Sahara and Sahel Observatory

AFD
Agence Française de Développement

Copernicea

AfrikENCA 2001-2020
A First Set of Ecosystem Natural Capital Accounts for the African Continent

This document was prepared under the coordination of the Sahara and Sahel Observatory in the framework of the COPERNICEA project. It has been validated by all countries involved in the project.

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Summary

The COPERNICEA project "Regional Cooperation for New Ecosystem Accounting Indicators in Africa" is being implemented by the ***Sahara and Sahel Observatory*** *(OSS). It is co-financed by AFD, the French agency for development, OSS and the six participating countries: Burkina Faso, Guinea-Conakry, Morocco, Niger, Senegal and Tunisia.*

COPERNICEA's objective is to eventually provide these six countries with an autonomous and independent capacity to produce ecosystem accounts of natural capital using the ENCA (Ecosystem Natural Capital Accounting) methodology. This objective implies mastering the acquisition of input data (collection, verification, harmonization and validation) as well as the ENCA accounting method as a software for processing incoming data, producing quantified data and summary indicators that are both comparable and aggregable. The OSS, as international organization and owner of the COPERNICEA project, capitalizes on the ENCA method, the incoming data, the data produced and the institutional and technical support of its members

As part of the implementation of the COPERNICEA Project, a first step was to produce for the entire African continent and for the island of Madagascar, an initial version of the ENCA accounts at the scale of spatialized statistical units of about 100-150 km² (about 200 000 elementary units). These accounts were established for the years 2001, 2005 and annually from 2010 to 2020. This set of Tier 1 accounts using international databases is called AfrikENCA. The ENCA accounts are then detailed in the projects conducted by the national institutions participating in the project with the data available in the country, at Tier 2 (national) or Tier 3 (local).

This document presents the COPERNICEA approach, recalls the operational applications of the ENCA method in Africa and around the world, details the construction of the version 1 of AfrikENCA, presents various applications that have been conducted on important topics such as the Great Green Wall, the management of protected areas and the evolution of ecological corridors between protected areas, the evolution of ecosystem health in protected areas with vulnerable or endangered fauna (in the sense of the IUCN red list), and the state of the forest and woodland ecosystems

1 The COPERNICEA project and ecosystem accounting in Africa

The COPERNICEA project of "Regional Cooperation for New Ecosystem Accounting Indicators in Africa", is a multi-country initiative funded and implemented by the Sahara and Sahel Observatory (OSS) and co-financed by the French Agency for Developement (AFD) and the six participating countries (Burkina-Faso, Guinea, Morocco, Niger, Senegal and Tunisia). It was launched in March 2020 and was initially planned to last 4 years (2020-2023).

The objective of the project is to provide OSS and the six countries with an operational mechanism for producing ecosystem natural capital accounts using the ENCA methodology, which is presented in tAnnex 1. The OSS is in charge of the COPERNICEA project, the regional coordination and support of the national work, the scientific and technical capitalization of the ENCA method, the centralization of data, the communication on and the dissemination of the accounting results.

The actions of the COPERNICEA project are structured around four main components:

- Institutional strengthening and establishment of structures at regional and national levels;
- Creation of the ENCA operational infrastructure;
- Reinforcement of the capacity of stakeholders involved in the accounts implementation process;
- Communication and promotion of the integration of ecosystem accounts into assessment and decision-making processes as indicators of sustainable development.

The implementation of the project relies on a dedicated team within the OSS and on six national teams, which mobilize and federate the relevant services of different organizations, notably the ministries in charge of the environment and sustainable development, agencies specialized in the fields of water, forest, biodiversity and protected areas, as well as national statistical offices, research centers and universities. The structures holding or producing information and data will therefore be led to pool them and optimize their accessibility for a wide variety of users.

The mechanism will enable the rapid development of an initial set of ecosystem natural capital accounts, first in biophysical terms according to the ENCA accounting framework, then socio-economical. This first accounts, implemented with a common methodology, provides results that are comparable from one country to another and can be aggregated at the regional level. The multi-country nature of the project (two Mediterranean countries, two coastal countries, two Sahelian countries) allows for emulation of teams, pooling of resources and cost optimization.

This accounting aims to quantify and assess the state and resilience of ecosystems, and allow a spatio-temporal monitoring of the state of ecosystem services. In addition to the specific needs of the participating countries, the project intends to strengthen their reporting capacity to international and regional programs related to desertification, climate change, biological diversity, and more generally to the Sustainable Development Goals and the SEEA-EA[1].

The ENCA methodology mobilizes geo-localized data, which it processes according to the different steps described in the quick start package (see Appendix) to assign them to territorial statistical units. The method then calculates an accounting value for these statistical units, known as ecosystem capability, calculated in a non-monetary metric. It is then possible to follow the evolution of this accounting value over time to observe whether the situation of the ecosystem associated with the territorial unit is improving, remaining stable or deteriorating, and what are the drivers of these changes. In order to establish a national capacity to produce ENCA accounts, there are two steps to be taken:

- Build, harmonize, and validate a relevant and coherent database over several years (at least free international data, more or less enriched by national data)
- Understand and master the ENCA accounting software, in order to feed it with data, produce accounts and maps, and carry out analyses.

The COPERNICEA project proposes to support the national teams in these two steps, in order to build an independent and autonomous production capacity in each of the 6 countries. In addition, the COPERNICEA project aims to raise awareness of the issues at stake, and to provide the international community with data, analyses and tools to understand the evolution of ecosystem health, on which most African households depend.

It is within this framework that the OSS team decided to produce a first series of ENCA accounts for the entire African continent, for the years 2001-2005-2010-2011-2012-2013-2014-2015-2016-2017-2018-2019-2020. Version 1 of AfrikENCA has been available since November 2022 and is now freely accessible on the OSS website [OSS, 2023].

This foundational activity was made possible by the progress observed in speed and computing power, the availability of international statistics and monitoring data but also and above all, by the preliminary experiments conducted by different teams in different territories (see Section 2).

The next step, which began in the spring of 2022, is the implementation of the ENCA method on a national scale by national teams in Burkina Faso, Guinea, Morocco, Niger, Senegal and Tunisia. This step was prepared by a series of training sessions using the Kangaré-Ecosystem tutorial, which allows the practical handling of the methodology based on a case study that follows step by step the steps of the process of accounts production using a geographic information system (GIS). The GIS used for the training is the one used to make the AfrikENCA ecosystem accounts, SAGA GIS [2] [Conrad, 2015].

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[1] *ENCA is a variant of the SEEA Ecosystem Accounting framework published by the UN in 2022. The relationship of ENCA and SEEA-EA and the compatibility of the accounts in biophysical terms are presented in the Appendix.*

[2] *SAGA stands for System for Automated Geoscientific Analyses. SAGA is a free and open source software (FOSS) developed at the University of Hamburg. It is intuitive to use and performs well on a good PC running with MSWindows or Linux. SAGA is ODBC interfaced and allows access to the PostgreSQL database manager. It can be used with the statistical software R (RSAGA) and with the application programming interface SAGA GIS API for Python. ENCA accounts can of course be produced with other*

2 A reminder of the first operational applications of ENCA accounting in Africa and around the world

ENCA has inherited of pioneer works at the European Environment Agency (EEA) where first "land and ecosystem accounts" (LEAC) were published in 2006 [Haines-Young, 2006] and have been updated, 2018 being the most recent year [(EEA 2019 (a) and EEA 2019 (b)]. The LEAC methodology has been adopted by the ENCA-QSP framework for land cover accounting.

In 2016-2020, the European Environment Agency (EEA) implemented an EU-funded project to establish a shared environmental information system (ENI SEIS II East) in the EU Eastern Partnership countries of Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine. As part of the Kangaré training sessions for national experts, LEAC-type land use accounts were produced for each of these countries for 2000 and 2015 [Tafi, 2020].

Other pilot applications using ENCA-QSP are the Mauritius ecosystem capital accounts of 2014 [Weber, 2014 (b)], the Rhone river watershed accounts, a PhD thesis at Ecole Normale Supérieure de Lyon, France [Argüello Velazquez, 2019], and the Ecosystem natural capital accounting in the Guiana Shield in 2000 and 2015 [Rahm, 2021] produced for WWF France by the French Office National des Forets International (ONFI) with the contribution of agencies from the 4 participating countries (Guyana, Suriname, French Guyane and Brazilian Amapà). IUCN, with the support of ONFI, has recently finalized a report using the ENCA method applied in Vietnam [Mittempergher, 2023b].

In Madagascar, a team at the IOGA laboratory at the University of Antananarivo has developed, with support from the Global Development Network (GDN) and funding from AFD, an application of ENCA accounting for monitoring protected areas [Rakotondraompiana, 2015].

In Africa, several projects have also used the ENCA methodology. An IUCN team has worked with WWF-Gabon and ONFI on accounts in Gabon [WWF-Gabon, 2021] [Mittempergher, 2022]. IUCN has just published a study based on ENCA accounts in Kenya in 2023 [Mittempergher, 2023a].

This paper would like to highlight two ENCA projects in Guinea and Senegal, coordinated with COPERNICEA: PAPBio ENCA (operated by IUCN and VITO with the support of a committee of local experts) [Buchhorn, 2023] and ZAEG (operated by a team of Guinean technicians with the support of IGNFI and CIRAD) [Morand, 2023].

2.1 The PAPBio application of ENCA on nature protection parks in Senegal and the Republic of Guinea

PAPBio[3] is an IUCN programme funded by the European Union for the purpose of improving the governance of nature protected areas in Western Africa. A pilot ENCA application is carried out within PAPBio.

"*The project is run with the technical assistance of the Flemish Institute for Technological Research (VITO). The aim of this study was to develop and evaluate an effective and harmonized Natural Capital Accounting platform (Sys4ENCA) to support protected areas management in western Africa, based on the Ecosystem Natural Capital Accounting framework.*

An initial platform evaluation was performed on a transboundary region between Senegal and Guinea including two protected areas, Niokolo and the Bafing-Falémé landscape. The semi-automatized Sys4ENCA platform combined with a multi-level approach, showed to be a valuable tool to facilitate protected area management as it provides not only consolidated information at local scale but also the broader context and external pressures; i.e. climate change and demand for land. Given its automatized nature, the platform reduces human errors, increases efficiency, speed and harmonization of computation over long time frames and spatial scales" [Buchhorn, 2023].

software (e.g. QGIS, ARCGis, etc.) following the same accounting model. The map backgrounds used for this article come from the Google-Satellite database.

[3]*PAPBio stands for "Programme d'appui pour la préservation de la biodiversité et les écosystèmes fragiles, à la gouvernance régionale et au changement climatique en Afrique de l'Ouest - PAPBio" of the European Union (EU).*

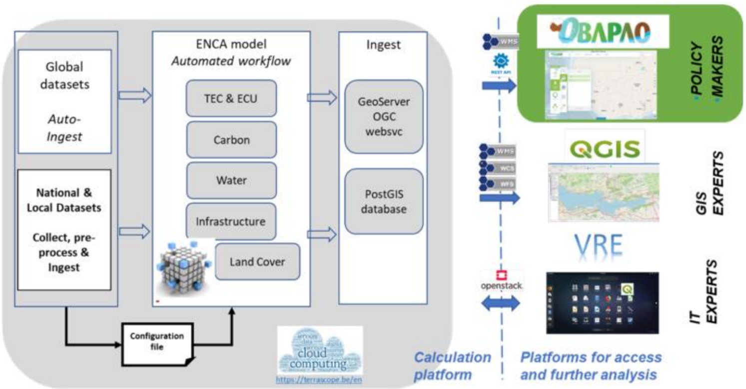

Figure 1 The Sys4ENCA processing platform for semi-automatic Ecosystem Natural Capital Accounting (ENCA) following the ENCA Quick Start Package (QSP) [source: Buchhorn, 2023].

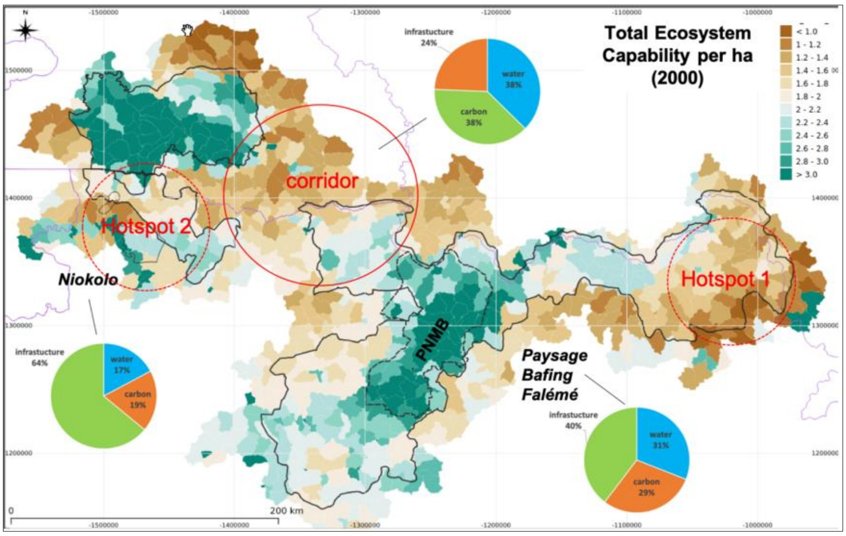

Figure 2 Total Ecosystem Capability (TEC) per hectare of the transboundary region including Niokolo and Bafing-Falémé landscape as simulated by Sys4ENCA for the year 2000 using regional datasets (Tier-2) at the highest level of sub-basin breakdown [source: Buchhorn, 2023]

The ENCA PAPBio project covers nature parks of Niokolo-Koba, Niokolo-Badiar and Bafing-Faleme as well as their geographical context. Experts from Guinea and Senegal as well as of the Wild Chimpanzee Foundation are involved, in the project which proposes a 3 tiers approach, with tier 1 accounts produced with international data, tier 2 with national data and tier 3 with local data provided by parks managers. The project is now extended to cover the so-called W of Niger trans-boundary nature protection park.

2.2 ENCA accounts derived from agroecological zoning (ZAEG) in the Republic of Guinea

The Guinean Ministry of Agriculture has undertaken an agroecological zoning for the country from high resolution satellite images, aimed at identifying and quantifying current agricultural areas, assessing agricultural potential, and mapping land cover and land cover change over a 10-year period (2005-2015). This project was implemented over two years in a partnership framework between a team of Guinean technicians and experts and a team of experts of IGN France International and CIRAD, the French agricultural research and cooperation organization.

The project included capacity building to ensure a full transfer of skills on all project activities, from the production of a land cover layer to relevant agricultural and environmental applications, with the aim of providing decision support tools to multiple Guinean stakeholders. As an application of the ZAEG, land cover accounts following the ENCA methodology were first produced. Last year, this application was extended to full ENCA accounts through research conducted by a master's student in agronomy [Morand, 2023].

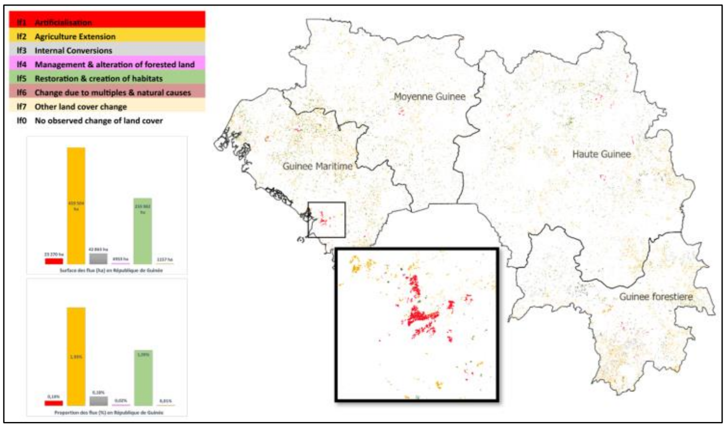

Figure 3 Land Cover Flows Accounts 2005-2015 by natural regions (Source: IGNFI and CIRAD)

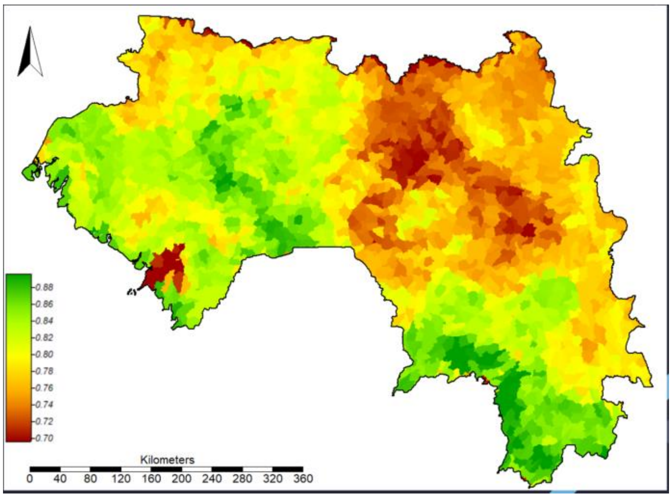

Figure 4 ENCA's Health Index of the Ecosystem Infrastructure, Guinea 2015 (Source: Morand, 2023)

Figure 3 shows that at the national scale, land cover change in 10 years is of 3% and mostly driven by shifting agriculture highlighted by important flows of lcf2 Agriculture Extension and lcf5 Restoration of habitats (following agriculture abandonment). However, we can note that the period Agriculture Extension (459 504 ha) is two times more important than Restoration of habitats (259 982). The national trends cover a variety of situations, including fast change as the lcf1 Artificialisation process around the Capital city, Conakry. Figure 4 shows, for the reference pattern of SELUs, the Health Index of ENCA's Ecosystem Infrastructure account and highlights contrasted situations.

