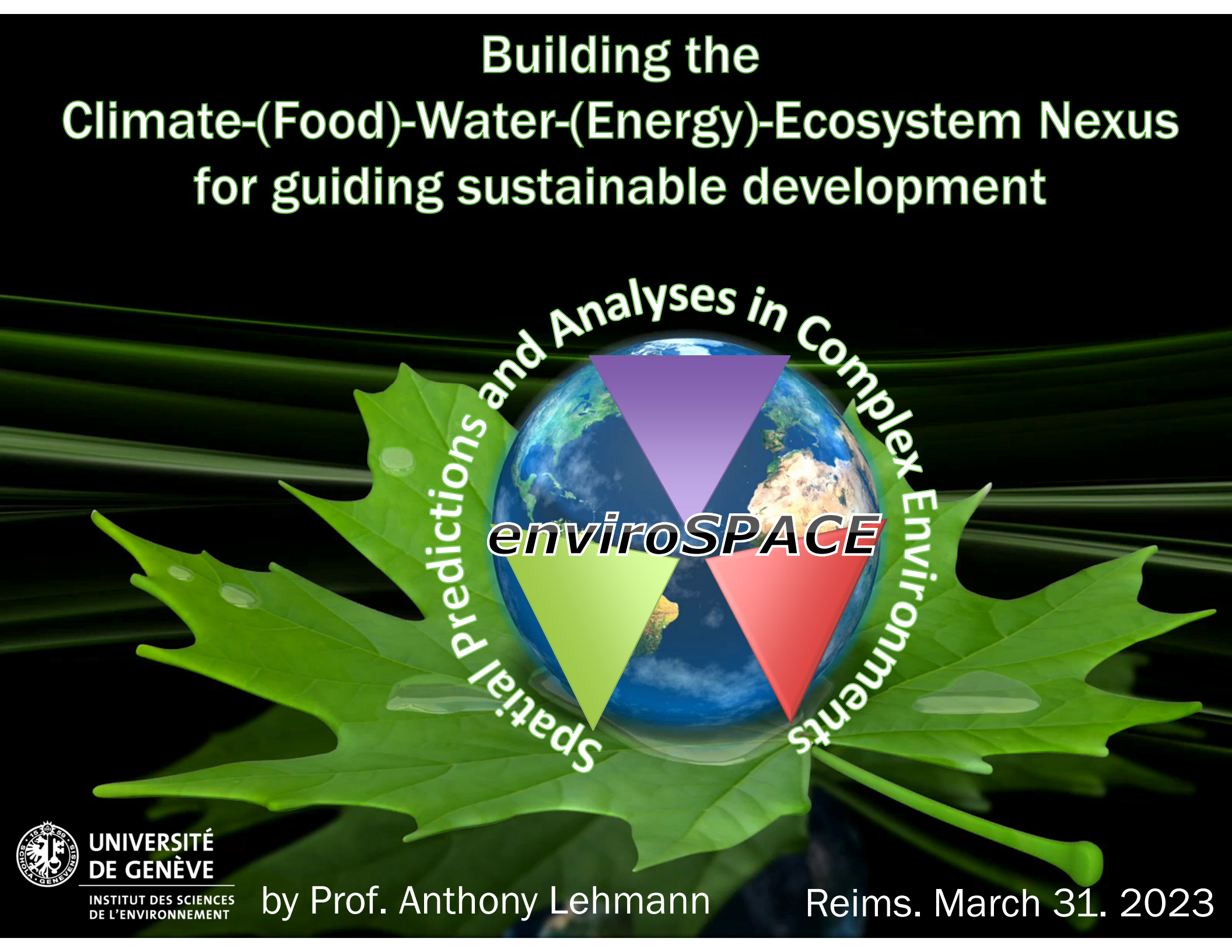
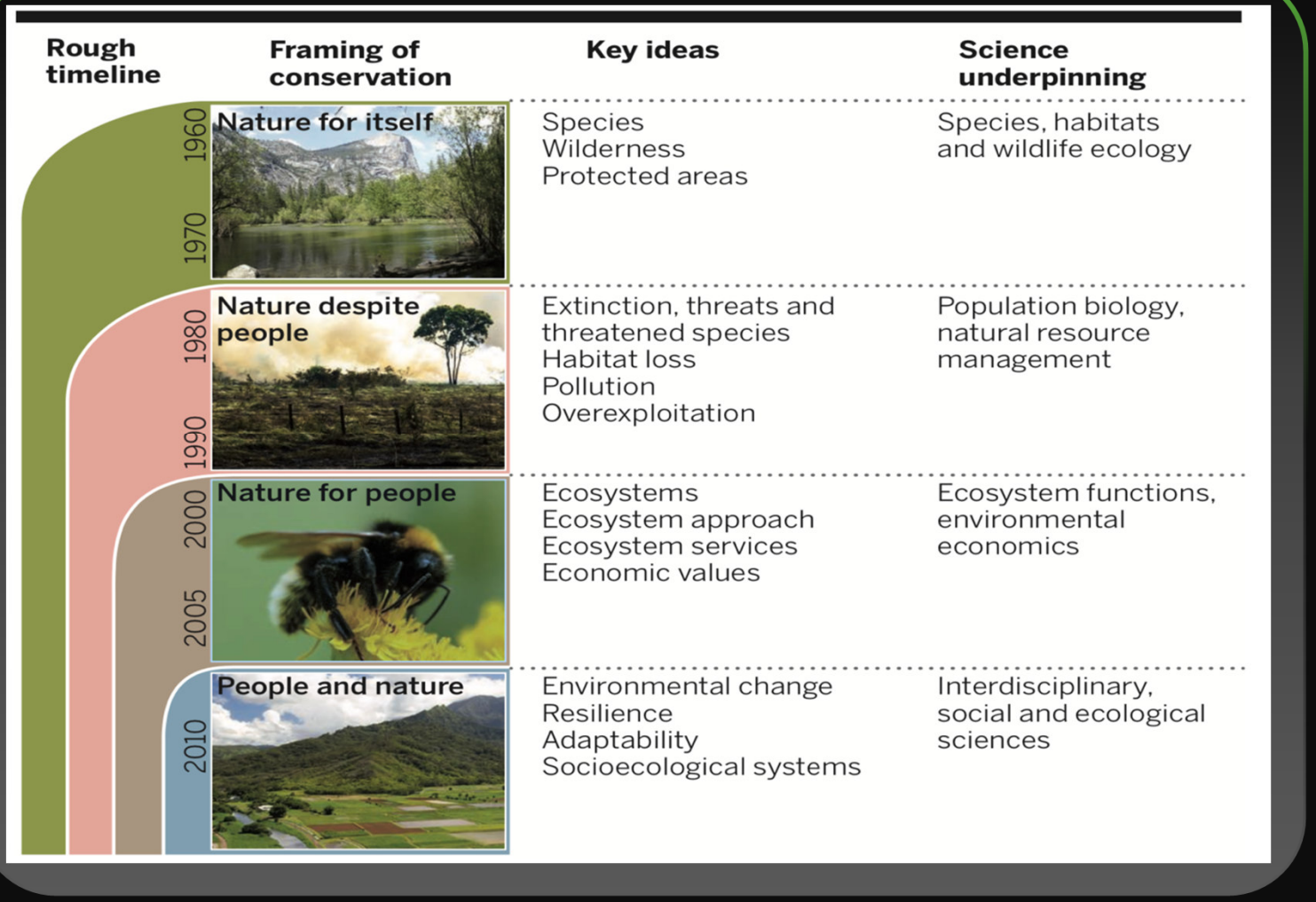
Building the Climate-(Food)-Water-(Energy)-Ecosystem Nexus for guiding sustainable development



