Threatened ecosystems of Ruritania

An IUCN Red List of Ecosystems Assessment

Jane Smith José García Wei Wang

1234-12-31

Table of contents

Home

Jane Smith
José García
Wei Wang

1234 | Version 0.1

❗ How to customize the Home page

- Edit the `_quarto.yml` file:
  - Update the `version` value
  - Update the `book.title` value
- Edit the `index.qmd` file:
  - Update the `subtitle` value
  - Update the `authors` list

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

Foreword

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sagittis posuere ligula sit amet lacinia. Duis dignissim pellentesque magna, rhoncus congue sapien finibus mollis. Ut eu sem laoreet, vehicula ipsum in, convallis erat. Vestibulum magna sem, blandit pulvinar augue sit amet, auctor malesuada sapien. Nullam faucibus leo eget eros hendrerit, non laoreet ipsum lacinia. Curabitur cursus diam elit, non tempus ante volutpat a. Quisque hendrerit blandit purus non fringilla. Integer sit amet elit viverra ante dapibus semper. Vestibulum viverra rutrum enim, at luctus enim posuere eu. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

! How to customize the Foreword page

- To modify the foreword text, edit the `content/0.1_foreword.qmd` file.
- To add an author to the foreword, add the author's name to the `authors` list in the YAML header of the `0.1_foreword.qmd` file. For example:

```yaml
authors:
    - name: Ima Author
```

- To remove the foreword section, edit the `_quarto.yml` file and remove the `- content/0.1_foreword.qmd` line.

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

Preface

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sagittis posuere ligula sit amet lacinia. Duis dignissim pellentesque magna, rhoncus congue sapien finibus mollis. Ut eu sem laoreet, vehicula ipsum in, convallis erat. Vestibulum magna sem, blandit pulvinar augue sit amet, auctor malesuada sapien. Nullam faucibus leo eget eros hendrerit, non laoreet ipsum lacinia. Curabitur cursus diam elit, non tempus ante volutpat a. Quisque hendrerit blandit purus non fringilla. Integer sit amet elit viverra ante dapibus semper. Vestibulum viverra rutrum enim, at luctus enim posuere eu. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

! How to customize the Preface page

- To modify the preface text, edit the `content/0.2_preface.qmd` file.
- To add an author to the preface, add the author's name to the `authors` list in the YAML header of the `0.2_preface.qmd` file. For example:

```yaml
authors:
    - name: Ima Author
```

- To remove the preface section, edit the `_quarto.yml` file and remove the `- content/0.2_preface.qmd` line.

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

Acknowledgments

We gratefully acknowledge the efforts of hundreds of scientists and practitioners who have contributed to the understanding of Ruritania's terrestrial ecosystems. Our work is largely a synthesis exercise that would not have been possible without the dedication and contributions of those before us.

We also acknowledge all contributors to this project, particularly those who attended workshops in Ruritania. Without input from a large and diverse expert group, the development of the Ruritania Ecosystem Typology, the ecosystem descriptions and the application of the criteria would not have been possible. We also acknowledge the crucial support of … Contributors to this assessment are listed within each ecosystem assessment and in Appendix 1.

The work to develop an IUCN Red List of Ecosystems of Ruritania was made possible through the funding and support of …

! How to customize the Acknowledgments page

- To modify the acknowledgments text, edit the `content/0.3_acknowledgments.qmd` file.
- To remove the acknowledgments section, edit the `_quarto.yml` file and remove the `- content/0.3_acknowledgments.qmd` line.

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

Coordinating Organizations

Organization #1

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sagittis posuere ligula sit amet lacinia. Duis dignissim pellentesque magna, rhoncus congue sapien finibus mollis. Ut eu sem laoreet, vehicula ipsum in, convallis erat. Vestibulum magna sem, blandit pulvinar augue sit amet, auctor malesuada sapien. Nullam faucibus leo eget eros hendrerit, non laoreet ipsum lacinia. Curabitur cursus diam elit, non tempus ante volutpat a. Quisque hendrerit blandit purus non fringilla. Integer sit amet elit viverra ante dapibus semper. Vestibulum viverra rutrum enim, at luctus enim posuere eu. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

Organization #2

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sagittis posuere ligula sit amet lacinia. Duis dignissim pellentesque magna, rhoncus congue sapien finibus mollis. Ut eu sem laoreet, vehicula ipsum in, convallis erat. Vestibulum magna sem, blandit pulvinar augue sit amet, auctor malesuada sapien. Nullam faucibus leo eget eros hendrerit, non laoreet ipsum lacinia. Curabitur cursus diam elit, non tempus ante volutpat a. Quisque hendrerit blandit purus non fringilla. Integer sit amet elit viverra ante dapibus semper. Vestibulum viverra rutrum enim, at luctus enim posuere eu. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

! How to customize the Coordinating Organizations page

- To modify the coordinating organizations text, edit the `content/0.4_coordinating_orgs.qmd` file.
- To remove the coordinating organizations section, edit the `_quarto.yml` file and remove the `- content/0.4_coordinating_orgs.qmd` line.

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

Summary

We gratefully acknowledge the efforts of hundreds of scientists and practitioners who have contributed to the understanding of Ruritania's terrestrial ecosystems over the past two centuries. Our work is largely a synthesis exercise that would not have been possible without the dedication and contributions of those before us.

We also acknowledge all contributors to this project, particularly those who attended workshops in Ruritania. Without input from a large and diverse expert group, the development of the Ruritania Ecosystem Typology, the ecosystem descriptions and the application of the criteria would not have been possible. We also acknowledge the crucial support of … Contributors to this assessment are listed within each ecosystem assessment and in Appendix 1.

The work to develop an IUCN Red List of Ecosystems of Ruritania was made possible through the funding and support of …

❗ How to customize the Summary page

- To modify the summary text, edit the `content/0.5_summary.qmd` file.
- To remove the summary section, edit the `_quarto.yml` file and remove the `- content/0.5_summary.qmd` line.

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

Introduction

Background

To support the Ruritania National Ecosystem Assessment, Ruritania's terrestrial ecosystems were assessed under the International Union for the Conservation of Nature (IUCN) Red List of Ecosystems Categories and Criteria.

This report describes the development of the IUCN Red List of Ecosystems for Ruritania, which included:

- A detailed literature review of all published and unpublished material relevant to the status of ecosystems in Ruritania;
- The development of an ecosystem typology for Ruritania suitable for conducting a national scale IUCN Red List of Ecosystems assessment;
- …
- An expert review process for the ecosystem typology, descriptions and assessments.

! How to customize the Background section of the Introduction

- To modify the background text, edit the `content/1.1_background.qmd` file.
- To remove the background section, edit the `content/1.0_introduction.qmd` file and remove the `{{< include 1.1_background.qmd >}}` line.

To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.

The ecosystems of Ruritania: an overview

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis sagittis posuere ligula sit amet lacinia. Duis dignissim pellentesque magna, rhoncus congue sapien finibus mollis. Ut eu sem laoreet, vehicula ipsum in, convallis erat. Vestibulum magna sem, blandit pulvinar augue sit amet, auctor malesuada sapien. Nullam faucibus leo eget eros hendrerit, non laoreet ipsum lacinia. Curabitur cursus diam elit, non tempus ante volutpat a. Quisque hendrerit blandit purus non fringilla. Integer sit amet elit viverra ante dapibus semper. Vestibulum viverra

Figure 1: A map of Ruritania showing the area of assessment in grey

rutrum enim, at luctus enim posuere eu. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

Nunc ac dignissim magna. Vestibulum vitae egestas elit. Proin feugiat leo quis ante condimentum, eu ornare mauris feugiat. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris cursus laoreet ex, dignissim bibendum est posuere iaculis. Suspendisse et maximus elit. In fringilla gravida ornare. Aenean id lectus pulvinar, sagittis felis nec, rutrum risus. Nam vel neque eu arcu blandit fringilla et in quam. Aliquam luctus est sit amet vestibulum eleifend. Phasellus elementum sagittis molestie. Proin tempor lorem arcu, at condimentum purus volutpat eu. Fusce et pellentesque ligula. Pellentesque id tellus at erat luctus fringilla. Suspendisse potenti.