Following ZAEG update for year 2021, the first ENCA 2005-2015 accounts have been updated accordingly and will be incorporated to the COPERNICEA project.

3 The making of AfrikENCA 2001-2020

3.1 The ENCA data model

AfrikENCA is a continental version of the ENCA accounts corresponding to a Tier 1, with Tier 2 being accounts based on national data and Tier 3 being local scales. This three-tiered approach is quite similar to the three tiers of reporting to the Climate Convention. The objectives of AfrikENCA are to provide a continent-wide overview of situations and trends, to allow for an initial appropriation of the ENCA language, and a progressive approach to Tier 1 and Tier 2 accounts. Because available Tier 2 and Tier 3 data are often incomplete for ENCA accounting purposes, the pre-processed database compiled for AfrikENCA allows COPERNICEA countries to focus their efforts on priority issues or areas and limit data collection to these priorities. The AfrikENCA data then act as defaults, which from the outset allows for useful perspective when analyzing the detailed accounts.

AfrikENCA is compiled according to the ENCA data model which uses statistics and geo-data (GIS). Approximately 50 datasets were assimilated according to the data model and integrated (Appendix).

The data are checked, cross-checked with similar data in the case of multiple sources. If it appears that data consistently covering a sub-topic of a general database is better than what the general database offers, a substitution can be made. Data are extrapolated and interpolated when they do not cover the entire accounting period.

The data are also gridded (rasterized) if necessary and the data available in raster format are generally resampled to match the grid used for the accounts. This assimilation of the data then facilitates their integration into the accounts themselves.

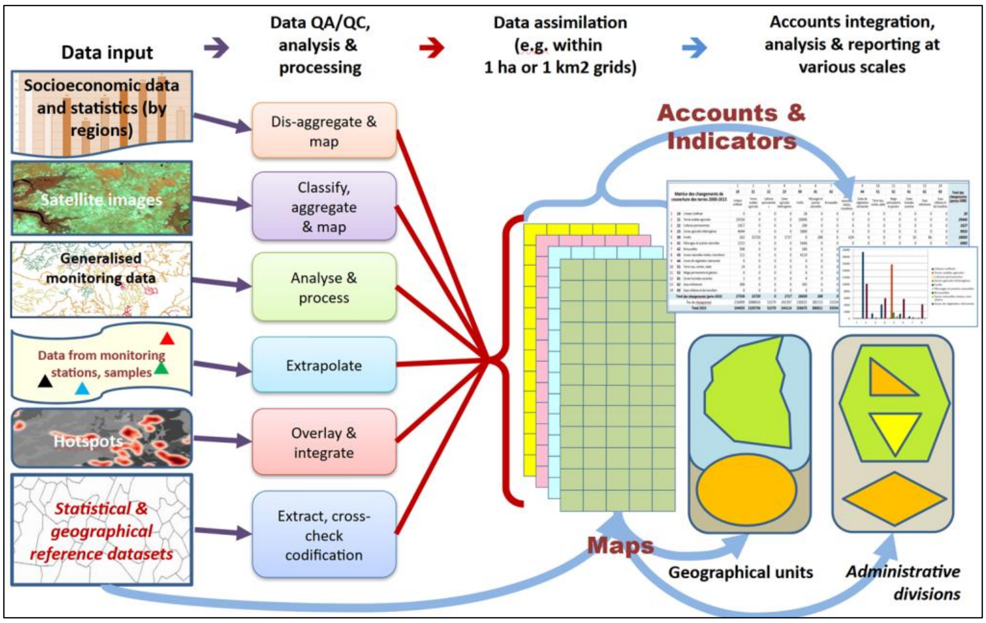

Figure 5 The ENCA-QSP data model

AfrikENCA uses the best available open source data. This version 1 is based on information available in international databases and statistics. It is a first version relevant to the continental scale. It is intended to improve at this scale with the (rapid) progress of monitoring systems and at finer scales with the commitment of countries and the mobilization of their own data and scientific expertise. About fifty databases and statistics were used. The main sources are listed in the Appendix.

Due to insufficient resolution or missing data in several international databases, accounts for small island states are incomplete and inaccurate. Accounts for marine coastal units are not currently compiled in AfrikENCA version 1 but will be in version 2 and in national projects.

The AfrikENCA v1 accounts are compiled for all of Africa for the years 2001, 2005, 2010, and annually through to 2020 to 1) match the accounts to the policy agenda and 2) make assessments of relevant trends. The accounts are compiled on an annual basis to identify possible anomalies due to either fragile data or atypical weather years.

4 The AfrikENCA 2001-2020 accounts

For their continental version, the ecosystem natural capital accounts are compiled by socio-ecological landscape units (SELU) of about 100 to 150 km² on average.

SELUs are the elementary statistical units for which complete ecosystem accounts are calculated. SELUs are the cartographic representation of theoretical units known in ecology as social-ecological systems, geosystems, ecozones or ecocomplexes. In general, SELUs are composed of a number of land cover units. In ecosystem accounting, the definition of a SELU combines a dominant landscape type with watershed boundaries. The objective is to integrate into terrestrial ecosystems the rivers which irrigate and connect them. At the scale of the African continent, SELUs have been defined as hydrographical basins of level 10 in Pfafstetter's classification, which corresponds to an average area of 150 km². The SELUs can be characterized by their dominant land use type (urban, agricultural, forestry...) and by other geographical characteristics such as relief (altitude and slope...), climate type (arid, semi-arid, semi-humid, humid...), or proximity to the sea. For national or local accounting purposes, the SELUs can also be subdivided by sub-dominant land cover types.

There are over 200,000 SELUs in the AfrikENCA database.

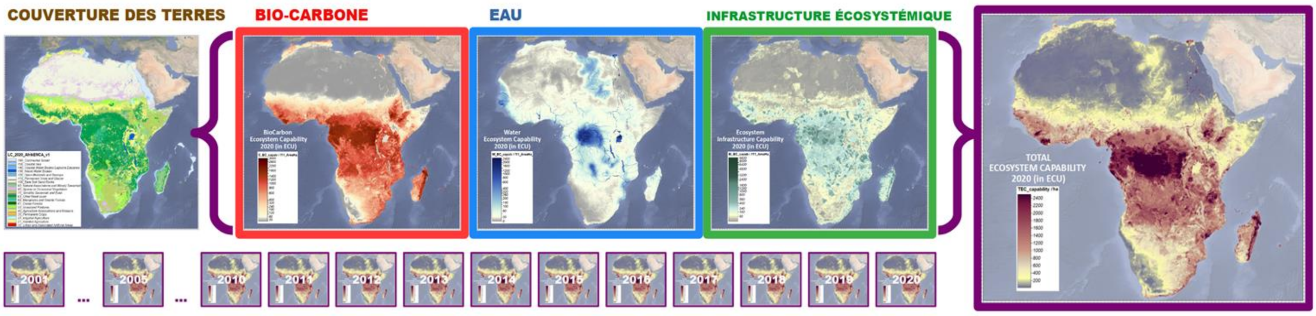

Figure 6 Presentation of the sequence of Capability accounts and Total Ecosystem Capability

Each individual SELU can be queried for all ENCA variables (Figure 7).

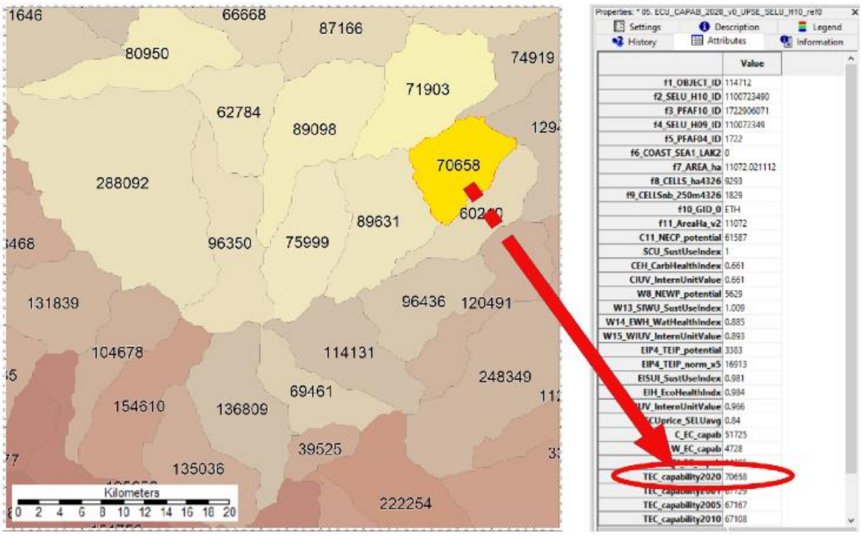

Figure 7 Example of a SELU account accessible with a GIS [NB: the table can easily be exported]

SELU accounts can be aggregated to larger territories such as administrative divisions, countries or river basins (see below, Table 1 and Figure 8 an example of an account for the Congo River basin).

Compte de la couverture des terres (étendue des écosystèmes) 2001-2020 en km² — Bassin versant du fleuve Congo		Zones urbaines et zones développées associées 10-UrbArtif	Agriculture cultures annuelles pluviales 21-AgriPluv	Agriculture cultures irriguées 22-AgriIrrig	Cultures permanentes 30-PermCul	Associations et mosaïques agricoles 40-MosaAgri	Prairies et herbages naturels 50-Herbages	Forêts denses 61-ForDens	Mangroves et forêts marécageuses 62-Mangrov	Autre couvert forestier 63-AutreFor	Savanes arbustives, broussailles 70-SavaBrouss	Végétation éparse ou occasionnelle 80-VegEpars	Associations de végétation naturelle, savanes boisées 90-MixNat	Sols nus, sable, roche 100-SablRoch	Neige permanente et glaciers 110-NeigGlac	Zones humides ouvertes, marais 120-MaraisOuv	Eaux continentales 130-EauxConti	Plans d'eau côtiers, lagunes, estuaires 140-EstuPlan	Total
Total Couverture des terres 2001		**1471**	**225414**	**2155**	**1277**	**140980**	**52339**	**31259**	**199873**	**2666204**	**108890**	**11**	**136744**	**559**	**0**	**75182**	**71061**	**117**	**3713536**
Consommation de couverture des terres 2001																			
Étalement urbain/artificiel	C_lcf1	0	598	5	1	443	114	0	4	243	166	0	484	3	0	26	12	0	**2099**
Extension de l'agriculture	C_lcf2	0	0	0	0	0	44	18	574	29051	213	0	391	5	0	40	69	0	**30406**
Conversions internes	C_lcf3	0	8500	1013	10	98	0	0	0	0	0	0	0	0	0	0	0	0	**9622**
Gestion et altération des espaces forestiers	C_lcf4	0	16755	296	90	27710	1724	8440	19494	149073	11896	2	12133	16	0	3707	0	0	**251337**
Restauration et extension des habitats naturels	C_lcf5	15	3202	300	32	6207	800	0	0	23	1935	0	0	0	0	984	252	0	**13749**
Changements dus à des causes naturelles et multiples	C_lcf6	5	33	90	0	159	18	15	266	3766	446	2	178	6	0	250	2071	0	**7304**
Érosion et accrétion côtières	C_lcf7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**2**
Autres changements non classés ailleurs	C_lcf8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Sous-total consommation		***20***	***29089***	***1703***	***133***	***34617***	***2700***	***8473***	***20338***	***182157***	***14655***	***4***	***13187***	***30***	***0***	***5007***	***2404***	***1***	**314518**
Formation de couverture des terres 2020																			
Étalement urbain/artificiel	F_lcf1	2099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2099**
Extension de l'agriculture	F_lcf2	0	18858	1000	68	10480	0	0	0	0	0	0	0	0	0	0	0	0	**30406**
Conversions internes	F_lcf3	0	1041	8549	32	0	0	0	0	0	0	0	0	0	0	0	0	0	**9622**
Gestion et altération des espaces forestiers	F_lcf4	0	0	0	0	0	2230	20	0	102003	7646	7	139431	0	0	0	0	0	**251337**
Restauration et extension des habitats naturels	F_lcf5	0	0	0	0	197	0	0	1634	15	0	0	11848	0	0	55	0	0	**13749**
Changements dus à des causes naturelles et multiples	F_lcf6	0	0	0	0	0	88	1	475	1452	306	105	84	78	0	4186	529	0	**7304**
Érosion et accrétion côtières	F_lcf7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**2**
Autres changements non classés ailleurs	F_lcf8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Sous-total dormationes changementsf		***2099***	***19898***	***9549***	***100***	***10677***	***2318***	***21***	***2109***	***103472***	***7952***	***112***	***151362***	***78***	***0***	***4241***	***529***	***1***	**314518**
Aucun changement observés	**F_lcf9**	**1451**	**196325**	**451**	**1145**	**106363**	**49640**	**22786**	**179535**	**2484047**	**94235**	**7**	**123557**	**529**	**0**	**70175**	**68657**	**116**	**3399018**
Total Couverture des terres 2020		**3551**	**216223**	**10001**	**1245**	**117040**	**51957**	**22808**	**181644**	**2587519**	**102186**	**119**	**274918**	**607**	**0**	**74416**	**69187**	**117**	**3713536**
Formation nette de couverture des terres		***2079***	***-9191***	***7846***	***-33***	***-23939***	***-382***	***-8452***	***-18230***	***-78685***	***-6703***	***107***	***138175***	***48***	***0***	***-766***	***-1875***	***0***	
Formation nette de couverture des terres en % de 2001		***141.3%***	***-4.1%***	***364.1%***	***-2.5%***	***-17.0%***	***-0.7%***	***-27.0%***	***-9.1%***	***-3.0%***	***-6.2%***	***965.7%***	***101.0%***	***8.6%***	***0.0%***	***-1.0%***	***-2.6%***	***-0.1%***	

Table 1 Example of Account of Land Cover Change 2001-2020 for the Congo River Catchment (table)

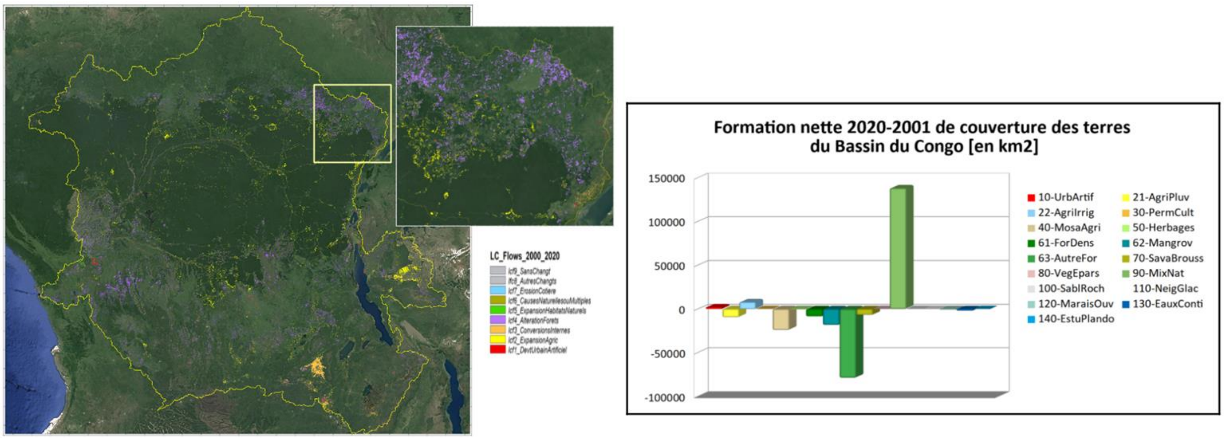

Figure 8 Example of an Account of Land Cover Change 2001-2020 for the Congo River Catchment (map and chart)

Table 1 highlights that agricultural extension and forest alteration (without agricultural conversion) has taken place mainly at the expense of "Other forests" (open forests). The significant forest alteration is only compensated by forest management (reforestation or natural regrowth) to the extent of 3%, which indicates a deforestation process. The net formation of consumption graph clearly shows the loss of open forest (lc63) and to a lesser extent swamp forest (lc62) to the lc90 class (composite natural landscape). The map of land cover flows Figure 8 shows the different spatial distributions of agricultural expansion [lcf2 - yellow] and forest alteration and management [lcf4 - purple].

