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Project funded by the European Union
STATISTICS MAURITIUS

System of Environment-Economic Accounts (SEEA)

Experimental Ecosystems/Natural Capital Accounts of Mauritius, 2000 – 2010

Preliminary results, 31 October 2013

The SEEA "Experimental Ecosystem Accounts" have been endorsed by the UN Statistical Commission at its meeting of February 2013. Although not enough experience exists so far to adopt an international standard of the level of the SNA 2008 (System of National Accounts) or of the SEEA Part1 of 2012 (so-called "Central Framework"), the SEEA-EEA presents a conceptual framework prone at giving some guidance for countries willing to progress in this area. Up to now, experiments of ecosystem accounting are ongoing in Europe (27 countries, project steered by the European Environment Agency), in Australia, in Canada and are in project in several places. One of the motivations of the UNSC decision is the demand for such accounts in support to various assessments such as TEEB (The Economics of Ecosystems and Biodiversity - UNEP), WAVES (Wealth Assessment and Valuation of Ecosystem Services – The World Bank), and last but not least, the 2010 Aichi-Nagoya Strategy adopted by the Parties of the CBD which states that 'ecosystem and biodiversity values should be incorporated into 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 have decided to launch an experiment of ecosystems/natural capital accounts in the context of Implementation of the Small Island Developing States 'Mauritius Strategy' in the Eastern and Southern Africa and Indian Ocean (ESA-IO) region.

Limited in time, the project aimed at checking the feasibility of ecosystems/natural capital accounts using data presently available in Mauritius and assessing the first outcomes in terms of statistical quality and policy relevance.

Steered by Statistics Mauritius in relation to the IOC's Islands office, the project has involved stakeholders and information providers. The success obtained is due to a large extent to the positive contribution of the various institutions asked for data in their respective domains, to their advices and expertise as well as to SM's capacity to carry out an extensive collection. [1]

The main results

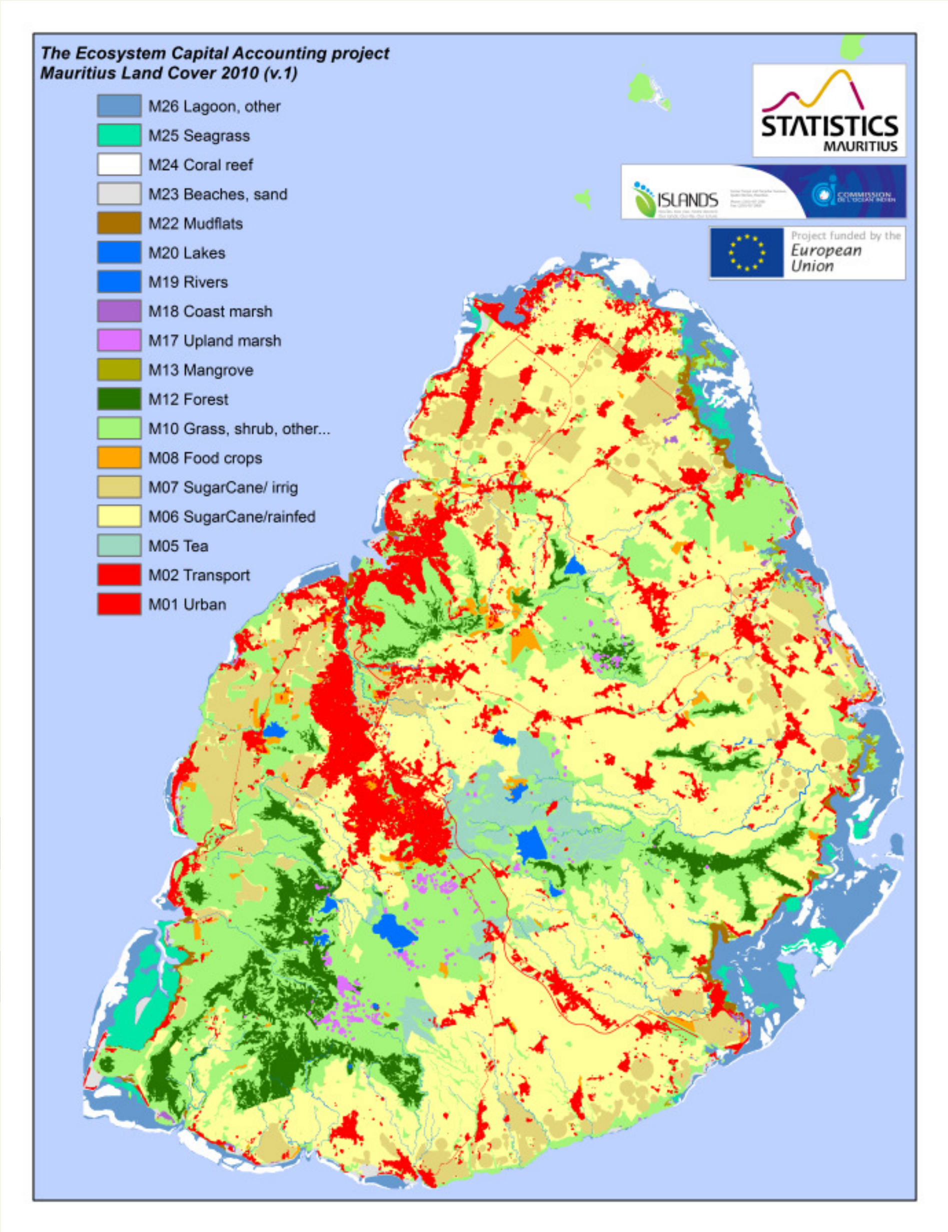
Beyond the proof of concept achieved by producing a first set of accounts for year 2010, and some elements for 2000, the first results present a certain interest. It has to be stated clearly at this stage that these results are provisional and require further validation and completion. Under theses reservations, an overview

[1] *Experimental Ecosystems/Natural Capital Accounts of Mauritius have been computed and the present report drafted by Jean-Louis Weber, Consultant for MWH Global, former Special Adviser on Economic-Environmental Accounting to the European Environment Agency and Honorary Professor, School of Geography of the University of Nottingham. It has been made possible by the invaluable support from Anand Sookun, Statistician at Statistics Mauritius and international expert in environmental and energy statistics and a PhD candidate, who has collected the abundant data and statistics used and provided constant guidance. Emil D. Ivanov. Ph D student at Nottingham University, UK, has kindly accepted to provide basic data and assessments for the biomass/bio-carbon account.*

of the first SEEA-Experimental Ecosystems/Natural Capital Accounts of Mauritius can be presented.

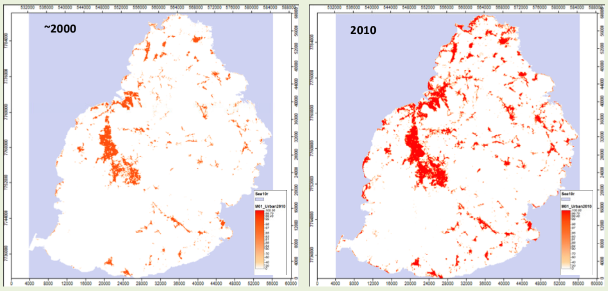
1. Land cover and changes from 2000 to 2010

Land cover is the basic infrastructure for implementing ecosystem accounts. As no land cover map fit for accounting was available, one had to be produced using the excellent geographical datasets on buildings, roads, forests and environmentally sensitive areas.



