FROM LAND USE & LAND COVER DATA TO THE FIRST ECOSYSTEM NATURAL CAPITAL ACCOUNTING EXPERIMENTATION IN THE REPUBLIC OF GUINEA

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Key words: remote sensing, satellite images, environmental indicators, biodiversity, carbon, water.

ABSTRACT:

The alarming observation of the collapse of plant and animal populations linked to the deterioration and disappearance of ecosystems has been undeniable for the past few decades throughout the world. On the whole planet, 60% of natural environments have been degraded over the last 50 years (WWF, 2018). Species are now disappearing at a rate 100 to 1000 times higher than normal, and human activities are the main cause (De Vos, 2015). Unfortunately, there are currently few ways to report on the responsibility of production and consumption patterns for ecosystem degradation and its integration into societal and government policies (Weber, 2022). On the other hand, with the Kyoto Protocol (1997) and the Paris Agreement at the COP21 of the UNFCCC (2015), climate negotiations are based on atmospheric carbon accounting in order to allow the transition from fossil fuels to renewable energies. However, this carbon approach does not take into account ecosystems despite their fundamental role in climate regulation. A global assessment of all natural resources and ecosystem services, known as natural capital, is necessary from a sustainable development perspective. This evaluation must then be taken into account in national accounting systems. This article will focus on the Ecosystem Natural Capital Accounting (ENCA) method developed by Weber, 2014, in which earth observation tools and derived space products have a significant place in measuring and monitoring these ecosystems. Indeed, the diversity, repetitiveness, spatial and spectral resolution of the satellite sensors make it possible to observe human activities and other natural pressures anywhere and at any time. The experimentation of ENCA (Weber, 2014) will be applied in the Republic of Guinea in the framework of the agroecological zoning project (Jaffrain et al., 2021). Based on three accounts (ecosystem infrastructure, ecosystem carbon and water resources), this method aims to measure the sustainable capacity or 'sustainability' of ecosystems to provide services. The land cover layers are the basic structural data for monitoring and describing the evolution of the territory at different temporal intervals. Thus, several environmental indicators were defined from these combined geospatial data and allowed to define the evolution of the total sustainability of the Guinean territory's ecosystem between 2005 and 2015. A clear degradation of this sustainability value was identified, which reflects the numerous land use changes affecting the country in the recent period (2005-2015).

1. INTRODUCTION

1.1 From land cover to ecosystem accounting

IGN FI is participating in the implementation of an ecosystem-based accounting of natural capital (ENCA) based on its land-use maps produced as part of the Guinea Agroecological Zoning Project (ZAEG) (Jaffrain et al., 2021). The project, carried out in collaboration with the Guinean Ministry of Agriculture, aims to provide a decision-making tool for the government by mapping land use and land use dynamics over a 10-year period and identifying and assessing agricultural potential. Within the framework of this project, two land use maps were produced (2005 and 2015) thanks to photointerpretation and remote sensing work carried out on site by a national team of Guinean technicians trained and supervised by IGN FI experts. The land use data produced from recent and old satellite images are the basis of the ecosystem accounting of natural capital developed by Jean-Louis Weber (Babin & Weber, 2019). It is worth recalling here that the Convention on Biological Diversity (CBD) published a manual in 2014 to support countries in the implementation of ENCA.

The Republic of Guinea, a West African country whose capital Conakry is located on the Atlantic coast, is therefore the territory chosen for our experimentation with Ecosystemic Accounting of Natural Capital. With an area of 245,857 sq.km, the country is subdivided into four large geographical zones (see Fig.1), otherwise known as natural regions: Lower Guinea (coastal zone), Middle Guinea (mountainous zone), Upper Guinea (savannah zone located in the north-east) and Forest Guinea (dense rainforest zone). With a rapidly growing population and the largest bauxite and iron reserves in the world, its territory has been marked in recent years by numerous changes in land use (artificialization, agricultural expansion, major development projects, etc.).

Figure 1: Natural regions of Republic of Guinea (Jaffrain, 2021)

1.2 Accounting in line with the Sustainable Development Goals (SDGs)

Since the end of the 20th century, climate has become an important policy issue worldwide. Numerous scientific studies point to climate change and a rapid decline in biodiversity. In 1997, at the third Conference of the Parties (COP 3) of the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol committed to a global policy to reduce greenhouse gas emissions, as the increase of carbon dioxide (CO_2) in the atmosphere is one of the main causes of climate change. Since then, a climate accounting system based on the guidelines of the Intergovernmental Panel on Climate Change (IPCC) has been set up around a unit of measurement: the CO2 equivalent. However, this accounting does not take into account the functions of ecosystems or their role in regulating the climate. Ecosystems are therefore only considered as carbon stocks, even though they are important assets in adapting to climate change, since they are at the origin of biological, biophysical and biogeochemical processes. Their state of health is not taken into account in the wealth of States (Weber, 2022). However, the degradation of ecosystems (reduction in biodiversity, reduction in sequestration functions, etc.), as well as the emission of greenhouse gases, is also one of the causes of global warming (Delangue & Teillac-Deschamp, 2019).

