on processing sites and buffer area around the locations (to compensate for poor information). • Inferred area footprint based on quantities and yield. • Area of savanna/grassland within buffer, or distance to nearest area of habitat. • Inferred location and supply shed of associated facilities. **Site-specific activities** *If specific locations and areas not known:* • Inferred locations based on mining/processing sites and buffer. • Inferred area footprint based on quantities and yield. • Inferred location of associated facilities.
Indirect connection	*For business sites in grassland and savanna biome, or with potential dependencies on the biome:* • Geographic location. • Size and activity (numbers of staff/budget).

28 If specific information is secured from suppliers, refer to guidance for direct operational control.

Table 17: Illustrative dependency and impact assessment indicators and metrics for the savannas and grasslands biome by sector

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
General	Location prioritisation	N/A	Volume of biome area affected by business activities. Percentage overlap of business activities with habitat range of locally or globally important species (Global IUCN Red List, National IUCN Red List, listed on international conventions such as CITES or CMS).[29]
	Dependencies and impacts: Impact drivers	Resource use/ replenishment	Total water consumption and withdrawal (total, freshwater, other) by source (e.g. surface water, groundwater) in water-stressed areas as a percentage of maximum extraction compatible with e-flows.[30] Use of CITES-listed wild species.
		Land/freshwater/ ocean use change	Amount (ha) and rate (ha/yr) of conversion of natural habitat in the supply shed.
		Ecosystem condition and extent	Loss of ecosystem quality or condition as a result of business activities (potentially measured by the disappearance of a fraction of a species, changes in ecological community composition and changes in species abundance). Change in ecosystem condition (weighted hectares). Locally appropriate metrics of habitat connectivity, where available.
		Species	Species diversity measures, controlling for sampling effort and using standardised methods. Contribution to extinction risk (see the Species Threat Abatement and Restoration [STAR] metric).[31]

29 IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2; ZSL and IUCN National Red List Working Group (2022) National Red List Database. Version 2022-1; CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora; CMS. Convention on the Conservation of Migratory Species of Wild Animals.

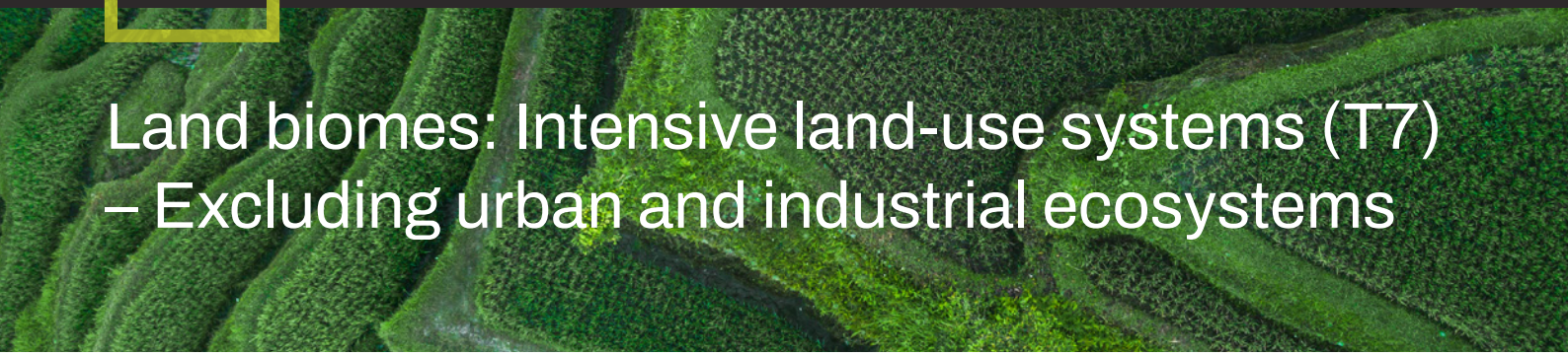
30 International Water Management Institute. Global Environmental Flow Information System.

31 CITES (2023) Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
General	Dependencies and impacts: Impact drivers	Land/freshwater/ ocean use change	Amount (ha) and rate (ha/yr) of conversion of natural habitat in the supply shed.
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Loss of ecosystem quality or condition as a result of business activities (potentially measured by the disappearance of a fraction of a species, changes in ecological community composition and changes in species abundance). Change in ecosystem condition (weighted hectares). Locally appropriate metrics of habitat connectivity, where available.
		Species	Species diversity measures, controlling for sampling effort and using standardised methods. Contribution to extinction risk (see the Species Threat Abatement and Restoration [STAR] metric).[32]
	Dependencies and impacts: Ecosystem services	Provisioning services	Absolute yields per hectare of each commodity.
			Total water provision (surface and groundwater for drinking and non-drinking purposes).
		Regulating and maintenance services	Total carbon sequestration.
Energy (oil and gas and renewable energy) sector	Location prioritisation	N/A	Overlap of operating locations with protected areas and habitat distributions of endangered species.
	Dependencies and impacts: Impact drivers	Pollution/ pollution removal	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood.
	Dependencies and impacts: State of nature	Species	Birds of the habitat/region and migratory species affected.

32 IUCN. Species Threat Abatement and Restoration (STAR) metric.

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
Forestry, paper and pulp; mining and metals; and agriculture and food sectors	Dependencies and impacts: Impact drivers	Pollution/ pollution removal	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood.
		Resource use/ replenishment	Volume of water extraction for industrial purposes.
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Eutrophication.
		Species	Assessment of chronic and acute effect levels of pollutants on grassland species.



Land biomes: Intensive land-use systems (T7) – Excluding urban and industrial ecosystems

Introduction

The intensive land-use systems biome (T7) includes all ecosystems shaped by intensive human activity, including the world's croplands, pasture lands and plantations. They are created through the transformation of natural habitats by people and are often actively maintained by human activities, such as sowing and planting particular plant species, irrigation and fertiliser application.

Sub-biomes included within the intensive land-use systems biome:

- **Short-rotation croplands (T7.1)** – These are systems that are dominated by annually harvested crops such as grains, vegetables, legumes, fibre species or ornamental flowers.
- **Sown pastures and fields (including intensive livestock pastures) (T7.2)** – These are high-productivity grass pastures used for livestock grazing or harvested for livestock feed.
- **Plantations (T7.3)** – This covers plantations of woody plant species from which timber, bioenergy, rubber, oils or food crops are harvested.
- **Derived semi-natural pastures and old fields (T7.5)** – These are similar to T7.2 but less intensively managed. They include grasslands or open shrublands resulting from human modification of natural habitats, or from the abandonment of former agricultural land.

The urban and industrial ecosystems sub-biome (T7.4) is covered in the next section of this document.

Scoping a LEAP assessment

In considering the activities, assets, sectors and value chains in scope, your organisation should consider the diverse ways in which it may interact with this biome through its value chain:

A. **Does the company own or manage land, or have significant operational control over value chain activities in the intensive land-use systems biome?** For example, a company that owns and manages forestry plantations or agricultural land.

B. **Are the company's value chains linked to the intensive land-use systems biome, but with limited operational control over suppliers?** For example, a company that owns and manages forestry plantations or agricultural land, such as a food, or pulp and paper retailer.

C. **Does the company have an indirect connection to the intensive land-use systems biome?** This will cover almost all companies, since almost all depend indirectly on services provided by this biome. Examples include companies in the food, fibre, timber and paper products industries.

Businesses that do not directly own or manage land should ensure that they have a clear understanding of the quantity of each product in their supply chain that is sourced from the intensive land-use systems biome.

Locating the organisation's interface with nature

Organisations interfacing with this biome can do so with different degrees of connection and control. For businesses that directly own or manage land, it should be possible to accurately locate the land that is owned or managed, in the form of a polygon outline of the land

area, for example. Businesses that are connected to the intensive land-use systems biome through their value chains will be affected by the transparency and traceability of the sources of their inputs.

The most important impact on nature in this biome is the habitat loss that occurs when natural biomes and ecosystems are converted into intensive land uses in the first place. Therefore, companies should consider not only the footprint of the intensive land-use systems biome itself, but also the biomes that have been converted to create those areas, and the surrounding areas that might be at risk from further expansion. The biodiversity significance of these other areas will help to identify priority locations.

Data sources that can be used to assess displaced and surrounding areas include:

- Nature Map Explorer for identification of whether the land cover is classed as a an intensive land-use system;[33]
- Recent historical land cover maps, or historical satellite imagery (e.g. Landsat images go back to 1972).

Ecosystem degradation is a widespread and important problem, but more difficult to identify than ecosystem conversion as the reference baselines vary depending on location and context.

Evaluating nature-related dependencies and impacts

Companies should consider both the dependencies and impacts associated with this biome and the surrounding areas that may be converted or degraded.

Impact drivers

The principal impact drivers in this biome come from the agriculture and forestry sectors, especially the conversion of natural habitat to intensive land uses, including cropland, pasture and plantations. Further impact drivers arise from reducing within-field plant diversity and increasing fertiliser and pesticide inputs. Table 18 includes more examples of typical impact drivers in this biome.

Organisations should consider the interactions between impact drivers from intensification and expansion. All else being equal, expansion is likely to cause more biodiversity loss than intensification.[34] However, intensification should be pursued in the framing of sustainable intensification to mitigate potential negative impacts such as increased soil and water pollution.[35] Yield increases have in some cases been accompanied by localised footprint expansion by increasing the short-term financial return to conversion,[36] highlighting the need for explicit strategies to ensure yield increases do indeed spare land for nature.[37]

Organisations operating in the agriculture sector in this biome should also refer to the TNFD Food & Agriculture sector guidance.

33 Nature Map Initiative (2023) Nature Map Explorer.

34 Phalan, B. et al. (2011) Reconciling food production and biodiversity conservation: land sharing and land sparing compared. Science 333, 1289–1291.

35 Balmford, A. et al. (2018) The environmental costs and benefits of high-yield farming. Nat Sustain 1, 477–485; Garnett, T. et al. (2013) Sustainable Intensification in Agriculture: Premises and Policies. Science 341, 33–34.

36 Goulart, F. F. et al. (2023) Sparing or expanding? The effects of agricultural yields on farm expansion and deforestation in the tropics. Biodivers Conserv.

37 Phalan, B. et al. (2016) How can higher-yield farming help to spare nature? Science 351, 450–451.

Table 18: Drivers of nature change and impact drivers associated with common business activities in the intensive land-use systems biome

Business activity	Driver of nature change	Impact driver
Conversion of natural habitats to forestry plantations and agriculture Conversion of forests to the intensive land-use biome to allow for agriculture requires deforestation, and so reduces the extent and condition of the ecosystem, including through increased fragmentation. Land conversion is also often associated with forest fires as a way to clear the land.	Land/freshwater/ ocean use change	Land ecosystem use
	Climate change	GHG emissions
Agricultural intensification Intensification of agricultural and forestry production, e.g. mono-cropping, removing natural features and other habitat such as hedgerows can lead to reduced extent and condition of the ecosystem, including through increased fragmentation.	Land/freshwater/ ocean use change	Land ecosystem use
Agricultural pesticide use Agricultural and industrial activities involve pesticide application which can lead to overspray and run-off, polluting soil and water, also affecting adjacent ecosystems.	Pollution/pollution removal	Soil pollutants (ecotoxicity) Water pollutants
Agricultural fertiliser use Agricultural and industrial activities can involve excess fertiliser application, which includes associated volatilisation and run-off, which can pollute soil and water, affecting adjacent ecosystems.	Climate change	GHG emissions (NO_3)
	Pollution/pollution removal	Water pollutants (eutrophication) Non-GHG air pollutants (NO_x, NH_4) Soil pollutants

Business activity	Driver of nature change	Impact driver
Arable agriculture Tillage and removal of organic matter (context-dependent) can lead to loss of soil biodiversity, soil erosion and sequestered carbon.	Land/freshwater/ ocean use change	Land ecosystem use
	Climate change	GHG emissions
Irrigation Poorly planned or excessive irrigation can lead to salinisation.	Land/freshwater/ ocean use change	Land ecosystem use

Ecosystem services

Pollination is a particularly important ecosystem service in this biome. Maps and models of pollination services such as InVEST, PollMap and the pollination layer in the WWF Biodiversity Risk Filter can be used to assess suitable habitat for pollinators.[38] Actual levels of pollination will require primary data collection.

Table 19 sets out the ecosystem services that organisations and others may depend on that are provided by this biome. This can assist LEAP project teams to identify the ecosystem services most relevant to their assessment.

38 Natural Capital Project. InVEST; Rahimi, E. et al. PollMap: a software for crop pollination mapping in agricultural landscapes. Journal of Ecology and Environment 45, 27; WWF. Biodiversity Risk Filter.

