INDIAN OCEAN COMMISSION

EXPERIMENTAL ECOSYSTEMS NATURAL CAPITAL ACCOUNTS

MAURITIUS CASE STUDY

Methodology and preliminary results 2000 - 2010

June 2014

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ISLANDS
STATISTICS MAURITIUS
Project funded by the European Union

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Executive Summary

The United Nations Statistical Commission (UNSC) endorsed the System of Environmental-Economic Accounting – Central Framework (SEEA-CF) and the System of Environmental-Economic Accounting - Experimental Ecosystem Accounts (SEEA-EEA) in February 2013. Although insufficient experience exists to date in the field of ecosystem accounting to adopt international statistical standards at the level of the System of National Accounts 2008 (2008 SNA) or the SEEA Central Framework (SEEA CF2012), the SEEA-EEA presents a conceptual framework that can guide countries with a desire to progress in this domain.

Ecosystem accounting experiments are currently being undertaken in Europe (projects carried out by the European Environment Agency and the Joint Research Centre of the European Commission in 28 countries), Australia, and Canada, and are being tested in various projects in several other places.

One of the reasons behind the UNSC's decision is to meet the recurrent demand for accounts of natural capital and ecosystem services, which have been reiterated in recent years in global initiatives such as, The Economics of Ecosystems and Biodiversity (TEEB), launched by the G8 in Potsdam 2008 and taken up by UNEP, the World Bank's Wealth Accounting and Valuation of Ecosystem Services (WAVES), and last but not least, the 2010 Aichi-Nagoya Strategy adopted by the Parties of the Convention on Biological Diversity (CBD), which states that ecosystem and 'biodiversity values should be incorporated in national accounts' by 2020.

Because ecosystem resilience is a central component of sustainable development and adaptability to climate change, the Government of Mauritius and the Indian Ocean Commission (IOC) decided to launch an experiment on ecosystem natural capital accounting within the context of the Small Island Developing States, Mauritius Strategy project in the Eastern and Southern Africa and Indian Ocean (ESA-IO) region.

Limited by time, the Mauritius case study is aimed at checking the feasibility of ecosystems/natural capital accounting systems using data currently available in Mauritius and assessing initial outcomes in terms of statistical quality and policy relevance.

Steered by Statistics Mauritius (SM) under the technical assistance of the IOC's ISLANDS project, this case study involved a wide variety of stakeholders and information providers. The study's successful outcomes are due, for the most part, to the positive contributions, advice and expertise from the various institutions that were asked for data in their respective domains, as well as SM's capacity to conduct extensive data collection.

Main results

Beyond the proof of concept that has been achieved by producing a first set of accounts for 2010 and some elements for 2000, the initial results highlight ecosystem potential to deliver services, actual use of these systems and in several places, degradation, mainly due to land conversion. However, it should be clearly noted that the results produced are provisional and require further analysis, revision and validation. With this in mind, this document presents an overview of the first SEEA-Experimental Ecosystem Accounts: Natural Capital Accounts of Mauritius.

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Acronyms and abbreviations

ABS	Access and Benefit Sharing
BOD	Biochemical Oxygen Demand
BPoA	Barbados Plan of Action
BSU	Basic Statistical Units
CBA	Cost Benefit Analysis
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CH_4	Methane
CICES	Common International Classification of Ecosystem Services
CO_{2e}	Carbon dioxide equivalent
CoP	Conference of Parties
ECA	Ecosystem Capital Accounts
ECU	Ecosystem Capability Unit
EEA	European Environment Agency
ENCA	Ecosystem Natural Capital Accounts
ESA	Environmentally Sensitive Areas
ESA-IO	Eastern and Southern Africa and Indian Ocean
ET(a)	Evapotranspiration (actual)
FAO	(United Nations) Food and Agricultural Organization
GBLI	Green Background Landscape Index
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIN	Green Infrastructure Neighbourhood
GIS	Geographical Information System
IRWS	International Recommendations for Water Statistics
IOC	Indian Ocean Commission
IPCC	Intergovernmental Panel on Climate Change
LCEU	Land Cover Ecosystem Units
LULUCF	Land use, Land-use Change and Forestry
MCU	Marine Coastal Units
MS	Mauritius Strategy
nLEP	Net Landscape Ecosystem Portal
NPP	Net Primary Production
REDD	Reduced Emissions from Deforestation and Degradation
SEEA	System of Environmental-Economic Accounts
SELU	Socio-ecological Landscape Units
SIDS	Small Island Developing States
SM	Statistics Mauritius
SNA	System of National Accounts

SRU	Standard River Units
TECC	Total Ecosystem Capital Capability
TEEB	The Economics of Ecosystems and Biodiversity
TOE	Tonnes of Oil Equivalent
UNEP	United Nations Environment Programme
UNSC	United Nations Statistical Commission
UNSD	United Nations Statistical Division
UNU	United Nations University
VOC	Volatile Organic Compound
WAVES	Wealth Accounting and Valuation of Ecosystem Services

1. Introduction

The production of Ecosystem Natural Capital Accounts for Mauritius, covering the period 2000 to 2010, has been undertaken within the national context of the implementation of sustainable development policies illustrated by the 'Maurice, Ile Durable' project and within the international context, in close relation to the 2005 'Mauritius Strategy' for the further achievement of the Barbados Programme of Action (BPoA) for the Sustainable Development of Small Island Developing States (SIDS).

Very few ecosystem assessments have been carried out in Mauritius, therefore the level of ecosystem (or natural capital) deterioration and/or enhancement is relatively unknown. This lack of quantitative assessment, along with increasing demand for information on environmental sustainability has led to this initiative to develop accounts for the ecosystem, in line with projects such as, Maurice Ile Durable. Maurice Ile Durable has a policy "to conserve the natural assets of the nation by adopting the ecosystem approach",[1] and the requirements of internalizing the value of ecosystem services in national accounts under Target 2 of the 2010 Aichi Strategy adopted by the Parties of the Convention on Biological Diversity (CBD). In particular, Target 2 of the Aichi Biodiversity Targets states:[2]

> "By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems."

This need for accounts has also been felt internationally through initiatives such as the Millennium Ecosystem Assessment, The Economics of Ecosystems and Biodiversity (TEEB), the Stiglitz-Sen Fitoussi Report, the World Bank's WAVES project and the Convention on Biological Diversity Strategic Plan 2011-2020, which are all within the purview of ecosystem accounts.

At the Rio Earth Summit in 1992, environmental accounts were proposed as a way of integrating the environment in decision-making (United Nations 1993). As a result, a handbook for integrated environmental and economic accounting was published (SEEA 1993). Updated in 2003 and 2012, the handbook forms the basis of the international System of Environmental-Economic Accounts (SEEA), which employs accounting concepts and structures compatible with the System of National Accounts (SNA). This system enables the stocks and flows of environmental assets (natural resources, land and ecosystems) to be represented in physical as well as financial measures.

In 2012, the United Nations Statistical Commission (UNSC) adopted the System of Environmental-Economic Accounting Central Framework (SEEA CF) as an international statistical standard with the demand for a second volume aimed at proposing recommendations for experimental ecosystem accounts.[3] The purpose of such accounts is to assess ecosystem extent and condition and their possible degradation or enhancement as a result of human activities. The production of experimental ecosystem accounts aims to provide a better understanding of the condition and sustainability of market and non-market goods and services made available by healthy ecosystems.

[1] ROM. (2013). *Maurice Ile Durable: Policy, Strategy and Action Plan*, Ministry of Environment and Sustainable Development, Port Louis, pg. 39.
[2] See http://www.cbd.int/sp/targets/ - accessed 16 May 2014.
[3] The SEEA documents can be downloaded from http://unstats.un.org/unsd/envaccounting/pubs.asp

The present report takes place in the experimentation process of the ecosystem accounts. It learns from other experiences such as projects in Europe led by the European Environment Agency (EEA).

It relies as well on previous environmental accounts and assessments in Mauritius, such as the water accounts (SEEA-Water) and experience gained in monitoring climate change variables and biodiversity.

It is important to state clearly at this stage that this project was experimental and was aimed at delivering a proof of concept regarding the accounting framework and demonstration of its feasibility in a short period of time, using existing data. The following chapters eloquently show the relevance of the approach and present initial results based on processing the large amount of data and statistics made available for the project. However, it should be noted that further validation of these results is necessary if statistical and scientific quality standards are to be met. The application was made possible thanks to the cooperation of many organisations in Mauritius and the capacity of Statistics Mauritius to collect a large amount of data across a variety of areas. The intrinsic quality of these data is good enough but accounting is above all a matter of integration. It requires common formats and similar levels of data completeness. It was possible to put together a large amount of data for 2010, however gaps still exist. Missing data had to be estimated and these estimates need be reviewed by experts and scientists and revised in due course.

When reformatting and integrating data in the ecosystem capital accounting framework, uncertainties were detected regarding for example, the exact date of a specific sugar cane map or the exact date or degree of consistency between "old" and "new" urban maps. As a consequence, the 2000-2010 trend analysis is more fragile and incomplete than the overall picture for 2010.

Operational ecosystem capital accounts need further adjustment and require additional work. Because ecosystem accounts refer to spatially explicit units, it is clear that there is a need for diachronic monitoring of land cover change. The land cover map produced during the course of this project was made from the best available data for 2008-2010 based on, for the most part, analysis of 2008 LAVIMS images (aerial ortho-photographs) and subsequent applications in urban, forestry and nature conservation areas. No equivalent data exists for the past, although it is well known that land cover change has been an important driver, whether in the form of urban sprawl linked to demography and tourism development or important mutations in sugar cane cultivation and industry. Producing reference land cover data with existing satellite images from 1990, 2000, etc. consistent with the 2008-2010 image (and updating it) is a priority. Another priority is to foster the involvement - beyond the supply of data - of various players in the process and implicate them in the review, validation and assessment of the accounting results.

The set of accounts in this report covers carbon/biomass, land cover and water and landscape integrity/biodiversity for 2010, with a retrospective view on 2000 whenever possible. The accounts combine data on nature and socio-economic statistics on population, housing, agriculture, and fisheries, amongst others. Because of the duration of the project, emphasis was put on the production of physical accounts, as recommended in the SEEA. The valuation of economic benefits in terms of money and costs has been left out for future developments.

The spatial dimension was fully considered in the preparation of the accounts as it is founded on basic statistical units (BSU) that were used for the calculations. The UN SEEA on experimental ecosystem accounts (SEEA-EEA) describes BSUs as small spatial areas that can be defined at multiple scales. It is suggested that BSUs should be formed by delineating tessellations (small areas e.g. 1 km^2), typically by overlaying a grid on a map of the relevant territory, but they may also be land parcels delineated by the cadastre.

At the same time, BSUs can be grouped on a spatial basis according to common characteristics (e.g. land cover types) or geographic areas (e.g. river catchments). As data are managed with Geographical Information Systems (GIS), accounting results can be reported according to various zones, in particular administrative units.

Being experimental, the SEEA-Ecosystem Accounts do not provide precise practical guidelines for data collection and processing. Such guidelines will therefore have to be defined when undertaking ecosystem experiments, as was done for the Mauritius ENCA project.

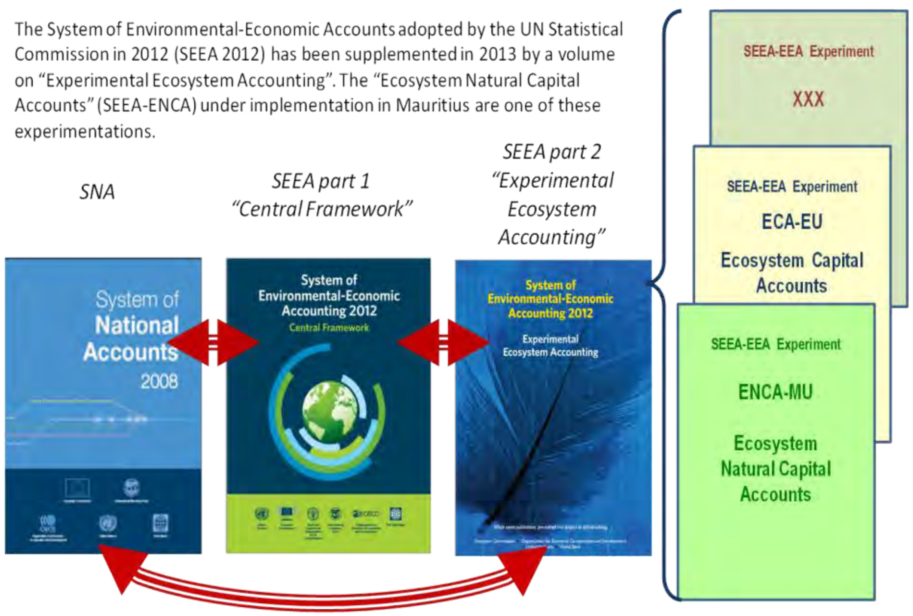
2. Putting the SEEA - Experimental Ecosystem Accounts to work

2.1 Ecosystem accounting - an overview

The impact of economic activities on the environment is generally a function of total population, per capita consumption, waste generation and the type of technologies used. The case for Mauritius may also include the effects of tourism, consumption behaviour, as well as the scale of production of goods and services. The SEEA shows how economic activities impact the environment through the consumption of resources such as energy, water and materials used in production. For instance, the consumption of energy results in atmospheric emissions whilst water use may cause water shortages and the generation of wastewater and water pollutants. The SEEA therefore shows the environment-economic relationship by relating environmental pressures in physical terms to economic drivers expressed in monetary terms. In this way it facilitates a more in-depth analysis of environmental concerns, since the different modules are broken down by sectors of the economy.

The SEEA Central Framework is an extension of the SNA to which it provides additional insights regarding materials and energy used for production, natural assets which supply them (subsoil reserves, forests, fish stocks, water bodies…), the monetary value of these assets and of their depletion, and of expenditure devoted to environmental protection and natural resource management. The consistency of the SEEA CF is given by the SNA itself, via its classifications of commodities and industries, its rules of valuation and to a large extent its definition of natural assets (economic-natural assets owned and managed in view of benefits).

Figure 1: SNA, SEEA CF, SEEA-EEA and experiments



Whilst resource depletion has a strong meaning when it comes to sustainability, it does not reflect the fact that living and cyclical natural systems are more than just stores of materials or energy, that they are renewable and that the intensity and condition of their use is vital when considering the future services that they are expected to deliver.

Depletion refers to the "weak sustainability" paradigm of maintenance of the flow of income and of the total wealth of various kinds of produced, human or natural capital that are assumed to be broadly substitutable. The fact that ecosystems are able to reproduce themselves and renew the many services they supply to the economy and to public wellbeing means they should be considered as "critical" natural capital that cannot be substituted with anything else (notably with produced capital), that they hold a potential that should be maintained. This is commonly known as "strong sustainability" and refers, in addition to a quantitative extent (surface, volume, mass, energy…), to concepts of ecosystem health, resilience, functions and the sustainable capacity to deliver services.

It should be noted that strong sustainability does not mean hard conservationism: as long as ecosystem functions can be developed or restored, as well as degraded, by human activities, mechanisms of mitigation or compensation (between ecosystems) when human needs lead to damaging ecosystems in one place.

This vision underlines the basis of ecosystem accounts whose purpose is to measure degradation (and enhancement) and human responsibility in the process. As not all aspects of ecosystems are accounted for but refer, for the most part, to their relationship with human activity, the process/system is known as ecosystem natural capital accounts (ENCA). In addition to ecosystems, natural capital also includes non-renewable subsoil assets (oil, gas, coal, minerals, etc.).

The use of the term of capital does not imply any acceptance of the standard capital model of the conventional economic theory where capital equals the net present value of expected future benefits. Capital in terms of ENCA is considered as a set of private and public, market and non-market assets, a patrimony to be forwarded from generation to generation. Such capital cannot be valued in monetary terms: only a few of its components can when they have a market value. Instead, the ecosystem capital has a specific value that can be measured in units other than money and can be used to assess our responsibility – our accountability in the use of nature.

2.2 The accounting framework

Multiple approaches for ecosystem accounting have been followed to date, exploring one or the other dimension without presenting the broader picture. As the issue is complex, there is a need for a holistic approach and a plan to avoid getting lost in the details. The approach to ecosystem capital accounts is definitely macroscopic, attempting to capture those elements that are essential to answering the central question: Has this ecosystem been degraded by human activities?

The approach is outcome oriented: beyond the minimum of data and rules (presented below), there is little standardisation of data "a priori". The broad categories of land cover are universal; the details are country or region specific. The variability of biodiversity is huge, reaching across the planet and the data even more heterogeneous; however biodiversity degradation is a clear symptom of ecosystem distress.

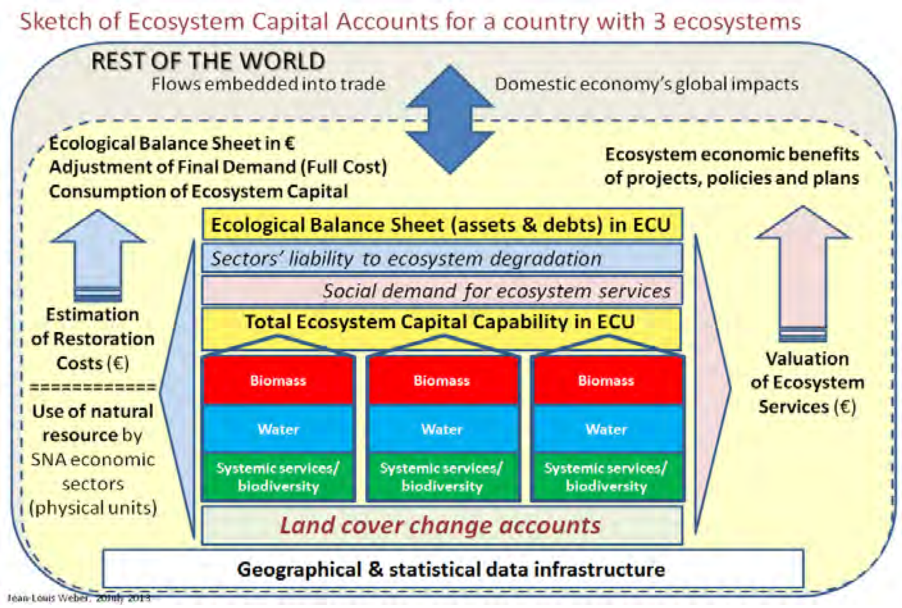
The approach is consistent with the principles of double- and quadruple-entry accounting (SNA 2008). This is indispensable when considering ecosystems and their interrelations as well as the relation between ecosystem accounts and the SNA. Partial accounts have limited use and entail the risk of sending misleading messages to decision-makers as only one aspect is considered.