The need to integrate natural ecosystems into international economic exchanges and policies has been apparent for several years. As early as 1992, the Convention on Biological Diversity (CBD), signed in Rio de Janeiro, expressed concern about the rapid degradation of biodiversity and set a number of main objectives: "the conservation of the various forms of life, the sustainable use of its components so as not to jeopardise the renewal capacity of natural environments and access to genetic resources, as well as the fair sharing of the benefits arising from their use" (Lévêque & Duhautois, 2006). In 2010, within the framework of the United Nations Convention on Biological Diversity in Nagoya, Japan, a Strategic Plan for Biological Diversity 2011-2020 was adopted. In it, 20 biodiversity targets called Aichi targets are established and organised into 5 strategic goals.

The integration of "biological diversity throughout government and society" (Convention on Biological Diversity & UNEP, 2010) is at the heart of the first strategic goal. The second Aichi Goal proposes to integrate biodiversity "into national and local development strategies and planning processes" and to incorporate it "into national accounts" (Convention on Biological Diversity & UNEP, 2010). In order to keep up with the evolution of society and respond to the challenges posed by climate change, the Sustainable Development Goals (SDGs) were adopted by the United Nations General Assembly in September 2015. 17 SDGs are set out in the 2030 Agenda for Sustainable Development, covering all development issues (climate, biodiversity, energy, agriculture, etc.).

Thus, SDG 15.9 (target 9), inspired by the second Aïchi Goal, deals with the integration of "the protection of ecosystems and biodiversity into national planning, development mechanisms and accounting" (United Nations, 2015). SDG 17.19 (target 19) leads to a reflection on the construction of indicators of progress in sustainable development, enriching the Gross Domestic Product (GDP) and strengthening the statistical capacities of developing countries (Babin & Weber, 2019). In this context, ENCA, developed by Jean-Louis Weber, is an approach that fits perfectly into the global political framework by responding to several Sustainable Development Goals such as the Convention on Biodiversity (SDG 15.9), the Convention on Combating Desertification and Land Degradation Neutrality (SDG 15.3) and the 2015 Paris Agreement on Climate Change... Indeed, ENCA appears to be a decision-making tool for countries in terms of environmental protection and management.

In the course of this work, it was therefore necessary to carry out a first experimentation of ENCA on the territory of the Republic of Guinea. The main accounting methods are reviewed, and the methodology of ecosystem accounting is then detailed. Finally, the first results of the application of this method in this West African territory are presented, accompanied by maps.

2. MATERIAL AND METHODS

2.1 Accounting tool

The economic performance of societies is one of the main priorities of governments worldwide. The economic activities of human societies are highly dependent on the services provided by ecosystems. Yet the "natural capital" that refers to ecosystems is not taken into account in national accounting. This "oversight" on the part of national decision-makers is one of the main factors behind the decline in biodiversity. To counteract this trend, initiatives have been launched since the end of the 20th century to develop accounting systems that combine environmental and economic dimensions. The term natural capital, at the crossroads of ecology and economics, is defined as "the natural wealth that provides society with renewable and non-renewable resources and ecosystem services" (Ten Brink, 2016).
In order to take ecosystems into account within natural capital, multiple measurement and quantification approaches are being developed. Among these tools, the Artificial Intelligence For Ecosystem Services (ARIES) developed by the University of Vermont makes it possible to map and quantify ecosystem services and their beneficiaries at the scale of a territory (IONESCU et al., 2019). Another example is the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), a suite of software models based on ecosystem services. These models are designed for different types of ecosystems (terrestrial, aquatic, coastal ...).
Governmental" natural capital accounting tools account for the variation and evolution of ecosystems at the scale of an entire territory. These integrated accounts seek to aggregate biophysical and socio-economic information in order to guide and provide a decision-making tool for public policies on ecosystems and also to inform the population on the ecosystem services provided by a territory (Feger & Mermet, 2021).
Initiated in 2003 by the feasibility study on land and ecosystem accounts conducted by the European Environment Agency (Weber & European Environment Agency, 2006), the ENCA approach developed by Jean-Louis Weber is in line with a perspective that favours the safeguarding of natural capital. The ENCA quick Start Package published by the Convention on Biological Diversity in 2014 to assist countries wishing to carry out ecosystem accounting.
In addition, the approach is recognised by the United Nations Statistical Commission as fitting within the broad ecosystem accounting framework of the System of Environmental and Economic Accounts (SEEA). ENCA is a comprehensive approach to integrating and synthesising biophysical and socio-economic data on sustainability and potential across all ecosystems (continental, coastal, natural, man-made...) in a territory or country. It aims to measure the capacity of ecosystems to provide services (ecosystem potential) both in the short term and in the future.

