THE BIODIVERSITY FOOTPRINT COMPANY

Unpacking Corporate Natural Capital Accounting

(BS 8632, BD Protocol and UN SEEA)

Comparative analysis of case studies

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Comparative analysis of case studies

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Highlights

- A working definition of Corporate Natural Capital Accounting (CNCA) has recently been proposed: *'the systematic process of identifying, measuring, recording, summarising and reporting the periodic and accumulated net changes to (a) the biophysical state of natural capital assets and (b) the associated values of natural capital to business and wider society'*; alongside several accounting principles and building blocks. Notably, it puts the going concern / viability of natural capital assets at the core of the corporate accounting process.
- CNCA draws from three main methods: The Biological Diversity Protocol (BD Protocol), the British Standard 8632:2021 Natural Capital Accounting for Organisations (BS 8632), and the UN System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA).
- This paper presents a comparative analysis of publicly available case studies, based on these CNCA-related methods and focused on ecosystem accounting. It aims is to showcase the key synergies and differences, highlight key limitations and make recommendations towards greater standardisation.
- 8 criteria from the working CNCA definition are used to that end: (1) ecosystem asset register, (2) ecosystem extent measurement, (3) ecosystem condition / integrity measurement, (4) ecological equivalency principle, (5) recording rules based on double-entry bookkeeping, (6) ecosystem-specific biophysical statements of position and performance, (7) valuation perspective and methodology and (8) organisational and value chain boundaries.
- Neither case study nor CNCA-related method cover all the dimensions of the working CNCA definition. While this comparative analysis shows broad alignment between the case studies using SEEA EA and BS8632, significant differences were found with the one using the BD Protocol. The comparative analysis shows how different purposes condition the rules, principles and measurement / valuation techniques underlying each case study and associated CNCA-related method. Differences in application of Criteria 1, 4 and 5 appear to be the primary causes of divergences.
- To conclude, recommendations to bridge the gaps between CNCA-related methods are organised into two broad themes: (a) the need for complete ecosystem state accounts in the context of the Global Biodiversity Framework (GBF) and (b) the need for segregated land use accounts with clear distinction between financial and non-financial values.

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1.1 Context, aims and scope of analysis

The growing calls to action on biodiversity and nature have given rise to a wave of "solutions" that all claim to address the issues at stake, notably to respond to the Kunming-Montreal Global Biodiversity Framework (GBF) (Box 1). In recognition of the limitations and challenges that flexible measurement, valuation and accounting approaches present to our transition towards nature-positive economies and companies (e.g., lack of data input and output comparability), several papers have called for greater standardisation, notably in the biodiversity space (Houdet *et al.*, 2012[1]; Houdet 2024[2]; objectives of the ALIGN project; UNEP – WCMC et al., 2022)[3].

In the face of an ever-changing methodological landscape and confusing marketing and communication from various stakeholders, a 2022 Natural Capital Coalition[4] report proposed a working definition of Corporate Natural Capital Accounting (CNCA), highlighting its core components and the various aspects warranting further discussions and eventual standardisations. This definition proposed to put the going concern / viability of natural capital assets at the core of the corporate accounting process. It argued that CNCA should be defined as *'the systematic process of identifying, measuring, recording, summarising and reporting the periodic and accumulated net changes to (a) the biophysical state of natural capital assets and (b) the associated values of natural capital to business and wider society'.* The definition further requires the following:

- *'An asset inventory recognising the biophysical properties and dynamics of each asset category,*
- *Measurement techniques that use spatially explicit data and apply the principle of ecological equivalency (like-for-like),*
- *Recording rules based on double-entry bookkeeping from financial accounting,*
- *Asset-specific biophysical statements of performance and position,*
- *A defined scope according to organisational and value chain boundaries'.*

[1] Houdet, J., Trommetter, M. and Weber, J. (2012). Understanding changes in business strategies regarding biodiversity and ecosystem services. Ecol. Econ. 73, 37–46.
[2] Houdet, J. (2024). Advances in corporate natural capital accounting. Chapter taken from: Atkins, J. (ed.), Protecting natural capital and biodiversity in the agri-food sector, pp. 135–150, Burleigh Dodds Science Publishing, Cambridge, UK, 2024, (ISBN: 978 1 80146 351 5;
[3] UNEP-WCMC, Capitals Coalition, Arcadis, ICF, WCMC Europe (2022) Recommendations for a standard on corporate biodiversity measurement and valuation, Aligning accounting approaches for nature.
[4] Finisdore, J., Houdet, J., Obst, C., Dickie, I., 2022. Time to Take Stock version 2.1. Capitals Coalition. URL: https://capitalscoalition.org/wp-content/uploads/2022/05/Time-to-Take-Stock-2.1.pdf

This working definition consolidated core components of existing methods which were developed (notably) for the purpose of generating greater comparability of information for end-users (i.e. as opposed to *ad hoc* assessments, accounts track impacts and performance over time), namely (listed in alphabetical order):

- **The Biological Diversity Protocol (BD Protocol)[5],**
- **The British Standard 8632:2021 Natural Capital Accounting for Organisations (BS 8632)[6], and**
- **The UN System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA)[7].**

As explained in a recent Global Accounting Alliance report[8], these methods are being applied by various companies, each at different stages of the CNCA journey.

Building on previous CNCA work, this paper compares publicly available case studies, which made use of these three methodologies and focused on ecosystem accounts. This aim is to showcase the key synergies and differences, highlighting key limitations and making recommendations towards greater standardisation. These case studies include:

- **Mixed BS8632 / SEEA EA compilation of examples from CSIRO's "The Natural Capital Handbook" report[9], thereafter named the "CSIRO" case study;**
- **SEEA EA case studies: BHP Billiton Beenup Mineral Sands closure site in southern Western Australia[10] ("BHP") and Forico's 2020 Natural Capital Report[11] ("Forico");**
- **BD Protocol case study: Sibanye-Stillwater's operations in South Africa and the United States of America[12] ("Sibanye-Stillwater").***

**NB: To the best of our knowledge, these case studies are the only complete CNCA examples made available to the public.*

[5] Endangered Wildlife Trust (2021). Biological diversity protocol (BD protocol). National Biodiversity and Business Network of South Africa. Available at: https://nbbnbdp.org/biodiversity-protocol/.
[6] BS 8632:2021 Natural Capital Accounting for Organizations. Specification. URL: https://knowledge.bsigroup.com/products/natural-capital-accounting-for-organizations-specification?version=standard
[7] UN (2021). System of Environmental-Economic Accounting— Ecosystem Accounting (SEEA EA). New York, White cover publication. Available at: https://seea.un.org/ecosystem-accounting.
[8] Finisdore, J., Dickie, I., Obst, C., Houdet, J., Couchman, A., NcLeod, R., Dayeh, A., 2024. Corporate natural capital accounting exploratory workshops. For the Global Accounting Alliance. ERM, Eftec, IDEEA Group and The biodiveristy Footprint Company.
[9] Smith, GS, Ascui, F, O'Grady, A, Pinkard, E (2023). The Natural Capital Handbook: A practical guide to corporate natural capital accounting, assessment, risk assessment and reporting. CSIRO.
[10] Meney, K., Pantelic, L., Cooper, T and Pittard, M. (2023). Natural Capital Accounting for The Mining Sector: Beenup Site Pilot Case Study. Prepared by Syrinx Environmental PL for BHP, Jan 2023. ISBN: 978-0-6456956-0-1
[11] Forico future fibre. Natural Capital Report 2020 of the Tasmanian Forest Trust for the year ended 30 June 2020.
[12] Houdet, J., Teren, G., Nelson, B., 2023. Sibanye-Stillwater's consolidated biodiversity footprint. Update assessment as per the Biological Diversity protocol – Group level consolidated report. National Biodiversity & Business Network – Endangered Wildlife Trust / Sibanye-Stillwater.

1.2 Comparative criteria

This section presents the comparative criteria for this case study analysis.

The first building block of CNCA is the development of an asset inventory recognising the biophysical properties and dynamics of each asset category. The focus of the case studies is on corporate ecosystem accounts, a key component of biodiversity. CNCA would involve clearly defining biodiversity and its components (i.e. ecosystems, species, genetic diversity) and organising them according to a relevant hierarchy and typology. While all three CNCA methodologies share the same definition of biological diversity[13], BS8632 remains unclear on the key building blocks of biodiversity. Both the BD Protocol and SEEA EA focus heavily on ecosystem accounts and largely ignore genetic diversity at this stage. While the SEEA EA community is working on species accounts, the BD Protocol has provided guidance on accounting for material species with a few examples publicly available[14].

Criterion 1: ecosystem asset register /inventory.

The second building block of CNCA requires measurement techniques that use spatially explicit data and apply the principle of ecological equivalency (like-for-like). From an ecosystem perspective, CNCA would involve:

Criterion 2: ecosystem extent measurement,
Criterion 3: ecosystem condition / integrity measurement, and
Criterion 4: the ecological equivalency principle.

How do the case studies deal with criteria 2, 3 and 4?

The third building block concerns the underlying accounting rules of CNCA to account for the periodic and accumulated net changes to the biophysical state of natural capital assets. From an ecosystem perspective, CNCA would involve:

Criterion 5: Recording rules for changes in the state of ecosystems based on double-entry bookkeeping from financial accounting,
Criterion 6: Ecosystem-specific biophysical statements of performance and position.

Do the case studies have the same accounting rules? Do their statements of position and performance show similar information?

The fourth building block relates to the values of natural capital to

[13] Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. URL: https://www.cbd.int/convention/articles?a=cbd-02

[14] E.g., Houdet *et al.*, 2021. Eskom's Biodiversity Footprint - BD Protocol pilot study; URL: https://www.researchgate.net/publication/350740781_Eskom's_Biodiversity_Footprint_-_BD_Protocol_pilot_study

business and wider society.

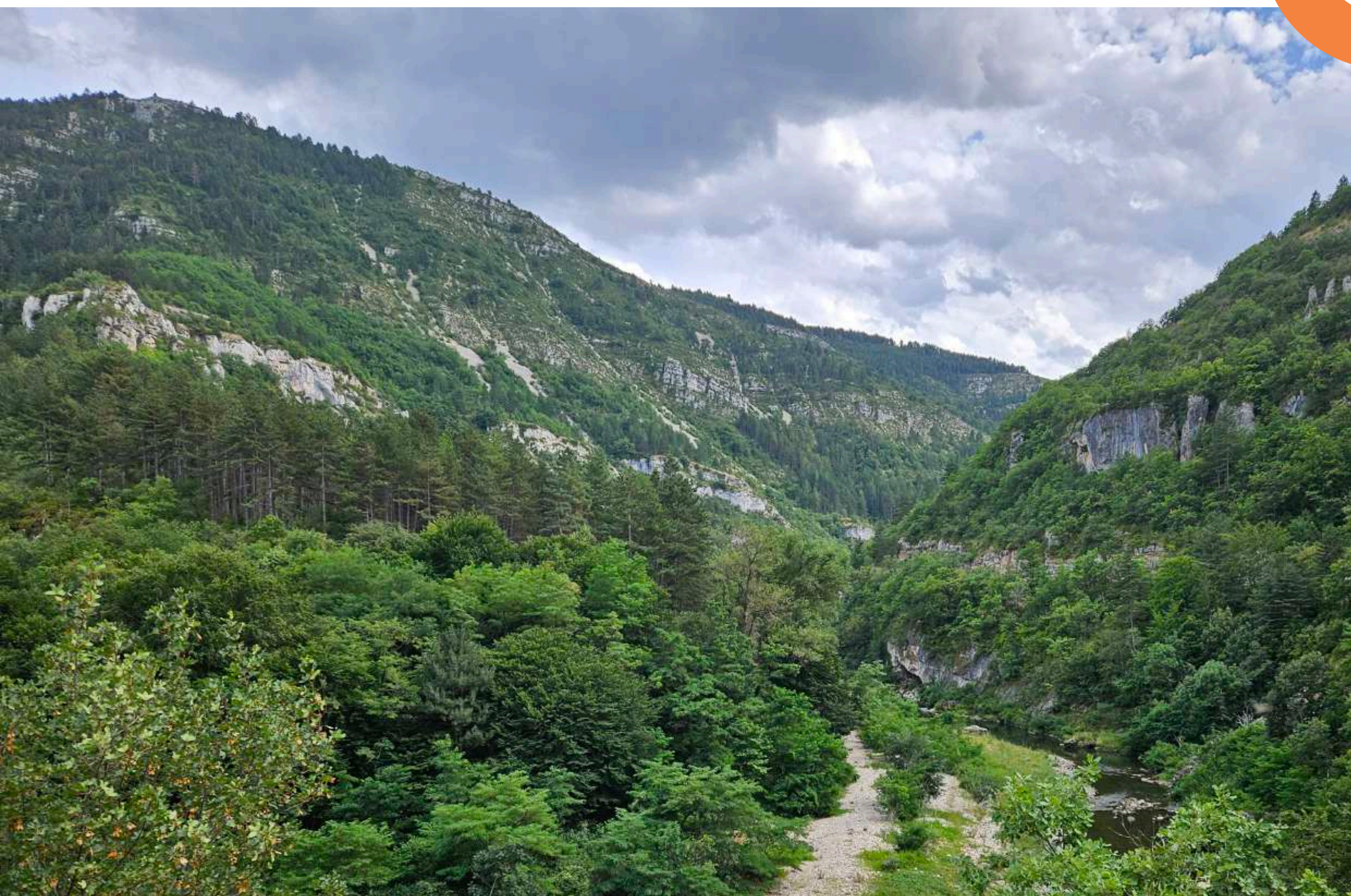
Criterion 7: Valuation perspective and methodology.

How do the case studies value ecosystems? What purposes do they support? For the benefit of whom?

The last building block requires a defined scope according to organisational and value chain boundaries of companies.