Ecosystem capital accounts are integrated which means greater harmonisation of classification categories and at some stage, the choice of a common measurement unit. Monetary accounts aggregate values that are defined by economic agents - they do not aggregate quantities. When physical quantities are recorded (company inventories, employment figures in national accounts), they are in the form of specific tables that do not contribute to the calculation of accounting results such as profit, loss, net worth, etc. The possibility of aggregating quantities is always limited and requires the acceptance of an equivalent unit linked to the qualities attached to such quantities. For example, the total land surface of a country assumes that all types of land use have the same value. Moving away from this assumption, it is possible to attach different weights to different pieces of land (this can be seen in the landscape/biodiversity accounts presented herein, where land is weighted according to its ecological potential). ECA propose unit equivalents to aggregate ecological values linked to three main ecosystem functions: biomass, water and systems and species biodiversity. For each component, values are calculated by combining the result of quantitative balances, which fall under the SEEA Central Framework type (intensity of use of the biomass, water and biodiversity resources), and diagnosis of ecosystem health based on available indicators. Finally, the three components are averaged. In ECA, the resulting composite unit is known as the Ecosystem Capability Unit (ECU). This is used to measure changes in the quantity and quality of any kind of ecosystem. A similar procedure is used in Intergovernmental Panel on Climate Change (IPCC) accounting where global warming units are defined as CO_2 equivalents (CO_{2e}) (converted sometimes into C equivalents) and used to quantify global and national targets (caps), calculate carbon credits and debits resulting from sector activities (emissions or sequestration) and organize mitigation mechanisms (regulation of use, carbon taxes, 'cap and trade', etc.).[4]

In terms of operational messages, the measure of ecosystem degradation in integrated physical accounts can be interpreted as an ecological debt (maintenance which is not carried out) and recorded as such in a specific balance sheet. The cost of restoring degradation can be also calculated. Lastly, accounts of ecosystem services recorded in physical terms should lead to better valuations compared to what is currently being undertaken without such accounts. Figure 2 summarizes the scope of ecosystem accounts.

[4] Unit-equivalents are widely used in various domains: tonnes of oil equivalent (TOE) are used to aggregate various forms of energy; livestock units convert various stocks of sheep, goats, etc. into cow-equivalents in order to measure grazing pressure on grassland; in the same way, in material flow accounting, all materials are measured in terms of weight regardless of any other properties (utility, toxicity, etc.).

Figure 2: Scope of integrated ecosystem capital accounts



At the core of integrated ENCA are accounts for each ecosystem of biomass/bio-carbon, water and functional services related to ecosystem integrity and biodiversity. These accounts relate to statistical units that are defined by their spatial characteristics, areas or linear features (in the case of rivers). The data infrastructure of statistics and monitoring information is built up accordingly. In the case of inland ecosystems, land cover and land cover change accounts play a major role in structuring information as well as detecting the main trends.

In addition to each individual ecosystem account, a value in ecosystem capability units (ECU) is calculated: this is a composite measurement unit that is common to all ecosystems and can be aggregated.[5] These ECU measurements can then be used to establish three accounts:

- The balance sheet of ecological debits and credits;
- Social demand for ecosystem services, which is of particular importance given that systemic services are assessed indirectly in proportion to the extent and health of ecosystems as well as their actual use by people;
- Sector liability to ecosystem degradation, which encompasses both resource use, as defined in the SEEA CF, and ecosystem degradation or enhancement. This account connects economic sectors and ecosystems on a spatial basis, and thus requires resampling statistics to space. In this way, it is an important gateway between the macro approach for national accounts and the micro approach for companies, farms or local governments.

Beyond measurements in ECU, monetary valuations can be calculated on the basis of physical accounts. Firstly, the cost of restoring degraded ecosystems is assessed by reviewing unpaid costs, or capital depreciation that are not recorded in accounting books – otherwise known as 'externalities'. Such restoration costs should be added to the final demand aggregate of the national accounts so that it is measured at full cost instead of on the basis of incomplete purchaser prices as is currently done in the SNA. ENCA restoration costs can be assessed based on the statistics of actual costs calculated by agronomists, foresters, water agencies for restoration programmes, as well as by calculating the opportunity costs of alleviating pressures on ecosystems by rotating crops or setting land aside to allow ecosystems time to recover.

Another type of valuation relates to the services supplied by ecosystems. Certain components of ecosystems are used for production and therefore have a market-attributed value: a joint economy-ecosystem value. It could prove interesting to separate these two components, using for example, econometric models. Other ecosystem services have little or no value because their legitimate owners are not in a position to negotiate the rent attached to them. A typical example of this is what is known as bio prospecting, where pharmaceutical companies use natural molecules from wild ecosystems without payment. Cases such as this have been addressed in the Access and Benefit Sharing Protocol of the CBD negotiated in the Aichi-Nagoya Conference of Parties (CoP) 10 in 2010. Finally, many ecosystem services are public goods that are not valued by the market. Therefore, there are no clear property rights or transaction costs.

[5] More on ECU principles, calculations and applications can be found in: *Mise en place expérimentale de comptes du capital-écosystème en Europe, l'enregistrement des dettes et crédits écologiques dans les comptes nationaux: possibilités ouvertes par le développement des comptes du capital-écosystème, Jean-Louis Weber, AEE, 14^e colloque de l'Association de Comptabilité Nationale, 6, 7 et 8 juin 2012 (FR)*
http://www.insee.fr/fr/insee-statistique-publique/colloques/acn/pdf14/acn14-session5-3-texte.pdf

Within the context of welfare economics, the value of such services can be calculated by different methods, which have been studied over the course of multiple research initiatives such as TEEB, WAVES (World Bank) or UNEP's Valuation & Accounting of Natural Capital for Green Economy (VANTAGE) programme. These methods are based on services, issues and purposes of valuation based on shadow prices calculated from replacement costs, production costs, transport costs, hedonic prices and contingent valuation (sampling survey where individuals are asked to express their preferences). Once services are valued, additional calculations of capital value can be carried out with reference to standard economic models with a view to ultimately calculating specific aggregates such as total wealth (World Bank) or inclusive wealth (UNEP/UNU).

This report focuses on accounts in physical units and does not cover the valuation of ecosystem services, however, two relevant points should be highlighted here. The first point being that valuation methods have proved feasible in the context of cost benefit analysis (CBA), particularly for projects, specific sectors or areas where terms of analysis can be safely established. Yet, the aggregation of CBA results in national accounts remains highly controversial because of the heterogeneity of pricing systems and risks of double counting. The second point relates to the fact that the SNA is not only made up of core accounts connected by double-entry accounting rules but also includes so-called functional analyses aimed at providing comprehensive and detailed accounts of social functions such as education, health, social security, research and development or environmental protection.

Functional accounts are commonly known as "satellite accounts" as opposed to "core accounts". Satellite accounts allow for specific aggregate calculations (e.g. national expenditure in a certain domain) and can be compared between themselves and SNA aggregates, e.g. GDP. However, the different accounts cannot be added together, unlike those of the various sectors, industries and commodities in core accounts. The reason for this is that any given expenditure can be recorded in several accounts. For example, research on environmental diseases can be recorded in the accounts for the environment, health, research and even education, if carried out by a university laboratory. If it is accepted that the valuation of ecosystem services falls under the framework of functional accounts, theoretical issues such as inconsistent pricing, double counts (when services are private as well as public) and incompleteness are of little importance. Figures can still be compared (in the spirit of CBA) even though they cannot be fully aggregated.

That is to say that ecosystem services accounts are satellite accounts of core accounts recording basic quantities (stock and flows) and health variables (robustness, resilience, integrity, etc. synthesized in an aggregate of potential or capacity, etc.). The use of stocks and flows to track changes in biophysical quantities is squarely compatible with the eco-systemic approach that is promoted by the regional project, IOC-ISLANDS, to build the resilience of island states/SIDS in the face of shocks (internal and external) using system dynamics modeling.[6]

[6] Deenapanray PNK, Bassi AM. (2014). The experience of ISLANDS in deploying system dynamics modeling as an integrated planning tool. *Natural Resources Forum* 38: 67-81.

ENCA core accounts are ecosystem accounts that are defined as biophysical entities and, therefore, do not detail all ecosystem services, but only bio-carbon and freshwater accounts. Intangible ecosystem services (regulations, recreation, etc.) are assessed indirectly through the good state of ecosystems and are recorded more explicitly in functional accounts where ecosystem potential for delivering such services is confronted by social demand (protection from floods, free amenities related to nature, commercial tourism, etc.).

2.3 A work plan for producing ecosystem accounts

ENCA can be produced by applying the building blocks or steps that are summarised in the box below.

Ecosystem natural capital accounts are produced by undertaking the following steps:

i. **Data collection and pre-processing:**
   - Geographical information infrastructure: administrative boundaries (country, districts, municipalities), watershed delineation, relief, rivers, roads, etc.
   - Thematic geographical layers: land cover, urban areas, forests, high natural value areas, soils, aquifers, etc.*
   - In situ monitoring data: species biodiversity, pollution, weather, etc.
   - Earth observation by satellite data: vegetation index, Net Primary Production, evapotranspiration, etc.
   - Socio-economic statistics: population, agriculture, forestry and fisheries, water use (municipal use, irrigation…)

ii. **Definition of statistical units for accounting** [1] **- general principles:**
   - Ecosystem units
   - Ecosystem services

iii. **Land cover maps and accounts**

iv. **Definition of statistical units for accounting** [2] **- implementation with land cover and other geographical data**

v. **Biomass carbon accounts**

vi. **Water accounts**

vii. **Ecosystem ecological integrity and functional services accounts**

viii. **Synthesis of v, vi and vii, calculation of ECU values**

ix. **Functional analysis of ecosystem services demand/ECU**

x. **Functional analysis of sector liability to ecosystem degradation/ECU**

xi. **Establishment of the ecological balance sheet/ECU per ecosystem and sector**

xii. **Valuation of selected ecosystem services**

xiii. **Estimation of ecosystem restoration costs**

** Note that in the case of Mauritius no land cover maps could be used for accounting purposes. A map had to be produced during the initial stage of the project.*

The ENCA for the Mauritius case study covers steps i to viii shown above.

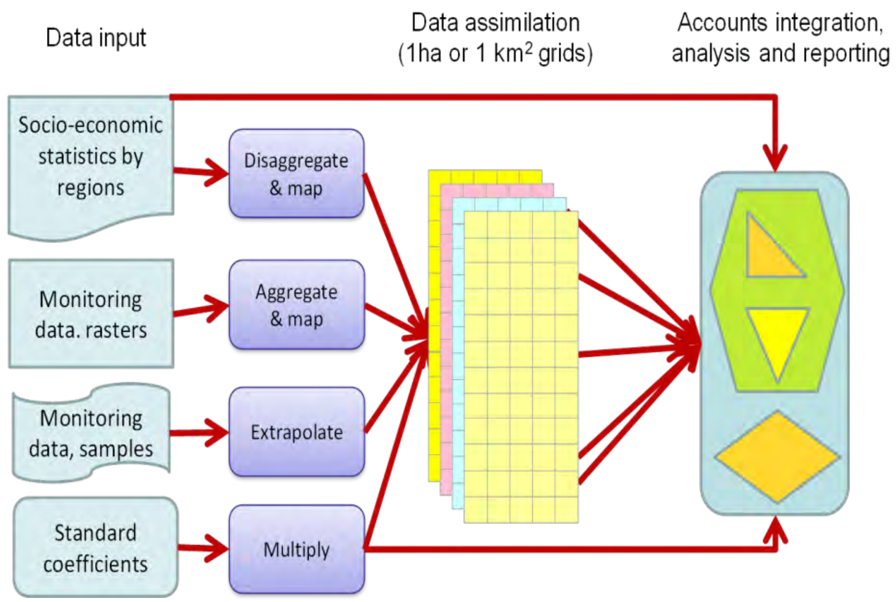
i. Data collection and pre-processing

Data collection was carried out in the first phase of the Mauritius ENCA project. Despite room for improvement regarding data collection for land cover change, meteorology, the sugar cane industry and the marine environment, an abundance of data was collected.

This data generated an important workload for pre-processing with regard to completeness, harmonisation of geographical projections, and consistency between geographical and statistical breakdowns, amongst others. It should be noted that investment in pre-processing information results in a consistent set of data, which can be reused in the continuation of this project or in the context of other research.

The main data flows and procedures to produce ecosystem accounts are illustrated in Figure 3 below. The multiplicity of data sources and input formats requires substantial harmonization and data assimilation. Converting data into a unique standard regular grid proves to be an efficient solution in most cases. Exceptions include linear features such as rivers, which first have to be analyzed in the context of river basins; this does not preclude converting outcomes into the standard grid at a later stage of an account's integration.

Figure 3: Main data flows to compile ecosystem natural capital accounts



ii. Definition of statistical units for accounting - general principles

The first step in creating ecosystem accounts is the definition of the statistical units to be used. In the case of economic accounts, these units are entities such as companies, households or government bodies identified based on legal or institutional criteria: they produce goods and services labeled by the market or accomplish transactions with a clearly defined legal status. These statistical units pre-exist the compilation of accounts and just need be grouped by nature or/and activity.

As no such units currently exist for ecosystems in Mauritius, they therefore had to be defined. SEEA EEA suggests that ecosystems refer to the spatial basis of statistical units and use a hierarchy from basic statistical units to encompass more functional units. Thereafter, these recommendations need be put into a consistent operational framework. Two levels of units should be distinguished: elementary analytical units and statistical reporting units. According to the SEEA, statistical units are defined as geographical units.

Analytical units combine data, which provide information about their status and performance whilst reporting units are used for aggregations at scale that correspond with policy making (e.g. regions or countries). Indeed a range of intermediate situations exists where large analytical units can be used due to their significance (e.g. river basins where river networks connect landscape features). At the same time, it might be convenient to collect data by smaller legal units such as municipal boundaries or cadastral parcels. Lastly, a distinction has to be made between functional units that are geographical objects and grid cells or pixels, which are elements of information that can be attributed to various functional units.

In the case of ENCA Mauritius, the units can be summarised as follows:

- Grid cells (grids, raster graphics…): data from 10m x 10m grid cells at the most detailed input level magnified to 100m x 100m. Magnification of 1ha cells to 1km x 1km cells as suggested in the SEEA is not difficult but it is not practical for an island measuring only 40 x 60 km. The 1 ha grid was therefore used for ENCA data.
- Analytical units: Statistical units for accounting are defined at various levels as socio-ecological systems: Socio-ecological Landscape Units (SELU), river units and marine coastal areas units. These last two categories are not mentioned in the SEEA but were discussed during the SEEA process. In any case, they should be included in the framework.
    - SELU and Marine Coastal Units (MCU) are areas that can be mapped (land cover, seabed cover, etc.). SELU can be described as the combination of dominant land cover types within the limits of river basins. SELU can be subdivided into more homogeneous units based on land cover and renamed 'land cover ecosystem units' (e.g. forests, wetlands, agriculture areas, urban areas, etc.). Instead of river basins, MCU are framed by delimited coastal areas such as large lagoons or archipelagos of smaller lagoons. Land cover ecosystem units include coral reefs, grass and algae beds, mudflats, etc.

- River systems are defined as a hierarchical set of connected reaches within a catchment (or basin) or sub-catchment area. These reaches are measured as standardized river kilometres or standard river units (SRU) and are calculated by multiplying their length by their discharge: 1 SRU = 1km x $1m^3$/second. An example of SRU calculations can be found in the SEEA-Water manual.[7]
- Ecosystem services have not yet been given an exact definition despite all the research that has been done, including the SEEA review process where the provisional Common International Classification of Ecosystem Services (CICES) was discussed. CICES is not yet a standard and only exists in parallel to other classification references such as those of TEEB. Differences between existing classifications are minor and of little consequence as long as ecosystem services are addressed in terms of functional analysis. One point that should be made clear however is that a large proportion of ecosystem services are de facto inputs to commodities and can only be assessed as part of joint products. This is notably the case of ecosystem services embedded in goods and services linked to agriculture, forestry, fishery, water supply or tourism.

iii. Land cover maps and accounts

For inland ecosystems, land cover is the basic infrastructure used. Land cover is exhaustive and can be updated periodically using remote sensing or/and area sampling. The development of high-resolution topographic databases enables another approach to land cover mapping through the generalisation of such data sources. In fact, the advantages of the three data sources can be combined. The issue of land cover was discussed in detail during the SEEA review and lead to a harmonised position between FAO and the European Environment Agency[8], through acknowledgment of the relevance of the FAO's Land Cover Classification System v.3. This system defines strict concepts, rules for combination and outlines a process for detailing them in a logical and consistent manner, at the same time enabling them to be matched to the various users' needs. Three logical tiers were defined for ecosystem accounting: elementary objects (e.g. grass, shrubs, trees, rock, sand, water, snow-ice, etc.); land cover types (e.g. artificial areas, herbaceous crops, woody crops, tree covered areas, etc.); and sub-types (e.g. with densities, irrigation, etc.) and land cover units. The latter refers to landscape systems that can be typical spatial combinations of types in any given place such as mosaics of agriculture, pasture and natural habitats, which are considered homogeneous from a systemic analysis standpoint.

[7] http://unstats.un.org/unsd/envaccounting/seeaw/ see pp. 104
[8] http://unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue3_EEA_FAO.pdf Land cover mapping, land cover classifications and accounting units/ Land cover classification for ecosystem accounting, prepared by Antonio di Gregorio (FAO), Gabriel Jaffrain (IGN-FI) and Jean-Louis Weber (EEA), Expert Meeting on Ecosystem Accounts, 5 - 7 December 2011, London, UK.

The SEEA Central Framework presents 'land cover types' whilst the SEEA EEA, on experimental ecosystem accounts, presents a provisional classification of land cover ecosystem units (LCEU). The overall idea is to have one standard international classification made up of a maximum of 15 categories, which can be subdivided according to national or regional requirements. This classification system has to be adapted to Mauritius according to the country's specific characteristics (e.g. the importance of sugar cane) and current limitations in terms of data (Table 1).