2.2 ENCA General methodology

This ecosystem capacity of ecosystem capital is calculated, at a given date for a defined area, based on three accounts: ecosystem carbon, water resources and ecosystem infrastructure (biodiversity and river, land infrastructure, etc.). The stocks and biophysical flows of natural capital are compared between two dates in order to better understand their evolution over time 'resulting from natural renewal and resource use flows' (Babin & Weber, 2019) (see Fig.2 below). ENCA therefore consists of an inventory and then a diagnosis of the degradation or improvement of ecosystems by establishing biophysical and ecological balances on geo-referenced land use bases.

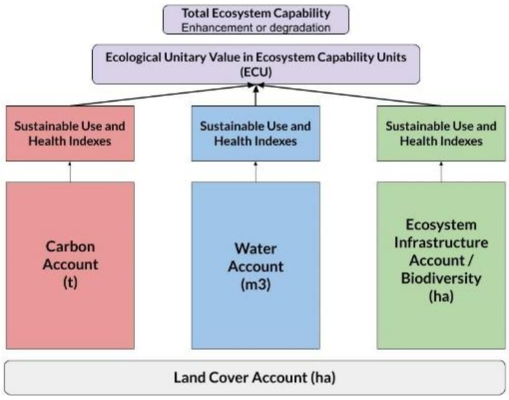

Figure 2: Overview of the Ecosystem Natural Capital Accounting (ENCA) Framework

As with carbon accounting and the CO2 equivalent unit, the aim is to establish an Ecosystem Capability Unit (ECU) to assess the sustainability of ecosystems. This ECU measure should, among other things, make it possible to measure the resource that is accessible, i.e. that can be used without causing ecosystem degradation. Subsequently, ENCA plans to transform this ECU into a monetary value on the basis of the costs of protection and restoration, among other things (Weber, 2022). The resilience of ecosystems is therefore at the heart of this approach, which is in line with a strong sustainability trend.

2.3 A robust infrastructure

The basic functional unit of ENCA is the socio-ecological landscape unit (SELU). It is a spatialized unit built around the combination of two dimensions: the dominant landscape type and the belonging to a watershed. It thus integrates an essential geographical element (the catchment area) and makes it possible to describe various variables such as the water resource and its accessibility on a territory. In order to produce it, the start-up manual of the Convention on Biological Diversity (Weber, 2014) proposes several methods. The one chosen for the Republic of Guinea consists in using the small river basins as the basic boundary of the units and assigning to them the dominant landscape type of land cover.

Figure 3 shows the socio-ecological landscape units selected for Guinea. These are based on the Hydroshed 10 (HYBAS 10) level retrieved from the HydroBASINS database which is composed of a series of vectorised polygon layers that follow the boundaries of sub-catchments of different sizes (Lehner & Grill, 2013). As illustrated in figure 4, ENCA requires a large amount of collected data (freely available online) with different resolutions (from 10-30 m to 250 m). A spatial resolution of 100 m by 100 m was chosen over the territory of the Republic of Guinea.

As a result, all geographic data are resampled to a 1 ha grid corresponding to the project grid. A common projection system is also chosen for the project, which may lead to a reprojection of some geographical data. SAGA software (Conrad et al., 2015) is used to carry out most of the ENCA process.

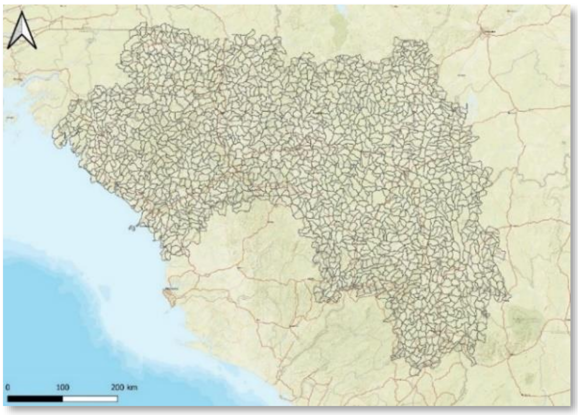

Figure 3: SELU cover the Republic of Guinea (HydroBASINS, Lehner & Grill, 2013)

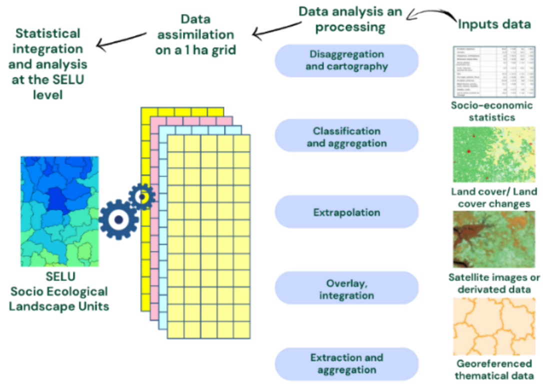

Figure 4: ENCA data model (based on the schema from Babin & Weber, 2019)