The AfrikENCA accounts are compiled and disseminated according to the initial zoning in SELUs and then aggregated according to different breakdowns. Figure 9 shows, in the center, the accounts presented by level 4 (inland basins) or level 5 (coastal basins) hydrological basins (HYBAS). On the right, the accounting results are mapped by level 3 hydrological basins (HYB03). The level basins at HYBAS 04-05 and HYBAS 03 have been given a name in order to facilitate their location and the reading of the tables.

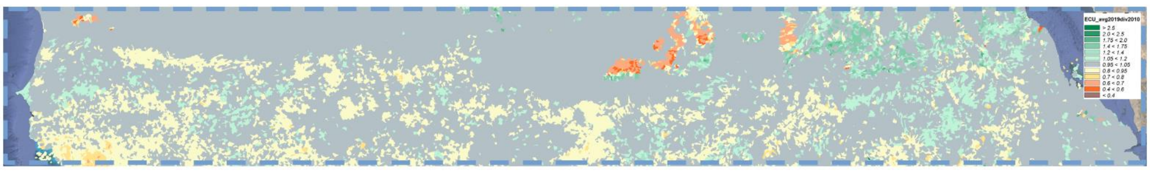

Figure 9 EIP4 indicator - Ecosystem Infrastructure Potential by SELU and aggregated by catchment

In addition to the full accounts by SELU, several sets of reprocessed accounting variables are also provided in 100m, 250m or 1km raster grids depending on the accuracy of the primary data used. On the OSS platform [OSS, 2023], primary data are not provided but linked to their source for download.

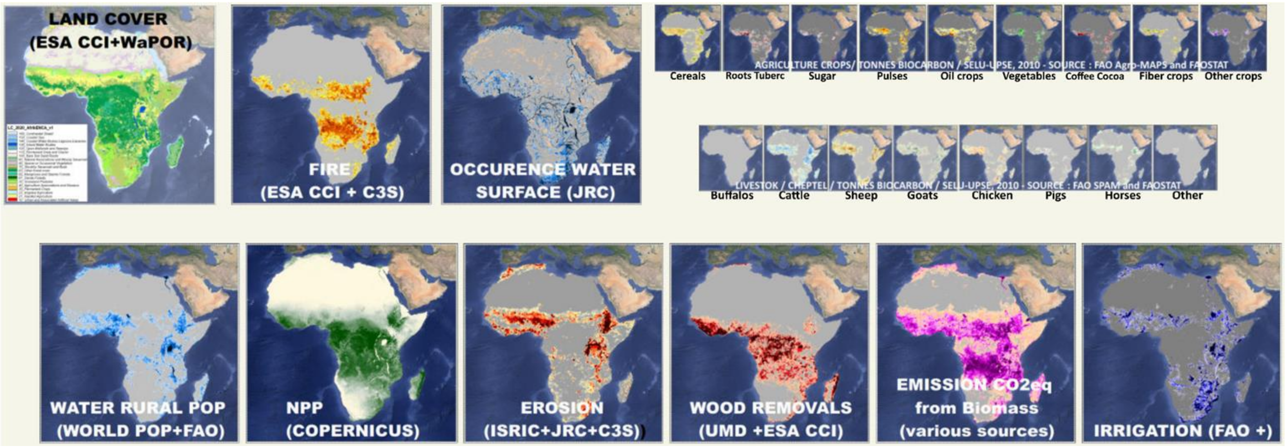

Figure 10 Examples of raster data resulting from the reprocessing of primary data for the purposes of ENCA

The ENCA-QSP accounting framework can be implemented at any scale, from global to local and to economic actors. It will provide the same accounting indicators. The difference is in the detail and accuracy. For a quick start, the global accounts set the scene and later set the context for more detailed and higher resolution accounts compiled for specific purposes. The scale hierarchy and time series allow local accounts to be contextualized in space and time and developed for their specific purposes.

5 A swift analysis of AfrikENCA 2001-2020 first results

AfrikENCA is a first step in the implementation of the ENCA methodology within the framework of the COPERNICEA program led by the Sahara and Sahel Observatory with the support of the French Development Agency (AFD).

The African continent and the island of Madagascar are home to a variety of flora and fauna, the details of which cannot be traced in Level 1 accounts, which are necessarily synthetic. For a presentation of the main African ecosystems, please refer to the documentary book published by the OSS (OSS [2022]).

The first version of AfrikENCA at the continental scale already provides usable results for the analysis of ecosystem status and degradation. The accounts first provide an overview of trends and allow comparisons between geographical regions. Preliminary results were presented at the COP 15 of the United Nations Convention to Combat Desertification (UNCCD) in May 2022 in Abidjan and final results at the CBD COP 15 in December 2022 in Montreal.

Beyond the macroscopic vision of major trends, they provide signals on where changes are most marked. These initial indications must of course be confirmed or corrected with more precise analyses based on more detailed data than those provided by international databases. As it stands, the continental-scale ENCA accounts can be used, particularly because they provide aggregate indicators that can be broken down to look for the elementary explanatory variables. For example, the CEC indicator of Carbon Ecosystem Capability is linked on the one hand to the natural processes that define the Net Ecosystem Carbon Potential (Net Primary Production [NPP] and biocarbon losses through soil erosion and recurrent fires) and on the other hand, via the “price” in ECU, to the Sustainable Use indicator that compares natural inputs and direct losses due to removals from agricultural and forestry harvests and indirect losses due to land use changes.

However, the analysis of the version 1 results must be done with caution for at least three reasons:

- The first is that there may be **anomalies** in the databases used.
- The second is that **estimates** have been made for several variables using default coefficients that are only available at an aggregate level, as is the case for values extracted from national agricultural and forestry statistics. In both cases, it is hoped that subsequent versions of AfrikENCA will allow for improvements.

- The third reason relates to **fluctuations in weather** from one period to the next and their impact on amounts of rainfall and biomass production, so-called Net Primary Production (NPP). Caution should therefore be exercised when comparing two years, in particular to avoid comparing an abnormally dry year with an abnormally wet year. This problem means that methods based on climatograms will have to be developed to correct the indicators for seasonal variations, in the same way as the economic indicators are corrected by the price indexes, which makes it possible to distinguish between values at current prices (the observed prices) and those at constant prices (the prices that can be compared from one year to another). These models will have to be carried out by the meteorologists themselves with the extremely abundant data at their disposal, in particular in the Copernicus Climate Change Service database [C3S, 2023], which aggregated variables were used for the first AfrikENCA calculations.

Figure 7 illustrates, for Africa as a whole, the nature of the problems encountered for the aggregate indicators of ecosystem capability. The histograms indicate what appear to be anomalies and, in the case of water, the effect of rainfall variation. These histograms are illustrative. The analysis requires at least some adjustment by bio-climatic zones, which can be done in future versions. However, it should be noted that the linear regression lines all indicate a decrease over the period in the ecosystem capability and its components at the scale of the African continent.

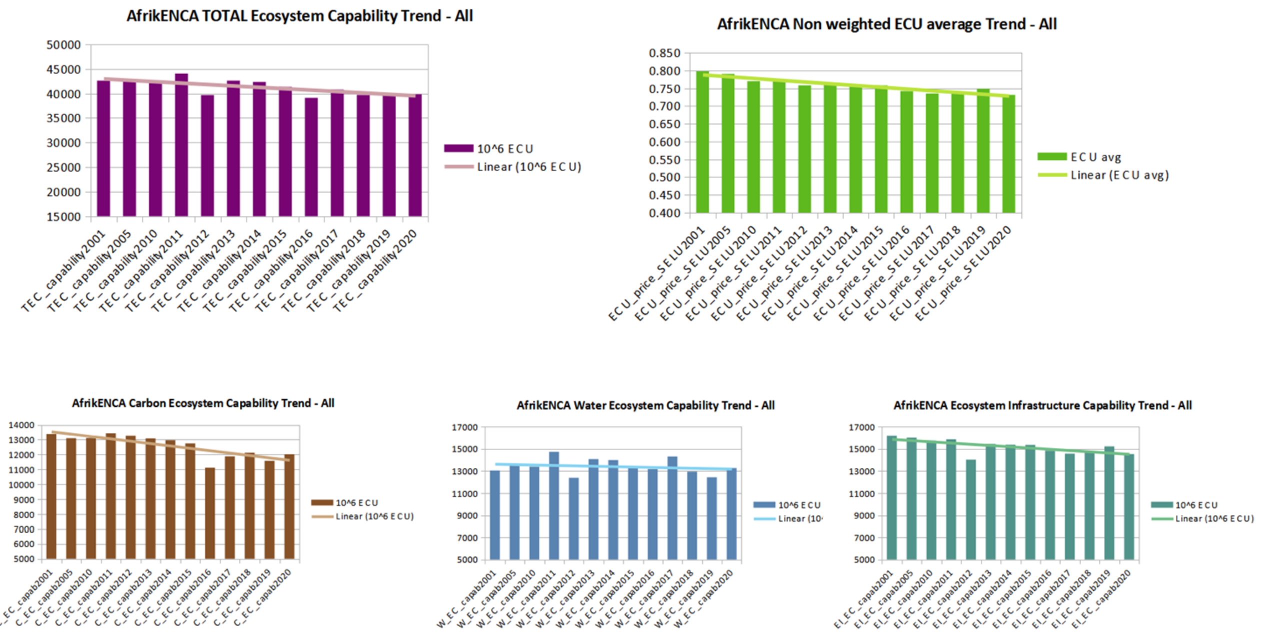

Figure 11 Histograms showing the variability of capability indicators for the period 2001-2020 and the overall trend across Africa

Empirically, the first analyses carried out relate to years 2005 and 2019, which seem comparable. For the Great Green Wall, launched in 2010, the 2010-2019 period is chosen.

We present in the following some insights on :

- The Great Green Wall
- Applications on natural parks
- Applications on forests

The objective is to show how elementary variables shed light on and explain the changes revealed by the aggregate indicators of the ENCA accounts, and therefore, how the ENCA accounts can shed light on trends, draw attention to worrying trends and could, in the end, help to inform decision-makers and guide public policies.

5.1 Swift assessment of Ecosystem Capability change of the Great Green Wall area 2010-2019

A Pan-African initiative for the restoration and sustainable management of ecosystems, the Great Green Wall (GGW) aims to combat land degradation and poverty (see OSS [2008] and OSS [2015]). To this end, several actions have been carried out since its launch in 2010 and thus the interest in analyzing the 2010-2019 period.

The change in Total Ecosystem Capability [TEC] is the result of multiple factors recorded in the ENCA tables, such as biomass productivity, wood removals, fires, soil erosion, land use, as well as precipitation, river runoff or fragmentation of landscapes and rivers and biodiversity losses. The evolution of TEC is an aggregated indicator that provides a first synthetic overview like GDP in the economic field.

Like GDP, TEC requires further analysis to understand the relative role of variables driving change in different contexts. Like the UNFCCC (Carbon Sequestration) and UNCCD (Land Degradation Neutral Development - LDN) indicators, TEC relies on spatialized carbon accounts. In all three cases, it is organic carbon, that of biomass and soil. In addition, the TEC incorporates water and the integrity and biodiversity of the ecosystem infrastructure into its composition.

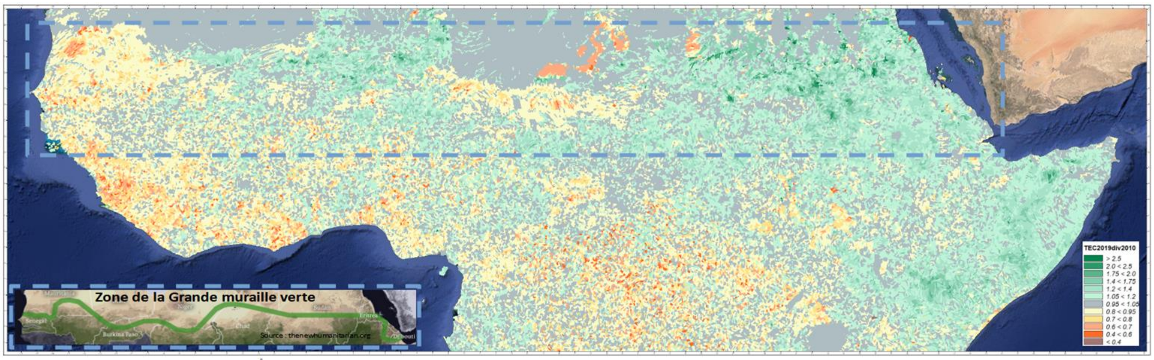

Figure 12 Evolution of Total Ecosystem Capability [TEC] per hectare, ratio 2019/2010

The above map comparing the year 2019 with 2010 (launch of the Great Green Wall initiative by the countries of the region) is a preliminary rough assessment that needs to be refined taking into account the influence of the rainfall factor. Also, TEC needs to be interpreted in its landscape context.

The loss of TEC in forested areas (southern part of the map Figure 12) suggests tree loss and deforestation, while in savannahs, pastures and rangelands it highlights the process of desertification. This analysis can be carried out using AfrikENCA's annual land cover accounts. Taking these observations into account, the preliminary assessment of TEC for the Great Green Wall area shows contrasts with greening in the northern and eastern parts of the area while the central/western part shows significant desertification (as well as tree loss in forested areas). It should be noted that the formula for the change indicator (TEC2019/TEC2010) means that the same result can be obtained for two UPSE areas from very different TEC stock levels and should be interpreted accordingly.