Table 1: Classification of land cover ecosystem units

1	Urban and associated developed areas	M01	Urban areas
		M02	Transport infrastructures
2	Homogeneous herbaceous cropland	M08 (p)	Food crops
3	Agriculture plantations, permanent crops	M05	Tea
		M06	Sugar cane, rain fed
		M07	Sugar cane, irrigated
4	Agriculture associations and mosaics	M08 (p)	Food crops
5	Pastures and natural grassland	M10 (p)	Grass, shrub, other n.e.c.
6	Forest tree cover	M12	Forest
		M13	Mangrove
7	Shrub land, bush land, heath	M10 (p)	Grass, shrub, other n.e.c.
8	Sparsely vegetated areas		
9	Natural vegetation associations and mosaics		
10	Barren land	M10 (p)	Grass, shrub, other n.e.c. (mountain)
		M23	Beaches, sand
11	Permanent snow and glaciers		Non applicable
12	Open wetlands	M17	Upland marsh
		M18	Coastal marsh
13	Inland water bodies	M19	Rivers
		M20	Lakes
14	Coastal water bodies and inter-tidal areas	M22	Mudflats
		M24	Coral reef
		M25	Seagrass
		M26	Lagoon, other n.e.c.
	Sea (p.m.)		Sea (p.m)

The principles of land cover accounting are defined in an EEA report on Land Accounts for Europe 1990-2000, 2006[9] and are being implemented in Europe (34 countries) based on updates of their Corine Land Cover inventories carried out over 5 years from satellite images (Landsat, Spot and IRS). This methodology has already been successfully tested in different contexts with minor adaptations, in countries such as Burkina Faso[10].

An example of a land cover stocks and flows account based on aggregated LECU is given in Annex 1 (Table A.1).

[9] Land accounts for Europe 1990–2000, Towards integrated land and ecosystem accounting, EEA Report No 11/2006 (EN) http://www.eea.europa.eu/publications/eea_report_2006_11
[10] Comptabilité environnementale et utilisation des terres au Burkina Faso http://www.cbd.int/doc/meetings/im/rwim-wafr-01/other/rwim-wafr-01-adama-oumar-fr.pdf

iv. Biomass/bio-carbon accounts

The biomass/bio-carbon accounts aim to measure: the accessible biomass resource; its use in human activities (agriculture, forestry and fishery); the sustainability of such use taking into consideration maximum exploitable yields; and the consequences on ecosystem health in terms of soil fertility and the condition of carbon pools. The basic quantitative balance starts from Net Primary Production (NPP) which is an output of photosynthesis; in a second step the extraction of biomass via crop harvests, grazing by livestock, tree felling, fishing, etc. is analyzed. Extraction is calculated net of leftovers, manure or by-catch.

Another element of the account relates to water leakages via erosion, Volatile Organic Compound (VOC) release and animal respiration (mostly that of decomposers, which break down biomass for reuse by plants). The Net Ecosystem Carbon Balance or Net Biome Production provides a summary of the account that reflects the state of biomass, timber and soil, and fish stocks. Calculation of the accessible resource shows the amount that can be withdrawn in a sustainable manner, without depriving biodiversity of its much-needed nutrition, and without depleting stocks or degrading the ecosystem's capability to reproduce itself.

The biomass/carbon ecosystem account holds a key position in the accounting framework because it is linked to essential resource issues (energy and food, as well as fibre) and because CO_2 and CH_4 atmospheric emissions are fundamental drivers of climate change. With regard to IPCC reporting, the overlap is definitely very important and synergies exist within the accounting framework, in particular for land use, land-use change and forestry (LULUCF) and its extensions.

ENCA biomass ecosystem accounts can contribute to IPCC reporting and a joint scheme could be put in place even if differences may appear concerning priorities or emphasis on specific aspects. For example, spatial distribution is essential for ENCA accounting, whereas IPCC emphasizes in situ measurements and the use of default values combined with statistics. However, such differences are merely provisional as noted in programmes such as REED+ that require high-resolution spatial monitoring of forests to verify progress and to justify financial aid for reforestation.

In ecosystem capital accounting, accessible resources are not simply measured in terms of the maximum amount that can be harvested, such as forest yields or fish stocks, but also take into consideration qualitative aspects: forest protection (any harvesting could cause damage in this case); the age of carbon pools (e.g. of forests or fish stocks); the quality of the carbon itself and its exploitability (algae from river eutrophication or sea algae blooms are not used at present and are therefore deducted from accessible resources).

An example of a simplified ecosystem carbon account can be found in Annex 1 (Table A.2).

iv. Water ecosystem accounts

Water ecosystem accounts are a development of the SEEA-Water accounting framework and have been experimented in Mauritius. For the SEEA-Water, the starting point is the supply and use of water to/by economic sectors. As sector accounts are compiled and analyzed at the national level, the SEEA-Water, as well as the International Recommendations for Water Statistics (IRWS), suggest starting at this level.

The connection with the water assets is approximate to give an indication of the origin of supplied water, and does not really focus on the amount that can be used. It should be noted that the concept of exploitable resource use by FAO in the AQUASTAT database has not been taken into consideration by the SEEA-Water. According to the FAO approach, only regular flow (available 90% of time, based on common hydrology criterion) and a limited fraction of irregular flow (e.g. a proportion of the rainwater that may recharge aquifers or reservoirs) are exploitable.

Other restrictions to exploitability result from environmental legal constraints (e.g. the maintenance of minimum river flow to avoid surpassing the BOD threshold, ensuring sufficient water for fish, etc.) or international conventions. In the case of Mauritius, FAO-AQUASTAT estimates that the exploitable water resource represents half of the effective rainfall: this is measured by the difference between rainfall and actual evapotranspiration.

Ecosystem water accounts aim to assess stress, both terrestrial and aquatic, at the ecosystem level. The measurement of stress on water resources from human activities is therefore particularly important: for example, gains in biomass productivity should not be recorded as an enhancement if they diminish water resources in terms of quantity and/or quality. For this reason, ecosystem water accounts are established at the level of river sub-basins. An example of an ecosystem water account is given in Annex 1 (Table A.3).

Current implementation of the SEEA-Water focuses on aspects of quantity: supply and use of water by economic sectors, waste water generation and water assets. Water quality accounts are still at an early stage. Water quality is an important issue with regard to resource management and a critical issue when considering water ecosystems.[11] Water quality accounts could not be developed in this initial study in Mauritius, despite their importance for inland as well as coastal waters. If the appropriate data had been available, water quality would have been taken into account in the composite index of ecosystem health change as shown in Table 2.

[11] A recent report published by UNEP/TEEB draws attention to water quality issues in environmental accounting: Russi D. and ten Brink P. (2013). Natural Capital Accounting and Water Quality: Commitments, Benefits, Needs and Progress. A Briefing Note. The Economics of Ecosystems and Biodiversity (TEEB). http://www.teebweb.org/wp-content/uploads/2014/01/TEEB_-NaturalCapitalAccounting-andwaterQualityBriefingnote_20131.pdf

Table 2: Composite index of ecosystem health change

		Lakes & reservoirs		River systems									
		Artificial reservoirs	*Lakes*	*Rivers*	*Canals*	Glaciers, snow & ice	Ground water	*Sub-total L/S/V*	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
IV. Table of indexes of intensity of use and ecosystem health													
W7	**Net Ecosystem Accessible Water Surplus = W7a+W7b**												
W8	**Total Use of Ecosystem Water**												
W13	**Water intensity of use impact = W7/W8**												
W141	Bio-chemical quality												
W142	Nutrients excess, eutrophication												
W143	Change in biotic indexes, bio-markers												
W144	Water borne diseases												
W145	Dependency from artificial inputs												
W146	Change in intensity of water natural stress												
W147	Other…												
W14	**Composite index of change in ecosystem health**												
W15	**Water ecological internal price = AVG(W13+W14)**												

v. Ecosystem ecological integrity and functional services accounts

The purpose of this account is not to measure biodiversity, which is more or less impossible, but to establish a diagnosis based on biodiversity trends from symptoms. It is well known that data on biodiversity is often incomplete and biased towards endangered or protected species. It is also true that important expertise is available for biodiversity-related issues in scientific communities and environmental agencies. Indirect limited knowledge on habitats, based on robust observation tools, can also be used to crosscheck and enhance scattered data on species. These trends enable the accounts required for the biodiversity assessment of ecosystem extent and health to be produced.

The quantitative component of the systems and species accounts records stocks and changes in 'green infrastructure', which is made up of landscapes, hydrological systems and coastal systems.

Landscape accounts are based on land cover change and hence are purely descriptive. On this basis, landscape change accounts can be developed according to the nature value of the various land cover types. A simple weighting related to 'greenness' can be established. This type of weighting is undoubtedly arbitrary but is acceptable if it remains simple and can be modified through an informed process. As change assessment is more important than providing an absolute value for land cover, modifications of weighting have limited consequences on the final result.

In general, weighting values range from 0 to 100: 10 for urban areas; 25 for intensive agriculture; 50 for small-scale mosaic agriculture and pastures; and 100 for forests, wetlands and other natural areas. Variants that consider the likelihood and sensitivity of the outcome can also be can also be introduced at this stage such as the Green Background Landscape Index (GBLI), which expresses the vegetation potential of a territory according to land use intensity.

Greenness is important but is not sufficient to characterize the nature value of an area. Some green areas may be of limited value because they are managed – or have been managed in the past - in a detrimental manner. Conversely, in large areas under urban stress, agriculture, even if intensive, can provide refuge for some species. Therefore, the GBLI should be adjusted with an index reflecting these aspects of nature value. This can be done by looking at the importance given by the scientific community and environmental agencies to particular habitats or areas through various types of protection. Obviously, this is not a flawless concept as protection may increase due to nature's vulnerability. Land fragmentation by man-made features (infrastructure, roads, etc.) is indeed another potential measurement that reflects such vulnerability. Negative impacts of fragmentation include the barrier effect on animal circulation as well as the disturbance of plant communities. Vulnerability can be measured by taking into account the impact of roads and agglomerations of a certain size.

Micro fragmentation by small roads however, may have a different effect through the creation of ecotones, landscape features which generally host high biodiversity. An ecotones index can therefore be calculated, based on an analysis of land cover maps. Combining various indexes allows the net landscape ecological potential (nLEP) to be calculated, where net means that the initial measurement has already been adjusted. When the nLEP is calculated at different dates with a different land cover assessment but using the same coefficients, an account can be established.

Similarly, the ecological potential of rivers and coastal ecosystems can also be estimated. In the case of rivers, dams (which block the circulation of fish as well as the flow of sediment) together with river/land ecotones are key components of the index definition. For coastal ecosystems, elements included in the index relate to the extent of the various seabeds and artificial impacts on terrestrial ecotones (constructions, dykes, etc.).

In the case of systems and species biodiversity accounts, where no clear harvests or abstractions take place, an analysis of the demand is particularly important. One component results from the consumption of land cover through land use and can be measured in LEP units. A second component results from the accessibility to such services in relation to neighbourhood, as well as to various obstacles to frequentation such as distance, cost, property exclusion, etc. An initial index for human settlements, known as the Green Infrastructure Neighbourhood (GIN), based on the spatial distribution of population and the availability of 'green infrastructure' in the vicinity, can be calculated.

As ecosystem degradation can result from any change in extent, green infrastructure accounts need to be supplemented by indexes that reflect the condition and change of species biodiversity. Such indexes relate to individual species or communities, including habitats or biotopes. The purpose of such accounts is not to quantify biodiversity but to use monitoring data for the diagnosis of ecosystem health. Because of this general purpose and due to the limitations of biodiversity data previously mentioned, support from biodiversity experts is required at this stage to produce such accounts.[12]

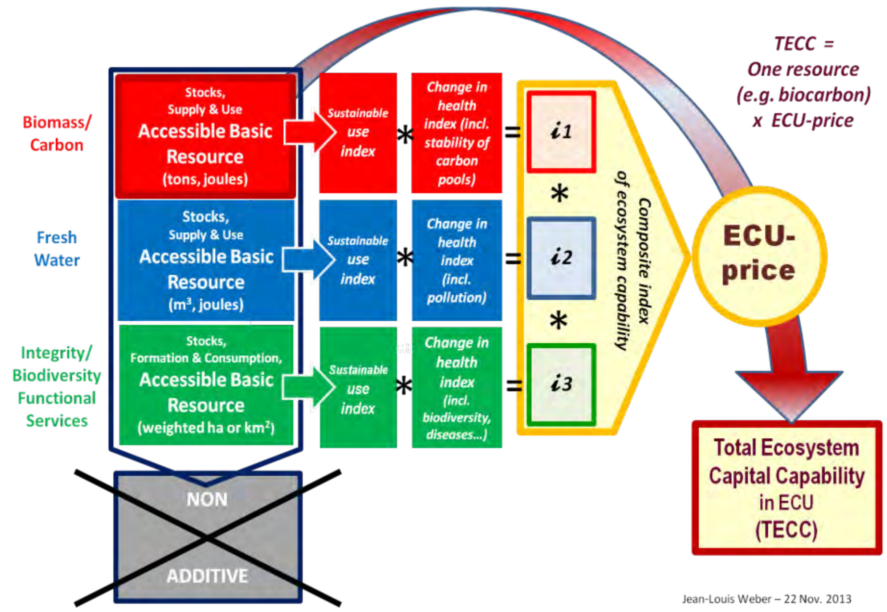
Examples of ecosystem ecological integrity and functional service accounts can be found in Annex 1 (Tables A.4 and A.5).

[12] In Europe, species biodiversity accounts are produced by Member States based on country biodiversity reports (Article 17 of the Habitats Directive). Countries asked for expert judgments on approximately 1,200 species, in 9 bio-geographical regions. A reference table has been produced showing the broad ecosystem types hosting different species. The assessment grid for each species relates to the area of repartition, coverage of this area, past population trends, future prospects, etc. Data on species have been resampled for dominant landscape types to produce two indexes related to the past and the future.

v. Synthesis of v, vi, and vii - calculation of ECU values

The calculation of ECU values is, without doubt, the easiest part of the accounting process. A simple way of doing this is to average indexes computed from the outcomes of the three basic accounts: biomass/bio-carbon, water and biodiversity. As shown in Figure 4 below, the calculation is carried out in two steps. Firstly, an index reflects the sustainability (the quantitative dimension) and change in health for each component. The three indexes (i1, i2, and i3) are averaged to calculate a composite index of ecological value, which is the equivalent of an ecological price (the ECU price). In principle, the quantity of each accessible resource can be multiplied by the ECU price to calculate the total ecosystem capital capability (TECC). However, the overwhelming importance of carbon related issues from energy and material for the economy, food security, mitigation of and adaptation to climate change, and last but not least, ecosystem renewal, suggest that TECC calculations should be based on accessible ecosystem carbon. The aim is to have one single measurement, which is sensitive to quantitative and qualitative changes as well as to what happens when the three are combined. In this way, the measurement of progress obtained in one particular dimension might be counterbalanced by deterioration of qualitative aspects in the same dimension and/or by degradation of other components.

Figure 4: Calculation of ecosystems' ecological value in ECU



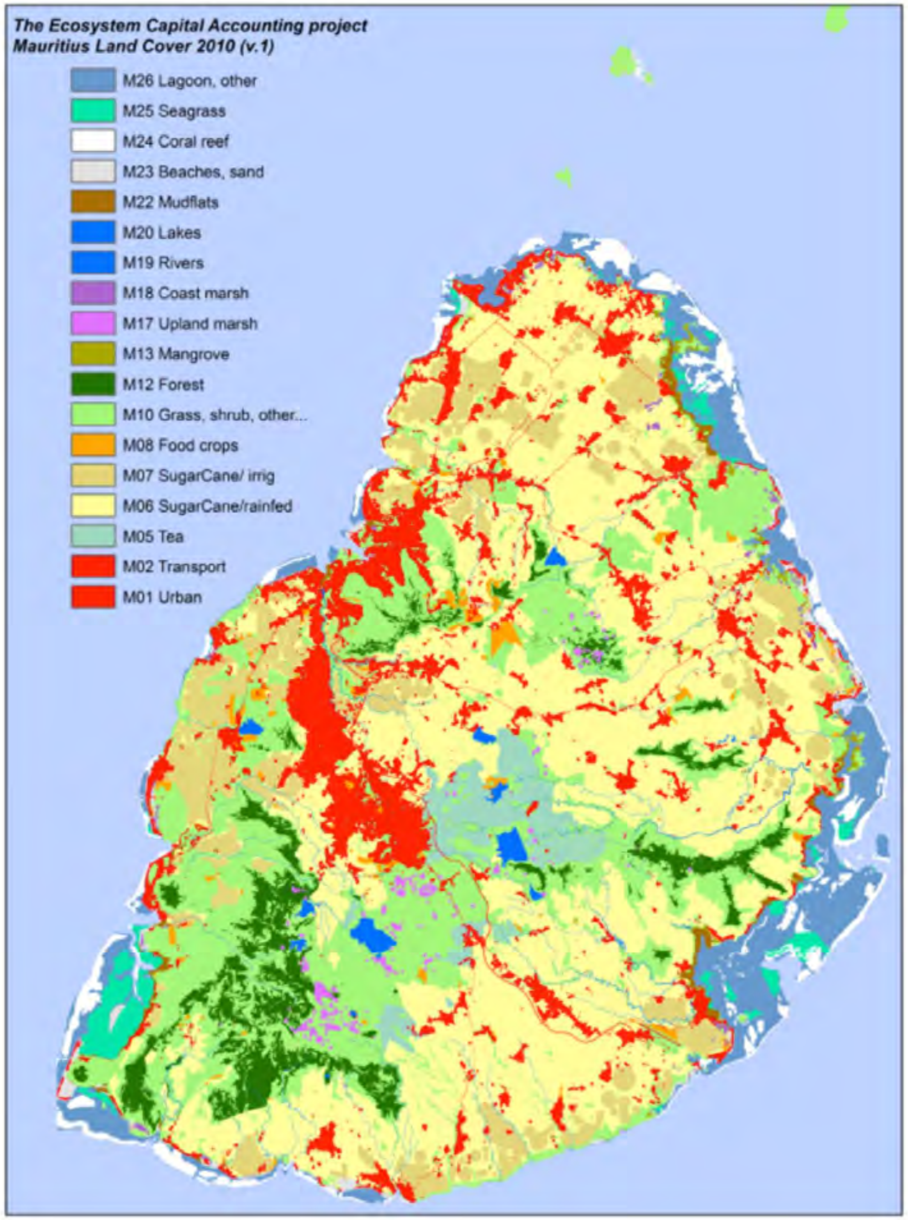
3. Natural capital accounts: Mauritius, 2000 to 2010

3.1 Land cover and changes in Mauritius

Land cover is the basic component necessary for the implementation of ecosystem accounts. As no land cover map suitable for accounting purposes was available for Mauritius, one had to be produced using existing geographical datasets for buildings, roads, forests and environmentally sensitive areas. Detailed layers were produced from photointerpretation of the LAVIMS 2008[13] high-resolution ortho-photographs. Other layers have been included to show irrigated and non-irrigated sugar cane, tea and food crops.

[13] The Land Administration, Valuation and Information Management System (LAVIMS) project was an initiative set up by the Government of Mauritius designed to modernise land administration by greatly improving access to information between different departments and creating a complete and up-to-date national valuation roll.

