Rwanda Spatial Biodiversity Assessment 2023

ACKNOWLEDGEMENTS

CITATION FOR THIS REPORT

SANBI, CoEB and REMA, 2022, Rwanda Spatial Biodiversity Assessment 2022, report compiled by S. Holness, A. Dayaram, S. Khatieb, E. Kudze and M. Moyeke and M. Child for University of Rwanda's Center of Excellence in Biodiversity and Natural Resource Management, Rwanda Environment Management Authority (REMA) and South African National Biodiversity Institute.

Note that this is a rapid/preliminary assessment undertaken in a workshop format, and significant improvements are likely in future iterations.

EXECUTIVE SUMMARY

The Spatial Biodiversity Assessment (SBA) 2022 is Rwanda's first national spatial systematic assessment of ecosystems. It introduces two new headline indicators for assessing the state of Rwanda's biodiversity: Ecosystem Threat Status and Ecosystem Protection Level. The primary purpose of the SBA is to provide a high-level summary of the state of Rwanda's biodiversity that can be regularly updated. The SBA is intended for decision-makers both inside and outside the biodiversity sector.

The SBA 2022 was led by the University of Rwanda's Center of Excellence in Biodiversity and Natural Resource Management, Rwanda Environment Management Authority (REMA) in partnership with a range of organisations and experts. The Spatial Biodiversity Assessment is the product of collaborative work of many individuals and institutions. National experts worked with international partners from the South African National Biodiversity Institute (SANBI), Nelson Mandela University and NatureServe. The SBA 2022 includes themes related to ecosystem classification, pressures on biodiversity, protected areas, the threat status and protection level of ecosystems.

In collaboration with the Rwanda Environment Management Authority (REMA), Rwanda Water and Forest Authority (RWFA), Ministry of Agriculture, the Center of Excellence in Biodiversity and Natural Resource Management (CoEB) will mainstream biodiversity information such as the SBA into different strategies and plans to ensure sustainable land use and responsible resource management.

The project applied the methodology outlined in Mapping Biodiversity Priorities: A Practical, Science-Based Approach to National Biodiversity Assessment and Prioritisation to Inform Strategy and Action Planning (SANBI and UNEP-WCMC, 2016).

Note that this SBA is a work in progress and the CoEB will lead the process of regular updating as more information becomes available and land use changes are detected. This SBA is a rapid and preliminary assessment to serve as foundation for significant improvements that are expected over time to refine the assessment and map.

Building blocks, assessments and outcomes

- There were three main building blocks (input data sets) used for the assessments, namely ecosystem types, ecological condition and protected areas.
    - **Map of ecosystem types:** A new fine scale map of Rwanda's ecosystems was developed, which identified 29 ecosystems across 9 biomes.
    - **Ecological condition:** New maps of ecological condition were prepared using landcover and other datasets. The analysis highlighted that only 28,3% of Rwanda is likely to remain in "Natural or Near Natural" ecological condition.
    - **Protected Areas:** A map of Rwanda's Protected Areas and Other Effective Area-based Conservation Measures (OECMs) was developed covering national parks, protected ecosystems and fully protected wetlands.
- Two headline assessments were undertaken, namely ecosystem threat status and ecosystem protection level:
    - **Ecosystem threat status**: The study applied the IUCN Red List of Ecosystems (RLE) methodology to evaluate the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function and composition, on which their ability to provide ecosystem services ultimately depends. According to this preliminary assessment, more than half (70.6%) of Rwanda's ecosystems are threatened, including

11.8% Critically Endangered; 41.2% Endangered, and 17.7% which are Vulnerable. Threatened terrestrial ecosystems are found across Rwanda, but particularly in the following biomes: Akagera Sub-humid Savanna, Highland Plateau, Humid Savanna, Plateau grassland savanna and Tropical Savanna (**Error! Reference source not found.**). Ecosystems that are declining largely due to functional threats (e.g., aquatic ecosystems) are likely to have been under-assessed, resulting in the under-estimation of their risk of collapse.

o **Ecosystem protection level:** Ecosystem protection level indicates whether ecosystems are adequately protected or under-protected according to this preliminary evaluation. More than half (64.2%) of Rwanda's ecosystems are not protected or poorly protected. Many under-protected terrestrial ecosystems are found in the following biomes: Akagera Sub-humid Savanna, Highland Plateau, Humid Savanna, Plateau grassland savanna, and Tropical Savanna.

These two headline indicators will be updated again in future revisions of the SBA.
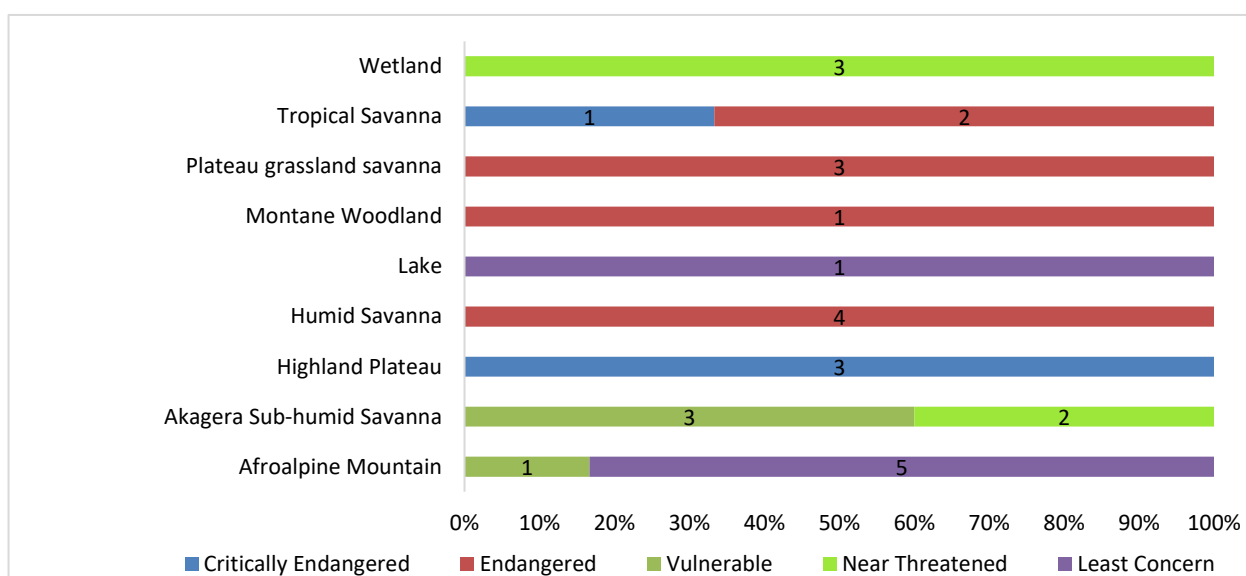
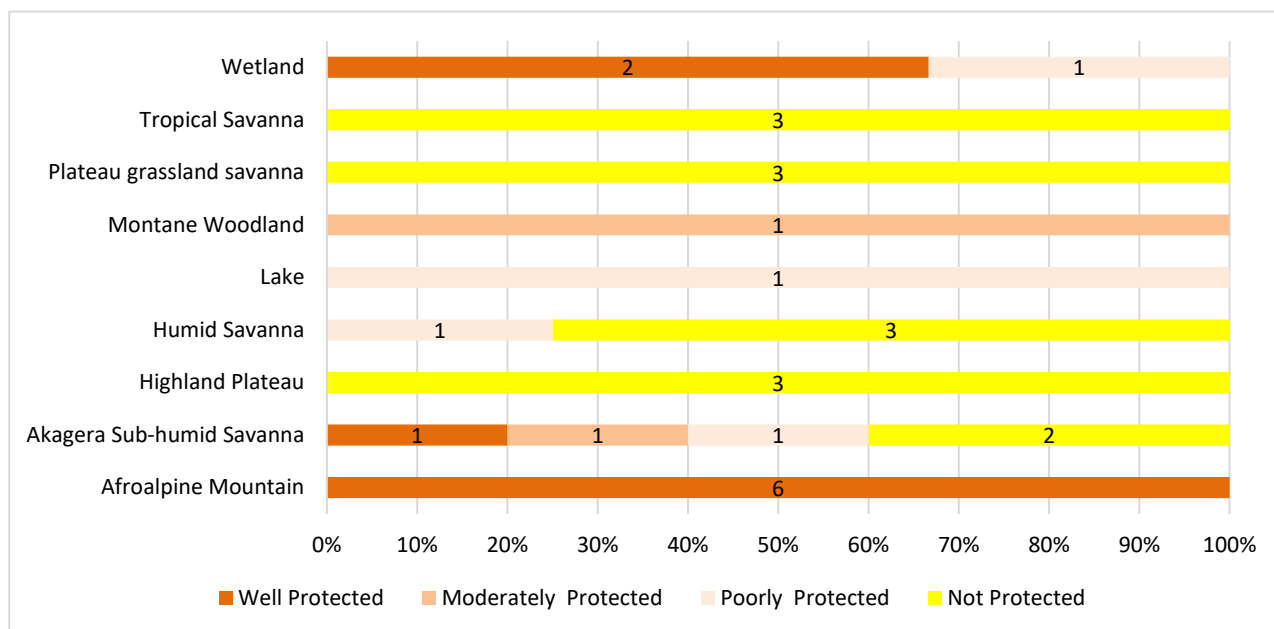**Figure 1: Threat Status for Rwanda's 29 ecosystem types, grouped by the major biomes in the country.** Combined assessments highlighting ecosystems which are both under-protected (especially Not Protected and Poorly Protected ecosystem types) and threatened (particularly Critically Endangered and Endangered)(Figure 2) were used to identify some initial priorities at an ecosystem level.

Knowledge gaps:

The current report is the first draft document reflecting the results of a rapid initial assessment. Key issues that need to be addressed and can be prioritised for research investments:

• Improvement to the classification and mapping of aquatic ecosystem types (especially open water ecosystem classification) and their condition. The expert validation identified this as a key area of potential improvement.

• Improved mapping of degradation (including alien invasive vegetation, overgrazing and especially degradation of aquatic ecosystems) to allow a more complete ecological condition map to be developed.

• Additional validation of input layers.

- A second iteration of the spatial analysis, ideally an expansion of the analysis to include degradation.
- Exploration of key findings and messages for mainstreaming.
- Expansion of the current report to national narratives and site-specific examples.
- Sharing of spatial data and metadata.
- Links to the development of indicators.

Figure 2: Ecosystem Protection Levels for Rwanda's 29 ecosystem types, grouped by biomes.

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1 INTRODUCTION AND APPROACH

1.1 What is the Spatial Biodiversity Assessment?

The Spatial Biodiversity Assessment (SBA) 2023 is Rwanda's first national spatial systematic assessment of ecosystems. It introduces two new headline indicators for assessing the state of Rwanda's biodiversity: Ecosystem Threat Status and Ecosystem Protection Level. The primary purpose of the SBA is to provide a high-level summary of the state of Rwanda's biodiversity that can be regularly updated. The SBA is intended for decision-makers both inside and outside the biodiversity sector. In collaboration with the Ministry of Environment, Rwanda Environment Management Authority (REMA), Rwanda Water Resources Board (RWB), Rwanda Forestry Authority (RWFA), and Ministry of Agriculture, the Center of Excellence in Biodiversity and Natural Resource Management (CoEB) will mainstream biodiversity information such as the SBA into different strategies and plans to ensure sustainable land use and responsible resource management.

The SBA 2023 was led by the University of Rwanda's Center of Excellence in Biodiversity and Natural Resource Management (CoEB) and Rwanda Environment Management Authority (REMA) in partnership with a range of organisations and experts. The Spatial Biodiversity Assessment is the product of collaborative work of many individuals and institutions. National experts worked with international partners from the South African National Biodiversity Institute (SANBI), Nelson Mandela University and NatureServe (https://www.natureserve.org/). The SBA 2023 includes themes related to ecosystem classification, pressures on biodiversity, protected areas, the threat status and protection level of ecosystems.

The project applied the methodology outlined in Mapping Biodiversity Priorities: A Practical, Science-Based Approach to National Biodiversity Assessment and Prioritisation to Inform Strategy and Action Planning (SANBI and UNEP-WCMC, 2016).

1.2 Headline indicators: ecosystem threat status and ecosystem protection level

The SBA 2023 utilizes two new headline indicators for assessing the state of Rwanda's biodiversity: ecosystem threat status and ecosystem protection level. Ecosystem threat status indicates the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function and composition, on which their ability to provide ecosystem services ultimately depends. It uses the relatively new IUCN Red List of Ecosystems (RLE) methodology (Rodríguez et al., 2015). Ecosystem protection level indicates whether ecosystems are adequately protected or under-protected. These two headline indicators will be updated again in future revisions of the SBA. These headline indicators provide a way of comparing results meaningfully across the different terrestrial and aquatic environments, and also a standardised framework that links with policy and legislation in Rwanda, facilitating the interface between science and policy.