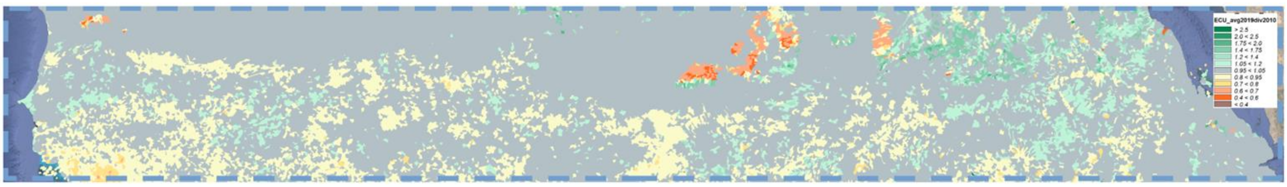

Figure 13 Evolution of SELUs' unweighted average value in Ecosystem Capability Unit [ECU], ratio 2019/2010

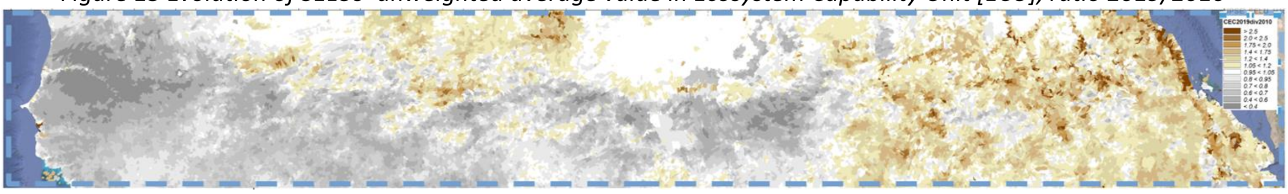

Figure 14 Evolution of Bio-Carbon Ecosystem Capability [CEC] per hectare, ratio 2019/2010

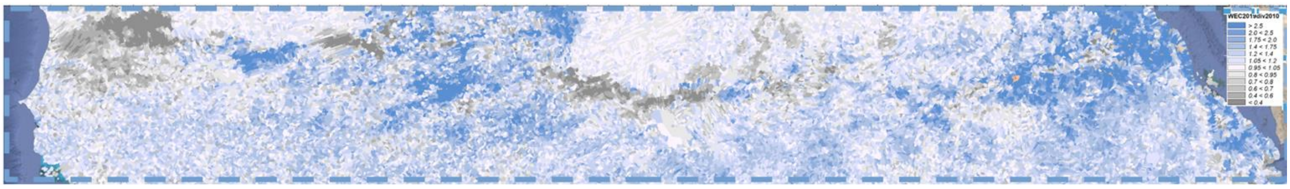

Figure 15 Evolution of Water Ecosystem Capability [WEC] per hectare, ratio 2019/2010

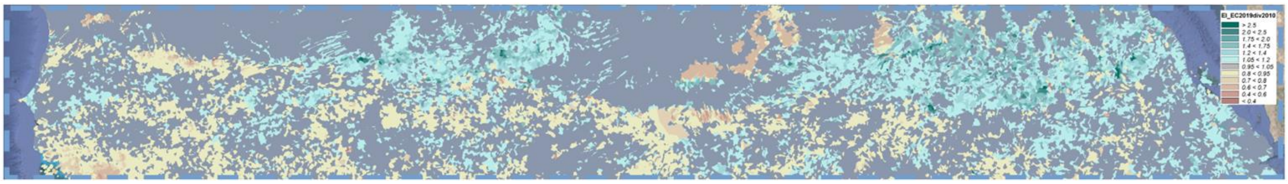

Figure 16 Evolution of Ecosystem Infrastructure Capability [EIC] per hectare, ratio 2019/2010

For the area of the Great Green Wall, we see that the changes in Figure 12 are nuanced in a large majority of SELUs by the importance of the rainfall in 2019 compared to 2010 (Figure 15), especially in the east and in the center. Those that have not benefited have declining TEC values, especially for bio-carbon. Conversely, those that have benefited greatly have higher TEC values.

On the other hand, in the zones of low precipitation, progress is very contrasted between the east of the zone where the various TEC improve overall while in the south-southwest part, the biocarbon and the infrastructure are degraded (but less in the case of the latter). This indicates that these first results should be taken with caution because they suggest that unusually low 2010 values may have suggested sometimes illusory gains in 2019. A test was therefore carried out to compare TEC evolution for the periods 2005-2010 and 2010-2019. It consists in producing a map of areas that are either growing or shrinking over the two periods, of areas growing from 2005 to 2010 then shrinking from 2010 to 2019, of those shrinking from 2005 to 2010 and then growing and finally the stable SELUs where change remains between -5% and +5%. This map (Figure 17) confirms the contrast between the west and the east of the zone and overall, the importance of ecosystem degradation which reveals the progress of desertification in the Sahelian zone and the degradation of forests further south.

Figure 17 Trends in Total Ecosystem Capability 2005-2010-2019

5.2 Application of ENCA accounts to the monitoring of protected areas and ecological corridors in Central Africa

The TEC indicator is applied to a selection of African protected nature areas in order to identify those which status is stable and those showing signs of degradation. Total Ecosystem Capability (TEC) is calculated by Socio-Ecological Landscape Units (SELU). AfrikENCA v.1 presents the accounts of more than 200,000 SELUs for the years 2001, 2005, 2010 and annually until 2020. The assessment was made for sets of entire SELUs making up the nature parks.

In Figure 14, the comparison of the TEC of the UPSEs constituting these natural parks in a transboundary area of Central Africa is for 2019.. It reveals contrasting situations [A]. The contrast is even greater if we consider the evolution of the TEC between 2005 and 2019 [B]. The TEC of the Zemongo park is clearly improving. That of Bomu-East, Lantoto and Garamba is stable. The South Sudan National Park ("Southern") shows a significant deterioration in its central zone, while in the case of Bomu-West, it is the periphery that is deteriorating.

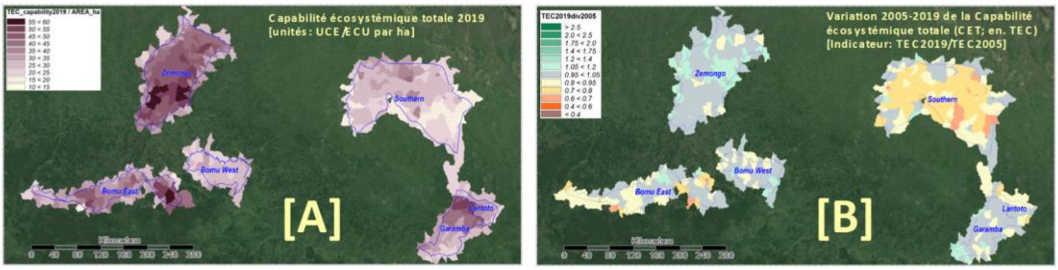

Figure 18 Total Ecosystem Capability 2019 of four natural parks and evolution 2005-2019

The first analysis can be taken further, by then studying the components of TEC: Ecosystem Infrastructure Capability, Water Capability and bioCarbon Capability (Figure 19, [C]).

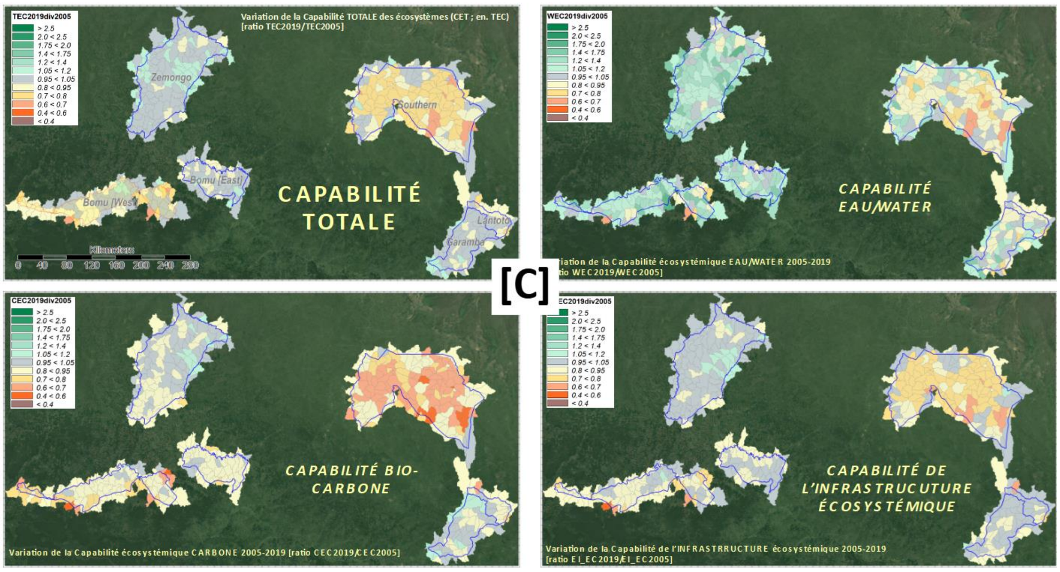

Figure 19 Breakdown of the 2005-2019 evolution of the Total Ecosystem Capability of four nature parks

More can be learned by studying the accounts themselves. They include hundreds of variables at the level of each individual SELU, some of them eing available on a per pixel basis. For example, the Green Background Landscape Index (GBLI; fr.: IFPV), which combines weighted land cover classes and tree density, is calculated in AfrikENCA v.1 by 250m pixels. Figure 20, the indicator shows the values per SELU [D] and the pixels [E] where changes occured.

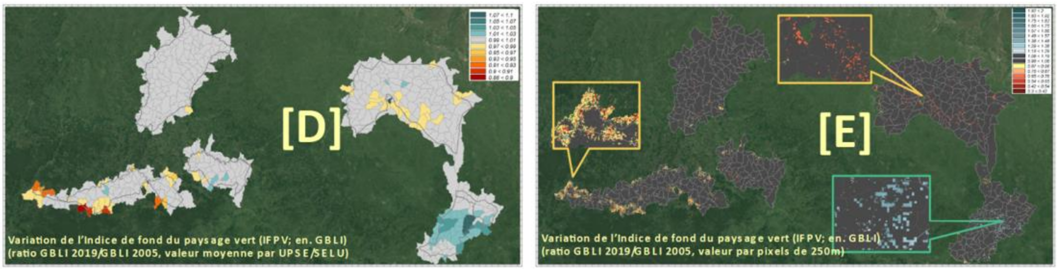

Figure 20 Green Landscape Background Index (GLBI; fr.: IFPV) per SELU and per 250m pixels for four nature parks

Other accounting variables can be analyzed in the same way by SELU. For example, Agricultural harvests by product [in F, Total only], Vulnerability to recurrent fires three years in a row [G], Wood formal and informal removals [H] or Biodiversity trends [I].

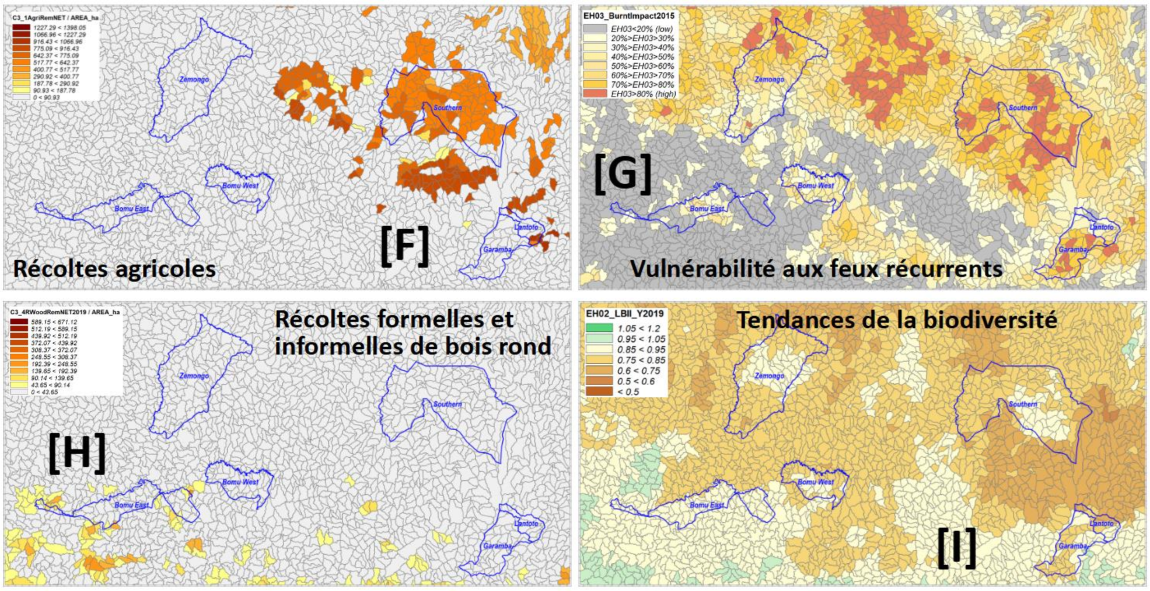

Figure 21 Explanatory variables for the state of four nature parks (examples)

The context of protected areas can also be assessed, for example considering the **extent and condition of ecological corridors**. Figure 22, the TEC2019/TEC2005 indicator shows a clear contrast between the north-eastern quadrant of the map where connectivity between parks is maintained or improved (in grey or green) and the south and east where the trend is towards degradation (in yellow or orange).

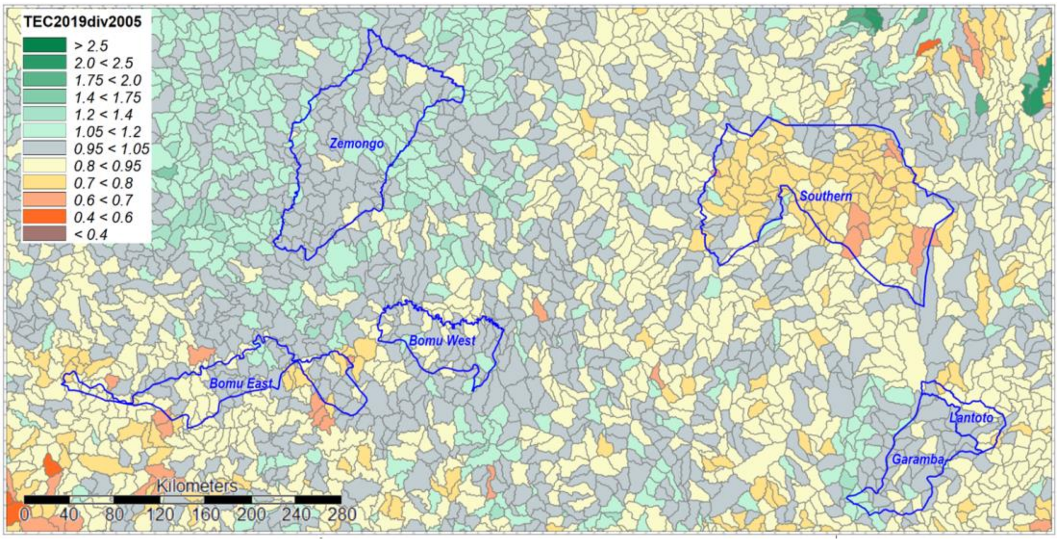

Figure 22 Evolution of connectivity between natural protected areas

These first quick analyses on two dates should be taken with caution as they carry the risk of over-interpreting atypical years. To remedy this problem, AfrikENCA v1 delivers a 13-year series: 2001, 2005 and annual accounts from 2010 to 2020.

5.3 Examples of assessment of nature protected areas with probable presence of IUCN Red List species Endangered [EN] or Vulnerable [VU]

The results of the application are presented as examples for 6 endangered or vulnerable animal species: chimpanzees/bonobos, elephants, giraffes, lemurs, okapis, and rhinoceroses.

The natural protected areas for each of these species were selected from the World Database of Protected Areas (WDPA) [UNEP-WCMC, 2023]. First, the most characteristic IUCN categories of protection types I to IV were selected. The probable presence of endangered (EN) or vulnerable (VU) species is deduced from the IUCN red list maps that are intersected with WDPA.

The rapid assessment of nature parks is made from the point of view of their capacity to protect vulnerable [VU] or endangered [EN] species as defined by the IUCN red lists.

It should be remembered that :

- The presence of species is recorded only in those protected areas where their status is EN or VU.
- Several of these species coexist in certain parks (which will be found on several maps).
- Applications on natural parks

- The presence of species is recorded only in those protected areas where their status is EN or VU.
- Several of these species coexist in certain parks (which will be found on several maps).
- It is only a "probable presence", inferred from the red list maps.

The indicator used is CET2019/CET2005.

The rapid assessment shows different situations with stable areas (grey), slightly improving areas (light green) and critical areas (yellow to red).