ENCA is produced from various types of national and international data. Geographic reference layers (administrative boundaries, road networks, etc.) are easily accessible online via national mapping agencies or ministries, such as those in charge of spatial planning (Weber, 2014).
Examples include watershed data available in HydroBASINS or river maps obtained from WWF-HydroSHEDS/FAO-AQUASTAT sources. Socio-economic statistical data are used in the calculation of ENCA, notably national agricultural statistics (FAOSTAT). Thus, apart from the land use maps produced by IGN FI, all the data used come from global and national open access databases.
Depending on the availability of the data, the scale of the information is adapted. Thus, for local applications, more precise monitoring data or even field observation data can be integrated to enrich the calculation of the accounts. If the data is not available on a local/regional scale, the use of national and international databases is preferred. The latter are constantly being improved and updates are to be expected over time, particularly with the availability of regularly updated high-resolution satellite images (Sentinel, Landsat 8, SPOT, etc.) and the development of more efficient monitoring systems.

2.4 Land accounts: the foundation for the account

In the ENCA system, land cover data are central, as they reflect biophysical characteristics (vegetation cover, density, height...) and land use. According to the FAO, land cover indicates the physical cover of the land such as forests and wetlands. Land use indicates the use of the land cover by humans activities (such as crops or fallow land).
Within the framework of the Guinea agro-ecological zoning project, land use maps are produced based on the CORINE Land Cover nomenclature (Jaffrain, in Feranec, 2016) and integrating modifications linked to regional specificities, notably by relying on the Yangambi classification (Aubréville, 1957). Two land coverages were carried out by remote sensing and photointerpretation for the years 2005 and 2015. SPOT 4/5 and SPOT 6/7 satellite data were used for 2005 and 2015, respectively, over the entire territory of Guinea (Jaffrain et al., 2021).

The land account based on information from the land cover databases provides a first assessment of land cover changes over a period of time. It is the basic account required for the construction of the ENCA. Based on the gains and losses of areas (in ha) between two dates, it first allows the establishment of a matrix of changes in terms of land cover classes. This matrix is produced from the SAGA GIS software.
The interpretation of land cover classification changes allows the identification of the processes at their origin and thus to group them into fluxes. A land cover flux is thus 'a grouping of changes of the same nature' (Jaffrain et al., 2021) which allows a better understanding of the changes that have occurred by integrating information on the land cover prior to the change. These main flows can then be detailed at finer sub-levels according to the specificities of the regional context. This requires a land cover classification also detailed at different levels. The realization of the land account already allows the characterization of some indicators such as deforestation, artificialisation, etc.
The ENCA method combines qualitative (e.g. ecosystem health indicators) and quantitative (e.g. soil carbon content in tonnes) measures on three basic accounting balances: biocarbon, water and ecosystem infrastructure. These accounts are built around land cover as a foundation. The combination of these accounts makes it possible to measure the total ecosystem capacity of natural capital (unit ecological value) in order to gauge its evolution (improvement or degradation) over a given territory and time interval. The integrated nature of the accounting framework makes it possible to calculate, for each of the thematic accounts, an index of sustainable use and an index of resilience or health.

2.5 Infrastructure account

According to the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment (Program), 2005), ecosystems are multifunctional, providing a range of both tangible and directly measurable services (e.g. provisioning services) and intangible services (e.g. cultural and regulatory services). In ENCA, the latter are included in the ecosystem account of functional landscapes (also called "ecosystem infrastructure") which measures the capacity of ecosystems to provide these intangible services. It includes the services of landscapes, rivers and coastal marine areas to provide services that cannot be directly measured as physical quantities. The ecosystem infrastructure account describes changes in stocks between two dates. Its balance sheet is structured in four tables. It focuses first on a quantitative description of the extent of ecosystems with the calculation of stock, land cover in hectares, and a balance of rivers in terms of linear lengths.
The potential of the ecosystem infrastructure to provide services is measured by a combination of several types of environmental indicators. On the one hand, indicators on the biophysical characteristics of the ecosystem infrastructure and on the other hand indicators on the health of the ecosystem.
The first type of indicator consists of the Net Ecosystem Potential of Landscapes (NEPP) and Rivers (NEP). These two composite indicators are classified and take into account an index of sustainability of terrestrial and river environments, based on land use and forest density in the case of the PENP. Combined with this, an index specifying the natural value of the territory based on the status of natural protection (wildlife reserves, national parks, etc.) extracted from national and international maps. Also taken into consideration is the degree of artificial fragmentation of the territory linked to road and rail infrastructures and dams (on rivers), which

at a certain level limits exchanges between ecosystems (reduces the movement of species and the connectivity of habitats). The PENP and PENR are finally aggregated in the total ecosystem infrastructure potential (TEIP).
In order to complete this account of the biophysical integrity of ecosystems, a table dealing with their state of health is included. This includes, among others, an index of local biodiversity integrity, the Local Biodiversity Intactness Index (LBII - GEO BON, n.d.), which estimates the proportion of biodiversity of a terrestrial environment in relation to human use.
The overall access to these functional ecosystem services is based on the proximity between the ecosystem infrastructure and people. A series of indicators (local access of the population to the EITP, access to water regulation services, etc.) is grouped together in another accounting table. These indicators combine the different potentials of the ecosystem infrastructure with demographic data (Babin & Weber, 2019).