Criterion 8: organisational and value chain boundaries.

How do the case studies define their scope of corporate assessments? What does it mean for apportionment of responsibility and the management of impacts on ecosystems ?



II. Comparative analysis

As shown in Table 1, our comparative analysis has identified two main groups of case studies. Their distinctive features are discussed in depth in 8 sections:

- 2.1: Ecosystem asset inventory / register,
- 2.2: Measurement of ecosystem extent,
- 2.3 Measurement of ecosystem integrity / condition,
- 2.4 The ecological equivalency principle,
- 2.5: Recording rules for changes in the state of ecosystems based on double-entry bookkeeping from financial accounting,
- 2.6: Ecosystem-specific biophysical statements of performance and position,
- 2.7: Valuation perspective and methodology,
- 2.8: Organisational and value chain boundaries.

Table 1: Comparative analysis of the BHP, CSIRO, Forico and Sibanye-Stillwater case studies according to the core building blocks of CNCA

Core building blocks of Corporate Natural capital Accounting		BHP, CSIRO, Forico	Sibanye-Stillwater
Recognition of the biophysical properties and dynamics of each asset category	Ecosystem extent and condition / integrity	Yes	Yes
Employing measurement techniques that use spatially explicit data		Yes	Yes
Measuring net change applying the principle of ecological equivalency (like-for-like)		No due to problems with ecosystem definition and classification	Yes
Use of recording rules adapted from double-entry bookkeeping (inancial accounting)		No, single-entry bookkeeping focused on asset extent and condition accounts	Yes, with account categories organised around Statements of Position and Performance equations
Compilation of asset-speci ic statements of performance and position	Positive changes in state of biodiversity	Yes	Yes
	Negative changes in state of biodiversity	No, accumulated negative changes in original ecosystem surface areas are not shown (only residual surface areas of current land uses)	Yes
Distinguishing accounts according to organisational and value chain boundaries		Flexible approach	All impacts within direct operations
Valuation approaches explicitly supported by each accounting framework		Ecosystem services valuation (dependency and impact analysis) / Exchange values + asset maintenance costs	Quantitative priority ranking and target setting for biophysical metrics, financial (liabilities, expenses) and budgetary (cost savings, return on investment) implications of applying or striving for international, national or voluntary biodiversity targets, regulations or standards

2.1 Ecosystem asset register / impact inventory

Table 2 shows a typology of ecosystems used in the CSIRO report, Table 3 the ecosystem classification for Forico's case study, Table 4 the different ecosystem categories for the BHP case study and Figure 1 the typology of ecosystem assets for the South African operations of Sibanye-Stillwater. While there is no common hierarchy of ecosystem assets across the case studies, the CSIRO, Forico and BHP case studies share a similar approach: they separate 'natural' ecosystems from human-modified ecosystems and account for them separately.

On the other hand, the Sibanye-Stillwater case study list all natural ecosystems (classified according to the national vegetation typology of South Africa) impacted / controlled by the company, irrespective of whether they are in good state or completely modified to various land uses (e.g., industrial, farming, tree plantations). When ecosystems are completely modified, the BD Protocol requires identifying the historical (pre-transformation) ecosystems, in line with traditional biodiversity conservation planning which identifies the original and residual extent of ecosystems to define protection or restoration targets.

Table 2: List of ecosystems from CSIRO (top line), which distinguishes plantations, urban and industrial ecosystems with 3 categories of natural ecosystems

Example Ecosystem Extent Account:

Ecosystem Functional Group		T7.3 plantations	T7.6 Temperate pyric sclerophyll forests and woodlands	T7.5 Derived semi-natural pastures and oldfields	F.1.1 Permanent upland streams	T7.4: Urban and industrial ecosystems	
Ecosystem type	**Units**	**Plantation Forest**[a]	**Native forest**[b]	**Upland streams**[c]	**Native pastures**[d]	**Infrastructure and other**[e]	**Total**
Opening extent (baseline/ previous year)	ha 000's	20	30	7	40	3	100
Additions	ha 000's	-	1	-	-	-	1
Reductions	ha 000's				1		1
Closing extent (reporting year)	ha 000's	20	31	7	39	3	100
Net Change	ha 000's	-	1	-	-1	-	-

Table 3: List of ecosystems for the Forico case study (left column), which separate "modified land" from various vegetation communities.

30 June 2020

Vegetation Community	Mean VCA Score	Number of VCAs conducted	Number of VCAs score < 55	Total Natural Forest Area of the Estate (hectares)	Less: Pro rata area where Mean VCA < 55 (hectares)	Attributed Natural Forest Habitat (hectares)	Attributed Natural Forest Habitat ($K)
Dry eucalypt forest and woodland	70	107	14	21,872	2,862	19,010	69,951
Moorland, sedgeland, rushland and peatland	88	5	-	3,036	-	3,036	13,261
Native Grassland	73	38	3	2,166	171	1,995	7,469
Non-eucalypt forest and woodland	71	22	3	6,028	822	5,206	19,423
Rainforest and related scrub	80	25	-	13,989	-	13,989	55,756
Saltmarsh and wetland	80	6	-	327	-	327	1,300
Scrub, heathland and coastal complexes	81	2	-	1,419	-	1,419	5,716
Wet eucalypt forest and woodland	75	72	3	22,410	934	21,476	81,304
Highland treeless vegetation*	-	-	-	37	-	-	-
Other natural environments*	-	-	-	511	-	-	-
Modified Land*	-	-	-	5,035	-	-	-
Total	73	277	23	76,830	4,789	66,458	254,181

* VCA not conducted in this vegetation community

Table 4: List of ecosystems for the BHP case study (bottom of figure), which distinguishes pastures, artificial land uses from natural and modified / semi natural land uses.

Land Classifications

	FAO Level 3	IUCN Level 1: Realm	Level 2: Biome	ALUM V8 Primary Land Use Class	Ecosystem (Geomorphic) Units
Natural	A12. Natural and Semi-Natural Vegetation	Terrestrial	T2 Temperate-Boreal Forests and Woodlands	1. Conservation and Natural environments	Dryland Plains
					Dunes
	A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation	Freshwater /Terrestrial	TF1 Palustrine Wetlands	6. Water	Paluslopes
					Sumplands
					Palusplains
					Ironstone Palusplains
Modified /Semi-natural	B27. Artificial Waterbodies	Terrestrial	A12. Natural and Semi-Natural Vegetation	1. Conservation and Natural environments	MDSA
		Freshwater	F1 Rivers and Streams	6. Water	Drainage Channnels
			F3 Artificial Wetlands	6. Water	Lakes/pools
Pasture	A12. Natural and Semi-Natural Vegetation	Terrestrial	T7 Intensive Land Use Systems	3. Production from Dryland Agriculture and Plantations	Pasture
					Plantation
Artificial	B15. Artificial Surfaces and Associated Areas	Terrestrial	T7 Intensive Land Use Systems	5. Intensive Uses	Artificial Surfaces and Associated Areas (Mine)

Figure 1: Typology ecosystem assets for the Sibanye-Stillwater case study according to the South African national vegetation map, with no land use included.

	Total Biodiversity Footprint (TBF, in Ha)	Positive Biodiversity Footprint (PBF, in Ha eq.)	Negative Biodiversity Footprint (NBF, in Ha eq.)
Carletonville Dolomite Grassland	8915.86	676.16	8239.70
Carletonville Dolomite Grassland Wetland	1055.49	317.24	738.26
Central Free State Grassland Wetlands	306.24	96.85	209.39
Gauteng Shale Mountain Bushveld	5561.27	622.80	4938.47
Gauteng Shale Mountain Bushveld Wetland	686.13	204.21	481.92
Gold Reef Mountain Bushveld	10.92	0.00	10.92
Highveld Alluvial Vegetation	441.79	49.78	392.02
Highveld Alluvial Vegetation Wetlands	246.22	55.42	190.81
Highveld Salt Pan	556.69	115.77	440.93
Loskop Mountain Bushveld	382.27	137.06	245.22
Loskop Mountain Bushveld Wetland	158.24	94.94	63.30
Loskop Thornveld	470.93	142.33	328.59
Loskop Thornveld Wetland	74.10	44.46	29.64
Marikana Thornveld	14742.54	1122.82	13619.72
Marikana Thornveld Wetland	1299.94	471.53	828.41
Moot Plains Bushveld	1357.17	66.83	1290.34
Moot Plains Bushveld Wetland	10.93	4.37	6.56
Norite Koppies Bushveld	0.00	0.00	0.00
Rand Highveld Grassland	2756.59	176.78	2579.81
Rand Highveld Grassland Wetland	416.70	166.68	250.02
Soweto Highveld Grassland	2986.85	59.46	2927.39
Soweto Highveld Grassland Wetland	604.66	237.70	366.96
Vaal-Vet Sandy Grassland	4717.93	229.13	4488.80
Vaal-Vet Sandy Grassland Wetlands	19.90	3.98	15.92
Western Free State Clay Grassland	405.31	89.89	315.41

2.2 Ecosystem extent measurement

For extent measurement, CNCA involves ensuring that all ecosystems in the asset register or impact inventory are mapped, with unique GIS coordinates and surface area information. Any change to the extent of an ecosystem should be justified and backed-up with science-based evidence.

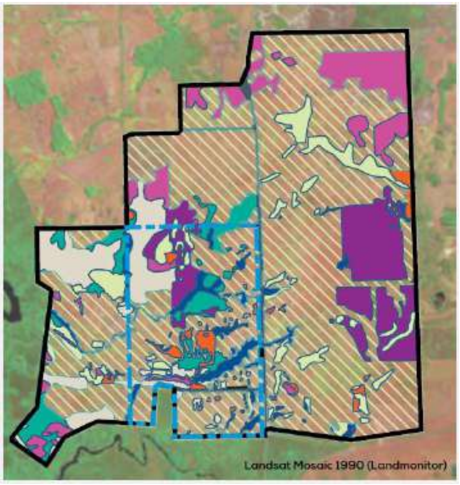
All the case studies have measured the spatial extent of *what they define as ecosystems* over time and then produce surface area information:

- Table 2 for the CSIRO report (see section 2.1),
- Table 3 for the Forico case study (see section 2.1),
- Table 4 for the BHP case study, and
- Figure 1 for the Sibanye-Stillwater case study (see section 2.1).

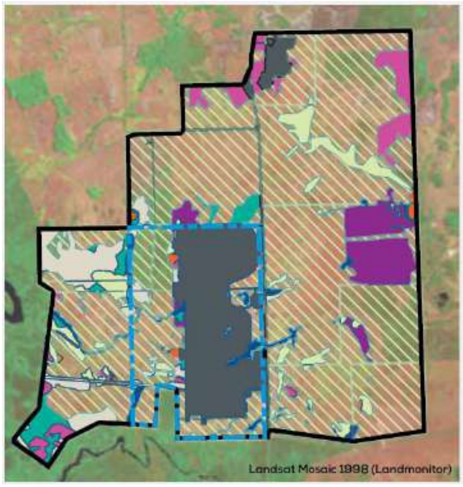
In addition, Figure 2 shows the maps of the changes in land use extent over time for the BHP case study and Figure 3 the ecosystem extent map for a Sibanye-Stillwater mine in 2022. No ecosystem / land use extent maps could be found for Forico and the CSIRO case studies, though they should be available.

Figure 2: Map of the changes in land use extent over time for the BHP case study.

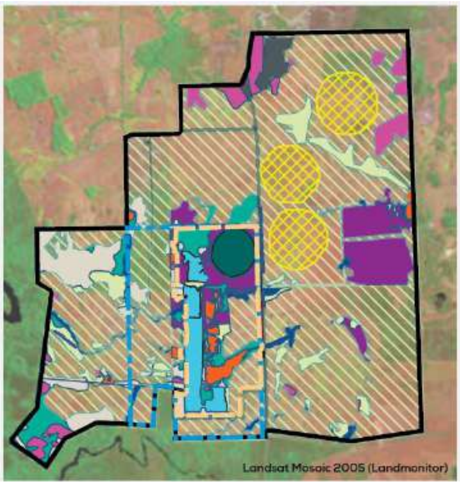
Scenario 1: Pre-Mining



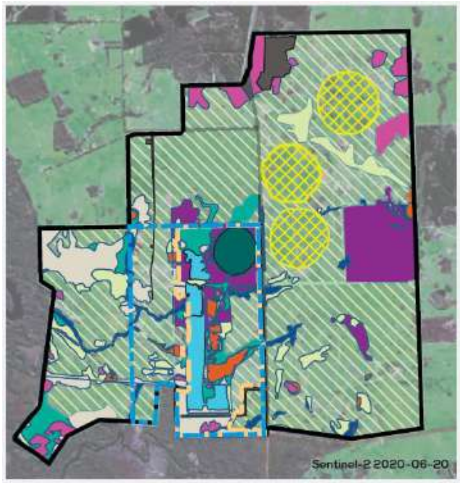
Scenario 2: Mining



Scenario 3 Phase 1:
Rehabilitation Works



Scenario 3 Phase 2:
Post Rehabilitation



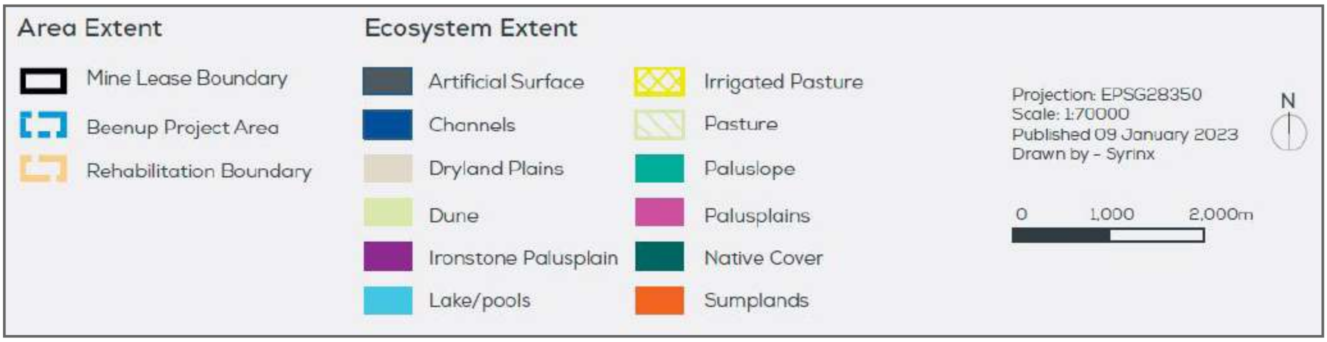


Table 5: Changes in land use extent over time for the BHP case study

	Land Use Type (area in ha)					
	Artificial Surfaces & Associated Areas	Native Cover (MDSA)	Pasture	Plantation	Natural Ecosystems	Total - BHP owned & leased areas
Scenario 1 - July 1982 (opening)	-	-	-	-	-	-
Change due to sale or purchase/ lease of land	-	-	802	3	514	1,319
Transfer to conservation estate	-	-	-	-	-	-
Conversion due to direct mining operations	-	-	-	-	-	-
Conversion to natural ecosystem (rehabilitation/ restoration)	-	-	-	-	-	-
Net Change	-	-	802	3	514	1,319
Scenario 1 - June 1991 (closing)	-	-	**802**	**3**	**514**	**1,319**

Table 5: Changes in land use extent over time for the BHP case study (cont.)

