IPBES nexus assessment
Chapter 3, data management report 1 – review of scenarios and allocating scenarios to entry points

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Project leader(s)
Zuzana Harmáčková (harmackova.z@czechglobe.cz)
Mark Rounsevell (mark.rounsevell@kit.edu)
Odirilwe Selomane (odirilwe.selomane@gmail.com)
Emma Marjorie Awuku-Sowah
Sugeng Budiharta
Marta Coll Monton
Simon Hales
Martin Jung
Pankaj Kumar
David Leclere
Anna Metaxas
Charity Nyelele
Bruno Oliveira
Margaret Awuor Owuor
Alexander Popp
Brenda Rashleigh
Stephanie Thomas
Kazuaki Tsuchiya
Grace Villamor
TianXiang Yue

Technical support unit
Tiff van Huysen (tiff.vanhuysen@un.org)

Data curator(s)
Zuzana Harmáčková (harmackova.z@czechglobe.cz)
Mark Rounsevell (mark.rounsevell@kit.edu)
Odirilwe Selomane (odirilwe.selomane@gmail.com)
Tiff van Huysen (tiff.vanhuysen@un.org)

Description
The review detailed in this report was carried out in IPBES Nexus Assessment Chapter 3. It explored which trade-offs and synergies between the Nexus elements are described in available future scenarios, visions, pathways and other documents and materials describing potential future development. To this end, various data collection activities were carried out to cover a full range of relevant materials. The steps followed in each activity are described below.

A. Structured review

Process overview

The core review activity was a structured keyword-based search of different types of nexus-oriented futures works and scenarios. The keyword chain was designed through an iterative effort involving the chapter authors and was tested multiple times before its final use in identifying futures works for review. Acknowledging that any effort to define a keyword chain is limited, we argue that a) this keyword chain incorporates most of the terms commonly used in the futures literature focusing on nature, nature's contributions to people and good quality of life in parallel, while also focusing on the nexus and its individual elements, and b) this keyword chain has performed sufficiently well in capturing relevant studies.

Protocol

- Type of analysis/search/review: Structured review
- Search language(s): English
- Search terms: the general structure of the keyword chain was "Futures AND Nexus terms AND Nature/Biodiversity AND Food AND Water AND Health AND Climate" – see the full keyword chain below in Box 1
- Search engine: Clarivate Analytics Web of Science
- Date: 16 July 2022 – 29 October 2023
- Methodology (including the overview of selection criteria and search results):
    1. Step A.1: Keyword-based search
        - Number of hits: 4407
    2. Step A.2: Refinement by Web of Science Categories "Environmental Sciences or Environmental Studies"
        - Number of hits: 1900
        - Files: "Chapter 3 Step A.2 results.xlsx"
    3. Step A.3: Refinement by Title and Abstract scan
        - Approach: Scanning the content of the titles and abstracts of the identified study
        - Number of hits: 365
        - Files: "Chapter 3 Step A.3 results.xlsx"
    4. Step A.4: Refinement by study content
        - Approach: Text analysis of the full study
        - Number of hits: 52
        - Files: "Chapter 3 Step A.4 results.xlsx"
    5. Step A.5: Retrieving scenarios
        - Approach: Identifying individual scenarios described in each study
        - Number of identified scenarios: 186
        - Files: "Chapter 3 Step A.5 results.xlsx"
    6. Step A.5: Coding study characteristics
        - Approach: Coding key information from each study; see Table 1 for the study coding fields
    7. Step A.6: Coding scenario characteristics
        - Approach: Coding key information on each scenario included in the reviewed studies; see Table 2 for the study coding fields
    8. Step A.7: Analysis (see section C below).