2.6 Ecosystem carbon account

The ecosystem carbon account records carbon stocks and flows. It aims to assess the sustainable capacity of ecosystems to produce biomass (measured in biocarbon). The evolution of this biomass value is also taken into account through various biophysical processes: agriculture and crops, soil erosion, forest fires, etc. This account therefore deals with the entire carbon cycle, with the exception of fossil carbon resources. As with the ecosystem infrastructure account, each element of the carbon cycle is considered in structured tables. For the time being, only carbon stored in the biosphere has been considered. Atmospheric carbon will be considered in an additional table at a later stage.
First, carbon stocks are recorded for vegetation (living above-ground biomass), litter and roots and soil organic carbon. Forestry data from ESACCI (ESA Climate Change Initiative) and Hansen (University of Maryland) are used to estimate forest biomass at both dates.
The International Soil Reference and Information Centre (ISRIC) provides soil biocarbon data per hectare at different depths. Terrestrial animal biocarbon is also taken into account, starting with livestock (FAO data). All data produced is converted to tonnes of carbon using the equivalence of 50% biocarbon in biomass.
The account then describes biocarbon flows within ecosystems. Inputs are mainly based on net primary production (NPP) data. Biocarbon outputs include agricultural and forestry harvests (tree felling), soil erosion, losses due to land use changes (such as artificialisation), wood burning, forest fires. FAO data and national statistics are used to determine agricultural crops. Forest biomass stocks, previously calculated for carbon stocks, are used to estimate the extraction of roundwood from the forest and the residues of forestry (dead leaves, branches, bark...). In ENCA, carbon inputs are also taken into account in the "input" flows. Indeed, part of the biocarbon used by human activities returns to the ecosystem (production returns): crop residues, forestry residues, livestock manure. The carbon content of manure is estimated on the basis of livestock units (LU).
Thus, the ENCA ecosystem carbon account starts with a baseline ecosystem carbon balance (total inputs) and then records the accessible resource, i.e. the measure of ecosystem carbon that can be used in a sustainable manner.
Thereafter, the ENCA method deals with total ecosystem biocarbon use presented as the sum of total removals and indirect anthropogenic net losses of biocarbon due to land use (such as artificialisation). The accounting concludes with a table of indices of use intensities and

ecosystem health. In particular, an index of the stability of carbon pools in forest ecosystems and an index of soil resistance to erosion are calculated in the implementation done on the Republic of Guinea.

2.7 Water accounts

Water accounts (especially in the form of water balance) are commonly used in hydrology and agronomy around the world. As early as the 1980s, accounts of water quantities per catchment area were produced in France and Spain, taking into account both the volume and the quality of the water. These experiences allow the CSEE to integrate, in 2007, a sub-system of economic and environmental water accounting focusing on the use of water by the economy. In ENCA, the objective is to diagnose the components of the ecosystem and thus to assess the impact of a degradation of the water resource on the whole ecosystem. The ecosystem water account is therefore an extension to the CESG water accounts (Weber, 2014).

The ENCA water account addresses all the interactions and exchanges of the water cycle in a territory by recording the different stocks and flows. The hydrological system is treated as a whole as well as the flows of water use by human activities. To begin with, the basic ecosystem water balance records the water stocks of lakes, rivers, soil and vegetation. In the infrastructure account, rivers are treated only in terms of their accessibility through the Weighted River Accessibility Index (WRAI). However, in both the infrastructure and water accounts, rivers are calculated in terms of their potential, not just their volume of water. The River Measurement Unit (RMU) allows for the length as well as the flow of rivers. A single unit of flow can only provide information at a single point on the river, whereas a river is a continuum of points. The concept of a "standardized river-kilometer" was suggested (Heldal & Østdahl, 1984).

It is defined as a 1 km long stretch of watercourse (river, stream) that has a flow of 1 m^3/s at any point along its course. The basic balance then describes the inflow and outflow of rivers and groundwater following the series "precipitation, evapotranspiration, infiltration and runoff" (Weber, 2021).

Data are mainly taken from global meteorological databases (such as WorldClim, n.d.) but local monitoring stations can also be used. Natural inflows and outflows from HYBAS 10 catchments (on which the PESU is based) are measured, as well as water flows related to irrigation and other uses (hydropower dams, cooling water, etc.), based on national statistical data where available. The water use account summarises all recorded water uses. In order to assess the sustainability of the water resource, it is important to know the accessible water resource, i.e. the water whose use by humans does not endanger the provision of the service by the ecosystem. One of the final calculations in the water accounts is the net accessible water surplus balance, which describes the exploitable water resource, taking into account potential limitations on use (Weber, 2014). Finally, as with the other accounts, the water accounts end with a table on the intensity of use index, which specifies the degradation (below 1) or not of ecosystems. It is defined by the ratio of the exploitable water resource of the ecosystem to the total water use. In addition to this, a composite indicator on the change in ecosystem water health (including biochemical water quality) is calculated (Babin & Weber, 2019).