The assessment of ecosystem threat status is completely independent of the assessment of ecosystem protection level. As shown in Figure 3, ecosystem threat status is based on the condition of an ecosystem type, while ecosystem protection level is based on the extent to which an ecosystem type is formally protected. Thus, ecosystems that are not threatened may still be under-protected and require attention in order to deliver a protected area network representative of the country's ecosystems.
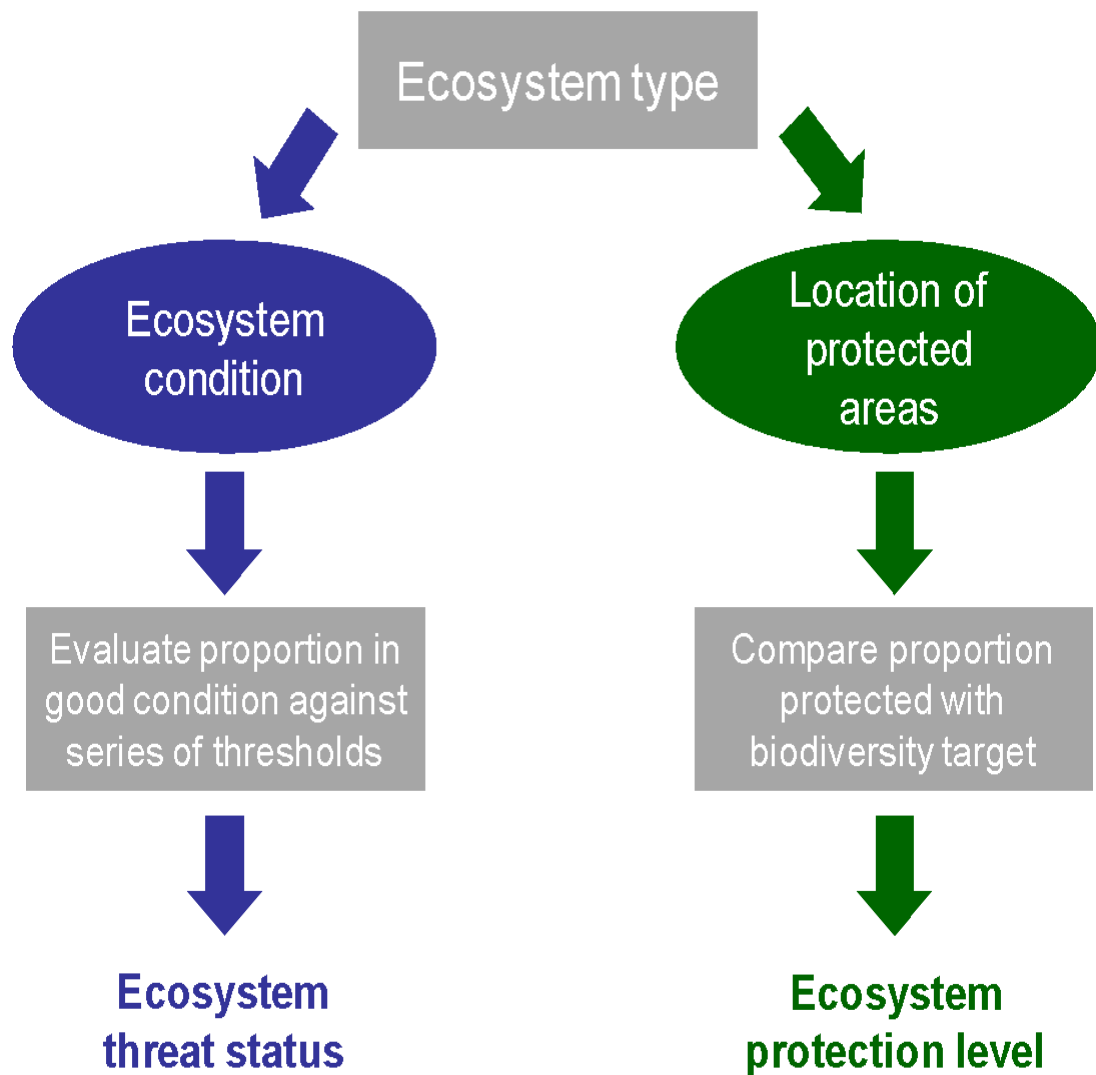
Figure 3: Steps in assessing ecosystem threat status and ecosystem protection level.

2 INPUT DATA USED FOR THE ASSESSMENTS

2.1 Map of Ecosystem types

The primary biodiversity input for the Spatial Biodiversity Assessments is a map of ecosystem types, which is used as a surrogate for a range of other biodiversity features (SANBI and UNEP-WCMC, 2016). Ecosystem types are spatial units that are likely to share broadly similar ecological characteristics and functioning. Using ecosystem types is a precautionary approach in situations where other biodiversity data may be limited or geographically biased. Ecosystem types serve as a proxy for biodiversity that would otherwise be excluded from the analysis, such as unknown species, species for which there is poor data availability and even some local-scale ecological processes.

The Mapping Biodiversity Guidebook (SANBI and UNEP-WCMC, 2016) highlights key characteristics of a map of ecosystems types that are necessary to optimize its use in a Spatial Biodiversity Assessment:

Complete coverage of the country or region. The map of ecosystem types should cover the entire region or country being assessed. Complete coverage will mean that biodiversity is fairly represented across the country or region and no part of the land is excluded from the analysis. Complete coverage can highlight pressures on overlooked areas that have not been the focus of previous research or conservation efforts. Complete coverage is also necessary for making meaningful comparisons, such as countrywide proportions of threat status and protection level.

Map the historical extent of the ecosystem types. It is necessary to know the historical extent of ecosystems to assess their current status and understand the extent to which they have undergone loss. Establishing a historical baseline for the extent of an ecosystem type provides a stable measure against which to assess the degree of loss. Preferably, the historical extent should be mapped to a pre-industrial baseline, before large-scale human modification of the landscape occurred. Detailed spatial delineation of historical extent is not always possible or necessary, and it may be sufficient to use an expert process to estimate the extent to which some ecosystem types have been lost or modified.

Use ecologically meaningful units. Meaningful ecological units make it easier to interpret the results and incorporate them into conservation policy, strategy and action. Ideally, the map of ecosystem types should be supported by ground-truthed data on species composition where available.

Improve integration across different biomes or realms. Ideally, the map of ecosystem types should be continuous across the relevant realms (broader landscape types terrestrial, inland water etc.). This enables integrated prioritisation across biomes and realms and all-in-one map products and allows better incorporation of the specialised ecosystems that form the boundary between biomes.

Establish a sensible classification with a nested hierarchy. Local ecosystem types should be nested within broader categories. If no other data are available, start with a broad-scale biome-level or ecoregion-level map, and work towards refining the lower levels of the hierarchy over time. Fully nested hierarchies will enhance the utility of the map of ecosystem types, making it more appropriate as a basis for assessment and prioritisation at a range of spatial scales. A national map and classification of ecosystem types that becomes well-established is an extremely valuable product in its own right that is likely to have a wide range of applications.

2.1.1 Method

To develop the ecosystem map for Rwanda we gathered all available data from continental, global and local data sourced from partners from within the country. In consultation with country experts, we created several iterative versions of the ecosystem map representing terrestrial and freshwater ecosystem types. During review processes experts provided advice on i) the general approach; ii) whether ecosystem types were well represented; iii) provide or point us to data that would assist in refining the map; iv) provide advice on the names and colours of the ecosystem types; and v) provide guidance on possible experts to approach for further input.

The current version of the map was accepted at an in-person workshop in September 2022 in Kigali as a first version that could be used in an ecosystem assessment process. During this process we also outlined short, medium and long-term goals for improving the ecosystem map so that future assessment, planning and prioritisation goals can be improved. A full account of the approach used to develop the draft map of ecosystem types is captured in the Technical Notes (SANBI, 2022).

2.1.1.1 Key underlying data

Regional vegetation maps were available for the east African region that formed the foundation for building the ecosystem map. Vegetation types are often a useful starting point for a terrestrial ecosystem map because vegetation diversity and pattern are strong predictors of diversity in ecosystem patterns and processes since vegetation is sedentary and the physiognomy of vegetation and the distribution of species becomes strongly coupled with ecosystem processes. Therefore, we used the East African Potential Vegetation Map (PVM) as a starting point and merged this layer with finer-scale local data.

Data used to create the ecosystem map were gathered through a combination of data supplied by the Biodiversity Information Management Forum (BIMF – the annual gathering of data holders and data users hosted by Ministry of Environment and coordinated by the CoEB), data downloaded online, and static maps from peer reviewed publications. The following datasets were used to develop the ecosystem map.

1. Terrestrial:
    a. East Africa Potential Vegetation Map, (Kindt et al., 2014; van Breugel et al., 2015; Van Breugel et al., 2011).
    b. Static Climate and rainfall map (obtained from the internet).
    c. Agroecological Zones (supplied by country partners).
    d. Paper including a static map for Virunga National Park (Akayezu et al., 2019).
    e. Various literature.
2. Freshwater:
    a. Rwanda wetlands 2016 (Rwanda Water Resources Board, 2016).
    b. Lakes (Rwanda Surveys and Mapping, 2022a).

2.1.1.2 Integration method

The global East Africa Potential Vegetation Map (PVM) for Rwanda was combined with wetlands from the more accurate wetland layer 'Rwanda 2016', and with the Lakes layer supplied by country partners (Rwanda Surveys and Mapping, 2022a; Rwanda Water Resources Board, 2016). All spatial errors were cleaned and any gaps along the country border were filled using the ecosystem type closest to the data gap.

A broader classification level that acted as a possible biomes class was developed using a static climate and rainfall map as a guide. We also further divided biomes using the Agricultural Zones layer supplied (AEZ). We first divided the East Africa Potential Vegetation Map (PVM) savanna into Humid and Arid savanna types using a static image of the climate map. Then we divided the PVM Arid savanna into 3

further regions using the Agro-Ecological Zones (AEZ) layer that overlapped with this region. Evidence for a more humid savanna in the east than indicated in the PVM was supported by literature. In this way each ecosystem type was nested within a broader ecosystem unit.

The 2016 wetlands layer was modified by lumping all converted wetlands (converted into agriculture land uses) either to the nearest natural wetland type, or if no adjacent natural type was present these were assigned to an 'Other wetland' class. All other wetland classes from the 2016 layer were maintained. Spellings of names were standardised and lumped into suitable classes where types were similarly labelled. This spatial layer replaced all 'Freshwater Swamp' and 'edaphic grassland on drainage impeded or seasonally flooded soils + freshwater swamp' in the PVM. Wetland polygons were used to replace polygons in the Lakes dataset where they overlapped. Very small polygons (<500m^2) were merged with the nearest ecosystem type.

Two large online expert workshops were held, and several smaller one-on-one discussions were conducted over email to review earlier versions of the map of ecosystem types. Several names of ecosystem types and broad units were renamed more appropriately with guidance from local experts including Afroalpine Mountain, Highland Plateau, and Montane Forest. Several ecosystem types were also merged to form Bamboo Afroalpine Mountain Vegetation, Upland Acacia savanna Wooded Grassland Mosaic, Evergreen Semi-evergreen Bushland and Thicket, Evergreen Semi-evergreen Sub-humid Savanna. Furthermore experts noted a publication with a static map for Virunga National Park by Akayezu et al. (2019). We adjusted the classification of some of the ecosystem types to match those of the publication more closely since this was a partially ground-truthed study. For this reason, we considered it to be more accurate that the existing classification and mapping for the area obtained by the East Africa PNV.

Colours for each ecosystem type and broader types were created with expert input. We drafted descriptions of the biophysical and biological features that are unique to that ecosystem type by matching each type to the closest vegetation classes in the Potential vegetation map of east Africa/VECEA map from 2014 and the vegetation in Virunga National Park was described using a combination of data from gorilla forage studies (Akayezu et al., 2019) and East Africa vegetation map (Kindt et al., 2014) . Populating the descriptions for ecosystem types also allowed us to highlight types that were repeated and should be combined with other existing types. Therefore, we re-assigned the last remaining polygon of the Afromontane Hagenia forest and bamboo mosaic to Hagenia forest. ***We were unable to describe all ecosystem types at the completion of this first draft of the Spatial Biodiversity Assessment due to the need for on-the-ground sampling, and this should be a priority for future work***.

2.1.2   Results

The analysis identified a total of 29 ecosystem types across 9 biomes (Figure 4, Figure 5 and Table 1).
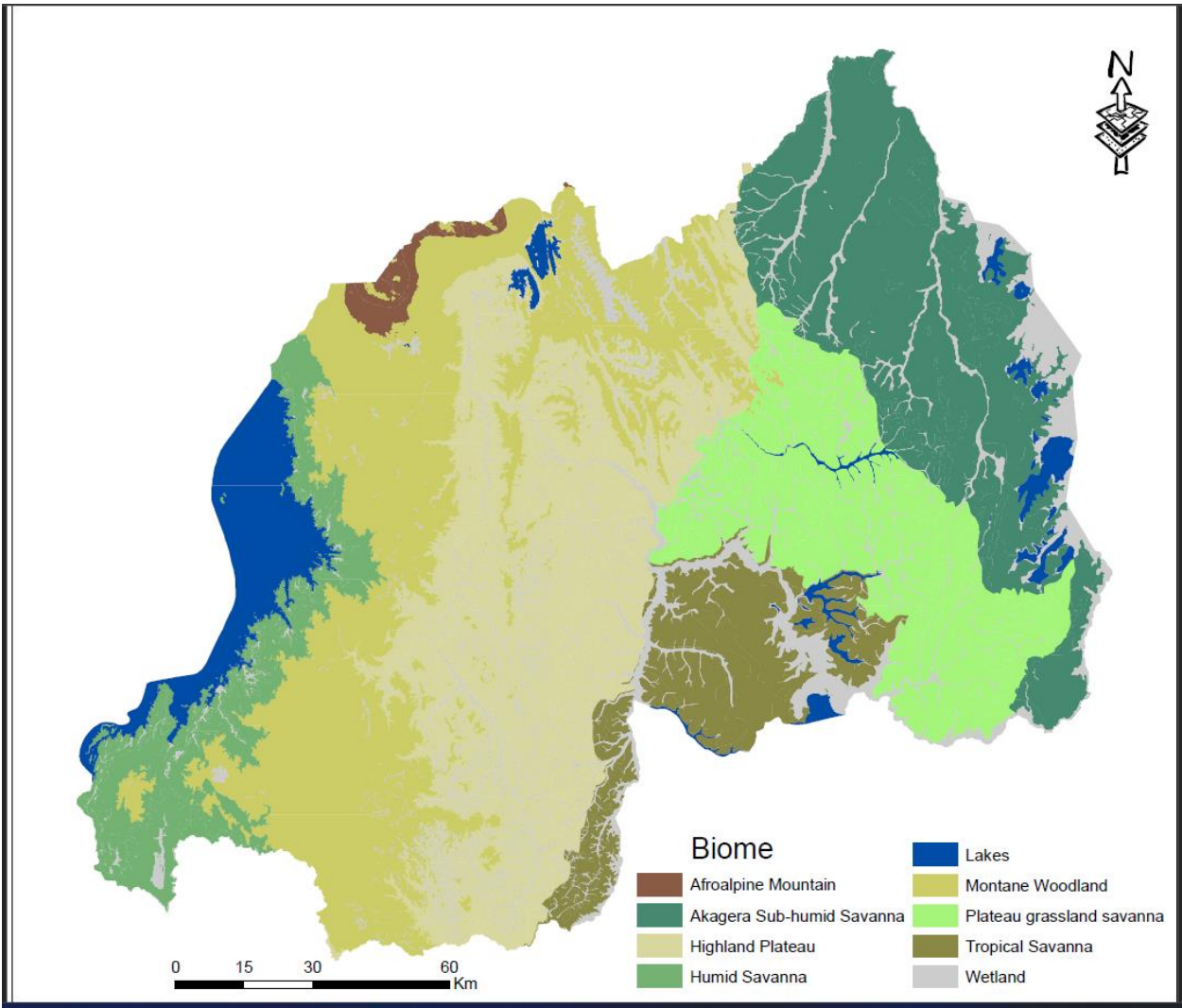
Figure 4: Map of the biomes of Rwanda.
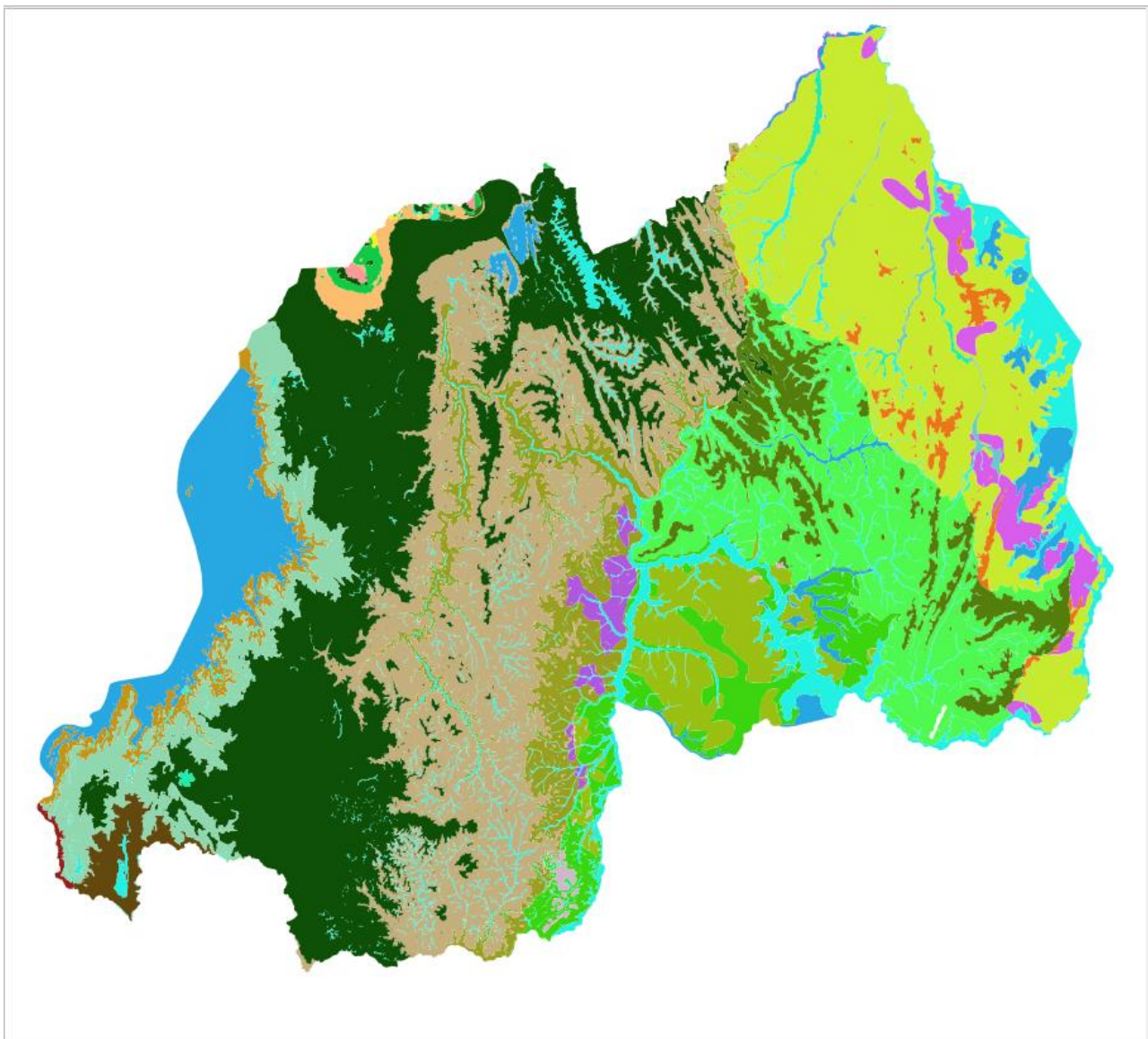
Figure 5: Map of the ecosystem types of Rwanda showing terrestrial and freshwater types. The legend for the map is shown below.