> **!** How to customize the Overview section of the Introduction
>
> - To modify the overview text, edit the `content/1.2_overview.qmd` file.
> - To remove the overview section, edit the `content/1.0_introduction.qmd` file and remove the `{{< include 1.2_overview.qmd >}}` line.
>
> **To hide these instructions on all pages, set `show-instructions: false` in the `_quarto.yml` file.**

Introduction to the IUCN Red List of Ecosystems

The IUCN Red List of Ecosystems (RLE) aims to support conservation in resource use and management decisions by identifying ecosystems most at risk of loss or collapse (D. A. Keith et al. 2013, 2015). Similar to the IUCN Red List of Threatened Species, the outcome of an RLE assessment is a list of ecosystems and their status for a region (Figure 1.4; (Rodríguez et al. 2011)). Because the RLE was developed to promote a consistent framework suitable for assessing and monitoring the status of ecosystems, it enables comparisons of collapse risk between countries, locations and ecosystem types (D. A. Keith et al. 2013).

For further information on the development of the RLE protocol, the theory and scientific foundations upon which they were developed, and detailed information on the purpose of each of the five criteria refer to the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria (L. Bland et al. 2017). More information on the IUCN Red List of Ecosystems, is available in multiple languages on the IUCN Red List of Ecosystems website (www.iucnrle.org).

Assessments of ecosystem types (commonly termed ‘assessment units’ within Red List of Ecosystems assessments) are conducted by applying five criteria and their associated thresholds, enabling each ecosystem type to be classified according to their risk of collapse (termed ‘status’). To ensure the assessment process is transparent and repeatable, each ecosystem type is clearly described according to the IUCN Red List of Ecosystems guidelines (L. Bland et al. 2017).

This standard approach of applying the IUCN Red List of Ecosystems Categories and Criteria to clearly described ecosystems is critical to allow for accurate, comparable and repeatable assessments of ecosystems status and to contribute to the global IUCN Red List of Ecosystems programme.

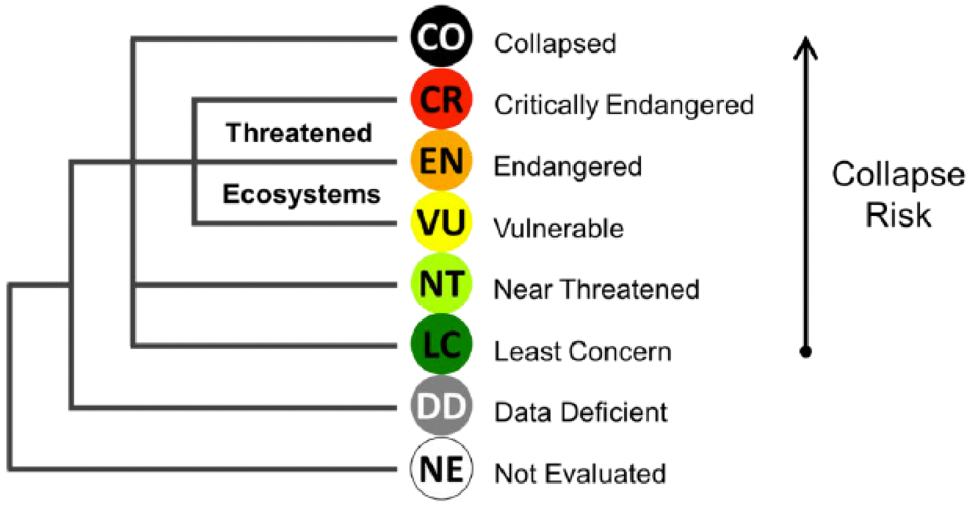

Figure 2: The IUCN Red List of Ecosystems categories, indicating the status of ecosystems. Threatened ecosystems are those assessed as Vulnerable, Endangered, or Critically Endangered. Source: (L. Bland et al. 2017)

Definitions

There are several key concepts that must be clearly defined to allow for repeatable ecosystem risk assessments:

Risk

Risk is defined as the probability of an adverse outcome over a specified time-frame. Here, the adverse outcome is the endpoint of ecosystem decline, which the RLE terms ecosystem collapse.

Ecosystem collapse

Understanding the concept of ecosystem collapse is critical for interpreting IUCN RLE assessments. For the purposes of the RLE, "an ecosystem is Collapsed when it is virtually certain that its defining biotic or abiotic features are lost from all occurrences, and the characteristic native biota are no longer sustained. Collapse may occur when most of the diagnostic components of the characteristic native biota are lost from the system, or when functional components (biota that perform key roles in ecosystem organisation) are greatly reduced in abundance and lose the ability to recruit." According to the IUCN guidelines (L. Bland et al. 2017), risks to ecosystems can be caused by a variety of threatening processes that are expressed through different symptoms of ecosystem collapse. The RLE risk model groups these symptoms into four major types, which ultimately form the RLE criteria (Figure 3).

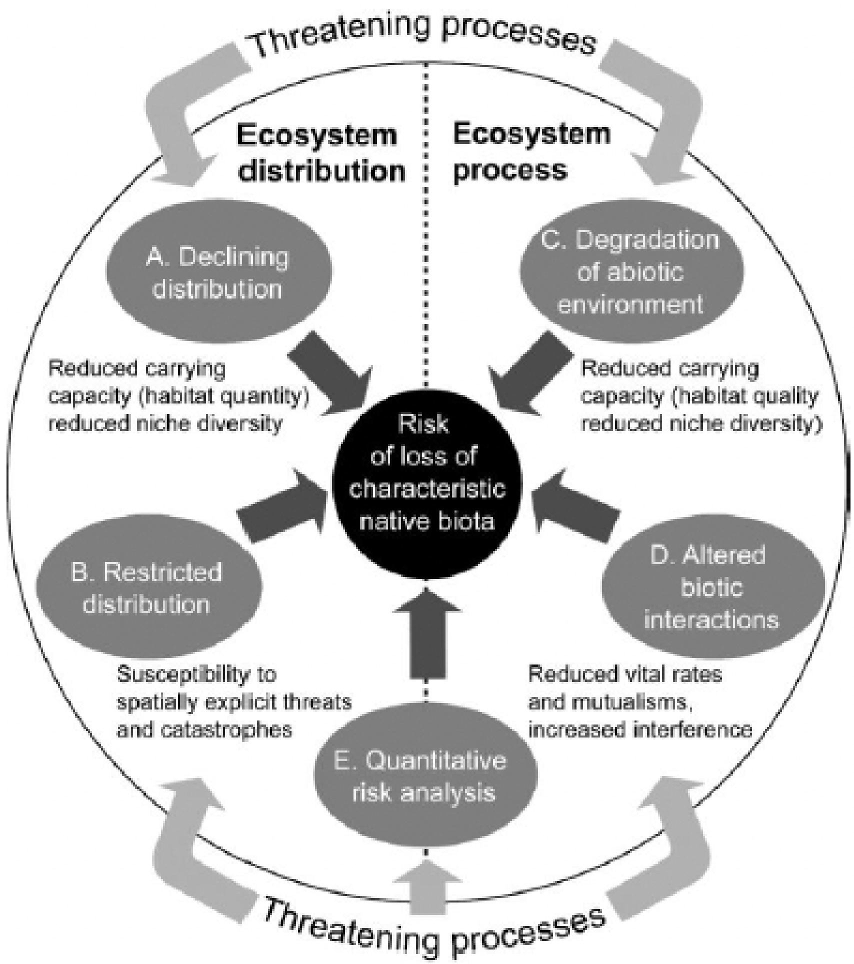

Figure 3: The IUCN Red List of Ecosystems risk assessment model. Source: (L. Bland et al. 2017).

For more information on the concept of collapse and how to identify when an ecosystem is collapsed, we recommend referring to the IUCN Red List of Ecosystems guidelines, which describes this in detail (Bland et al., 2017a; Bland et al., 2018). In this report and as recommended by the guidelines, we explicitly define collapse for each ecosystem type in Myanmar in their ecosystem descriptions (See section 3).