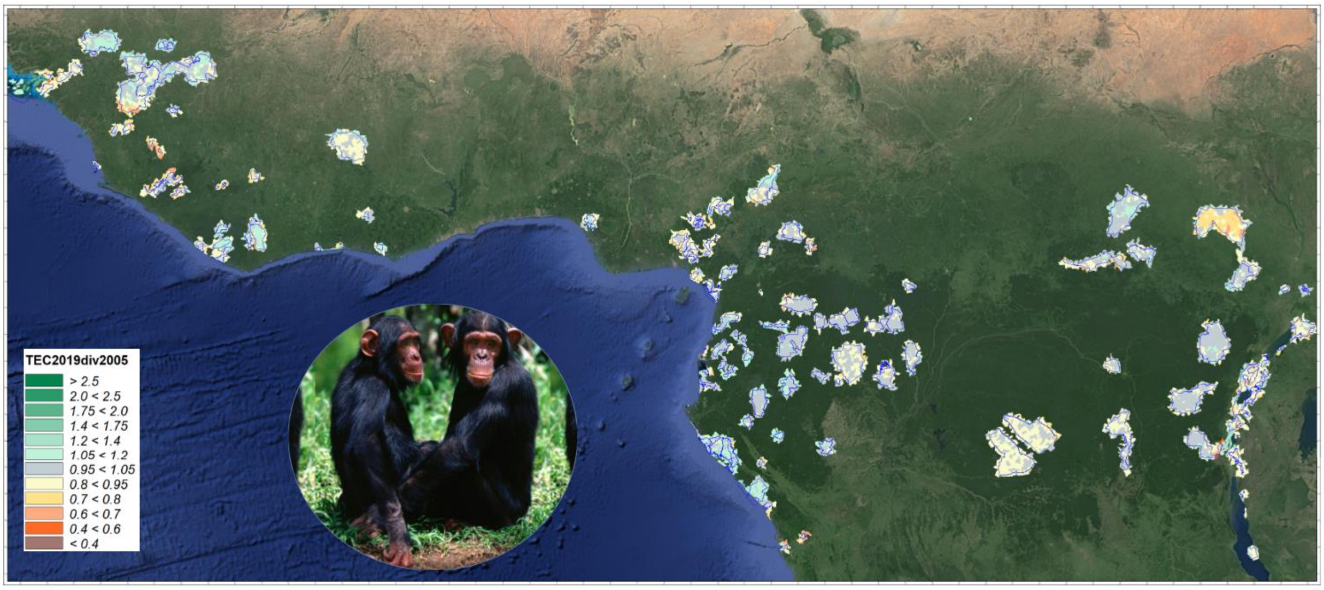

*Figure 23 Change in Total Ecosystem Capability 2005-2019: Parks with **chimpanzees and bonobos***

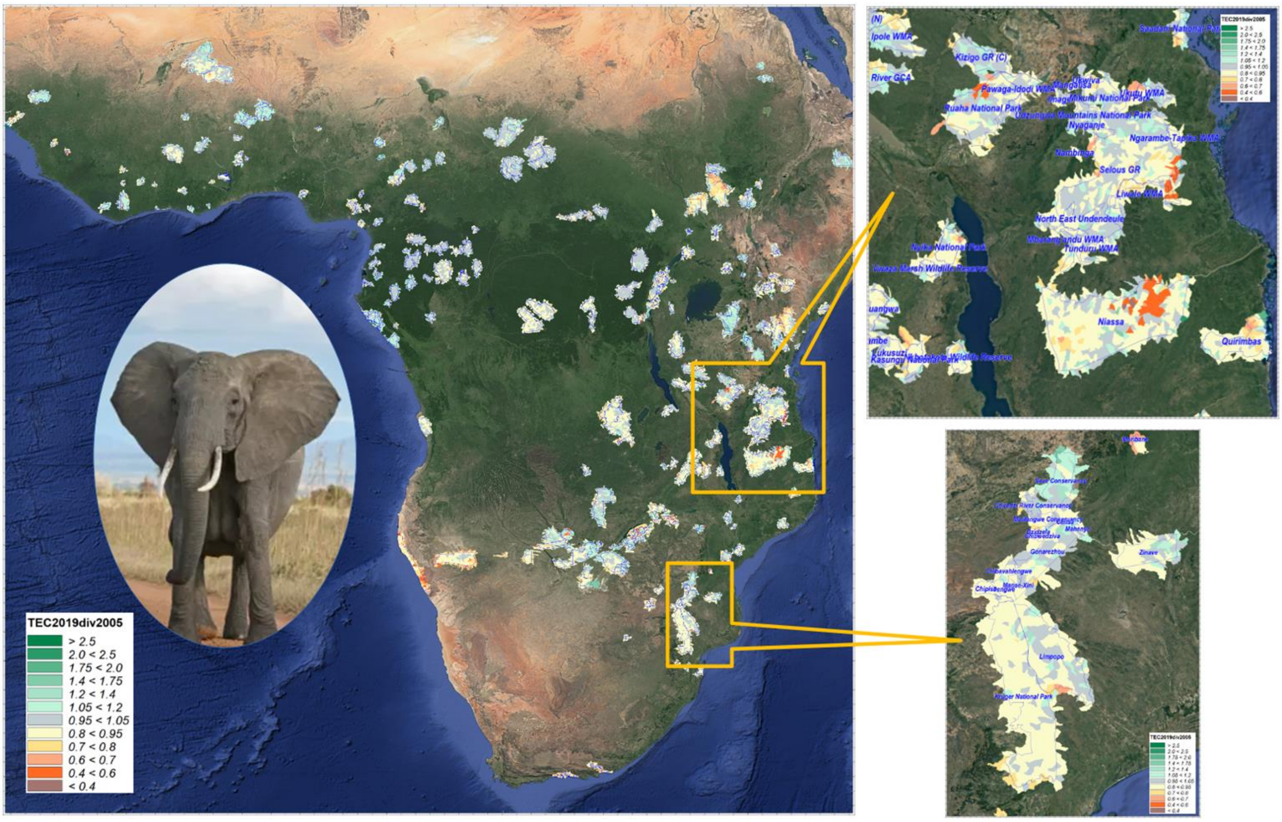

*Figure 24 Change in Total Ecosystem Capability 2005-2019: Parks with **elephants***

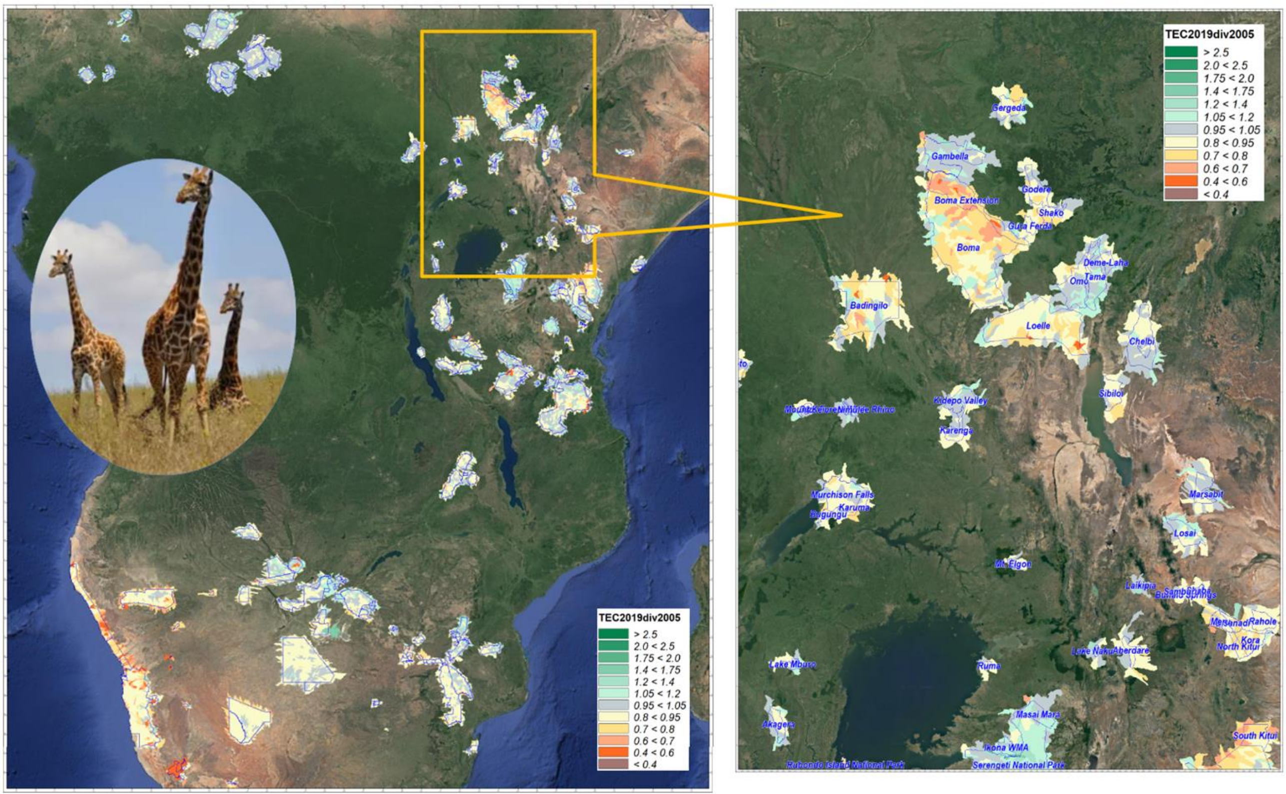

*Figure 25 Change in Total Ecosystem Capability 2005-2019: Parks with **giraffes***

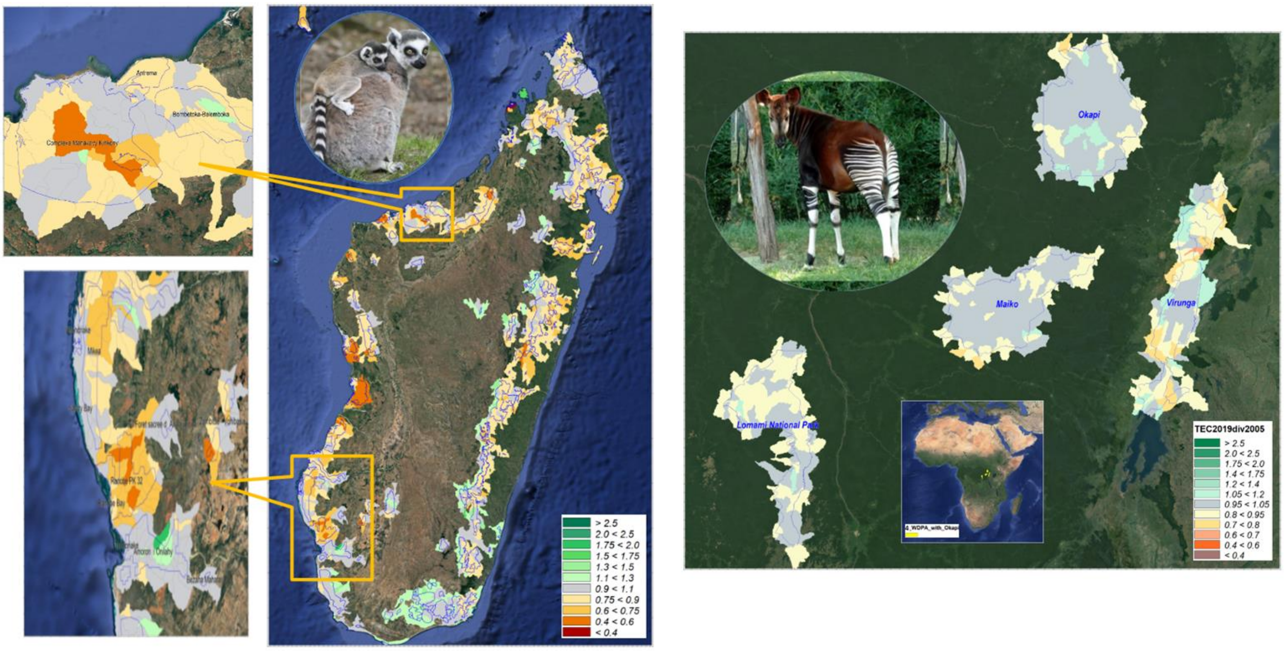

*Figure 26 Change in Total Ecosystem Capability 2005-2019: Parks with **lemurs** (left) and **okapis** (right)*

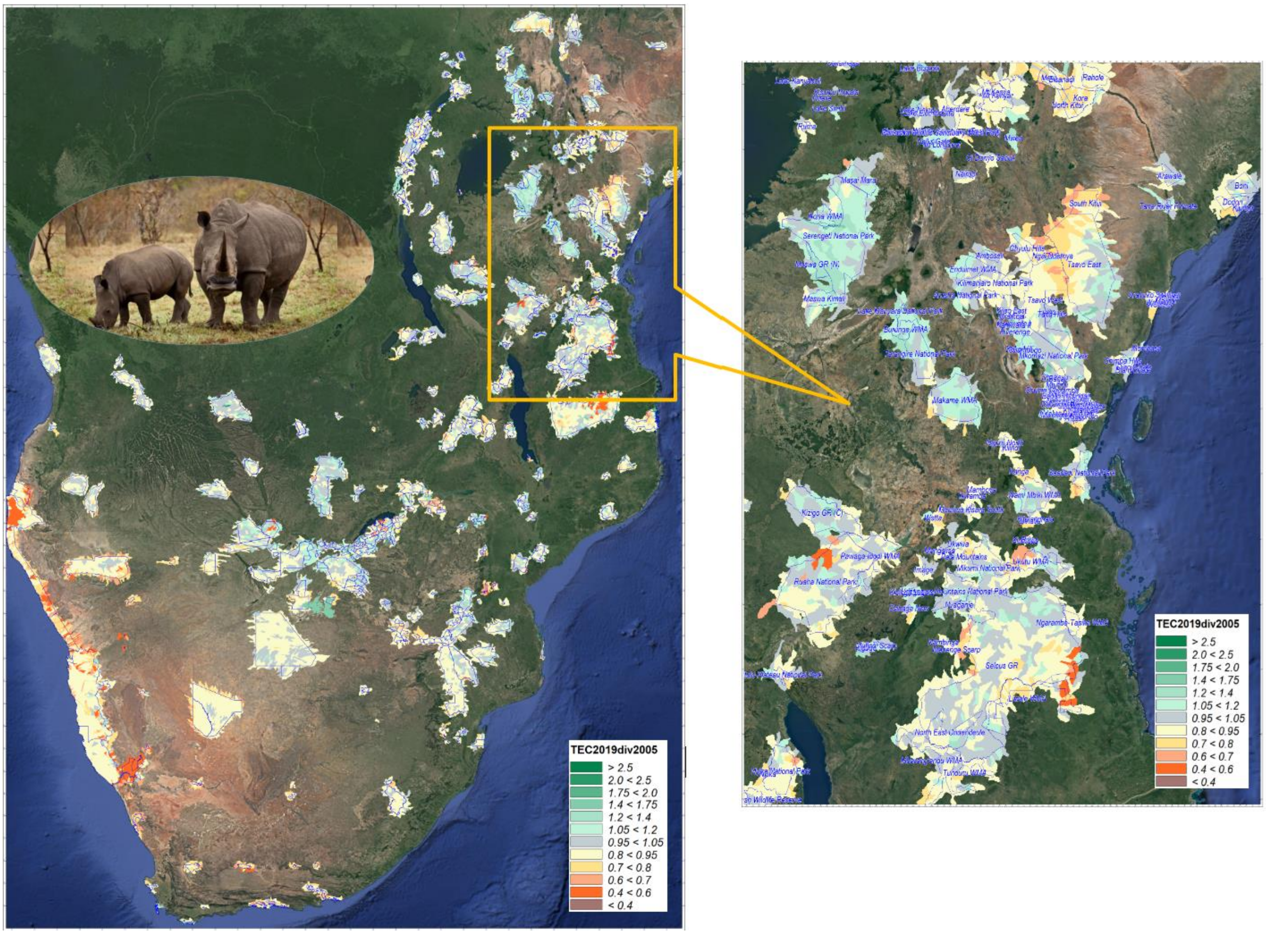

*Figure 27 Change in Total Ecosystem Capability 2005-2019: Parks with **rhinos***

5.4 Rapid assessment of forests and other natural wooded areas with AfrikENCA

5.4.1 Forests in the ENCA accounting framework

Trees and forests appear multiple times in the ENCA tables, particularly in the accounts of land cover (area), ecosystem infrastructure (trees density) and biocarbon (stocks and flows of biomass). In the ecosystem capability final synthesis, the assessment of forested SELUs also includes the water dimension through precipitation and evapotranspiration. Trees are considered from the point of view of above-ground and root biomass stock, dead organic matter production and other flows affecting them: net primary production, formal and informal wood harvests, losses due to land-use changes (urbanization, agricultural intensification, etc.) and fire.

Forests are more or less natural landscape systems dominated by trees. This dominance can be assessed in various ways. For example, FAO statistics define a forest as 10% tree cover, whereas satellite image classifications refer to 20-30% tree cover, with dense forests having a cover of over 60%. Given the importance of trees in ecosystems, they are taken explicitly into account beyond forests in the classification of "closed-open" territories in ESA CCI land cover classification [ESA, 2018] which follows the FAO LCCS satellite image classification system. In the ENCA classification adapted to AfrikENCA, trees appear in the definition of "wooded savannahs" and "mixed natural territories".

ENCA forests are defined as Land Cover Ecosystem Units (LCEUs) classified as "dense forest", "mangrove and swamp forest", and "other forest" which corresponds to open forest. As the full accounts are synthesized by SELUs, the accounts of forest LCEUs in the strict sense are limited to the core variables: land cover, biocarbon stock, NPP, and harvested and indirect tree losses, and other pixel variables, including rasterized summary indicators.