✓ 📂 **Rwanda Ecosystem Type Map**

◻ Acacia Gallery Forest	◻ Humid Savanna Wetland
◻ Afromontane Rain Forest	◻ Lakes
◻ Eastern Evergreen Plateau Grassland Savanna	◻ Miscanthus and Cyperus Wetland
◻ Euphorbia Dawei and Strychnos Dry Forest	◻ Mixed Forest
◻ Evergreen Riverine Tropical Savanna	◻ Mixed Vegetation Wetland
◻ Evergreen Semi-Evergreen Plateau	◻ Mountain Bamboo Forest
◻ Evergreen Semi-Evergreen Bushland and Thicket	◻ Mountain Mixed Forest
◻ Semi-Evergreen Forest Wetland	◻ Neoboutonia Forest
◻ Evergreen Semi-Evergreen Humid Savanna	◻ Sub -Humid Wooded Savanna
◻ Evergreen Semi-Evergreen Riverine Highland	◻ Subalpine Vegetation
◻ Evergreen Semi-Evergreen Riverine Highland Savanna	◻ Transitional Humid Forest
◻ Evergreen Semi-Evergreen Riverine Sub-Humid Highland Savanna	◻ Transitional Plateau Rain Forest
◻ Evergreen Semi-Evergreen Sub-Humid Savanna	◻ Transitional Tropical Savanna
◻ Evergreen Tropical Savanna	◻ Wooded Savanna
◻ Hagenia Hypericum Forest	

Figure 6: Summary of biomes and ecosystem types of Rwanda, generated based on the number of ecosystem types within each biome (broad regional vegetation type).

Given Rwanda's location in a zone between the drier East African savannas and the moist West African rain forests, combined with high altitude ranges, the country has a variety of ecosystems (Figure 6; Table 1). Higher rainfall montane and plateau woodland and savanna areas cover more than 77% of Rwanda, encompassing 29 different ecosystem types. Grassy savanna covers about 13% of Rwanda, while only 1% in the northern boundary was classified as Afroalpine vegetation with a mix of forest and sparse heathlands. However, as many as six ecosystem types occurred in this concentrated but highly diverse region (Table 1).

The aquatic realm of Rwanda is characterised by extensive lake ecosystems, covering more than 6% of the country and is dominated by Lake Kivu in the western border. However, other lakes may need to be classified in the east and these lakes may need to be subdivided into different ecosystem types. These systems are critical habitats, offering breeding and nursery areas for fish.

The aquatic realm is further characterised by extensive areas vegetated wetland types (4 specific ecosystem types; 7% of area) and these ecosystem types have been highlighted for further subclassification in future work.

Table 1: Biome number, total area (ha) and percentage area.

Realm and Biomes	Ecosystem Types	Total Area (ha)	Percentage Area
Terrestrial	25	2,039,444.60	86.40%
Afroalpine Mountain	6	23,945.49	1.00%
Akagera Sub-humid Savanna	5	407,484.47	16.20%
Highland Plateau	3	569,371.80	22.50%
Humid Savanna	4	164,281.88	6.70%
Montane Forest	1	551,001.77	23.30%
Plateau grassland savanna	3	32,339.55	13.70%
Tropical Savanna	3	170,556.12	7.20%
Aquatic	4	321,639.80	13.60%
Wetlands	3	177,286.70	7.00%
Lakes	1	144,353.6	5.70%
Grand Total	**29**	**2,361,084.40**	**100.00%**

During the identification of ecosystem types with stakeholders, some very small ecosystem types with limited information about vegetation composition were merged into adjacent larger and similar ecosystem types. These ecosystems, shown below, warrant further investigation to determine their extent and species composition.

	Initial Ecosystem Type	Merged into….	Area merged in Ha
1	Edaphic and Palm Wooded Grassland	Evergreen Semi-evergreen Bushland and Thicket	108.75
2	Evergreen Semievergreen Subhumid Riverine Savanna	Evergreen Semi-evergreen Sub-humid Savanna	53.04
3	Mixed Vegetation Wetlands	Evergreen Semi-evergreen Sub-humid Savanna Miscanthus and Cyperus Wetland Mixed Vegetation Wetland	0.30 4980.06 10067.16
4	Evergreen Riverine Temperate Highland Savanna	Eastern evergreen Plateau Grassland Savanna Transitional Plateau Rain Forest	22682.86 42.72
5	Evergreen semievergreen highland plateau Savanna Grassland Mosaic	Evergreen Semi-evergreen Plateau	491.09

2.2 Ecological condition

One of the key steps in any Systematic Conservation Planning process is the development of an ecological condition map that shows the remaining intact areas of natural ecosystems (SANBI and UNEP-WCMC, 2016), which is primarily based on a land use/ land cover map. The map of ecological condition defines the degree of modification of the landscape, varying from areas that remain in a natural or near-natural condition, to those that are severely or irreversibly modified (SANBI and UNEP-WCMC, 2016). The purpose of the map of ecological condition is to determine the amount and location of natural habitat that remains

available for achieving biodiversity targets. Maps of ecological condition combine information on the impact of different drivers of ecosystem change (such as land cover change, forest loss and overharvesting of resources) into a single map. Thus, mapping ecological condition is a way of summarising the many pressures acting on ecosystems, since an ecosystem with many severe pressures is likely to be in poor ecological condition. Similar to the use of ecosystem types as a surrogate for biodiversity, ecological condition is a surrogate for a range of human pressures on the natural environment.

2.2.1   Method

The recent Rwanda landcover map (Esri Rwanda Ltd., 2018) was the primary input into the ecological condition map. It is a useful starting point but has a number of issues. Although urban areas are well covered, individual buildings and even villages in rural areas are often below the resolution of the dataset. Roads are not mapped. In a number of cases natural and severely or irreversibly modified areas are combined in a single category. For example, natural forests and artificial (human-planted) forest plantations are a single category; dams and lakes are not distinguished from each other; and natural open areas and open ground are not distinguished from impacted land cover classes. Some natural landcover classes are misidentified as impacted classes; for example, large areas of alpine herbaceous vegetation within Volcanoes NP are mapped as agriculture. Therefore, for the SBA analysis the ecological condition map was produced based on the best available data from the landcover and several additional sources:

- Selected landcover classes were used from the land use /land cover map (Esri Rwanda Ltd., 2018). These were:
    o   Permanent and seasonal agriculture.
    o   Settlements and buildings (covering urban areas, including industrial and mining areas).
- Point data on buildings (especially useful for rural villages and households in farmland) and data on settlement areas were collated from the OpenStreetMap data (Open Street Map, 2022a).
- Roads data on roads and tracks were collated from the OpenStreetMap data (Open Street Map, 2022b).
- Selected landcover classes, such as coffee, were specifically mapped in the erosion mapping dataset (Rwanda Ministry of Environment, 2020).
- Dams were identified from the Rwandan toposheet data (Rwanda Surveys and Mapping, 2022b).
- Plantations (Eucalyptus and Pine), including small woodlots were mapped from the 2019 forest dataset (Rwanda Ministry of Environment, 2019).
- Alien bamboo areas from the 2019 forest dataset (Rwanda Ministry of Environment, 2019).
- Tea plantations were mapped from a slightly older but high quality spatial dataset (National Agricultural Export Development Board, 2016).

To reduce misclassification, natural areas were identified from a number of data sources. These were used to over-ride more general data from the land use/ land cover dataset (Esri Rwanda Ltd., 2018):

- Natural forest specifically mapped in the 2019 forest dataset (Rwanda Ministry of Environment, 2019).
- Data on intact natural wetlands from the 2016 SWAM wetlands dataset (Rwanda Water Resources Board, 2016) was used to identify intact natural areas of wetlands.
- It was assumed that high altitude herbaceous alpine areas within national parks were natural rather than agricultural lands. This was based on a combination of the draft ecosystem map (SANBI, 2022) and the Protected Areas dataset (IUCN, 2021; Rwanda Ministry of Environment, 2022a).
- It was assumed that the fine scale ecosystems specifically mapped and identified for gazetting as protected ecosystems are natural (Biodiversity Conservation, Environmental Management and Rural Development, 2015; Rwanda Ministry of Environment, 2022b).

The various datasets were integrated as follows (Table 2):

- Where there are known natural areas mapped from specific and accurate datasets (i.e. the forest, wetland, Protected Area and protected ecosystems layers), these took priority. These areas were classified as "Natural or Near Natural". Areas that were not specifically mapped as "Not Natural" were assumed to be "Natural or Near Natural".
- Small scale or detailed datasets (e.g. buildings and roads) of "Not Natural" types trumped other more broadly mapped landcover classes. Specifically mapped agricultural or cultivated features trumped other more broadly mapped land use classes. These specially mapped features were tea, bamboo, coffee, artificial plantations and dams. Selected general categories from the Rwanda ESRI landcover were used in areas not otherwise mapped as another landcover class. These were permanent and seasonal agriculture, settlements, industry and mining.
- After the integration of the two above steps, a GIS based fragmentation analysis was undertaken to identify very small (under 2 ha) areas of isolated areas that had not been specifically mapped as "Natural or Near natural". We assumed that these very small areas were likely to be highly degraded and hence were reclassified as "Not Natural".

Table 2: Classification scheme used for allocating land use or land cover categories to ecological condition categories.

Ecological Condition	Land Use or Land Cover
Natural or Near Natural	Areas not mapped as a not natural category
	Fine scale mapped natural areas
Not Natural	Agriculture
	Non-native Bamboo
	Coffee
	Cultivated pasture
	Plantations
	Roads
	Tea
	Urban and buildings Highly fragmented areas (under 2ha)

2.2.2 Results

The map of ecological condition is shown in Figure 7. The analysis highlighted that only 28.3% of Rwanda is likely to be in "Natural or Near Natural" ecological condition.

Importantly, this is a rapid initial analysis:

- The mapping is largely based on the assumption that anywhere that is not specifically mapped as "Not Natural" is in fact "Natural or Near Natural". Even with the correction for highly fragmented areas, this is likely to significantly underestimate actual levels of landscape transformation.
- There is no specific mapping of landscape degradation (e.g. alien invasive vegetation or over-grazing), and no direct mapping of processes that cause degradation of aquatic ecosystems (e.g. pollution). This will result in underestimation of actual threat levels in these ecosystem types.
- The areas identified as fragmented may include important natural areas. Although the analysis is likely to be broadly accurate, the results should not be used for site level decisions without robust field verification of results.