Box 1. Keyword chain structure

"TS = ((future OR scenario OR vision OR pathway OR model OR impact OR ""scenario analysis"" OR ""scenario planning"" OR ""scenario building"" OR ""future scenario$"" OR ""participatory scenario$"" OR anticipatory OR ""anticipatory planning"" OR foresight OR narrative OR storyline OR strategy OR projection OR simulation OR backcasting OR forecasting OR ""scenario development"" OR ""forward$looking"" NOT (""future stud*"" OR ""future research"" OR ""future need$""))

AND (nature OR ecosystem OR biodiversity OR ecological OR environment* OR cosmos OR creation OR ""global commons"" OR protected areas OR wilderness OR wetland OR river OR forest OR grassland OR mangroves OR ?urbanization OR ecosystem services OR Nature contributions to people)

AND (food OR fisheries OR agriculture OR aquaculture OR mariculture OR paludiculture OR diet OR food production OR food consumption OR livestock OR wild animals)

AND (water OR surface water OR groundwater OR drinking water OR irrigation OR desalination OR catchment OR watershed OR snow)

AND (health OR nutrition OR disease OR pest OR zoonoses OR pollution OR zoonotic OR mental health OR psychological wellbeing OR pollen OR spillover OR public health OR allergen OR endemic OR epidemic OR outbreak OR human well-being OR dilution effect OR health OR animal health OR transmission OR virus OR bacteria OR funghi OR pathogen OR parasite OR heat stress OR heat death OR water-borne disease* OR food-borne disease* OR vector-borne disease*)

AND (climate OR mitigation OR adaptation OR climate grief OR emission OR ""greenhouse gas$"" OR methane OR carbon OR carbon dioxide)

AND (nexus OR integrated OR interacting OR interlinkages OR holistic OR complex OR systems OR tradeoffs OR synergies OR security OR rights-based OR coupled OR nexus OR multifunctional))"

Table 1. Fields used to code studies

Coded field
ID
Full reference
Does the study indeed include **future scenario(s) for the nexus (or assessment of potential future interactions within the nexus),** in order to fit the Ch3 framing? (1 = yes/ 0 = no: if 0, the study doesn't match our criteria and won't be coded)
Does the study assess the relationships between **at least three nexus elements**? (1/0: if 0, the study doesn't match our criteria and won't be coded)
Geographic scale (global/ regional/ national/ local)
IPBES region (Africa, Americas, Asia-Pacific, Europe)
Country
Location
Study type (exploratory or normative/ target-seeking)
Qualitative (L)/ Quantitative (N)/ Both?
Have the scenarios in the study been developed solely by **researchers** (R) or co-developed with **stakeholders**? (S)

Coded field
Has **indigenous or local knowledge** been incorporated in the study? (1/0)
If so, how?
Time horizon (e.g. 2025; 2030; 2050; 2100)
Full reference
Coder

Table 2. Fields used to code scenarios

Theme	**Coded field**	**Coded field ID**
General characteristics	ID	1
	Reference	1a
	Full reference	1b
	Name of scenario/ vision/ future alternative in the study (e.g. SSP1, Half Earth, etc.)	2
How many entry points does the study include? (number of elements out of biodiversity/ climate/ water/ food/ health/ other)	How many nexus element(s) does the study depart from?	3
	Which ones are they? (biodiversity/ climate/ water/ food/ health/ other)	4
	Specific focal theme (entry point as per Chapter 3 list)	5
	What intervention/target(s) does the study state for the entry point(s)? (e.g. 0%/10%/20% increase in protected areas)	6
Which nexus elements does the study assess effects on? (0/1) Please provide further specification of the type of phenomenon/ indicator in focus.	Year of effect (if the scenario includes multiple time steps, please use multiple rows)	7
	Biodiversity (B)	8
	Indicator (e.g. species distribution, a specific species, species richness...)	8a
	Baseline level of the indicator (quantified; absolute)	8b
	Resulting level (quantified; absolute)	8c
	Resulting level (quantified; relative)	8d
	Water (W)	9
	Indicator (e.g. water quality, water quantity, ...)	9a
	Baseline level of the indicator (quantified; absolute)	9b
	Resulting level (quantified; absolute)	9c
	Resulting level (quantified; relative)	9d
	Food (F)	10
	Indicator	10a
	Baseline level of the indicator (quantified; absolute)	10b