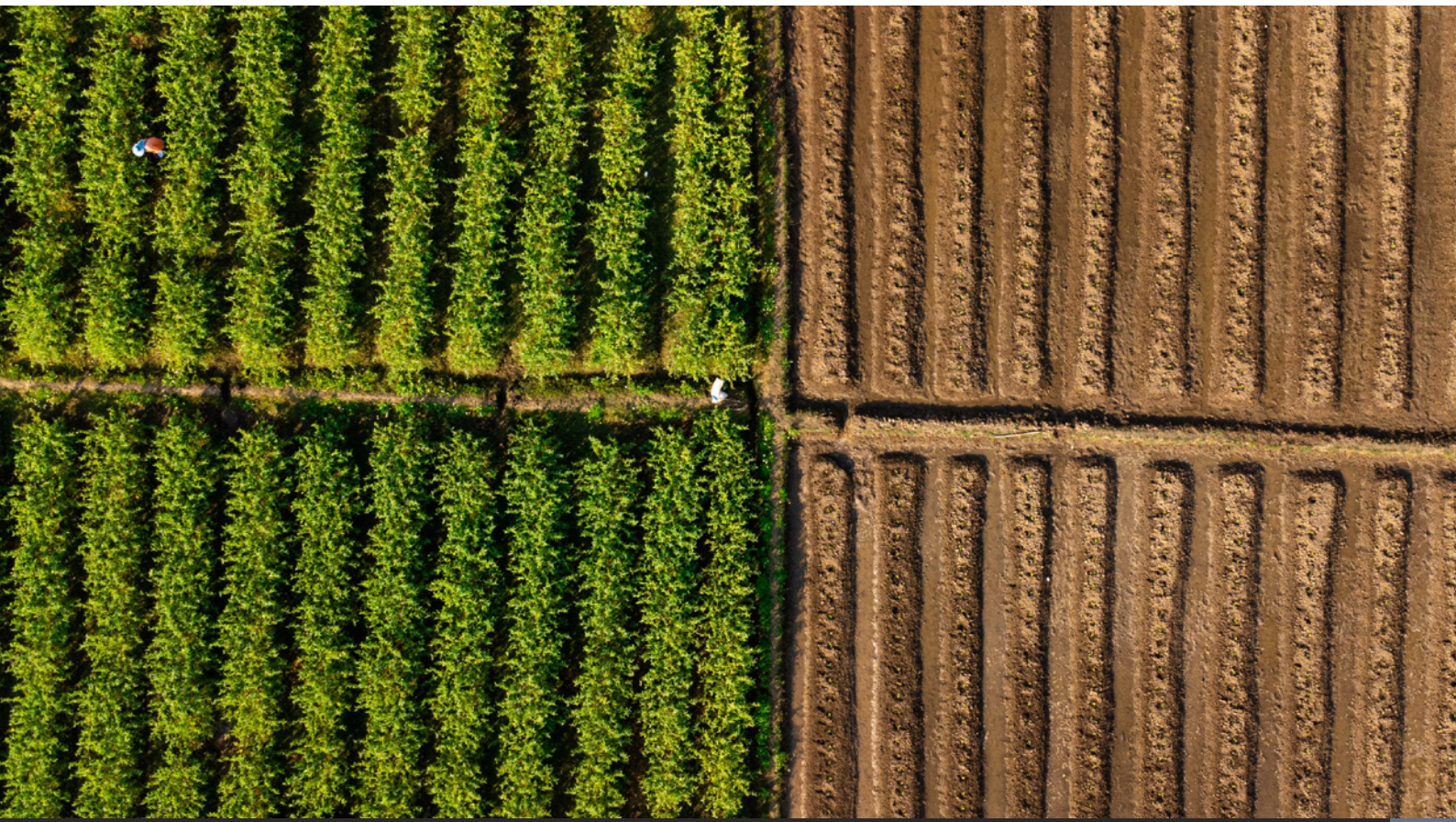


Table 19: Principal ecosystem services in the intensive land-use systems biome

Principal ecosystem services		Example
Provisioning services	Genetic material services	Genetic materials from animal and plant breeds.
	Biomass provisioning	Food, animal fodder, materials, fibre and biomass from cultivated annual or perennial crops; and meat, milk and materials from livestock.
Cultural services	Recreation-related services	Outdoor recreation, walking, hunting.
	Visual amenity services	Appearance of traditionally managed landscapes.
	Spiritual, artistic and symbolic services	Sense of place, cultural identity.
Regulating and maintenance services	Pollination	Pollination by wild species (according to management practices).
	Biological control	Pest control by wild species (according to management practices).
	Soil quality regulation	Maintenance of soil fertility (according to management practices).

Assessing nature-related risks and opportunities

The intensive land-use systems biome sources the majority of the world's food, fibre and wood products. Conversion of natural habitat for intensive land uses is the biggest driver of terrestrial biodiversity loss. As such, risks and opportunities in this biome have high social, economic and policy salience and there is a wide range of risks and opportunities to consider. Organisations should also refer to the TNFD Food & Agriculture sector guidance.

Preparing to respond and report

When considering the responses in the agriculture sector, organisations should consider trade-offs between the conversion of natural ecosystems and sustainable agricultural practices, such as habitat restoration and regenerative agriculture practices that may decrease yields at least in the short run.

Engaging with local stakeholders is particularly important for organisations operating in the intensive land-use systems biome, including communities and smallholder farmers. This may include understanding how ecosystems are understood and interpreted locally, and engagement in order to reduce barriers to access to zero-deforestation commitments.

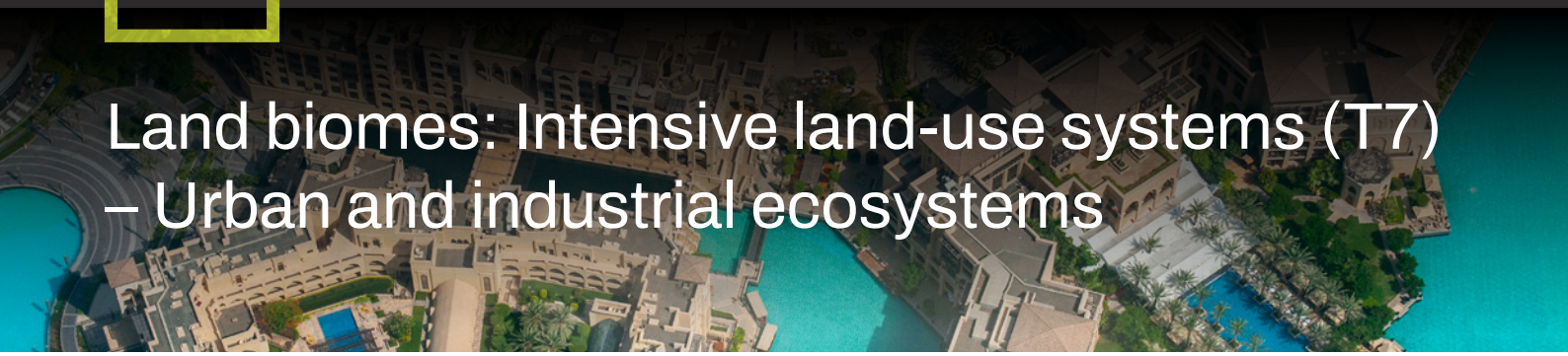
Biome-specific standards and reporting frameworks to consider include:

- Science Based Target Initiative (SBTi) and Forest, Land and Agriculture Guidance (FLAG), which contains useful guidance on setting targets as well as a FLAG target-setting tool;
- SBTN Step 1 and Step 2 guidance, and SBTN Land Hub Step 3 guidance, which includes targets for avoiding conversion of natural habitats, reducing land footprint and landscape engagement, all of which are highly relevant to companies operating in the grassland ecosystems sub-biome;
- Align project;
- EU Taxonomy;
- OP2B Framework for Restoration Actions;
- High Conservation Value (HCV) approach;
- IUCN Global Standard for Nature-based Solutions guidelines on engaging with stakeholder rights;
- GBF complementary indicator around Target 2: 'Percentage of cropped landscapes with at least 10% natural land'. Note that some institutions may promote more ambitious targets; and
- UNCCD Land Degradation Neutrality (LDN).[39]

Assessment indicators and metrics for the intensive land-use systems biome

Organisations operating in this biome should refer to the TNFD sector guidance for Food & Agriculture and Forestry for assessment metrics.

39 Science Based Targets (2022) Forest, Land and Agriculture Science Based Target-Setting Guidance; Science Based Targets Network (2032) Step 1: Assess and Step 2: Interpret & Prioritize; Science Based Targets Network (2023) Step 3: Measure, Set, Disclose: Land (Version 0.3); Capitals Coalition (2023) Aligning Accounting Approaches for Nature; European Commission (2023) EU taxonomy for sustainable activities; WBCSD (2022) OP2B's Framework for Restoration Actions; HCV Network. HCV Approach; IUCN (2020) IUCN Global Standard for Nature-based Solutions: first edition; Convention on Biological Diversity (2022) Kunming-Montreal Global Biodiversity Framework: Target 2; United Nations Convention to Combat Desertification. Land Degradation Neutrality.



Land biomes: Intensive land-use systems (T7) – Urban and industrial ecosystems

Introduction

The urban and industrial ecosystems (T7.4) sub-biome within the intensive land-use biome (T7) is broadly found on land (in the terrestrial realm), but coastal urban and industrial areas will also border the marine realm. It is also frequently located alongside the freshwater realm and can heavily influence and impact it. It can also interact with subterranean biomes, e.g. the anthropogenic subterranean freshwaters biome. Mined landscapes (included in this biome) follow different distribution patterns, but also cross the same realms: terrestrial, freshwater, marine (even more directly than the urban ones) and subterranean.

Urban ecosystems include cities, towns, villages and any kind of human settlements and their associated infrastructure. Industrial ecosystems can be adjacent to the urban residential areas or situated in remote areas to optimise for resource extraction and processing. Both categories are created and shaped by human activity and characterised by very high human population density.

They are all derived from the conversion of natural ecosystems, although these changes may have happened centuries or millennia ago. The biome continues to expand at the expense of natural habitats. Areas adjacent to urban ecosystems, by location and/or function, are known as peri-urban areas and/or the hinterland. While intensive land use is classified as a separate biome in the GET, urban and industrial ecosystems can be framed as heavy land use of natural ecosystems (i.e. areas of inherently low ecosystem condition). It is also important to consider the ecosystems surrounding this biome that are likely to be affected by it or are at risk of future conversion.

A large element of human impact on nature is created within this biome, notably GHG emissions contributing to climate change, and other forms of pollution. Ecosystem services of this sub-biome are different and to some extent limited when compared to those provided by other ecosystems. This results in a higher need to import resources to support the human population (water, food, energy and all other necessary commodities) than is found in other biomes. At the same time, cities and their hinterlands are driving forces of the economy via demand and supply of goods and services.[40] Urban and peri-urban agriculture is one strategy to supply goods and services from within the urban and industrial sub-biome.[41]

The sub-biome T7.4 is defined by patches of different land uses (primarily buildings, roads and other paved surfaces, transport infrastructure, parks, gardens and brownfield sites; but also, agricultural areas, bare grounds, excavations and others). The urban and industrial sub-biome is extending globally because of the combined effects of population growth and migration to urban areas. Some estimations expect urban areas to reach a total of 1.7 million km^2 globally by 2050.[42] By 2030, the world's urban population is estimated to reach around 5.2 billion, with growth in this period of

40 Lee, S. E. et al. (2016) Advancing City Sustainability via Its Systems of Flows: The Urban Metabolism of Birmingham and Its Hinterland. Sustainability 8: 220.

41 Erwin, D. (2022) Urban and peri-urban agriculture case studies – Overview, conclusions and recommendations. An annex to Urban and peri-urban agriculture – From production to food systems. FAO and Rikolto.

42 Zhou, Y. et al. (2019) High-resolution global urban growth projection based on multiple applications of the SLEUTH urban growth model. Scientific Data 6, 34.

around 1.7 million people per week.[43] This sub-biome is therefore highly dependent on human presence and activities and cannot be considered in isolation from the people that live in and depend upon it.

Regardless of the extensive human presence in and influence on this sub-biome, it is not detached from natural ecosystems, or without value. Some argue that achieving global conservation goals depends on the contribution of cities, both because of their role in the conservation of urban and adjacent biodiversity, but also because of the impact they have on ecosystems further away.[44] Some urban and peri-urban areas are essential for biodiversity, despite their proximity to the city's impacts. For example, a survey of a peri-urban park in Libreville (Gabon) found 24 threatened plant species that grow nowhere else. They are now protected in the Raponda Walker Arboretum, around which the city grows.[45] In the UK, the lizard orchid, one of the UK's rarest plants, is found in old quarries, as are several other orchid species.[46]

Concepts and definitions

Brownfield: A brownfield site is any land or premises that has previously been used or developed and is not currently in full use, although it may be partially occupied or utilised. It may also be vacant, derelict or contaminated. Therefore, a brownfield site is not available for immediate use without intervention.[47]

Green Urban Infrastructure (GUI): This term relates to a network of green and blue spaces and other natural features that can provide a wide range of environmental, economic, health and wellbeing benefits for nature, the climate and local and wider communities.[48] Green infrastructure comprises different components (e.g. parks, green roofs, urban forests and road verges) which can be classified according to several parameters (e.g. spatial scale, dimension and location).[49]

Hinterland: The surrounding areas of a city which receive high demand for resources and services from the city itself. The hinterland is not limited by geographic proximity to the city, given the trend to procure services from an increasingly broad area. With the growth of cities and parallel globalisations, hinterlands are becoming international and global.[50] In most cases, the resource footprint of a city will cover areas that are geographically distant.

Peri-urban: This term describes the landscape interface between town and countryside, or the rural-urban transition zone, which connects urban and rural areas in functional ways.[51] Proximity to a town or city does not in itself define peri-urban. Rather, it is the existence of both rural and urban characteristics and the linkages

43 United Nations, Department of Economic and Social Affairs, Population Division (2019) World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). New York: United Nations.

44 Pierce, J. R. (2022) Cities and biodiversity in: The Routledge Handbook of Sustainable Cities and Landscapes in the Pacific Rim. Routledge, London.

45 Walters, G. et al. (2016) Peri-urban conservation in the Mondah forest of Libreville, Gabon: Red List assessments of endemic plant species, and avoiding protected area downsizing. Oryx 50: 419–430.

46 Hampton, M. (2011) The Lizard Orchid - one of the UK's rarest plants; Pienkowski, M.W. (Ed.) (2005) Review of existing and potential Ramsar sites in UK Overseas Territories and Crown Dependencies; Cole, S. et al. (2020) Britain's orchids: a field guide to the orchids of Great Britain and Ireland. Princeton University Press, Princeton, New Jersey.