Verification and improvement of the ecological condition map should be the focus for any updated assessment. It will result in significantly improved results at a site level. However, it should be noted that the overall pattern of results is likely to be robust.
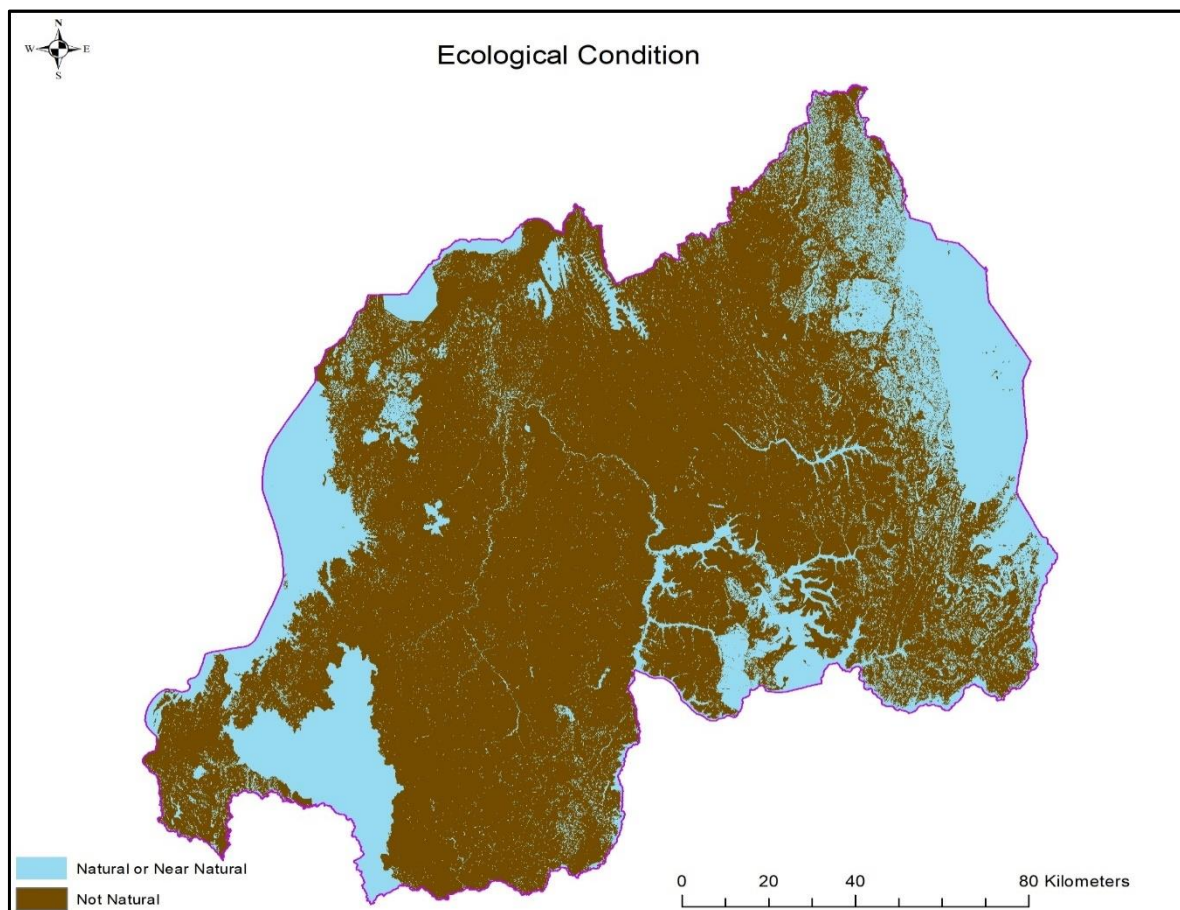
Figure 7: Ecological condition (Natural or Near Natural and Not Natural) map of Rwanda.

2.3 Protected Areas and Other Effective Conservation Area Based Measures

2.3.1 Method

A combined Protected Areas and Other Effective Area-based Conservation Measures layer was developed from the following layers:

- The formally protected national parks (IUCN, 2021; Rwanda Ministry of Environment, 2022a).
- Gazetted protected forests and other ecosystems (Rwanda Environment Management Authority, 2015).
- Fully Protected Wetlands (Rwanda Water Resources Board, 2016) are considered to be a form of Other Effective Area-based Conservation Measure (OECM).

2.3.2   Results

The individual layers were combined to form a single map (Figure 8).
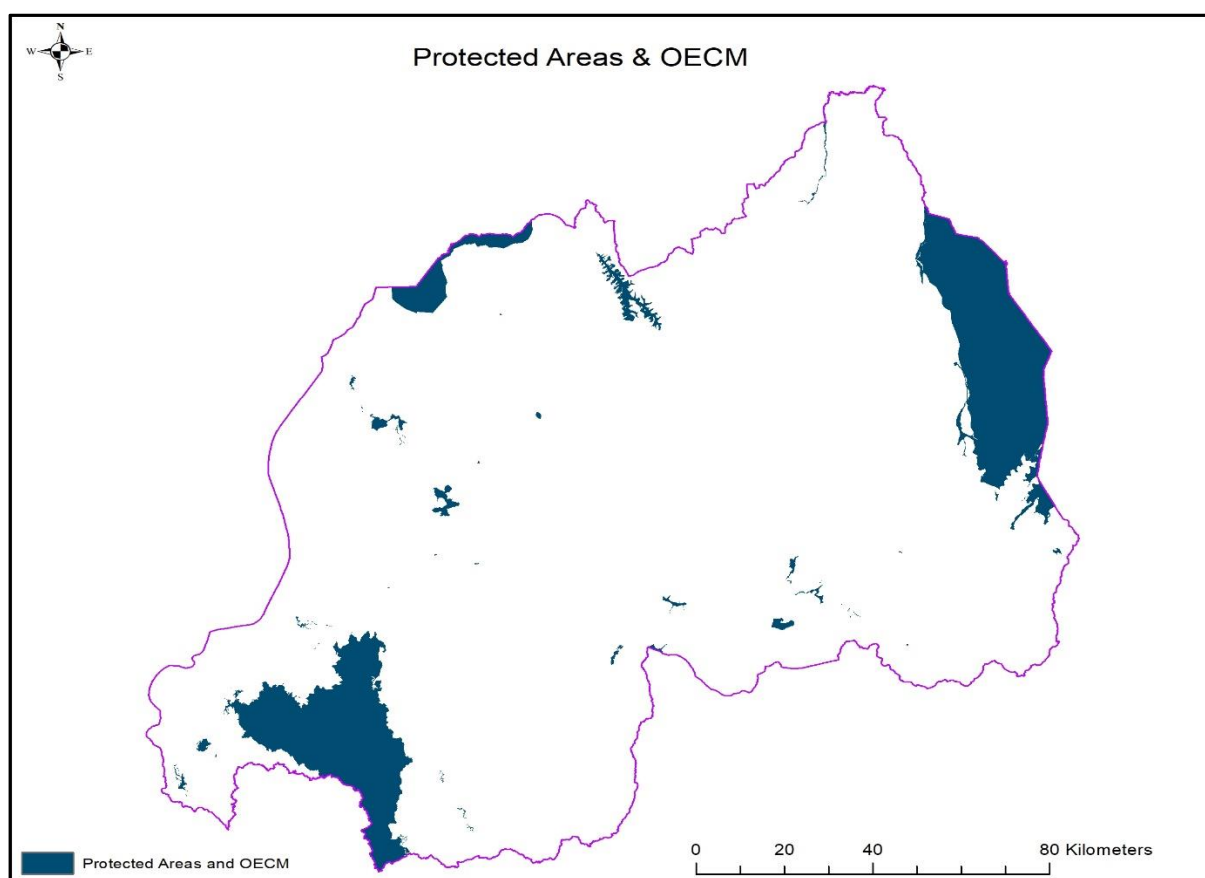
Figure 8: Protected Areas and Other Effective Conservation Measures of Rwanda.

3   ASSESSMENTS

3.1   Ecosystem threat status

Ecosystem threat status is based on the current IUCN risk assessment framework for ecosystems. The IUCN Red List of Ecosystems (RLE) is relatively new from a global perspective (v1.0 released in 2016) (Bland et al., 2017; Keith et al., 2015, 2013; Rodríguez et al., 2015).

Rwanda is one of the first African countries to use the International Union for Conservation of Nature (IUCN) Red List of Ecosystem (RLE) standards. The IUCN RLE is an internationally-accepted standard for assessing threats to ecosystems and it consists of a suite of categories that rank how close each ecosystem type is to collapsing (Bland et al. 2017). A *collapsed state* is the IUCN RLE category that is triggered once it is evident that the defining biotic and abiotic features of an ecosystem type are lost from all occurrences and the characteristics of the native biota can no longer be sustained. A collapsed state is the ecosystem equivalent of an extinct species. Threatened ecosystems refer to a group of categories where ecosystems are close to collapse. These are *Critically Endangered* (i.e. ecosystems that are on a verge of collapse), *Endangered* (i.e. ecosystems that are at high risk of collapse), and *Vulnerable* (i.e. ecosystems that have not yet experienced rapid declines, but have signs and signals warning that they are likely to become

either Critically Endangered or Endangered in the near future under the 'business as usual scenario'). In addition, a *Near Threatened* category is defined for ecosystems that are not yet threatened but are close or may qualify in the future. The *Least Concern* category represents ecosystems that are still in a relatively healthy state or intact condition (Bland et al., 2017) .

The IUCN classifies ecosystem threatening processes into spatial and functional criteria and these feed into a number of potential evaluations. The criteria assess the risk of collapse based on *reduction in geographic distribution* (criterion A), *restriction in geographic distribution* (criterion B), *severity and extent of environmental degradation* (criterion C) and the *disruption in biotic processes and interactions* (criterion D), or *simulation models* (criterion E) to estimate the probability of ecosystem collapse. Each criteria has a range of specifically defined thresholds and specifications (Bland et al., 2017; Rodríguez et al., 2015).

Ideally, one would apply the full range of criteria, but in this initial assessment, we have focussed on the robust application of Criteria A3, which is for reduction in geographical distribution over a long time period (i.e. since 1750). This approach has been robustly and repeatedly applied in other assessments such as South Africa's National Biodiversity Assessment (NBA) (Driver et al., 2012; Skowno et al., 2019). Experience has shown that in initial assessments it is preferable to obtain robust results using this criterion, rather than to attempt to apply the full range of criteria when not all supporting data are in place (e.g. of degradation processes or robust time series of loss).

Both the assessment criteria and categories are built on a scientific methodology and ecological theory that ensures RLE assessments are rigorous, credible, and justifiable. The criteria are applicable across different environments and spatial scales, producing ecosystem assessments that are comparable between countries and regions across the globe (Bland et al., 2017). Like many other countries across the globe, the strongest motivation for Rwanda to adopt the IUCN RLE standards is to use the list of threatened ecosystems to mainstream biodiversity considerations into policy development, and land-use planning. Furthermore, it is to increase legitimacy of the ecosystem threat status assessment outcomes by basing them on a body of sound scientific literature.

3.1.1   Ecosystem threat status calculation

Under the A3 criteria various thresholds are set for reduction in distribution compared to the original extent of each ecosystem type (See Figure 9). To evaluate the criteria all that is needed is:

- The map of ecosystem types which shows the original extent of each ecosystem (See section 2.1). This provides an historical snapshot of original extent that for practical purposes we can assume as a 1750 baseline. This date predates large scale industrial and arable agriculture activities, and expansion of human populations, and their associated impact footprints, which have largely taken place over the last 270 years.
- The map of ecological condition showing remaining natural and semi-natural areas (See section 2.2).

A basic GIS process was used to evaluate the areas which have been lost. This allows a calculation of threat status for each ecosystem type.

Criterion A. Reduction in geographic distribution

A3. since 1750

CR	≥ 90%
EN	≥ 70%
VU	≥ 50%

Near Threatened = Within 10% of Vulnerable

Least Concern = Does not trigger any criteria

Figure 9: The Rwanda Spatial Biodiversity Assessment applied the IUCN Red List Criteria A3 for reduction in geographical distribution over a long time period (since 1750). Various thresholds are set for reduction in distribution compared the original extent of each ecosystem type: CR >= 90%, EN>= 70%, VU>= 50%, NT = within 10% of Vulnerable and the last LC = does not triger any Criteria

3.1.2 Ecosystem threat status results

A full list of threat statuses for each ecosystem type are provided in the Appendix. Maps of ecosystem threat status are given in Figure 10 (which shows the full original extent of each ecosystem type) and Figure 11 (which only shows the remaining natural and near natural areas of each ecosystem type). Data are summarised in Figure 12.

Of the 29 ecosystem types occurring in Rwanda, 71% (amounting to 24 types) have been classified as threatened in accordance with the IUCN RLE standards. Only 12% (amounting to 4) of these threatened ecosystems were categorised as Critically Endangered, 41% (amounting to 14) as Endangered, and 18% (amounting to 6) as Vulnerable (Figure 11, **Error! Reference source not found.**, Table 4). More than half (59%) of these threatened ecosystems are concentrated in the following five regions: Akagera Sub-humid Savanna, Highland Plateau, Humid Savanna, Plateau grassland savanna, and Tropical Savanna. The Highland

> **Ecosystem types and species are referred to as 'threatened' when they have been categorised as Critically Endangered, Endangered or Vulnerable.**

Plateau and Tropical Savanna contain the entire distribution of ecosystems on the verge of spatial collapse (i.e., Critically Endangered) making up 20% (4) of threatened ecosystems found in these five regions. In addition, 60% (12) of the threatened ecosystems in these five regions have been classified as Endangered and their majority are Savanna types (Figure 11, **Error! Reference source not found.**, Table 4). The Akagera Sub-humid Savanna biome has a high concentration of ecosystems on the verge of being at immediate risk of spatial collapse (i.e., Vulnerable), making up 20% (4) of ecosystems in these regions. These threatened ecosystems call for immediate conservation interventions to reduce or even halt the rates of complete collapse, particularly for the Critically Endangered and Endangered ecosystems as they have little of their natural extent remaining.

On the other hand, ecosystems occurring in the Afroalpine Mountain region are the least affected by anthropogenic land-use activities. Most of the types occurring in this part of the country have been classified as Least Concern. For the inland aquatic ecosystems, the wetlands were classified as threatened under the Endangered and Vulnerable categories while the lakes were classified as Least Concern. Although the risk of collapse for these aquatic ecosystems has been assessed, their risk of collapse is likely to have been under-estimated as the change in the ecosystem integrity was not considered in this round of the assessment (Figure 11, **Error! Reference source not found.**, Table 4). Major data limitations in this Rwandan RLE assessment included the lack of ecosystem integrity data for both terrestrial and aquatic systems and the unavailability of multiple land-cover data important for projecting and back-casting the risk of collapse over a 50-year period. As such, the full range of the IUCN RLE criteria were not applied. There will likely be an improvement in the threat status of some of the ecosystems classified as Least Concern or Near Threatened once the symptoms exacerbating spatial and functional change over multiple time points are considered in future assessments.