At the end of each account (water, carbon, infrastructure) the internal ecological unit value per PESU is calculated by combining these two indicators, a health status indicator and a change indicator. This value calculated for each ecosystem component reflects its integrity, health and resilience.

3. RESULTS

As explained above, the years 2005 and 2015, for which land cover data are available, were selected for the implementation of the ENCA for the Republic of Guinea. All indicators were therefore calculated for both dates. For the sake of simplicity, only a few relevant and representative indicators for the territory dealing with 2015 data appear in this section.

3.1 Some indicators for the infrastructure account

The Net Ecosystem Potential of Landscapes (NEPP) is composed of the Green Background Landscape Index (GBLI). This estimates the naturally sustainable biomass of various land cover types. For example, natural forests with little anthropogenic activity and wetlands have a high index, whereas a large-scale monoculture, because of its dependence on human inputs (seeds, fertilisers, etc.), has a low GBLI. In order to calculate this index, a score from 0 to 100 is assigned to the different land cover classes. To improve the GBLI, we combined it with a forest density index produced by the University of Maryland (Hansen data). By averaging these two indices (Fig.5), a synthetic index is obtained that is more representative of changes in the natural landscape and takes into account density variations within classes (especially in mixed landscapes).

The High Nature Value Landscape Index (HVNP) is based on maps of protected areas. The aim is to get an indication of the natural conservation value of the area concerned. Indeed, the index should reflect the level of protection of the area. Similarly, where an area has more than one type of protection, it is assumed that it has a higher value and therefore the protections add up. An area that is not protected or not designated for its high nature value has a value of 1.

In this way, one level of protection provides a score of 2, and so on. As illustrated in figure 6, in the case of Guinea, there are 3 levels of protection:

- Level 1: Unprotected areas
- Level 2: Sacred forests; Wildlife reserves
- Level 3: Classified forests; Strict reserves, National parks

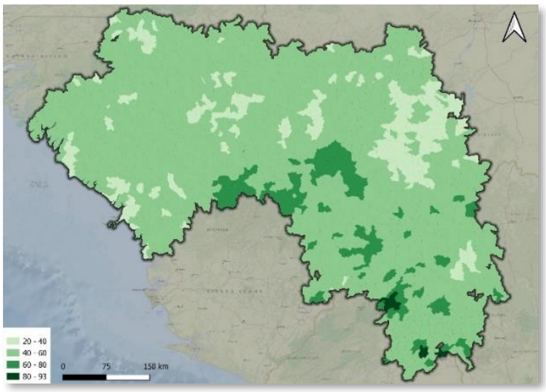

Figure 5: Green background landscape Indicator (GBLI) by SELU - 2005

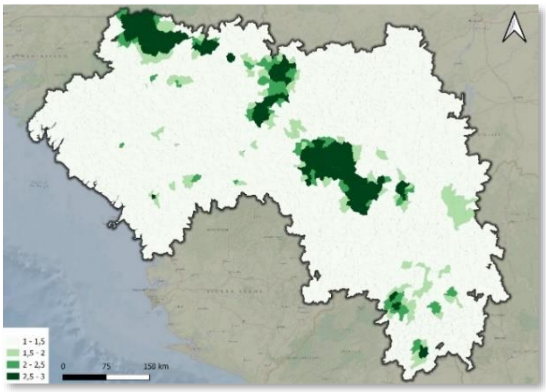

Figure 6: High Nature Value Landscape Indicator (HVNP) by SELU - 2005

According to the maps produced, Forest Guinea, a natural region in the south-east of the country, has a high green landscape background index. This could be correlated with the existence of several protection zones. However, this correlation between the GBLI and HVNP indices does not necessarily hold true for the whole country.

In ENCA, the landscape fragmentation index is used to adjust the green and high nature value landscape fund indices by taking into account the barrier effects that can limit interactions between ecosystems. Produced from maps of the main road and rail networks, it represents the "strong" fragmentation of the landscape, i.e. that which induces significant negative effects (isolation of populations, disruption of trophic chains, etc.) on the ecosystems. Thus, the landscape fragmentation index reflects the degree of fragmentation of natural (non-artificial) land cover areas. An unfragmented landscape unit (SELU) has a value of 1. The lower the mesh value, the more fragmented the natural areas within the unit are. On the map below (Fig.7), a low mesh size value and therefore a high fragmentation index (red on the map) can be observed in PSUs with dense transport infrastructures, such as the capital, Conakry.