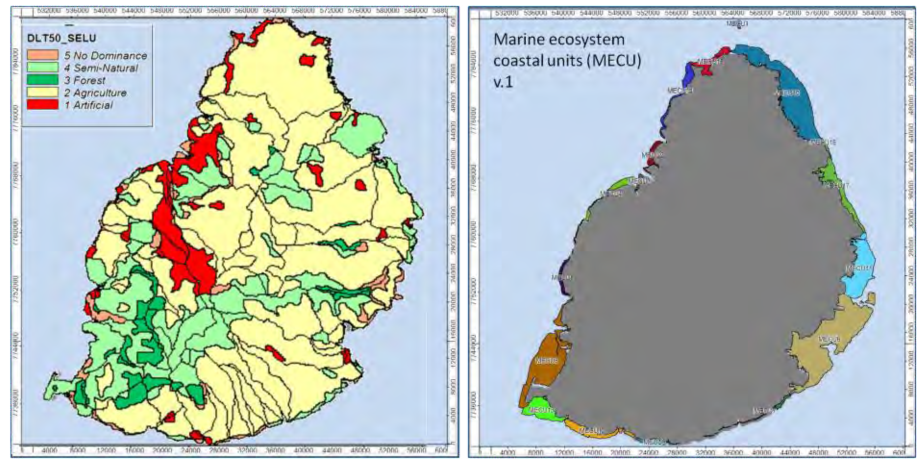
Figure 5: Mauritius land cover 2010 (ENCA version 1)



Creation of the map and directory of statistical units for accounting

The first application of the land cover map is to create a directory of statistical units for ecosystem accounting. These are known as socio-ecological landscape units (SECU) and highlight the fact that human activities are included within a particular ecosystem. In the case of marine coastal ecosystems, they are known as marine coastal units. To produce SELUs, the basic land cover map has been generalized into a map of dominant landscape types and intersected with the limits of river sub-basins. Each unit is given an ID and a code corresponding to its dominant landscape type. Figure 6 shows the map of SELUs classified by dominant land cover types, which has been used for accounting purposes. Whilst ecosystem accounts results can also be usefully reported in terms of administrative units, their analytical relevance is higher when they are based on specific statistical units such as SELU or MCU.

Figure 6: Socio-ecological landscape units and marine coastal units (ENCA version 1)



Land cover accounts

The land cover account describes changes taking place between two dates in terms of consumption of cover and the formation of new cover, for example, the conversion of agricultural land cover into shrubs or forest into agriculture, etc. Land cover flows are grouped into categories reflecting the main processes taking place: artificial development, agricultural development, internal conversions, rotations, management and alteration of forest land, restoration and development of habitats or changes of land cover due to natural or multiple causes.

In Mauritius, land use/land cover changes are more difficult to record and map, as no systemic information exists for the past. In the future, this gap could be bridged by obtaining the necessary information from a series of land cover maps produced from high-resolution satellite images and calibrated with the land cover image from 2010. This would allow for, as well as improve, several additional fields in the 2010 map such as agricultural areas, grassland and shrub land.

In the current experimental accounts, a test to account for urban sprawl could be carried out by comparing the urban database, updated by Statistics Mauritius (SM) using LAVIMS 2008 and subsequent comprehensive field surveys (which have taken place up to 2011), with the earlier version of the map of urban settlements dated circa 2002.

There is certainly a bias towards overestimation of urban development in this approach as the new map (circa 2010) has improved the knowledge of the past and not simply updated the 2000/2002 database. The results make sense and the methodology bypassed issues linked to minor but numerous revisions to building plans. Examination of the results by an expert knowledgeable in both Mauritian urban and population data has lead to the conclusion that trends have been identified correctly (despite being overestimated) and cross-match what is well known of the underlying processes.

Figure 7 A: Urban and associated areas - 2000 and 2010 and urban sprawl

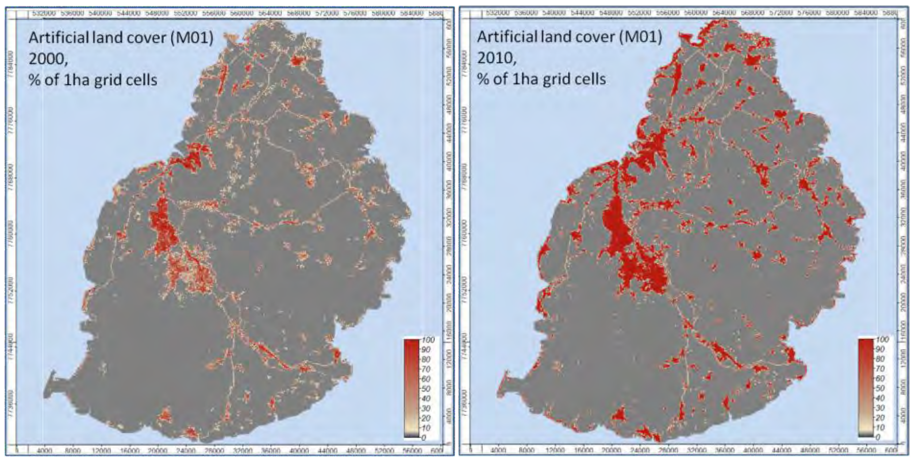
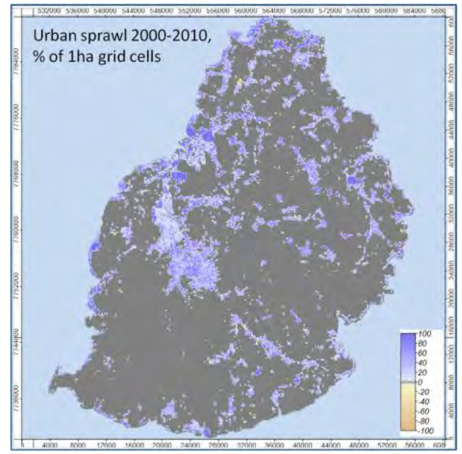


Figure 7 B: Urban sprawl 2000 - 2010



This map of urban sprawl was obtained by subtracting data from 2000 from the map of 2010. This map shows the intensity and spatial distribution of urban sprawl. This first account of land cover change is fragile and has to be interpreted with care, although the general trends make sense. During this period, urban sprawl was stimulated by various factors such as economic development and social demand for dwellings (both in agglomerations and in villages) and easier access to land due to the reduction of sugar cane plantations.

Table 3 below shows the land cover stock and change account by district, 2000 - 2010.

Table 3: Land cover stock and change account/urban sprawl, Mauritius, 2000 - 2010

Experimental account km²

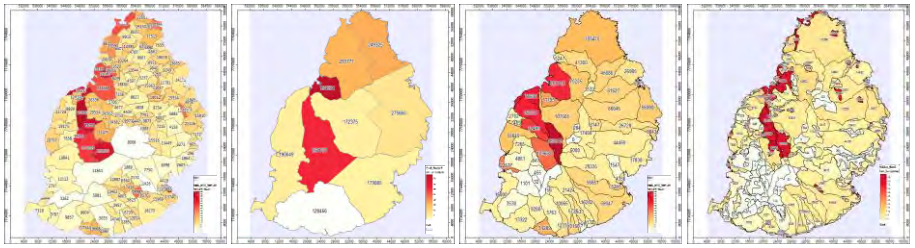
	Rivière du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	TOTAL
District area SQKM	14703	18019	29826	23512	26134	19839	25558	24758	3976	186325
M01 Urban land cover 2000 v0	747	705	405	282	406	2060	334	266	2667	7872
M01 Urban land cover 2000 v1, adjusted	1225	1172	667	510	549	2456	542	379	3284	10782
Lf1 Urban sprawl	478	467	263	228	143	396	208	112	616	2911
M01 Urban land cover 2010	1704	1639	930	738	691	2852	749	491	3900	13693

Land cover data are stored using geographical datasets which use grids (10m x 10m and 100m x 100m) at the most detailed level. The maps in Figure 8 display percentages of artificial/urban land cover in 1ha cells. These grids enable statistics to be computed and produce ecosystems/natural capital accounts for various statistical units such as municipal and village council areas, districts, coastal zones, river basins, socio-ecological landscape units and any other relevant zoning areas.

Examples of statistical maps of urban and associated land cover areas in 2010 produced for: (1) Municipalities/Villages, (2) Districts, (3) River basins and (4) Socio-ecological Landscape Units (SELU), the standard analytical statistical units for ecosystem accounting, are given in Figure 8.

Figure 8: Examples of statistical maps of urban and associated land cover areas in 2010

From left to right: (1) Municipalities, (2) Districts, (3) River basins and (4) Social-ecological landscape units, the standard analytical statistical units for ecosystem accounting.



3.2 The ecosystem biomass-carbon accounts, Mauritius

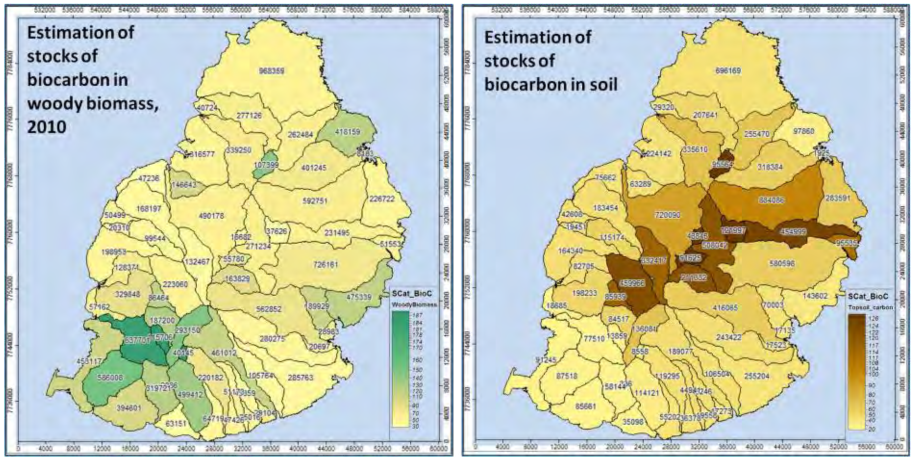
The biomass-carbon account shows the capacity of ecosystems to produce biomass and highlights the way it is used through means such as harvesting, sterilization by artificial developments or destroyed by soil erosion or forest fires. Biomass is an important resource, providing food, energy, fibre and industrial materials. As a source of food, biomass has to be shared between human beings and biodiversity; if this does not happen, ecosystems' capacity to reproduce biomass is degraded, creating an unsustainable economic environment where only artificial inputs can temporarily overcome the deficit. As biomass falls under policies of climate change mitigation, biomass is accounted for in terms of carbon.

Stocks of biomass and natural primary production by photosynthesis are assessed by in situ measurements (samples) and satellite images. As the harvesting of crops and timber are generally reported by administrative units, accounts need to resample these statistics to the actual land areas where the harvests take place.

In the biomass/bio-carbon accounts, flows explain changes in stocks, in particular trees (and to a lesser extent shrubs) and soil. Stocks of woody biomass have been estimated by combining satellite observations (MODIS VCF - measuring tree density) and forest statistics from the FOA's country report (FRA2010).

Stocks of soil carbon have been roughly estimated using an ORSTOM map from 1984 and the FAO world database on soil. This is an initial assessment, which shows the variability of soil with regard to its organic carbon content, which is a good proxy for fertility. Accounting for change in soil carbon, beyond the obvious losses due to urban sprawl, requires more precise data and further analysis.

Figure 9: Estimates of stocks of bio carbon in woody biomass (left) and soil (right)

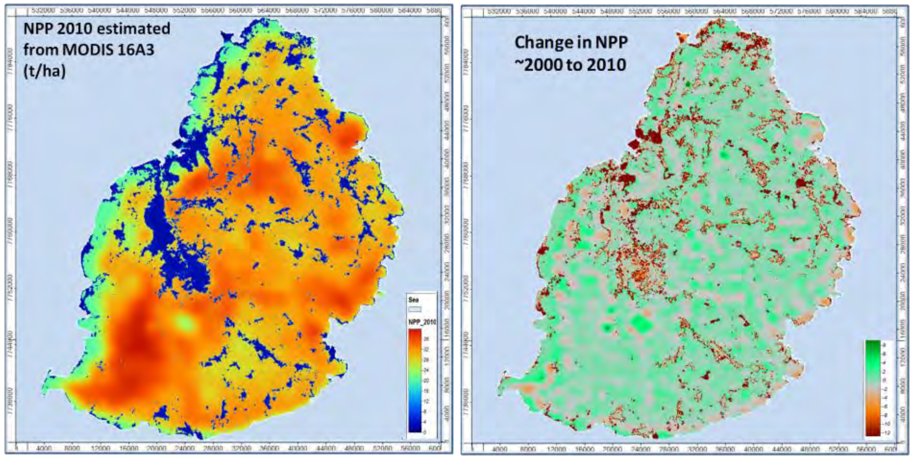


(the above results are displayed per river sub-basin and figures are in tonnes of carbon)

The carbon account is drawn up by first measuring the Net Primary Production (NPP) of vegetation. In Mauritius, this was done with the use of standard international assessments provided by US NASA[14] and fine-tuned with higher resolution data on photosynthesis (vegetation index) and land cover.

Figure 10 below shows the distribution of NPP for 2010 according to the standard ENCA grid (colours reflect tonnes per ha). The assessment of NPP changes, 2000 to 2010, highlights the overall situation, contrasted with local improvements and the severe impact of urban sprawl.

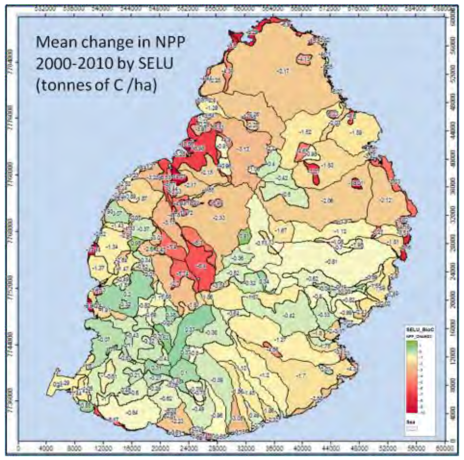
Figure 10: NPP estimation 2010 (left) and changes 2000 - 2010 (right)



[14] The NPP data used are computed for NASA from MODIS satellite images by the Numerical Terradynamic Simulation Group (NTSG) at The University of Montana http://www.ntsg.umt.edu/

Visualisation of NPP change per SELU (Figure 11) provides an interesting view of the overall process showing clear positive values in mountain areas, intermediate values in basins where agriculture is predominant and significant drops where urban development has taken place. More complete data on sugar cane would lead to a slightly different assessment of change in some regions.

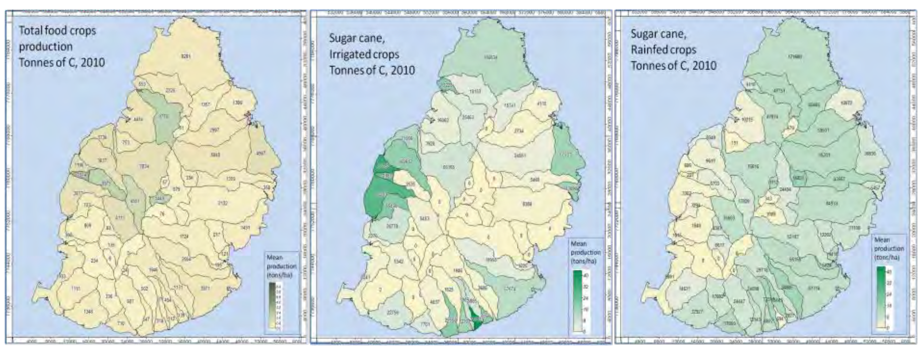
Figure 11: NPP change 2000 - 2010 per socio-ecological landscape unit



Regarding harvests, only agriculture was considered here. In the absence of spatially explicit statistics, national statistics were evenly attributed to agricultural land cover. However, mean yields were estimated separately for irrigated sugar cane, rain fed sugar cane, tea, potatoes from sugar cane fields, family gardens and other food crops.

These results are only approximate but constitute a starting point for further improvements once more comprehensive input data is available. Figure 12 below shows 2010 estimates for: total food crops - including family gardens and cane field secondary production e.g. potatoes (left), irrigated sugar cane (centre) and rain fed sugar cane harvests (right).

Figure 12: Total food, irrigated and rain fed sugar cane harvests, 2010 (tonnes of carbon)



In addition to harvests, biomass is consumed by animals, in particular micro fauna, leading to what is known as secondary respiration (as opposed to plant respiration which was previously deducted in the calculation of NPP). Estimations of soil respiration (via decomposers) have been tempted, and losses of bio-carbon due to fires or soil erosion have been recorded from memory. However, it was not possible to complete the biomass/bio-carbon accounts without statistical adjustments to close the gap between the calculation of the Net Ecosystem Carbon Balance from positive and negative flows on the one hand and differences between the opening and final stocks on the other. By taking these adjustments into consideration, the net accessibility of bio-carbon and the land-use intensity index was estimated as shown in Tables 4 and 5 below.