Time frames

Because risks must be assessed over specified time frames, a standard set of time frames are carefully defined in the IUCN Red List of Ecosystems Categories and Criteria. There are four specified time frames used in the RLE:

- The historical past. We notionally use the year 1750, which marks the onset of industrial-scale exploitation of ecosystems in South-East Asia;
- The recent past. This is the past 50 years (1969-2019), which is considered long enough to distinguish directional change from natural variability;
- Any 50-year period including the recent past, present and future. Predictions and inferences based on past declines, simulation models and any other model considered suitable for assessing risks into the future may be used.
- The future. Again, predictions are required to assess risks over this time frame and are usually based on models that use information about the response of ecosystems to threatening processes.

IUCN Red List of Ecosystems Categories and Criteria

IUCN Red List of Ecosystems Criteria

To assess the risk of ecosystem collapse, each ecosystem is assessed under five rule-based criteria that form the IUCN Red List of Ecosystems Criteria. These criteria were developed following nearly a decade of scientific work focused on understanding pathways of ecosystem decline, degradation, loss and collapse (Nicholson, Keith, and Wilcove 2009; Rodríguez et al. 2011, 2015; D. A. Keith et al. 2013, 2015; L. M. Bland et al. 2017; Murray et al. 2017, 2018; D. A. Keith, Akçakaya, and Murray 2018). Importantly, they relate the symptoms of ecosystem decline with the risk that an ecosystem will lose its defining features. The five criteria were designed to target different symptoms of ecosystem collapse (Figure 3). These symptoms are both distributional and functional:

- **Criterion A**: declines in distribution, which reduce carrying capacity for dependent biota;
- **Criterion B**: restricted distribution, which predisposes the system to spatially explicit threats;
- **Criterion C**: degradation of the abiotic environment, reducing habitat quality or abiotic niche diversity for component biota; and
- **Criterion D**: disruption of biotic processes and interactions

- **Criterion E**: allows for the integration of the above four symptoms into a simulation model of ecosystem dynamics to allow quantitative estimates of the risk of ecosystem collapse.

For further information on the criteria refer to the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria (L. Bland et al. 2017).

Categories

Applying thresholds (decision rules) for each of the IUCN RLE criteria enables each ecosystem to be assigned to a category of risk ('status'). An ecosystem assessed under the RLE criteria can be placed into eight categories: Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE, Figure 2).

The first six categories (CO, CR, EN, VU, NT and LC) are ordered in decreasing risk of collapse. The categories Data Deficient and Not Evaluated do not indicate a level of risk. For further details of the categories refer to the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria (L. Bland et al. 2017). We applied version 2.2 of the IUCN Red List of Ecosystems Criteria (Table 1.1).

> ⚠ TODO: Add Table 1.1
>
> The IUCN Red List of Ecosystems Criteria, Version 2.2. Source: (L. Bland et al. 2017).

Assessment process

Application of the IUCN Red List of Ecosystems Categories and Criteria follows a generic sequential process that includes:

- Adapting the newly developed global ecosystem typology (D. A. Keith, Ferrer-Paris, Nicholson, Bishop, et al. 2020; D. Keith et al. 2022) to the area of assessment (Myanmar's terrestrial environment, Figure 1). This process is guided by experts and the result is a list of ecosystem types for the area of assessment that will be assessed under the RLE protocol;
- Describing each of the ecosystem types in ecosystem typology following the standard approach detailed in the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria (L. Bland et al. 2017);
- If no map data is available to support the assessment, an ecosystem mapping project is required to support the ecosystem descriptions and assessment of several of the RLE criteria;

- Applying the assessment criteria to each ecosystem type, which requires extensive data searches and analyses. The outcome of each ecosystem assessment consists of a status of the ecosystem under 5 criteria and 18 subcriteria of the IUCN Red List of Ecosystems categories and criteria;
- Compiling the results into a comprehensive IUCN Red List of Ecosystems for the area of assessment (this report), which describes each ecosystem and identifies ecosystems according to their risk of collapse.

This report details each of these steps in the following sections.

Terrestrial Ecosystems of Ruritania

The Ruritania ecosystem typology includes 3 ecosystem types across 3 biomes (Table 1). The ecosystem typology is consistent with the IUCN global ecosystem typology (D. A. Keith, Ferrer-Paris, Nicholson, and Kingsford 2020) to support crosswalks and comparisons with Red Lists of ecosystems in other countries and regions. The Ruritania ecosystem typology has a hierarchical structure, where each ecosystem type is assigned to a realm, biome and functional group (ecotype). Realm refers to one of the four component media in the biosphere (Figure 1), biome is the segment of the biosphere united by major functional traits and macro-environmental features (Figure 2), and functional group is a group of related ecosystems within a biome (Figure 3). The distribution of Ruritania's ecosystem types is shown in Figure 4, and map data is made publicly available (reference?).

Table 1: List of the terrestrial ecosystems of Ruritania developed in this project.

ECO_CODE	id	COD	ECO_NAME	Glob_Typol
REALM: Terrestre (T)				
Bioma de bosques tropicales y subtropicales (T1)				
Bosques lluviosos tropicales y subtropicales de tierras bajas (T1.1)				
T1.1.1	00000000000000000000	D01	Null Island Tropical Forest	T1.1_NullIsland_forest_D01
Bioma polar/alpino (criogenico) (T6)				
Pastizales y herbazales de altas montanas tropicales (T6.5)				
T6.5.1	00000000000000000001	D03	Null Island Alpine Grassland	T6.5_NullIsland_alpine_D03
REALM: Marina (M)				
Bioma de plataforma marina (M1)				
Praderas marinas (M1.1)				
M1.1.1	00000000000000000002	D02	Null Island Marine Shelf	M1.1_NullIsland_marine_she

! How to customize the Ecosystem Overview page

- To modify the ecosystem overview text, edit the `content/2_ecosystem_overview.qmd` file.
- To remove the ecosystem overview section, edit the `_quarto.yml` file and remove the `- content/2_ecosystem_overview.qmd` line.

To hide these instructions on all pages, set `show-instructions: false` in the

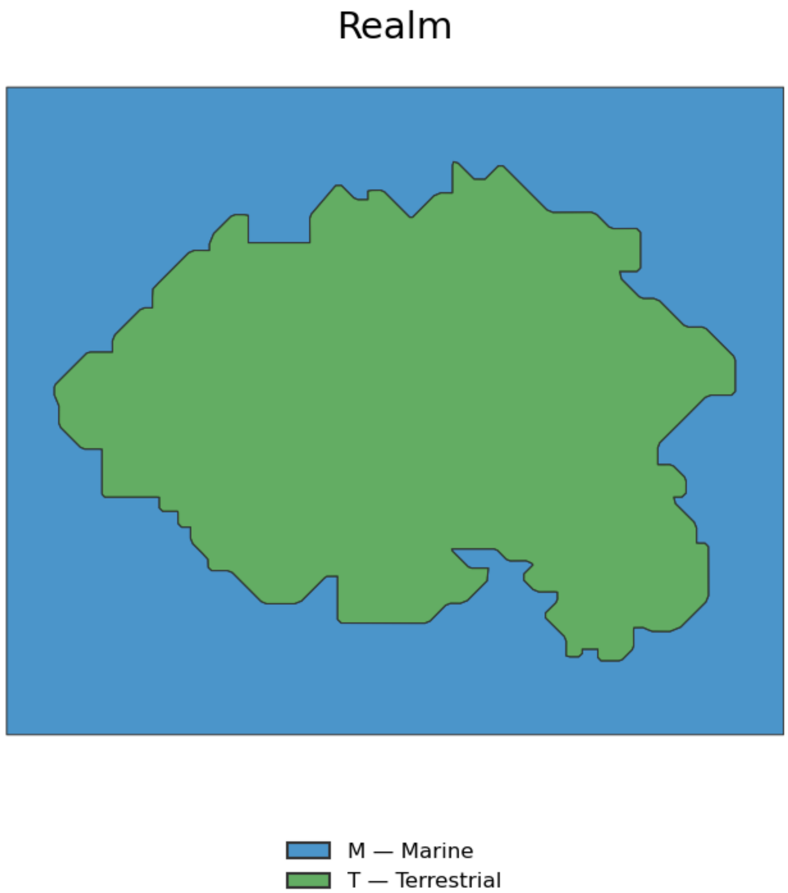

Figure 1: The distribution of the realms of Ruritania.