Another level of forest accounting is possible in ENCA, that of forest-dominated social-ecological systems (SELUs). Full accounts are then available for these units.

For the purposes of the present application, SELUs have been classified according to dominance in the landscape of forest and other wooded land. In order to get closer to the nomenclature of ecosystems proposed for the SEEA-EA, a climatic criterion was introduced. The dominant landscape types of the SELUs were defined by combining the land cover (>33% of the pixels in a SELU) and the "ombrotypes" of the USGS ELU database [USGS, 2018][4]. The >33% dominance rule is applied to the sum of the pixels of the LC61 Dense Forest, LC62 Mangrove and LC63 Other Forest classes. This gives the Dominant Landscape Type (DLT) Dominant Forest Landscape [FOR].

Forest pixels <33% are taken into account for the calculation of the "Other Wooded" dominance. The DLT "Other natural wooded landscape" [WOOD] is defined as the sum of the pixels of the classes LC70 Wooded savannah and LC90 Natural mixed vegetation plus the forest pixels (LC61, LC62 and LC63) present but below the 33% threshold. Note that the < or > 33% thresholds don't refer anymore to trees density as for land cover definition of forests but to the percentage of forest land cover units (ha) or pixels per SELU.

Dry and wet characteristics are added to the Dominant Landscape Type [FOR] only. They are extracted from the USGS ELU (Ecosystem Land Units) database which identifies 8 categories of "Ombrotypes" ranging from "1_UltrahyperArid" to "5_Dry", "6_Subhumid" and finally "7_Wet" to "9_UltrahyperWet". This detail is useful for assessing a specific forest, a USGS' ELU or a small region.

Considering accounting of forest change by SELU, the USGS types are grouped into three: Dry_Arid [FORDRY] (classes 1 to 5), Sub-humid [FORSUBHU] (class 6) and Humid [FORHUMID] (classes 7 to 9).

[4] The United States Geological Survey (USGS) Ecosystem Land Units (ELU) database is also used by SEEA-EA to define "ecosystem extent" classes in combination to land cover type.

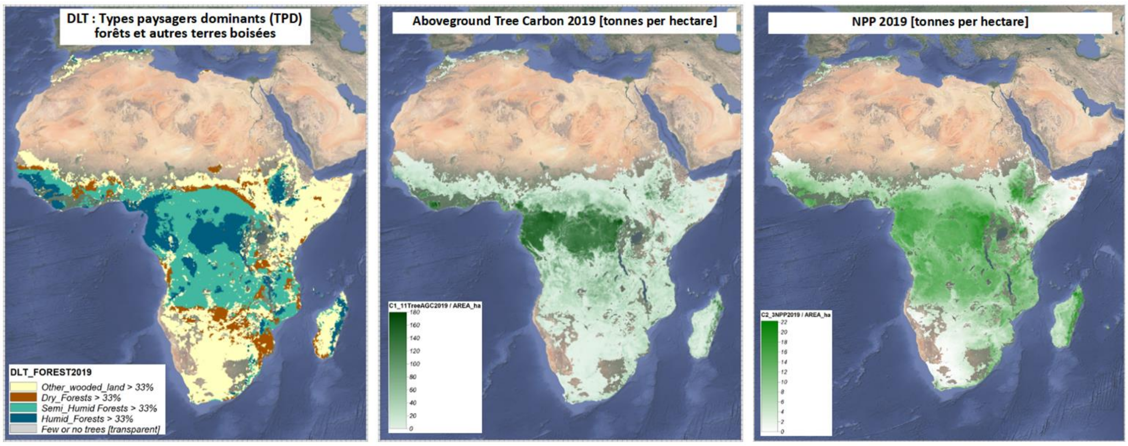

Figure 28 Dominant Landscape Types forest and other tree cover [left]
|| *Aboveground tree carbon stock (tonnes of C per ha, 2019)* **||** *NPP of forest and other tree cover (t of C per ha, 2019)*

5.4.2 First Assessment of African Forest Trends with AfrikENCA

On the scale of the African continent, where there are extremely contrasting climatic situations ranging from "hyper arid" to "hyper humid" in the sense of the USGS classification and values of Total Ecosystem Capability of less than 100 to more than 15,000 ECU per hectare, local variations from one SELU to another are necessarily different. A quick comparison of TEC at the beginning and end of the period shows areas that are deteriorating while others are maintaining or appear to be improving.

As explained in the introduction to this chapter, this two-date assessment is fragile, both because of accidental anomalies in the data and fluctuations in rainfall. The observation of the maps in Figure 26 shows both areas where the trends seem to be correlated and others where they are not.

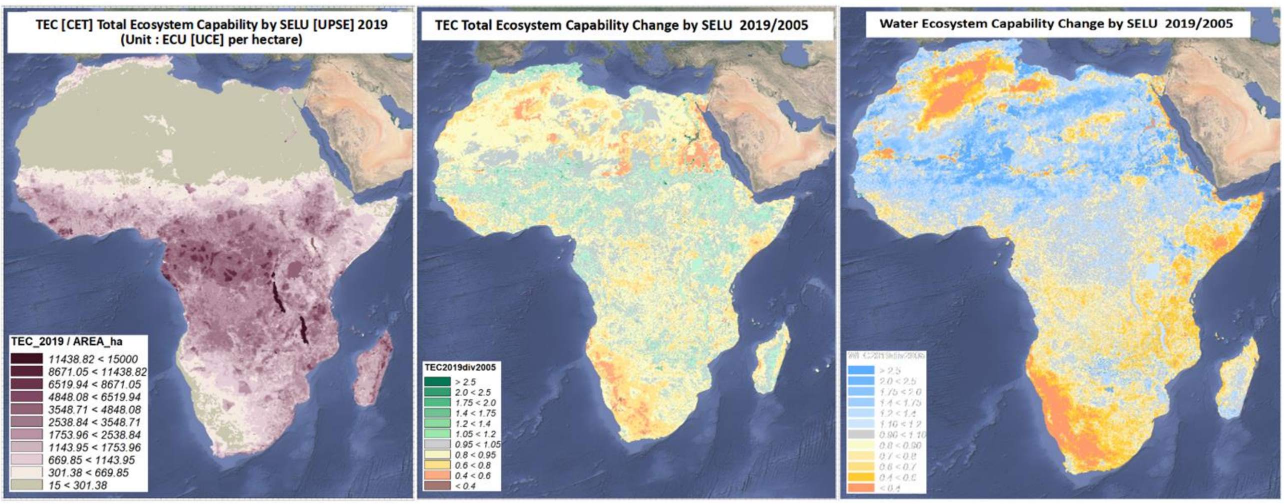

Figure 29 Total Ecosystem Capability [TEC] 2019 (ECU/ha) **||** *Change in TEC 2019/2015* **||**
Change in Water Ecosystem Capability 2019/2005 [WEC]

An examination of the TEC trend map over the periods 2005-2010 and 2010-2019, presented in section 4.1 on the Great Green Wall of the Sahel, shows the extent to which forest or other wooded dominated natural areas are experiencing TEC degradation, including in a large part of central Africa that has benefited from increased rainfall, as shown in Figure 30. Note that areas in red are degrading over the whole period, those in green are improving and those in light yellow are stable.

The observation of the Crbon Ecosystem Capability change map shows a correlation with the evolution of TEC and a decline in the densest forest areas. However, LBII, the the Local Biodiversity Intactness Index [Sanchez-Ortiz, 2019] annualized for the purposes of the accounts shows that these areas seem to be maintaining or improving in this respect.

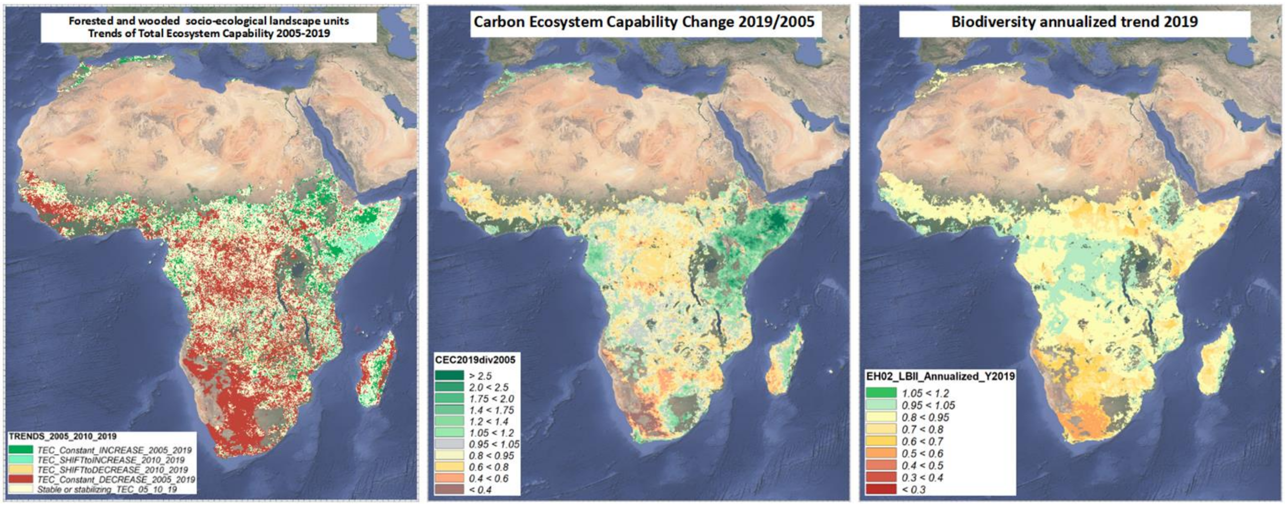

Figure 30 Forested and Wooded SELUs : Change in Total Ecosystem Capability 2005-2010-2019 **||** *Change in Carbon Ecosystem Capability 2019/2015* **||** *Annual change in LBII biodiversity indicator [annualized]*

The analysis can be taken further with other accounting variables. For example, one can look at the impact of fires and the impact of logging.

The Recurrent Fire Impact Index [EH03_BurntImpact] of the ENCA ecosystem infrastructure account is the inverse of the average fire occurrence observed over 3 years. Less than 30%: limited impact; more than 50%: recurrent fires. This is not a measure of the carbon losses that are estimated in the biocarbon account, but of the areas burnt by fire as identified by satellite. The bio-carbon account using the Global Forest Change [Hansen, 2013] trees annual loss data, on the other hand, provides a differentiated estimate of carbon losses from trees and other vegetation. As expected, the dense rainforests visible as very dark green-brown in the Google-Satellite background image are little affected. In contrast, the SELUs dominated by semi-humid and dry forests and other tree cover are affected.

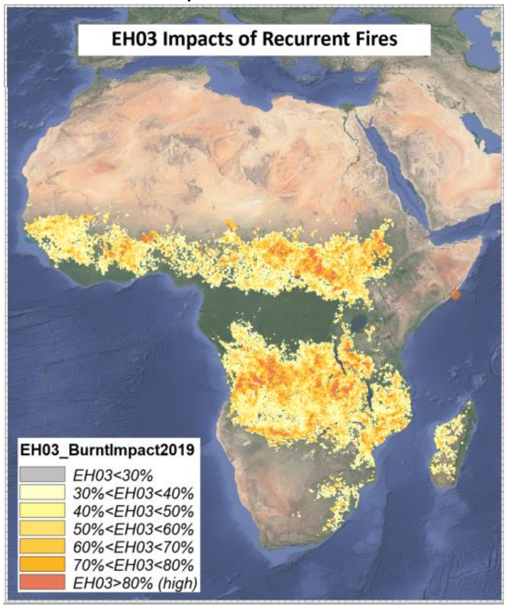

Figure 31 Forested and Wooded SELUs : Recurrent Fires Impact Index in 2019

The ENCA flow “Legal and Informal Roundwood Removals” [C3_4] of the ecosystem carbon account, is measured net of production returns (bar, branches…), so as to be conceptually compatible with current definitions of logging statistics. C3_4 is estimated from measures of tree biomass stocks from ESA CCI Biomass and annual tree losses from

Global Forest Change. Elements not traded by loggers (bark, roots, branches, etc.) are recorded under separate headings in the bio-carbon account. Similarly, ancillary losses from logging and the impacts of land artificialisation as well as losses due to fire are recorded under specific headings. The indicator of "net roundwood removals" obtained is much higher than the official statistics due to the inclusion of informal felling, which generally escapes official statistics. In addition, the destruction of trees for the purposes of logging itself can be very significant. These include the opening of logging tracks to be used by the operation machinery to access high value trees and the damage caused by the falling of large trees during felling. Similar significant impacts are caused by mining and other infrastructure construction, including dams. The gap was not estimated for AfrikENCA version 1, but is documented in the Guiana Shield ENCA 2000-2015 report [Rahm, 2021], for which total tree losses amount to 2.6 times the official logging.

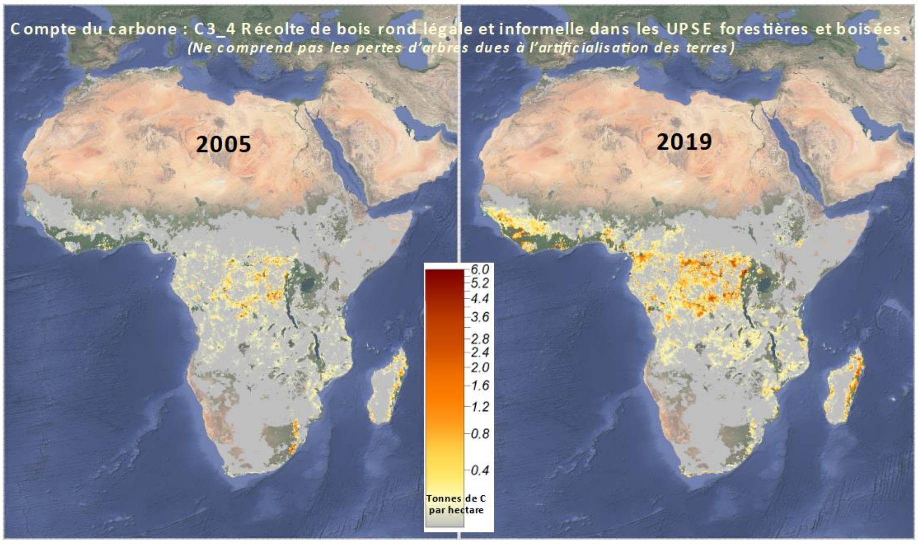

Figure 32 Forest and woodland SELUs: Legal and informal net roundwood removals 2005 and 2009 (in t. of C per ha)

The maps in Figure 32 show a very large increase in logging in the densest forest areas of Central and West Africa.

6 Perspectives beyond the initial version of AfrikENCA (v1)

The preceding developments have shown different uses and types of analysis that can be conducted when multi-year ecosystem natural capital accounts are available. The comments also highlighted how one can trace back to the driving variables, where the areas of uncertainty lie, and how to attempt to reduce or circumvent them. These data are accessible on the OSS digital platform http://copernicea.oss-online.org:8090/

This section outlines the work that will be done in the next steps. Some of the tasks are related to updating the first accounts and extending the domain covered by AfrikENCA to marine coastal areas. This will lead to a version 2 of AfrikENCA. Other work concerns the production of national and local accounts in the six countries participating IN COPERNICEA, enriched as much as possible with national data. Finally, we propose an approach in the form of ecological balance-sheets that will allow to link the accounts of ecosystem territories to the accounts of economic sectors and actors in order to provide them with the means to measure their ecological liability.

6.1 AfrikENCA future update and development : towards a version 2

AfrikENCA v1 is the first set of ecosystem integrated accounts with time series. Subsequent updates will include new datasets which were not available at the time of v1 production, in order to improve the accuracy of the accounts.

It consists for example in the Global Cropland Dynamics dataset produced by the Global Land Analysis and Discovery (GLAD) laboratory of the University of Maryland [Potapov, 2021]. As well improvements of existing datasets will be embodied in new accounts. Updates and upgrades will be facilitated by the forthcoming availability of tools such as Sys4ENCA developed by VITO [Buchhorn, 2023] which allows fast semi-automated data processing. In any case, the

consistency of time series will be maintained as it is important feature for data analysis, in particular regarding ecosystem degradation.