47 Alker, S. et al. (2000) The Definition of Brownfield. Journal of Environmental Planning and Management 43: 49–69.

48 Ministry of Housing, Communities and Local Government (2021) National Planning Policy Framework.

49 Mollashahi, H. et al. (2021) Urban Ecosystem: An Interaction of Biological and Physical Components in: Biodiversity of Ecosystems. IntechOpen.

50 Lee, S. E. et al. (2016) Advancing City Sustainability via Its Systems of Flows: The Urban Metabolism of Birmingham and Its Hinterland. Sustainability 8, 220.

51 Iaquinta, D. and Drescher, A. W. (2000) Defining the peri-urban: Rural-urban linkages and institutional connections. Land Reform, Land Settlement and Cooperatives 8–27.

and flows of goods and services between rural areas and urban centres.[52]

Peri-urban interface: This is a concept referring to a social, economic and environmental space in which the agricultural system, the urban system and the natural resource system are in constant interaction.[53]

Structural connectivity for species: A measure of habitat permeability based on the physical features and arrangements of habitat patches, disturbances and other land, freshwater or seascape elements presumed to be important for organisms to move through their environment. Structural connectivity is used in efforts to restore or estimate functional connectivity where measures of it are lacking.[54]

Urban and industrial ecosystems: Structurally complex ecosystems of cities, smaller settlements and industrial areas. Defined by high patchiness, change through time and density of human population.[55]

Urban land teleconnections (ULT): ULT conceptualises how urbanisation and land use intertwine, to show how places are linked through processes. Examples of ULTs include the extraction of raw materials for construction of the built environment, and the unique patterns of residential development and land use that occur when tourists become residents with permanent or second homes.[56]

Urban metabolism: Urban metabolism analysis represents a useful tool to study urban ecosystems.[57] It can be approached from two points of view, either in terms of energy or in terms of the city's water, mineral and nutrient flow, measuring the rate of mass flow per unit area (called mass fluxes).[58] These approaches are used to address, urban sustainability indicators, for example.

Urban and peri-urban agriculture (UPA): Practices that yield food and other outputs through agricultural production and related processes (e.g. transformation, distribution, marketing and recycling) taking place on land and other spaces within cities and surrounding regions. It involves urban and peri-urban actors, communities, methods, places, policies, institutions, systems, ecologies and economies, using and regenerating local resources to meet changing needs of local populations while serving multiple goals and functions.[59]

Scoping a LEAP assessment

In considering the activities, assets, sectors and value chains in scope, your organisation should consider the diverse ways in which it may interact with this sub-biome through its value chain:

A. **Does the company own or manage assets, or have significant operational control over value chain activities in the urban and industrial ecosystems sub-biome?**
For example, a company that owns offices or manufacturing facilities within urban industrial areas or in cities.

52 Narain, V. (2009) Growing city, shrinking hinterland: land acquisition, transition and conflict in peri-urban Gurgaon, India. Environment and Urbanization 21, 501–512.

53 Allen, A. (2003) Environmental planning and management of the peri-urban interface: perspectives on an emerging field. Environment and Urbanization 15, 135–148.

54 Hilty, J. et al. (2019). Corridor Ecology: Linking Landscapes for Biodiversity Conservation and Climate Adaptation. 2nd ed. Washington, DC: Island Press; as cited in Hilty. J. et al. (2020) Guidelines for conserving connectivity through ecological networks and corridors. Best Practice Protected Area Guidelines Series No. 30. Gland, Switzerland: IUCN.

55 Keith, D.A. et al. (2022) A function-based typology for Earth's ecosystems. Nature 610, 513–518.

56 Güneralp, B., Seto, K.C. & Ramachandran, M. (2013) Evidence of urban land teleconnections and impacts on hinterlands. Current Opinion in Environmental Sustainability 5, 445–451.

57 Zhang, Y. (2013) Urban metabolism: A review of research methodologies. Environmental Pollution 178, 463–473.

58 Kennedy, C., Pincetl, S. & Bunje, P. (2011) The study of urban metabolism and its applications to urban planning and design. Environmental Pollution 159, 1965–1973.

59 Food and Agriculture Organization of the United Nations. Urban and peri-urban agriculture.

B. **Are the company's value chains linked to the urban and industrial ecosystems sub-biome, but with limited operational control over suppliers?** For example, a company whose servers are in an urban setting but are managed by a service provider. Or a retailer who purchases products manufactured in an industrial ecosystem sub-biome.

C. **Does the company have an indirect connection to the urban and industrial ecosystems sub-biome? Does the company employ people who live in the sub-biome?** Most companies will have a direct connection to the urban and industrial ecosystems sub-biome through the location of their headquarters, offices, warehouses or manufacturing facilities. An indirect connection is also assumed for most companies, as their upstream and downstream value chains are likely to be in an urban or an industrial setting. Any company's transport logistics rely on the infrastructure associated with the urban and industrial ecosystems sub-biome. Many companies will employ people who live in the urban biome. The ecosystem services that biodiversity provides in urban settings influence employee wellbeing, bringing benefits to workplace productivity and wellbeing.

Locating the organisation's interface with nature

All sectors of human activities operate within the urban and industrial ecosystems sub-biome. It is the focus of human impacts on the natural world, particularly GHG emissions and pollution. Land use change and resource extraction are also among the impacts created within this biome. Key sectors within the urban and industrial ecosystem sub-biome include:

- Consumer goods;
- Electric utilities and power generators;
- Hospitality and recreation (tourism);
- Infrastructure;
- Metals and mining;
- Resource transformation;
- Services (business and professional services); and
- Transportation.

The precision with which businesses can locate their dependencies and impacts in relation to this sub-biome depends on the accuracy of the organisation's value chain mapping. However, activities in the urban and industrial ecosystems sub-biome are often thoroughly mapped, monitored and regulated, and should therefore be easy to identify:

- For businesses that directly own or manage assets, it should be easy to locate the land that is owned or managed, in the form of a polygon outline of the land area, for example; and
- Businesses connected to the urban and industrial ecosystems sub-biome through their value chain should also have good and direct access to the relevant information, through engagement with their suppliers.

Urban ecosystems have a unique character and can, in some cases, host species that are found nowhere else (often species with small ranges that occur in and near urban areas), have high level of spatial variation in biodiversity because of microhabitat complexity, and comprise combinations of species that have not been found together before due to the large number of exotic species.[60]

The most significant impact on nature in this biome is the habitat loss resulting from the conversion of natural ecosystems into urban and industrial ecosystems. In many places, urban expansion may take place in already highly modified ecosystems such as cropland and high-input pastures, which entails a lower level of direct nature loss but may indirectly drive the conversion of natural habitats to intensive land uses further away. Organisations should consider not only

60 Kowarik, I. (2011) Novel urban ecosystems, biodiversity, and conservation. Environmental Pollution, Selected papers from the conference Urban Environmental Pollution: Overcoming Obstacles to Sustainability and Quality of Life (UEP2010), 20-23 June 2010, Boston, USA 159, 1974–1983.

the footprint of the urban and industrial ecosystems sub-biome itself, but also whether ecosystems in other biomes were recently converted to create those areas, and the surrounding natural ecosystems that might be at risk from any further expansion and resulting spillover effects.

The biodiversity significance of these other ecosystems will help to identify priority locations. The historical development of human settlements means it might not always be viable or meaningful to estimate the original natural habitat; the focus should be on more recent expansion. Assessment should extend to adjacent ecosystems to assess the risk of conversion and impacts spilling over from the urban and industrial ecosystems sub-biome. Impacts frequently arise from densification and infilling of urban ecosystems, resulting in loss of urban green spaces.[61]

Given the substantial demand for water resources in this sub-biome, the urban and industrial ecosystems sub-biome can significantly contribute to the water-stress status of watersheds and can also contribute to declines in water quality due to excessive nutrient inputs and other types of pollution.

Data sources that can be used to assess displaced and surrounding biomes include:

- Nature Map Explorer for identification of whether the land-cover is classed as in the urban sub-biome;[62]
- Recent historical land cover maps, or historical satellite imagery (e.g. Landsat images go back to 1972); and
- Newer high-resolution satellite imagery such as ESA WorldCover (10m) and Planet (50cm to 5m).[63]

Evaluating nature-related dependencies and impacts

Impact drivers and impacts

This biome is expected to expand by approximately 40% in the period 2012-2050.[64] On the global scale, this land use change is not comparable to that driven by agriculture, but increases in population in the urban areas, and the consequential increase of demand for water, food, energy and other resources, will represent an important driver of nature and biodiversity loss far beyond this sub-biome.

Impact drivers and impacts on the state of nature include:

- **Land/freshwater/ocean use change** due to increasing demand for resources needed to support the population in the area; this can include loss of soil biodiversity and soil erosion from removal of vegetation and construction of infrastructure, or from mining activities such as strip and open pit mining; and smaller-scale nature loss within the urban and industrial ecosystems sub-biome due to the removal of urban greenery;
- **Resource use:** for example, depletion of water resources due to increased demands from population growth within this biome;
- **Pollution:** such as the excessive addition of nutrients (referred to as eutrophication) into water bodies from waste waters released from both urban and industrial activities, with potential impacts on nature and human health, and damage to adjacent ecosystems; and pollutants (e.g. ozone, nitrous oxides and mercury) from the combustion of fossil fuels, industrial processes and mining; and
- **Climate change** due to GHG emissions from fossil fuels combustion for transport and energy sectors, as well as industry.

Table 20 provides further examples of impact drivers associated with common business activities in this sub-biome.

61 Richards, D.R. and Belcher, R.N. (2020) Global Changes in Urban Vegetation Cover. Remote Sensing 12, 23.

62 Nature Map Initiative (2023) Nature Map Explorer.

63 European Space Agency (2020-23) WorldCover; Planet.com.

64 Zhou, Y. et al. (2019) High-resolution global urban growth projection based on multiple applications of the SLEUTH urban growth model. Scientific Data 6, 34.

Table 20: Drivers of nature change and impact drivers associated with common business activities in the urban and industrial ecosystems sub-biome

Business activity	Driver of nature change	Impact driver
Conversion of natural habitats to urbanisation Conversion of natural habitats for urbanisation leads to reduced extent and condition of the ecosystems in the biome, including through increased fragmentation.	Land/freshwater/ocean use change	Land ecosystem use
Conversion of natural habitats to mining activities Conversion of natural habitats for mining activities leads to reduced extent and condition of the ecosystems in the biome, including through increased fragmentation. Supporting infrastructure further contributes to fragmentation and can increase access to facilitate further land use change.	Land/freshwater/ocean use change	Land ecosystem use
Transport Transport can generate pollution including microplastics from tyre-wear and particulate air pollution, as well as GHG emissions.	Climate change	GHG emissions
	Pollution	Water pollutants Non-GHG air pollutants
Carbon emissions from commercial transport and other industrial activities Commercial transport and industrial activities generate carbon emissions. Climate change represents a key risk to the biome and beyond it due to changing climatic temperatures and rainfall patterns. This leads to increased risks of desertification in some areas, changes in fire regimes, and risks of woody vegetation encroachment in others.	Climate change	GHG emissions
Domestic and industrial water use Water use can lead to water stress in the biome and beyond it. This can include effects on the water table which may go undetected.	Resource use/replenishment	Water use

Business activity	Driver of nature change	Impact driver
Wastewater treatment Wastewater treatment can release pollutants into soil and water, leading to ecotoxicity and eutrophication.	Pollution/pollution removal	Soil pollutants Water pollutants
Waste management Waste management, including incineration, can release pollutants into soil, water and air, leading to ecotoxicity, eutrophication and air pollution.	Pollution/pollution removal	Soil pollutants Water pollutants Non-GHG air pollutants
Energy supply Energy supply, where fossil-fuel based, can contribute to climate change. Renewable energy will also require mineral extraction such as aluminium, copper, lithium and other metals.	Climate change	GHG emissions
	Resource use/replenishment	Other resource use (mineral)
Pesticides application Pesticides application for urban pest control can leak into the water supply or pollute the soil. Some also contribute to air pollution.	Pollution/pollution removal	Water pollutants Non-GHG air pollutants Soil pollutants
Arable agriculture in urban food systems Tillage and removal of organic matter (context-dependent) leading to loss of soil biodiversity, soil erosion and sequestered carbon.	Land/freshwater/ocean use change	Land ecosystem use
	Climate change	GHG emissions
Importation of exotic species for horticulture and urban parks and gardens Many exotic species are imported to urban and industrial ecosystems, and some of these may become invasive, and be pests or pathogens.	Invasive alien species introduction/removal	Introduction of alien invasive species
Irrigation Poorly planned or excessive irrigation can lead to salinisation.	Land/freshwater/ocean use change	Land ecosystem use

Ecosystem services

The substantive transformation of this sub-biome from the natural state affects the availability of ecosystem services provided by the sub-biome. Table 21 sets out the ecosystem services that organisations and others may depend on in this biome. This can assist LEAP project teams to identify the ecosystem services most relevant to their assessment.

Table 21: Principal ecosystem services present in the urban and industrial ecosystems sub-biome[65]

Principal ecosystem services		Example
Provisioning services	Water supply	The sub-biome can host local water sources.
	Biomass provisioning	Food from urban and peri-urban agriculture.
Cultural services	Recreation-related services	Urban greenspaces provide opportunities for physical exercise and urban biodiversity can boost psychological wellbeing of urban dwellers. They can also provide tourism opportunities.
	Education, scientific and research services	Supporting education about nature.
	Spiritual, artistic and symbolic services	Urban biodiversity is part of the intangible fabric of sense of place to urban dwellers.
Regulating and maintenance services	Pollination	Urban greenery can provide habitat for pollinators, supporting urban and peri-urban agriculture.
	Soil and sediment retention	Trees can reduce the risk of landslides.
	Air filtration	Urban greenery can help to purify air in the area.
	Flood mitigation	Trees can slow the flow of excess water, and mangroves can reduce the risk of coastal flooding.
	Water flow regulation	
	Local (micro and meso) climate regulation	Urban greenery can reduce local temperatures by providing shade.
	Noise attenuation	Urban greenery can support dampening of noise.