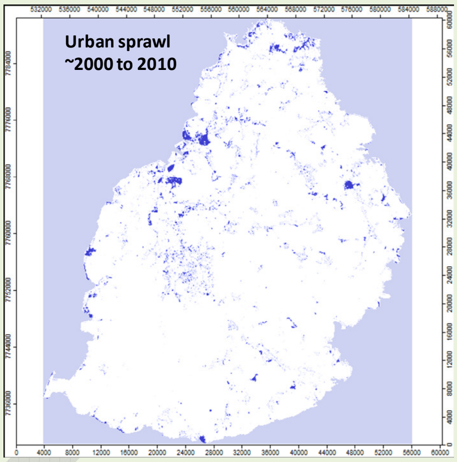
Land use/land cover changes are difficult to record and map at this stage because not such information exists for the past. This important information could be obtained by a series of land cover maps produced from high resolution satellite images and calibrated with the 2010 land cover image. It would allow as well improving some classes in the map such as agriculture, grassland and shrubland. However, a test could be carried out by producing a map of urban areas using an earlier version of the urban database updated by SM with the LAVIMS ortho-photographs of 2008 and subsequent field surveys. As long as on the one hand the date of the old database is not certain (2000 or before) and as on the other has important improvements have been done since 2008 (resulting into the present 2010 map) it is certain that the change detected are overestimated.

Urban and associated areas circa 2000 and 2010:



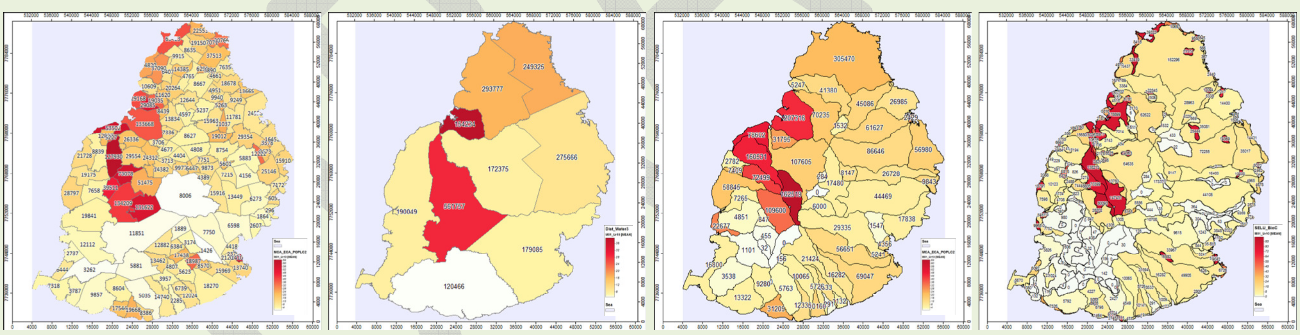
This first account of land cover change is fragile and has to be interpreted with care, although the general trends make sense.

The map obtained by subtraction of 2000 data from 2010's shows intensity and spatial distribution of urban sprawl.



The land cover data are stored using geographical datasets which use grids (10m x 10m and 100m x 100m) at the most detailed level. These grids allow computing statistics and producing 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 relevant zoning.

Examples of statistical maps of Urban and associated areas land cover 2010 produced for (from left to right): (1) MCA/VCA, (2) Districts, (3) River basins and (4) Socio-Ecological Landscape Units, the specific analytical statistical units for ecosystem accounting.



In tabular format, land cover accounts 2000-2010 by districts read:

Land cover stock and change account/ urban sprawl — 2000 2010 - 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

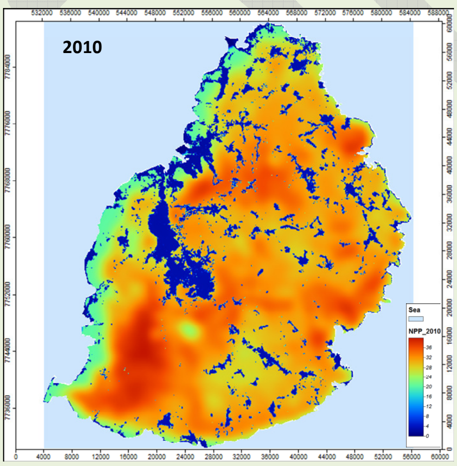
2. The biomass-carbon account

This account shows the capacity of the ecosystems to produce biomass and the way it is used by harvests or sometimes sterilised by artificial developments or destroyed by soil erosion or forest fires. Biomass is important resource, food, energy, fibre materials. As food, biomass has to be shared by human beings with biodiversity; if it is not done, the capacity of the ecosystem to reproduce biomass is degraded, an unsustainable economic path where only artificial inputs can temporarily overcome the deficit. Because it is part of the policies on climate change mitigation, biomass is accounted in carbon.

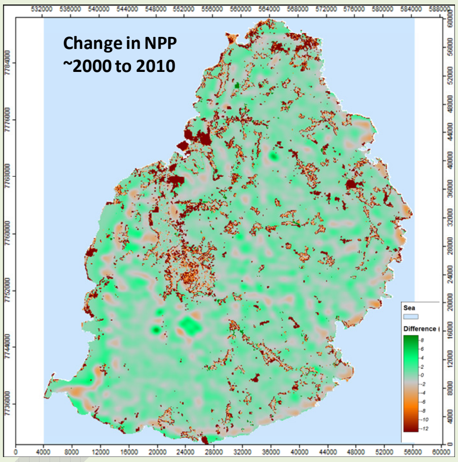
Ecosystem accounts are established for statistical units defined as areas. The stocks of biomass and the natural primary production by photosynthesis are assessed with in situ measurements (samples) and satellite images. The harvests of crops and timber being generally reported by administrative units, accounts need to resample these statistics to the land where harvests take place.

The carbon account starts from the measurement of the Net Primary Production (NPP) by vegetation. It was done in Mauritius using standard international assessments provided by the US NASA and fine tuned with higher resolution data on photosynthesis (vegetation index) and land cover.

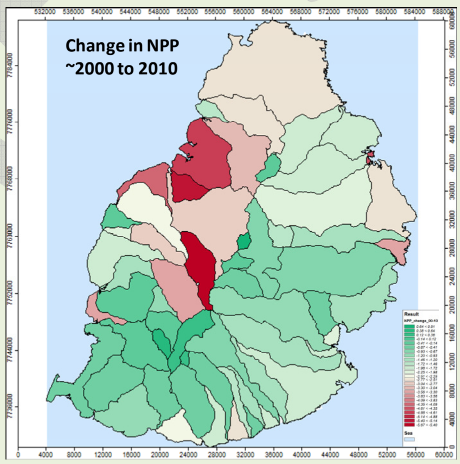
The NPP assessment shows for 2010 the following distribution (the colours reflect tons by ha):



The assessment of the NPP change ~2000 to 2010 shows that the overall situation is contrasted with local improvements and a severe impact of urban sprawl.