	Artificial Surfaces & Associated Areas	Native Cover (MDSA)	Pasture	Plantation	Natural Ecosystems	Total - BHP owned & leased areas
Scenario 2 - July 1991 (opening)	**-**	**-**	**802**	**3**	**514**	**1,319**
Change due to sale or end of lease	-	-	-158	-	-109	-267
Change due to purchase or lease of land	1	-	434	-	227	662
Transfer to conservation estate	-	-	-	-	-	-
Conversion due to direct mining operations	360	-	-194	-1	-167	-2
Conversion to natural ecosystem (rehabilitation/ restoration)	-	-	-	-	-	-
Net Change	361	-	82	-1	-49	393
Scenario 2 - June 1999 (closing)	**361**	**-**	**884**	**2**	**465**	**1,712**

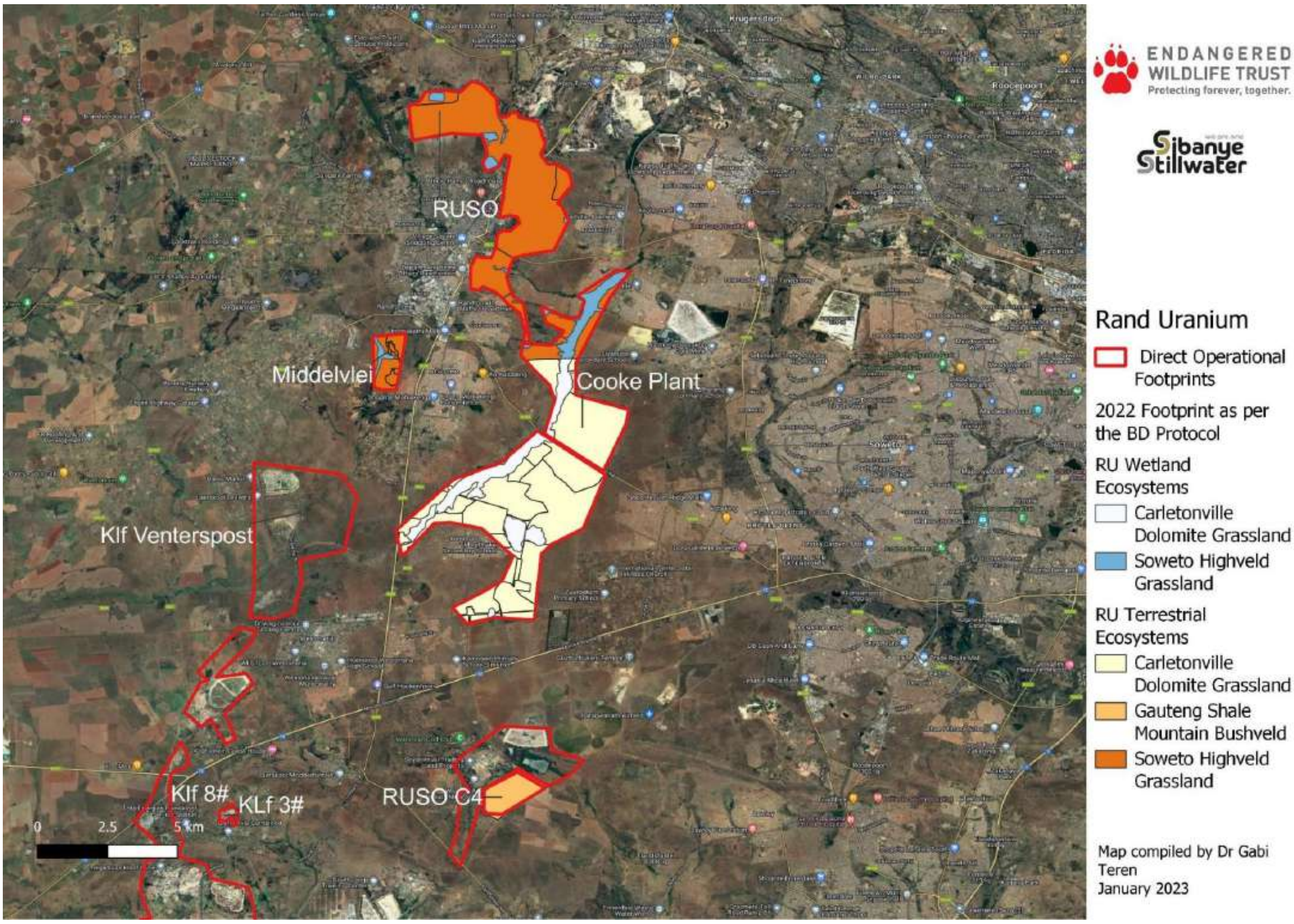
Table 5: Changes in land use extent over time for the BHP case study (cont.)

	Artificial Surfaces & Associated Areas	Native Cover (MDSA)	Pasture	Plantation	Natural Ecosystems	Total - BHP owned & leased areas
Scenario 3 Phase 1 - July 1999 (opening)	**361**	**-**	**884**	**2**	**465**	**1,712**
Change due to sale or purchase/ lease of land	-30	-	-691	-	-178	-899
Transfer to conservation estate	-	-	-21	-	-132	-153
Conversion due to direct mining operations	-	-	-	-	-	-
Conversion to natural ecosystem (rehabilitation/ restoration)	-330	40	41	-1	250	-
Net Change	-360	40	-671	-1	-60	-1,052
Scenario 3 Phase 1 - June 2005 (closing)	**1**	**40**	**213**	**1**	**405**	**660**

Table 5: Changes in land use extent over time for the BHP case study (cont.)

	Artificial Surfaces & Associated Areas	Native Cover (MDSA)	Pasture	Plantation	Natural Ecosystems	Total - BHP owned & leased areas
Scenario 3 Phase 2 - July 2005 (opening)	**1**	**40**	**213**	**1**	**405**	**660**
Change due to sale or purchase/ lease of land	-	-	-	-	-	-
Transfer to conservation estate	-	-	-	-	-	-
Conversion due to direct mining operations	-	-	-	-	-	-
Conversion to natural ecosystem (rehabilitation/ restoration)	-	-	-35	-	35	-
Net Change	-	-	-35	-	35	-
Scenario 3 Phase 2 - June 2020 (closing)	**1**	**40**	**178**	**1**	**440**	**660**

Figure 3: Ecosystem extent map for Rand Uranium mine (Sibanye-Stillwater case study).



2.3 Ecosystem integrity / condition measurement

For ecosystem condition / integrity measurement, CNCA should use methods[15] with a reference state (i.e. natural, original, pristine or pre-human transformation state) as the maximum potential score for the ecosystem assessed[16]. Land-use condition assessment tools are different: they rate environmental assets and the associated land uses from the perspective of maximizing the provisioning of ecosystem services (e.g., wood production, cattle grazing). In other words, rating the state of ecosystem differs from assessing the "quality" of a land use (e.g. competing perspectives on "sustainable" agriculture: 'industrial agriculture' vs 'agro-ecology')[17].

Table 6 shows ecosystem condition variable accounts for the CSIRO example. There appears to be no embedded reference state in the various variables (i.e. forest age class distribution, crown cover, carbon stock – above and below ground, etc.). For instance, for forest age class distribution, is 50% of mature trees (good or bad (what is the reference state)? Furthermore, Table 7 shows the corresponding juxtaposed extent and condition accounts. Surface areas of different ecosystem types are allocated to "good", "fair" and "poor" condition sub-accounts.

The BHP case study is like that of the CSIRO. Table 8 shows the breakdown of different land uses into low, medium and high condition surface area accounts.

The Forico case study makes uses of a Vegetation Condition Assessment (VCA) methodology[18] (see Table 3 in section 2.1 and Figure 4 in this section), which has reference states for its variables and has been applied at several sample sites. As with the CSIRO example, extent of different ecosystem types are allocated into different condition classes and scores are averaged overall.

Finally, Sibanye-Stillwater uses an ecosystem integrity scale for terrestrial ecosystems (adapted from the South African National Biodiversity Institute's methodology[19])

15. As argued by UNEP-WCMC *et al.* (2023), *"the condition of an ecosystem is determined by its characteristics. Characteristics of ecosystems describe elements of structure, composition, and function. Interpretation of measures of these characteristics, however, may vary based on management goals, e.g., biodiversity conservation versus maximizing provisioning of ecosystem services. The concept of 'integrity' helps interpret condition variables, where integrity is defined as the degree to which the composition, structure, and function of an ecosystem fall within their natural range of variation, and is often seen as the degree to which an ecosystem's key characteristics have been modified from a 'natural' state."*

16. In areas with a long history of human uses, practitioners and researchers often must extrapolate such reference states using various data sources (e.g., archaeological and climatic records, historic documents, closest ecosystems in "natural" state). Improving the integrity / condition of ecosystems for biodiversity conservation purposes may involve a broad range of measures, which should ultimately all contribute towards allowing ecosystems to fully express their evolutionary potential, unconstrained by human activities. This does not imply going back to the reference state. The latter is merely used as a reference point to help (a) monitor the integrity of ecosystems over time and (b) guide management decisions.

17. McNeill, D. (2019). The contested discourse of sustainable agriculture. Global Policy 10: Suppl.1 doi: 10.1111/1758-5899.12603 URL: https://onlinelibrary.wiley.com/doi/epdf/10.1111/1758-5899.12603

18. Department of Primary Industries, Parks, Water and Environment, TASVEG – The Digital Vegetation Map of Tasmania, https://dpipwe.tas.gov.au/conservation/development-planning-conservation-assessment/planningtools/monitoring-and-mapping-tasmanias-vegetation-(tasveg)/tasveg-thedigital-vegetation-map-of-tasmania; URL: https://nre.tas.gov.au/Documents/TASVEG%20VCA%20Manual%20Scoring%20Tables.pdf

19. South African National Biodiversity Institute (SANBI). 2020. Species Environmental Assessment Guideline. Guidelines for the implementation of the Terrestrial Fauna and Terrestrial Flora Species Protocols for environmental impact assessments in South Africa. South African National Biodiversity Institute, Pretoria. Version 3.1. 2022.

and WET-Health[20] for freshwater ecosystems (Figure 5 shows of a map of ecosystem condition). Both have reference state imbedded as their maximum scores.

There is a significant difference with the other CNCA case studies. The ecosystem condition score is used to calculate the **condition-adjusted surface areas** (equation: *surface area multiplied by condition score at time of assessment / maximum condition score of reference state*), which gives rise to three inter-related metrics which are tracked (See Figure 1 in section 2.1):

- The total surface area of the ecosystem asset or Total Biodiversity Footprint (TBF),
- The corresponding residual ecosystem state (condition-adjusted surface area) or Positive Biodiversity footprint (PBF),
- The corresponding gap (condition-adjusted surface area) to the reference state or Negative Biodiversity Footprint.

In other words: TBF = PBF + NBF

[20] Macfarlane, D. M., Kotze, D. C., Ellery, W. N., Walters, D., Koopman, V., Goodman, P., et al. (2008). WET-Health: a technique for rapidly assessing wetland health. WRC report TT340/08. South Africa: WRC

Table 6: Ecosystem condition variables for CSIRO. NB: there appears to be no reference state embedded. Variables are compared from one period to the other from an opening measurement.

Example Ecosystem Condition Variable Account

Ecosystem asset	SEEA ecosystem condition typology class: Variable (units)	Opening condition (baseline / previous year)	Closing condition (reporting year)	Net change
Plantation forest	Structural state: Forest age class distribution (% mature)	50	60	10
	Structural state: Crown cover (%)	83	88	5
	Chemical state: Carbon stock (above ground) (tC/ha)	70	65	-5
	Chemical state: Carbon stock (below ground) (tC/ha)	40	40	0
Native forest	Chemical state: Carbon stock (above ground) (tC/ha)	140	158	18
	Chemical state: Carbon stock (below ground) (tC/ha)	116	124	8
	Compositional state: Threatened species (Number)	67	67	0
Upland streams	Physical state: Water turbidity (Nephelometric Turbidity Unit NTU)	4.5	5.0	0.5
Native pastures	Physical state: % bare ground (%)	20	15	-5

Table 7: Ecosystem extent and condition accounts for CSIRO. NB: Ecosystem extent are allocated to "good", "fair" and "poor" condition sub-accounts. There is no accounting of accumulated negative changes per se, but a reallocation of surface areas in different condition categories.