Another enhancement foreseen for AfrikENCA v2 is the inclusion of marine coastal units [MCU] which have not been processed in v1. The basic geographical reference layer of marine coastal units has been produced but has still to be populated with data. MCUs are restricted to a depth of -30 m which is a threshold for light and photosynthesis. The rationale is to be able to use for accounting maps of the bottom of the sea in a similar way as terrestrial land cover. MCUs are broken down and coded by seafronts according to the coastal HYBAS05 basins breakdowns. HYBAS05 being aggregations of SELUs, it makes it possible to use ENCA for integrated coastal zones management. Due to their size MCUs are broadly embedded into other zoning such as marine Exclusive Economic Zones or FAO fishing areas. If needed, subdivisions can be introduced, in particular for assessing coastal fisheries which are of the highest importance both considering the social-economic aspect and biodiversity. Figure 30 illustrates possible outcome of ENCA extended to MCUs.

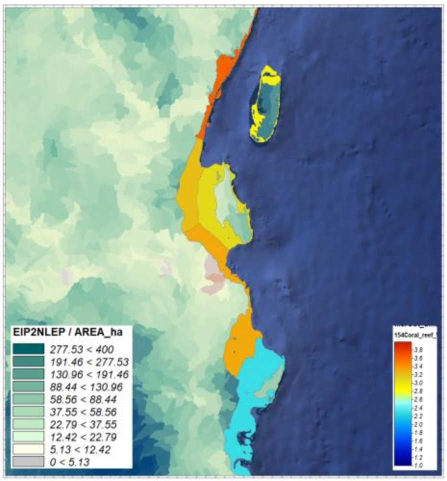

Figure 33: Illustration of the extension of ENCA to marine coastal units.

On the left side of the map Figure 30, shades of blue-green indicate the value per ha of the Net Landscape Ecosystem Potential (NLEP). On the middle-right of the map, rainbow colors express the condition index of coral reefs as mapped in WRI's "Coral reef at threat" map. The scale of scores is 0 = good condition, 1 = moderate pressure and 4 very high threat.

In addition, the year 2021 accounts will be produced in addition to the 13 years already available.

6.2 From continental scale accounts to national and local ENCA accounts

The COPERNICEA project aims at the implementation of ecosystem capital accounts in countries by national institutions. AfrikENCA is a first overall application which frames the project for the participating countries and make accessible international datasets in a format fit for accounting.

As stated in Section 1, six countries are partnering with the OSS for ENCA: Burkina Faso, Guinea-Conakry, Morocco, Niger, Senegal and Tunisia. National projects have started with the purpose to use national data whenever possible. These national projects have a countrywide component as well as local applications for areas of particular policy interest (protected areas, coastal areas, development areas...).

AfrikENCA purposely does not deliver accounts by countries, leaving that to the responsibility of the countries are on the lead for national projects.

Synthetic accounts and indicators are provided by the Level 3 and 4-5 watersheds provided by the HydroSHEDS database [2006-2023]. Figure 9, Section 4 shows, on the left, accounts by UPSE, in the center, accounts presented by level 4 (inland basins) or 5 (coastal basins) watersheds. On the right, the results of the accounts are mapped by Level 3 watersheds (HYBAS 03). The basins in HYBAS 04-05 and HYBAS 03 have been named to make it easier to locate them and read the tables. If a researcher wishes to extract the AfrikENCA data by country, he or she can initially obtain somewhat blurred but acceptable pictures by simply aggregating the UPSEs within national boundaries.

6.3 Development of applications based on AfrikENCA

Now, AfrikENCA databases can be used to develop applications in practical ways to support ecological planning, which is increasingly recognized as an essential tool in the urgent need to adapt to climate change and cope with its consequences. Ecosystems are important features of climate regulation and should not be considered only as economic resources. ENCA-QSP adopts a strong sustainability perspective with the principle of no net ecosystem degradation at the core of its construction. Degradation been assessed in an integrative way from the accounts of bio-carbon, water and ecosystem infrastructure integrity, risks of unilateral judgments are mitigated. From this perspective, the present AfrikENCA v1 accounts contribute at setting the scene to more detailed and precise analyses of the condition and evolution of zones of interest such as, for example coastal zones, nature protection parks, agriculture perimeters, urban areas, forested areas, etc. Forward looking studies are as well feasible using spatial modelling tools combining expert knowledge with spatial and statistical data. They are relevant for framing policies as well as projects and for land planning.

Ecosystem accounting is not a substitute to the broad knowledge needed, technical, scientific, as well as that coming from the more empirical experience of population. What integrated ecosystem accounts bring is a holistic view of main dimensions and its translation into a set of quantified indicators based on verifiable data. This is essential for the social debate on the responsibility of each and every one and for the fairness of needed policies. Of course, the interpretation of the data is not simple and their good use require the expertise of the respective specialists of the various domains, in particular when coming to the bottom of the accounting tables where basic material balances of surfaces, lengths, volumes or masses are supplemented with diagnoses based on semi-quantitative or complex variables. Ecosystem accounts can play the role of a forum where more specialist visions are confronted to the other facets of the systems.

ENCA-QSP is a simplified model which attempts to take stock of a minimum of interactions: between components measurable quantities (in very practical terms), between quantitative balances and qualitative factors, between elementary statistical units exchanging through neighborhood as well as because of their connection by the water flows, between scales which influence each other, top-down and bottom-up. As well, ENCA-QSP describes interactions with the economy via land use as well as use of biomass and water resources which are classified according to the usual nomenclatures of products (agriculture, forestry and fishery) and economic sectors (water use).

ENCA-QSP aims as well as addressing the social dimension, primarily by defining its accounting units as socio-ecological systems, also by using some population variables for estimating water consumption and finally by proposing indicators of accessibility to good landscape potential. More should be done, in line with the “Ecohealth” theory of David Rapport who states that one essential symptom of the “ecosystem distress syndrome” is the capacity of ecosystems to support healthy populations [Rapport, 1999]. Socio-ecosystems which are not able to provide food and fair quality water to people are not healthy. The ENCA-QSP model has lines to record this kind of indicators, would data be available.

The range of application using the ENCA-QSP database for Africa is high and first hints have been given in previous chapters. Next developments have started for enhancing accounts in order to meet the requirements of national policies and of local action. They should ultimately address economic actors book-keeping and the need to record their responsibility regarding the ecosystems that they may degrade when they exploit them. This is the purpose of ecological balance-sheets to be compiled first by sector and then by company.

6.4 Towards the establishment of ecological balance sheets ?

With regard to the future establishment of ecological balance sheets by companies, sectors, countries, etc., the logic of the ENCA is to start with balance sheets of ecological assets, claims and debts in bio-physical terms, hence in ECUs.

Ecosystem assets are altogether a receivable (a right to use them) and a liability (an obligation to return them to the state in which they were received). The balance of receivables and debts will therefore take into account the ecological improvements of the asset (receivables) and its degradation due to human activities (debts). The restoration of a degraded asset will be recorded as a reduction in liabilities compared to a baseline situation. The net value of the asset will therefore be an important indicator for measuring the responsibility of economic actors towards nature and a measure of the risk taken by those who degrade: risk of loss of resources, reputational risk and, above all, risk linked to the difficulty of adapting to the standards imposed by the climate and biodiversity crises.

In addition to assets which are directly used, the ecological balance-sheet records as debt the increase ecosystem degradation embodied in purchased products and in reduction of debts the acquisition of ECU through restoration or compensation. Lastly, creation of new ecological value will entitle to record receivables.

Of course, such market mechanisms will have to be regulated in terms of verification of facts as well as considering eligible compensations inside or between regions. The creation of new receivables will have to be certified. Regarding nature conservation, allocations of ECUs to nature protection parks can be decided acknowledging the liability of the global community considering historical degradation. Maintaining or increasing the ECU value of protected areas would then provide an income through the eligible compensation mechanisms. Oppositely, degradation of these areas would result in reduced income. A tentative balance-sheet template is proposed in the CBD TS77 report on ENCA-QSP, Chapter 9 [Weber, 2014 (a)].

Recording ecological debts in a standardized way is an important incentive for companies as long as such indicator is likely to be taken into account in financial risks by rating agencies, banks and insurance companies, and more generally by investors.

For public authorities, the measurement of ecosystem degradation provides a new tool for incentive or conditionality policies for access to public markets and credit, complementing those presently based on pollution, and in particular CO_2 emissions. To reduce the costs of this situation, ecological debtors will therefore either have to restore if they can, or have others restore (compensation). With an integrative measure of ecosystem degradation, the effectiveness of offsetting can be measured in ECUs, thus avoiding "*green washing*" practices. This would also make it possible to generate new funding flows for nature protection and ecosystem restoration with a view to development without net degradation of ecosystems. As for companies having to face these costs, they will seek to amortize the provisions they may have to make, and thus calculate the corresponding amounts in money themselves.

Annex 1 : A brief description of Ecosystem Natural Capital Accounting and its relationship to existing accounting systems

Ecosystem Natural Capital Accounting (ENCA) is a methodology for measuring the state of social-ecological systems, their stability, degradation or enhancement, published by the CBD in 2014 as a "Quick Start Package" (ENCA-QSP) [Weber, 2014 (a)] to support the implementation of ecosystem accounts as called for in Goal 2 of the Aichi Strategy 2010. ENCA-QSP is a variant of the United Nations SEEA Ecosystem Accounts (SEEA-EA) (United Nations 2021) adopted as an international statistical standard in 2021. While the SEEA-EA aims to measure the economic monetary benefits of ecosystem services considered as assets, the ENCA Quick Start Package addresses the potential and resilience of ecosystems in biophysical terms in order to measure their degradation.

The ENCA-QSP framework consists of a land cover and change account on which three other accounts are built: biocarbon, water and ecosystem infrastructure (landscapes, rivers and marine coastal zones). Complete accounts are established for socio-ecological statistical units for which the ecosystem-human activity interaction can be assessed. In practice, this composition is deduced for terrestrial ecosystems from the dominant land use (forests, wetlands, grasslands, cultivated areas, urban areas...) and catchment areas where river water flows. As far as the sea is concerned, only coastal marine areas are treated in the Quick Statrt Package (QSP) of ENCA.

ENCA tables are integrated according to the principles of accounting, notably exhaustiveness and double-entry for the basic balances. For example, the water account records for each socio-ecological landscape unit (SELU) the outflow from the rivers, which is included for the same amount in the inflow from the downstream unit. When aggregating the SELUs into larger basins, only the final flow is recorded. The ENCA-QSP calculation model is presented in the form of spreadsheets where the exogenous variables introduced and the different accounting equations are explained: totals, balances, carryovers between sub-accounts and, if necessary, the default values used for certain estimates. The accounts each provide indicators defined as specific accounting balances. Examples are the Net Ecosystem Carbon Balance, the Net Ecosystem Water Balance and the Total Ecosystem Infrastructure Potential.

Each of the three quantitative balances is completed by a table calculating its Internal Unit Value. This is defined as the product of two indicators. The first is derived from the quantitative balances and indicates whether the use of the resource is sustainable. Its format is the ratio of accessible resource divided by total use. If this ratio is ≥ 1, there is no depletion and the indicator is conventionally 1. On the other hand, depletion is measured by ratio values < 1. The second indicator is the health status of the resource. It is established on the basis of a diagnosis based on the observation of symptoms of ecosystem distress other than quantitative depletion. These symptoms are varied and the diagnosis depends on our knowledge of the ecosystems. They may relate to variables of pollution intoxication, dysfunction, fragmentation, vulnerability, biodiversity loss, etc. This part of the ecosystem account requires the expertise of specialists in different fields[5].

Measuring the ecological value

The implementation of policies requires the setting of quantifiable targets and assessment tools. For climate, a target is set based on the relationship between average atmospheric temperature and greenhouse gas concentration, and actions are taken to limit the latter by reducing net emissions measured by a composite unit, the CO_2-equivalent. These policies and actions are based on a standardized accounting of the commitments and performance of countries and companies, known as “carbon accounting”. This is not the case for the biosphere, where complexity and the lack of a metric on which to base integrated policies are cited. This imbalance is reflected in the nature and scale of action in two closely related areas. In response to this problem, ENCA proposes a metric to measure the ecological value of the biosphere and its changes in order to enable new policies to be put in place that take the economy-nature interaction more fully into account, beyond administrative regulations. This unit-equivalent is close in spirit to the *Econd* currency proposed by Peter Cosier and tested in Australia [Cosier, 2010] and to the composite indicator for measuring land degradation promoted by the UN Convention to Combat Desertification and used for the SDG 15.3.

To measure ecological value, ENCA uses a special currency called the Ecosystem Capability Unit (ECU), which is the arithmetic average of the internal unit values of bio-carbon, water and ecosystem infrastructure. The "price" in ECU reflects both the sustainable use of each resource and its health. It is not a market price but a social value that is more akin to an administered price. However, once the calculation formula has been agreed, this price varies according to natural conditions and the practices of economic agents, independently of any administrative decision. The aggregated ENCA indicators converted into ECUs can then be added together to calculate Total Ecosystem Capability (TEC). The ecosystem potentials of bio-carbon, water and ecosystem infrastructure first calculated in physical units (tonnes, m^3 and hectares) are multiplied by the average ecological value of each elementary socio-ecological unit, giving the value of their capability in ECU. The sum of these three capabilities gives the TEC. The advantage of this aggregate indicator is that it responds to what happens to each of its three components. As the TEC is the ultimate aggregate produced by the ENCA's integrated accounting model, it allows the identification of anomalies, general trends and comparisons. It is then possible to go back to the different explanatory variables contained in the tables.

[5] *The mapping of the good ecological status of rivers produced every six years by EU Member States for their report to the Water Framework Directive is an example of the type of diagnosis that can be used in ecosystem accounting. These data were used in Jazmin Arguello's PhD thesis on the feasibility of ecosystem accounts at the scale of the Rhône River catchment (Argüello, 2019)*

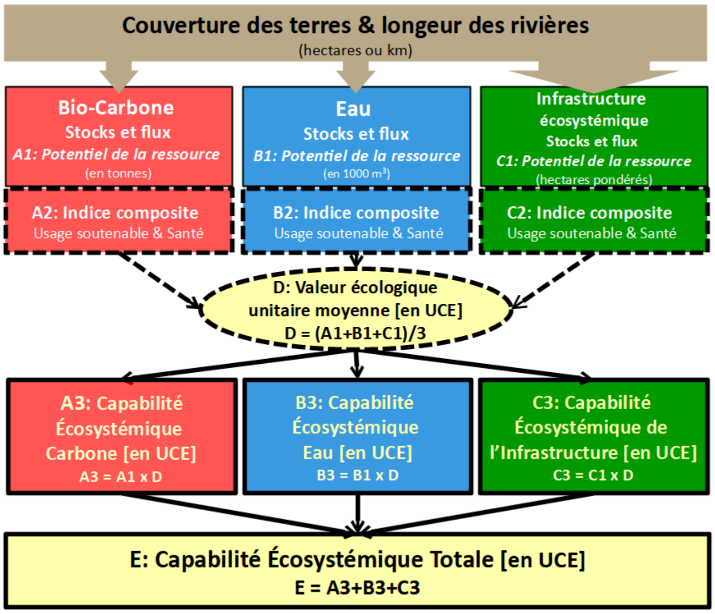

Figure 34 Structure of the ENCA accounting framework

Ecosystem accounting and money

The rationale of ENCA is to measure ecosystem degradation so that it can be taken into account by economic agents and in national accounting. The process is designed in several steps: ecosystem accounts by geographical functional units (the Quick Start Package), establishment of ecological balances in physical units and, finally, calculation of the restoration, compensation or avoidance costs necessary to counterbalance the direct and indirect degradation resulting from economic activity. In this approach, the estimation in monetary terms is generally only foreseen for the fraction of ecosystems that are degraded as a result of economic activities. These unpaid costs can then be recorded by businesses as an additional depreciation [Rambaud 2015] to finance restoration and in national accounting as a correction for the calculation of Final Demand at full price [Vanoli, 2017].

The SEEA-EA proposes a complete accounting in physical and monetary terms of ecosystem services and ecosystems themselves as natural assets, to be integrated with the economic accounts. The monetary value of ecosystems is estimated according to the general theoretical rule of the economic value of a capital as the present value of the whole set of services expected from it. Curiously, the question of restoration costs is left out of a few paragraphs, only from the standpoint of possible valuing of assets at the restoration costs, which is (wisely) rejected. No mention of costs as an essential economic variable per se. There is no mention of costs considered as an essential economic variable in itself for calculating the economic operation surplus, the full cost of final demand or the effort required to maintain the state of ecosystem capital.