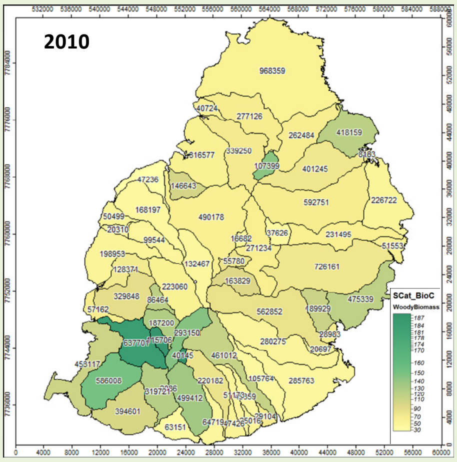


The visualisation of NPP change by river basins provides an interesting hint on the overall process with clear positive values in mountain areas, intermediate values in basins where agriculture is predominant and important drops where urban development has taken place. *[N.B. All these numbers need further validation and are presented only to give a sense of the information delivered by the accounts]*



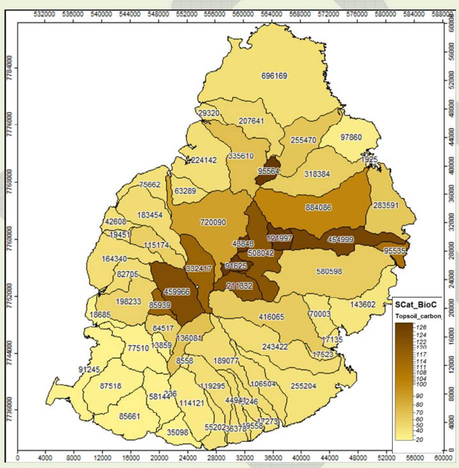
In the biomass/bio-carbon account, flows explain changes in stocks, the most important of them been trees (and to a smaller extent shrubs) and soil. The stocks of woody biomass have been estimated by combining satellite observations (MODIS VCF) and FAO forest statistics (FRA2010).

Results for stocks of woody biomass 2010 are as follows (in tons of carbon):



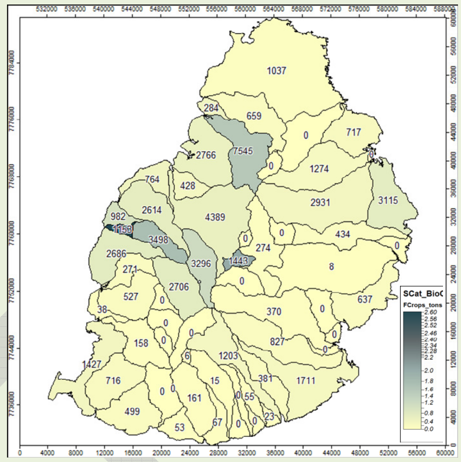
Stocks of soil carbon have been estimated in a coarse way using the ORSTOM map of 1984 and the FAO world database on soil. It is a first assessment which shows the variability of soil regarding carbon organics contents, a good proxy for fertility. Accounting for change in soil carbon beyond losses due to urban sprawl will require more precise data.

The soil carbon first estimation is presented on the following statistical map:

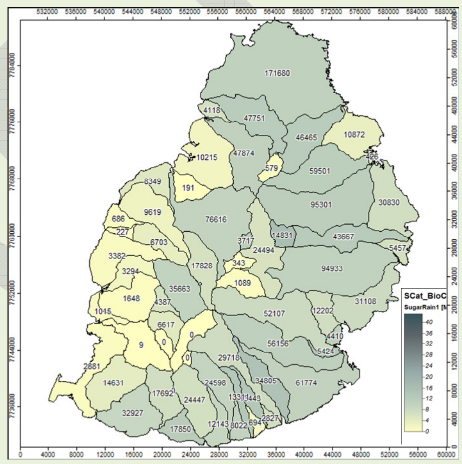


Regarding harvests, only agriculture has been considered. In absence of spatially explicit statistics, national statistics have been distributed to agriculture lands cover. Mean yields have been estimated separately for irrigated sugar cane, rainfed sugar cane, tea, potatoes from sugar cane fields, family gardens and other food crops. These estimations are certainly coarse but constitute a starting point for further improvements with better input data. As example, the estimations are, for:

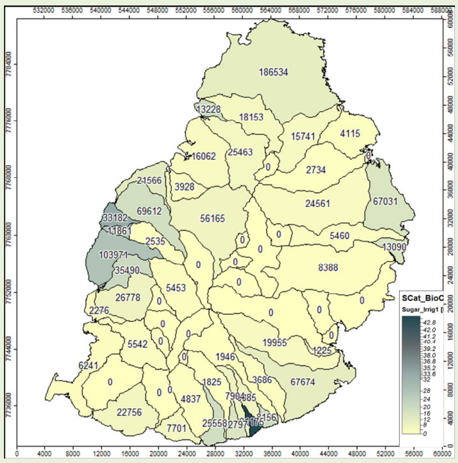
Total food harvest 2010 (incl. family gardens & cane fields secondary crops), (tons)



Sugarcane harvest, rainfed crops, 2010 (tons):



Sugarcane harvest, irrigated crops, 2010 (tons):



Estimations of soil respiration (decomposers) have been tempted, and losses of bio-carbon in fires or soil erosion recorded per memory. However the biomass/bio-carbon account could completed without a statistical adjustment to close the gap between the calculation of the Net Ecosystem Carbon Balance from positive and negative flows on the one had and difference between final and opening stocks. Under these reserves, the Net accessibility of bio-carbon and the index of intensity of use could be estimated.

Simplified bio-carbon accounts by districts, 2000 — 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	**385900**	**500654**	**937618**	**748768**	**767475**	**533500**	**691312**	**777509**	**87942**	**5430677**
Removals, harvests	78189	107662	129251	67005	107613	41993	104669	97945	1880	**736207**
Wood removals										**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 cops	*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 decrease (fire, erosion…)	13973	21484	44897	45161	32395	36534	37254	36095	4299	**272091**
Soil/decomposers respiration v2	289636	366746	757708	632973	624227	449757	546508	641180	80375	**4389110**
Net Ecosystem Carbon Balance 1 (flows)	***-9302***	***-35090***	***-60399***	***-36557***	***992***	***-27282***	***-19532***	***-15331***	***-5135***	**-207636**
Statistical adjustment	12336	32764	42693	19006	-20198	10970	-8047	-5314	5259	**89470**
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	**89997**	**96492**	**101805**	**61687**	**125035**	**40148**	**97693**	**100355**	**2555**	**715765**
Change in stocks in the 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 (-)	289636	366746	757708	632973	624227	449757	546508	641180	80375	**4389110**
Index of intensity of use of bio-carbon	**115**	**90**	**79**	**92**	**116**	**96**	**93**	**102**	**136**	**97**