Example Combined Ecosystem Extent and Condition Account

Ecosystem Functional Group		T7.3 Plantations	T7.6 Temperate pyric sclerophyll forests and woodlands	F.1.1 Permanent upland streams	T7.5 Derived semi-natual pastures and oldfields	T7.4: Urban and industrial ecosystems	
Ecosystem type	Units	Plantation forest	Native forest	Upland streams	Native pastures	Infrastructure and other	Total
Opening extent (baseline / previous year)	ha 000's	**20**	**30**	7	**40**	**3**	**100**
Good	ha 000's	9	15	2	20	N/A	N/A
Fair	ha 000's	9	10	4	15	N/A	N/A
Poor	ha 000's	2	5	1	5	N/A	N/A
Additions	ha 000's	**10**	**1**	**2**	**2**	**-**	**15**
Good	ha 000's	2	-	2	2	N/A	N/A
Fair	ha 000'	2	-	-	-	N/A	N/A
Poor	ha 000's	6	1	-	-	N/A	N/A
Reductions	ha 000's	**10**	**-**	**2**	**3**	**-**	**15**
Good	ha 000's	6	-	-	-	N/A	N/A
Fair	ha 000's	2	-	2	2	N/A	N/A
Poor	ha 000's	2	-	-	1	N/A	N/A

Table 7: Ecosystem extent and condition accounts for CSIRO. NB: Ecosystem extent are allocated to "good", "fair" and "poor" condition sub-accounts. There is no accounting of accumulated negative changes per se, but a reallocation of surface areas in different condition categories. (Cont.)

Example Combined Ecosystem Extent and Condition Account

Ecosystem Functional Group		T7.3 Plantations	T7.6 Temperate pyric sclerophyll forests and woodlands	F.1.1 Permanent upland streams	T7.5 Derived semi-natual pastures and oldfields	T7.4: Urban and industrial ecosystems	
Ecosystem type	Units	Plantation forest	Native forest	Upland streams	Native pastures	Infrastructure and other	Total
Closing extent (reporting year)	ha 000's	**20**	**31**	7	**39**	**3**	**100**
Good	ha 000's	9	15	4	22	N/A	N/A
Fair	ha 000's	11	10	2	13	N/A	N/A
Poor	ha 000's	-	6	1	4	N/A	N/A
Net Change	ha 000's	**-**	**1**	**-**	**-1**	**-**	**-**
Good	ha 000's	-	-	2	2	N/A	N/A
Fair	ha 000'	2	-	-2	-2	N/A	N/A
Poor	ha 000's	-2	1	-	-1	N/A	N/A

Figure 4: Vegetation Community Scores for the Forico case study

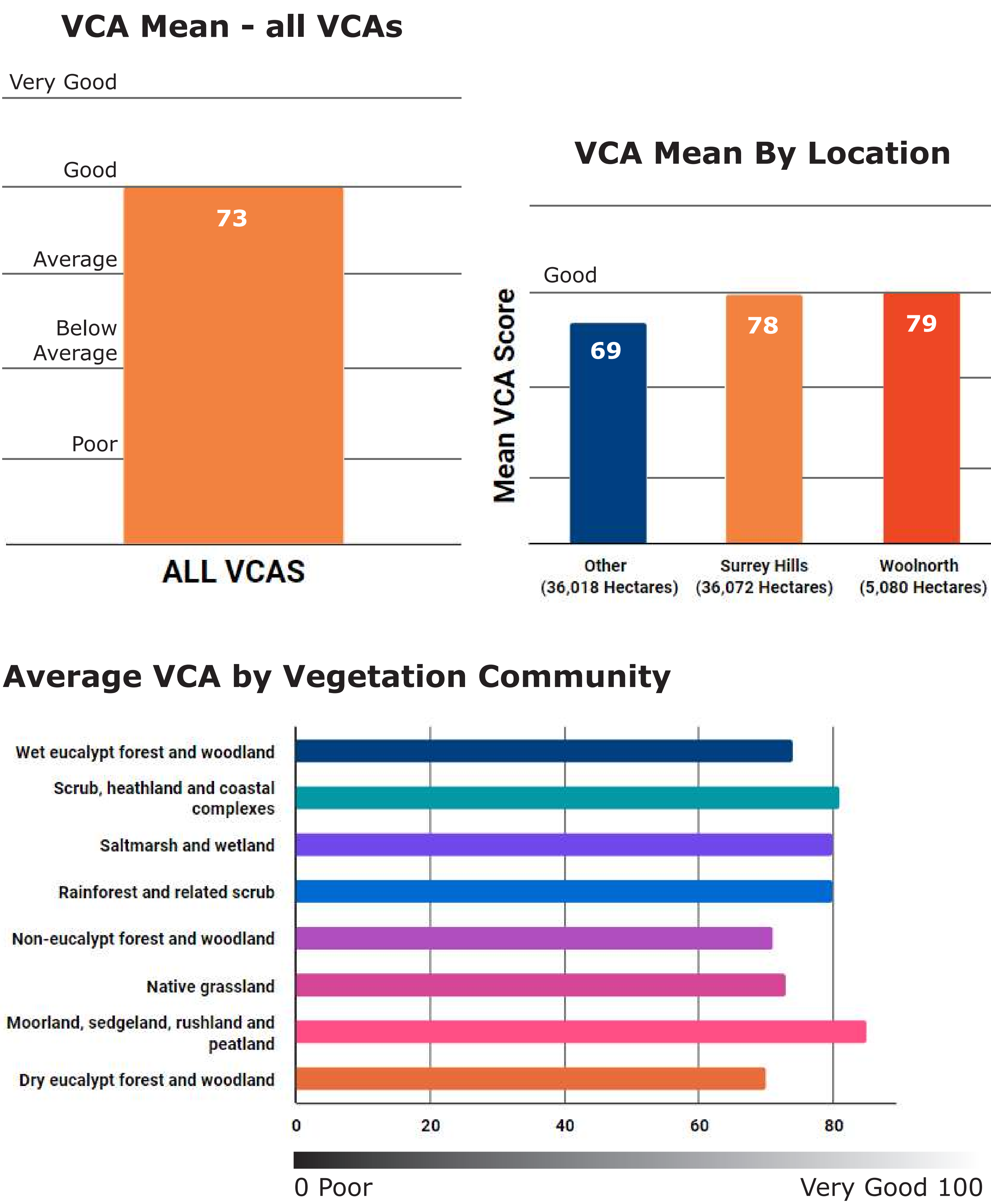
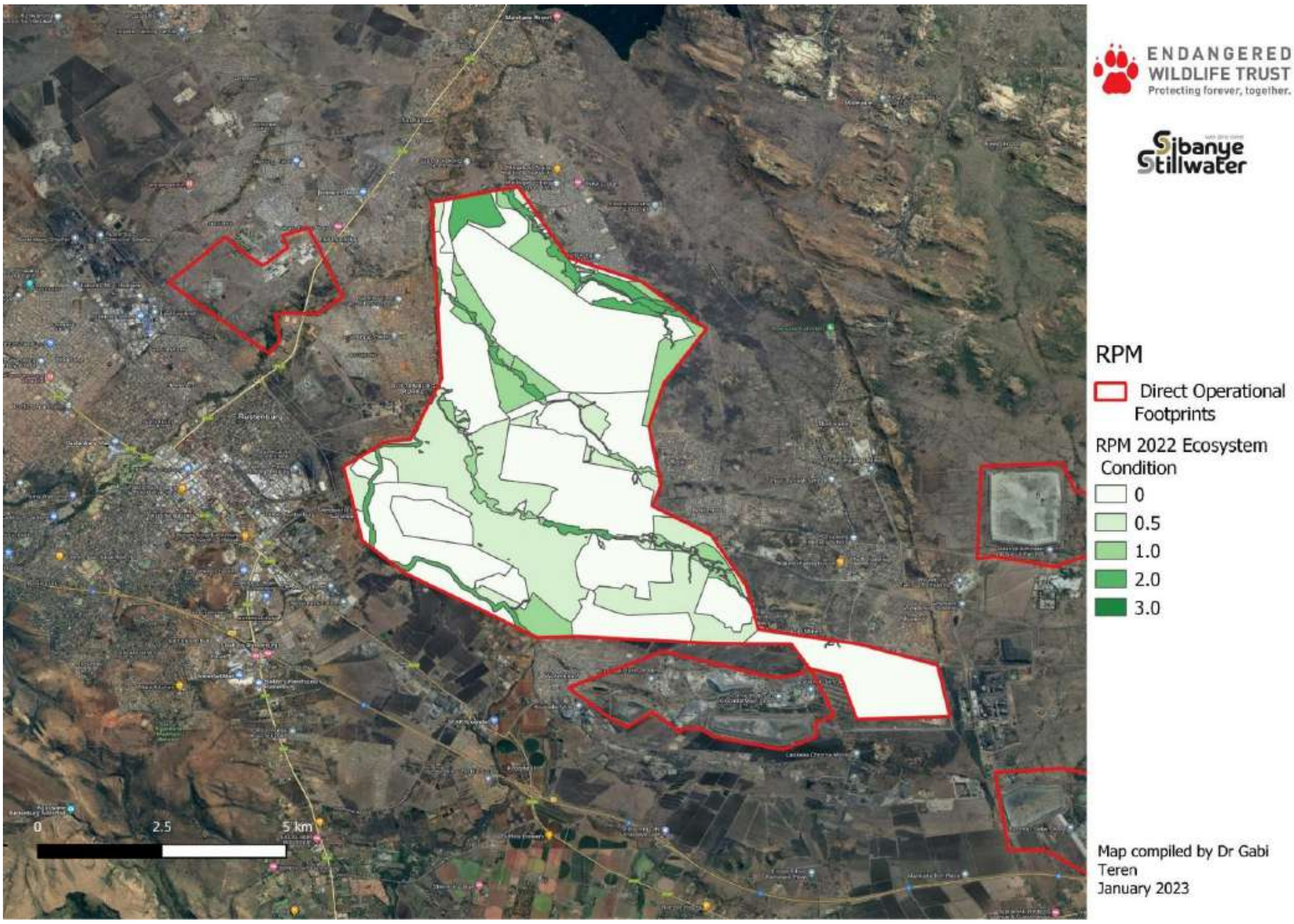


Table 8: BHP's condition scoring breaks land use surface areas into low, medium and high conditions sub-accounts.

						Scenario 1 Pre-Mining		Scenario 2 Mining		Scenario 3 Phase 1 Rehabilitation Works		Scenario 3 Phase 2 Post-Rehabilitation	
Land Classification						Ecosystem Assets - Extent & Condition at Scenario End Date							
	FAO Level 3	**IUCN Level 1: Realm**	**Level 2: Biome**	**ALUM V8 Primary Land Use Class**	**Ecosystem (Geovmorphic) Units**	**Extent (ha)**	**Condition**	**Extent (ha)**	**Condition**	**Extent (ha)**	**Condition**	**Extent (ha)**	**Condition**
Natural	A12. Natural and Semi-Natural Vegetation	Terrestrial	T2 Temperate-Boreal Forests and Woodlands	1. Conservation and Natural environments	Dryland Plains	23	HIGH	66	MEDIUM	65	HIGH	96	HIGH
					Dunes	53	HIGH	84	HIGH	22	HIGH	23	HIGH
	A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation	Freshwater /Terrestrial	TF1 Palustrine Wetlands	6. Water	Paluslopes	59	HIGH	46	HIGH	88	HIGH	89	HIGH
					Sumplands	28	HIGH	15	MEDIUM	32	MEDIUM	33	HIGH
					Palusplains	132	HIGH	63	HIGH	35	HIGH	36	HIGH
					Ironstone Palusplains	148	HIGH	130	HIGH	68	MEDIUM	68	HIGH
Modified /Semi-natural	B27. Artificial Waterbodies	Terrestrial	A12. Natural and Semi-Natural Vegetation	1. Conservation and Natural environments	MDSA	-	-	-	-	40	LOW	40	LOW
		Freshwater	F1 Rivers and Streams	6. Water	Drainage Channels	71	HIGH	61	MEDIUM	17	MEDIUM	17	HIGH
			F3 Artificial Wetlands	6. Water	Lakes/pools	-	-	-	-	78	MEDIUM	78	HIGH
Pasture	A12. Natural and Semi-Natural Vegetation	Terrestrial	T7 Intensive Land Use Systems	3. Production from Dryland Agriculture and Plantations	Pasture	802	LOW	884	LOW	213	LOW	179	LOW
					Plantation	3	LOW	2	LOW	1	LOW	-	-
Artificial	B15. Artificial Surfaces and Associated Areas	Terrestrial	T7 Intensive Land Use Systems	5. Intensive Uses	Artificial Surfaces and Associated Areas (Mine)	-	-	361	-	1	-	1	-

Figure 5: Map of ecosystem condition scores for ecosystem assets of RPM operations (Sibanye-Stillwater)