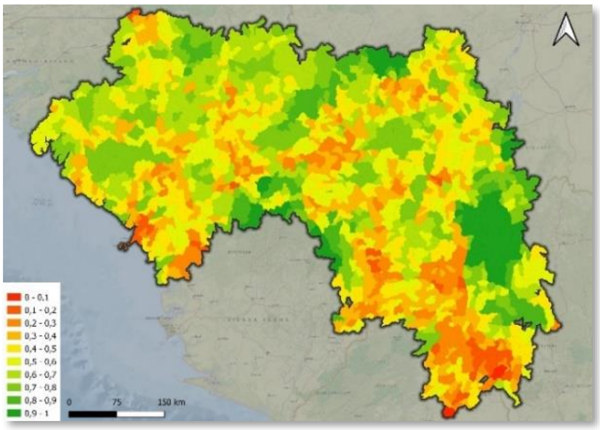

Figure 7: Landscape Fragmentation Indicator, by SELU – data in 2005

3.2 Some indicators of carbon accounts

The main causes of variation in ecosystem carbon stocks are variations in above-ground biomass stocks (living biomass and litter, dead wood) and soil organic carbon (also includes living roots, litter and dead wood). As illustrated in figure 8, in the Republic of Guinea, the levels of tree biomass stocks are particularly high in the natural region of Guinee forestiere.

Up to 200 t/ha of tree biomass are observed in the classified forest of the Massif de Ziama, designated as a biosphere reserve in 1980 by UNESCO (Le massif de Ziama: vestige de la diminution de l'écosystème forestier de Haute-Guinée | Afrique occidentale, n.d.).

From this biomass value in tons is estimated the biocarbon stock (Fig.9) using the ratio of ½ of biocarbon in the biomass.

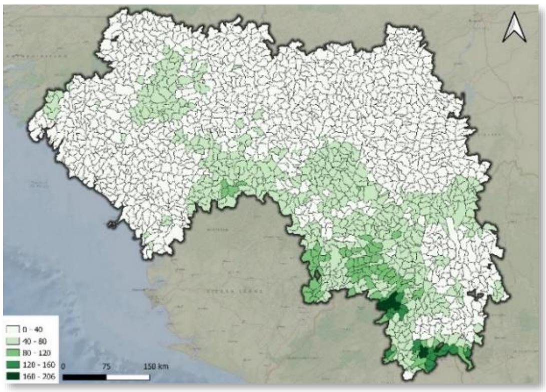

Figure 8: Living above-ground biomass in 2015 (t/ha)

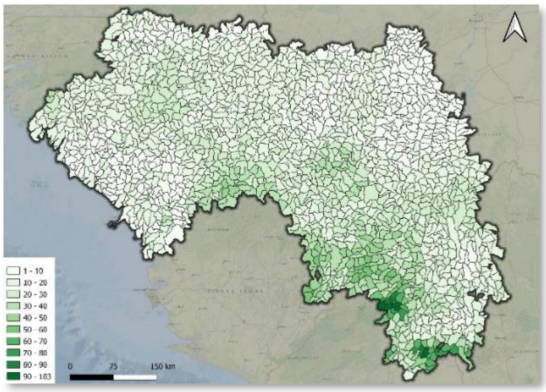

Figure 9: Biocarbon stock in biomass in 2015 (t/ha)

Based on data from the International Soil Reference and Information Centre (ISRIC), the soil organic carbon stock is essentially the result of residues of plant and animal matter, decomposed under the influence of temperature, humidity, environmental conditions, and soil micro-organisms.

Soil organic carbon is heterogeneously distributed over the Guinean territory. By cross-referencing this map with the land use layer, it can be seen that the coastal mangrove areas have the highest carbon rates per hectare (300 to 400t/ha). Land use changes, particularly agricultural expansion dynamics in these areas, should therefore have an impact on soil organic carbon stocks.One of the main biocarbon input streams into the system is the net primary production of Net Primary Productivity (NPP),in tons of carbon per ha, by SELU – data in 2005 (left) and 2015 (right)ecosystems, which is based on the overall dry matter productivity directly related to the growth rates of vegetation biomass. Net primary productivity is higher in 2015 compared to 2005.

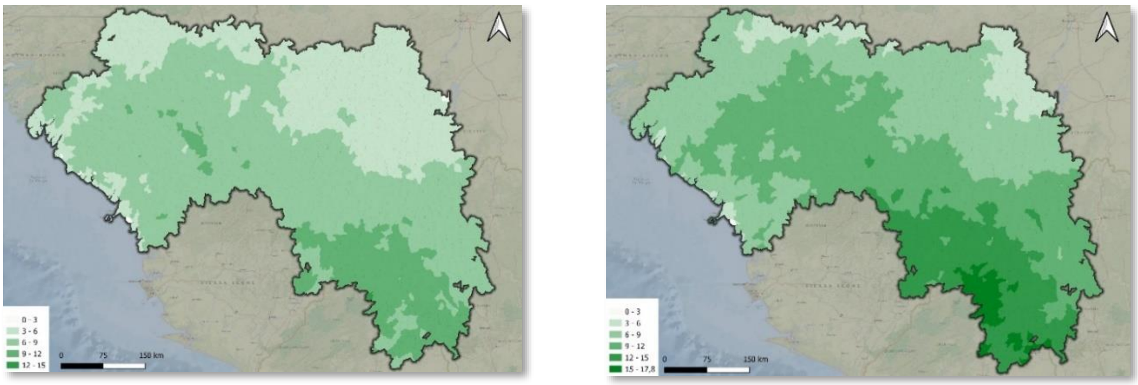

Figure 10: Net Primary Productivity, in tons of carbon per ha, by SELU – data in 2005 (left) and 2015 (right)