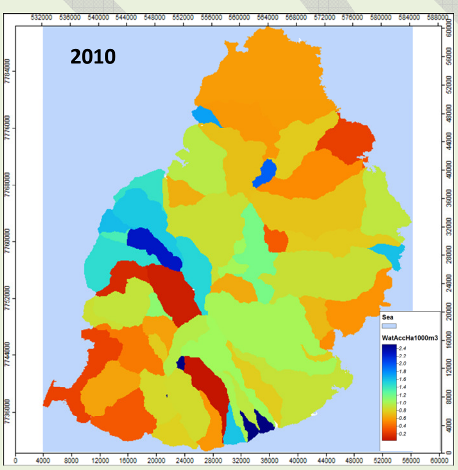
Simplified bio-carbon accounts by districts, 2010 — Tons of carbon

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 removals										**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 cops	*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 decrease (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. The ecosystem water account

This account can be considered as an extension of the SEEA-Water account. The main difference is that water availability is assessed ecosystem by ecosystem on a strict basis, deducting water which is not exploitable (e.g. in case of floods) alongside FAO AQUASTAT recommendations. The ecosystem water accounts are established by river basins and sub-basins where the hydrological system can be described consistently. Stocks of water are mainly aquifers and lakes/reservoirs, which play important role in Mauritius. Primary input data relate to rain and actual evapotranspiration. Their difference is the effective rainfall which is adjusted from aquifers recharge and runoff (springs) to calculate surface runoff. Once taken into account water uses (mainly municipal uses and irrigation) and water transfers from and or to reservoirs, it is possible to estimate rivers runoff and to check the results of the calculation against monitoring data from gauging stations. This is what has been done for ecosystem water accounts. The result of this lengthy exercise is an assessment of the water which is accessible by river basins which makes possible a comparison with the actual water abstraction and the calculation of a stress index related to water consumption. Despite gaps at this stage in data availability (in particular meteo and detailed transfers between reservoirs), the first assessment of accessible water shows uneven situations considering irrigated sugar cane, with a situation more favourable in the central western area than in the north (which need to be fed for part by the Midlands reservoir up to 41 Mm3 per year).

Accessible water, mean amount by ha, 10^3 m3

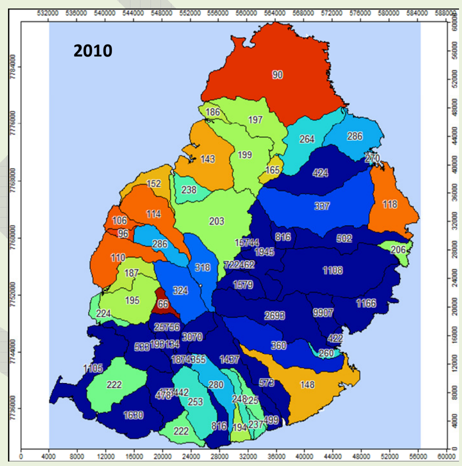


Considering water stress (next statistical map), the picture is somehow different. The Water Intensity of Use Index is the ratio between Accessible Resource and Total Abstraction of Water.

The map reads that values below 100 reflect a structural deficit (which is clearly the case in the northern catchment…).

Values between 100 and 120 seem to reflect a more balanced situation but some vulnerability to climate variations and / or a dependency from external supply cannot be excluded. It is the case of basins where irrigated agriculture is widespread.

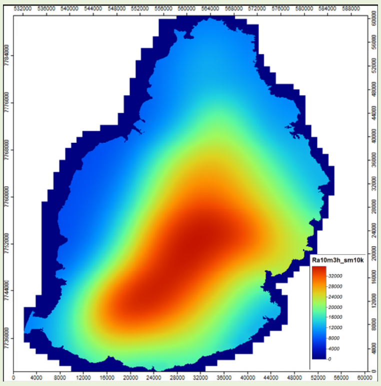
Catchments beyond 150 have certainly an exceeding position despite a low (but sufficient) accessible resource (e.g. in the South West).



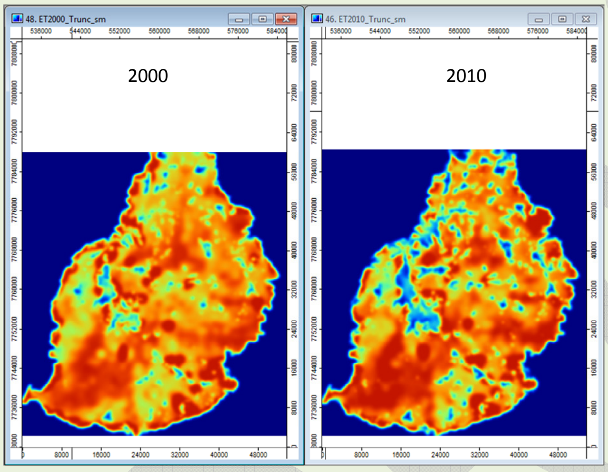
[NB: These results are experimental and require further validation and completion as well as clarification regarding transfers from reservoirs.]

The water account by river basins is an interesting work on data integration.

Considering rainfall, the limited monitoring data available have lead to coarse estimations based on mean isohyets and a small number of monitoring stations. This is probably the source of some of the anomalies detected further on in the accounts. The input rainfall data have, after being smoothed to avoid unnecessary border effect between isohyets have this format (m3/ha):

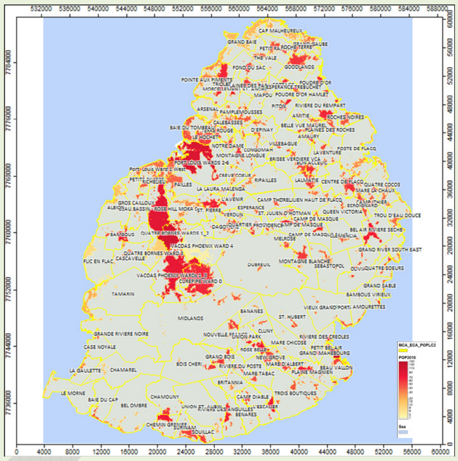


Evapotranspiration (actual) has been estimated from the so-called MODIS16A3 product reprojected from sinusoidal to UTM and corrected of border effects with the sea. Final results seem satisfactory when comparing ETA and vegetation images.

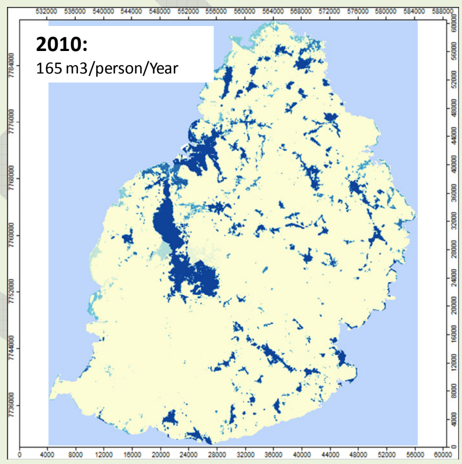


As a general remark, the assessment of ETA from this source give significantly higher values than the 30% of rainfall default value commonly accepted and used in the national SEEA-Water accounts. While the default value used results in an ETA of 1100 Mm3, the MODIS assessment leads to 2000 Mm3, closer to the FAO AQUASTAT estimation of 1800 Mm3.