2.4 The ecological equivalency principle

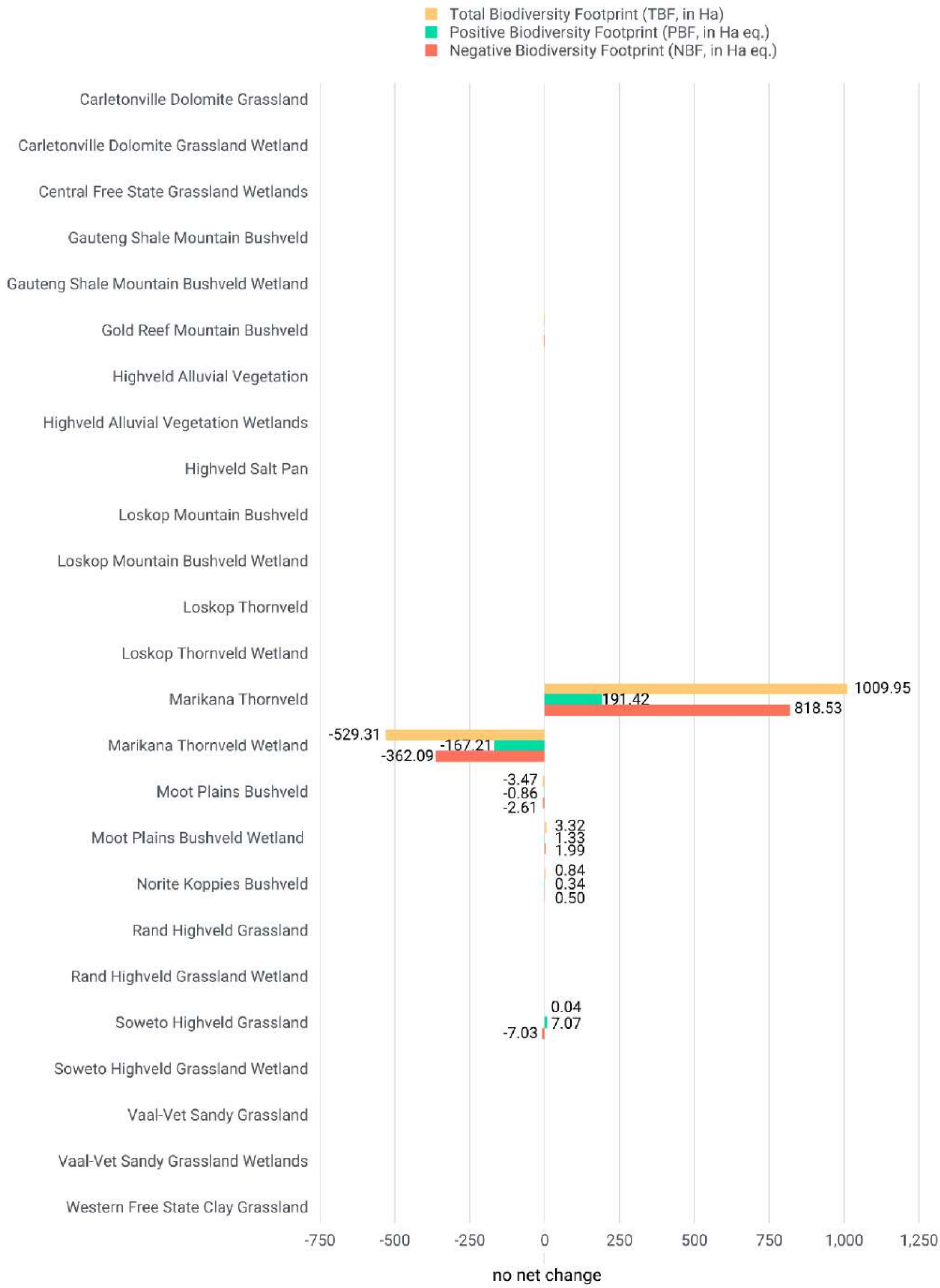
The ecological equivalency principle ensures that gains / losses or increases / decreases in the extent of ecosystems are matched for the same ecosystem type and spatial area. Conflating ecosystem type with land use type is the critical test for ecological equivalency.

While the SEEA Central Framework defines environmental assets as *'the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity'* (SEEA Central Framework, para. 2.17), the BHP (Tables 5 and 8), CSIRO (Table 7), and Forico (table 3) case studies do not appear to adhere to the ecological equivalency test because they confuse land use with ecosystem type. As soon as "natural areas" change to various productive uses (i.e. vegetation significantly different to natural conditions: e.g., crop farming, urban areas), the "natural ecosystem" extent accounts are reduced and the corresponding land use accounts are increased. Gains / losses in specific ecosystem types are thus not tracked in these case studies[21].

On the other hand, while the Sibanye-Stillwater also maps land use as a key data input for condition / integrity scoring, only changes to extent accounts of original ecosystems are tracked, hence satisfying the ecological equivalency principle. Only when there is scientific evidence for ecosystem type change (e.g., due to climate change or the emergence of novel ecosystems[22]) would the BD Protocol would record changes in the extent of ecosystem assets. Anthropogenic ecosystems such as agricultural and urban landscapes do not meet the definition of novel ecosystems because they are not self-organising: they require constant, intensive human management to maintain themselves in the optimal state of their intended land use.

[21] Arguing that this can be justified by ecosystem conversion (e.g. urban or agricultural areas are new ecosystem types) amounts to assuming that various land uses cannot be restored to (largely) natural ecosystems (i.e. irreversibility of ecological damages). Assessing whether this is the case is not the focus of this paper, though this could be challenged by numerous papers (e.g., Shen, Z., Tian, Y., Yao, Y., Jiang, W., Dong, J., Huang, X., Wu, X., Farooq, T.H., Yan, W., 2023. Ecological Indicators 155, https://doi.org/10.1016/j.ecolind.2023.110968).
[22] Definition: "Novel ecosystems are ecological assemblages that form self-organizing systems that have no historical precedent." McDonald E. & King, E.G., 2018. Novel ecosystems: A bridging concept for the consilience of cultural landscape conservation and ecological restoration. Landscape and Urban Planning 177, 148-159. https://doi.org/10.1016/j.landurbplan.2018.04.015.

Figure 6: Net change in surface area equivalents of (original) ecosystem types for the Sibanye-Stillwater case study in the 2022 update assessment (2021 baseline), ensuring ecological equivalency in extent increases / decreases .



2.5 Recording rules for changes in the state of ecosystems based on double-entry bookkeeping from financial accounting

There are two key differences between the case studies and associated methods:

- The underlying equation, accounts and associated journal entries,
- The unit of measurement recorded.

In line with BS8632 / SEEA EA, the BHP, CSIRO and Forico case studies have *asset accounts*, which get increased or decreased over time with changes in the extent or condition of the associated land uses. This gives rise to the following equation:
Asset account (T0) + increases / decreases in asset account (T1) = Asset account (T1)
This is illustrated by the various BHP scenarios in Table 5, the net changes in extent accounts in Tables 2 and 6 for CSIRO and yearly extent accounts in Table 9 for Forico. This is akin to *single entry* accounting because changes recorded in the Statement of Position involve changes to a single account type.
Moreover, the underlying single-entry bookkeeping equations generate extent accounts which are separate from condition accounts. In other words, asset accounts have two distinct, separate accounts:

- Extent accounts with surface are metrics (e.g., hectares in Table 9 for Forico): *Asset extent (T0) + increases / decreases in asset extension (T1) = Asset extent (T1).*
- Condition accounts with various measurement units (e.g. VCA scores in Table 3 for Forico and various indicators in Table 6 for CSIRO): *Asset condition (T0) + increases / decreases in asset condition (T1) = Asset condition (T1).*

It means that BS8632 / SEEA EA based accounts do not explicitly record accumulated positive and negative changes to the extent and state of ecosystems. They merely record periodic changes, i.e. changes from one period to another, or changes from a baseline.

Table 9: Extent account of land uses over 4 years for Forico

Indicator	Measure	2017	2018	2019	2020
Plantation	hectares	96,639	92,620	90,675	89,538
Natural Vegetation	hectares	81,043	79,722	76,857	76,830
Infrastructure	hectares	3,761	3,446	2,787	2,917
Other	hectares	-	-	3,051	3,043
Forest Management Unit	**hectares**	**179,443**	**175,788**	**173,370**	**172,328**

The underlying accounting equations are different for the BD Protocol. It builds from the foundations of financial accounting through two equations, adapted from double entry bookkeeping, which ensures that the total biodiversity impacts of a company are equal to the sum of its accumulated positive and negative impacts (Table 10):

- Statement of Biodiversity Position: (A accounts) total impacts on biodiversity features = (B accounts) accumulated positive impacts on biodiversity + (C accounts) accumulated negative impacts on biodiversity (for all periods to date);
- Statement of Biodiversity Performance: (X accounts) net biodiversity impacts on biodiversity features over the accounting period = (Y accounts) periodic positive biodiversity impacts or gains - (Z accounts) periodic biodiversity negative impacts or losses.

Accordingly, there are six account categories, three within each equation (Table 10). This is why this is akin to the *double-entry bookkeeping* of financial accounting, where the Statement of Financial Position shows how assets are financed by debt and equity (Assets = Debt + Equity) and annual changes are recorded in the Statement of Financial Performance (Profit / Loss = Revenues – Expenses).

What's more, the other key difference with the previous accounting system is that extent and condition accounts are *integrated*, not separate (Table 10 and Figure 7); in line with the ecosystem integrity / condition measurement approach outlined in section 2.3. Extent measurement units (e.g. surface area in hectares) only apply to asset accounts while all the other accounts involve surface area adjusted for condition / integrity metrics (e.g., Hectares equivalents). This is opposed to the previous approach, which can be illustrated by Table 7 for CSIRO and Table 8 for BHP where condition (qualitative rating) and extent (hectares) accounts are recorded separately (i.e. no equation hold the two set of data) but can be presented within the same table, juxtaposed.

In other words, the focus of the Sibanye-Stillwater case study is on recording the changes to the *state* of asset accounts, which involves recording changes in two other balance sheet accounts (i.e. the current state of ecosystems is the result of accumulated positive and negative changes in surface area equivalents over time), themselves influenced by periodic changes captured in the accounts of the Statement of Performance (gains and / or losses in surface area equivalents for the period). Changes in asset extent accounts themselves (e.g., changes of the spatial boundaries of the assessment) also involve dedicated journal entries (see journal entry 2 in Figure 7).

Table 10: The various accounts of the BD Protocol used for the Sibanye-Stillwater case study[23].

	Statement of Position		-	Statement of Performance	
	Ecosystems	Species		Ecosystems	Species
Total impacts (A)	Sum of accumulated positive and negative impacts expressed in surface area	Target population (e.g. number of breeding or mature individuals) or habitat size (e.g., ha /Km2) of a species	Periodic net impacts	Gains minus losses (can be consolidated across asset categories)	Gains minus losses (per species)
Accumulated positive impacts (P)	Actual areas (A) of ecosystem assets multiplied by their current condition/ integrity score (1), divided by the maximum potential condition score (J), or P=AX (I/J).	Actual/current population (e.g. number of breeding or mature individuals) or habitat size (e.g., ha/km2) of a species.	Periodic gains (G)	An increase in the condition of the ecosystem assets, in area equivalents (e.g. ha eq., MSA eq.).	An increase in the population (e.g. number of breeding or mature individuals) or habitat size (e.g., ha /km2) of a species.
Accumulated negative impacts (N)	Difference between the actual areas (A) of ecosystem assets and their condition/integrity adjusted extent (P), also expressed in area equivalents (e.g. hectare equivalents): N=A-P.	Gap to target population (e.g. number of breeding or mature individuals) or habitat size (e.g., ha /Km2) of a species (i.e. N=A-P)	Periodic losses (L)	A decrease in the condition of the ecosystem assets, in area equivalents (e.g. ha eq., MSA eq.).	A decrease in the population (e.g. number of breeding or mature individuals) or habitat size (e.g., ha/km2) of a species.

[23] Houdet, J, Teren, G. 2022. Quality Biodiversity Footprint Assessments in Practice: Why Organisational Biodiversity Accounting Matters. A Position Paper of the Biodiversity Disclosure Project (BDP). National Biodiversity and Business Network, Endangered Wildlife Trust, South Africa. URL: https://407264.p3cdn1.secureserver.net/wp-content/uploads/2022/11/BDP-Quality-Biodiversity-Footprints.pdf

Figure 7: Accounting journal entries for Sibanye-Stillwater, showing how debits and credits link all the different accounts, with asset accounts in surface area metric (hectares) and all the other accounts in surface area adjusted for condition / integrity metric (hectare equivalents).

Journal entries	Accounting events	Account	Account category	Ecosystem Asset	Condition score	DR	CR
(a) Reference state							
1	Accounting for reference state of new ecosystem assets (boundary adjustments), which underpins their subsequent condition scoring	Ecosystem asset (Ha)	A (Statement of Biodiversity Position)	Marikana Thornveld	5	156.70	
				Gold Reef Mountain Bushveld	5	19.53	
				Moot Plains Bushveld Wetland	5	3.32	
				Norite Koppies Bushveld	5	0.84	
		Periodic gains (Ha eq.)	Y (Statement of Biodiversity Performance)	Marikana Thornveld	5		156.70
				Gold Reef Mountain Bushveld	5		19.53
				Moot Plains Bushveld Wetland	5		3.32
				Norite Koppies Bushveld	5		0.84
(b) At time of assessment							
2	Stock tacking of Marikana Thornveld assets, according to their condition scores (increase in asset sizes due to boundary adjustments)	Ecosystem asset (Ha)	A (Statement of Biodiversity Position)	Marikana Thornveld	0	41.84	
					0.5	16.30	
					1		206.77
					2	125.58	
					3	179.75	
					5		156.70
3	Stock tacking of Gold Reef Mountain Bushveld assets, according to their condition scores (increase in asset sizes due to boundary adjustments)	Ecosystem asset (Ha)	A (Statement of Biodiversity Position)	Gold Reef Mountain Bushveld	0		0.08
					1	19.61	
					5		19.53
4	Stock tacking of Moot Plains Bushveld Wetland assets, according to their condition scores (increase in asset sizes due to boundary adjustments)	Ecosystem asset (Ha)	A (Statement of Biodiversity Position)	Moot Plains Bushveld Wetland	2	3.32	
					5		3.32
5	Stock tacking of Norite Koppies Bushveld assets, according to their condition scores (increase in asset sizes due to boundary adjustments)	Ecosystem asset (Ha)	A (Statement of Biodiversity Position)	Norite Koppies Bushveld	2	0.84	
					5		0.84
6	Recording condition-adjusted losses and gains associated to 2022 condition scores of Marikana Thornveld assets	Periodic losses (Ha eq.)	Z (Statement of Biodiversity Performance)	Marikana Thornveld	5	156.70	
		Accumulated negative Impacts (Ha eq.)	C (Statement of Biodiversity Position)	Marikana Thornveld	0		41.84
					0.5		14.67
					1	165.42	
					2		75.35
					3		71.90
		Periodic gains (Ha eq.)	Y (Statement of Biodiversity Performance)	Marikana Thornveld	0.5		1.63
			Z (Statement of Biodiversity Performance)	Marikana Thornveld	1	41.35	
			Y (Statement of Biodiversity Performance)	Marikana Thornveld	2		50.23
					3		107.85

2.6 Ecosystem-specific biophysical statements of performance and position.

Because of the underlying single-entry bookkeeping equation, the BHP, CSIRO and Forico case studies do not have distinct Statement of Position and Statement of Performance. Only a single table is presented to show periodic changes to asset accounts, for both extent and condition. For instance, see Tables 2 and 7 for CSIRO and Table 8 for BHP.