Figure 10: Ecosystem threat status across Rwanda. This map shows the original extent of the nine biomes, colored according to threat status today, which is calculated by determing the reduction in geographic extent for each.
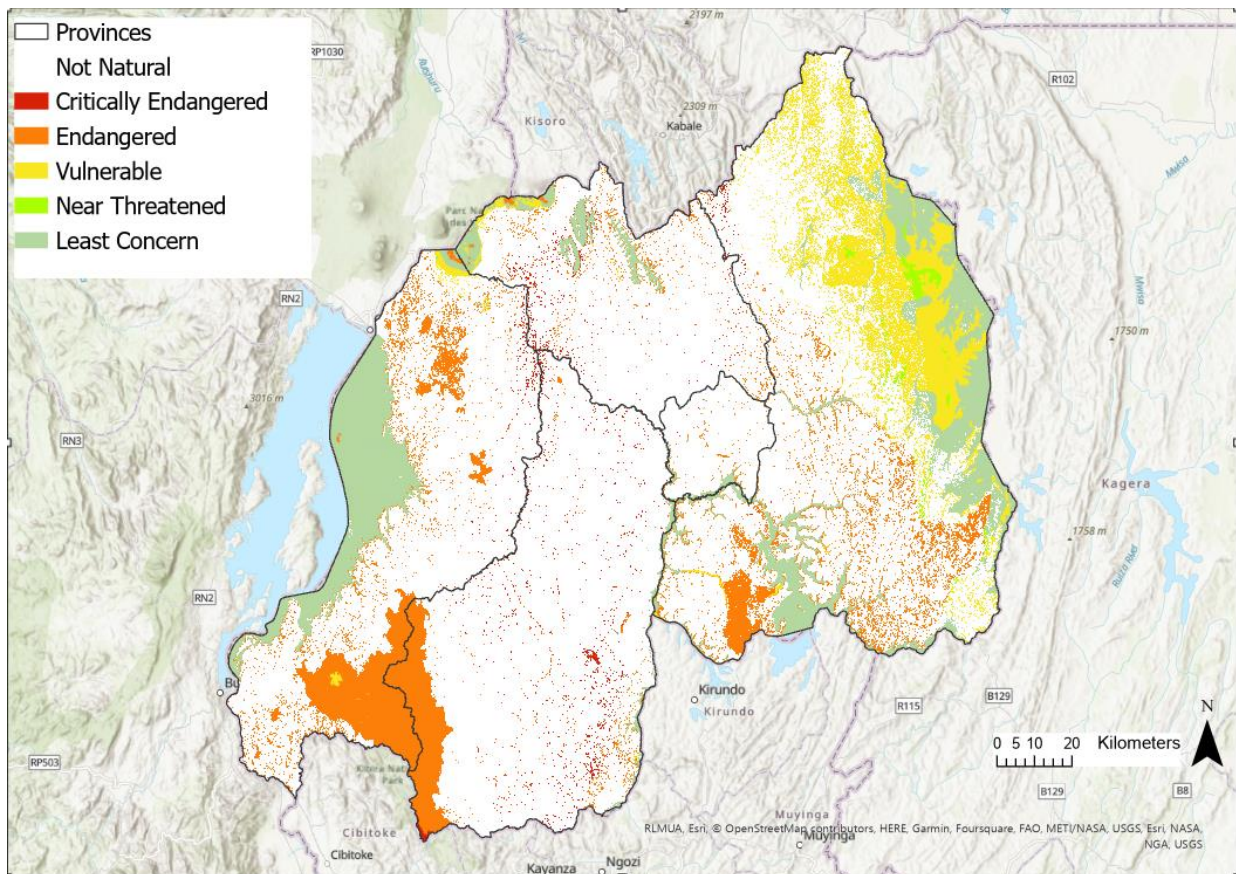
Figure 11: Ecosystem threat status across Rwanda. Map shows remaining intact areas of ecosystems.
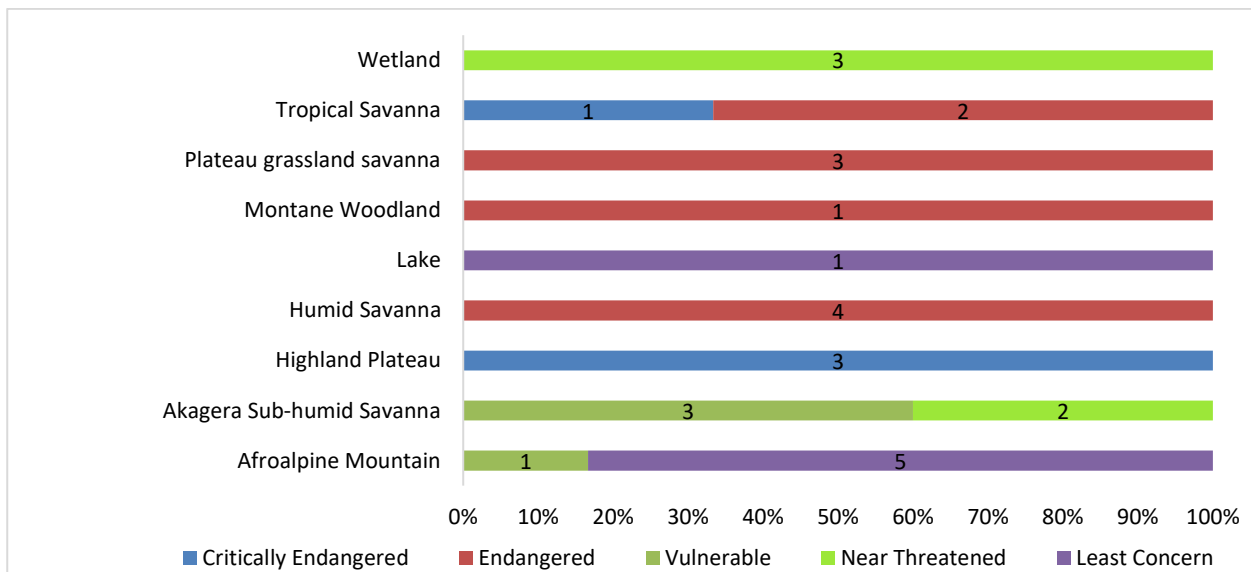
Figure 12: Percentage of ecosystem types in each threat category within Rwanda. The data labels show the number of ecosystem types in each category.

Table 3: Number of ecosystem types in each threat category (Critically Endangered, Endangered, Near Threatened and Least Concern) in Rwanda.

Realm and Broad types	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Total
Terrestrial	3	10	4	2	6	25
Afroalpine Mountain			1		5	6
Akagera Sub-humid Savanna			3	2		5
Highland Plateau	3					3
Humid Savanna		4				4
Montane Forest		1				1
Plateau grassland savanna		3				3
Tropical Savanna		2			1	3
Aquatic	0	0	0	3	1	4
Lake					1	1
Wetland				3		3
Grand Total	3	11	4	5	7	29

Table 4: Percentage of ecosystem types in each threat category (Critically Endangered, Endangered, Near Threatened and Least Concern) in Rwanda.

Realm and Broad types	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern
Terrestrial	12.0	40.0	16.0	8.0	24.0
Afroalpine Mountain	0.0	0.0	16.7	0.0	83.3
Akagera Sub-humid Savanna	0.0	0.0	60.0	40.0	0.0
Highland Plateau	100.0	0.0	0.0	0.0	0.0
Humid Savanna	100.0	100.0	0.0	0.0	0.0
Montane Forest	0.0	100.0	0.0	0.0	0.0
Plateau grassland savanna	0.0	100.0	0.0	0.0	0.0
Tropical Savanna	0.0	66.7	0.0	0.0	33.3
Inland Aquatic	0.0	0.0	0.0	75.0	25.0
Lake	0.0	0.0	0.0	0.0	100.0
Wetland	0.0	0.0	0.0	100.0	0.0
Grand Total	10.3	37.9	13.8	17.2	24.1

3.2 Ecosystem protection level

Ecosystem protection level is an indicator that tracks how well represented an ecosystem type is in the protected area network. It is computed by intersecting the map of remaining natural areas of each ecosystem type with the map of protected areas. Ecosystem types are then categorised based on the proportion of the target for each ecosystem type that is included in one or more protected areas.

Protection level evaluations are relative to a percentage target of the original extent of each ecosystem type. To some extent it is not important what percentage is used, as the assessments will still identify which ecosystems are relatively well protected and which are not. Nevertheless, there is strong mainstreaming benefit in aligning with national commitments, strategy and reporting. This is complicated by the fact that the Convention on Biological Diversity targets are currently being negotiated. Draft Target 2 of the post-2020 global biodiversity target is currently: 'By 2030, protect and conserve through well connected and effective system of protected areas and other effective area-based conservation measures at least 30 percent of the planet with the focus on areas particularly important for biodiversity.' Known more widely as the '30 by 30' target, it is the most well-known of the 20 targets in the new Global Biodiversity Framework, and it replaces the previous target (intended to be

> **Under-protected ecosystem types and species** are those categorised as Not Protected, Poorly Protected and Moderately Protected in the protection level assessment.

achieved by 2020) of 17% of land area and 10% of marine areas of the planet protected. In order to be forward looking we have used the likely 2030 target (30% of each ecosystem type) as the baseline for the protection level evaluation.

The categories for protection level are Well Protected (WP) where the extent protected exceeds the target; Moderately Protected (MP) where the extent protected is from 50% to just less than 100% of the target; Poorly Protected (PP) where the extent protected is from 5% to just less than 50% of the target; and Not Protected (NP) where the extent protected is less than 5% of the target (Table 5).

Table 5: Ecosystem protection levels are calculated based on the proportion of the target met in a protected area (or other effective area-based conservation measure).

Proportion of target met in a protected area	
Not protected	*Zero or less than 5% of target*
Poorly protected	*5% or less than 50% of target*
Moderately protected	*50% or less than a 100% of target*
Well protected	*100% or more than a 100% of target*

3.2.1 Ecosystem protection level calculation

The ecosystem protection level requires a basic GIS calculation using the following components and method:

- The map of ecosystem types shows the original extent of each ecosystem (See Section 2.1). This provides an historical snapshot of original extent that can be used to calculate the 30% target requirement.

- The map of protected areas shows areas within Protected Areas and OECMs (Other Effective Area-based Conservation Measures) (See Section 2.3). This is used to identify the areas of each ecosystem type that are protected.

- The map of ecological condition showing remaining natural and semi-natural areas (See section 2.2) is used to ensure that only these areas contribute to meeting targets. This ensures that we do not count fields, dams, plantation forest (e.g. eucalypts), urban areas etc in the calculation of effective protection. The inclusion of this layer allows us to eliminate the impact of errors in the PA layer, remove the potential contributions of areas which are effectively no longer PAs (e.g. where they have been transferred to agriculture), remove the small but important impacts of park infrastructure (e.g. buildings and roads), remove the impacts of artificial features in PAs (e.g. dams are often included in PAs) , and deal with issues where a PA category may include areas that are not managed for conservation of natural intact ecosystems (e.g. in Rwanda many forest reserves are managed for wood production using plantations of pines or eucalypts).

A basic GIS process was used to evaluate the area of each ecosystem type that is in a Protected Area or OECM (Other Effective Area-based Conservation Measures) that is in intact natural or semi-natural ecological condition. These values are compared to the targets and a protection level category is calculated for each ecosystem type.

3.2.2 Ecosystem protection level results

Maps summarising ecosystem protection level are given in Figure 13 (showing the full extent of each ecosystem type) and Figure 14 (showing the remaining natural and semi-natural areas of each ecosystem type). The data are further summarised in Figure 15 and Table 6 and Table 7.

Most of Rwanda's landscape consists of Not Protected ecosystem types. Of the 29 terrestrial ecosystem types occurring in Rwanda, 59% (amounting to 17) have been classified as Not Protected, with much of the central portion of the country having little to no effective protection (Figure 13, Figure 14). All of the ecosystem types within the following biomes are classified as Not Protected: Tropical Savanna, Plateau Grassland Savanna, and Highland Plateau (Figure 13, 14 and 15). Three of the four Humid Savanna ecosystem types are in national parks, and the fourth one is categorised as poorly protected. (There are only two poorly protected terrestrial ecosystem types; the other poorly protected ecosystem falls within the Akagera Sub-humid Savanna biome).

Some regions are better protected. There is 10% of the terrestrial ecosystem types (amounting to 3) classified as moderately protected. These ecosystem types occur partially within the national parks (Figure 16). A large proportion of the Moderately Protected Akagera Sub-humid Savanna ecosystem types falls within the Akagera National Park, occurring in the east of Rwanda.