In absence of sufficient details, estimations have been done in the ecosystem water account for irrigation (total SEEA-W amount distributed in proportion of irrigated surfaces), abstraction from aquifers (proportionally to the number if boreholes) and use by population. In this last case, population has in a first step been redistributed from statistics by MCA/VCA to the urban land cover map (persons by 1 ha cells).

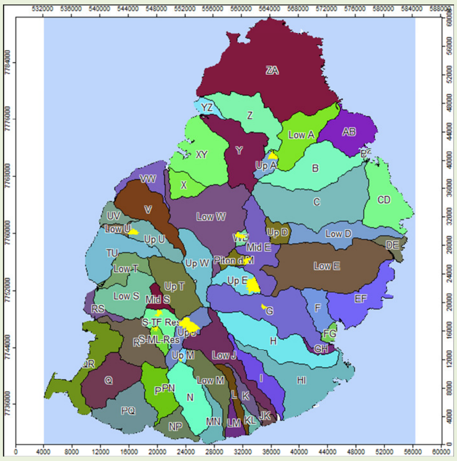


Then, mean water use per person has been calculated from national data (155 m3/person in 2000, 165 in 2010), which results in the following statistical map:



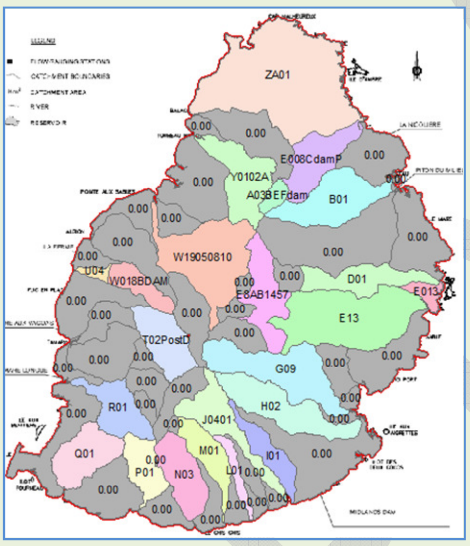
One particular difficulty in compiling the accounts by river basins related to the incomplete documentation of reservoirs management. Despite abundant details on the reservoirs themselves, the main issue was their incompleteness regarding the destination of their yields. With the exception of the transfers between the Midlands and La Nicoliere reservoirs, little information was given of where water is going. Therefore, transfers between basins have not been taken in a satisfactory way and will need being revised.

River Catchments/Sub-Catchments and Lakes (in yellow)



Finally, the water balances by sub-catchments have been integrated which lead to a first calculation of rivers runoff. This accounting calculation has been cross-checked with the outcome of gauging station selected by the Mauritius Water Resource Unit and allocated to river-basins.

<u>Rivers gauging stations representative of river basins</u>



With exception of few anomalies to be clarified, the final check up has given acceptable results several good matches. There is definitely room for improvement of the water account.

Water quality data exist but were not sufficiently available and detailed to produce at this stage the water quality account.

The tables of simplified ecosystem water accounts by districts are aggregations of accounts by sub-basins. The work are been carried out for 2010 but 2000 is just an estimation with limited inputs (rainfall, evapo-transpiration, and municipal and irrigation uses).

An interesting finding is that simple statistical aggregations and means hide to a large extent possible issues. This would imply 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 be > or = to 100. The first decile value will be used to represent the overall situation of an aggregated area. Checking first decile values of the index shows unsustainable situations in several districts.

Simplified water accounts by Districts, 2000 — **Mm3**

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_nb	*105*	*164*	*100*	*83*	*110*	*146*	*131*	*30*	*12*	*881*
River runoff districts coeff	*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**
Rivers 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**	

Simplified water accounts by Districts, 2010 — 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_nb	*105*	*164*	*100*	*83*	*110*	*146*	*131*	*30*	*12*	*881*
River runoff districts coeff	*35*	*20*	*150*	*150*	*100*	*100*	*80*	*100*	*20*	*755*
Lake 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
EvapoTranspitation (actual), total	155	199	367	290	338	224	308	326	40	2247
EvapoTranspitation (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**
Rivers 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**	

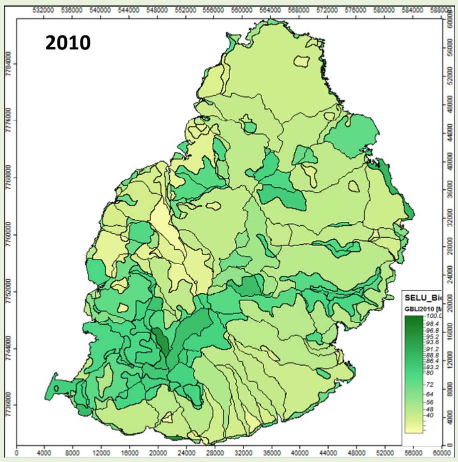
4. The systems and species biodiversity account

The systems and species biodiversity account is made of two accounts which describe the state of ecosystems green infrastructure (landscapes, rivers and sea coastal zones) on the one hand and changes in species biodiversity on the other hand.

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

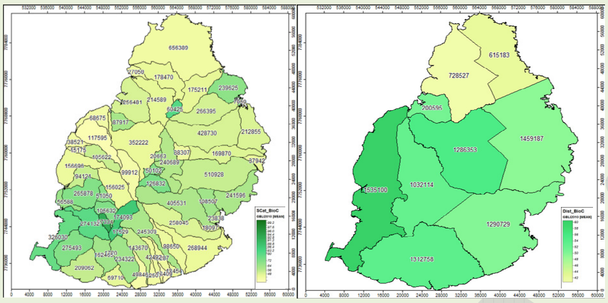
Following this methodology GBLI has been calculated for 2010 (scale from 10 to 100):

<u>Green Background Landscape Index 2010</u>



Highest GBLI values can be found in SELUs where forests, shrubs, grass and natural habitats are predominant, in particular in mountainous and land coastal areas. Low GBLI values correspond to urbanised areas and intermediate score reflect agriculture dominated catchments.

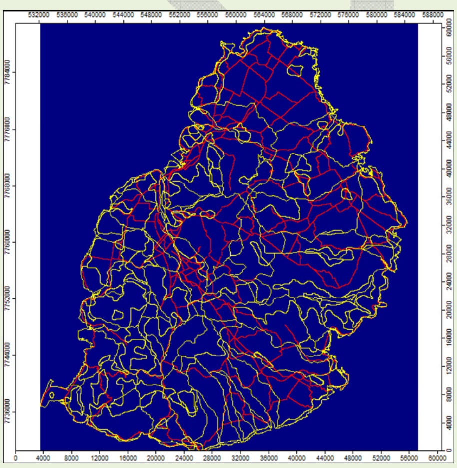
Accounts in GBLI weighted hectares have been produced by various geographical breakdowns. The maps below present accounts results (numbers) for rivers sub-basins and administrative districts. Colours relate to the mean GBLI index of each zone.