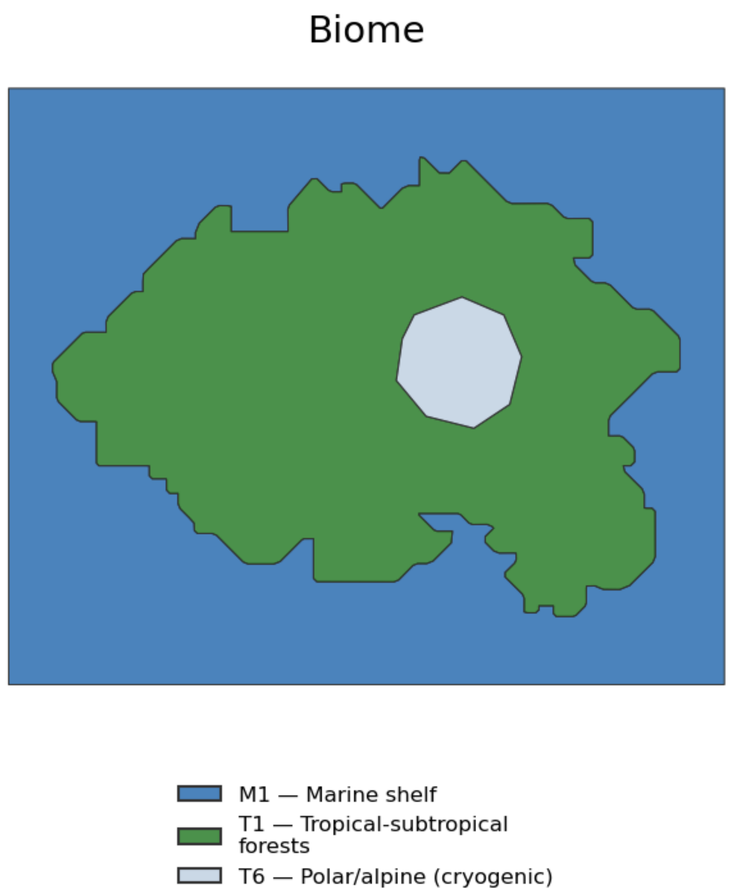

Figure 2: The distribution of the biomes of Ruritania.

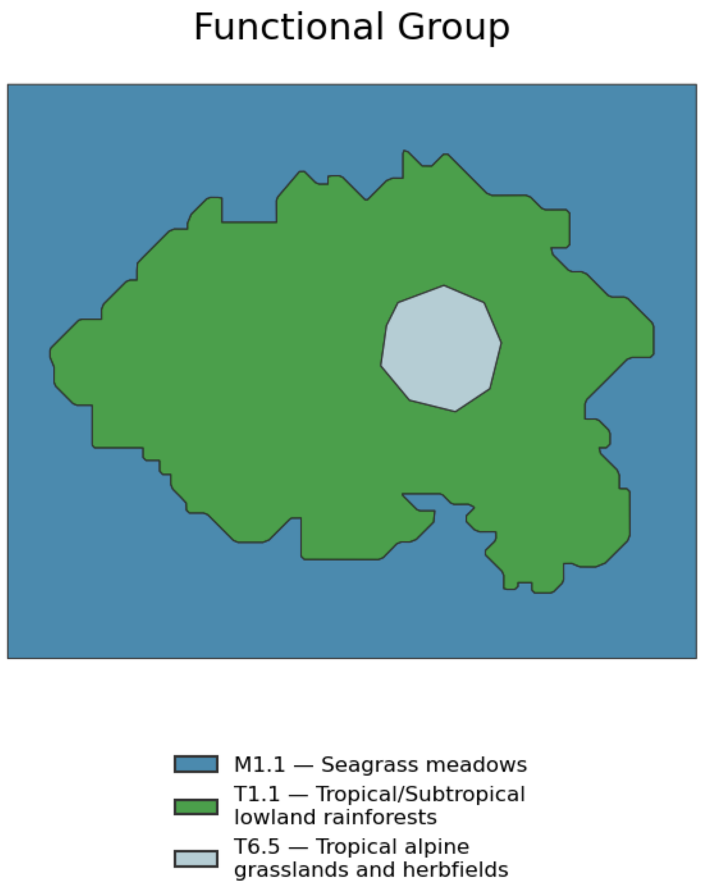

Figure 3: The distribution of the biomes of Ruritania.

`(Heat map of the distribution of natural ecosystem types not implemented yet.)`

Figure 4

_quarto.yml file.

Ecosystem description and assessment

Ecosystem accounts provided in this section consist of two components, an ecosystem description and a detailed summary of the application of the IUCN Red List of Ecosystem criteria. The ecosystem description follows the standard format suggested by the IUCN. Ecosystem descriptions are an essential component of IUCN Red List of Ecosystems assessments and serve the purpose of clearly defining each assessment unit. This allows repeated application of the categories and criteria to a single defined unit and supports red listing and cross-walking at the global scale. The associated assessment section provides the details the Red List assessments, including the data sources, methods of analysis, evidence statements and key references.

Table 1: Components of ecosystem description

Component	Description
Authors	Authors of the description and the assessment.
Myanmar ecosystem names	Alternative names of the ecosystem.
Biome	Biome membership according to the global ecosystem typology.
Functional group	Functional group membership according to the global ecosystem typology.
Global classification	Classification code according to the global ecosystem typology.
Description	General overview of the principal components and dynamics of the ecosystem. Includes a photograph of the ecosystem.
Distribution	Short written description and range map of the spatial distribution of the ecosystem.
Characteristic native biota	Identifies the defining biotic features of the ecosystem, including diagnostic native taxa, functional components of the characteristic biota.
Abiotic environment	Identifies the defining abiotic features of the ecosystem, including descriptions of the characteristic states or summary of values of the key abiotic variables.
Key processes and interactions	Describes the key ecosystem drivers and interactions among biota and the abiotic environment.

Component	Description
Major threats	Short summary of the major threats and impacts to the ecosystem.
Ecosystem collapse definition	Short description of the collapsed state of the ecosystem and any associated thresholds.
Assessment summary	Short summary of the red list of ecosystems assessment.
Assessment outcome	Short format assessed status of the ecosystem.
IUCN Red List of Ecosystems Categories and Criteria	Version of the IUCN Red List of Ecosystems criteria used in the assessment.
Year published	Publication year.
Date assessed	The date the ecosystem assessment was completed.
Assessment credits	Names the authors, reviewers and contributors to the assessment.
Assessment summary	Short summary of the red list of ecosystems assessment.
Criterion A	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion B	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion C	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion D	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion E	Description of data, analysis and methods used to assess the criterion and the status outcome.

M1.1.1 - Null Island Marine Shelf

Assessment

Null Island Marine Shelf

Authors: John Smith, Jane Smith

Biome: TODO

Functional Group: M1.1

Global classification: M1.1.1

IUCN Status: TODO

Description: TODO

Distribution: TODO

Characteristic Native Biota: TODO

Abiotic environment: TODO

Key processes and interactions: TODO

Major threats: TODO

Ecosystem collapse definition: TODO

Assessment summary: **TODO**

Assessment information:

Criteria

Status

Criterion A

A1

NE

A2a

NE

A2b

NE

A3

NE

Criterion B

B1

NE

B2

NE

subcriteria

NE

B3

NE

Criterion C

C1

NE

C2a

NE

C2b

NE

C3

NE

Criterion D

D1

NE

D2a

NE

D2b

NE

D3

NE

Criterion E

E

NE

Assessment outcome: **TODO**

Year published: TODO

Date assessed: TODO

Assessment credits:

Assessed by: TODO

Reviewed by: TODO

Contributions by: TODO

Criterion A: TODO

Criterion B: AOO was measured as 4 (10 km x 10 km) grid cells . EOO was measured as 148 km^2.