Theme	Coded field	Coded field ID
	Resulting level (quantified; absolute)	10c
	Resulting level (quantified; relative)	10d
	Climate (C)	11
	Indicator	11a
	Baseline level of the indicator (quantified; absolute)	11b
	Resulting level (quantified; absolute)	11c
	Resulting level (quantified; relative)	11d
	Health (H)	12
	Indicator?	12a
	Baseline level of the indicator (quantified; absolute)	12b
	Resulting level (quantified; absolute)	12c
	Resulting level (quantified; relative)	12d
Causal matrices	**Causal matrix of the nexus effect (coding a 5 x 5 matrix of the direction and magnitude of effect of each nexus element on each nexus element in the given scenario)**	13
Synergies/trade-offs	What **synergies/ trade-offs** has the scenario identified among the affected nexus elements?	14
Indirect drivers: standardized	Do indirect drivers in the study develop according to any standardized scenarios/ archetypes? (e.g. Economic Optimism, SSP1, SRES A1, ...). If so, please fill in the name of the scenario.	15
Indirect drivers: if the indirect drivers do not follow standardized scenarios, please indicate which indirect drivers the study focuses on (0/1).	Demography	15a
	Economy	15b
	Technology	15c
	Institutions/ governance	15d
	Socio-cultural change (incl. diets)	15e
	Other	15f
Direct drivers: standardized	Do direct drivers in the study develop according to any standardized scenarios/ archetypes? (e.g. RCP2.6). If so, please fill in the name of the scenario.	16
Direct drivers: if the direct drivers do not follow standardized scenarios, please indicate which direct drivers the study focuses on (0/1)	Climate change	16a
	Land use change	16b
	Natural resource use	16c
	Pollution	16d
	Invasive species	16e
	Other	16f
	What are the response options identified in the study? [link to Ch4, Ch5 and Ch6]	17
Policy targets: Which policy targets does the scenario influence?	SDGs	18a
	GBF	18b
	Paris Agreement	18c

Theme	Coded field	Coded field ID
Comments		19

B. Snowball sampling

Process overview

A snowball sampling approach was adopted with the aim of filling the gaps left by the systematic search. This approach focussed on the review of peer-reviewed future scenarios, visions and pathways in selected studies not identified and highlighted in the keyword search. The materials were selected based on the expertise of the Lead Authors and based on the First and Second Order Draft reviewers' comments.

Protocol

- Type of analysis/search/review: Snowball sampling of studies based on expert knowledge
- Search language(s): English
- Date: July 2022 – October 2023
- Methodology (including the overview of selection criteria and search results):
    1. Step A:1: Snowball sampling
        - See Chapter 3 references for the list of identified studies
    2. Step B.2: Analysis
        - Qualitative analysis: Expert-led content and thematic analysis of the scenario descriptions

C. Analysis

C.1. Counting scenarios

Approach:

Each of the chapter sections starts with the count of scenarios identified by the structured review (see section A above) relevant to the given section. These counts are based on the database of 186 scenarios, coding field 4 (see Table 2). It is important to note that each of the chapter sections also cites other nexus scenario studies, which were identified through snowball sampling (see section B above) and used to gain additional insights, but were not captured by the structured review.

Similarly, scenario counts are stated throughout the chapter to indicate the number of studies and scenarios matching a particular characteristic (e.g. geographic region, scale, including Indigenous and local knowledge). Again, these counts are based on the databases of 186 scenarios from 52 studies, coded as per Table 1 and Table 2.

C.2. Clustering scenarios into scenario archetypes

Approach:

Clustering the scenarios based on their causal matrices (Table 2, coded fields 13). The 186 assessed scenarios were clustered into six groups. These were derived from an analysis of the outcomes of interactions between the nexus elements in terms of the direction (positive or negative) and magnitude (seven-point scale) of each interaction and the ensuing impacts on each nexus element. and the outcomes (positive vs. negative) for each nexus element.