65 Maes et al. (2016) Mapping and assessment of ecosystems and their services: urban ecosystems. Publications Office, LU.

Changes to the state of nature

Considering changes to the state of nature resulting from your organisation's impact drivers and external factors, and determining appropriate responses, your organisation should consider:

- **Spatial location,** as it will influence the types of biodiversity and species that are likely to be affected (that could include threatened, range restricted and migratory species). Some urban areas happen to be located in and near the ranges of globally important threatened species found nowhere else. Some urban and industrial ecosystems might be situated in water-stressed catchments and catchments susceptible to cumulative effects on water quality, connectivity, and hydrological balance. Availability of data can also vary depending on the location;
- **Proximity to designated areas:** The organisation should consider any overlap or proximity to nationally or internationally designated areas and habitat types, as these factors can significantly impact the organisation's activities;
- Climate change interactions: Interactions with climate change can intensify the impacts of other impact drivers and external factors, increasing the likelihood of invasive alien species' introduction and ecosystem collapse;
- **Connectivity** is an essential feature of Green Urban Infrastructure (GUI);[66] and
- **Species habitat ranges** that include urban biodiversity and migratory species, as well as biodiversity associated to adjacent natural habitats.

Assessing nature-related risks and opportunities

The urban and industrial ecosystems sub-biome consumes most of the world's energy from fossil fuels and renewable resources. Growth of urban population and area is increasing several drivers of nature change such as climate change, resource extraction and pollution. For this reason, risks and opportunities in this biome have significant social, economic and policy implications and there is a wide range of risks and opportunities to consider.

66 Beninde, J. et al. (2015) Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecology Letters 18, 581–592; Mollashahi, H. et al. (2021) Urban Ecosystem: An Interaction of Biological and Physical Components in: Biodiversity of Ecosystems. IntechOpen.

Table 22: Examples of nature-related risks in the urban and industrial ecosystems sub-biome

Category	Nature-related risk	Urban and industrial ecosystems sub-biome examples
Physical risks	Changes to the supply of natural inputs (provisioning services)	Loss of business value as a result of degraded biodiversity and ecosystem services attributed to business activities. Loss of business value because of water stress and water scarcity.
	Changes to protection from natural hazards due to change in hazard mitigation services	Estimated loss of value as a result of loss of biodiversity and ecosystem services such as flood and erosion control. Costs and revenue losses because of changes in water cycle and water flow maintenance leading to floods.
	Changes in regulating and maintenance services	Costs and revenue losses due to changes in air quality because of the loss of urban trees and forests. Loss of business value because of decreased noise mitigation by urban vegetation.
	Changes in recreational value of an area	Changes in the aesthetic value of a landscape. Loss of recreational value as a result of ecosystem degradation (e.g. wastewater release into a lake might discourage swimming there) and ecosystem service losses (e.g. the same release might lead to changes in the functioning of the lake) attributed to business activities.
	Effects on species, including ones that an organisation depends upon	Introduction and proliferation of invasive and non-native species. Over time this can lead to loss of species diversity through adaptable, generalist weed-type species displacing others, with knock-on consequences for ecosystem function. Species diversity may also be affected by hybridisation.
	Increased susceptibility to pest outbreaks and diseases	Increased risk of disease transmission and pest outbreaks due to lack of control of invasive alien species.

Category	Nature-related risk	Urban and industrial ecosystems sub-biome examples
Transition risks	Changes to legislation/ regulations	Changes to zoning/land use change laws (e.g. allowed percentage of construction within the zoning area). Tourism restrictions in tourist areas (e.g. limited number of visitors to an area).
	More stringent nature-related reporting obligations	Required air and water quality monitoring. Required GHG emissions monitoring.
	Shifting customer/investor values or preferences	Increasing demand for locally grown products (e.g. vegetables from urban gardens, “km 0” movement).
	Stakeholder conflicts	Impacts on Indigenous Peoples and Local Communities who have rights relating to, and use, the biome, or who have rights to and use biomes that urban and industrial land use may expand into. Illegal construction on periphery of urban areas.
	Change in brand and value proposition/changes in sentiment towards the organisation/brand due to impacts on nature	Destruction of biomes of high biodiversity importance through expansion of urban and industrial land use (e.g. loss of tropical rainforest due to mining activities). Accidents in industrial areas or along the transport infrastructures (chemical spills, explosions, fires).
	Volatility/changes to costs of materials	Reduction in water availability due to over-abstraction of water for consumption and processing.
	Requirements to transition to more efficient, resilient and less environmentally damaging technologies	Imposition of requirements for reduced water/air pollution, or greater efficiency of production. Environmental regulation of industrial machinery.
Systemic risks	Ecosystem collapse and biodiversity loss	Risk of collapse of certain guilds and communities of species due to climate change and over-exploitation (e.g. extreme weather events and water stress may drive prioritisation of resources in the urban and industrial sub-biomes away from biodiversity, towards human needs).
	Financial contagion	Economic crises spreading from one market or region to another due to ecosystem collapse and loss of ecosystem services affecting dependencies.

Opportunities stemming from use of the urban and industrial ecosystems sub-biome are often linked to habitat creation and/or improvement, both for connectivity across the vast urbanised areas and for creation of islands of habitat for nature and biodiversity.

Urban and peri-urban agriculture can serve several purposes, playing a role of habitat creation, providing ecosystem services and building connectivity, while also ensuring resilience of food supplies for the area and providing multiple benefits to people.[67]

Table 23: Examples of nature-related opportunities in the urban and industrial ecosystems sub-biome

Category	Nature-related opportunity	Urban and industrial ecosystems sub-biome examples
Systemic opportunities	Ecological.	Supporting urban biodiversity conservation efforts by preventing the conversion of remaining patches of natural habitat and restoring degraded sites. Urban and peri-urban agriculture.
Resource efficiency	Diversification of use of natural (e.g. use of different plant species).	Shift to drought/heat-tolerant plant species or varieties in Green Urban Infrastructure (GUI).
	Adoption of resource efficiency/ circularity mechanisms that reduce dependencies and impacts on nature.	Mimic natural processes to enhance water availability and quality, and to reduce flood risk (such as engineered wetlands and vegetated areas known as riparian buffers). Develop self-sustaining Green Urban Infrastructure with circulating water systems, recycling urban wastewater systems or optimisation of rainfall implemented in the maintenance of the system.
	Transition to efficient and circular production systems and value chains.	Transition to circularity to reduce waste/pollution entering the urban environment.
	Transition to processes with reduced negative impacts on nature/increased positive impacts on nature.	Shift to more selective/less damaging power, mining, industrial and transportation technologies such as recycling, reusing water and implementing waste management systems. Encourage urban and peri-urban agriculture on unused brownfield through the urbanised area.

67 Erwin, D. (2022) Urban and peri-urban agriculture case studies – Overview, conclusions and recommendations. An annex to Urban and peri-urban agriculture – From production to food systems. FAO and Rikolto.

Category	Nature-related opportunity	Urban and industrial ecosystems sub-biome examples
	Adoption of nature-based solutions within service and product lines.	Biomimetic elements in urban development (e.g. façade of a building made as an imitation of animal skin structure aiming to reduce heat loss). Implementation of Green Urban Infrastructure for thermal isolation, air pollution reduction and noise reduction (e.g. green walls and roofs planned for resource efficiency).
		Use of unpaved areas to increase pollinator and natural predator abundance.
	Wellbeing improvement.	Access to nature (e.g. green spaces, birdsong) can enhance the wellbeing and physical health of people who live and/or work in urban and industrial ecosystems.
Markets	Access to new assets and locations.	Growth in the tourism sector for newly established urban and peri-urban protected areas.
	Educate consumers.	Provide information needed by consumers to promote sustainable consumption patterns.
Capital flow and financing	Access to nature-related green funds, bonds or loans.	Access to sustainable finance via sustainability-linked loans and sustainability-linked bonds such as green bonds, blue bonds and green loans.
	Use of public-sector incentives (e.g. biodiversity credits, payments for ecosystem services).	Potential for payments for ecosystem services.
Reputational capital	Actions that create positive changes in sentiment towards the organisation/brand due to impacts on environmental assets and ecosystem services, which in turn impact society and local economic capabilities.	Actioning and signalling departure from unsustainable resources usage in supply chain.
		Supporting conservation of urban biodiversity.

Category	Nature-related opportunity	Urban and industrial ecosystems sub-biome examples
Ecosystem protection, restoration and regeneration	Direct restoration, conservation or protection of ecosystems or habitats.	Watershed management and rehabilitation.
		Use of land unsuitable for construction of buildings or infrastructure for natural habitats/carbon sequestration.
	Supporting conservation or restoration projects.	Financially supporting nature-based solutions projects that target the restoration or sustainable use of urban ecosystems (e.g. urban forests, water bodies, etc.).
	Communicating with the public on the importance of ecosystem protection.	Supporting or facilitating educational campaigns to raise awareness about protection of urban landscapes (e.g. non-destructive recreational use of urban parks and forests, citizen science projects on urban biodiversity).
Sustainable use of natural resources	Transition to processes with lower negative impacts on nature/ increased positive impacts on nature.	Establishment of sustainable urban biodiversity management practices (e.g. application of biocontrol instead of chemical pesticides). Postponing or avoiding mowing of green areas to promote pollinator abundance and support urban biodiversity.
		Improvements in remote monitoring of urban and industrial ecosystems.
		Recreational opportunities from urban green spaces.

Preparing to respond and report

Responses to nature-related issues in this sub-biome should be mindful of the fact that there may be global trade-offs between avoiding impacts in this sub-biome versus avoiding impacts in other biomes with intact ecosystems. Furthermore, nature in the urban and industrial biome is of considerable value to the many people (most of the world's population) that live there.

As outlined in the TNFD recommendations, the mitigation hierarchy should be applied by avoiding impacts on nature in this biome where possible (e.g. not converting remaining fragments of natural or semi-natural ecosystems, and avoiding the release of certain pollutants, for example by not using mercury in gold mining processes), minimising and reducing impacts (e.g. increasing the density of development to reduce the land footprint, and reducing excess water usage) and restoring nature within urban and industrial ecosystems where feasible (e.g. abandoned mines and quarries).

There are widespread opportunities to improve the state of nature in urban and industrial ecosystems. Many urban green spaces are poorly managed for biodiversity and ecosystem services (e.g. large areas with monoculture lawn turf), providing potential for low-

cost, but high-impact changes. Restoring semi-natural ecosystems to these spaces would provide a range of benefits and cut maintenance costs.

Further responses could include:

- **Contributing to sector and business** models that reduce negative impacts and increase positive impacts on urban biodiversity, for example by participating in strategic urban planning to ensure the conservation and connectivity of patches of urban and industrial ecosystems relevant to the functioning of biodiversity and ecosystem;
- **Decreasing GHG emissions** by lowering the demand for energy consumption through application of energy-efficient construction principles, for example;
- **Investing in circular economy solutions** to reduce the dependency of this sub-biome on others;
- **Engaging stakeholders:**
  - Working with the local population and users and managers of Green Urban Infrastructure to raise the awareness of their value, motivate interest in urban green and blue spaces and stimulate conservation; and
  - Supporting citizen science projects and promote corporation engagement programmes through employees' voluntary action; [68] and
- **Designating areas for urban and peri-urban agriculture,** promote the use of empty lands and support irrigation systems across cities. Promote the involvement of residents, integrate habitat connectivity and create pathways for biodiversity across the urban landscape.

Biome-specific standards and reporting frameworks to consider include:

- IUCN Urban Nature Indexes (UNI);
- InVEST for modelling ecosystem services – has been applied to urban areas;
- Singapore Index on Cities' Biodiversity is an index for cities to measure their biodiversity conservation efforts;
- European Urban Biodiversity Index;
- Ecocity Standards;
- IUCN Global Standard for Nature-based Solutions;
- Green Building Councils and sustainable building certifications;
- SEEA EA approach for Urban Ecosystem Accounts;
- World Bank Group Urban Sustainability Framework.[69]

Assessment indicators and metrics for the urban and industrial ecosystems sub-biome

The IUCN Urban Nature Indexes are organised in a series of six topics (consumption drivers, human pressures, habitat status, species status, nature's contributions to people and governance responses). These can help companies identify and asses their impacts on urban nature and beyond. The indexes do not include all calculations or datasets but offer a systematic approach to quantification, definition of impacts and dependencies and description of local landscapes.

To support the assessment of nature-related issues in this biome, a LEAP assessment team may wish to consider the assessment metrics in Table 24. These are suggested by the TNFD to support assessment only and are not part of the TNFD's recommended core sector metrics.

68 These responses should be considered in a wider governance context.

69 IUCN (2023) IUCN Urban Nature Indexes; Lourdes, K. T. et al. (2022) Planning for green infrastructure using multiple urban ecosystem service models and multicriteria analysis. Landscape and Urban Planning 226, 104500; Natural Capital Project. InVEST; Chan, L. et al. (2021) Handbook on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index). Montreal: Secretariat of the Convention on Biological Diversity and Singapore National Parks Board, Singapore; Ruf, K. et al. (2018) The European Urban Biodiversity Index (EUBI): a composite indicator for biodiversity in cities; Ecocity Standards; IUCN (2020). Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN; World Green Building Council. Sustainable Building Certifications; Global Platform for Sustainable Cities, World Bank (2018) Urban Sustainability Framework. 1st ed. Washington, DC; World Bank.