Criterion C: TODO

Criterion D: TODO

Criterion E: TODO

Criterion B Details

```
# Default ecosystem code for template development.
# This line is replaced by build_ecosystem_pages.py for each ecosystem.
ecosystem_code = 'M1.1.1'
```

Import Python modules.

```
import os
import yaml
from pathlib import Path
from lonboard import Map
from rle_python_gee.ecosystems import Ecosystems
from rle_python_gee.eoo import make_eoo
from rle_python_gee.aoo import make_aoo_grid
```

Load the country config file.

```
project_root = os.environ.get('PIXI_PROJECT_ROOT', str(Path('..').resolve()))
config_path = Path(project_root) / 'config' / 'country_config.yaml'
with open(config_path) as f:
    config = yaml.safe_load(f)
```

Load & Filter Ecosystem Data

Load data for all the ecosystems.

```
source = config['ecosystem_source']
ecosystems = Ecosystems.from_file(
    source['data'],
    ecosystem_column=source['ecosystem_code_column'],
    ecosystem_name_column=source['ecosystem_name_column'],
    functional_group_column=source['functional_group_column']
)
```

Filter by the M1.1.1 and check the number of features.

```
ecosystem = ecosystems.filter(ecosystem_code)
has_data = ecosystem.size() > 0
print(f'{ecosystem.size() = }')
if not has_data:
    from IPython.display import Markdown, display
    display(Markdown(
        f'**No spatial data found for {ecosystem_code}.** '
        f'Criterion B calculations are skipped.'
    ))
```

```
ecosystem.size() = 1
```

Extent of Occurrence (EOO) (subcriterion B1)

> **Extent of occurrence (EOO).** The EOO of an ecosystem is the area (km2) of a minimum convex polygon – the smallest polygon in which no internal angle exceeds 180° that encompasses all known current spatial occurrences of the ecosystem type.
>
> The minimum convex polygon (also known as a convex hull) must not exclude any areas, discontinuities or disjunctions, regardless of whether the ecosystem can occur in those areas or not. Regions such as oceans (for terrestrial ecosystems), land (for coastal or marine ecosystems), or areas outside the study area (such as in a different country) must remain included within the minimum convex polygon to ensure that this standardised method is comparable across ecosystem types. In addition, these features contribute to spreading risks across the distribution of the ecosystem by making different parts of its distribution more spatially independent.

Calculate EOO

Start by calculating the convex hull of the ecosystem's distribution.

```
import geopandas as gpd

if has_data:
    ecosystem_geometry = ecosystem.geometry.union_all()
    gdf_ecosystem_polygons = gpd.GeoDataFrame(geometry=[ecosystem_geometry], crs=ecosystem.ge
    hull = ecosystem_geometry.convex_hull
    gdf_hull = gpd.GeoDataFrame(geometry=[hull], crs=ecosystem.geometry.crs)
```

Display the ecosystem's distribution and the convex hull.

```
from lonboard import Map, PolygonLayer
from rle_python_gee.viz import smart_map

if has_data:
    eoo_hull = make_eoo(ecosystem).compute()
    display(smart_map([eoo_hull, ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f959853cb50>, VBox(children=(ErrorOutput(), E
```

```
if has_data:
    hull_ea = gdf_hull.to_crs("ESRI:54034")
    eoo = hull_ea.geometry.iloc[0].area / 1e6
    print(f'EOO is {eoo:.1f} km2')
```

```
EOO is 147.7 km2
```

Then calculate the area of the convex hull polygon.

Direct calculation of EOO

EOO can also be calculated directly using …

```
if has_data:
    ecosystem.eoo
```

Verify that the area returned by calling `make_eoo(ecosystem).compute().area_km2` is the same as the area of the convex hull polygon.

```
if has_data:
    assert ecosystem.eoo == eoo
```

Area of Occupancy (AOO) (subcriterion B2)

The protocol for this adjustment includes the following steps:

(1) Intersect AOO grid with the ecosystem's distribution map.
(2) Calculate extent of the ecosystem type in each grid cell (`area`) and sum these areas to obtain the total ecosystem area (`total area`).
(3) Arrange grid cells in ascending order based on their area (smaller first). Calculate accumulated sum of area per cell (`cumulative area`).
(4) Calculate `cumulative proportion` by dividing `cumulative area` by `total area` (cumulative proportion takes values between 0 and 1)
(5) Calculate AOO by counting the number of cells with a `cumulative proportion` greater than 0.01 (i.e. exclude cells that in combination account for up to 1% of the total mapped extent of the ecosystem type).

AOO Calculation Details

Intersect AOO grid and ecosystem map

(1) Intersect AOO grid with the ecosystem's distribution map

```
from pathlib import Path
from rle_python_gee.aoo import make_aoo_grid_cached

if has_data:
    cache_path = Path(project_root) / '.cache' / 'aoo_grid.parquet'
    aoo_grid = make_aoo_grid_cached(ecosystems, cache_path=cache_path)
    aoo_grid_filtered = aoo_grid.filter_by_ecosystem(ecosystem_code)
```

Visualize variations in the AOO grid.

```
from matplotlib.colors import LinearSegmentedColormap
from lonboard.colormap import apply_continuous_cmap
from rle_python_gee.aoo import slugify_ecosystem_name

ecosystem_column = slugify_ecosystem_name(ecosystem_code)
if has_data:
    cmap = LinearSegmentedColormap.from_list("white_red", ["white", "red"])
    values = aoo_grid_filtered.grid_cells[ecosystem_column].values
    normalized = (values - values.min()) / (values.max() - values.min())
    colors = apply_continuous_cmap(normalized, cmap)
    display(smart_map([(aoo_grid_filtered, {"get_fill_color": colors}), ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f9590603ad0>, VBox(children=(ErrorOutput(), E
```

Calculate grid cell area and total area

(2) Calculate extent of the ecosystem type in each grid cell (`area`) and sum these areas to obtain the total ecosystem area (`total area`).

```
if has_data:
    keep = ['geometry', 'grid_col', 'grid_row', ecosystem_column]
    gdf = aoo_grid_filtered.grid_cells[keep]
    display(gdf)
```

	geometry	grid_col	grid_row	M1_1_1
0	POLYGON ((0 -0.09044, 0 0, -0.08983 0, -0.0898...	-1	-1	0.230587
1	POLYGON ((0 0, 0 0.09044, -0.08983 0.09044, -0...	-1	0	0.219648
2	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.193924
3	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.195383

The column M1_1_1 contains the (fractional) area of the ecosystem in each grid cell.

Sum up the areas of each grid cell to get the total area.

```
if has_data:
    total_area = gdf[ecosystem_column].sum()
    display(total_area)
```

```
np.float64(0.8395422984320867)
```

Calculate cumulative area

(3) Arrange grid cells in ascending order based on their area (smaller first). Calculate accumulated sum of area per cell (`cumulative area`).

```
if has_data:
    gdf = gdf.sort_values(by=ecosystem_column)
    gdf["cumulative_area"] = gdf[ecosystem_column].cumsum()
    display(gdf)
```

	geometry	grid_col	grid_row	M1_1_1	cumulative_area
2	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.193924	0.193924
3	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.195383	0.389307
1	POLYGON ((0 0, 0 0.09044, -0.08983 0.09044, -0...	-1	0	0.219648	0.608955
0	POLYGON ((0 -0.09044, 0 0, -0.08983 0, -0.0898...	-1	-1	0.230587	0.839542

Calculate cumulative proportion

(4) Calculate `cumulative proportion` by dividing `cumulative area` by `total area` (cumulative proportion takes values between 0 and 1)

```
if has_data:
    gdf["cumulative_proportion"] = gdf["cumulative_area"] / total_area
    display(gdf)
```

	geometry	grid_col	grid_row	M1_1_1	cumulative_area
2	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.193924	0.193924
3	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.195383	0.389307
1	POLYGON ((0 0, 0 0.09044, -0.08983 0.09044, -0...	-1	0	0.219648	0.608955
0	POLYGON ((0 -0.09044, 0 0, -0.08983 0, -0.0898...	-1	-1	0.230587	0.839542

Count AOO cells

(5) Calculate AOO by counting the number of cells with a `cumulative proportion` greater than 0.01 (i.e. exclude cells that in combination account for up to 1% of the total mapped extent of the ecosystem type).

```
if has_data:
    aoo = len(gdf[gdf["cumulative_proportion"] > 0.01])
    print(f'AOO is {aoo} cells')
```

```
AOO is 4 cells
```