Table 4: Simplified bio carbon accounts by district, Mauritius, 2000

Experimental account — Tons of carbon

2000	*Riviere du Rempart*	*Pamplemousses*	*Flacq*	*Moka*	*Grand Port*	*Plaines Wilhems*	*Black River*	*Savanne*	*Port Louis*	**Total**
Initial stock 2000	**1397259**	**2148448**	**4489656**	**4516140**	**3239482**	**3653354**	**3725443**	**3609489**	**429852**	**27209122**
Woody biomass	812707	1183736	2422684	2095355	2180158	1969724	2776239	2822467	262727	**16525797**
Topsoil organic carbon	584551	964712	2066972	2420785	1059325	1683629	949204	787022	167124	**10683324**
Flows/inputs	**376598**	**465564**	**877219**	**712210**	**768467**	**506218**	**671780**	**762179**	**82807**	**5223041**
Net Primary Production	376598	465564	877219	712210	768467	506218	671780	762179	82807	**5223041**
Flows/outputs and decrease	**390727**	**500654**	**937618**	**748768**	**767475**	**533500**	**691312**	**777509**	**87942**	**5435504**
Removals, harvests	78189	107662	129251	67005	107613	41993	104669	97945	1880	**736207**
Wood removal										**0**
Sugarcane	*76462*	*103902*	*125076*	*63038*	*104650*	*38381*	*100528*	*96268*	*1094*	**709398**
Food crops	*1727*	*3759*	*4175*	*3656*	*2918*	*3565*	*4141*	*1633*	*786*	**26362**
Other crops	*0*	*0*	*0*	*311*	*46*	*46*	*0*	*44*	*0*	**447**
Decrease due to land use change	4102	4761	5762	3629	3240	5216	2881	2290	1388	**33269**
Other decreases (fire, erosion…)	13973	21484	44897	45161	32395	36534	37254	36095	4299	**272091**
Soil/decomposers respiration v2	294463	366746	757708	632973	624227	449757	546508	641180	80375	**4393937**
Net Ecosystem Carbon Balance 1 (flows)	***-14129***	***-35090***	***-60399***	***-36557***	***992***	***-27282***	***-19532***	***-15331***	***-5135***	**-212463**
Statistical adjustment	17164	32764	42693	19006	-20198	10970	-8047	-5314	5259	**94297**
Net Ecosystem Carbon Balance 2 (stocks)	***3035***	***-2326***	***-17706***	***-17551***	***-19206***	***-16312***	***-27579***	***-20644***	***123***	**-118166**
Final Stock 2000	**1400293**	**2146122**	**4471950**	**4498589**	**3220276**	**3637042**	**3697864**	**3588845**	**429975**	**27090956**
Woody biomass	815742	1181410	2404979	2077804	2160952	1953412	2748659	2801823	262851	**16407632**
Topsoil organic carbon	584551	964712	2066972	2420785	1059325	1683629	949204	787022	167124	**10683324**
Net accessible bio-carbon resource 2000	**85170**	**96492**	**101805**	**61687**	**125035**	**40148**	**97693**	**100355**	**2555**	**710938**
Change in stocks in previous year	3035	-2326	-17706	-17551	-19206	-16312	-27579	-20644	123	**-118166**
Flows/inputs (+)	376598	465564	877219	712210	768467	506218	671780	762179	82807	**5223041**
Soil/decomposers respiration v2 (-)	294463	366746	757708	632973	624227	449757	546508	641180	80375	**4393937**
Index of intensity of use of bio-carbon 2000	**109**	**90**	**79**	**92**	**116**	**96**	**93**	**102**	**136**	**97**

Table 5: Simplified bio carbon accounts by district, Mauritius, 2010

Experimental account

2010	Riviere du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	Total
Initial stock 2010	**1457955**	**2101934**	**4135543**	**4165122**	**2855365**	**3327114**	**3173857**	**3196601**	**432317**	**24845808**
Woody biomass	873403	1137222	2068571	1744337	1796040	1643485	2224653	2409579	265193	**14162483**
Topsoil organic carbon	584551	964712	2066972	2420785	1059325	1683629	949204	787022	167124	**10683324**
Flows/inputs	**335582**	**417954**	**819601**	**675923**	**736068**	**454057**	**642970**	**739278**	**68922**	**4890354**
Net Primary Production	335582	417954	819601	675923	736068	454057	642970	739278	68922	**4890354**
Flows/outputs and decrease	**349143**	**448659**	**870542**	**708508**	**725853**	**481532**	**650835**	**744290**	**74976**	**5054339**
Removals, harvests	65446	90345	108405	56498	90172	35596	87914	81900	1698	**617974**
Wood removal										**0**
Sugarcane	*63718*	*86585*	*104230*	*52531*	*87208*	*31984*	*83773*	*80223*	*912*	**591165**
Food crops	*1727*	*3759*	*4175*	*3656*	*2918*	*3565*	*4141*	*1633*	*786*	**26362**
Other crops	*0*	*0*	*0*	*311*	*46*	*46*	*0*	*44*	*0*	**447**
Decrease due to land use change	4102	4761	5762	3629	3240	5216	2881	2290	1388	**33269**
Other decreases (fire, erosion…)	14580	21019	41355	41651	28554	33271	31739	31966	4323	**248458**
Soil/decomposers respiration v2	265016	332534	715020	606730	603888	407449	528301	628133	67567	**4154638**
Net Ecosystem Carbon Balance 1 (flows)	***-13562***	***-30705***	***-50941***	***-32585***	***10215***	***-27475***	***-7865***	***-5012***	***-6054***	**-163985**
Statistical adjustment	16597	28379	33235	15034	-29421	11163	-19714	-15632	6178	**45819**
Net Ecosystem Carbon Balance 2 (stocks)	***3035***	***-2326***	***-17706***	***-17551***	***-19206***	***-16312***	***-27579***	***-20644***	***123***	**-118166**
Final Stock 2010	**1460990**	**2099608**	**4117837**	**4147571**	**2836159**	**3310802**	**3146278**	**3175957**	**432440**	**24727642**
Woody biomass	876438	1134896	2050865	1726786	1776835	1627173	2197074	2388935	265316	**14044318**
Topsoil organic carbon	584551	964712	2066972	2420785	1059325	1683629	949204	787022	167124	**10683324**

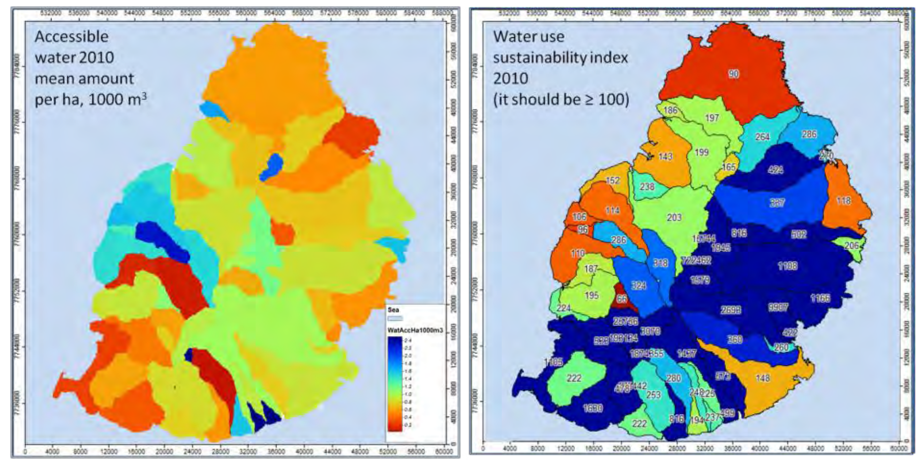
Net accessible bio-carbon resource 2010	**73600**	**83094**	**86875**	**51642**	**112974**	**30296**	**87089**	**90500**	**1479**	**617550**
Change in stocks in the previous year	3035	-2326	-17706	-17551	-19206	-16312	-27579	-20644	123	**-118166**
Flows/inputs (+)	335582	417954	819601	675923	736068	454057	642970	739278	68922	**4890354**
Soil/decomposers respiration v2 (-)	265016	332534	715020	606730	603888	407449	528301	628133	67567	**4154638**
Index of intensity of use of bio-carbon 2010	**112**	**92**	**80**	**91**	**125**	**85**	**99**	**111**	**87**	**100**

3.3 The ecosystem water account, Mauritius

This account can be considered as an extension of the SEEA-Water accounts. The main difference is that water availability is assessed stringently per ecosystem, deducting water that is not exploitable (e.g. flood water) according to FAO AQUASTAT recommendations. The ecosystem water accounts are established from river basins and sub-basins where hydrological systems' accessible resources and their uses can be described consistently in view of detecting possible stresses. Stocks of water mainly take the form of aquifers and lakes/reservoirs, which play an important role in Mauritius. Primary input data relate to rainfall and actual evapotranspiration. The difference between total rainfall and actual evapotranspiration is known as effective rainfall, which is calculated directly from climatic parameters and useable ground reserves (aquifer recharge and runoff).

Once water use (mainly municipal use and irrigation) and water transfers to and/or from reservoirs, are taken into account it is possible to estimate runoff and these results can be checked against monitoring data from gauging stations as has been done for the ecosystem water accounts. The result of this lengthy exercise is an assessment of the water that is accessible from river basins and makes it possible to calculate actual water abstraction and draw up a stress index related to water consumption. Despite gaps in data availability (in particular meteorological data and detailed information concerning transfers between reservoirs), this initial assessment of accessible water highlights irregular conditions with regard to irrigated sugar cane, with a more favourable situation in the central western area than in the north (which needs to be fed by water from Midlands Reservoir with up to 41 mm^3 per year).

Figure 13: Assessment of water accessibility and areas under risk of stress by river basins



The picture is somewhat different for water that is accessible from river basins and water stress resulting from use intensity (as shown on the statistical map).

The Intensity of Use Impact Index is the ratio between accessible resources and total water abstraction. This index measures the sustainable use of the resource and should be greater than or equal to 100. The map shows where values below 100 reflect structural deficits (which is clearly the case in the northern catchment area). Values between 100 and 120 seem to reflect a more balanced situation but these areas are vulnerable to climate variations and/or dependency from external water supplies. This is the case of some basins in the west of the country where abundant accessible water (shades of blue) hardly cover the water used by irrigated agriculture. Catchments with an index over 150 are certainly better off despite relatively low (but sufficient) accessibility to water resources (e.g. in the south west of the country). Water accounts based on river basins provide an interesting concept for data integration.

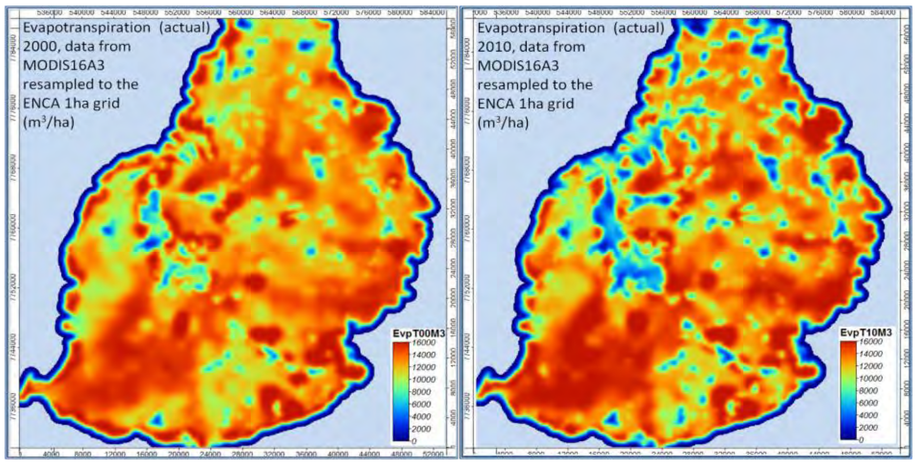
These results are experimental and require further completion and validation as well as clarification in terms of reservoir transfers.

In the case of rainfall, only rough estimates - based on mean isohyets and data from a small number of monitoring stations - could be made due to limited monitoring data. These estimations are no doubt the cause of anomalies detected in other areas of the accounts.

The methodology used to estimate rainfall did not fully meet expectations. Actual annual data were only available from a limited number of monitoring stations. As data were representative of isohyets (equal rainfall areas) they were extrapolated as such and the results were smoothed out to avoid any unnecessary border effect between isohyets (m^3/ha). Improvements will require more local meteorological data and/or the use of monitoring data collected for the purpose of monitoring climate change and delivered in a grid format.

Evapotranspiration (actual) (ETa) was estimated in this way from a product known as MODIS16A3 (see footnote 13), re-projected from sinusoidal to UTM and corrected for border effects with the sea. The final results appear to be satisfactory when compared with ETa and vegetation images.

Figure 14: Estimation of evapotranspiration (actual)

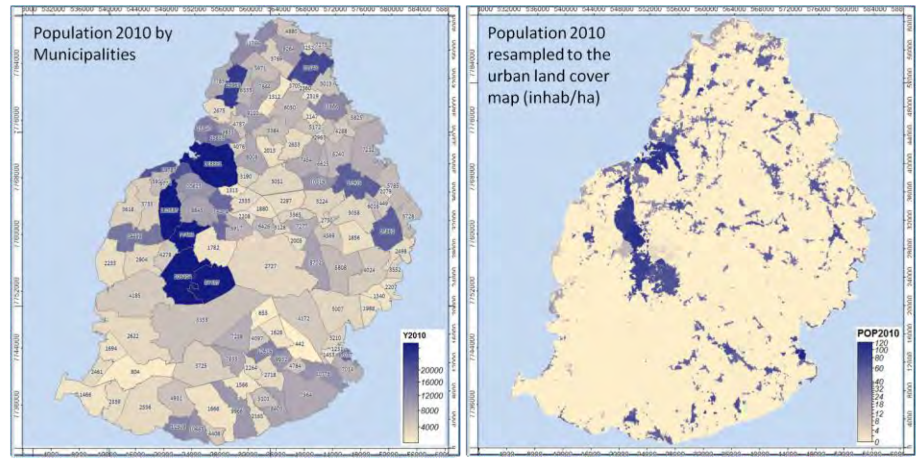


It should be noted that the assessment of ETa from MODIS16A3 gave significantly higher values than the 30% rainfall default value commonly accepted and used in the national SEEA-Water accounts. Whilst the default value used results in an ETa of 1,100 mm^3, the MODIS assessment gives 2,000 mm^3, which is closer to the FAO AQUASTAT estimate of 1,800 mm^3.

Due to insufficient details, estimates were used for the ecosystem water account. The total amount of water used by irrigation calculated for the SEEA-Water, was distributed in proportion to irrigated surfaces. Abstraction from aquifers was estimated as a proportion of the number of boreholes and population use. For population use, statistics from municipalities/villages were first redistributed on the urban land cover map (number of people per 1 ha cells).

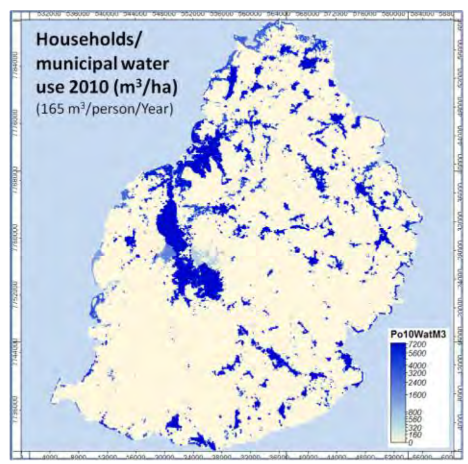
The estimation of water used by the population was based on demographic statistics from municipalities/villages that were first redistributed on the urban land cover map (number of people per 1 ha cell). This work was carried out for 2000 and 2010.

Figure 15: Resampling population data to the standard grid used for accounting



Thereafter, the mean water use per person was calculated from national data (155 m^3/person in 2000, 165 m^3/person in 2010), resulting in the following statistical map of water use (Figure 16). Once inserted in the standard grid, the water consumption data can easily be regrouped by river basin or SELU.

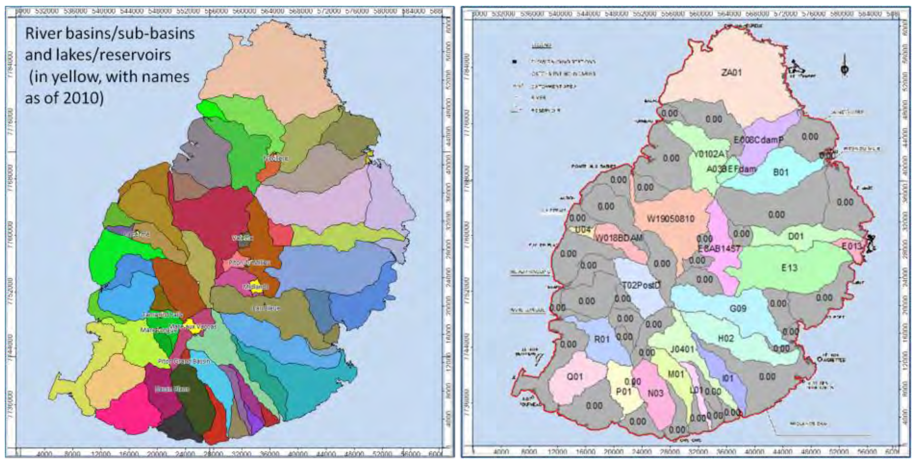
Figure 16: Households/municipal water use, 2010 (m^3/ha)



One particular difficulty in compiling the Mauritius accounts based on river basin information relates to incomplete published documentation at the reservoir management level. Despite plenty of details on the reservoirs themselves, information concerning the destination of their yields was missing for the ENCA test. With the exception of transfers between Midlands and La Nicolière reservoirs, little information was available as to where the water is going. Therefore, transfers between basins were not accounted for appropriately and will need to be revised.

Finally, water balances by sub-catchment areas were integrated in the results leading to initial calculations of river runoff. These calculations have been crosschecked with the outcome of gauging stations selected by the Mauritius Water Resource Unit and allocated to river basins (see Figure 17).

Figure 17: River catchments/sub-catchments and lakes (in yellow) and river basins with representative river gauging



(with codes: 0.00 values mean that no gauging data has been used)

With the exception of a few anomalies that need to be clarified, final checks presented acceptable results and several good matches. However, there is definitely room for improvement when it comes to the compilation of the water accounts.

Water quality data exist but were not available or detailed enough to produce water quality accounts at this time.

Tables 6 and 7 show the simplified ecosystem water accounts per district and are aggregated accounts by sub-basin. Figures for 2010 were calculated however, results for 2000 are only approximate given the limited input data available (rainfall, evapotranspiration, and municipal & irrigation use).

One interesting finding was that simple statistical aggregations and averages hide, to a large extent, potential issues. For example, accepting the implicit unrealistic assumption that water is transferable from place to place at no cost. The intensity of use index is defined as accessible resource/abstraction and should therefore be greater or equal to 100. The first decile value is used to represent the overall situation of an aggregated area. If the first decile values of the index are checked however, the results show unsustainable situations in several districts.