Table 24: Illustrative dependency and impact assessment indicators and metrics for the urban and industrial ecosystems sub-biome by sector

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
General	Location prioritisation	N/A	Volume of sub-biome area affected by business activities. Percentage overlap of business activities with habitat range of locally or globally important species (Global IUCN Red List, National IUCN Red List, listed on international conventions such as CITES or CMS, indicators in theme 3 of IUCN Urban Nature Indexes).[70]
	Dependencies and impacts: Impact drivers	Resource use/ replenishment	Total water consumption and withdrawal (total, freshwater, other) by source (e.g. surface water, groundwater) in water-stressed areas as a percentage of maximum extraction compatible with e-flows.[71] Use of CITES-listed wild species. The indicators in theme 1 of IUCN UNI. Total waste water discharge. Concentration of dissolved and suspended solids in waste water. Total solid waste.
		Land/Freshwater/ Ocean use change	Amount (ha) and rate (ha/yr) of conversion of natural habitat in the supply shed.

70 IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2; ZSL and IUCN National Red List Working Group (2022) National Red List Database. Version 2022-1; CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora; CMS. Convention on the Conservation of Migratory Species of Wild Animals; IUCN (2023) IUCN Urban Nature Indexes.

71 International Water Management Institute. Global Environmental Flow Information System.

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Locally appropriate metrics of habitat connectivity, where available (indicators in theme 3.5 of IUCN Urban Nature Indexes).[72]
		Species	Species diversity Contribution to extinction risk (see the Species Threat Abatement and Restoration (STAR) metric).[73] The indicators in theme 4 of IUCN Urban Nature Indexes.[74]
	Dependencies and impacts: Ecosystem services	Provisioning services	Total water provision (surface and groundwater for drinking and non-drinking purposes).
		Regulating and maintenance services	Total carbon sequestration by urban trees and forests. Modelled urban temperature regulation (°C). Modelled noise reduction by urban vegetation and GUI (dB). The indicators in theme 5 of IUCN Urban Nature Indexes.[75]

72 IUCN (2023) IUCN Urban Nature Indexes.

73 IUCN. Species Threat Abatement and Restoration (STAR) metric.

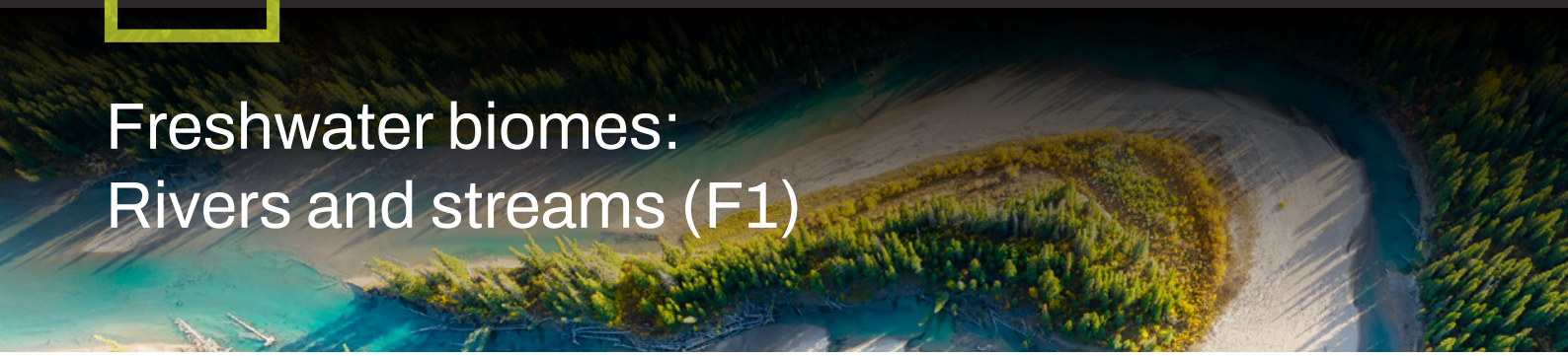
74 IUCN (2023) IUCN Urban Nature Indexes.

75 IUCN (2023) IUCN Urban Nature Indexes.

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
Energy (oil and gas, and renewable energy) sector	Location prioritisation	N/A	Overlap of operating locations with protected areas and habitat distributions of endangered species.
	Dependencies and impacts: Impact drivers	Pollution/pollutants removed	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood. The indicators in theme 2 of IUCN Urban Nature Indexes.[76]
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Changes in ecosystem extent and condition metrics due to infrastructure.
	Dependencies and impacts: State of nature	Species	Avifauna and migratory species affected. The indicators in theme 4 of IUCN Urban Nature Indexes.[77]
Forestry, paper and pulp; mining and metals; and food sectors	Dependencies and impacts: Impact drivers	Pollution/pollutants removed	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood.
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Eutrophication.
		Species	Assessment of chronic and acute effect levels of pollutants on urban species.

76 IUCN (2023) IUCN Urban Nature Indexes.

77 IUCN (2023) IUCN Urban Nature Indexes.



Freshwater biomes: Rivers and streams (F1)

Introduction

The rivers and streams biome (F1) includes running water ecosystems that flow from uplands to deltas, and coastal estuaries. The water draining into a particular river is known as a catchment.

Rivers and streams are inextricably connected with other freshwater and transitional biomes, including lakes (F2), subterranean freshwaters (SF1), anthropogenic subterranean freshwaters (SF2), wetlands (TF1) and artificial wetlands (TF3). All freshwater and freshwater-transitional biomes should be considered together, not in isolation, and the guidance developed here for F1 will be broadly relevant to all freshwater biomes.

Rivers and streams can be characterised by their temperature, elevation, and whether they run throughout the year. Sub-biomes in the rivers and streams biome include:

- **Permanent upland streams (F1.1) and permanent lowland streams (F1.2)**, which flow throughout the year without ever freezing or drying up, typically in humid tropical and temperate regions;
- **Freeze-thaw rivers and streams (F1.3)** occur in cold climates at high latitudes, and freeze in winter and thaw in summer;
- **Seasonal upland streams (F1.4)** vary in flow depending on seasonal rainfall patterns; for example, drying up during dry seasons. They are found in elevated regions in seasonal tropical, sub-tropical and temperate climates worldwide;
- **Seasonal lowland rivers (F1.5)** vary in flow depending on seasonal rainfall patterns. They are distributed in tropical, sub-tropical and temperate lowlands;
- **Episodic arid rivers (F1.6)** are typically dry but occasionally run during periods of heavy rainfall, for example in deserts; and
- **Large lowland rivers (F1.7)** are very large rivers that transport high volumes of freshwater through lowlands and are mostly situated in tropical or sub-tropical regions. Some examples of this functional type of river are the Amazon and Congo Rivers.

Concepts and definitions

Catchment management agency: National or regional government agency that has the authority to make decisions on the allocation of water. This includes catchment management authorities, water resource management agencies, and catchment municipality councils.

Delta: An area of low, flat land where a river divides into several smaller rivers before flowing into the sea.

Downstream flow: This term indicates the final flow regime once e-flows and flows for other water demands, such as irrigation and hydropower generation, have been combined. Some holistic environmental flow assessments analyse scenarios that include all such considerations. In such assessments, the scenario chosen through negotiation contains a flow regime that becomes the e-flows for the river and is effectively the downstream flow.

Environmental water: Water managed to deliver specific ecological outcomes or benefits. It may refer to specific water allocations or releases made for ecological purposes.

Environmental flow (e-flow): Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems

and the human livelihoods and wellbeing that depend on these ecosystems.

Eutrophic: A river or stream where levels of nitrates and phosphates exceed natural thresholds.

Floodplain: A floodplain is a flat area of land next to a river or stream. It stretches from the banks of the river to the outer edges of the valley.

Lateral connection: The riparian/floodplain/terrestrial-river nexus which connects the adjacent land next to rivers to the instream part of the river.

Longitudinal connection: The upstream-downstream nexus of a river, from the headwaters in the uplands to the mouth of the river by the ocean. Longitudinal connectivity of rivers and streams can also be considered on a various scale (sub-catchment).

Mainstem river: In hydrology, a mainstem river is the primary downstream segment of a river. Water enters the mainstem from the river's catchment (the land area through which the mainstem and its tributaries flow).

Mesotrophic: A river or stream with a moderate amount of nutrients (nitrate and phosphates).

Minimum flow: A general term used to describe a flow that must be maintained without further reduction over a specified period, either during the dry season or over the entire year. It implies that ecosystem functioning can be protected through the delivery of a minimum and constant flow, whereas evidence shows within- and between-year-flow variability is essential to maintaining healthy rivers.

Oligotrophic: A river or stream relatively poor in nutrients (nitrate and phosphates) and containing abundant oxygen.

River catchments and watersheds: A water catchment (also known as a watershed or basin) is an area of land where all water flows and is directed into a single stream or river. Natural boundaries of water catchments can vary in scale and can be very small for a single stream or river, or very broad for a large river such as the Amazon or Congo Rivers. Land and freshwater use in a watershed can affect the entire length of river depending on the intensity of the use and impact.

Tributary: A tributary is a stream or river that flows into a larger stream or mainstem river. A tributary does not flow directly into a sea or ocean.

Vertical connection/groundwater connection/ vadose zone: The terrestrial sub-surface water that has a connection to surface water and to the regional groundwater table.

Scoping a LEAP assessment

In considering the activities, assets, sectors and value chains in scope, your organisation should consider the diverse ways in which it may interact with this biome through its value chain:

- Water-based enterprises: What business activities take place in rivers and streams, with or without complete conversion?
- Enterprises with indirect use of water resources: Where the company's business activities involve no direct use of rivers and streams, do they require resources or services from them, such as industry, mining, cooling for nuclear and coal, solar energy, agriculture, manufacturing, food retailing and cosmetic products? Do they use rivers and streams as a place to dispose of waste materials or waste heat?

Table 25 provides further examples of sectors with different degrees of connection to this biome.

Table 25: Connections to the rivers and streams biome

Degree of connection	Examples
A. Business manages freshwater resources and has significant and direct operational control over supply chain in rivers and streams biome	Hydropower company with operations in rivers and/or streams Fisheries Water utility River-based tourism Instream mining operations Manufacturing company using rivers and streams as a place to dispose of waste
B. Business supply chain is linked to rivers and streams biome, but with indirect and limited operational control over suppliers	Water bottling company Fishery retailers and processors
C. Business supply chain is linked to rivers and streams biome, but with limited operational control over suppliers	This includes all companies that use water resources or freshwater biodiversity indirectly, which effectively covers most businesses, for example: • Food retailer sourcing from consolidating commodity trader • Manufacturer requiring water from direct supplier • Downstream consumers littering packaging and leakage from waste management systems into rivers and streams

Locating the organisation's interface with nature

Many sectors will have some interface with rivers and streams, as users of water in some form. Organisations in water-intensive sectors should pay particular consideration to this biome, including:

- Agriculture and food;
- Aquaculture;
- Consumer goods (including apparel and textiles);
- Electric utilities and power generators;
- Fisheries;
- Infrastructure;
- Mining and metals; and
- Resource transformation (including chemicals).

The agriculture, apparel and textiles, aquaculture, chemicals, energy, forestry and mining and metals sectors have both direct and indirect connections with rivers and streams in terms of their dependencies and impacts. Tourism is highly dependent on rivers and streams, namely their functionality for recreational services and for regulating and maintenance services, such as storm and flood protection.

The methods to locate interfaces with the rivers and streams biome will vary depending on the degree of connection with the biome. Organisations should also consider how river and stream systems are connected, causing interactions that may span the length, breadth and depth of a river or stream, and the surrounding area, including floodplains and groundwater. In particular, threats to freshwater hydrology and biodiversity are not necessarily delimited by geography and are often driven by transboundary geopolitical and economic factors.

Table 26: Tools and methods for locating interfaces with the rivers and streams biome

Degree of connection and control	Tools and methodologies for Locate
Companies with localised interfaces under direct control	Companies such as inland fisheries, hydropower operators, textile manufacturers, beverage companies, some mining operators and water utilities should locate primary spatial data on infrastructure (e.g. point coordinates or polygons of hydropower, water storage and aquaculture infrastructure) or localised utilisation of resources (e.g. point coordinates of water abstraction). This can be overlayed with spatial data on rivers and streams from IUCN ecosystem typology data as well as data from: • WWF HydroSHEDS; • WWF HydroRIVERS; • Global River Classification (GloRiC); • Distribution of IUCN Red List of Threatened Species; • Freshwater Protected Areas; • Freshwater Key Biodiversity Areas; and • Ramsar Sites.[78]
Diffused and under direct control	This includes companies who have direct control over operations, but who have diffuse impacts on rivers and streams. For example, companies managing agricultural lands or industries with downstream impacts through pollution (e.g. eutrophication) on rivers and streams. These companies should identify the catchments they operate in, and the criteria for priority locations in those catchments. The same tools regarding watershed location and biodiversity importance as for companies with localised interfaces under direct control are relevant.
Indirect interactions via investments or value chains	Companies such as retailers of products derived from inland fisheries require knowledge of how business activities interface with water catchments. Tools such as HydroSHEDS can help.[79] Water stress could be assessed at a national level using Aqueduct Country Rankings; secondary data from suppliers on the locations of their activities; primary data on flow (connectivity); and data on water abstraction and water quality (from water-stressed-area databases, for example). Third party satellite imagery (e.g. tools like Aqueduct or Water Risk Filter)[80] could be used to identify potential high-risk areas for further assessment.

78 WWF et al. HydroSHEDS, HydroRIVERS and Global River Classification; IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2; Key Biodiversity Areas; Protected Planet; Ramsar.

79 WWF et al. HydroSHEDS.

80 World Resources Institute. Aqueduct; WWF. Water Risk Filter.

Freshwater ecosystems, including rivers and streams, are particularly threatened, and have experienced greater declines in biodiversity than ecosystems on land.[81] All interactions with rivers and streams are therefore potentially sensitive locations, given their biodiversity importance, rapid declines in ecosystem integrity and crucial ecosystem services.