AOO Calculation (direct call)

```python
if has_data:
    aoo_count = ecosystem.aoo
    print(f'AOO: {aoo_count} grid cells')
```

```
AOO: 4 grid cells
```

```python
if has_data:
    display(smart_map([aoo_grid_filtered, ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f95905bd150>, VBox(children=(ErrorOutput(), E
```

Criterion B Summary

Ecosystem Code	Ecosystem Name	EOO	AOO
M1.1.1	Null Island Marine Shelf	148 km^2	4 cells

T1.1.1 - Null Island Tropical Forest

Assessment

Null Island Tropical Forest

Authors: John Smith, Jane Smith

Biome: TODO

Functional Group: T1.1

Global classification: T1.1.1

IUCN Status: TODO

Description: TODO

Distribution: TODO

Characteristic Native Biota: TODO

Abiotic environment: TODO

Key processes and interactions: TODO

Major threats: TODO

Ecosystem collapse definition: TODO

Assessment summary: **TODO**

Assessment information:

Criteria

Status

Criterion A

A1

NE

A2a

NE

A2b

NE

A3

NE

Criterion B

B1

NE

B2

NE

subcriteria

NE

B3

NE

Criterion C

C1

NE

C2a

NE

C2b

NE

C3

NE

Criterion D

D1

NE

D2a

NE

D2b

NE

D3

NE

Criterion E

E

NE

Assessment outcome: **TODO**

Year published: TODO

Date assessed: TODO

Assessment credits:

Assessed by: TODO

Reviewed by: TODO

Contributions by: TODO

Criterion A: TODO

Criterion B: AOO was measured as 4 (10 km x 10 km) grid cells . EOO was measured as 73 km^2.

Criterion C: TODO

Criterion D: TODO

Criterion E: TODO

Criterion B Details

```
# Default ecosystem code for template development.
# This line is replaced by build_ecosystem_pages.py for each ecosystem.
ecosystem_code = 'T1.1.1'
```

Import Python modules.

```
import os
import yaml
from pathlib import Path
from lonboard import Map
from rle_python_gee.ecosystems import Ecosystems
from rle_python_gee.eoo import make_eoo
from rle_python_gee.aoo import make_aoo_grid
```

Load the country config file.

```
project_root = os.environ.get('PIXI_PROJECT_ROOT', str(Path('..').resolve()))
config_path = Path(project_root) / 'config' / 'country_config.yaml'
with open(config_path) as f:
    config = yaml.safe_load(f)
```

Load & Filter Ecosystem Data

Load data for all the ecosystems.

```
source = config['ecosystem_source']
ecosystems = Ecosystems.from_file(
    source['data'],
    ecosystem_column=source['ecosystem_code_column'],
    ecosystem_name_column=source['ecosystem_name_column'],
    functional_group_column=source['functional_group_column']
)
```

Filter by the T1.1.1 and check the number of features.

```
ecosystem = ecosystems.filter(ecosystem_code)
has_data = ecosystem.size() > 0
print(f'{ecosystem.size() = }')
if not has_data:
    from IPython.display import Markdown, display
    display(Markdown(
        f'**No spatial data found for {ecosystem_code}.** '
        f'Criterion B calculations are skipped.'
    ))
```

```
ecosystem.size() = 1
```

Extent of Occurrence (EOO) (subcriterion B1)

> **Extent of occurrence (EOO).** The EOO of an ecosystem is the area (km2) of a minimum convex polygon – the smallest polygon in which no internal angle exceeds 180° that encompasses all known current spatial occurrences of the ecosystem type.
>
> The minimum convex polygon (also known as a convex hull) must not exclude any areas, discontinuities or disjunctions, regardless of whether the ecosystem can occur in those areas or not. Regions such as oceans (for terrestrial ecosystems), land (for coastal or marine ecosystems), or areas outside the study area (such as in a different country) must remain included within the minimum convex polygon to ensure that this standardised method is comparable across ecosystem types. In addition, these features contribute to spreading risks across the distribution of the ecosystem by making different parts of its distribution more spatially independent.

Calculate EOO

Start by calculating the convex hull of the ecosystem's distribution.

```
import geopandas as gpd

if has_data:
    ecosystem_geometry = ecosystem.geometry.union_all()
    gdf_ecosystem_polygons = gpd.GeoDataFrame(geometry=[ecosystem_geometry], crs=ecosystem.ge
    hull = ecosystem_geometry.convex_hull
    gdf_hull = gpd.GeoDataFrame(geometry=[hull], crs=ecosystem.geometry.crs)
```

Display the ecosystem's distribution and the convex hull.

```
from lonboard import Map, PolygonLayer
from rle_python_gee.viz import smart_map

if has_data:
    eoo_hull = make_eoo(ecosystem).compute()
    display(smart_map([eoo_hull, ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f6c38b93e50>, VBox(children=(ErrorOutput(), E
```

```
if has_data:
    hull_ea = gdf_hull.to_crs("ESRI:54034")
    eoo = hull_ea.geometry.iloc[0].area / 1e6
    print(f'EOO is {eoo:.1f} km2')
```

```
EOO is 73.2 km2
```

Then calculate the area of the convex hull polygon.

Direct calculation of EOO

EOO can also be calculated directly using …

```
if has_data:
    ecosystem.eoo
```

Verify that the area returned by calling `make_eoo(ecosystem).compute().area_km2` is the same as the area of the convex hull polygon.

```
if has_data:
    assert ecosystem.eoo == eoo
```

Area of Occupancy (AOO) (subcriterion B2)

The protocol for this adjustment includes the following steps:

(1) Intersect AOO grid with the ecosystem's distribution map.
(2) Calculate extent of the ecosystem type in each grid cell (`area`) and sum these areas to obtain the total ecosystem area (`total area`).
(3) Arrange grid cells in ascending order based on their area (smaller first). Calculate accumulated sum of area per cell (`cumulative area`).
(4) Calculate `cumulative proportion` by dividing `cumulative area` by `total area` (cumulative proportion takes values between 0 and 1)
(5) Calculate AOO by counting the number of cells with a `cumulative proportion` greater than 0.01 (i.e. exclude cells that in combination account for up to 1% of the total mapped extent of the ecosystem type).

AOO Calculation Details

Intersect AOO grid and ecosystem map

(1) Intersect AOO grid with the ecosystem's distribution map

```
from pathlib import Path
from rle_python_gee.aoo import make_aoo_grid_cached

if has_data:
    cache_path = Path(project_root) / '.cache' / 'aoo_grid.parquet'
    aoo_grid = make_aoo_grid_cached(ecosystems, cache_path=cache_path)
    aoo_grid_filtered = aoo_grid.filter_by_ecosystem(ecosystem_code)
```

Visualize variations in the AOO grid.

```
from matplotlib.colors import LinearSegmentedColormap
from lonboard.colormap import apply_continuous_cmap
from rle_python_gee.aoo import slugify_ecosystem_name

ecosystem_column = slugify_ecosystem_name(ecosystem_code)
if has_data:
    cmap = LinearSegmentedColormap.from_list("white_red", ["white", "red"])
    values = aoo_grid_filtered.grid_cells[ecosystem_column].values
    normalized = (values - values.min()) / (values.max() - values.min())
    colors = apply_continuous_cmap(normalized, cmap)
    display(smart_map([(aoo_grid_filtered, {"get_fill_color": colors}), ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f6bbdbd9a90>, VBox(children=(ErrorOutput(), E
```

Calculate grid cell area and total area

(2) Calculate extent of the ecosystem type in each grid cell (`area`) and sum these areas to obtain the total ecosystem area (`total area`).

```
if has_data:
    keep = ['geometry', 'grid_col', 'grid_row', ecosystem_column]
    gdf = aoo_grid_filtered.grid_cells[keep]
    display(gdf)
```

	geometry	grid_col	grid_row	T1_1_1
0	POLYGON ((0 -0.09044, 0 0, -0.08983 0, -0.0898...	-1	-1	0.138685
1	POLYGON ((0 0, 0 0.09044, -0.08983 0.09044, -0...	-1	0	0.149624
2	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.164326
3	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.143245

The column T1_1_1 contains the (fractional) area of the ecosystem in each grid cell.