There is 24% of the terrestrial ecosystems (amounting to 7) classified as well protected. The well protected terrestrial ecosystem types are concentrated around Volcanoes National Park in the north, and to the east (in and around Akagera National Park). All six Afroalpine Mountain ecosystem types are classified as well protected (Figure 15, Table 6, Table 7).
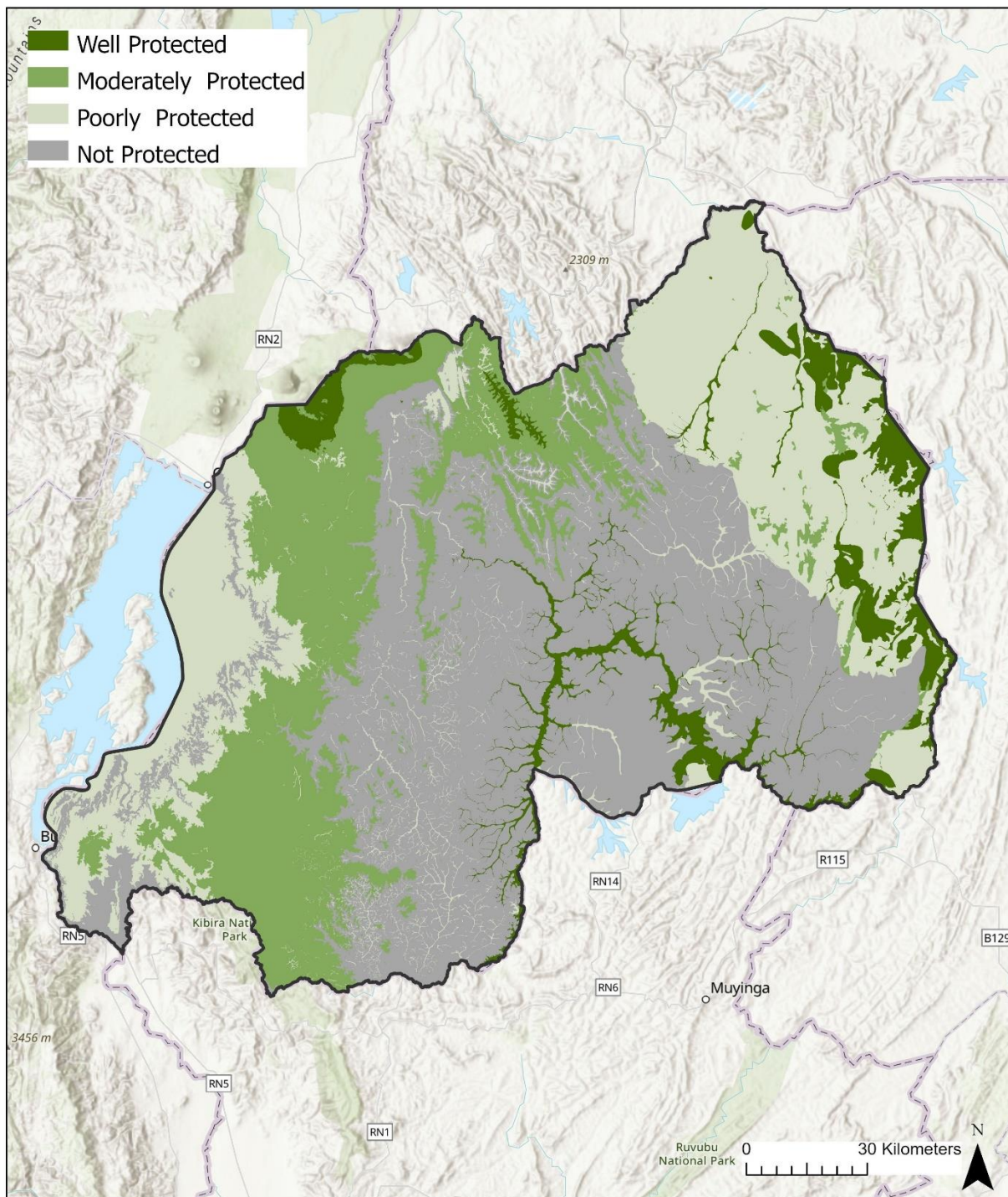
Figure 13: Protection level across Rwanda of remaining ecosystems. Map shows former full extent of each ecosystem types.
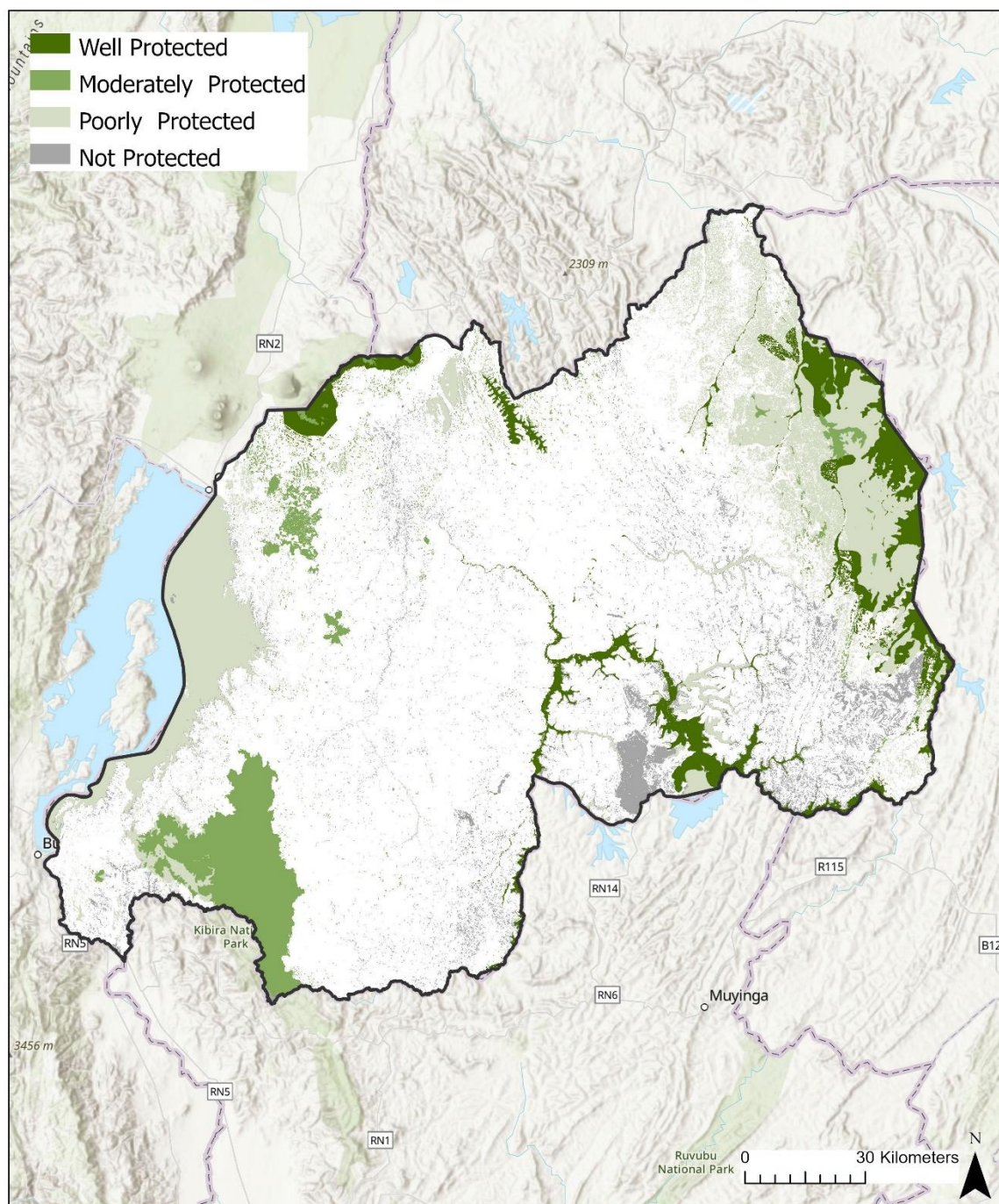
Figure 14: Protection level of ecosystems across Rwanda. Map shows the remaining intact areas of each ecosystem.

There are only three wetland types in Rwanda, and a little over 30% of these are poorly protected; the remaining are well protected (Figure 15, Table 7).
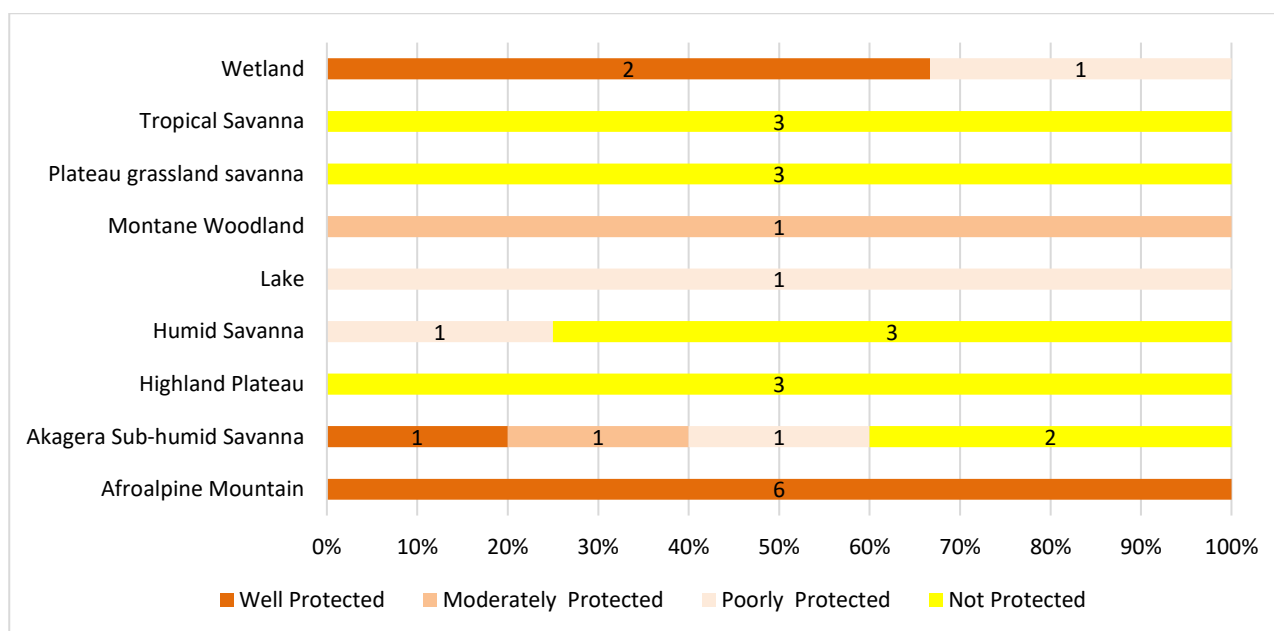
Figure 15: Percentage of ecosystem types in each protection category within Rwanda. The data labels show the number of ecosystem types in each category

Table 6: Number of ecosystem types in each protection level category in Rwanda

Biome	Well Protected	Moderately Protected	Poorly Protected	Not Protected	Total Type Number
Terrestrial					
Afroalpine Mountain	6	0	0	0	6
Akagera Sub-humid Savanna	1	1	1	2	5
Highland Plateau	0	0	0	3	3
Humid Savanna	0	0	1	3	4
Montane Forest	0	1	0	0	1
Plateau grassland savanna	0	0	0	3	3
Tropical Savanna	0	0	0	3	3
Total Terrestrial	**7**	**2**	**2**	**14**	**25**
Aquatic					
Wetland	2	0	1	0	3
Lake	0	0	1	0	1
Total Aquatic	**2**	**0**	**2**	**0**	**4**
Grand Total	9	2	4	14	**29**

Table 7: Percentage of ecosystem types in each protection level category in Rwanda.

Biome	Well Protected	Moderately Protected	Poorly Protected	Not Protected
Terrestrial	28.0	8.0	8.0	56.0
Afroalpine Mountain	100.0	0.0	0.0	0.0
Akagera Sub-humid Savanna	20.0	20.0	20.0	40.0
Highland Plateau	0.0	0.0	0.0	100.0
Humid Savanna	0.0	0.0	25.0	75.0
Montane Forest	0.0	100.0	0.0	0.0
Plateau grassland savanna	0.0	0.0	0.0	100.0
Tropical Savanna	0.0	0.0	0.0	100.0
Aquatic	50.0	0.0	50.0	0.0
Wetland	66.7	0.0	33.3	0.0
Lake	0.0	0.0	100.0	0.0
Grand Total	31.0	6.9	13.8	48.3
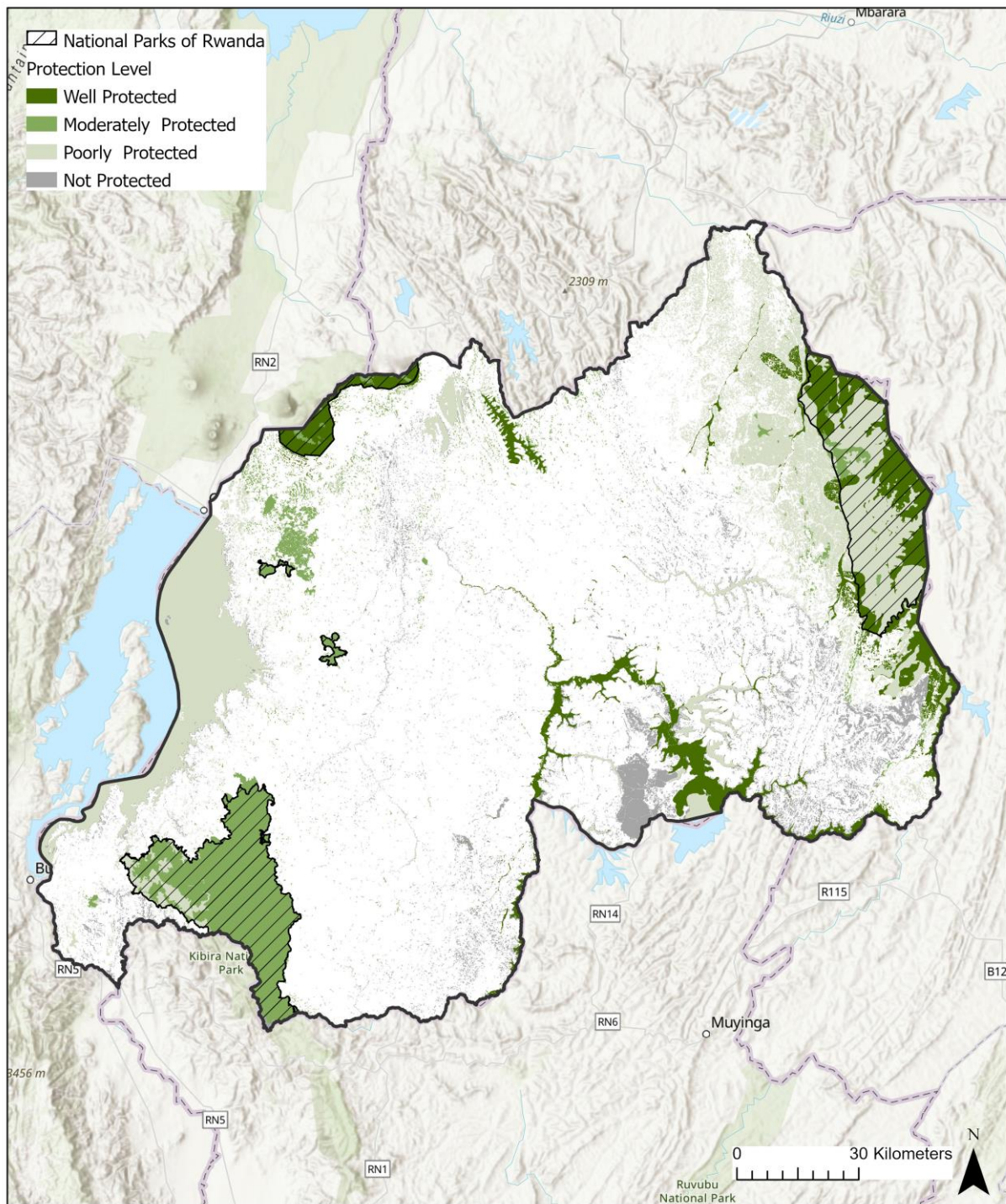
Figure 16: Location of National Parks in relation to the remaining extent of ecosystem types with various protection levels.

3.3   Initial Prioritization for Conservation Action

Spatial biodiversity prioritisation identifies areas in which to focus conservation action most urgently, referred to as biodiversity priority areas. Biodiversity priority areas are those parts of the landscape or seascape that are most important for conserving viable representative samples of ecosystems and

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species, for maintaining ecological processes, or for the provision of ecosystem services. Conservation resources are always limited and need to be directed towards the areas of high biodiversity importance and the most urgent conservation needs. As importantly, securing biodiversity priorities often has a significant opportunity cost for other sectors (i.e. it can restrict their options and increase costs), and therefore it is important that biodiversity priority areas focus clearly on an efficient, robust and clearly justified set of priority areas. As with assessments, the results of prioritization processes can feed into a range of implementation mechanisms and planning processes e.g. strategic plans for a sector such as agriculture.