Evaluating nature-related dependencies and impacts

All sectors are dependent on fresh water from rivers and streams and interface with this biome in some way. This either happens directly when companies access surface water for operations (e.g. hydropower, water supply dams and infrastructure), or indirectly, such as when they purchase water for the processing of minerals, or water is used in their supply chain to produce retail products.

Impact drivers

Table 27 sets out the impact drivers associated with common business activities in the rivers and streams biome.

Table 27: Drivers of nature change and impact drivers associated with common business activities in the rivers and streams biome

Business activity	Driver of nature change	Impact driver
Fisheries and harvesting of plant materials Freshwater species are used for food, furniture and clothes manufacture and can lead to over exploitation of freshwater species.	Resource use/ replenishment	Other resource use
Hydropower Hydropower dam placement and storage dams for water consumption (urban) and use of water for processing (mining) and agriculture disrupts connectivity along the river.	Land/freshwater/ocean use change	Freshwater ecosystem use
Hydropower and water storage Freshwater use change occurring from hydropower and water storage activities can lead to hydrological regime from disturbing natural conditions and seasonality, which can in turn result in biological alterations such as accidental mortality of species.	Land/freshwater/ocean use change Invasive alien species introduction/removal	Freshwater ecosystem use Introduction of alien invasive species

81 WWF (2022) Living Planet Report 2022 – Building a nature-positive society. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds). WWF, Gland, Switzerland.

Business activity	Driver of nature change	Impact driver
Mining Instream aggregate mining for building projects, dredging for freshwater transport routes or freshwater ports and storage facilities can lead to the destruction of water habitats, particularly downstream deltas reliant on sediment flows.	Land/freshwater/ocean use change	Land ecosystem use
Powerhouse operation and fisheries Water use for powerhouse operation and fisheries can lead to water stress of biome.	Resource use/ replenishment	Water use
Wastewater treatment and release of industrial and domestic waste Wastewater treatment can release pollution to water, leading to eutrophication. Further toxicity comes from industrial and domestic wastewater and pollution from effluent discharges, urban and agricultural run-off, emerging pollutants such as pharmaceuticals and plastics, solid waste and thermal pollution.	Pollution/pollution removal	Water pollutants
Water extraction at bottling plant Removing water disrupts the naturally available water in the ecosystem.	Resource use/ replenishment	Water use
Water use and pollution in the chemicals sector Parts of the chemicals sector may use water as a product input or as a coolant in production processes. Spills and other releases can also lead to water pollution.[82]	Resource use/ replenishment Pollution/pollution-removal	Water use Water pollutants
Water use and pollution in the textiles sector Textile operations use water in their dyeing and tanning operations. Water pollution with chemicals and microplastics can occur during these phases.[83]	Resource use/ replenishment Pollution/pollution-removal	Water use Water pollutants

82 United States Environmental Protection Agency (2023) Water Releases by Chemical & Industry.

83 Cairns, R. (2023) One-fifth of water pollution comes from textile dyes. But a shellfish-inspired solution could clean it up. CNN.

Ecosystem services

Table 28 sets out the ecosystem services provided by this biome that organisations and others may depend. This can assist LEAP project teams to identify the ecosystem services most relevant to their assessment.

Table 28: Principal ecosystem services present in the rivers and streams biome

Principal ecosystem services		Example
Provisioning services	Water supply	Supply of water for industry, irrigation, human and animal consumption.
	Biomass provisioning	Harvested fish, shellfish and plants; aquaculture.
	Other provisioning services	Hydro-electric energy; water surface for navigation.
Cultural services	Recreation-related services	Tourism; outdoor recreation such as sailing, swimming, fishing and waterfowl hunting.
	Visual amenity services	Scenic beauty.
Regulating and maintenance services	Soil and sediment retention	Erosion control, regulation of sediment flow, augmentation of fertile land in floodplains and maintenance of productive deltas.
	Flood mitigation	Mitigation of flood events by river floodplains.
	Nursery population and habitat maintenance	Maintenance of nurseries and migratory connections for fish species.
	Water purification	Pollutant control by fringing or wetland vegetation; dilution of pollutants.

Changes to the state of nature

When considering changes to the state of nature resulting from your organisation's impact drivers and external factors, and determining appropriate responses, your organisation should examine:

- **Spatial location:** This will influence the types of freshwater biodiversity and species that are likely to be affected (that could include threatened, range restricted and migratory species). Some freshwater ecosystems may be in water-stressed catchments and catchments impacted cumulatively by water quality, connectivity and hydrological impacts;
- **The nature of the business activity** and whether the activity requires permanent freshwater habitat conversion that will affect downstream and upstream users. This is the case for hydropower dams and storage dams, for example;
- **Species habitat ranges** that include all dimensions of the river and stream biome, including longitudinal, lateral (floodplain and riparian) and vertical (groundwater/vadose zone) impacts;
- **The lifespan of impacts**, including permanent changes to flow, half-life of pollutants in effluents;
- **Climate change interactions** that may increase impact intensity by intensifying the impacts of other impact drivers and increasing the chance of alien species invasion and ecosystem collapse;
- **The natural flow regime,** a critical ecological concept that should be accounted for. The appropriate flows, timing and location of water movement are more important than water quantity;
- **Measures to improve water security,** such as dams and reservoirs, are frequently negative for biodiversity;
- **Maintaining connectivity** is essential for riverine ecosystem integrity and function;
- There may be **substantial time lags** between activities and positive and negative impacts on nature; and
- **Water quality, temperature and dissolved oxygen** are important metrics.

Assessing nature-related risks and opportunities

Table 29 and Table 30 provide examples of nature-related risks and opportunities in this biome.

Table 29: Examples of nature-related risks in the rivers and streams biome

Category	Nature-related risk	Freshwater river and stream examples
Physical risks	Changes to the supply of natural inputs (provisioning services)	Declining fish stocks.
	Changes to protection from natural hazards due to change in hazard mitigation services	Estimated loss of value as a result of degraded biodiversity and ecosystem services such as flood and erosion control.
	Changes in other regulating and maintenance ecosystem services	Degradation of freshwater water quantity and quality.
	Changes in recreational value of area	Loss of aesthetic and recreational value due to disruption of hydrological regime.
	Effects on species, including ones that an organisation depends upon	Introduction and proliferation of invasive and non-native species.

Category	Nature-related risk	Freshwater river and stream examples
Transition risks	Policy and legal: Changes to legislation/regulations	Restrictions on water supply and transfers, trade restrictions on freshwater species (e.g. fish, crustaceans, mussels, plants that are listed on CITES and IUCN Red List).[84]
	Policy and legal: More stringent nature-related reporting obligations	Requirements to report on flow releases (e-flows).[85] Requirements to report on bycatch in fisheries.
	Market: Shifting customer/investor values or preferences	Decline in demand for at-risk species.
	Market: Stakeholder conflicts	Conflicts of water-use rights and conflicts over fisheries permits.
	Market and reputation: Change in brand and value proposition/ changes in sentiment towards the organisation/brand due to impacts on nature	Reduction in revenue due to lower demand for products and services.
	Market: Volatility/changes to costs of materials	Reduction in water availability due to over abstraction of water for processing; collapse of fish stocks (directly through overexploitation or indirectly through degradation of habitat).
Systemic risks	Ecosystem collapse and biodiversity loss	Combined threats of hydrological disruption, climate change and over-exploitation, among other factors, threaten many freshwater biomes.
	Financial contagion	Risk of financial contagion from effect of widespread ecosystem collapse affecting dependencies.

84 CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora; IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2.

85 International Water Management Institute. Global Environmental Flow Information System.

Table 30: Examples of nature-related opportunities in the rivers and streams biome

Category	Nature-related opportunity	Freshwater river and stream examples
Resource efficiency	Diversification of use of natural resources (e.g. use of different plant species).	Diversification of fish stocks and/or aquaculture species towards in-season and/or less threatened.
	Adoption of resource efficiency/ circularity mechanisms that reduce dependencies and impacts on nature.	Mimic natural processes to enhance water availability, quality and reduce flood risk such as engineered wetlands and riparian buffers.
	Transition to processes with reduced negative impacts on nature/ increased positive impacts on nature.	Shift to more selective/less damaging hydropower, mining, industrial and fishing technologies such as fish-friendly turbines, recycling and reusing water etc.
		eDNA, freshwater quantity, discharge and quality loggers.
Markets	Access to new and emerging markets.	Growth in aquaculture market for lower-impact species.
	Access to new assets and locations.	Growth in ecotourism sector for newly established freshwater protected areas.
Capital flow and financing	Access to nature-related green funds, bonds or loans.	Access to sustainable finance via sustainability-linked loans and sustainability-linked bonds such as green bonds, blue bonds and green loans.
Reputational capital	Actions that create positive changes in sentiment towards the organisation/brand due to impacts on environmental assets and ecosystem services that have impacts on society and local economic capabilities.	Actioning and signalling departure from unsustainable freshwater resources usage in supply chain.

Category	Nature-related opportunity	Freshwater river and stream examples
Ecosystem protection, restoration and regeneration	Direct restoration, conservation or protection of ecosystems or habitats.	Watershed management and rehabilitation.
		Conservation of freshwater Key Biodiversity Areas and Protected Areas.
Sustainable use of natural resources	Transition to processes with lower negative impacts on nature/ increased positive impacts on nature.	Establishment of fisheries management practices for sustainable fishing yields.
		Improvements in remote monitoring of freshwater habitat change and fishing activities.

Preparing to respond and report

Responses to manage nature-related issues associated with this biome can include actions to:

- **Avoid impacts on rivers and streams:** This includes avoiding certain species, ecosystems, areas and projects entirely;
- **Minimise/reduce impacts on rivers and streams:** This includes reducing the extent of impacts or reducing investments; reducing impacts on specific biodiversity features; and adopting lower-impact technologies and practices, processes and due diligence to manage impact drivers along the value chain, such as engagement with suppliers;
- **Restore and rehabilitate rivers and streams:** This includes the restoration of affected river and stream ecosystems and catchment management land use; contribution to water and catchment management plans; involvement in cumulative impact assessments; and opportunities to coordinate water use;
- **Contribute to sector and business models to reduce negative impacts and increase positive impacts on rivers and streams,** for example by participating in cumulative impact assessments and strategic planning to coordinate water use in larger basin areas;
- **Decrease demand for water extraction** by increasing the amount of water reuse, for example; and
- Engage stakeholders.

For companies operating within the rivers and streams biome, a number of existing standards and reporting practices are available:

- SBTN Step 1 and Step 2 guidance, and SBTN Water Hub Step 3 guidance, which includes targets for water use and nutrient pollution;
- GRI 303 Water and Effluents;
- SASB Standards;
- Various water-quality guidelines for limits on freshwater pollutants (international and national) (e.g. South African water-quality guidelines for aquatic ecosystems);
- CDP Water;
- SBTi Forest, Land and Agriculture (FLAG) guidance;
- Greenhouse Gas Protocol Land Sectors and Removals Guidance;
- E-flows guidance – This is a guideline to understanding the level of e-flow studies required for businesses to apply based on their activities (e.g. run of river hydropower will require a much lower level

of e-flows assessment than a peaking, cascading hydropower operation would require);

- Connectivity data from free-flowing rivers;
- International Hydropower Association Tool; and
- IFC Good Practice for Hydropower Developments.[86]

Assessment indicators and metrics for the rivers and streams biome

To support the assessment of nature-related issues in this biome, a LEAP assessment team may wish to consider the assessment metrics in Table 31. These are suggested by the TNFD to support assessment only and are not part of the TNFD's core disclosure metrics.

Table 31: Illustrative dependency and impact assessment indicators and metrics for the rivers and streams biome by sector

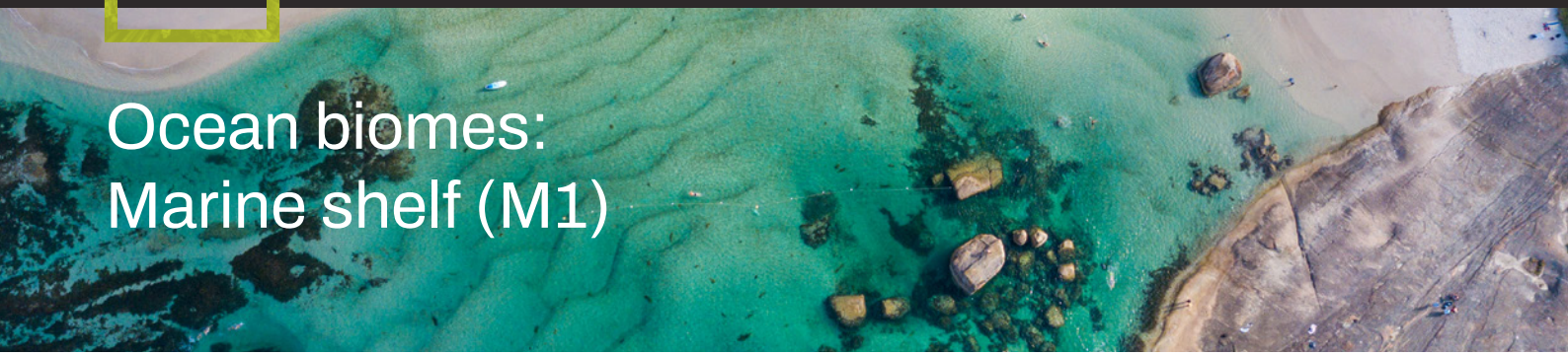
Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
General	Location prioritisation	N/A	Volume of freshwater area impacted by business activities. Percentage overlap of business activities with habitat range of locally or globally important freshwater species (Global IUCN Red List, National IUCN Red List, listed on international conventions such as CITES or CMS).[87]
	Dependencies and impacts: impact drivers	Resource use/ replenishment	Use of CITES-listed wild species.
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Loss of ecosystem quality or condition as a result of business activities (potentially measured by the potentially disappeared fraction of species, changes in ecological community composition, changes in species abundance).
		Species	Contribution to extinction risk (freshwater version of the Species Threat Abatement and Restoration (STAR) in development).