On top of GBLI, a first calculation of nLEP, the net Landscape Ecosystem Potential to deliver systemic ecosystem services – those intangible services (regulation, amenities…) which cannot be measured as tons of carbon or m3 of water but are assessed indirectly regarding . nLEP enhances GBLI by taking into accounts other elements of ecosystem landscape assessment such as the different nature value or quality of similar land cover types or their fragmentation.

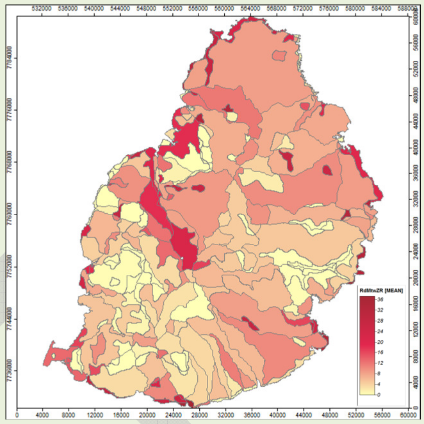
The present calculation of nLEP accounts integrates SELU's fragmentation by roads (motorway, roads A and B).

Fragmentation of SELUs by main roads (barrier effect)

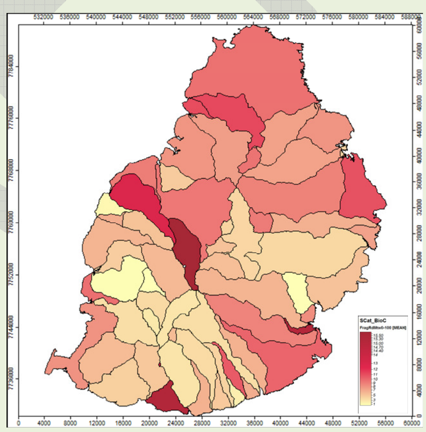


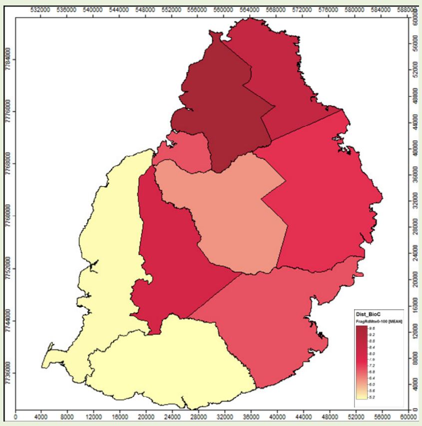
The GIS analysis results in the following fragmentation index by SELU's:

SELU Fragmentation index 0-100 as % of road corridors (100m pixels)



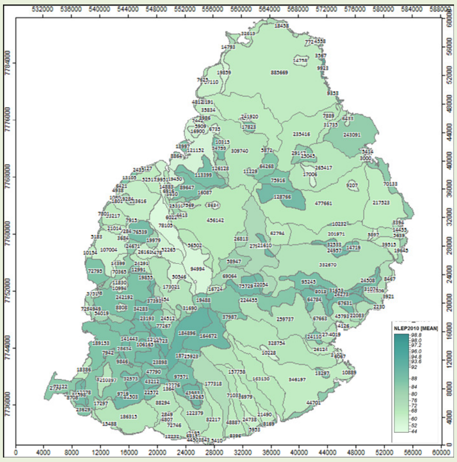
The same fragmentation index by river basins and districts reads:





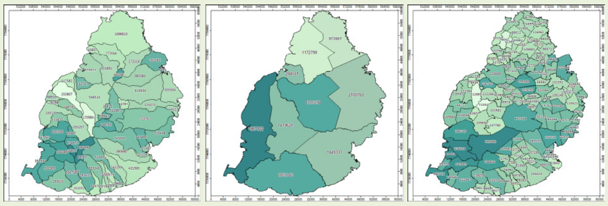
The combination of GBLI and of the fragmentation index gives the nLEP index which is used to compute the system biodiversity account in weighted hectares for 2010.

<u>NLEP, the Net Landscape Ecosystem Potential 2010 by SELU (values = weighted ha, legend: mean nLEP index)</u>



nLEP is important indicator of ecosystem capacity to deliver services. nLEP accounts can be computed at various scale.

NLEP 2010 by river basins, districts and MCA-VCA (values = weighted ha)



nLEP change provides first hint of ecosystem degradation or enhancement. It was not done at this stage because of missing information on the spatial coverage of sugar cane in the past. The current mutations in sugar cane industry have resulted in changes like abandonment of slope areas with consequences on landscapes without the inclusion of which nLEP (e.g. of 2000) would be very fragile index. It is important policy relevant information on ecosystem sustainable use and capacity to adapt to climate change.

The nLEP accounts of the green infrastructure are combined in a last step with indexes of change in species biodiversity. This could not be done at this stage.

Green Infrastructure Accounts

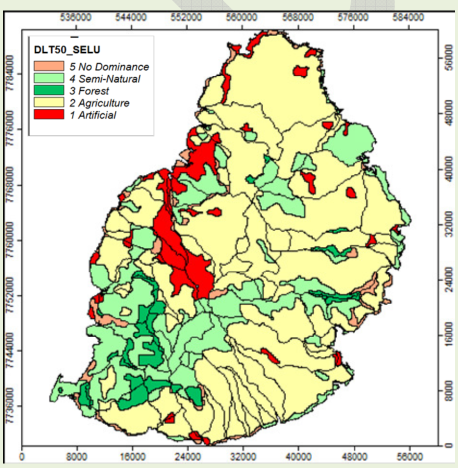
	Riviere du Rempart	Pamplemousses	Flacq	Moka	Grand Port	Plaines Wilhems	Black River	Savanne	Port Louis	**Total** / *Mean values*
AREA_ha	14703	18019	29826	23512	26134	19839	25558	24758	3976	186325
Indexes (0-100 value per ha)										
GBL 2000 index	*43.4*	*41.7*	*49.7*	*55.6*	*50.1*	*53.4*	*61.0*	*53.7*	*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. One may note that it is taking stock at this stage only of the impacts of urban sprawl. The important mutations of the sugar industry in the last decade have certainly had effects (probably positive and negative) which would be reflected by the nLEP account.