While assessment follows a relatively uniform process, prioritisation methods can vary widely depending on the context and purpose. The initial Rwanda SBA process followed a rapid basic spatial prioritization approach that combined:

- Threatened Ecosystems, identified in this assessment (See Section 3.1).
- Under-protected Ecosystems, identified in this assessment (See 3.2).

3.3.1 Methods

For the initial biodiversity priority areas analysis, we simply combined the protection level results with the threat status results, with only the natural and near natural areas being prioritized. Integrating threat status and protection levels for ecosystems is useful for identifying ecosystems in particular need of protection. This could, in turn, provide input into conservation planning such as protected areas expansion strategies.

3.3.2 Results

There are nine Well Protected ecosystems in Rwanda; of these nine, one is considered threatened and the other eight are all classified as least concerned (Table 8). The other 25 ecosystems are under-protected (Not Protected, Poorly Protected and Moderately Protected) and threatened or near-threatened (CR, EN, NT, VU) (Table 8). This latter group are ecosystem types that have both a high risk of collapse and are under-represented in the current protected areas network. In most situations, options for protecting the CR types are limited as they tend to be fragmented.

Table 8: Integrated table highlighting ecosystems which are both under-protected (especially Not Protected and Poorly Protected ecosystem types) and threatened (particularly Critically Endangered and Endangered). Red indicates highest priority systems, orange is the next level of priority and yellow are additional priorities.

Threat Status	Protection Level			
	Well Protected	Moderately Protected	Poorly Protected	Not Protected
Critically Endangered (CR)	0	0	0	4
Endangered (EN)	0	1	1	8
Near Threatened (NT)	3	0	1	1
Vulnerable (VU)	1	1	1	1
Least Concern	5	0	1	0
TOTAL	9	2	4	14

The remaining extent of ecosystems that are classified as threatened and under-protected are mapped in Figure 17. From this map it is clear that there are two large intact patches of EN and under-protected ecosystem types. One is found to the southwest of Rwanda (occurring within Nyungwe National Park) and the other occurs around the district of Bugesera. There are also several patches of VU and under-protected ecosystem types to the east of Rwanda, around Akagera National Park. Note that this does not mean that these National Parks are badly managed, it simply means that a greater portion of these ecosystem types should be protected.
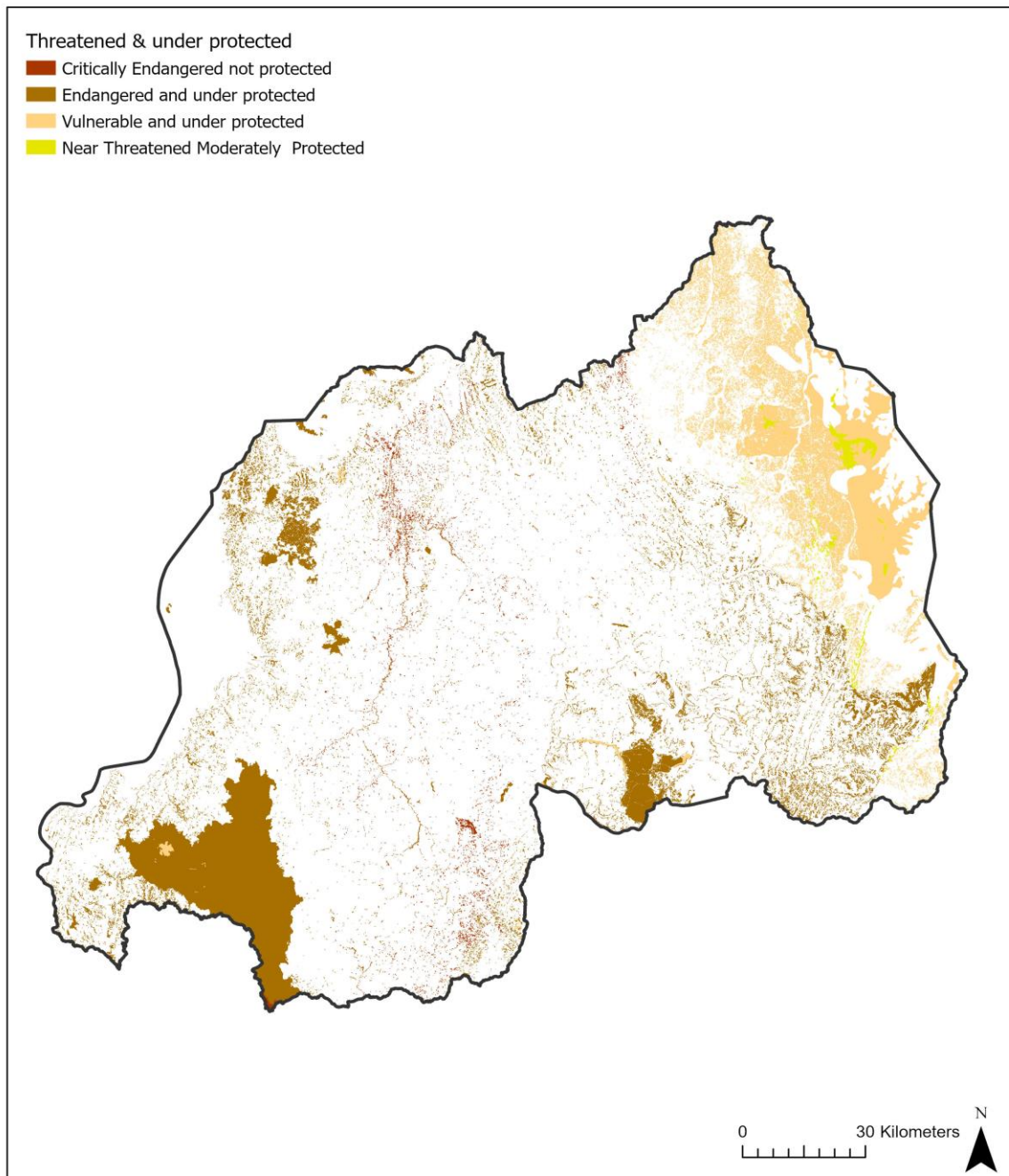
Figure 17: The remaining extent of ecosystems which are threatened (CR, EN, VU) and under-protected (NP, PP, MP).

Table 9 in the Appendix shows details of ecosystem threat status and protection level for each ecosystem type in Rwanda.

This assessment and narrative will be expanded in the next iteration of the report. A greater understanding of what drives habitat loss within in each ecosystem type needs to be investigated.

3.4 KNOWLEDGE GAPS AND NEXT STEPS

Note that this is a rapid and preliminary assessment undertaken in a workshop format, and significant improvements are likely in future iterations.

Key issues that need to be addressed:

- Improvement to the classification and mapping of aquatic ecosystem types (especially open water ecosystem classification) and their condition. The expert validation identified this as a key area of potential improvement.
- The development of full descriptions of each ecosystem type including the major features of the landscape, drivers of ecosystem function, and dominant and diagnostic communities will be vital to the next assessment.
- Improved mapping of degradation (including alien invasive vegetation, overgrazing and especially degradation of aquatic ecosystems) to allow a more complete ecological condition map to be developed.
- Additional validation of input layers.
- A second iteration of the spatial analysis, ideally an expansion of the analysis to include degradation.
- Exploration of key findings and messages for mainstreaming.
- Expansion of the current report to national narratives and site-specific examples.
- Sharing of spatial data and metadata.
- Links to the development of indicators.

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Van Breugel, P., Kindt, R., Lillesø, J.P.B., Bingham, M., Dudley, C., Friis, I., Gachathi, F., Kalema, J., Mbago, F., Minani, V., 2011. Potential Natural Vegetation of Eastern Africa (Ethiopia, Kenya, Ma. Forest & Landscape Denmark University of Copenhagen 23 Rolighedsvej DK-1958 ….

Clarification on IUCN Red List status and Ecosystem Protection Level

The Rwanda SBA applied the IUCN Red List Criteria A3 (since 1750) for a reduction in geographical distribution over a long time period. Various thresholds are set for a reduction in distribution compared to the original extent of each ecosystem type. The Critically Endangered (CR) category comprises the ecosystems that lost more than or equal to 90% of their original area, the Endangered category (EN) covers the ecosystem types that lost more than or equal to 70% of their original area, The Vulnerable (VU) ecosystems lost more than or equal 50%, Near Threatened (NT) lost the percentage within 10% of Vulnerable of its original areas whereas the Least Concern (LC) does not trigger any Criteria

Ecosystem protection level is an indicator of the extent to which different ecosystem types are adequately represented in the existing protected area network. The assessment of ecosystem protection level is based on a percentage target of the original extent of each ecosystem type. To align with the Global Biodiversity Framework, a target of 30% is used. Ecosystems can be categorized into different levels of protection. So, a well-protected ecosystem has 100% or more than 100% of the target met, the Moderately protected ecosystem is represented by 50% or less than 100% of the target, Poorly protected ecosystem is represented by 5% or less than 50% of target whereas Not protected ecosystems are represented by Zero or less than 5% of target.

5 APPENDIX: ECOSYSTEM THREAT STATUS AND PROTECTION LEVELS

Table 9: Details of ecosystem threat status and protection level for each ecosystem type for Rwanda.

ID	Realm	Biome	Ecosystem Type	Original extent (ha)	Loss (ha)	Loss (%)	Ecosystem Threat Status	Intact Area in PA (ha)	PA Target (ha)	Percentage PA Target Achieved	Protection Level
1	Terrestrial	Afroalpine Mountain	Mountain mixed forest	602.824	0.119995	0.02	Least Concern	584.477	180.847	323.189	Well Protected
2	Terrestrial	Afroalpine Mountain	Mountain bamboo forest	13981.8	7768.12	55.56	Vulnerable	4864.3	4194.54	115.967	Well Protected
3	Terrestrial	Afroalpine Mountain	Subalpine vegetation	1532.62	0.160034	0.01	Least Concern	1529.65	459.786	332.687	Well Protected
4	Terrestrial	Afroalpine Mountain	Hagenia hypericum forest	6317.52	132.04	2.09	Least Concern	6129.71	1895.26	323.423	Well Protected
5	Terrestrial	Afroalpine Mountain	Mixed Forest	544.737	2.92401	0.54	Least Concern	535.043	163.421	327.402	Well Protected
6	Terrestrial	Afroalpine Mountain	Neoboutonia Forest	969.614	36.775	3.79	Least Concern	628.623	290.884	216.108	Well Protected
7	Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Bushland and Thicket	2187.68	1419.5317	64.88	Vulnerable	12.2984	656.304	1.87388	Not Protected
8	Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Riverine Sub-humid Highland Savanna	40633.8	12929	31.82	Least Concern	12731	12190.1	104.437	Well Protected
9	Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Sub-humid Savanna	344094.5588	186251.6414	54.12	Vulnerable	49436	103228.7676	47.88975	Poorly Protected
10	Terrestrial	Akagera Sub-humid Savanna	Acacia Gallery Forest	444.547	304.176	68.42	Vulnerable	90.2954	133.364	67.706	Moderately Protected
11	Terrestrial	Akagera Sub-humid Savanna	Sub - humid Wooded savanna	19445.6	9447.24	48.58	Near Threatened	5040	5833.68	86.3949	Moderately Protected
12	Terrestrial	Highland Plateau	Evergreen Semi-evergreen Plateau	129226.692	121318.365	93.88	Critically Endangered	23.4352	38768.008	0.0604498	Not Protected
13	Terrestrial	Highland Plateau	Evergreen Semievergreen Riverine Highland	18366.4	18150.2	98.82	Critically Endangered	0	5509.92	0	Not Protected
14	Terrestrial	Highland Plateau	Wooded savanna	421785	410196	97.25	Critically Endangered	827.802	126536	0.654203	Not Protected
15	Terrestrial	Humid Savanna	Euphorbia dawei and Strychnos dry Forest	22274.1	18003.8	80.83	Endangered	99.2288	6682.23	1.48497	Not Protected
16	Terrestrial	Humid Savanna	Evergreen Semi-evergreen Humid Savanna	2254.42	1703.43	75.56	Endangered	0	676.326	0	Not Protected
17	Terrestrial	Humid Savanna	Evergreen Semi-evergreen Riverine Highland Savanna	37295.1	32067.4	85.98	Endangered	104.036	11188.5	0.929848	Not Protected
18	Terrestrial	Humid Savanna	Transitional Humid Forest	102463	84988.5	82.95	Endangered	9212.94	30738.9	29.9716	Poorly Protected
19	Aquatic	Lake	Lake	144352	953	0.66	Least Concern	15364.4	43305.6	35.479	Poorly Protected
20	Terrestrial	Montane Forest	Afromontane Rain Forest	550967	424554	77.06	Endangered	96402.5	165290	58.3232	Moderately Protected
21	Terrestrial	Plateau grassland savanna	Eastern evergreen Plateau Grassland Savanna	239724	209406.7	87.35	Endangered	21.99299	71917.2	0.03058099	Not Protected
22	Terrestrial	Plateau grassland savanna	Semi-evergreen Forest Wetland	605.228	435.734	72	Endangered	0	181.568	0	Not Protected
23	Terrestrial	Plateau grassland savanna	Transitional Plateau Rain Forest	83705.2	73246.5	87.51	Endangered	0	25111.6	0	Not Protected
24	Terrestrial	Tropical Savanna	Evergreen Riverine Tropical Savanna	83835.4	70677.9	84.31	Endangered	966.209	25150.6	3.84169	Not Protected
25	Terrestrial	Tropical Savanna	Evergreen Tropical Savanna	82467.9	63839.8	77.41	Endangered	432.489	24740.4	1.74811	Not Protected
26	Terrestrial	Tropical Savanna	Transitional Tropical Savanna	4246.53	3878.78	91.34	Critically Endangered	27.1607	1273.96	2.13199	Not Protected
27	Aquatic	Wetland	Humid Savanna Wetland	8420.59	3093.52	36.74	Least Concern	2562.44	2526.18	101.435	Well Protected
28	Aquatic	Wetland	Miscanthus and Cyperus Wetland	153926.9	53609.7	34.8	Least Concern	43638.16	46178.1	94.49968	Moderately Protected
29	Aquatic	Wetland	Mixed Vegetation Wetland	14932	8259.31	55.31	Vulnerable	1660.09	4479.6	37.0589	Poorly Protected