We conducted a hierarchical cluster analysis using the matrices to identify archetypes of scenarios, representing diverse plausible future projections of biodiversity and the other nexus elements. For this analysis, we used the mean effect on each nexus element in each scenario. To calculate pairwise dissimilarities between observations, Gower distance metrics were employed using the daisy function in the R package 'cluster' (Gower 1971; Maechler et al., 2023). It was necessary to choose a distance metric that is able to handle missing values as our dataset was characterized by a very high number of missing values (e.g., health counts 148 NA out of 186 observations). Hence, neither omitting scenarios with NA values present nor imputation of missing values was feasible. Gower distances are able to handle missing values by setting the weight of the contribution of missing values to 0 (Maechler et al., 2023). Next, we used the R package 'stats' to conduct hierarchical clustering using Ward's minimum variance method, which is specifically useful for our data as it minimizes total within-cluster variance, promoting the formation of compact and homogeneous clusters (Murtagh and Legendre 2014; R Core Team 2022). The methods have been tested on several subsets of the data and proved to produce consistent results of cluster across the subsets. All calculations have been conducted in R (R Core Team 2022).

Output:
Figure 3.6. Clusters of nexus interactions ("nexus scenario archetypes") as represented in scenarios and projected impacts of nexus scenario archetypes on each nexus element

Figure 3.7. Interactions among nexus elements for each nexus archetype showing how nexus elements influence each other

C.3. Assessing trends in indirect drivers, direct drivers and response options

Approach:
Identifying the key indirect drivers, direct drivers and response options characterizing each cluster by a content and thematic analysis of the scenario descriptions.

Trends in indirect drivers for each scenario were scored on a Likert scale {-2, -1, 0, 1, 2} based on the general trends in their underlying Shared Socioeconomic Pathway (SSP; O'Neill et al., 2017) or their scenario family (IPBES Global Assessment, 2019; chapter 4) (Table 3). Scenarios without an explicitly stated underlying SSP or scenario family were scored based on an expert interpretation of the qualitative information on indirect drivers included in the scenario description. The aggregation in trends for each archetype was calculated as a mean value.

Table 3. Key to the scoring of indirect drivers

		Indirect drivers			
		Economic (GDP)	**Institutional (Environmental regulations)**	**Cultural (Per-capita consumption)**	**Technological (Renewable energy)**
Source of rationale for the scores:		(IPBES Global Assessment; O'Neill et al., 2017)	(O'Neill et al., 2017)	(O'Neill et al., 2017)	(IPBES Global Assessment; O'Neill et al., 2017)
IPBES Global Assessment scenario family	**Shared Socioeconomic Pathway (O'Neill et al., 2017)**	**Allocated scores and rationale**			
Global Sustainable Development/ Regional sustainability	SSP1	1 "(high or) medium"	2 (Improved management of local and global issues; tighter regulation of pollutants)	0 (Low growth in material consumption, low-meat diets, first in HICs)	2 "(medium to) rapid"
Business as usual	SSP2	1 "medium"	-1 (Concern for local pollutants but only moderate success in implementation)	1 (Material-intensive consumption, medium meat consumption)	1 "medium"
Regional competition	SSP3	0 "slow"	-2 (Low priority for environmental issues)	1 (Material-intensive consumption)	0 "slow"
[Inequality]	SSP4	1 "medium"	-1 (Focus on local environment in MICs, HICs; little attention to vulnerable areas or global issues)	1 (Elites: high consumption lifestyles; Rest: low consumption, low mobility)	1 "medium"
Economic optimism/ Reformed markets	SSP5	2 "very rapid"	-1 (Focus on local environment with obvious benefits to well-being, little concern with global problems)	2 (Materialism, status consumption, tourism, mobility, meat-rich diets)	2 "rapid"

Output:
Figure 3.8. The aggregate trends in indirect drivers represented in the scenarios across the six nexus scenario archetypes

C.4. Assessing outcomes for policy goals

Approach:
Each scenario was scored based on its relevance for achieving policy goals (Table 2, coded field 18a-18c). Each policy goal was scored on a scale of 1 (positive influence on achieving a policy goal), 0 (neutral influence on achieving a policy goal) or -1 (negative influence on achieving a policy goal). The aggregate relevance for achieving each policy goal for each archetype was calculated as a mean value across included scenarios.