Table 6: Simplified ecosystem water accounts by district, Mauritius, 2000

Experimental account — mm^3

2000	Riviere du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	Total
Area ha	*14703*	*18019*	*29826*	*23512*	*26134*	*19839*	*25558*	*24758*	*3976*	*186325*
Boreholes no.	*105*	*164*	*100*	*83*	*110*	*146*	*131*	*30*	*12*	*881*
River runoff district coeffic.	*35*	*20*	*150*	*150*	*100*	*100*	*80*	*100*	*20*	*755*
Lakes 2000 (ha)	*0*	*103*	*0*	*206*	*41*	*511*	*109*	*19*	*0*	*989*
Stocks	**3345**	**5231**	**3189**	**2663**	**3510**	**4687**	**4183**	**961**	**383**	**28152**
Aquifers	3343	5222	3184	2643	3503	4649	4171	955	382	28052
Lakes/reservoirs		7	0	14	3	35	7	1		68
Rivers	2	2	5	6	5	3	4	4	1	32
Soil/vegetation										
Net Inflows	**59**	**127**	**291**	**407**	**368**	**287**	**118**	**372**	**12**	**2002**
Rainfall	168	254	604	672	659	504	308	633	49	3832
EvapoTranspitation (actual)	155	204	378	300	344	245	315	322	40	2324
EvapoTranspitation (actual), spontaneous	121	141	336	283	311	232	209	280	40	1973
Transfers surface - groundwater	11	14	23	18	20	15	20	19	3	143
Transfers between basins										0
Abstraction and Uses	**50**	**84**	**62**	**27**	**50**	**71**	**114**	**53**	**22**	**532**
Municipal Water Use	15	19	19	10	16	56	8	10	21	174
Use of water	*7*	*10*	*9*	*5*	*8*	*28*	*4*	*5*	*11*	*87*
Loss of water in distribution	*7*	*10*	*9*	*5*	*8*	*28*	*4*	*5*	*11*	*87*
Irrigation	34	64	43	16	33	13	106	42	0	351
Other	1	1	1	0	1	2	0	0	1	7
Waste water to rivers	**5**	**7**	**7**	**4**	**6**	**21**	**3**	**4**	**8**	**65**
Outflow to the sea	**78**	**46**	**324**	**318**	**217**	**212**	**172**	**213**	**50**	**1632**
River runoff	74	42	318	318	212	212	170	212	42	1602
Waste water to the sea	4	4	6	0	5	0	2	1	8	30
Induced ETA, Evaporation	**34**	**64**	**43**	**16**	**33**	**13**	**106**	**42**	**0**	**351**
Net Flows	-94	-56	-125	49	79	12	-268	68	-44	-417
Closing stocks	**3251**	**5176**	**3065**	**2712**	**3589**	**4699**	**3915**	**1029**	**339**	**27735**
Accessible renewable water	**65**	**90**	**217**	**237**	**227**	**183**	**174**	**224**	**37**	**1470**
Water use intensity (1): Average/ha	**132**	**107**	**350**	**878**	**458**	**258**	**153**	**425**	**169**	
Water use intensity (2): 1st decile	**91**	**84**	**152**	**318**	**196**	**131**	**112**	**304**	**156**	

Table 7: Simplified ecosystem water accounts by district, Mauritius, 2010

Experimental account — mm³

2010	Riviere du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	Total
Area ha	*14703*	*18019*	*29826*	*23512*	*26134*	*19839*	*25558*	*24758*	*3976*	*186325*
Boreholes no.	*105*	*164*	*100*	*83*	*110*	*146*	*131*	*30*	*12*	*881*
River runoff district coeffic.	*35*	*20*	*150*	*150*	*100*	*100*	*80*	*100*	*20*	*755*
Lakes 2010 (ha)	*0*	*103*	*0*	*468*	*41*	*511*	*109*	*19*	*0*	*1251*
Stocks	**3345**	**5231**	**3189**	**2681**	**3510**	**4687**	**4183**	**961**	**383**	**28170**
Aquifers	3343	5222	3184	2643	3503	4649	4171	955	382	28052
Lakes/reservoirs	0	7	0	32	3	35	7	1	0	86
Rivers	2	2	5	6	5	3	4	4	1	32
Soil/vegetation										
Net Inflows	**75**	**176**	**292**	**342**	**355**	**293**	**155**	**353**	**12**	**2052**
Rainfall	173	236	579	633	629	484	302	603	49	3688
EvapoTranspiration (actual), total	155	199	367	290	338	224	308	326	40	2247
EvapoTranspiration (actual), spontaneous	109	115	310	268	294	207	167	269	40	1779
Net transfers surface - groundwater	11	14	23	18	20	15	20	19	3	143
Transfers between basins		41		-41						0
Abstraction and Uses	**63**	**109**	**80**	**36**	**63**	**83**	**152**	**69**	**23**	**678**
Municipal Water Production	17	23	23	13	18	64	11	11	22	202
Use of water	*8*	*12*	*11*	*7*	*9*	*32*	*5*	*6*	*11*	*101*
Loss of water in distribution	*8*	*12*	*11*	*7*	*9*	*32*	*5*	*6*	*11*	*101*
Irrigation	46	85	57	22	44	17	141	57	0	468
Other	1	1	1	1	1	3	0	0	1	8
Waste water to rivers	**6**	**8**	**8**	**5**	**6**	**22**	**4**	**4**	**8**	**70**
Outflow to the sea	**78**	**46**	**324**	**318**	**217**	**212**	**172**	**213**	**50**	**1632**
River runoff	74	42	318	318	212	212	170	212	42	1602
Waste water to the sea	4	4	6	0	5	0	2	1	8	30
Induced ETA, Evaporation	**46**	**85**	**57**	**22**	**44**	**17**	**141**	**57**	**0**	**468**
Net Flows	-103	-52	-156	-29	41	2	-304	19	-46	-626
Closing stocks	**3242**	**5179**	**3034**	**2652**	**3551**	**4690**	**3879**	**980**	**337**	**27544**
Accessible renewable water	**83**	**124**	**217**	**200**	**219**	**187**	**228**	**213**	**36**	**1507**
Water use intensity (1): Average/ha	**132**	**114**	**270**	**561**	**345**	**224**	**150**	**310**	**155**	
Water use intensity (2): 1st decile	**90**	**90**	**118**	**203**	**148**	**114**	**110**	**222**	**143**	

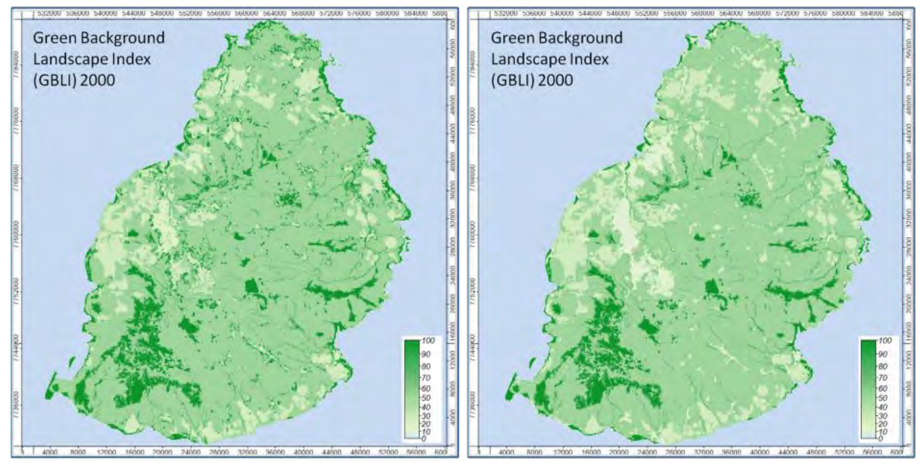
3.4 The ecosystems integrity/biodiversity account, Mauritius

The ecosystems integrity/biodiversity account is made up of two accounts that describe the state of ecosystems' green infrastructure (landscapes, rivers and coastal zones) on the one hand and changes in species biodiversity on the other.

The landscape green infrastructure account is derived from monitoring land cover and mapping where the various land cover classes are first weighted according to their greenness (from 10 for urban areas to 100 for forests and wetlands). The Green Background Landscape Index (GBLI) is then calculated. In a second step the GBLI is adjusted to take into account other ecological dimensions such as the nature conservation value given by scientists and environmental agencies and landscape fragmentation, which perturbs ecosystem functioning.

Following this methodology, the GBLI was calculated for 2010 (scale from 10 to 100). For the purpose of this experiment, the GBLI was estimated 'backwards' based on the only information available, which was the sprawl of urban and associated areas.

Figure 18: Green background landscape index 2000 and 2010 (0 - 100 values, 1 ha grid)

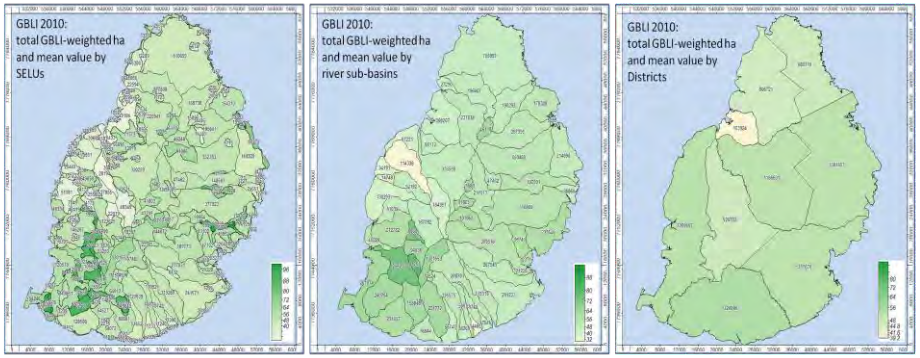


Totals can be calculated by weighting hectares by GBLI and compiled accounts.

The highest GBLI values can be found in Socio-ecological Landscape Units (SELU) where forests, shrubs, grass and natural habitats are predominant, in particular in mountainous and coastal areas. Low GBLI values correspond to urban areas and intermediate scores reflect predominantly agricultural catchment areas.

Accounts in GBLI weighted hectares have been produced by various geographical breakdowns. The maps in Figure 19 below present the account results for SELUs, river sub-basins and administrative districts. The colours relate to the mean GBLI index for each zone.

Figure 19: Total GBLI-weighted ha and mean value per SELU, river sub-basin and districts (2010)

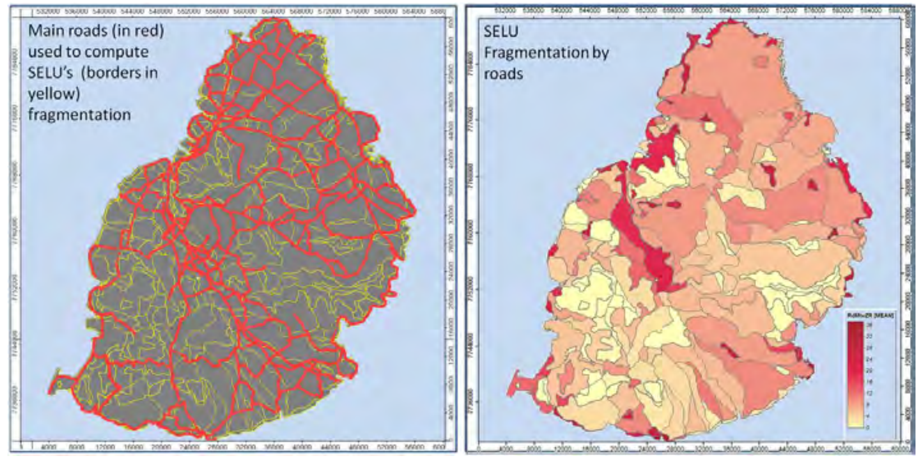


The net landscape ecological potential

In addition to the GBLI, the Net Landscape Ecosystem Potential (nLEP) to deliver systemic ecosystem services can also be calculated. Such services include those that cannot be measured in terms of tonnes of carbon or volumes of water but can only be assessed indirectly (regulation, amenities, etc.). The nLEP enhances the GBLI by taking into account other elements of ecosystem landscape assessments such as different nature values or the quality of similar land cover types or their fragmentation.

The present calculation of nLEP accounts integrates SELU's road fragmentation (motorway, primary and secondary roads). The GIS analysis results in the following fragmentation index per socio-economic landscape unit (Figure 20).

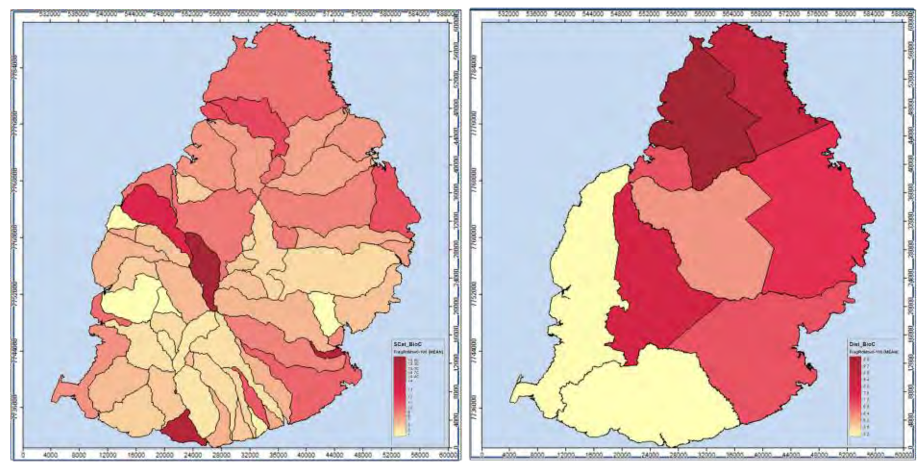
Figure 20: Fragmentation of SELUs by main roads and SELU fragmentation



(fragmentation index 0 - 100 as a percentage of road corridors - 100m pixels)

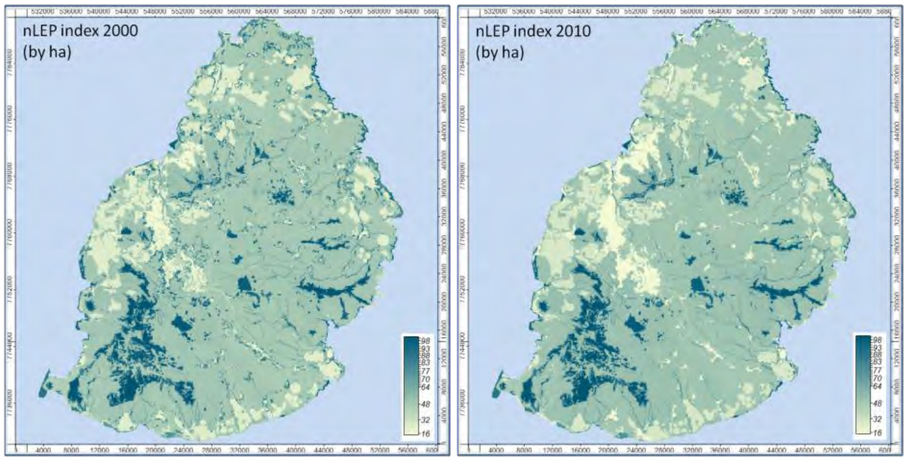
The same fragmentation index, computed per SELU, can be aggregated by river basins and districts, as shown in Figure 21.

Figure 21: SELU fragmentation index aggregated by sub-basins and districts



Combining the GBLI and the fragmentation index gives the nLEP index, which is used to calculate the system biodiversity account in weighted hectares for 2010. A simple formula was used for the test: nLEP = GBLI * (100 - FRAG). Other dimensions can be introduced in the nLEP index to improve its relevance and sensitivity. Even this simple formula, when used in the same way for different dates, gives meaningful results of nLEP changes. In Figure 22, a nLEP decrease can be observed in the central region under rapid development, as well as in some sectors on the coast, in particular in the North and Northwest of the island.

Figure 22: Net landscape ecosystem potential 2000 and 2010



Changes in the nLEP provide the first hint of ecosystem degradation or enhancement. Due to missing information on the spatial coverage of sugar cane in the past, this particular aspect was not reviewed as part of this case study.

Current developments in the sugar cane industry have resulted in various changes such as the abandonment of sloping areas, which in turn has an effect on landscapes. If such changes are not included in the nLEP, the index remains fragile and incomplete. It is important to complete the index as the nLEP presents relevant information for policies on sustainable ecosystem use and their capacity to adapt to climate change.

nLEP accounts

nLEP can be used to weight hectare values and compile nLEP accounts. nLEP stocks and change accounts reflect overall ecosystem integrity and the capacity of the accounting units to deliver services. Figure 22 shows the results at various scales and Table 8 is an example of such an account per district.

Table 8: Green infrastructure accounts Mauritius, 2000 and 2010

Experimental account

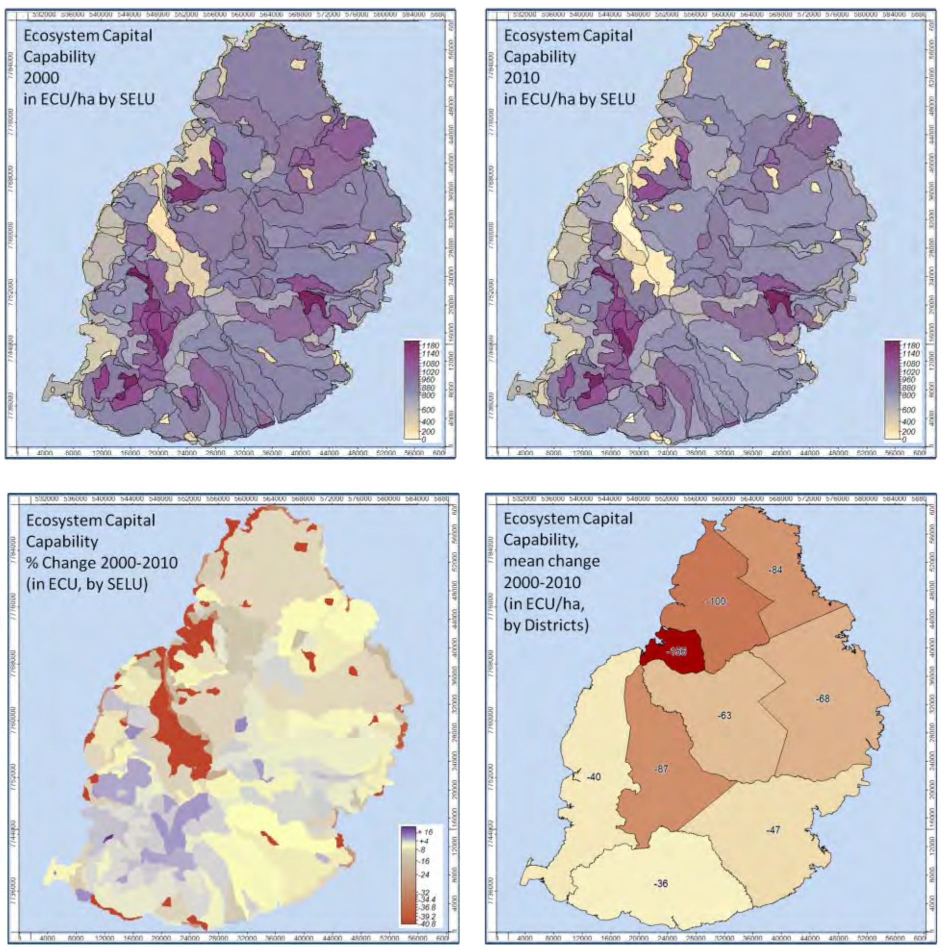
	Riviere du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	Total/ *Mean values*
AREA_ha	14703	18019	29826	23512	26134	19839	25558	24758	3976	186325
Indexes (0-100 value per ha)										
GBL 2000 index	*43.4*	*41.7*	*49.7*	*55.6*	*50.1*	*53.4*	*61.0*	*53.7*	*58.6*	*51.9*
Fragmentation index	*8.6*	*9.8*	*7.3*	*6.2*	*6.9*	*7.9*	*5.1*	*5.1*	*6.9*	*6.9*
nLEP 2000 index	*39.7*	*37.6*	*46.0*	*52.1*	*46.6*	*49.2*	*57.9*	*51.0*	*54.5*	*48.4*
Green Infrastructure Account										
GBL 2000 / weighted ha	638105	751152	1481482	1307506	1309039	1060139	1559660	1330151	232911	9670145
nLEP 2000 / weighted ha	583021	677761	1373059	1226033	1218167	976061	1479992	1262700	216727	9013521
Indexes (0-100 value per ha)										
GBL 2010 index	*42.0*	*40.6*	*49.2*	*55.1*	*49.8*	*52.4*	*60.5*	*53.5*	*50.7*	*51.1*
Fragmentation index	*8.6*	*9.8*	*7.3*	*6.2*	*6.9*	*7.9*	*5.1*	*5.1*	*6.9*	*6.9*
nLEP 2010 index	*38.4*	*36.7*	*45.6*	*51.6*	*46.4*	*48.2*	*57.4*	*50.8*	*47.2*	*47.7*
Green Infrastructure Account										
GBL 2010 / weighted ha	617999	732184	1468542	1294945	1301938	1039397	1547086	1324150	201660	9527900
nLEP 2010 / weighted ha	564651	660647	1361066	1214254	1211558	956963	1468060	1257003	187648	8881851
Change in nLEP 2000-2010	-18370	-17114	-11993	-11779	-6608	-19097	-11932	-5697	-29079	-131670
Change in nLEP index % 2000-2011	-3.2	-2.5	-0.9	-1.0	-0.5	-2.0	-0.8	-0.5	-13.4	-1.5

The nLEP index shows a decrease in all districts. It should be noted that this nLEP index only takes stock of the impacts of urban sprawl at this time. Important changes in the sugar industry over the last decade have certainly had an effect (both positive and negative), and indeed this is reflected in the nLEP account.