3.3 Some indicators of water accounts

The ENCA water account is calculated from available input data on stocks (lakes and reservoirs, rivers) and input and output flows (rainfall, evapotranspiration, irrigation abstraction).

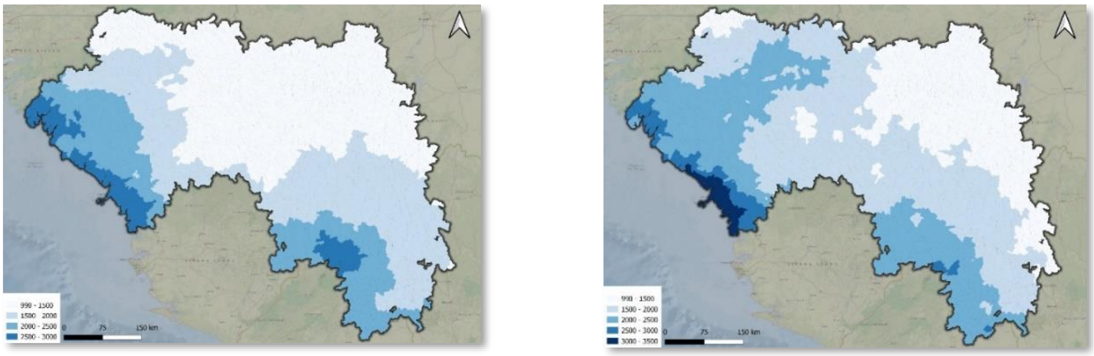

Figure 11: Average rainfall (mm) for 2005 (left) and 2015 (right)

The main input to the water account is rainfall (see Fig.11). An increase in average annual rainfall in Guinea between 2005 and 2015 was observed, which partly explains the increase in net primary productivity (see Fig. 10) observed in the area. The distribution of rainfall is heterogeneous and varies across the country. The coast is wetter, while the north-east of the country is drier. In order to smooth out interannual variations, 3-year averages were used.

3.4 Final summary of ecosystem potentials

From the table below (Table.1), we see a decrease in the total ecosystem potential at the scale of Guinea. The value went from 1.03.10-9 to 1.01.10-9. This variation can be explained by the numerous land use and land cover changes that took place in the territory between 2005 and 2015.

Table 1: Total ecosystem capability (TEC) of Guinea for the years 2005 and 2015

Potentials	Years	
	2005	**2015**
Carbon Ecosystem Capability	1,56E+08	2,03E+08
Water Ecosystem Capability	1,23E+08	1,39E+08
Ecosystem Infrastructure Capability	7,49E+08	6,67E+08
Total Ecosystem Capability (TEC)	***1,03E+09***	***1,01E+09***

4. DISCUSSION

Ecosystem-based natural capital accounting allows the evolution of the capacity of ecosystems to provide sustainable services to be assessed. This intrinsic capacity is an integral part of measuring the ecological value of each of the ecosystem components. The land cover produced by the IGN FI teams provided a perfect testing ground for the CECN at the scale of a national territory. The results of this work in Guinea already demonstrate the importance of a policy to maintain the integrity of ecosystems with regard to the degradation of the total ecosystem potential linked to that of the internal unit value of the ecosystem infrastructure.
ENCA process thus appears to be an interesting decision-making tool for countries on environmental issues.

From an economic point of view, when this total capacity reflects a degradation of the ecosystem, it leads to unpaid ecological costs produced by the perpetrator(s) of the degradation. These ecological debts could be measured to estimate the restoration value of the degraded ecosystem (Babin & Weber, 2019). In addition, this experimentation makes it possible to advance on the problems of implementing such a method in the Republic of Guinea. As the ENCA method depends on the data used, the latter play an essential role in the smooth running of the method. The quality and availability of the data for the periods studied (2005 and 2015) sometimes raise difficulties. Indeed, some data, such as the OpenStreetMap road network map, are too heterogeneous and/or undated, making the resulting indicator (of landscape fragmentation) less representative of the reality on the ground and more static (available only for one date).

The ENCA protocol is currently being improved, in particular to better integrate the morphology of the territory and the relief in the definition of socio-ecological landscape units (SELU), or to better take into account marine coastal ecosystems in the accounts.

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