86 Science Based Targets Network (2023) Technical Guidance: Step 3 Freshwater Measure, Set & Disclose; GRI Standards (2018) GRI 303: Water and effluents; SASB Standards; Department of Water Affairs and Forestry (1996) South African Water Quality Guidelines, Volume 7, Aquatic Ecosystems; CDP. Water security; Science Based Targets Initiative (2022) Forest, Land and Agriculture Science Based Target-Setting Guidance; Greenhouse Gas Protocol (2023) Land Sector and Removals Guidance Draft for Pilot Testing and Review, Parts 1 and 2; Brown, C. et al. (2018) Environmental flows for hydropower projects : guidance for the private sector in emerging markets (English). Washington, D.C.: World Bank Group; Grill G. et al. (2019) Mapping the world's free-flowing rivers, Nature 569, 215–221; International Hydropower Association. Tools; IFC (2018) Good Practice Handbook: Environmental Flows for Hydropower Projects

87 IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2; ZSL and IUCN National Red List Working Group (2022) National Red List Database. Version 2022-1; CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora; CMS. Convention on the Conservation of Migratory Species of Wild Animals.

Industry/ sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
Hydropower and water storage	Dependencies and impacts: impact drivers	Resource use/ replenishment	Implementation of e-flow flow releases (m^3/s) for monthly/ daily/flow releases depending on the scale of the business activities.[88]
	Dependencies and impacts: impact drivers	Land/freshwater/ ocean use change	Number of barriers to freshwater biodiversity movement.
	Dependencies and impacts: State of nature	Species	Migratory freshwater species affected.
Forestry, paper and pulp; mining and metals; and agriculture and food sectors	Dependencies and impacts: impact drivers	Pollutants/ pollution removal	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood. Assessment of chronic and acute effect levels of pollutants on freshwater species.
		Ecosystem condition and extent	Eutrophication.
	Dependencies and impacts: State of nature	Species	Assessment of chronic and acute effect levels of pollutants on freshwater species.
Fishing and aquaculture sector	Location prioritisation	N/A	Overlap of fishing locations with freshwater protected areas and habitat distributions of endangered species. Overlap of fishing locations with overfished stocks.
	Dependencies and impacts: impact drivers	Resource use/ replenishment	Harvest volumes by species, method of production (i.e. wild caught vs. farmed, and gear type/farm type) and location (e.g. ocean at a minimum, spatially explicit standardised fishing effort as gold standard).

88 International Water Management Institute. Global Environmental Flow Information System.



Ocean biomes: Marine shelf (M1)

Introduction

The marine shelf biome (M1) is distributed globally between the shoreline and deep-sea floor. It includes ecosystems with habitats made by living organisms (such as seagrass meadows, kelp forests, oyster beds and coral reefs) or based on the underlying rock or sediments (including rocky reefs, sandy bottoms and muddy bottoms). The availability of light and nutrients are key structuring factors in the marine shelf biome, which influence the ecosystem's structure, function and the biodiversity present.

Functional groups in the marine shelf biome include:

- **Seagrass meadows (M1.1)** – Shallow marine shelf ecosystems along sheltered coastlines dominated by sea grasses;
- **Kelp forests (M1.2)** – Marine shelf ecosystems with large (up to 30m long) seaweeds known as kelp;
- **Photic coral reefs (M1.3)** – Marine shelf ecosystems dominated by coral reefs;
- **Shellfish beds and reefs (M1.4)** – Marine shelf ecosystems dominated by oyster and mussel (or other mollusc) beds;
- **Photo-limited marine animal forests (M1.5)** – Marine shelf ecosystems dominated by marine animals adapted to low light levels, including sponges, tunicates, sea squirts and deep-sea corals;
- **Subtidal rocky reefs (M1.6)** – Subtidal marine shelf ecosystems without kelp;
- **Subtidal sand beds (M1.7)** – Subtidal sand beds shaped by strong currents and wave actions;
- **Subtidal mud plains (M1.8)** – Subtidal muddy marine shelf ecosystems;
- **Upwelling zones (M1.9)** – Transition zones between open ocean and marine shelf ecosystems with cold, nutrient-rich water; and
- **Rhodolith/maërl beds (M1.10)** – Marine shelf environments dominated by red algae that resemble corals.

Concepts and definitions

Subtidal: The area below low tide that is always underwater, typically referring to depths <100 m.

Photo-limited: Used to describe organisms/ ecosystems that are limited by light availability.

Upwelling: A process in which deep, cold water rises toward the surface.

Biogenic: Produced by living organisms.

Minerogenic: Formed by geological processes.

Scoping a LEAP assessment

In considering the activities, assets, sectors and value chains in scope, your organisation should consider the diverse ways in which it may interact with this biome through its value chain. It should also consider:

- Are the company's operations or value chain associated with coastal or at-sea infrastructure development?
- Is the company producing or sourcing seafood or other wildlife products that are directly harvested from marine biomes?
- Does the company know which oceans or specific fisheries its marine products are sourced from throughout its supply chain?
- Are the company's operations or value chain associated with high marine-pollution risk?
- Are the company's operations or value chain associated with coastal or at-sea infrastructure development?

Locating the organisation's interface with nature

The mobility of marine species and marine currents means that interfaces with the marine shelf can be hard to specify precisely.

Organisations should consider whether its interfaces with the biome are likely to be localised or diffuse, at what depth they occur, and whether they involve conversion and occupation of parts of the marine shelf (e.g. for infrastructure) or use of resources within the biome (e.g. fishing).

Organisations should at a minimum look to identify the jurisdiction in which it is operating (e.g. which country's Exclusive Economic Zone (EEZ) or Areas Beyond National Jurisdiction (ABNJ)). Where possible, organisations should consider the depth at which interfaces with nature occur, as this will influence which sub-biomes and species will be implemented. Where pollutants or water are discharged or spilled by an organisation into this biome, it should consider modelling the potential dispersion effects.

Further examples of tools and methods are provided in Table 32.

Table 32: Tools and methods for locating interfaces with the marine shelf biome

Degree of connection and control	Tools and methodologies for Locate
Companies with localised interfaces under direct control	• Polygons and GPS coordinates can be identified for fixed facilities, such as wind farms and fisheries, and activities in a specific area, such as fishing. • Ocean+ can be used to source data on coral reefs, mangroves, seagrasses and critical habitats. • Data on protected areas can be found in sources such as the World Database on Protected Areas. • The IUCN Red List species distributions or Aquamaps can be used to source data on distributions of threatened marine species and on ecological integrity, such as the richness of species, status of fish stocks and pollution levels. • Other tools include Hub Ocean.[89] It is important to recognise the limitations and uncertainties associated with this methodology: data collection, harmonisation and interpretation and collaboration between different stakeholders help ensure that data is used transparently and accountably.
Diffused and under direct control	This may require an understanding of how business activities interface with water catchments that eventually run off into marine shelf areas of high or rapidly declining ecosystem integrity or high biodiversity importance. These interfaces could be located using data on river basins and terrestrial run-off into the ocean to locate sites at high risk of polluting the marine shelf.

89 Ocean+; Protected Planet. World Database on Protected Areas; IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2; Kaschner, K. et al. (2019) AquaMaps: Predicted range maps for aquatic species; Hub Ocean.

Degree of connection and control	Tools and methodologies for Locate
Indirect interactions via investments or value chains	• **Secondary data** from suppliers on the locations of activities. • **Industry averages** (from Regional Fishery Management Organisation databases, for example), or **third-party satellite imagery** such as Global Fishing Watch could be used to identify potential high-risk areas for further assessment.[90] • **Traceability systems** can help track fish from catch to consumption and provide valuable data on the origin, movement and destination of fish products. Analysis of this data may make it possible to identify potential high-risk areas where illegal or unsustainable fishing may be occurring. • **Remote sensing technologies** such as acoustic sensors, drones and cameras can provide real-time data on fish stocks, vessel movement and other indicators of fishing activity. This information can be used to identify potential high-risk areas and track changes in fishing activity over time. • **Risk mapping** involves identifying and analysing the various risks associated with a particular fishery or region and mapping these risks spatially. This approach can help identify areas that are at higher risk for a particular type of risk, such as overfishing or illegal fishing. • **Stakeholder engagement** such as with fishers, local communities and civil society organisations can help identify potential high-risk areas and understand the perspectives of those who are most affected by the fishery. This approach can also help build trust and cooperation among stakeholders.

90 Global Fishing Watch.

Evaluating nature-related dependencies and impacts

Impact drivers

The primary sectors with impact drivers in the marine shelf biome are:

- **Agriculture and food; consumer goods:** Leakage of plastic packaging pollution into the ocean has been identified as a significant issue;
- **Fishing and aquaculture:** Most likely to be associated with localised and direct interfaces, with direct exploitation being a priority impact driver (as well as invasive alien species through escapes from fishfarms also spreading pathogens and introducing diseases to wild populations; pollution and ocean use change);
- **Energy (oil and gas, and renewable energy)**: Most likely to be associated with localised and direct interfaces that cause ocean use change (through infrastructure, for example) and pollution; and
- **Forestry, paper and pulp; mining and metals; and agriculture and food:** Likely to have diffuse interfaces, with primary impact drivers for the marine shelf being pollution, climate change and water extraction.

Table 33 sets out impact drivers associated with common business activities in this biome.

Table 33: Drivers of nature change and impact drivers associated with common business activities in the marine shelf biome

Business activity and/or process	Driver of nature change	Impact driver
Aquaculture development, commercial and industrial development, energy infrastructure, coastal development for tourism These reduce the habitat area and can contribute to fragmentation.	Land/freshwater/ocean use change	Ocean ecosystem use
Aquaculture management Accidental release of farmed fish contributes to invasive alien species; farming can also spread pathogens and introduce diseases to the wild population.	Invasive alien species introduction/removal	Introduction of invasive alien species
Collision mortality caused by offshore wind turbines	Other	Other
Commercial shipping and other industrial activities These sectors often make use of fossil fuels, leading to GHG emissions.	Climate change	GHG emissions

Business activity and/or process	Driver of nature change	Impact driver
Fishing and harvesting of other natural resources for trade or use in industrial activities This exploitation, if unsustainable, can lead to declines in species populations.	Resource use/ replenishment	Other resource use
Industry and agriculture Industrial and agricultural run-off can contribute to eutrophication and ecotoxicity. Further pollution includes macro and microplastics from garbage, and solid waste.	Pollution/pollution removal	Water pollutants
Mining at sea Mining at sea can lead to habitat degradation due to the change in the seabed and water. It can also affect the functioning of the ecosystem and lead to the entrance of exotic weeds and vertebrate pests.	Land/freshwater/ocean use change Invasive alien species introduction/removal	Ocean ecosystem use Introduction of invasive alien species
Nuclear power plants and industry using seawater as a coolant Thermal pollution from plumes discharged into the sea by power plants can affect the local ecosystem.	Pollution/pollution removal	Water pollutants
Salt manufacturing, mineral industries Use of water by these sectors can affect the availability and quality of water in the area .	Resource use/ replenishment	Water use
Shipping, aquaculture, aquariums Ballast water and biofouling of ship hulls, and the overspill of non-native species carried for aquaculture, aquarium trade can all lead to invasive alien species.	Invasive alien species introduction/removal	Introduction of alien invasive species
Waste management Weak or non-existent waste management systems can lead to plastics leaking into rivers and oceans.	Pollution/pollution removal	Water pollutants

Ecosystem services

Table 34 sets out the ecosystem services that organisations and others may depend on provided by this biome. This can assist LEAP project teams to identify the ecosystem services most relevant to their assessment.

Table 34: Principal ecosystem services present in the marine shelf biome

Principal ecosystem services		Example
Provisioning services	Biomass provisioning	Wild and farmed fish, shellfish and seaweed.
	Other provisioning services	Water surface for navigation.
Cultural services	Recreation-related services	Recreational fishing, diving, whale watching .
Regulating and maintenance services	Flood mitigation	Reefs or sandbanks protecting coasts.
	Global climate regulation	Carbon sequestration and mitigation of GHG fluxes; heat sink.
	Nursery population and habitat maintenance	Nursery provision for marine species.
	Water purification	Removal of nutrients and other pollutants.

Changes to the state of nature

When considering changes to the state of nature resulting from your organisation's impact drivers and external factors, and determining appropriate responses, your organisation should examine:

- **Spatial location:** This will influence the ecosystems and species that are likely to be affected, as well as potential data availability, since this is not uniform across countries and biomes;
- **Overlap with/proximity to national/internationally designated areas and habitat types;**
- **Three-dimensional overlap with species habitat ranges**, including the consideration of the depth at which impacts will occur, as well as their spatial location; and
- **The lifespan of impacts**, including, for example, whether it is one-off damage or a permanent occupation, and the half-life of pollutants.

Data issues

The TNFD recognises that organisations will face data limitations when evaluating dependencies and impacts on the marine shelf biome. In particular:

- Databases for global trade and environmentally extended input-output analysis do not typically include ocean impacts; and
- There are challenges and uncertainties associated with global fisheries trade data with poor reporting and species misidentification exposing companies to significant risks. These include the potential of being associated with Illegal, Unreported and Unregulated (IUU) fishing, human rights abuses and bycatch of charismatic and critically endangered species.

Assessing nature-related risks and opportunities

Table 35 and Table 36 provide examples of nature-related risks and opportunities in this biome.