3.5 Calculation of ecosystem capability, experimental results based on estimations from 2000 and 2010 (provisional) accounts

As a proof of concept, ECA methodology for calculating Ecosystem Capability by means of the Ecosystem Capability Unit (ECU) was applied to data from Mauritius. The composite index (based on bio carbon/biomass, water and landscape/biodiversity indexes) plays the role of price in the calculation of the ecological value of ecosystem capability. Again, the experimental nature of this study and the provisional status of data must be highlighted. Despite doubts concerning the magnitude of ECU accounts, trends and spatial distribution do not appear to be unrealistic, as shown in Figure 23. Initial results emphasise the need for a more comprehensive process to review the data and accounts, supplement missing data with other sources (e.g. satellite images for land cover and bio-carbon accounts), involve institutional partners, research and economic actors, as well as to validate the use of this data and the results obtained.

Figure 23: Ecosystem capital capability (inland ecosystems) mean ECU value and change, 2000 and 2010



The first tentative account of ECU values for Mauritius shows an overall decline of 15%, somewhat overestimated in some areas and underestimated or wrongly estimated in others due to insufficient agricultural data (see Table 9). Change is unevenly distributed among SELUs and districts.

The spatial distribution, by district, of the resulting accounts in ECU for inland ecosystems shows interesting contrasts between potential and degradation - although net losses can be seen everywhere. Impacts of urban sprawl have been well noted (districts of Plaines Wilhems and Port Louis and to some extent in the Northern District). Poor performance in the district of Moka could result from the way that water from Midlands Reservoir (developed during the period) has been recorded (this is an assumption which needs further validation).

Table 9: Experimental account of ecosystem capital capability in ECU, inland ecosystems, Mauritius 2000 and 2010

Inland ecosystems (Socio-Ecological Landscape Units)	Rivière du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	**TOTAL**
Accessible bio-carbon resource 2000	85170	96492	101805	61687	125035	40148	97693	100355	2555	710938
Index of sustainable use of bio-carbon 2000	108.9	89.6	78.8	92.1	116.2	95.6	93.3	102.5	135.9	96.6
Accessible bio-carbon resource 2010	73600	83094	86875	51642	112974	30296	87089	90500	1479	617550
Index of sustainable use of bio-carbon 2010	112.5	92.0	80.1	91.4	125.3	85.1	99.1	110.5	87.1	99.9
Accessible renewable water, 2000, Mm3	65	90	217	237	227	183	174	224	37	1470
Water sustainable use (2): 1st decile, 2000 (adjusted)	90.6	84.5	122.2	227.8	166.3	131.4	112.4	253.6	155.6	
Accessible renewable water, 2010, Mm3	83	124	217	200	219	187	228	213	36	1507
Water sustainable use (2): 1st decile, 2010	90.1	90.1	117.6	203.1	147.8	114.4	110.2	221.8	143.1	
Accessible systemic services (nLEP 2000 / weighted ha)	583021	677761	1373059	1226033	1218167	976061	1479992	1262700	216727	9013521
nLEP 2000 index	39.7	37.6	46.0	52.1	46.6	49.2	57.9	51.0	54.5	48.4
Accessible systemic services (nLEP 2010 / weighted ha)	564651	660647	1361066	1214254	1211558	956963	1468060	1257003	187648	8881851
nLEP 2010 index	38.4	36.7	45.6	51.6	46.4	48.2	57.4	50.8	47.2	47.7
Change in BioCarbon sustainable use index % 2000-2010	3.2	2.6	1.7	-0.7	7.8	-11.0	6.1	7.8	-35.9	
Change in Water sustainable use index (2) % 2000-2010	-0.5	6.7	-3.7	-10.8	-11.1	-13.0	-2.0	-12.5	-8.0	
Change in nLEP index % 2000-2010	-3.2	-2.5	-0.9	-1.0	-0.5	-2.0	-0.8	-0.5	-13.4	-1.5
Mean ECU price 2000, v0	79	70	82	124	110	92	88	136	113	
Mean ECU price 2010, v0	80	73	81	115	106	83	89	128	92	
Inland Ecosystem Capability in ECU, 2000, v0	6754512	6779076	8366804	7638831	13704307	3684073	8568899	13609354	288508	69394364
Inland Ecosystem Capability in ECU, 2010, v0	5912136	6059187	7048015	5959329	12028249	2501975	7741432	11556887	136714	58943924
Net change in inland Ecosystem Capability 2000-2010, in ECU, v0	-842376	-719889	-1318789	-1679502	-1676057	-1182098	-827467	-2052467	-151794	-10450441
Net change in inland Ecosystem Capability 2000-2010, in ECU, % v0	**-12.5**	**-10.6**	**-15.8**	**-22.0**	**-12.2**	**-32.1**	**-9.7**	**-15.1**	**-52.6**	**-15.1**

4. Towards integrated core accounts of the ecosystem natural capital and functional accounts of ecosystem services: the example of coastal land and marine waters, Mauritius

Core ecosystem natural capital accounts deliver an assessment of the resilience of ecosystems and the ecological sustainability of the services that they have the capability to deliver. Total ecosystem capability is measured in ECUs for a specific ecosystem. River basins or regions are indicators (a balancing item in accounting language) that can be aggregated at the national level in the same way as national accounts. Core accounts do not give the whole picture and therefore need to be supplemented by functional accounts that highlight critical aspects.

The first functional account relates to the accountability of economic sectors to ecosystem degradation (or improvement). The basic balances of ecosystem carbon and water are connected to the SNA via the supply and use and assets accounts via the SEEA Central Framework. The connection of land and ecosystem functional services is only done in part (in the land cover flows classification). Ecosystem degradation due to human activities is not reviewed at this stage. This has to be done in the same way as the IPCC ‘budgets’ by sector in terms of CO_{2e} – an equivalence unit that takes into account the global warming potentials of different greenhouse gases - on the one hand, and carbon sequestration, on the other. Similar to the way in which the IPCC derives ‘credits’ and ‘debits’ from this equivalence calculation (and the achievement of country targets), accounting of ECU by sectors allows an ecological balance sheet of credits and debts to be drawn up. Once ecosystem liabilities have an ECU value, they can be priced with appropriate restoration or avoidance costs in order to compute an ecological balance sheet in monetary terms.

The second important set of functional accounts relates to ecosystem services, in particular intangible services known as regulations and socio-cultural services in CICES (following the Millennium Ecosystem Assessment of 2005), but which are not easily described in the SEEA CF accounts. These services are made available by ecosystem functions but they only exist when they are used. The social demand for ecosystem services is therefore an important account to establish, for the most important ones at least. Once accounts of ecosystem services supply and use are computed, valuation is possible. It is indeed possible to assess and value ecosystem services outside of the ENCA framework, but the advantage of doing it within the ENCA is the direct relation established between ecosystem service values and the resilience of ecosystems themselves.

An initial test was carried out for Mauritius’ coastal zones. However, due to the time constraints of the project, the results could not be further developed and the elements below should be considered as an incomplete inception study rather than an experimental account.

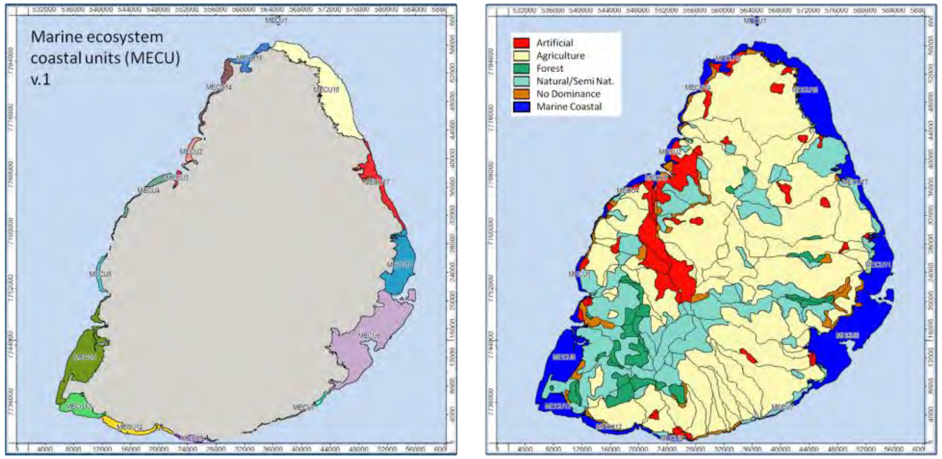
Coastal areas play an important role in small island states such as Mauritius in terms of food supply, tourism, or quality of life. Coastal areas have suffered from multiple pressures on both land and at sea and their inclusion in Ecosystem/Natural Capital Accounts is a priority. Not much experience exists in accounting for the marine part of costal zones but Ecosystem Capital Accounting methodology provides enough guidance to start and develop such accounts.

Mapping marine ecosystem units

The first step in establishing these accounts is the definition of statistical units for which accounts will be calculated. For inland ecosystems, such units could be the administrative entities or zones such as: country, regions, districts, municipalities, etc. On the other hand, ecosystem accounts must be built on analytical units that reflect the interaction of natural and socio-economic systems. For land ecosystems, these units are defined as Socio-ecological Landscape Units (SELU). It should be noted that land coastal zones are obviously characteristic SELUs, but they attract attention due to the policy importance of these areas. Mauritian SELUs have been mapped by combining the river basins and sub-basin limits that frame specific landscapes and the water cycle with a map of dominant landscape types derived from the land cover map. In Figure 24 below, inland coastal zones can be identified although no specific zoning has so far been used at this stage. The reason for this identification is the specific dominant land cover which contrasts with the hinterland.

A similar approach has been taken for marine coastal zones. This is definitely a first step but it was possible to produce a (preliminary) map of marine coastal units based on existing information for a first set of accounts. As with SELUs, each MCU is given an ID, which is used later on for accounting purposes.

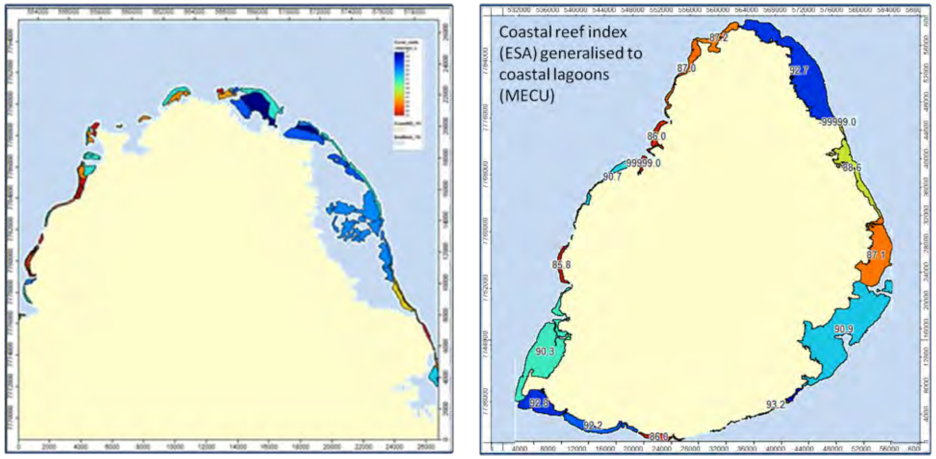
Figure 24: Marine coastal units and SELU



Computing the core ecosystem capital accounts

The first account drawn up is that of the biodiversity status of MCUs. Data for these accounts were taken from the Ministry of the Environment's Report on Environmentally Sensitive Areas (ESAs), 2009. For demonstration purposes only, detailed measurements of the vulnerability of coral reefs have been converted into an indicator of their condition (Figure 25). The coral reef status index derived from the ESA assessment[15] ranges from 80 to 96. In a first instance, the index can be used to weight the lagoon surface area and calculate an account of biodiversity status. The MCU for lagoon ecosystems is shown in Table 10.

Figure 25: Coral reef status index derived from the ESA assessment (left) and illustration of an account for marine coastal units (right)



The ecosystem biodiversity account should be supplemented by:

- A sea-bed cover account, similar to the inland land cover account;
- A carbon ecosystem account with a focus on fish, bio carbon levels in water, dissolved or/and in algae and seagrass and their underlying layer of decomposed mater and in coral reefs as long as they are living systems;
- A water account: quantity in lagoons is not an important variable but water quality is;
- Elements of ecosystem integrity not captured in the ESA assessment (if any...).

[15] Environmentally Sensitive Areas (ESA), 2009, Report by NWFS Consultancy, Portland, USA for the Ministry of Environment of Mauritius

Table 10: Illustration of an account of ecosystem capability for lagoons (MCU), in weighted ha, Mauritius 2000 and 2010

Experimental account

	Riviere du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	Total
Coral reef area ha	2222	658	1472		2167		1821	814		**9154**
MCU/Lagoon area ha	61009	13244	45083		46136		45952	14540	537	**226501**
Coral reef index 2000	100	100	100		100		100	100	no data	
Coral reef Index 2010	92.3	86.7	87.8		91.2		90.8	94.1	no data	
MCU/Lagoon capability 2000 *	6E+06	1E+06	5E+06	0	5E+06	0	5E+06	1E+06	0	**2E+07**
MCU/Lagoon capability 2010 *	5629540	1148778	3956325	0	4206240	0	4171756	1368632	0	**2E+07**

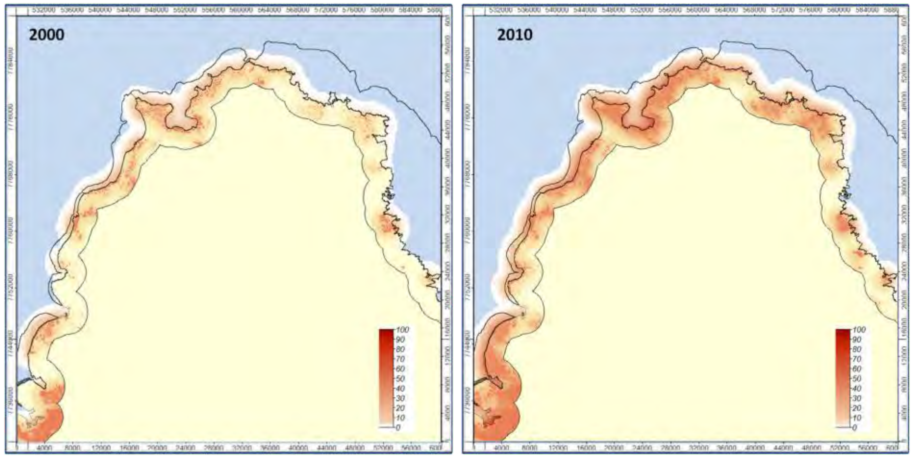
ha weighted by the coral reef index

Sector accountability and social demand

Regarding sector accountability and social demand for ecosystem services, most significant elements are pressures of urban sprawl, in particular related to tourism, the impact of fisheries, of maritime transport and on tourist activities.

A test account shows coastal stress from artificialization using 'urban temperature'. Artificial areas have been smoothed out in order to calculate 'values in the neighbourhood' (Gaussian filter, 10x). The 'urban temperature' over MCUs can be observed (Figure 26) and changes measured.

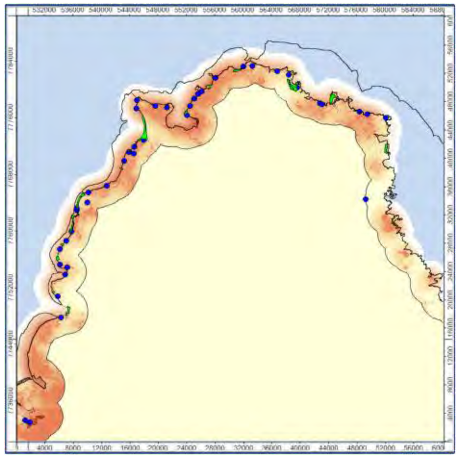
Figure 26: Increased 'urban temperature' on the coastal ecotone, 2000 to 2010



Assessing ecosystem services in physical units

Socio-economic data and statistics on fish catches, hotels and local frequentation of beaches make it possible to compile ecosystem services accounts. As an example, Figure 27 highlights hotels and public beaches for which Statistics Mauritius carried out a survey in 2006.

Figure 27: Public beaches (in green) and hotels (in blue)



Tourism is an important economic activity for Mauritius and a source of foreign currency. Mauritius' public beaches are also essential recreation areas for families, and are highly frequented during weekends, attracting small beach businesses. Ecosystem services contribute here in terms of commercial services and free amenities. The existence of a legal buffer alongside the coastline (the 'geometric footprint') guarantees, in principle, public access to all. Interesting developments of the ENCA should bring together accounts on frequentation and revenue generated, as well as a valuation(s) of amenities.

Valuing ecosystem services

Valuation methodologies are not specific to ENCA, which relies on the abundant literature published so far on the subject by UNEP/DEPI, TEEB, the World Bank's WAVES and many other academic papers. A review of these methods is presented and discussed in the SEEA-EEA. Regarding SIDS, a manual was prepared in 2014 by UNEP/DEPI (forthcoming publication)[16] under the title "Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States".