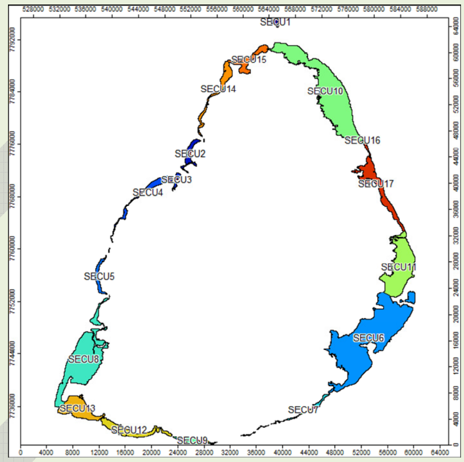
5. The ecosystem capital account of coastal sea

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

The first technical step in implementing accounts is the definition of the statistical entities for which accounts will be computed. For inland ecosystems, such entities are on the one hand the administrative entities or zones for which accounts will be produced: country, regions, districts, municipalities. On the other hand, ecosystem accounts must be built on analytical units which reflect the interaction of natural and socio-economic systems. They are elementary mappable ecosystem units extracted from the land cover map (forests, wetlands, agriculture areas, urban areas…), rivers basins for water assessment and in between, entities so-called socio-ecological systems in the literature. For the land ecosystems these units are defined as Socio-Ecological Landscape Units (SELU). One can note at this stage that the land coastal zones are obviously characteristic SELUs which because of the policy importance of the areas attract attention. The SELU for Mauritius have been map by combining the river basins and sub-basins limits which frame landscapes and the water cycle with a map of dominant landscape types derived from the land cover map. On the map below, it is noticeable that coastal zones can be identified although no specific zoning has been used so far:



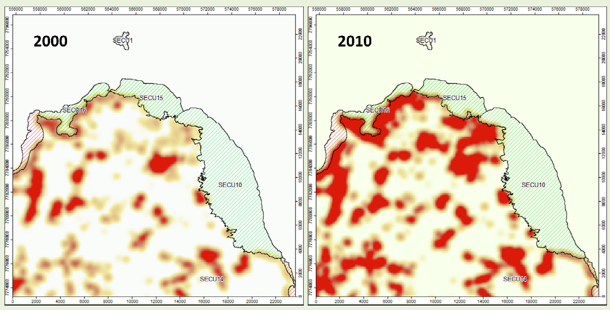
A similar approach has been undertaken out for marine coastal zones. This is definitely a first step but a (preliminary) map of Sea Ecosystem Coastal Units (SECU) could be produced on the basis of existing information and use for first accounts. As SELUs each SECU is given an ID which is used later on for accounting.

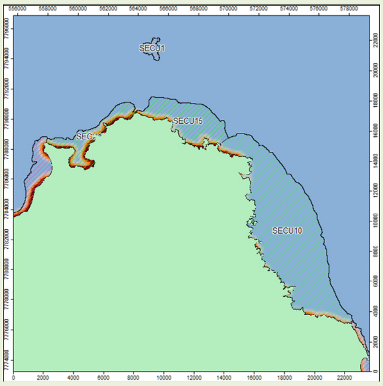


Not all data was accessible for the test but two accounts could be produced. The first one shows the pressure by the artificialisation of the coastline using the methodology of 'urban temperature' where artificial areas are smoothed in order to calculate values in the neighbourhood.

The 'urban temperature' other SECUs can be observed and change measured.

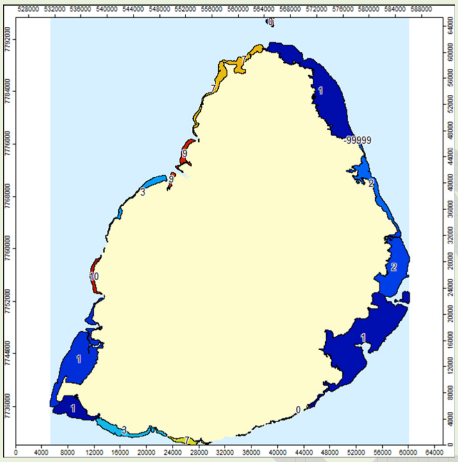
<u>Increase of 'urban temperature' on the coastal ecotone, 2000 to 2010</u>





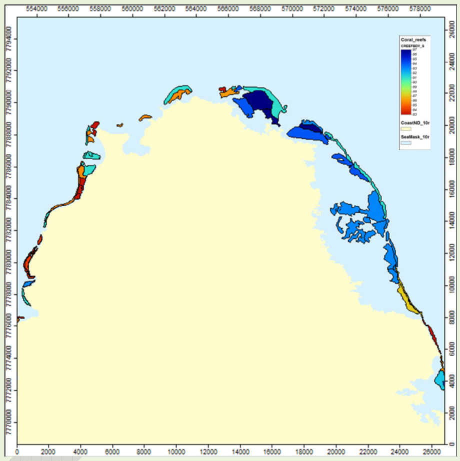
Accounts by SELUs show this result:

Mean increase of urban temperature on the coastal ecotone , 2000 to 2010, in points per ha on a scale from 0 to 100

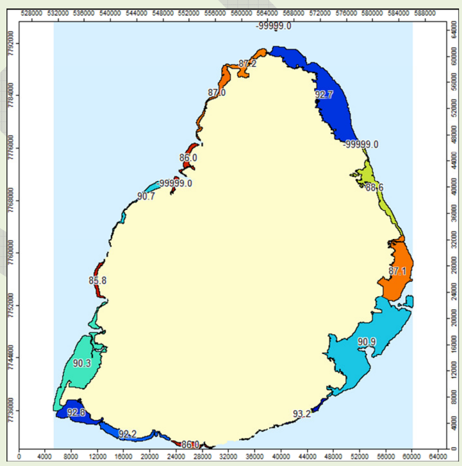


Another accounts has been done regarding the biodiversity status of SECU. The data source is the report on environmentally sensitive areas done in 2008 for the ministry of environment. For the demonstration, detailed measurements of vulnerability of coral reefs have been converted into an indicator of condition.

The coral reefs state index derived from the ESA assessment ranges from 80 to 96



In first instance and for a first hint, the index can be used to weight lagoons surface and compute an account of biodiversity status for Sea Ecosystem Coastal Units (based on the coral reefs index, mean values)



6. Calculation of Ecosystem Capability in ECU, experimental results based on 2010 (provisional) accounts and estimations for 2000

As a proof of concept, the ECA methodology for calculating Ecosystem Capability in a common currency called ECU for Ecosystem Capability Unit has been attempted. Again, the experimental character of the project and the provisional status of data, recalled several times in this report, must be underlined at this stage. As well, even though there might be doubts on the magnitude of ECU accounts, trends and spatial distribution are not unrealistic. This first attempt justifies fully a more important process in order to revise 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 for supplying more data in their respective domains as well as for validating the use made of these data and the results obtained).

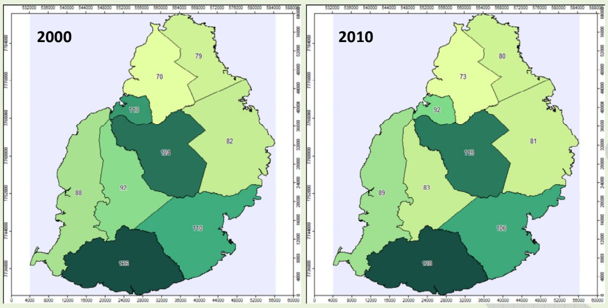
The first tentative assessment of ECU values for Mauritius shows an overall decline of 15% (probably over estimated) unevenly distributed among districts. Impacts of urban sprawl are well taken (Districts of Plaines Wilhems and Port Louis). The bad performance in the District of Moka could result from the way the water from the Midlands dam (developed during the period) has been recorded (this is an assumption which needs of course further validation).