6. Appendix: Location of National Parks and OECMS in relation to the remaining extent of the ecosystem types.

Realm	Biome	Ecosystem Type	Ecosystem Threat Status	Protection Level	Intact Area in PA (ha)	Location of National Parks and OECMS in relation to the remaining extent of ecosystem types	Location- District
Terrestrial	Afroalpine Mountain	Mountain mixed forest	Least Concern	Well Protected	584.477	Volcano National Park	Burera, Musanze and Nyabihu
Terrestrial	Afroalpine Mountain	Mountain bamboo forest	Vulnerable	Well Protected	4864.3		
Terrestrial	Afroalpine Mountain	Subalpine vegetation	Least Concern	Well Protected	1529.65		
Terrestrial	Afroalpine Mountain	Hagenia hypericum forest	Least Concern	Well Protected	6129.71		
Terrestrial	Afroalpine Mountain	Mixed Forest	Least Concern	Well Protected	535.043		
Terrestrial	Afroalpine Mountain	Neoboutonia Forest	Least Concern	Well Protected	628.623		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	66.3	Ibanda -makera	Kirehe
Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Riverine Sub-humid Highland Savanna	Least Concern	Well Protected	75.49		
Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Sub-humid Savanna	Vulnerable	Poorly Protected	30.86		
Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Bushland and Thicket	Vulnerable	Not Protected	12.39	Muvumba Gallery forest	Nyagatare
Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Sub-humid Savanna	Vulnerable	Poorly Protected	15.49		
Terrestrial	Akagera Sub-humid Savanna	Acacia Gallery Forest	Vulnerable	Moderately Protected	91.68		
Aquatic	Wetland	Mixed Vegetation Wetland	Vulnerable	Poorly Protected	565.99		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	7.05		
Terrestrial	Tropical Savanna	Evergreen Riverine Tropical Savanna	Endangered	Not Protected	861.66	Karama Natural Forest	Bugesera
Terrestrial	Tropical Savanna	Evergreen Tropical Savanna	Endangered	Not Protected	142.37		
Aquatic	Wetland	Mixed Vegetation Wetland	Vulnerable	Poorly Protected	5.69		
Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Riverine Sub-humid Highland Savanna	Least Concern	Well Protected	12703.36	Akagera National Park	Nyagatare, Gatsibo and kayonza
Terrestrial	Akagera Sub-humid Savanna	Evergreen Semi-evergreen Sub-humid Savanna	Vulnerable	Poorly Protected	49658.76		
Aquatic	Lake	Lake	Least Concern	Poorly Protected	15438.23		
Aquatic	Wetland	Humid Savanna Wetland	Least Concern	Well Protected	523.088		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	29629.44		
Terrestrial	Akagera Sub-humid Savanna	Sub - humid Wooded savanna	Near Threatened	Moderately Protected	5078.53		
Terrestrial	Montane Forest	Afromontane Rain Forest	Endangered	Moderately Protected	159.71	Busaga forest	Muhanga
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	0.39		
Terrestrial	Highland Plateau	Wooded savanna	Critically Endangered	Not Protected	17.89	Buhanga Ecopark	Musanze
Terrestrial	Highland Plateau	Wooded savanna	Critically Endangered	Not Protected	14.79	Sanza Nyabitukura forest	Ngororero
Terrestrial	Montane Forest	Afromontane Rain Forest	Endangered	Moderately Protected	9.3		
Terrestrial	Highland Plateau	Evergreen Semi-evergreen Plateau	Critically Endangered	Not Protected	1.39	Ndoha Forest	Karongi
Terrestrial	Highland Plateau	Wooded savanna	Critically Endangered	Not Protected	27.488		
Terrestrial	Tropical Savanna	Evergreen Riverine Tropical Savanna	Endangered	Not Protected	91.66	Kibirizi Forest	Nyanza
Terrestrial	Highland Plateau	Evergreen Semi-evergreen Plateau	Critically Endangered	Not Protected	22.47		
Terrestrial	Tropical Savanna	Evergreen Tropical Savanna	Endangered	Not Protected	241.86		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	1.34		
Terrestrial	Tropical Savanna	Transitional Tropical Savanna	Critically Endangered	Not Protected	27.77	Karehe Gatuntu Forest complex	Ngororero
Terrestrial	Highland Plateau	Wooded savanna	Critically Endangered	Not Protected	16.63		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	2.65		
Terrestrial	Montane Forest	Afromontane Rain Forest	Endangered	Moderately Protected	91147.21	Nyungwe National Park	Rusizi, Nyamasheke, Nyamagabe, Nyaruguru
Terrestrial	Humid Savanna	Euphorbia dawei and Strychnos dry Forest	Endangered	Not Protected	75.54		
Terrestrial	Highland Plateau	Evergreen Semievergreen Riverine Highland	Critically Endangered	Not Protected	27.047		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	9.1		
Aquatic	Wetland	Mixed Vegetation Wetland	Vulnerable	Poorly Protected	847.99		
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	38.065		

Terrestrial	Humid Savanna	Transitional Humid Forest	Endangered	Poorly Protected	9027.17		
Terrestrial	Highland Plateau	Wooded savanna	Critically Endangered	Not Protected	715.48		
Terrestrial	Humid Savanna	Euphorbia dawei and Strychnos dry Forest	Endangered	Not Protected	6.12	Cyamudongo Forest	Rusizi
Terrestrial	Montane Forest	Afromontane Rain Forest	Endangered	Moderately Protected	473.71		
Terrestrial	Humid Savanna	Transitional Humid Forest	Endangered	Poorly Protected	180.42		
Terrestrial	Humid Savanna	Euphorbia dawei and Strychnos dry Forest	Endangered	Not Protected	15.33	Mashyuza Natural Forest	Rusizi
Terrestrial	Montane Forest	Afromontane Rain Forest	Endangered	Moderately Protected	10.85	Dutake Natural Forest	Karongi
Terrestrial	Plateau grassland savanna	Eastern evergreen Plateau Grassland Savanna	Endangered	Not Protected	17.93	Mashoza natural Forest	Ngoma
Terrestrial	Montane Forest	Afromontane Rain Forest	Endangered	Moderately Protected	3446.22		
Aquatic	Wetland	Mixed Vegetation Wetland	Vulnerable	Poorly Protected	20.6	Gishwati-Mukura National Park	Rutsiro,Ngororero
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	1.19		
Terrestrial	Plateau grassland savanna	Eastern evergreen Plateau Grassland Savanna	Endangered	Not Protected	4.17	Nyagasenyi	Kirehe
Aquatic	Wetland	Miscanthus and Cyperus Wetland	Least Concern	Moderately Protected	14.64		

6 APPENDIX: GIS DESCRIPTIONS AND METADATA FOR KEY LAYERS

6.1 Generic descriptions for all GIS inputs and outputs

GIS Details

All SBA data layers were processed in a standardized/identical raster grid, with identical projections, extent, and pixel resolution.

Layer details:

30m raster GIS layers in .tif format

GIS Shapefiles

Specific description of projections:

Africa_Albers_Equal_Area_Conic
WKID: 102022 Authority: Esri

Projection: Albers
False_Easting: 0,0
False_Northing: 0,0
Central_Meridian: 25,0
Standard_Parallel_1: 20,0
Standard_Parallel_2: -23,0
Latitude_Of_Origin: 0,0
Linear Unit: Meter (1,0)

Geographic
Geographic Coordinate System: GCS_WGS_1984
Datum: D_WGS_1984
Prime Meridian: Greenwich
Angular Unit: Degree

6.2 Ecosystem types (with threat status and protection level)

Layer description:

Key spatial layer showing all ecosystem types, calculations and the results of the SBA.

Layer name:

Rwanda_Ecosystem_Types_Threat_Status_Protection_2022.shp

The shapefile with biome, ecosystem types, calculations and ecosystem threat status and protection level.

Rwanda_Ecosystem_Types_Threat_Status_Protection_2022 Original Extent.tif

The raster tif file with biome, ecosystem types, calculations and ecosystem threat status and protection level showing results for the full/original extent of each ecosystem

Rwanda_Ecosystem_Types_Threat_Status_Protection_2022 Showing Intact Areas Only.tif

The raster tif file with biome, ecosystem types, calculations and ecosystem threat status and protection level showing the same resulst as above, but clipped to intact areas only.

Storage location:

https://livenmmuac-
my.sharepoint.com/:f:/g/personal/sholness_mandela_ac_za/Ep4TCy6lOehDpDXIOZvGne0BECUI4TTtrJh
7VXT7NOC4zw?e=rqfLjW

Key fields:

Field	Description
Biome	Broad classification at a biome level, e.g. Dry Savanna, Woodland, Thicket and Grassland
EcosystemT	The specific ecosystem type. The assessment is done at this level.
ha_orig	The original / historical area of the ecosystem types in hectares.
val	Ecosystem identification number
PA_tar	The protection level target in hectares using a 30% target.
PA_intact	The area in hectares for each ecosystem type that is in a Protected Area or OECM (Other Effective Areas-based Conservation Measures) that is in good condition (i.e. in intact natural or semi-natural ecological condition).
PA_per_tar	The percentage of the protection level target that is met.
Protection	The protection level category: The categories for protection level are Well Protected (WP) where the extent protected exceeds the target; Moderately Protected (MP) where the extent protected is from 50% to just less than 100% of the target; Poorly Protected (PP) where the extent protected is from 5% to just less than 50% of the target; and Not Protected (NP) where the extent protected is less than 5% of the target.
intact	The area in hectares which is in intact natural or semi-natural ecological condition.
Ha_loss	The area in hectares which is no longer in intact natural or semi-natural ecological condition.
Per_loss	The percentage of the original extent of each ecosystem type which is no longer in intact natural or semi-natural ecological condition.

ThreatStat	The IUCN Red List of Ecosystems category of the ecosystem based on the A3 evaluation criterion. If loss is 90% or higher, then the ecosystem is classified as Critically Endangered; 70% to >90% is Endangered; 50% to >70% is Vulnerable; 40% to >50% is Near Threatened; <40% is classified as Least Concern.

6.3 Ecological Condition

Layer description:

The map of ecological condition defines the degree of modification of the landscape, divided into areas that remain in a natural or near-natural condition; and areas that are not natural.

Layer name:

Rwanda Ecological Condition.tif

Storage location:

https://livenmmuac-my.sharepoint.com/:f:/g/personal/sholness_mandela_ac_za/Es5MPm954rlCm0HDYQcZR6UBWnDa2zBzp5M15xMLmF2QHQ?e=9FqJAJ

Key fields:

Field	Description
Value	Numerical code linked to condition class: 1 Natural or Near Natural 3 Not Natural
Ecocon	Condition class divided into two categories: Natural or Near Natural; and Not Natural.

6.4 Protected Areas and OECM

Layer description:

Map of areas considered to be either Protected Areas or Other Effective Area-based Conservation Measures.

Layer name:

Rwanda Protected Area and OECM.shp

Storage location:

https://livenmmuac-
my.sharepoint.com/:f:/g/personal/sholness_mandela_ac_za/Es5MPm954rlCm0HDYQcZR6UBWnDa2zBz
p5M15xMLmF2QHQ?e=9FqJAJ

Key fields:

Field	Description
Value	Numerical code linked to inclusion in PA or OECM: 1 Protected Area and OECM
PA	Protected Area and OECM

7 APPENDIX: DESCRIPTIONS OF BIOMES (BROAD ECOSYSTEM DESIGNATIONS) AND ECOSYSTEM TYPES

The table shows the descriptions of the nine biomes (broad ecosystems) based on published literature and reports, and the IUCN Global Ecosystem Typology (Keith et al. 2020) along with the 29 ecosystem types in Rwanda. Based on the IUCN criteria and process for Ecosystem Red Listing, this Spatial Biodiversity Assessment has identified threatened ecosystems in Rwanda. Remember that **ecosystem types are referred to as 'threatened' when they have been categorised as Critically Endangered, Endangered or Vulnerable.**

Table X……. Description of each biomes and respected ecosystem types.

ID	Biomes	Description	Ecosystem types	Description
1	Afroalpine Mountain	Afroalpine climate is determined by vicinity to the equator, and high elevation above sea level (Hedberg 1957).	Mountain Mixed Forest	
			Mountain Bamboo Forest	
			Sub-Alpine Vegetation	
			Hagenia Hypericum Forest	
			Mixed Forest	
			Neoboutonia Forest	
2	Akagera Sub-humid Savanna	900–1200 mm rainfall (sub-arid savanna has 600-900 mm rainfall)(Ker 1995)	Acacia Gallery Forest	
			Evergreen Semi-evergreen Bushland and Thicket	
			Evergreen Semi-evergreen Riverine Sub-humid Highland Savanna	
			Sub-Humid Wooded Savanna	
			Evergreen Semi-evergreen Sub-humid Savanna	
3	Highland Plateau	Rwanda's central plateau area is 1500-2000m in elevation which corresponds with the Central Plateau agro-ecological zone (Mukashema et al. 2014) and the eastern Congo-Nile Highlands subsistence farming zone (USAID 2012). Rainfall 1000-1260mm/annually (Rwanda Meteorological Agency). More research is needed into	Evergreen Semi-evergreen Plateau	
			Evergreen Semi-evergreen Riverine Highland	
			Wooded Savanna	

		the original vegetation in this Highland Plateau region.		
4	Humid Savanna	1200–1500 mm rainfall (Ker 1995)	Ephorbia Dawei and Strychnos Dry Forest	
			Evergreen Semi-evergreen Humid Savanna	
			Evergreen Semi-evergreen Riverine Highland Savanna	
			Transitional Humid Forest	
5	Montane Forest	Forest above 1500masl; altitude and topography are two major environmental drivers of tree species composition in montane forest (Chapman et al. 2016; Homeier et al. 2010). Montane forest occurs in tropical montane environments that experience cooler temperatures, moderate frosts and regular fogs; they are distinguished by their simpler evergreen tree canopies with a relatively smaller range of leaf sizes, high epiphyte loads, abundance of ferns and bryophytes, high local endemism and lower plant and animal diversity.	Afromontane Rain Forest	
6	Plateau grassland savanna	Mostly continuous ground cover of grasses that contribute moderate to very high primary productivity driven by strongly seasonal cycles of water surplus and deficit; woody vegetation may be completely absent or vary to a height and stature	Eastern Evergreen Plateau Grassland Savanna	
			Semi-evergreen Forest wetland	
			Transitional Plateau Rain Forest	

		resembling a forest; co-existence between trees and grasses, and grasses and interstitial forbs mediated by herbivory and fire (Keith et al. 2020).		40
7	Tropical Savanna		Evergreen Riverine Tropical Savanna	
			Evergreen Tropical Savanna	
			Transitional Tropical Savanna	
8	Wetland		Humid Savanna Wetland	
			Miscanthus and Cyperus Wetland	
			Mixed Vegetation Wetland	
9	Lakes		Lakes	