Furthermore, these biophysical statements appear to be presented as input information for the main outputs of the process: i.e. natural capital profit / loss statements and balance sheets (see section 2.7). This, coupled to the land use approach to the asset inventory (section 2.1) and the lack of ecological equivalency (section 2.4), suggests that these accounting approaches are not designed and / or applied to account for the changes in state of ecosystems. They are primarily designed for another purpose, as illustrated by the focus on the condition of different land uses to supply ecosystem services (see sections 2.3 and 2.7).

On the other hand, Sibanye-Stillwater presents distinct Statement of Position (Figure 8) and Statement of Performance (Figure 9), highlighting the double-entry bookkeeping foundations of the BD Protocol.

The Statement of Position shows the residual state of ecosystems, through their associated accumulated negative and positive impacts (e.g., out of 8 915.863 ha of Carletonville Dolomite Grassland ecosystems, only 676.16 ha eq. are left). The Statement of Performance records all the actual gains (e.g., 12.22 ha eq. of condition 2 / 5 of Marikana thornveld ecosystems were gained) and losses, per ecosystem asset and associated condition / integrity scores, over the period. Biophysical Statements of Ecosystem Position and Performance are the main outputs of the Sibanye-Stillwater case study, which shows that the BD Protocol's primary function is to account for the changes in state of ecosystems.

Figure 8: The Statement of Ecosystem Position for Sibanye-Stillwater (baseline), with asset accounts in surface area metric (hectares) and accumulated positive and negative accounts in surface area adjusted for condition / integrity metric (hectare equivalents).

	Total Biodiversity Footprint (TBF, in Ha)	Positive Biodiversity Footprint (PBF, in Ha eq.)	Negative Biodiversity Footprint (NBF, in Ha eq.)
Carletonville Dolomite Grassland	8,915.86	676.16	8,239.7
Carletonville Dolomite Grassland Wetland	1,055.49	317.24	738.26
Central Free State Grassland Wetlands	306.24	96.85	209.39
Gauteng Shale Mountain Bushveld	5,561.27	622.8	4,938.47
Gauteng Shale Mountain Bushveld Wetland	686.13	204.21	481.92
Gold Reef Mountain Bushveld	10.84	0	10.84
Highveld Alluvial Vegetation	441.79	49.78	392.02
Highveld Alluvial Vegetation Wetlands	246.22	55.42	190.81
Highveld Salt Pan	556.69	115.77	440.93
Loskop Mountain Bushveld	382.27	137.06	245.22
Loskop Mountain Bushveld Wetland	158.24	94.94	63.3
Loskop Thornveld	470.93	142.33	328.59
Loskop Thornveld Wetland	74.1	44.46	29.64
Marikana Thornveld	15,752.49	1,314.24	14,438.25
Marikana Thornveld Wetland	770.63	304.32	466.31
Moot Plains Bushveld	1,353.71	65.98	1,287.73
Moot Plains Bushveld Wetland	14.25	5.7	8.55
Norite Koppies Bushveld	0.84	0.34	0.5
Rand Highveld Grassland	2,756.59	176.78	2,579.81
Rand Highveld Grassland Wetland	416.7	166.68	250.02
Soweto Highveld Grassland	2,986.89	66.53	2,920.36
Soweto Highveld Grassland Wetland	619.26	238.52	380.74
Vaal-Vet Sandy Grassland	4,717.93	229.13	4,488.8
Vaal-Vet Sandy Grassland Wetlands	19.9	3.98	15.92
Western Free State Clay Grassland	405.31	89.89	315.41

Figure 9: The Statement of Ecosystem Performance for Sibanye-Stillwater's Kroondal operations (2022 – 2021 period), with gains, losses and net impact accounts in surface area adjusted for condition / integrity metric (hectare equivalents).

Journal entries	Periodic gains (Y)		Condition score	Hectares equivalents (Ha eq.)
1	Accounting for reference state of new ecosystem assets (boundary adjustments), which underpins their subsequent condition scoring	Marikana Thornveld	5	440.35
		Marikana Thornveld Wetland	5	42.77
4	Recording condition-adjusted losses and gains associated to 2022 condition scores of Marikana Thornveld assets	Marikana Thornveld	0.5	10.76
		Marikana Thornveld	1	12.22
		Marikana Thornveld	2	5.63
5	Recording condition-adjusted losses and gains associated to 2022 condition scores of Marikana Thornveld Werland assets	Marikana Thornveld Wetland	2	22.66
		Sub-total periodic gains (Y)		534.39

Journal entries	Periodic losses (Z)		Condition score	Hectares equivalents (Ha eq.)
4	Recording condition-adjusted losses and gains associated to 2022 condition scores of Marikana Thornveld assets	Marikana Thornveld	5	440.35
5	Recording condition-adjusted losses and gains associated to 2022 condition scores of Marikana Thornveld Werland assets	Marikana Thornveld Wetland	1	3.09
		Marikana Thornveld Wetland	5	42.77
		Sub-total periodic losses (Z)		486.21
		Net ecosystem impacts (X = Y - Z)		48.18

2.7 Valuation perspective and methodology

This criterion helps to clearly differentiate between BS8632 / SEEA EA and BD Protocol based case studies. The BD Protocol focuses on the intrinsic values of ecosystem assets: i.e. their value for themselves, with the goal of ensuring their survival and evolutionary potential (i.e. ensuring biodiversity's "going concern"[24]). This is why Statements of Position and Performance (a) are exclusively in biophysical metrics, (b) integrated extent and condition information (no juxtaposed accounts) and (c) show accumulated negative / positive changes to ecosystem assets in reference to their original state.

This enables two complementary valuation approaches:

- Ranking ecosystem assets according to their threat or importance level for priority assessment[25],
- Assessing the financial (tangible) costs (expenses, liabilities) and benefits (cost savings) of various biodiversity risk management scenarios with respect to the implementation of the mitigation hierarchy: i.e. impact avoidance, minimisation, restoration, offsets, voluntary conservation measures, in this sequence as per best practice.

This approach aims to focus the attention and efforts on managing the biodiversity impacts of companies, with a clear path towards setting, budgeting and implementation mandatory biodiversity requirements and voluntary biodiversity targets. The monetary valuation component is thus aligned with permitting legislation related to biodiversity impact assessment and actual corporate financial accounting which records actual expenses and liabilities (though this is not covered by the Sibanye-Stillwater case study). This is indeed a very narrow valuation perspective based on biodiversity conservation and recovery (i.e. focus on "wild, living nature"). This case study says nothing about the positive and negative externalities linked to existing and planned land uses.

On the other hand, the other case studies focus on the instrumental values of components of ecosystems, for the company and other stakeholders. Their focus is on measuring ecosystem extent and condition for different land uses and use this information to value, in monetary terms, various ecosystem services such as climate regulation services (carbon sequestration), water supply or mineral sands (see Figure 10 for BHP). This much broader valuation perspective leads the case studies to generate:

- Profit / loss statements, in monetary terms, which add up / subtract costs and benefits associated with each periodic

24. Houdet, J. (2024). Advances in corporate natural capital accounting. Chapter taken from: Atkins, J. (ed.), Protecting natural capital and biodiversity in the agri-food sector, pp. 135–150, Burleigh Dodds Science Publishing, Cambridge, UK, 2024, (ISBN: 978 1 80146 351 5; www.bdspublishing.com)
25. Sibanye-Stillwater identified 25 ecosystem types, with 6 are threatened as per the National List of Threatened Ecosystems.

ecosystem service change (ex. Figure 10 for BHP and Figure 13 for Forico),
- Balance sheets, in monetary terms, add up the asset values and subtract liability values (ex. Figure 12 for BHP and Figure 14 for Forico).

This enables to showcase the past, current, and future values of ecosystem stocks and associated flows of services which the companies manage for various purposes.
It provides information on how corporate decision-making and practices influences (a) the state of land-uses, (b) the associated stocks and flows ecosystem services and (b) the benefits / costs to the company and external stakeholders.

Figure 10: Extract from the Net Natural Capital Profit / Loss statement for BHP

					Scenario 2 Mining EP&L for the period July 1991–June 1999					
					Physical Account		Monetary Flow Account			
					Flows		Benefits		Costs	
							Realisable or potentially realisable benefits of physical flows		Costs associated with generation of physical flows	
	Services	**Notes**	**(physical account) Measure**	**(physical account) Metric**	**Flows to business**	**Flows to society**	**Benefits to business (AUD$)**	**Benefits to society (AUD$)**	**Costs to business (AUD$)**	**Costs to society (AUD$)**
Environmental Assets - Other										
Land (as provision of space)	**Land Change**	PL 1	area	ha	393	-	-	-	1,178,190	-
Mineral and Energy Resources	**Mineral sands**	PL 2								
	Mineral sands extracted		volume/ amount extracted	tonnes	-	-400,000	80,000,000	-	(60,000,000)	-
	Depletion of resource	PL 2	volume/ amount extracted	tonnes	-	-	-	-	-	(20,000,000)
	Expenses - environmental assets (other)	PL 3					-	-	(2,408,851)	-
Environmental Assets - Ecosystems										
Pastures and Native ecosystems	**Grazed Biomass**									
	Increase in fodder to support grazing	PL4	area supporting grazing	ha	-	886	-	1,247,615	-	-
	Carbon	PL5								
	Carbon sequestration - Pasture		quantity of above and below ground sequestered carbon	t CO_2e	-	2,380	-	45,222	-	-
	Carbon sequestration - Natural Ecosystem				-	69,107	-	1,313,029	-	-
	Adjustments to carbon due to land area changes	PL 5		t CO_2e	-	-41,794	-	-	-	(793,892)
	Water									
	Water quality regulation	PL 6	mass of nutrients removed	tonnes	-	-	-	-	-	-
			mass of sediment removed	tonnes						
	Water flow regulation	PL 7	volume discharged	ML	-	31,292	-	3,129,220	(3,200,000)	-
	Water supply	PL 8	volume supplied to third party	ML	-	-	-	-	-	-
	Natural products									
	Native seed supply	PL 9	seed harvested	tonnes	-	-	-	-	-	-
	Beekeeping and production of honey		quantity commercially produced	tonnes	-	-	-	-	-	-
	Commercial wildflower harvesting		area supporting wildflower	ha	-	-	-	-	-	-
	Habitat provision									
	Provision of high quality habitat to support/sustains matters of national conservation significance	PL 10	maintenance of MNES	no of MNES	-	1	-	112,000	-	-
	Habitat value adjustment - gains/(losses) in flows						-	-	-	(1,650,737)
	Education, Scientific & Research	PL 11								
	Technical visits		number of visits	no.	-	-	-	-	-	-
Total							80,000,000	5,847,086	(66,787,041)	(22,444,,629)
Net Natural Capital Profit/(Loss)	(3,384,584)									

Figure 10: Extract from the Net Natural Capital Profit / Loss statement for BHP (cont.)