ENCA does not place the valuation of ecosystem services and assets at the heart of its model without excluding it. Chapter 9 of the CBD TS77 Technical report outlines satellite accounts that can accommodate valuation of particular ecosystem services. Indeed, so-called provisioning ecosystem services are recorded in ENCA tables of uses of bio-carbon and water. Being goods, they are in principle all recorded in national accounts and in related survey systems such as the World Bank's family budget surveys. The prices of products that are not traded are defined in relation to the market prices of similar products. For these products, as well as for all other commodities, ENCA postulates that the market price is not complete when a product has been degraded during its production and that the unpaid restoration costs must be incorporated. For functional or intangible regulatory and socio-cultural services, the measurement is more complex because it generally involves the confrontation of a natural function and a population that has access to it. These services have a place in the table of uses of the ecosystem infrastructure account. At this stage, only a limited number of functional services are proposed and the table does not add them up. As there is a broad compatibility between the SEEA-EA physical accounts and ENCA, the latter provides economists with some of the data they need for their valuations, either in the SEEA-EA framework or in studies of the costs and benefits of projects and their impacts.

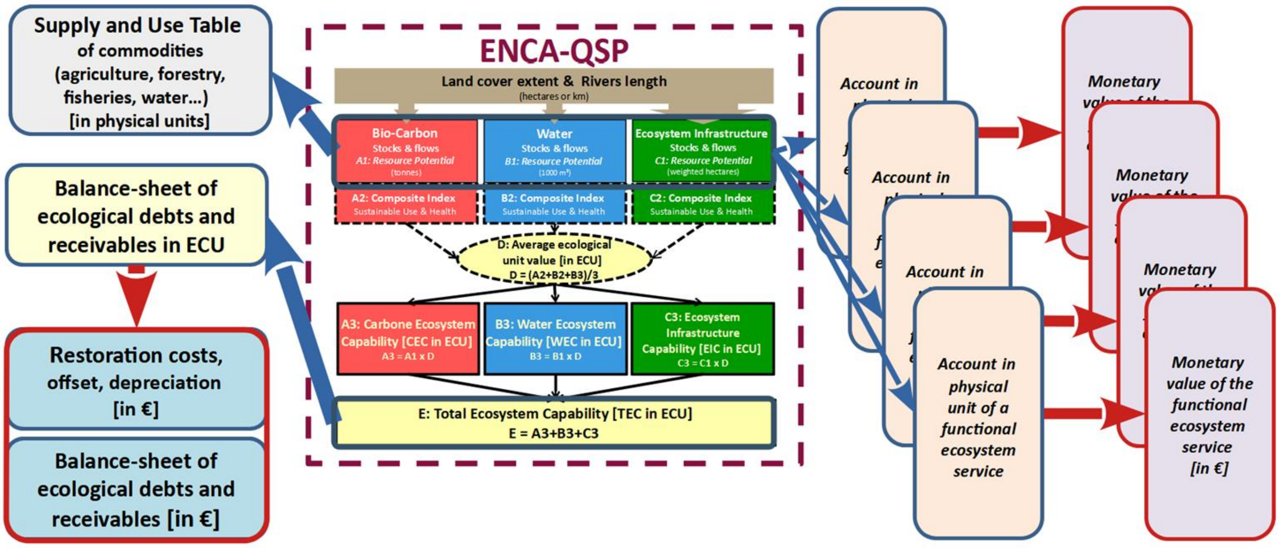

Figure 35 ENCA-QSP accounting framework and derived or satellite accounts

Finally, we note the possibility of establishing **socio-economic satellite accounts** of the ENCA-QSP framework to record the actual observed flows of formal and informal economic activities, the actual expenditures for nature protection and also key social variables of the relationships of the populations to their ecosystem: health, living conditions, food, access to water...

Finally, the comparison between SEEA-EA and ENCA shows that regarding the accounts in biophysical terms which are a prerequisite to economic valuations in money, the two systems are broadly compatible.

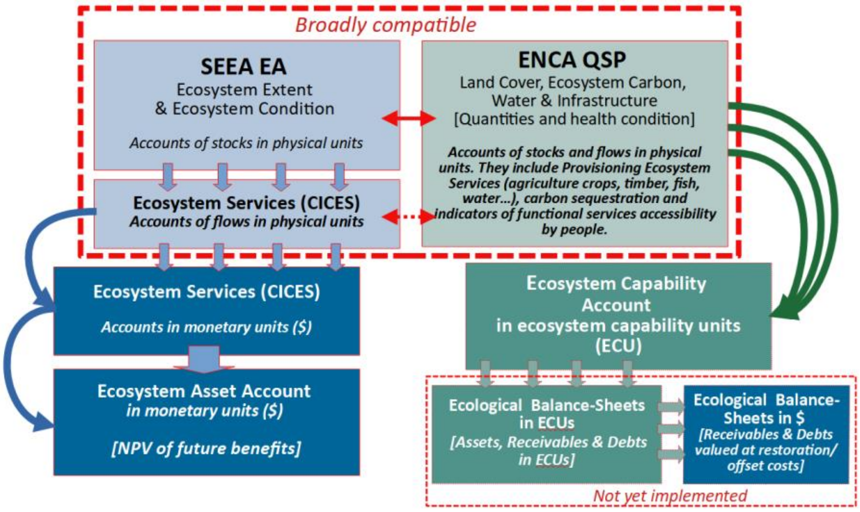

Figure 36 Compatibility between the SEEA Ecosystem Accounting and the Ecosystem Natural Capital Accounts

Annexe 2 : Main international data sources for use in Tier 1 Ecosystem Accounting

- EU Copernicus Climate Change Service (C3S, meteorology, evapotranspiration)
- EU Copernicus Global Land (DMP/NPP)
- Agence spatiale européenne Climate Change Initiative (ESA CCI biomass et ESA CCI land cover)
- UMD-GLAD/University of Maryland/USGS/NASA (Global Forest Change, Global maps of cropland extent and change)
- UN Biodiversity LAB (catalog giving access to a large number of databases)
- NASA (GRACE, groundwater level)
- World Table Depth (WTD, shallow groundwater)
- FAO/WaPOR (for Africa ; land cover, water biomass productivity)
- FAOSTAT (harvests, livestock, statistics)
- FAO/CGIAR (SPAM, harvests per mesh)
- FAO/GLW (GLW 3, livestocks per mesh)
- FAO AQUASTAT (sharing of surface water/groundwater use)
- ISRIC (soil organic carbon)
- WWF/USGS/UMcGill (HydroSHEDS, hydrographic network and watersheds, average river flows)
- EC-JRC (occurrence of water surfaces and soil erosion)
- Prospects/GEOBON (LBII, Local Biodiversity Intactness Index)
- IUCN (KBA/Key Biodiversity Areas, Red Lists)
- WCMC (WDPA, World Database of Protected Areas)
- WCMC/Ocean Wiewer (catalog giving access to a large number of databases on coastal areas)
- WorldClim (average rainfall per kilometre grid cell)
- WorldPOP (population kilometre grid cell)
- OpenStreetMap (OSM, transport networks)
- GADM (administratives boundaries)

Bibliographical references

Argüello Velazquez J. [2019]: Implementing Ecosystem Natural Capital Accounting Methodology to the Rhone watershed : the proof-of-concept. Biodiversity. Université de Lyon, [2019]. English. https://www.theses.fr/2019LYSEN040

Buchhorn M., Van den Hoof C., Smets B., Weber J.-L., Sanon A., Tiemtoré S. [2023]: Facilitating the management of protected areas in West Africa through multi-level ecosystem accounting, Sustainablity, 2023 [forthcoming]C3S [2023]:

Copernicus Climate Change Service implemented by ECMWF
https://climate.copernicus.eu/ & https://cds.climate.copernicus.eu/cdsapp#!/search?type=dataset

Conrad, O., Bechtel, B., Bock, M., Dietrich, H., Fischer, E., Gerlitz, L., Wehberg, J., Wichmann, V., and Böhner, J. [2015]: System for Automated Geoscientific Analyses (SAGA) v. 2.1.4, Geosci. Model Dev., 8, 1991-2007, doi:10.5194/gmd-8-1991-2015 https://saga-gis.sourceforge.io/en/index.html https://sourceforge.net/projects/saga-gis/files/

Cosier P. and McDonald J. [2010] : A common currency for building environmental (ecosystem) accounts, LG/16/22, 16th Meeting of the London Group on Environmental Accounting Santiago, Chile, 25 – 28 October 2010 https://seea.un.org/sites/seea.un.org/files/11_21.pdf

EEA(a) [2019]: Corine Land Cover Accounting Layers 2000, 2006, 2012 and 2018, European Environment Agency https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers,

EEA(b) [2019]: Land cover and change accounts 2000-2018, European Environment Agency https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

ESA CCI [2018]: Climate Change Initiative Land cover Products, European Space Agency https://www.esa-landcover-cci.org/?q=node/164

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest

Cover Change." Science 342 (15 November): 850–53. Source: Hansen/UMD/Google/USGS/NASA. Data available on-line from: https://glad.earthengine.app/view/global-forest-change .

HydroSHEDS [2006-2023], HydroSHEDS by WWF, McGill University, USGS et. al. https://www.hydrosheds.org/

Haines-Young, R., and Weber, J.-L. [2006]: Land accounts for Europe, 1990-2000, EEA report 11/2006. http://www.eea.europa.eu/publications/eea_report_2006_11

Mittempergher, D., Vergez, A. [2023a]. Natural capital assessment and ecosystem accounts for Kenya. IUCN, Gland, Switzerland https://drive.google.com/file/d/1Li7JQ8PfAHa9fAlTNMTKmQRlUmuUIdkD/view?usp=share_link

Mittempergher, D., Vergez, A. [2023b]. Natural capital assessment and ecosystem accounts for Viet Nam. IUCN, Gland, Switzerland https://drive.google.com/file/d/1zA36dLbkbfE_Hdg58OYGMZFFD_wqzvJ4/view?usp=share_link

Mittempergher, D., Vergez, A., Puydarrieux, P. [2022]. Rapport de restitution: Comptes du capital naturel – Gabon. IUCN, Gland, Switzerland https://drive.google.com/file/d/1gbgNvt96iKXPUgyJ-2QkxAN6rNBco0T9/view?usp=share_link

Morand J.-A., Jaffrain G., Weber J.-L., and Sannier C. [2023], Experimental Ecosystem Natural Capital Accounts in the Republic of Guinea, accepted paper for presentation at the 39th Symposium of Remote Sensing of Environment, Antalya, Türkiye, 24-28 April 2023

Observatoire du Sahara et du Sahel (OSS) [2008] La Grande Muraille Verte, http://www.oss-online.org/fr/publications/Muraille-verte

Observatoire du Sahara et du Sahel (OSS) [2015] La Grande Muraille Verte, un programme de développement pour le Sahara et le Sahel : une approche de suivi-évaluation des projets à partir des applications géospatiales http://www.oss-online.org/fr/publications/OSS-BRICKS-GMV_fr

Observatoire du Sahara et du Sahel (OSS) [2022] Les écosystèmes africains entre dégradation et restauration http://www.oss-online.org/fr/ld-ecosystemes-afrique

Observatoire du Sahara et du Sahel (OSS) [2023], Plateforme COPERNICEA http://copernicea.oss-online.org:8090/

Potapov P., Turubanova S., Hansen M.C., Tyukavina A., V., Khan A., Song X.-P., Pickens A., Shen Q., Cortez J. [2021] : Global maps of cropland extent and change show accelerated cropland expansion in the 21st century. Nature Food. https://www.nature.com/articles/s43016-021-00429-z

Rahm M., Lardeux C., Weber JL, Ramihangihajason T. [2021] Ecosystem natural capital accounting in the Guiana Shield in 2000 and 2015. Application of the quick start package of the convention on biological diversity (CBD) for implementing Aichi biodiversity target 2 on integration of biodiversity values in national accounting systems. ECOSEO project. WWF. 98 p. https://www.wwf.fr/sites/default/files/doc-2022-11/Ecosystem%20Natural%20Capital%20Accounting%20in%20the%20Guiana%20Shield%20-%20ECOSEO%20Project.pdf

Rakotondraompiana S., Edmond R., Rakotoniaina S., Faramalala M., Randriamihagason T., et al. [2015]. Comptabilité du Capital Naturel pour la Gestion d'une Aire Protégée. Cas de la Nouvelle Aire protégée d'Antrema (Nord-Ouest Madagascar). https://www.researchgate.net/publication/286372770_Comptabilite_du_Capital_Naturel_pour_la_Gestion_d%27une_Aire_Protegee_Cas_de_la_Nouvelle_Aire_protegee_d%27Antrema_Nord-Ouest_Madagascar

Rambaud A. and Richard J. [2015]: The "Triple Depreciation Line" instead of the "Triple Bottom Line": Towards a genuine integrated reporting. Critical Perspectives On Accounting, 2015, Special Issue on Social and Environmental Accounting, 33, pp.92-116. http://base.alliance-respons.net/docs/elseviertdl_richard.pdf

Rapport D. J., Whitford, W. [1999]. How Ecosystems Respond to Stress: Common Properties of Arid and Aquatic Systems. BioScience. 49.193-203.10.2307/1313509. https://www.researchgate.net/publication/240310960_How_Ecosystems_Respond_to_Stress_Common_Properties_of_Arid_and_Aquatic_Systems

Sanchez-Ortiz et al. [2019]: Global maps of Biodiversity Intactness Index (- bioRxiv) LBII Local Biodiversity Intactness Index, PREDICTS, NHM London, WCMC, CSIRO, https://data.nhm.ac.uk/dataset/global-maps-of-biodiversity-intactness-index-sanchez-ortiz-et-al-2019-biorxiv and GeoBON https://geobon.org/ebvs/indicators/local-biodiversity-intactness-index/

Sayre R., Dangermond J. et al. [2014] A new map of global ecological land units — An ecophysiographic stratification approach, Association of American Geographers, U. S. Geological Survey, GEO BON https://pubs.er.usgs.gov/publication/70187380

UNEP-WCMC and IUCN (2023), Protected Planet: The World Database on Protected Areas (WDPA) [On-line], [February 2023], Cambridge, UK: UNEP-WCMC and IUCN. Available at: https://doi.org/10.34892/6fwd-af11 & www.protectedplanet.net

United Nations et al. [2021]: System of Environmental-Economic Accounting-Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. https://seea.un.org/ecosystem-accounting

USGS [2018]: Global Ecological Land Unit (ELUs), US Geological Survey https://www.usgs.gov/centers/geosciences-and-environmental-change-science-center/science/global-ecosystems-data

Vanoli A. [2017]: Prise en compte des relations entre l'économie et la Nature, 16e colloque de l'Association de Comptabilité Nationale, INSEE, Paris, 2017 https://www.insee.fr/fr/information/2834065

Weber J.-L. [2014 (a)]: Ecosystem Natural Capital Accounts: a Quick Start Package for implementing Aichi Biodiversity Target 2 on Integration of Biodiversity Values in National Accounting Systems in the context of the SEEA Experimental Ecosystem Accounting, CBD Technical Series No. 77, www.cbd.int/doc/publications/cbd-ts-77-en.pdf Traduit en français: "Comptes écosystémiques du capital naturel: une trousse de démarrage rapide" https://www.cbd.int/doc/publications/cbd-ts-77-fr.pdf

Weber J.-L. [2014 (b)]: Experimental Ecosystem Natural Capital Accounts - Mauritius Case Study (Methodology and preliminary results 2000 – 2010), Indian Ocean Commission, Mauritius, 2014, 41 pages https://www.wavespartnership.org/en/knowledge-center/experimental-ecosystem-natural-capital-accounts-mauritius-case-study-methodology

WWF [2021] Capital naturel et stratégies des organisations : une visite guidée des outils, 73 pages https://www.wwf.fr/sites/default/files/doc-2021-08/20210831_Guide_Capital-Naturel-Strategies-des-organisations_WWF.pdf

WWF-Gabon and IUCN [2021], Valoriser le capital naturel pour appuyer des politiques de conservation de la nature au Gabon, WWF-Gabon Policy Brief, https://drive.google.com/file/d/14UkBq0sKQbVoyYAuWduZQgisePQk2Osd/view?usp=share_link

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AfrikENCA 2001-2020
A First Set of Ecosystem Natural Capital Accounts for the African Continent

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