Output:
Table 3.5. Number of scenarios with relevance to each Sustainable Development Goal

Figure 3.9. Proportion of scenarios within each archetype that have negative, neutral or positive outcomes for the Sustainable Development Goals

C.5. Assessing future potential co-occurrence for nexus indicators

Approach:
An explorative spatial analysis of potential future co-occurrence of different two-way interactions between nexus elements (e.g., biodiversity-climate change, water-health, water-food) using globally available quantitative data.

Data sources:
ISIMIP (https://data.isimip.org/search/), and BES-SIM (https://portal.geobon.org/) gridded scenario projections of available indicators up to 2050. A full list of used data sources as well as R-scripts to reproduce the figure in principle can be found in https://github.com/Martin-Jung/IPBES_NexusRelativeScenarioTrends.

- Variables:
    - Biotic intactness
    - Terrestrial protected areas
    - Bioenergy production
    - Coastal flooding risk
    - Multi-sectoral climate risk
    - Ocean pH values
    - Irrigated summer wheat yield
    - Total fish catch
    - Heat mortality
    - Length of infections transmission season
    - Total actual water withdrawal
    - Total potential water supply

Data processing:
Scenario projections rely primarily on the Shared Socioeconomic Pathways (SSP) narratives and for each indicator a low and high ambition estimate was extracted from the original data sources, and mapped to two potential future policy ambition pathways:

- Low ambition climate mitigation policy pathway (e.g., SSP5-8.5)
- High ambition climate mitigation policy pathway (e.g., SSP1-2.6)

For scenario data not explicitly following an SSP or RCP pathway, the respective scenario data was mapped to low and high policy ambition respectively (e.g. 30x30 protection vs Half-Earth).

Analysis:
A description of the methodological steps can also be found in the Readme file on the repository linked above.

- Spatially explicit:
    1. Calculating a relative difference between the projected state of scenario indicators in 2050 and their current levels.
    2. Normalizing the difference to a range from 0 to 1.
    3. Calculating the average (arithmetic mean) across variables.
- Aggregate trends (non-spatial)
    1. Extracting the starting value and estimates for a timeline up to 2050 for each indicator.
    2. Plotting the results.
- Assessing spatial-explicit data gaps in terms of the potential availability of quantified indicators per each nexus element, realm (terrestrial/marine) and policy ambition pathway.

Gaps were estimated as the difference between grid cells with available future indicator projections and the theoretical possible number of having at least one indicator for each nexus element.

Scripts:
A full list of used R-scripts to produce the figure can be found in https://github.com/Martin-Jung/IPBES_NexusRelativeScenarioTrends.

Outcome:
Figure 3.10. Future potential co-occurrence for nexus interactions

File(s) attached

Chapter 3 Step A.2 results.xlsx
Chapter 3 Step A.3 results.xlsx
Chapter 3 Step A.4 results.xlsx
Chapter 3 Step A.5 results.xlsx

References

Gower J C (1971). A general coefficient of similarity and some of its properties, Biometrics 27, 857–874.

Maechler M, Rousseeuw P, Struyf A, Hubert M, Hornik K (2023). cluster: Cluster Analysis Basics and Extensions. R package version 2.1.6 — For new features, see the 'NEWS' and the 'Changelog' file in the package source), https://CRAN.R-project.org/package=cluster.

Murtagh F, Legendre P (2014). Ward's hierarchical agglomerative clustering method: which algorithms implement Ward's criterion? Journal of Classification, 31, 274–295.

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/