The outline of a full set of accounts for marine coastal units now needs to be populated with numbers.

[16] Manual drafted by Paulo A. Nunes, 2014

5. Conclusions

The purpose of the Experimental Ecosystem Natural Capital Accounts (Experimental ENCA), Mauritius Case Study was to test the relevance of the principles of SEEA on 'Experimental Ecosystem Accounts', and to look at the feasibility, at the island scale, of the implementation of a practical framework such as that implemented in Europe by the EEA. The objectives relate to the proof of concept of the methodology through the delivery of short-term results with existing and available data, in order to demonstrate policy relevance within the context of the strategy for the sustainable development of small island developing states. Initial results presented in this report confirm that such accounts can be undertaken and will provide useful information in the future for framing the development of policies and monitoring & evaluation in order to build the resilience of island states/SIDS against shocks within the broader context of sustainable development.

This report is, to some extent, a summary of the overall situation. During the compilation process, data supplied by Statistics Mauritius, the Ministry of Environment, research agencies and technical services were processed, harmonised and integrated. Detailed accounts have been produced based on information notably from river basins and socio-ecological units. These accounts form the basis for the reporting of various geographical breakdowns (e.g. inland coastal zones). The inclusion of coastal ecosystems in this application meets repeated policy requests and opens the way for enhanced ecosystems based on integrated coastal zone management.

However, it should not be forgotten that these accounts are provisional and should be used with care. More work has to be done and can be done without setting up huge, expensive programmes. Nowadays technology, which was a previous insurmountable cost constraint, has advanced rapidly over the years towards the supply of free services. Data processing and analysis for this report was carried out using open source free software packages.[17] More and more satellite images and associated products are also easily accessible for free and the dissemination of statistics on the Internet makes their use much easier.

This is not to say that there are no costs involved. A few gaps should be filled in, in particular regarding the systematic land cover monitoring needed to frame the accounts. However, more data can be obtained from existing programmes in Mauritius in the context of a partnership for ecosystems/natural capital accounting. Ecosystem accounts do not exist in isolation: they aim to bring together knowledge acquired in various contexts.

One of these contexts is the international arena, where beyond general statistical requirements by the UN, urgent policy demand for accounting has risen from concerns of climate change and biodiversity (as illustrated by the 2010 Aichi Strategy of the Convention on Biological Diversity),[18] not to mention various sustainable development goals reaffirmed in Rio in 2012.

[17] Namely SAGA-Gis and QGis and Libre Office.

[18] http://www.cbd.int/sp/targets/ The Strategic Goal A, Target 2, states that: *"By 2020, at the latest, biodiversity values […] are being incorporated into national accounting, as appropriate […]."*

With regard to the ecosystem carbon account, many links to the IPCC driven process have been identified as well as the possibility of using data. IPCC and the CDM mechanism (and other related programmes such as REDD+) are based on 'budgets' and 'accounts' of the global warming unit known as CO_{2e}, which is mirrored by the 'ECU' equivalent used in the ENCA. IPCC core efforts have so far been on global warming mitigation issues: when addressing adaption to climate change, the ecosystem dimension will matter considerably and ENCA will be in a position to contribute to such an assessment.

The scale at which these experimental accounts have been produced is very detailed with grids of $100m^2$ and 1 hectare (compared to accounts that are produced in Europe where grids of 1 hectare and 1 km^2 are used). The feasibility of accounts at such detailed scale enables the implementation of ENCA in the context of small islands – as well as on a regional level and on a local scale in larger countries.

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Annex 1. Sample ecosystem capital accounts

Table A1

Ecosystem capital accounts: land cover stocks and flows account

Table A1: Ecosystem capital accounts: land cover stocks and flows account

Land Cover Ecosystem Classes (LCEU) / Land cover stocks and flows (lf)		01 Urban and associated developed areas	02 Homogeneous herbaceous cropland	03 Agriculture plantations, permanent crops	04 Agriculture associations and mosaics	05 Pastures and natural grassland	06 Forest tree cover	07 Shrubland, bushland, heathland	08 Sparsely vegetated areas	09 Natural vegetation associations and mosaics	10 Barren land	11 Permanent snow and glaciers	12 Open wetlands	13 Inland water bodies	14 Coastal water bodies and inter-tidal areas	TOTAL	Sea (interface with land)
Opening Stock																	
Consumption of land cover																	
lf1	Artificial development																
lf2	Agriculture development																
lf3	Internal conversions, rotations																
lf4	Management and alteration of forested land																
lf5	Restoration and development of habitats																
lf6	Changes of land-cover due to natural and multiple causes																
lf7	Other land cover changes n.e.s. and revaluation																
Total consumption of land cover																	
Formation of land cover																	
lf1	Artificial development																
lf2	Agriculture development																
lf3	Internal conversions, rotations																
lf4	Management and alteration of forested land																
lf5	Restoration and development of habitats																
lf6	Changes of land-cover due to natural and multiple causes																
lf7	Other land cover changes n.e.s. and revaluation																
Total formation of land cover																	
Net change in land cover (formation - consumption)																	
No change																	
Closing Stock																	

Table A2

Ecosystem carbon account (simplified version, basic resource account)

Table A2: Ecosystem carbon account (simplified version, basic resource account)

		Ecosystem types											
	SEEA-ENCA land cover	*LCEU 1*	*LCEU 2, 3, 4*	*LCEU 5*	*LCEU 6*	*LCEU 7, 8, 9, 10, 11, 12*	*LCEU 12*	*LCEU 13, 14*	**Total inland and coastal ecosystems**	**Open sea, oceans**	**Atmosphere**	**Total Ecosystem**	***Supply & use system***
	IPCC land use	*Settlements (SL)*	*Cropland (CL)*	*Grassland (GL)*	*Forest Land (FL)*	*Other Land (OL)*	*Wetlands (WL)*	*Water bodies, rivers*					
I. Ecosystem Carbon Basic Balance													
C1	**Opening Stocks**												
C2.3	*NPP (Net Primary Production)*												
C2.4	*Secondary ecosystem repiration (heterotrophic)*												
C2.a	NEP (Net Ecosystem Production) = C2.3-C2.4												
C2.b	Secondary biocarbon resource												
C2	**Total inflow of biocarbon (gains) = C2.a+C2.b**												
C3.a	Harvest of agriculture crops, wood & other vegetation												
C3.b	Withdrawals of secondary biocarbon												
C3	**Total withdrawals of biocarbon = C3.a+C3.b**												
C4	**Net indirect anthropogenic losses of biocarbon & biofuel combustion**												
C5	**Total use of ecosystem biocarbon = C3+C4**												
C6	**Natural processes and disturbances**												
C7	**Total outflow of biocarbon (losses)**												
C8.1	**NECB 1 [Flows] = Inflows - Outflows = C2-C7**												
C8.2	**Adjustment and reappraisals**												
C8.3	**NECB 2 [Stocks] = Change of biocarbon stocks**												
C9	**Closing Stocks = C1+C8.1+C8.2 or = C1+C8.3**												
II. Accessible Resource Surplus													
C2	***Total inflow of biocarbon (gains) = C2.a+C2.b***												
C10	***Accessibility net correction***												
C11	**Net Ecosystem Accessible Carbon Surplus = C2 + C10**												
III. Total Uses of Ecosystem Bio and Geo-Carbon													
C5	**Total use of ecosystem biocarbon = C3+C4**												
C12.1	*Imports of biocarbon/ commodities & residuals content*												
C12.2	*Exports of biocarbon/ commodities & residuals content*												
C12a	**Direct use of biocarbon = C5+C12.1**												
C12.3	*Virtual biocarbon embedded into imported commodities*												
C12c	**Biocarbon requirement = C12a+C12.3**												
C12b	**Domestic consumption of biocarbon = C5+C12.1-C12.2**												
C13a	**Direct use of fossil carbon**												
C13.3	*Virtual fossil carbon embedded into used commodities*												
C13b	**Fossil carbon requirement = C13a+C13.3**												
C14a	**Total Carbon Direct Use = C12a+C13a**												
C14b	**Total Carbon Requirement = C12c+C13b**												
IV. Table of indexes of intensity of use and ecosystem health													
C11	Net Ecosystem Accessible Carbon Surplus = C2 + C10												
C5	Total use of ecosystem biocarbon = C3+C4												
SCU	**Sustainable intensity of carbon use = C11/C5**												
CEH	**Composite ecosystem biocarbon health index**												
CIP	**Biocarbon ecological internal price = AVG(SCU+CEH)**												

Table A3

Ecosystem water account

Table A3: Ecosystem water account

Code	Item	Lakes & reservoirs: Artificial reservoirs	Lakes & reservoirs: Lakes	River systems: Rivers	River systems: Canals	Sub-total river systems	Glaciers, snow & ice	Ground water	Land/ Soil/ Vegetation: Open wetlands	Sub-total L/S/V	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
I. Ecosystem Water Basic Balance															
W1	**Opening Stocks**														
W21	Precipitations														
W22	Internal spontaneous water transfers received														
W23	Natural inflows from upstream territories														
W24	Artificial inflows of water from other territories and the sea														
W25	Waste water returns/discharge to inland water assets														
W26	Other returns of abstracted water to inland water assets														
W2	**Total increase of stocks of water = SUM(W21 to W26)**														
W31	Spontaneous actual evapo-transpiration														
W32	Internal spontaneous water transfers supplied														
W33	Natural outflows to downstream territories and the sea														
W34	Abstraction from water assets														
W35	Abstraction/collection of precipitation water and urban runoff														
W36	Actual evapo-transpiration induced by irrigation														
W37	Evaporation from industry and other uses														
W38	Artificial outflow of water to other territories and the sea														
W39	Other change in volume of stocks and adjustment (+ or -)														
W3	**Total decrease in stocks of water = SUM(W34 to W39)**														
W4a	***Available Effective Rainfall = W21-W31***														
W4	**Net Ecosystem Water Balance (NEWB) = W2-W3**														
W5	**Closing Stocks = W1+W4**														
II. Accessible basic water resource surplus															
W2a	***Total natural renewable water resources (TNWR) = W21+W22+W23***														
W2b	***Total secondary water resources = W24+W25+W26***														
W33	Natural outflows to downstream territories and the sea														
W6	**Net primary & secondary water resource = W2a+W2b-W32-W33**														
W71	Total adjustment of natural renewable water resources (+ or -)														
W39	Other change in volume of stocks and adjustment (+ or -)														
W7a	***Exploitable natural water resources = W2a+W71+W39***														
W72	Total adjustment of secondary renewable water resources														
W7b	***Exploitable secondary water resources = W2b+W72***														
W7	**Net Ecosystem Accessible Water Surplus = W7a+W7b**														
III. Total water uses															
W81	Abstraction from water assets (W81 = W34)														
W82	Agriculture and forestry 'green water' use = W311+W312														
W83	Collection of precipitation water (rainwater harvest) (W84 = W351)														
W84	Abstraction/collection of urban runoff (W84 = W352)														
W8	**Total Use of Ecosystem Water**														
W91	Artificial inflows of water from other territories (W91=W241)														
W92	Withdrawal of water from the sea (W92=W242)														
W93	Use of water received from other economic units														
W94	Re-use water within economic units														
W95	Imports of Water/ commodities & residuals content														
W96	Exports of Water/ commodities & residuals content														
W9	**Direct Use of Water = W8+W91+W92+W93+W94+W95**														
W10	**Domestic Consumption of Water = W9-W96**														
W11	Virtual water embedded into imported commodities														
W12	**Total Water Requirement = W9+W11**														

Table A4

Ecosystem ecological integrity and functional services accounts

Table A4: Ecosystem ecological integrity and functional services accounts

		Ecosystem Accounting Unit Types																
		Socio-Ecological Landscape Units (SELU)							Marine Coastal Socio-Ecological Units (SELU_MCU)			TOTAL TERRESTRIAL & COASTAL ECOSYSTEMS	River System Units (RSU)					TOTAL RIVERS
		Urban/ developed areas (UR)	Large scale agriculture (LA)	Agriculture mosaics (AM)	Grassland (GR)	Forest cover (FO)	Other natural land cover (NA)	No dominant land cover (ND)	MC GR Seagrass	MC CR Coral reefs	MC NA Other		RS1 Large rivers, main drains	RS2 Medium rivers, main tributaries	RS3 Small rivers	RS4 Brooks, small streams	RS5 Canals	
I. Basic balances																		
I.1 Basic land cover accounts [km2]																		
LC01	**Urban and associated developed areas**																	
LC02	**Homogeneous herbaceous cropland**																	
LC03	**Agriculture plantations, permanent crops**																	
LC04	**Agriculture associations and mosaics**																	
LC05	**Pastures and natural grassland**																	
LC06	**Forest tree cover**																	
LC07	**Shrubland, bushland, heathland**																	
LC08	**Sparsely vegetated areas**																	
LC09	**Natural vegetation associations and mosaics**																	
LC10	**Barren land**																	
LC11	**Permanent snow and glaciers**																	
LC12	**Open wetlands**																	
LC13	**Inland water bodies**																	
LC14	**Coastal water bodies and inter-tidal areas**																	
LC15	**Sea (interface with land)**																	
LC1	**Opening stock of land cover**																	
LF1	**Artificial development**																	
LF2	**Agriculture development**																	
LF3	**Internal conversions, rotations**																	
LF4	**Management and alteration of forested land**																	
LF5	**Restoration and development of habitats**																	
LF6	**Changes due to natural and multiple causes**																	
LF7	**Other land cover changes n.e.s.**																	
LF/C	**Consumption of land cover**																	
LF1	**Artificial development**																	
LF2	**Agriculture development**																	
LF3	**Internal conversions, rotations**																	
LF4	**Management and alteration of forested land**																	
LF5	**Restoration and development of habitats**																	
LF6	**Changes of land-cover due to natural and multiple causes**																	
LF7	**Other land cover changes n.e.s.**																	
LF/F	**Formation of land cover**																	
LC01	**Urban and associated developed areas**																	
LC02	**Homogeneous herbaceous cropland**																	
LC03	**Agriculture plantations, permanent crops**																	
LC04	**Agriculture associations and mosaics**																	
LC05	**Pastures and natural grassland**																	
LC06	**Forest tree cover**																	
LC07	**Shrubland, bushland, heathland**																	
LC08	**Sparsely vegetated areas**																	
LC09	**Natural vegetation associations and mosaics**																	
LC10	**Barren land**																	
LC11	**Permanent snow and glaciers**																	
LC12	**Open wetlands**																	
LC13	**Inland water bodies**																	
LC14	**Coastal water bodies and inter-tidal areas**																	
LC15	**Sea (interface with land)**																	
LC2	**Closing stock of land cover**																	
I.2 Basic river systems account [srkm]																		
RS1	**Opening basic stock of rivers**																	
RSF1	Change of due to water use and rivers management																	
RSF2	Change due to natural causes																	
RSF	**Change in river basic stocks**																	
RS2	**Closing basic stock of rivers**																	

Table A5

Ecosystem ecological integrity and functional services accounts / accessibility, access and ecosystem health index

Table A5: Ecosystem ecological integrity and functional services accounts / accessibility, access and ecosystem health index

		Ecosystem Accounting Unit Types																	
		Socio-Ecological Landscape Units (SELU)							Marine Coastal Socio-Ecological Units (SELU MCU)				River System Units (RSU)						
		Urban/ developed areas (UR)	Large scale agriculture (LA)	Agriculture mosaics (AM)	Grassland (GR)	Forest cover (FO)	Other natural land cover (NA)	No dominant land cover (ND)	MC GR Seagrass	MC CR Coral reefs	MC NA Other	TOTAL TERRESTRIAL & COASTAL ECOSYSTEMS	RS1 Large rivers, main drains	RS2 Medium rivers, main tributaries	RS3 Small rivers	RS4 Brooks, small streams	RS5 Canals		TOTAL RIVERS
II. Accessible ecosystem infrastructure potential																			
LC1	**Opening stock of land cover in km2**																		
LEP_avg	***Average LEP composite index by km2***																		
NLEP1	**Net Landscape Ecosystem Potential = LC1 x LEP_avg**																		
RS1	**Opening stock of rivers in standard-river-km**																		
REP_idx	***REP composite index***																		
NREP1	**Net River Ecosystem Potential = RS1 x REP_idx**																		
REP_avg	***Average NREP by km2***																		
LREP1	**Landscape River Ecosystem Potential = LC1 x REP_avg**																		
TEIP1	**Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1**																		
CH_TEIP1	Change in ecosystem infrastructure potential due to land use																		
CH_TEIP2	Change in ecosystem infrastructure potential due to fragmentation																		
CH_TEIP3	Change in ecosystem infrastructure potential due to ecotones																		
CH_TEIP4	Change in ecosystem infrastructure potential due to other causes																		
CH_TEIP	**Change in Total ecosystem infrastructure potential = TEIP2 - TEIP1**																		
LC2	**Closing stock of land cover in km2**																		
LEP_avg	***Average Landscape Ecosystem Potential composite index by km2***																		
NLEP2	**Net Landscape Ecosystem Potential = LC2 x LEP_avg**																		
RS2	**Closing stock of rivers in standard-river-km**																		
REP_idx	***River Ecosystem Potential composite index***																		
NREP2	**Net River Ecosystem Potential = RS2 x REP_idx**																		
REP_avg	***Average NREP by km2***																		
LREP2	**Landscape River Ecosystem Potential = LC2 x REP_avg**																		
TEIP2	**Closing stock of ecosystem infrastructure potential =NLEP2+LREP2**																		
III. Overall access to ecosystem infrastructure functional services																			
TEIP1	**Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1**																		
AIP1	**Population local access to TEIP = sqrt(TEIP1xAIP13)**																		
AIP2	**Agriculture local access to TEIP = sqrt(AIP1xAIP23)**																		
AIP3	**Nature conservation local access to TEIP = sqrt(TEIP1xAIP31)**																		
AIP4	**Basin access to water regulating services = sqrt(AIP41xAIP42)**																		
AIP6	**Regional access to TEIP [tourism] = sqrt(TEIP1xAIP53)**																		
AIP7	**Global access of nature conservation services = sqrt(TEIP1xAIP71)**																		
IV. Table of indexes of intensity of use and ecosystem health																			
EIU	**Ecosystem infrastructure use intensity = TEIP2/TEIP1**																		
EIH01	Change in threatened species diversity																		
EIH02	Change in species population																		
EIH03	Change in biotopes health condition																		
EIH04	Change in species specialisation index																		
EIH05	Composite index of rivers species diversity, mean value by SELU																		
EIH06	Other indicator																		
EIH07	Other indicator																		
EIH	**Composite ecosystem health index**																		
EIIP	**Annual change in ecosystem ecological integrity = AVG (EIU, EIH)**																		