Sum up the areas of each grid cell to get the total area.

```
if has_data:
    total_area = gdf[ecosystem_column].sum()
    display(total_area)
```

```
np.float64(0.5958790773089089)
```

Calculate cumulative area

(3) Arrange grid cells in ascending order based on their area (smaller first). Calculate accumulated sum of area per cell (`cumulative area`).

```
if has_data:
    gdf = gdf.sort_values(by=ecosystem_column)
    gdf["cumulative_area"] = gdf[ecosystem_column].cumsum()
    display(gdf)
```

	geometry	grid_col	grid_row	T1_1_1	cumulative_area
0	POLYGON ((0 -0.09044, 0 0, -0.08983 0, -0.0898...	-1	-1	0.138685	0.138685
3	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.143245	0.281929
1	POLYGON ((0 0, 0 0.09044, -0.08983 0.09044, -0...	-1	0	0.149624	0.431553
2	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.164326	0.595879

Calculate cumulative proportion

(4) Calculate `cumulative proportion` by dividing `cumulative area` by `total area` (cumulative proportion takes values between 0 and 1)

```
if has_data:
    gdf["cumulative_proportion"] = gdf["cumulative_area"] / total_area
    display(gdf)
```

	geometry	grid_col	grid_row	T1_1_1	cumulative_area
0	POLYGON ((0 -0.09044, 0 0, -0.08983 0, -0.0898...	-1	-1	0.138685	0.138685
3	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.143245	0.281929
1	POLYGON ((0 0, 0 0.09044, -0.08983 0.09044, -0...	-1	0	0.149624	0.431553
2	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.164326	0.595879

Count AOO cells

(5) Calculate AOO by counting the number of cells with a `cumulative proportion` greater than 0.01 (i.e. exclude cells that in combination account for up to 1% of the total mapped extent of the ecosystem type).

```
if has_data:
    aoo = len(gdf[gdf["cumulative_proportion"] > 0.01])
    print(f'AOO is {aoo} cells')
```

```
AOO is 4 cells
```

AOO Calculation (direct call)

```python
if has_data:
    aoo_count = ecosystem.aoo
    print(f'AOO: {aoo_count} grid cells')
```

```
AOO: 4 grid cells
```

```python
if has_data:
    display(smart_map([aoo_grid_filtered, ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f6bbdbef450>, VBox(children=(ErrorOutput(), E
```

Criterion B Summary

Ecosystem Code	Ecosystem Name	EOO	AOO
T1.1.1	Null Island Tropical Forest	73 km^2	4 cells

T6.5.1 - Null Island Alpine Grassland

Assessment

Null Island Alpine Grassland

Authors: John Smith, Jane Smith

Biome: TODO

Functional Group: T6.5

Global classification: T6.5.1

IUCN Status: TODO

Description: TODO

Distribution: TODO

Characteristic Native Biota: TODO

Abiotic environment: TODO

Key processes and interactions: TODO

Major threats: TODO

Ecosystem collapse definition: TODO

Assessment summary: **TODO**

Assessment information:

Criteria

Status

Criterion A

A1

NE

A2a

NE

A2b

NE

A3

NE

Criterion B

B1

NE

B2

NE

subcriteria

NE

B3

NE

Criterion C

C1

NE

C2a

NE

C2b

NE

C3

NE

Criterion D

D1

NE

D2a

NE

D2b

NE

D3

NE

Criterion E

E

NE

Assessment outcome: **TODO**

Year published: TODO

Date assessed: TODO

Assessment credits:

Assessed by: TODO

Reviewed by: TODO

Contributions by: TODO

Criterion A: TODO

Criterion B: AOO was measured as 2 (10 km x 10 km) grid cells . EOO was measured as 4 km^2.

Criterion C: TODO

Criterion D: TODO

Criterion E: TODO

Criterion B Details

```python
# Default ecosystem code for template development.
# This line is replaced by build_ecosystem_pages.py for each ecosystem.
ecosystem_code = 'T6.5.1'
```

Import Python modules.

```python
import os
import yaml
from pathlib import Path
from lonboard import Map
from rle_python_gee.ecosystems import Ecosystems
from rle_python_gee.eoo import make_eoo
from rle_python_gee.aoo import make_aoo_grid
```

Load the country config file.

```python
project_root = os.environ.get('PIXI_PROJECT_ROOT', str(Path('..').resolve()))
config_path = Path(project_root) / 'config' / 'country_config.yaml'
with open(config_path) as f:
    config = yaml.safe_load(f)
```

Load & Filter Ecosystem Data

Load data for all the ecosystems.

```python
source = config['ecosystem_source']
ecosystems = Ecosystems.from_file(
    source['data'],
    ecosystem_column=source['ecosystem_code_column'],
    ecosystem_name_column=source['ecosystem_name_column'],
    functional_group_column=source['functional_group_column']
)
```

Filter by the T6.5.1 and check the number of features.

```
ecosystem = ecosystems.filter(ecosystem_code)
has_data = ecosystem.size() > 0
print(f'{ecosystem.size() = }')
if not has_data:
    from IPython.display import Markdown, display
    display(Markdown(
        f'**No spatial data found for {ecosystem_code}.** '
        f'Criterion B calculations are skipped.'
    ))
```

```
ecosystem.size() = 1
```

Extent of Occurrence (EOO) (subcriterion B1)

> **Extent of occurrence (EOO).** The EOO of an ecosystem is the area (km2) of a minimum convex polygon – the smallest polygon in which no internal angle exceeds 180° that encompasses all known current spatial occurrences of the ecosystem type.
>
> The minimum convex polygon (also known as a convex hull) must not exclude any areas, discontinuities or disjunctions, regardless of whether the ecosystem can occur in those areas or not. Regions such as oceans (for terrestrial ecosystems), land (for coastal or marine ecosystems), or areas outside the study area (such as in a different country) must remain included within the minimum convex polygon to ensure that this standardised method is comparable across ecosystem types. In addition, these features contribute to spreading risks across the distribution of the ecosystem by making different parts of its distribution more spatially independent.

Calculate EOO

Start by calculating the convex hull of the ecosystem's distribution.

```
import geopandas as gpd

if has_data:
    ecosystem_geometry = ecosystem.geometry.union_all()
    gdf_ecosystem_polygons = gpd.GeoDataFrame(geometry=[ecosystem_geometry], crs=ecosystem.ge
    hull = ecosystem_geometry.convex_hull
    gdf_hull = gpd.GeoDataFrame(geometry=[hull], crs=ecosystem.geometry.crs)
```

Display the ecosystem's distribution and the convex hull.

```
from lonboard import Map, PolygonLayer
from rle_python_gee.viz import smart_map

if has_data:
    eoo_hull = make_eoo(ecosystem).compute()
    display(smart_map([eoo_hull, ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f9c8733c1d0>, VBox(children=(ErrorOutput(), E
```

```
if has_data:
    hull_ea = gdf_hull.to_crs("ESRI:54034")
    eoo = hull_ea.geometry.iloc[0].area / 1e6
    print(f'EOO is {eoo:.1f} km2')
```

```
EOO is 4.2 km2
```

Then calculate the area of the convex hull polygon.

Direct calculation of EOO

EOO can also be calculated directly using …

```
if has_data:
    ecosystem.eoo
```

Verify that the area returned by calling `make_eoo(ecosystem).compute().area_km2` is the same as the area of the convex hull polygon.

```
if has_data:
    assert ecosystem.eoo == eoo
```

Area of Occupancy (AOO) (subcriterion B2)

The protocol for this adjustment includes the following steps:

(1) Intersect AOO grid with the ecosystem's distribution map.
(2) Calculate extent of the ecosystem type in each grid cell (`area`) and sum these areas to obtain the total ecosystem area (`total area`).
(3) Arrange grid cells in ascending order based on their area (smaller first). Calculate accumulated sum of area per cell (`cumulative area`).
(4) Calculate `cumulative proportion` by dividing `cumulative area` by `total area` (cumulative proportion takes values between 0 and 1)
(5) Calculate AOO by counting the number of cells with a `cumulative proportion` greater than 0.01 (i.e. exclude cells that in combination account for up to 1% of the total mapped extent of the ecosystem type).