Table 35: Examples of nature-related risks in the marine shelf biome

Category	Nature-related risk	Marine shelf examples
Physical risks	Changes to the supply of natural inputs (provisioning services).	Declining fish stocks.
		Degradation of marine water supply (e.g. due to pollutants).
		Estimated loss of value as a result of degraded biodiversity and ecosystem services attributed to business activities .
	Changes to protection from natural hazards due to change in hazard mitigation services.	Extreme weather events.
		Floods.

Category	Nature-related risk	Marine shelf examples
	Changes in other regulating and maintenance ecosystem services.	Carbon sequestration.
		Water cycling.
		Nutrient cycling.
	Changes in recreational value of area.	Declining populations of marine megafauna of tourism value (e.g. whales, turtles, sharks and rays).
		Degraded coral reefs.
		Increased plastic pollution that diminishes aesthetic value.
		Estimated loss of recreational value as a result of degraded biodiversity and ecosystem services attributed to business activities.
	Changes to species the organisation is dependent on.	Species diversity measures, controlling for sampling effort and using standardised methods.
		Relative abundance, controlling for sampling effort and using standardised methods.
		Changes in food web interactions between species.
Transition risks	Changes to legislation/regulations.	Trade restrictions on marine species (e.g. sharks and coral under CITES).
		Fishing/project permits and allocations.
		Changes to coastal zoning (e.g. establishment of marine protected areas [MPAs], no-take zones, recreational parks).
		Tourism restrictions in coastal areas (e.g. payment for marine recreational areas, closure of areas for conservation).

Category	Nature-related risk	Marine shelf examples
	More stringent nature-related reporting obligations.	Requirements to report on bycatch in fisheries.
	Shifting customer/investor values or preferences.	Declining demand for animal products (e.g. seafood).
		Increasing desire for sustainably sourced seafood (e.g. species that are proven to be not endangered).
		Plastic free products, or products made from recycled components (e.g. marine plastics).
	Stakeholder conflicts.	Social impacts on coastal Indigenous People and Local Communities who are dependent on and have rights relating to the use of marine shelf resources.
		Conflict of fishing rights in contested waters.
		Small-scale fishers that are engaged in Illegal, Unregulated or Unreported (IUU) fishing.
		Multiple users with differing interests (e.g. fishers vs. divers/recreational users).
Transition risks	Decline in brand and value proposition/ changes in sentiment towards the organisation/brand due to impacts on nature.	Impact on coastal Indigenous Peoples and Local Communities.
		Oil spills.
		Shipping container groundings.
		Plastic pollution.
		Mortality of endangered or charismatic species as a result of business activities.
		Destruction of important habitats (e.g. coral reefs, mangroves).

Category	Nature-related risk	Marine shelf examples
	Volatility/changes to costs of materials.	Collapse of fish stocks (directly through overexploitation or indirectly through degradation of habitat).
	Requirements to transition to more efficient, resilient and less environmentally damaging technologies.	Shift to more selective/less damaging fishing gears.
		Establishment of fisheries management practices for sustainable fishing yields.
		Removal or reduction of subsidies for fishing vessels.
	New monitoring technologies used by regulators and other stakeholder.	Improvements in remote (e.g. satellite and video) monitoring of fishing activities.
		Improvements in fishing vessel energy efficiency and emissions.

Table 36: Examples of nature-related opportunities in the marine shelf biome

Category	Nature-related opportunity	Marine shelf examples
Systemic opportunities	Ecological.	Supporting coastal or marine conservation efforts to reduce risk of ecosystem collapse.
Resource efficiency	Transition to processes with increased positive impacts on nature.	Transition to more selective/less damaging fishing practices.
		Sustainably managed fisheries.
		Improve feed-conversion ratio in aquaculture.
		Transition to nature-friendly marine infrastructure.
	Transition to efficient and circular production systems and value chains.	Transition to circularity to reduce waste/pollution entering the marine environment.
		Improvements in fishing vessel energy efficiency and emissions due to technological innovations.
		Improvements in remote (e.g. satellite and video) monitoring of fishing activities.
	Adoption of resource efficiency/circularity mechanisms that reduce dependencies and impacts on nature.	Adoption of aquaculture practices that are less reliant on feed sourced from wild fish populations.
	Diversification of natural usage (e.g. use of different plant species).	Diversification of fish stocks and/or aquaculture species towards in-season and/or lower-impact species (e.g. anchovies, muscles, low trophic aquaculture).
	Adoption of nature-based solutions within service and product lines.	Nature-inspired surfaces on built marine infrastructure.
		Wind-powered shipping.

Category	Nature-related opportunity	Marine shelf examples
Products/ services	New business model/activities with positive impacts on nature/reduced negative impacts on nature.	Low trophic aquaculture.
		Certified sustainable or bycatch-neutral fisheries (e.g. marine stewardship council).
	Development of nature-positive financial solutions.	Loan covenants for which interest rate is linked to marine sustainability performance (e.g. bycatch rates).
		Sustainability criteria in stock exchanges.
Markets	Access to new and emerging markets.	Increasing demand for sustainable seafood.
	Access to new assets and locations.	Growth in aquaculture market for lower impact species.
		Growth in ecotourism sector for newly established marine protected areas.
Capital flow and financing	Access to nature-related green funds, bonds or loans.	Sustainable stock exchange initiative.[91]
		Blue finance.[92]
	Use of financial incentives for suppliers to improve nature and ecosystem management.	Performance-based taxes and incentives for fisher sustainability.
	Use of public sector incentives (e.g. biodiversity credits, payments for ecosystem services).	Potential for emerging marine payment for ecosystem services structures in future (e.g. for access to marine protected areas).
		Removal or reduction of subsidies for fishing vessels.

91 Sustainable stock exchange initiative.

92 IFC (2022) Guidelines for Blue Finance.

Category	Nature-related opportunity	Marine shelf examples
	Collaborative engagement with stakeholders at local, national and international levels.	Cross-sectoral engagement with small-scale fishers and commercial fishers to establish sustainable fisheries management practices.
		Regional collaboration to collectively manage the sustainable catch of migratory species spanning the waters of multiple nations.
	Actions that create positive changes in sentiment towards the organisation/brand.	Supporting coastal or marine conservation efforts.
		Actioning and signalling departure from unsustainable marine resources usage in supply chain.
		Actioning and signalling of remediation or restoration of degraded marine shelf habitat.
Ecosystem protection, restoration and regeneration	Supporting conservation or restoration projects.	Financially supporting nature-based solutions projects that target the restoration or sustainable use of coastal marine habitats (e.g. mangroves, seagrass beds or coral reefs).
	Collaboration with external stakeholders.	Supporting or facilitating workshops or engagement initiatives with local community stakeholders (e.g. small scale fishers) to improve livelihoods while carrying out conservation activities.
	Communicating with the public on the importance of ecosystem protection.	Supporting or facilitating educational campaigns to raise awareness on protection of coastal landscapes (e.g. non-destructive coral reef tourism, sustainable seafood consumption practices).

Category	Nature-related opportunity	Marine shelf examples
Sustainable use of natural resources	Shifting to lower impact commodities in supply chain.	Sourcing seafood commodities from non-threatened or overfished populations.
		Shifting supply chain away from farmed marine species that rely on feed derived from wild fish populations.
	Supporting the education of stakeholders on sustainable resource consumption.	Financing or facilitating campaigns to educate consumers on issues relating to overfishing.
		Financing or facilitating workshops with local communities (e.g. small scale fishers) on sustainable fishing practices.
	Adjusting business activities and in-house operations to promote sustainable resource usage.	Educating staff on negative impacts associated with daily activities, such as seafood consumption and its relation to overfishing, or tourism and its degradation of coastal marine habitats.
		Establishment of fisheries management practices for sustainable fishing yields.
		Sustainably managed fisheries.

Preparing to respond and report

Organisations way wish to review these biome-specific standards in determining their responses:

- Marine Stewardship Council fisheries standards;
- International Seafood Sustainability Foundation conservation measures;
- Seagrass ecosystem restoration guidelines;
- High quality blue carbon principles;
- Methodology for tidal wetland and seagrass restoration;
- Coral reef restoration guidelines;
- SBTN Technical Guidance on Step 3 from the SBTN Ocean Hub (forthcoming);
- UNEP FI Sustainable Blue Economy Finance Principles;
- Aquaculture Stewardship Council Standards;
- Global Sustainable Tourism Council Criteria; and
- Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication.[93]

Assessment indicators and metrics for the marine shelf biome

To support the assessment of nature-related issues in this biome, a LEAP assessment team may wish to consider the following assessment metrics in Table 36 and below. These are suggested by the TNFD to support assessment only and are not part of the TNFD's recommended core sector metrics.

Further metrics are available from the United Nations Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction.[94]

Table 38 provides a set of illustrative response indicators and metrics for this biome.

93 Marine Stewardship Council. The MSC Fisheries Standard; International Seafood Sustainability Foundation (2023) Conservation Measures; United Nations Environment Programme (2020) Guidelines on Seagrass Ecosystem Restoration for the Western Indian Ocean Region; Friends of Ocean Action et al. (2022) High-quality blue carbon principles and guidance; Restore America's Estuaries and Silvestrum (2021) VM0033 Methodology for Tidal Wetland and Seagrass Restoration, v2.0, Verra; International Coral Reef Initiative. Coral Reef Restoration Guidelines; Science Based Targets Network. Ocean hub; United Nations Environment Programme Finance Initiative (2018) The Sustainable Blue Economy Finance Principles; Aquaculture Stewardship Council. ASC Standards; Global Sustainable Tourism Council. GSTC Industry Criteria and GSTC Destination Criteria; Food and Agriculture Organization of the United Nations (2015) Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication.

94 United Nations (2017) Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction.

Table 37: Illustrative dependency and impact assessment indicators and metrics for the marine shelf biome by sector

Industry/sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
General	Location prioritisation	N/A	Volume of marine area impacted by business activities. Percentage overlap of business activities with habitat range of locally or globally important marine species (Global IUCN Red List, National IUCN Red List, listed on international conventions such as CITES or CMS).[95] Magnitude/proportion of business activities in areas beyond national jurisdictions. Percentage of value chain interacting with this biome for which localised data has been used in the LEAP process.
	Dependencies and impacts: Impact drivers	Resource use/ replenishment	Total marine water consumption and withdrawal. Use of CITES-listed wild species.[96] Species used in feed raw material on the IUCN Red List Index.[97] Estimated mortality of marine species of local or international conservation value as a result of business activities (including intentional and unintentional, direct and indirect).

95 IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2; ZSL and IUCN National Red List Working Group (2022) National Red List Database. Version 2022-1; CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora; CMS. Convention on the Conservation of Migratory Species of Wild Animals.

96 CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora.

97 IUCN (2023) The IUCN Red List of Threatened Species. Version 2022-2.

Industry/sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
General	Dependencies and impacts: State of nature	Ecosystem condition and extent	Loss of ecosystem quality or condition as a result of business activities (potentially measured by the disappearance of a fraction of a species, changes in ecological community composition and changes in species abundance). Species diversity measures, controlling for sampling effort and using standardised methods. Benthic impact.
		Species	Contribution to extinction risk (marine version of the Species Threat Abatement and Restoration (STAR) metric forthcoming).
Energy (oil and gas, and renewable energy) sector	Location prioritisation	N/A	Overlap of operating locations with marine protected areas and habitat distributions of endangered species.
	Dependencies and impacts: Impact drivers	Pollution/pollutants removed	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood.
	Dependencies and impacts: State of nature	Ecosystem condition and extent	Extent and condition metrics for infrastructure.
Forestry, paper and pulp; mining and metals; and food sectors	Dependencies and impacts: Impact drivers	Pollution/pollutants removed	Modelled impacts of potential pollution events in terms of magnitude, dispersal and likelihood.
		Resource use/ replenishment	Volume of seawater extraction for industrial purposes.

Industry/sector	Metrics category	Sub-category	Additional indicators and metrics for assessment of dependencies and impacts on nature for this biome
Fishing and aquaculture sector	Location prioritisation	N/A	Overlap of fishing locations with marine protected areas and habitat distributions of endangered species. Overlap of fishing locations with overfished stocks.
	Dependencies and impacts: Ecosystem services	Provisioning services	Volume of seafood produced by species, by method of production (wild caught versus farmed and gear type/farm type) and by location. A spatially explicit standardised fishing effort is the gold standard.
	Dependencies and impacts: State of nature	Species	Status of fish stocks (relative to MSY).

Table 38: Illustrative response indicators and metrics for the marine shelf biome

Category	Sub-category	Metric
Dependency, impact, risk and opportunity management	Value chain	Percentage of supply volume sourced from sustainably certified suppliers. Percentage of supply volume sourced using lower-impact processes and technologies. Percentage of supply volume sourced from suppliers implementing no net loss commitments.
	Changes to nature (dependency and impact): mitigation hierarchy steps	Marine habitat loss averted due to avoidance and minimisation measures. Animal biomass loss averted due to avoidance and minimisation measures. Volume of macroplastic diverted from nature or landfill. Volume of primary microplastic diverted from nature or landfill. Nutrient pollution mitigated. Volume of contaminated wastewater diverted from waterways.
	Voluntary conservation, restoration and regeneration	Area of critical habitat for value chain-affected biodiversity protected or restored. Area of coral reefs, mangroves, seagrass, kelp forest (delineated by habitat type) protected or restored. Investment in (e.g. $ or % revenue), extent of (km^2), or estimated biodiversity benefits (e.g. gains in animal biomass) of marine shelf protection and restoration projects. Investment in (e.g. $ or % revenue), extent of (km^2), or estimated biodiversity benefits (e.g. gains in animal biomass) of biodiversity offsets located in marine shelf. Volume of animal biomass preserved or restored.

Taskforce on Nature-related Financial Disclosures

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