					Scenario 1 Pre-Mining EP&L for the period July 1982–June 1991					
					Physical Account		Monetary Flow Account			
					Flows		Benefits		Costs	
							Realisable or potentially realisable benefits of physical flows		Costs associated with generation of physical flows	
	Services	**Notes**	**(physical account) Measure**	**(physical account) Metric**	**Flows to business**	**Flows to society**	**Benefits to business (AUD$)**	**Benefits to society (AUD$)**	**Costs to business (AUD$)**	**Costs to society (AUD$)**
Environmental Assets - Other										
Land (as provision of space)	**Land Change**	PL 1	area	ha	1,319	-	-	-	(3,957,000)	-
Mineral and Energy Resources	**Mineral sands**	PL 2								
	Mineral sands extracted		volume/ amount extracted	tonnes	-	-	20,000,000	-	-	-
	Depletion of resource	PL 2	volume/ amount extracted	tonnes	-	-	-	-	-	-
	Expenses - environmental assets (other)	PL 3					-	-	(8,505,275)	-
Environmental Assets - Ecosystems										
Pastures and Native ecosystems	**Grazed Biomass**									
	Increase in fodder to support grazing	PL4	area supporting grazing	ha	-	805	-	1,275,120	-	-
	Carbon	PL5								
	Carbon sequestration - Pasture		quantity of above and below ground sequestered carbon	t CO_2e	-	2,575	-	48,917	-	-
	Carbon sequestration - Natural Ecosystem				-	93,497	-	1,776,443	-	-
	Adjustments to carbon due to land area changes	PL 5		t CO_2e	-	-	-	-	-	-
	Water									
	Water quality regulation	PL 6	mass of nutrients removed mass of sediment removed	tonnes tonnes	-	-	-	-	-	-
	Water flow regulation	PL 7	volume discharged	ML	-	26,660	-	2,665,953	-	-
	Water supply	PL 8	volume supplied to third party	ML	-	-	-	-	-	-
	Natural products									
	Native seed supply	PL 9	seed harvested	tonnes	-	-	-	-	-	-
	Beekeeping and production of honey		quantity commercially produced	tonnes	-	-	-	-	-	-
	Commercial wildflower harvesting		area supporting wildflower	ha	-	-	-	-	-	-
	Habitat provision									
	Provision of high quality habitat to support/ sustains matters of national conservation significance	PL 10	maintenance of MNES	no of MNES	-	4	-	504,000	-	-
	Habitat value adjustment - gains/(losses) in flows						-	10,900,745	-	-
	Education, Scientific & Research	PL 11								
	Technical visits		number of visits	no.	-	-	-	-	-	-
Total							20,000,000	17,171,178	(12,462,275)	-
Net Natural Capital Profit/(Loss)	24,708,903									

Figure 11: Extract from the Net Natural Capital Asset statement for BHP

	Scenario 3 Phase 2 2020 Statement	Scenario 3 Phase 1 2005 Statement	Scenario 2 1999 Statement	Scenario 1 1991 Previous Statement	Scenario 1 Opening Account 1982 Statement
Indicators	Value of assets (AUD$)	Value of assets (AUD$)	Value of assets (AUD$)	Value of assets (AUD$)	Value of assets (AUD$)
Natural Capital Assets					
Land assets	1,980,000	1,980,000	5,136,000	3,957,000	3,957,000
Mineral resource assets	-	-	-	20,000,000	-
Other	-	8,934,211	20,000,000	-	-
Habitat	9,000,791	7,152,459	9,250,008	11,225,496	11,225,495
Carbon storage	20,921,473	18,545,564	23,612,868	23,048,510	21,248,510
Water and Wetlands	11,101,413	2,099,448	2,595,173	2,665,953	296,217
Gross Natural Capital Asset Value	**43,003,677**	**38,711,682**	**60,594,049**	**60,896,959**	**36,727,222**
Natural Capital Liabilities					
Liabilities	(284,128)	(3,107,163)	(3,081,677)	-	-
Gross Natural Capital Liabilities Value	**(284,128)**	**(3,107,163)**	**(3,081,677)**	-	-
NET NATURAL CAPITAL ASSET VALUE	**42,719,549**	**35,604,519**	**57,512,372**	**60,896,959**	**36,727,222**

Figure 12: Net increase / decrease in Natural Capital for Forico

	30 June 2020					
	Note	Measure	Metric	Value to Business $k	Value to Society $k	Total $k
Enhancements to Natural Capital						
Biomass – Plantation						
Fibre from growth	3	1,232	'000 gmt	65,427	-	**65,427**
				65,427	-	**65,427**
Carbon Sequestration						
Increase in carbon sequestration due to growth - current year	4	5,013	kt CO_2-e	71	80,096	**80,167**
Increase/(decrease) in future estimate carbon sequestration due to current year changes in production profiles	4	11,693	kt CO_2-e	467	157,197	**157,664**
				538	237,293	**237,831**
Water						
Water flows to the estate	6a	977	GL	-	97,710	**97,710**
Sediment control - erosion prevented due to riparian buffers	6b	2,420	tonnes	-	41	**41**
				-	97,751	**97,751**
Natural Forest Habitat						
Investment in vegetation condition improvements	8	-	-	-	874	**874**
				-	874	**874**
Total Enhancements to Natural Capital				**65,965**	**335,919**	**401,884**

Figure 12: Net increase / decrease in Natural Capital for Forico (cont.)

	30 June 2020					
	Note	Measure	Metric	Cost/ Impact from Business $k	Cost/Impact from Society $k	Total $k
Reductions to Natural Capital						
Biomass – Plantation						
Harvested biomass from sustainable plantations	3	1,493	'000 gmt	64,372	-	**64,372**
Revaluation adjustment	3			37,302	-	**37,302**
				101,674	-	**101,674**
Carbon Sequestration						
Sequested carbon transferred on harvest - current year	4	2,659	kt CO_2-e	-	42,549	**42,549**
Carbon emissions from operations - current year	5	29	kt CO_2-e	460	-	**460**
				460	42,549	**43,009**
Water						
Water flows to the estate	6a	941	GL	-	94,145	**94,145**
Water consumed by plantation operations	6a	35.0	GL	3,520	-	**3,520**
Sales of water resources	6a	0.5	GL	45	-	**45**
Estimated sediment impact from operations	6b	245	tonnes	4	-	**4**
				3,569	94,145	**97,715**
Natural Forest Habitat						
Natural forest maintenance costs incurred	8	-	-	874	-	**874**
				874	-	**874**
Total Enhancements to Natural Capital				**106,578**	**136,694**	**243,272**
Net Increase/Decrease in Natural Capital				**(40,613)**	**199,225**	**158,612**

Figure 13: Net Natural Capital (assets – liabilities) for Forico

	Note	30 June 2020					30 June 2019		
		Measure	Metric	Value to Business $k	Value to Society $k	Total $k	Measure	Metric	Total $k
Environmental Assets									
Biomass – Plantation	3	10,944	‘000 gmt	423,897	-	423,897	11,205	‘000 gmt	460,143
Carbon Sequestration									
Productive Plantation									
Carbon - above ground	4	16,191	kt CO_2-e	71	258,944	259,015	16,711	kt CO_2-e	267,374
Carbon - below ground	4	54,858	kt CO_2-e	-	877,734	877,734	52,166	kt CO_2-e	834,661
Carbon - forest debris	4	1,309	kt CO_2-e	-	20,942	20,942	1,127	kt CO_2-e	18,037
Future carbon sequestration before harvest	4	57,791	kt CO_2-e	467	715,156	715,623	46,098	kt CO_2-e	557,959
Natural Forest									
Carbon – above & below ground	4	52,453	kt CO_2-e	-	839,259	839,256	52,453	kt CO_2-e	839,256
		182,602		538	2,712,032	2,712,569	168,556		2,517,287
Natural Forest Habitat	7	76,830	ha		254,181	254,181	76,856	ha	*not available
Total Environmental Assets				**424,434**	**2,966,213**	**3,390,647**			**2,977,430**
Environmental Liabilities									
Maintenance provision – Natural Forest	8			24,985	-	24,985			18,940
Total Environmental Liabilities				**24,985**	**-**	**24,985**			**18,940**
Total Net Natural Capital				**399,449**	**2,966,213**	**3,365,662**			**2,958,490**

2.8 Organisational and value chain boundaries

The Sibanye-Stillwater case study followed the BD Protocol to define the organisational boundary for its biodiversity impact inventory (or ecosystem asset register). In the BD Protocol, impact measurement includes all impacts within the selected organisational and value chain boundary, as required by the completeness accounting principle[26] (one among several). Accordingly, Sibanye-Stillwater elected to focus on the direct impacts[27] of the direct operations[28] it has control over.

While SEEA EA remains silent on impact definition and value chain boundaries (landscape approach is promoted, since it was not developed with corporations in mind), BS8632 has no minimum requirement. The latter is based on flexibility, which might explain why the BHP case study focuses on a specific site and the Forico case study on all its forestry operations.

These differences are significant from an accountability perspective in the context of the Global Biodiversity Framework (e.g. targets 3 and 15).

Sibanye-Stillwater discloses a complete assessment of the state of the ecosystem it directly impacts on, acknowledging the scale of historical losses to date, with a view to improve the situation from a chosen baseline. On the other hand, the other case studies do not focus on the state of biodiversity and are not designed to disclose the complete scale of their impacts. They focus on highlighting the benefits and costs of their chosen land uses.

26. Failure to meet this requirement prevents the company the company from declaring it has adhered to the BD Protocol.

27. In the BD Protocol, direct impacts refer to the changes in the state of biodiversity that can be directly correlated to the activities of your business. Indirect impacts involve third party, for instance in the broader landscape or down in the supply chain. Direct impacts constitute changes in the state of biodiversity which are caused directly by your business activities. In other words, direct impacts involve business impact drivers which can be traced to specific, verifiable biodiversity features, that is direct causal link between your company's actions (e.g. land clearing or ecosystem restoration measures) and a change in the state of ecosystems or taxa (e.g. decrease/increase in ecosystem condition, habitat loss/gain for several species). These impacts may be temporary (short-term or long-term), recurrent (e.g. seasonal, every time a specific activity is undertaken) or permanent impacts (e.g. built-up properties, such as office buildings or parking areas). For instance, the direct land footprint of your business operations leads to verifiable, on the ground changes in biodiversity. Similarly, water emissions may lead to verifiable changes in the state of freshwater ecosystems which can be attributed solely to your company, for instance when streams or wetlands are wholly contained within its direct operations or where it is the only significant polluter within the catchment.

28. The value chain boundaries of the BD Protocol differ from the three scopes of the GHG Protocol. In line with the Natural Capital Protocol (Natural Capital Coalition 2016, the BD Protocol first recognises three major parts of the value chain:

- Direct operations (gate-to-gate), which cover activities over which your business holds ownership or control;
- Upstream (cradle-to-gate), which covers the activities of suppliers;
- Downstream (gate-to-grave), which covers activities linked to the purchase, use, re-use, recovery, recycling, and final disposal of your business' products and services. All operations that an organisation owns and / or has control over.

III. Discussions and conclusions

The comparative analysis shows how different purposes condition the rules underlying each case study and associated CNCA-related method. While this comparative analysis shows broad alignment between the case studies using SEEA EA and BS8632, significant differences were found with the one using the BD Protocol.

In addition to the main findings of this comparative analysis, this section aims to discuss:

- The need for complete ecosystem state accounts in the context of the Global Biodiversity Framework (GBF),
- The need for segregated land use accounts with clear separation between financial and non-financial values, and
- Opportunities for greater alignment for CNCA methods.

3.1 Implications for biodiversity conservation in the context of the Global Biodiversity Framework (GBF)

While all methods and case studies theoretically start from ecosystem extent and condition measurement, the corporate natural accounts of BHP, CSIRO and Forico do not support reaching Goal A - Targets 2 and 3 of the Global Biodiversity Framework (see box 1) and this for several reasons.

Box 1: The Global Biodiveristy Framework and key conservation and restoration targets

The Kunming-Montreal Global Biodiversity Framework (GBF) was adopted during the fifteenth meeting of the Conference of the Parties (COP 15) following a four year consultation and negotiation process. This historic Framework, which supports the achievement of the Sustainable Development Goals and builds on the Convention's previous Strategic Plans, sets out an ambitious pathway to reach the global vision of a world living in harmony with nature by 2050. Among the Framework's key elements are 4 goals for 2050 and 23 targets for 2030, including:

"Goal A:

The integrity, connectivity and resilience of all ecosystems are maintained, enhanced, or restored, substantially increasing the area of natural ecosystems by 2050;

TARGET 2

Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and coastal and marine ecosystems are under effective restoration, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity.

TARGET 3

Ensure and enable that by 2030 at least 30 per cent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognizing indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean, while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes, recognizing and respecting the rights of indigenous peoples and local communities including over their traditional territories."

A- Their asset inventories / registers mix land uses with ecosystem types, so that changes in their extent cannot be tracked for conservation planning purposes (section 2.1): e.g. how much of an ecosystem type have we lost? How much should we protect legally from productive uses (Target 3)? They take (arbitrary) baseline land use extent as the starting point for the accounting process.

B- While it seems that most of the condition rating assessments undertaken for these case studies were designed to assess ecosystem integrity (section 2.3), because land use and ecosystem accounts are mixed, the assessment of their state may lead to the over- & under-assessment of their integrity, depending on prevailing political and cultural conditions, notably land use decision-makers. Land use quality assessments are framed by the final ecosystem services sought and captured by rights holders. It should be undertaken separately from ecosystem state assessments (i.e. biodiversity footprints).

For instance, within the same region of Southern France, there may be very diverse land-uses, including extensive pastoral landscapes, urban areas, intensive fruit monocultures and protected areas, among others. While different land uses may harbour different levels of species diversity (e.g., extensive pastoral landscapes are usually expected to be species richer than intensive fruit monocultures), they do not constitute different ecosystem categories. While extensive pastoral landscapes and intensive fruit monocultures may be spatially contiguous, they could be located within the same or across different historical ecosystem types (irrespective of the land use choice). The same applies to different urban land uses, from recreation areas / city parks, commercial districts to suburban housing areas.

In other words, an ecosystem state assessment would focus on the current state of the original ecosystems (land-use agnostic) to help assess and monitor trends in the state of ecosystems while a land use quality assessment might compare the sustainability of different agricultural systems to maximize the delivery of a specific set of ecosystem services (e.g., food production and surface water for drinking, while protecting specific species), notably with respect to their management of ecological infrastructure[29].

To further illustrate this distinction, let's use the example of a protected area. It may rate highly in terms of its management performance (i.e. land use assessment such as the Protected Area Management Effectiveness Tracking Tool - METT[30]), but very poorly from an ecosystem state

[29]Perschke, M.J., Harris, L.R., Sink, K.J., Lombard, A.T., 2023. Ecological Infrastructure as a framework for mapping ecosystem services for place-based conservation and management. Journal for Nature Conservation 73. https://doi.org/10.1016/j.jnc.2023.126389.
[30]Stolton, S. and Dudley, N. (2016). METT Handbook: A guide to using the Management Effectiveness Tracking Tool (METT). Woking, UK: WWF.

perspective for various reasons which may or may not be related to management performance (e.g., small / fragmented area, recent disturbances, historical loss of species which can't be reintroduced back). And the reverse could also be true: i.e. high ecosystem integrity for completely unmanaged, remote protected areas with low METT scores. This is why recent protected area accounting exercise based on land uses instead of ecosystem state may be problematic: they assume that legal status determines ecosystem state (e.g., see example of SEEA applied to protected areas in South Africa, Uganda and Andalusia[31]).

In other words, using their accounting approach, one could only partially answer this question: which ecosystem type should be restored and to what state in the context of its reference / natural state (Target 2)?