Calculation of Ecosystem Capability in ECU, experimental results based on 2010 accounts and estimations for 2000	*Rivière du Rempart*	*Pamplemousses*	*Flacq*	*Moka*	*Grand Port*	*Plaines Wilhems*	*Black River*	*Savanne*	*Port Louis*	**TOTAL**
A - Inland ecosystems (Socio-Ecological Landscape Units)										
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**
B - Sea Ecosystem Coastal Units / Only for test with coaral reefs vulnerability index; 2000 = 100.										
Coral_reefs area ha	2222	658	1472	No coast	2167	No coast	1821	814	No reef	9154
Conventional coral reef stock (bio-carbon not available)= ha x 10	22220	6580	14720	No coast	21667	No coast	18210	8143	No reef	91540
SECU/ Lagoons area ha	61009	13244	45083	No coast	46136	No coast	45952	14540	537	226501
Coral_reefs Index 2000	100	100	100	No coast	100	No coast	100	100	100	
Coral_reefs Index 2010	92	87	88	No coast	91	No coast	91	94	100	
SECU/ Lagoons capability/coral reefs, 2000	2222000	658000	1472000		2166700		1821000	814300		9154000
SECU/ Lagoons capability, coral reefs 2010	2050327	570745.8	1291775.3		1975381.6		1653196.5	766500.99		8307927
Net change in Laggos Ecosystem Capability 2000-2010, in ECU, v0	-171673	-87254	-180225	0	-191318	0	-167803	-47799	0	-846073
Net change in lagoons Ecosystem Capability 2000-2010, in ECU, % v0	**-7.7**	**-13.3**	**-12.2**		**-8.8**		**-9.2**	**-5.9**		**-9.2**
C - Total Ecosystem Capability, inland and coastal sea										
Total Ecosystem Capability in ECU, 2000, v0	8976512	7437076	9838804	7638831	15871007	3684073	10389899	14423654	288508	78548364
Total Ecosystem Capability in ECU, 2010, v0	7962463	6629933	8339790	5959329	14003631	2501975	9394629	12323388	136714	67251850
Net change in Total Ecosystem Capability 2000-2010, in ECU, v0	-1014049	-807144	-1499014	-1679502	-1867376	-1182098	-995270	-2100266	-151794	-11296514
Net change in Total Ecosystem Capability 2000-2010, in ECU, % v0	**-11.3**	**-10.9**	**-15.2**	**-22.0**	**-11.8**	**-32.1**	**-9.6**	**-14.6**	**-52.6**	**-14.4**

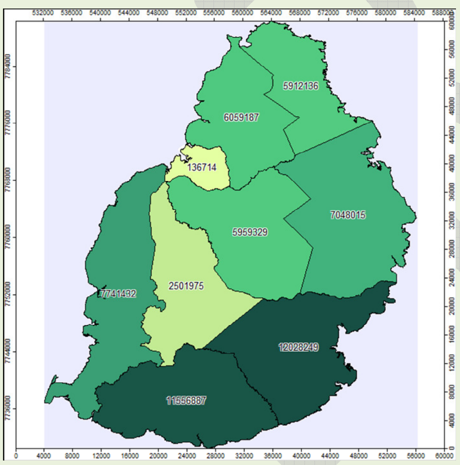
The spatial distribution by Districts of the results accounts in ECU for inland ecosystems shows interesting contrasts between potentials, pressures on these potentials and their degradation.

The first map(s) presents the composite index (based on bio-carbon/biomass, water and landscape indexes) which plays the role of a price in the valuation of ecosystem capability. Because of the importance of urban sprawl and insufficient data on agriculture, Plaines Wilhems and the Port Louis districts show the most important change.

Ecosystem Capital Capability (inland):
ECU mean prices by Districts, 2000 & 2010

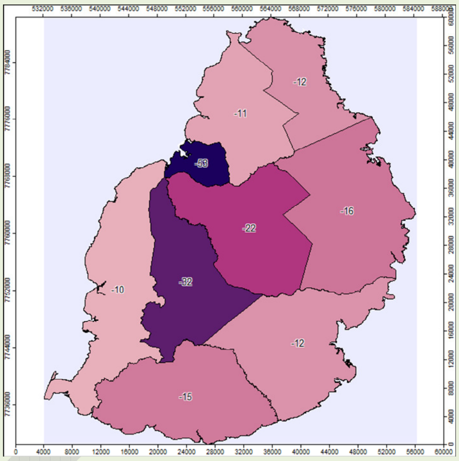


The map of the ecological values shows where potential or capabilities are.
Ecosystem Capital Capability (inland):
ECU Value by Districts, 2010



And the map of change 2000-2010 in % of 2000 shows where the losses of ecological values in ECU have been the more important.

Ecosystem Capital Capability (inland):
Change in ECU Value, % by Districts, 2000-2010



Conclusions

The purpose of the Ecosystems/Natural Capital Accounts study was to test the feasibility of the SEEA Part 2 on “Experimental Ecosystem Accounts”. The objectives related as much to methodology (proof of concept), to feasibility (short term results with existing data) and to policy relevance in the context of the strategy for sustainable development of a small island developing state. The first results presented in this report confirm that such accounts can be undertaken and will provide useful information.

The report is to some extent a summary. During the compilation process, amounts of data supplied by Statistics Mauritius, the Ministry of Environment, research agencies and technical services have been processed, harmonised and integrated. Detailed accounts have been produced, in particular by river basins and socio-ecological units. They are the basis for reporting for various geographical breakdowns (e.g. the inland coastal zone). The inclusion of sea coastal ecosystems in the application meets repeated policy requests and open the way for enhanced ecosystem based integrated coastal zones management.

<u>However, we should not forget that at this stage, accounts are provisional and should be used with care</u>. More has to be done and can be done without engaging in huge programmes. Firstly, the technology which was a cost constraint insurmountable in many circumstances has moved in swiftly the recent years towards the supply of free services. The data processing and analysis has been done in good conditions using open source free software packages[2]. More and more satellite images and derived products are made easily accessible for free. Web dissemination of statistics makes their use much easier.

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

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

One of them is the international one where beyond the general statistical requirements by the UN, an urgent policy demand for accounting has risen from climate change and biodiversity concerns (as illustrated by the 2010 Aichi Strategy of the Convention on Biological Diversity[3]), not to speak of the sustainable development goals reaffirmed in Rio in 2012.

As well, the scale at which these experimental accounts have been produced is very detailed with grids of reps. 10m and 100m when the accounts are for example produced in Europe use respectively grids of 100m and 1 km (which is also a suggestion of the SEEA). The feasibility of accounts at this scale make them candidates for implementation in the context of small islands – as well at the regional and local scales in larger countries.

[3] 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 […]."*