AOO Calculation Details

Intersect AOO grid and ecosystem map

(1) Intersect AOO grid with the ecosystem's distribution map

```
from pathlib import Path
from rle_python_gee.aoo import make_aoo_grid_cached

if has_data:
    cache_path = Path(project_root) / '.cache' / 'aoo_grid.parquet'
    aoo_grid = make_aoo_grid_cached(ecosystems, cache_path=cache_path)
    aoo_grid_filtered = aoo_grid.filter_by_ecosystem(ecosystem_code)
```

Visualize variations in the AOO grid.

```
from matplotlib.colors import LinearSegmentedColormap
from lonboard.colormap import apply_continuous_cmap
from rle_python_gee.aoo import slugify_ecosystem_name

ecosystem_column = slugify_ecosystem_name(ecosystem_code)
if has_data:
    cmap = LinearSegmentedColormap.from_list("white_red", ["white", "red"])
    values = aoo_grid_filtered.grid_cells[ecosystem_column].values
    normalized = (values - values.min()) / (values.max() - values.min())
    colors = apply_continuous_cmap(normalized, cmap)
    display(smart_map([(aoo_grid_filtered, {"get_fill_color": colors}), ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f9c8016bcd0>, VBox(children=(ErrorOutput(), E
```

Calculate grid cell area and total area

(2) Calculate extent of the ecosystem type in each grid cell (`area`) and sum these areas to obtain the total ecosystem area (`total area`).

```
if has_data:
    keep = ['geometry', 'grid_col', 'grid_row', ecosystem_column]
    gdf = aoo_grid_filtered.grid_cells[keep]
    display(gdf)
```

	geometry	grid_col	grid_row	T6_5_1
0	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.011022
1	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.030645

The column T6_5_1 contains the (fractional) area of the ecosystem in each grid cell.

Sum up the areas of each grid cell to get the total area.

```
if has_data:
    total_area = gdf[ecosystem_column].sum()
    display(total_area)
```

```
np.float64(0.04166626704366905)
```

Calculate cumulative area

(3) Arrange grid cells in ascending order based on their area (smaller first). Calculate accumulated sum of area per cell (`cumulative area`).

```
if has_data:
    gdf = gdf.sort_values(by=ecosystem_column)
    gdf["cumulative_area"] = gdf[ecosystem_column].cumsum()
    display(gdf)
```

	geometry	grid_col	grid_row	T6_5_1	cumulative_area
0	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.011022	0.011022
1	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.030645	0.041666

Calculate cumulative proportion

(4) Calculate `cumulative proportion` by dividing `cumulative area` by `total area` (cumulative proportion takes values between 0 and 1)

```
if has_data:
    gdf["cumulative_proportion"] = gdf["cumulative_area"] / total_area
    display(gdf)
```

	geometry	grid_col	grid_row	T6_5_1	cumulative_area
0	POLYGON ((0.08983 -0.09044, 0.08983 0, 0 0, 0 ...	0	-1	0.011022	0.011022
1	POLYGON ((0.08983 0, 0.08983 0.09044, 0 0.0904...	0	0	0.030645	0.041666

Count AOO cells

(5) Calculate AOO by counting the number of cells with a `cumulative proportion` greater than 0.01 (i.e. exclude cells that in combination account for up to 1% of the total mapped extent of the ecosystem type).

```
if has_data:
    aoo = len(gdf[gdf["cumulative_proportion"] > 0.01])
    print(f'AOO is {aoo} cells')
```

```
AOO is 2 cells
```

AOO Calculation (direct call)

```
if has_data:
    aoo_count = ecosystem.aoo
    print(f'AOO: {aoo_count} grid cells')
```

```
AOO: 2 grid cells
```

```
if has_data:
    display(smart_map([aoo_grid_filtered, ecosystem]))
```

```
VBox(children=(<lonboard._map.Map object at 0x7f9c8c189b90>, VBox(children=(ErrorOutput(), E
```

Criterion B Summary

Ecosystem Code	Ecosystem Name	EOO	AOO
T6.5.1	Null Island Alpine Grassland	4 km^2	2 cells

References

Bland, LM, DA Keith, RM Miller, NJ Murray, and JP Rodríguez. 2017. "Guidelines for the Application of IUCN Red List of Ecosystems Categories and Criteria, Version 1.1." *International Union for the Conservation of Nature, Gland, Switzerland*.

Bland, Lucie M, Tracey J Regan, Minh Ngoc Dinh, Renata Ferrari, David A Keith, Rebecca Lester, David Mouillot, Nicholas J Murray, Hoang Anh Nguyen, and Emily Nicholson. 2017. "Using Multiple Lines of Evidence to Assess the Risk of Ecosystem Collapse." *Proceedings of the Royal Society B: Biological Sciences* 284 (1863): 20170660.

Keith, DA, JR Ferrer-Paris, E Nicholson, MJ Bishop, BA Polidoro, E Ramirez-Llodra, et al. 2022. "Earth's Ecosystems: A Function-Based Typology for Conservation and Sustainability." *Nature* 610: 513–18.

Keith, David A, H Resit Akçakaya, and Nicholas J Murray. 2018. "Scaling Range Sizes to Threats for Robust Predictions of Risks to Biodiversity." *Conservation Biology* 32 (2): 322–32.

Keith, David A, Jose R Ferrer-Paris, Emily Nicholson, Melanie J Bishop, Beth A Polidoro, Eva Ramirez-Llodra, Mark G Tozer, et al. 2020. "Indicative Distribution Maps for Ecological Functional Groups-Level 3 of IUCN Global Ecosystem Typology."

Keith, David A, José R Ferrer-Paris, Emily Nicholson, and Richard Kingsford. 2020. *IUCN Global Ecosystem Typology 2.0: Descriptive Profiles for Biomes and Ecosystem Functional Groups*. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2020.13.en.

Keith, David A, Jon Paul Rodríguez, Thomas M Brooks, Mark A Burgman, Edmund G Barrow, Lucie Bland, Patrick J Comer, et al. 2015. "The IUCN Red List of Ecosystems: Motivations, Challenges, and Applications." *Conservation Letters* 8 (3): 214–26.

Keith, David A, Jon Paul Rodríguez, Kathryn M Rodríguez-Clark, Emily Nicholson, Kaisu Aapala, Alfonso Alonso, Marianne Asmussen, et al. 2013. "Scientific Foundations for an IUCN Red List of Ecosystems." *PLOS One* 8 (5): e62111.

Murray, Nicholas J, David A Keith, Lucie M Bland, Renata Ferrari, Mitchell B Lyons, Richard Lucas, Nathalie Pettorelli, and Emily Nicholson. 2018. "The Role of Satellite Remote Sensing in Structured Ecosystem Risk Assessments." *Science of the Total Environment* 619: 249–57.

Murray, Nicholas J, David A Keith, Lucie M Bland, Emily Nicholson, Tracey J Regan, Jon Paul Rodríguez, and Michael Bedward. 2017. "The Use of Range Size to Assess Risks to Biodiversity from Stochastic Threats." *Diversity and Distributions* 23 (5): 474–83.

Nicholson, Emily, David A Keith, and David S Wilcove. 2009. "Assessing the Threat Status of Ecological Communities." *Conservation Biology* 23 (2): 259–74.

Rodríguez, Jon Paul, David A Keith, Kathryn M Rodríguez-Clark, Nicholas J Murray, Emily Nicholson, Tracey J Regan, Rebecca M Miller, et al. 2015. "A Practical Guide to the Application of the IUCN Red List of Ecosystems Criteria." *Philosophical Transactions of the Royal Society B: Biological Sciences* 370 (1662): 20140003.

Rodríguez, Jon Paul, KATHRYN M RODRÍGUEZ-CLARK, Jonathan EM Baillie, Neville Ash, John Benson, Timothy Boucher, Claire Brown, et al. 2011. "Establishing IUCN Red List Criteria for Threatened Ecosystems." *Conservation Biology* 25 (1): 21–29.