C- The BHP, CSIRO and Forico do no support ecological equivalency between gains / losses of ecosystems (see section 2.4). They cannot be aligned to the main business tool for managing biodiversity impacts, risks and opportunities: i.e. the mitigation hierarchy. This directly affects efforts to compile business information regarding GBF Targets 2 and 3.

These three limitations work in synergy, enabling and supporting **environmental amnesia** (Trouwborst 2021[32]) and **shifting baselines** (Soga & Gaston, 2018[33]), which will directly contribute to further biodiversity loss. What's more, their focus on adding up monetary values of competing ecosystem services (e.g., logging and non-consumptive natural area values) primarily serve to (a) justify past decisions and (b) undertake innovative marketing on their current land use management practices in the hope of securing the social license to operate (e.g., BHP) and / or identifying potential new revenue streams (e.g., the value of carbon stocks and indigenous vegetation in the context of offset and conservation schemes for Forico). This argument is further supported by the lack of *debt* to society accounts for negative externalities (section 3.2), hence over-estimating the total value of natural capital assets.

In other words, for greater alignment between CNCA methods, all approaches should first account for the state of ecosystems, prior to any land use accounting and valuation exercise, while adhering to the equivalency principle.

31. King, S., Ginsburg, A., Driver, A., Belle, E.M.S., Campos, P., Caparros, A., Zaman, H., Borwn, C., 2023. Accounting for protected areas: Approaches and applications. Ecosystem Services 63, 101544.
32. Trouwborst, A. (2021). Megafauna Rewilding: Addressing Amnesia and Myopia in Biodiversity Law and Policy. Journal of Environmental Law 33(3), pp. 639–667, https://doi.org/10.1093/jel/eqab016
33. Soga, M., Gaston, K., 2018. Shifting baseline syndrome: causes, consequences, and implications. Frontiers in Ecology and Environment 16(4), pp. 222-230. https://doi.org/10.1002/fee.1794

3.2 Addressing limitations in valuation methods

As explained in section 2.7, the Sibanye-Stillwater case study is based on a narrow, target-based financial valuation approach (i.e. cost-effectiveness principle). The lack of information leaves us pondering about the tangible business implications, if any.

On the other hand, the other case studies provide ample information about the total value of chosen land uses and associated ecosystem stocks and flows, which also present several limitations and challenges:

A. Adding / subtracting externalities to actual revenues, expenses and liabilities is incompatible with the core foundations of financial accounting, while externality values used often confuse the value of externalities (e.g., social cost to society or uncompensated costs imposed on a neighbour) with actual opportunity costs and contract values that could arise from various market mechanisms.

B. An incomplete accounting framework, which reflects the underlying single entry bookkeeping system for land use assets, fails to identify improvement targets (e.g., in relation to reference state?) for (a) ecosystem state, (a) ecosystem services supply and (b) ecosystem service delivery and, hence, has no "liability to society" accounts.

C. Lack of recognition of trade-offs and / or competing interests between different categories of ecosystem services.

Let's address the first issue using the Forico example. The '*increase in carbon sequestration due to growth*' worth 42 549 AUDK did not lead to any payment with another party. This externality does not reflect any transaction between a buyer and seller (e.g., for voluntary carbon credits) and is based on the '*the social cost of carbon derived by the United States Environment Protection Agency in 2018 estimated a price of $61 AUD per tonne of CO2-e*'. Adding / subtracting such externalities to actual business expenses, such as 874 AUDK for actual operational costs (Figure 12)[34], is questionable. Also, carbon-related credit offset trade never involves the social costs of carbon, but reflect carbon offset project development costs[35]. These cost categories are not comparable and should not be netted off within the same table. They involve costs / benefits underpinned by completely opposed models: i.e. financial accounting vs micro-economics.

[34] These "*include ecological burns, restoration and rehabilitation activity, consultancy costs, internal specialist labour costs, weed and pest control and other goods and services required to manage the natural vegetation so that their extent and condition does not decline over time*".
[35] URL: https://www.bloomberg.com/professional/insights/sustainable-finance/long-term-carbon-offsets-outlook-2023/

Would the previous concern be ignored or rebuffed on the basis that these are micro-economic accounts which do not intend to represent the actual natural capital financial position and performance of the company, then the second concern arises. These accounts overstate the benefits of current land uses. First, they ignore any past negative impacts (e.g., natural vegetation loss due to conversions to plantations and artificial areas) and associated social costs. Second, there is no "debt account to society" *accounts*, only "*value to society*" accounts, which seems at odds with well documented evidence of negative externalities of companies (e.g., Trucost 2023[36]). Third, they imply that current business choices and practices about land use and the associated supply and capture of ecosystem services are inherently positive for people. However, these companies fail to identify these beneficiaries and whether they benefit from such practices.

Indeed, valuation is not without its challenges and controversies. Among them is capturing the diverse ways that nature is perceived and valued by people in different and often conflicting ways (Pascual *et al.*, 2017)[37]. For instance, monetary valuation can be counterproductive to its own purpose of taking the economic worth of unpriced environmental goods and service into account (Farrell, 2007)[38], as focusing on a narrow set of market values of nature for decision-making has been found to underpin the global biodiversity crisis (IPBES 2022[39]). As the need for pluralistic valuation methods arise, recognizing and addressing power relationships across stakeholder groups that hold different values on human nature relations and nature contributions to people are key. These case studies remain silent on these issues.

Last but not least, the BHP, CSIRO and Forico case studies fail to recognise that ecosystem services supply and delivery involve trade-offs and competing interests, which may lead to ecosystem dis-services[40], now and in the future, notably with respect to maximizing biodiversity conservation / recovery ("wild, living nature") versus the provisioning of ecosystem services for target beneficiaries.

36. Trucost 2023. Natural capital at risk: the top 100 externalities of business. TEEB for Business Coalition. URL: https://capitalscoalition.org//wp-content/uploads/2016/07/Trucost-Nat-Cap-at-Risk-Final-Report-web.pdf

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Ecosystem dis-services is the overwhelming realty for people and business. This explains why companies:

- Make trade-off decisions to capture of specific final ecosystem services at the expense of others and biodiversity in general (e.g., shorter single-aged tree lifecycles to maximise wood outputs at the expense of biodiversity),
- Suppress non-useful / detrimental elements of biodiversity (e.g., e.g., suppression of browsers or "harmful" insects in tree plantations).

This lack of recognition starts at both the asset register (section 2.1) and integrity / condition assessment level (section 2.3). Land uses are conflated with ecosystem types while land-use condition assessment tools differ from ecosystem condition assessments: these case studies rate environmental assets and the associated land uses from the perspective of maximizing the provisioning of ecosystem services (e.g., wood production, grazing) which are detrimental to ecosystem integrity. In other words, rating the state of ecosystem differs from assessing the "quality" of a land use (e.g. competing perspectives on "sustainable" agriculture: 'industrial agriculture' vs 'agro-ecology')[41]. By mixing different ecosystem services benefits within the same table, these case studies ignore the fundamental differences embedded within the underlying extent and condition measurement methodologies. Accordingly, for greater alignment between CNCA methods, land use (biophysical and monetary) accounts should be developed after ecosystem state (biophysical) accounts (section 3.1). These land use accounts should be kept separate from one another (i.e. no aggregation between different land use types) because:

- They are based on human decisions and intense management targeting the supply and delivery of specific final ecosystem services,
- Involve the controlled development and suppression of various ecosystem functions / processes and associated species, hence requiring dedicated condition assessment methods (e.g., urban area vs tree plantations vs natural ecosystems).

[41] McNeill, D. (2019). The Contested Discourse of Sustainable Agriculture. Global Policy 10: Suppl.1 doi: 10.1111/1758-5899.12603 URL: https://onlinelibrary.wiley.com/doi/epdf/10.1111/1758-5899.12603

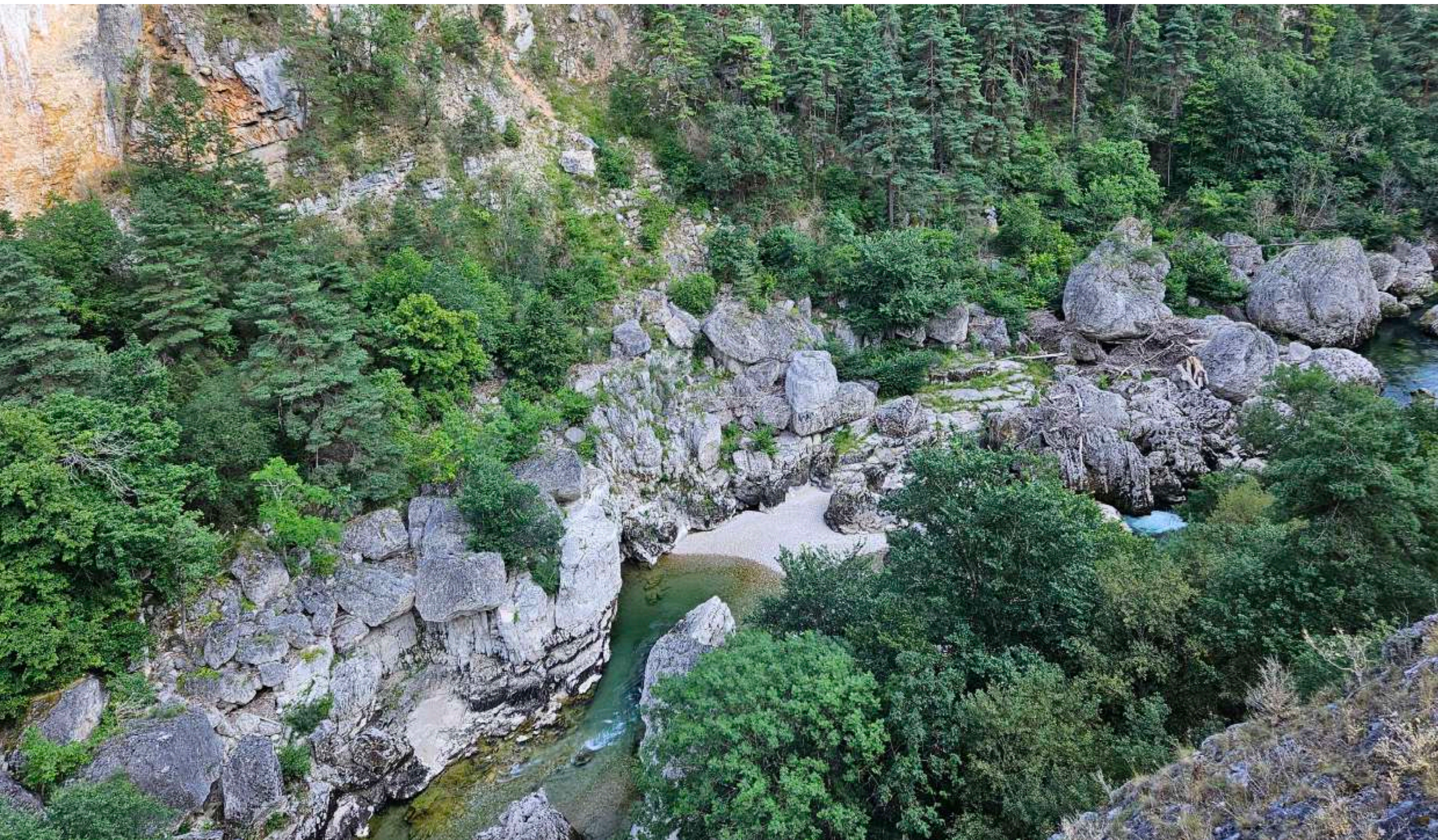
3.3 Recommendations for great alignment between CNCA methods

First, bridging the gaps between CNCA approaches involves recognising that:

- The state of ecosystems should be accounted for first, from a biodiversity conservation and recovery perspective (BD Protocol approach),
- The valuation of ecosystem services promoted or enabled by various land use choices (and associated management practices) are critical to better understand how business depends and impacts on natural capital (SEEA EA / BS 8632 approaches).

Second, this means that SEEA EA/ BS8632 should produce clearer guidance for companies so that they:

- Develop ecosystem asset typologies which would exclude land uses and be applied at the finest scale possible (sections 2.1 and 2.2),
- Produce ecosystem state information, agnostic of current or intended land use, in adherence with the ecological equivalency principle (sections 2.3 and 2.4),
- Record changes in the state of ecosystems which records periodic gains and losses as well as accumulated positive and negative impacts (section 2.5),
- Produce the associated ecosystem specific statements of position and performance (section 2.6),
- Better apply key accounting principles, such as completeness, with respect to organisational and value chain boundaries (section 2.8).



Finally, all stakeholders involved in these CNCA approaches should collaborate to find common ground on how to value and account for ecosystem services. To that end, we propose the development of separate accounts for each land use categories. This would involve:

- Characterising the land use and the various ecosystem services is it meant to supply and suppress, including beneficiaries and affected parties (type, number, location, etc.), so that ecosystem services synergies and trade-offs are explicitly accounted for,
- Developing double-entry bookkeeping equations and accounting rules for (a) the underlying biophysical measurements of the changes in their stocks and (b) externalities, separated from financial accounts,
- Producing the corresponding biophysical statements of position and performance for the different land uses, separately,
- Prescribing appropriate valuation methods for each land use, the associated ecosystem services and the relevant associated accounts (e.g., one could argue that carbon storage assets within a forest plantation could be valued differently from the broader GHG debt of a company), clearly differentiating biodiversity conservation and restoration land uses from others.

This would lead to complementary, yet separated sets of natural capital accounts, clearly illustrating how companies justify and market their past, current and future land use management practices.

Preferred reference: Houdet J., 2024. Unpacking Corporate Natural Capital Accounting. BS 8632, BD Protocol and UN SEEA). Comparative analysis of case studies. The Biodiversity Footprint Company, 54 p.

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