UNIVERSITÉ DE GENÈVE
INSTITUT DES SCIENCES DE L'ENVIRONNEMENT

by Prof. Anthony Lehmann

Reims. March 31. 2023

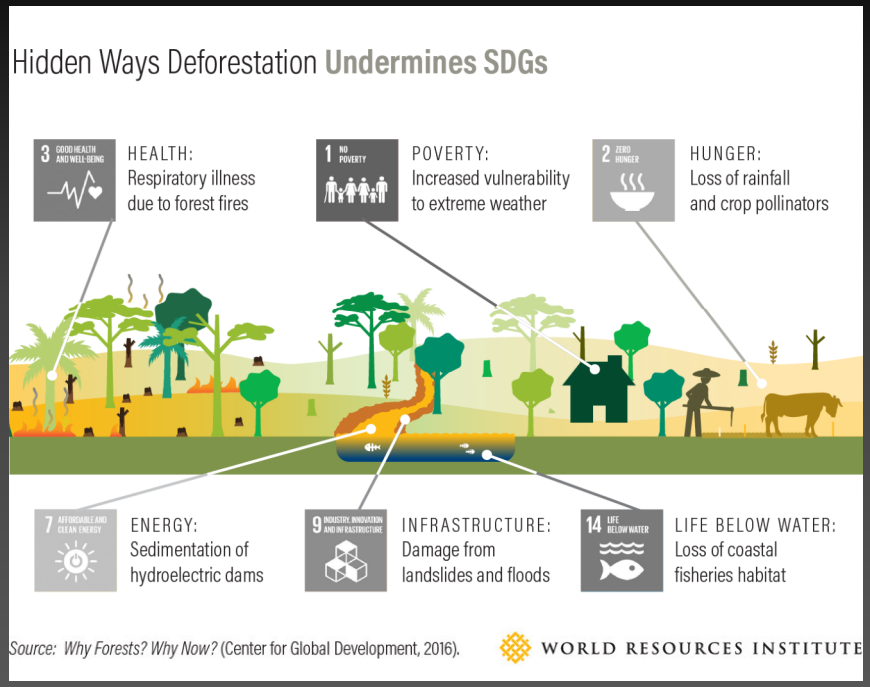


What conservation do we want?

The perception of biodiversity conservation has changed over the past 50 years

Mace 2014. Science 245

Healthy Ecosystems Provide ES to SDGs like in forests



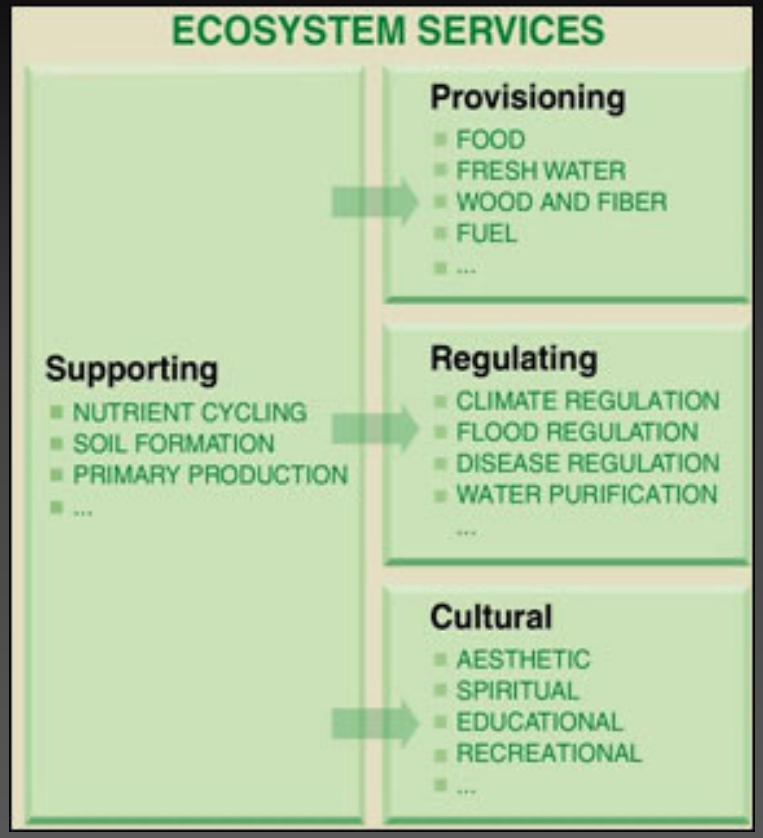
https://www.cgdev.org/sites/default/files/Seymour-Busch-why-forests-why-now-full-book.PDF

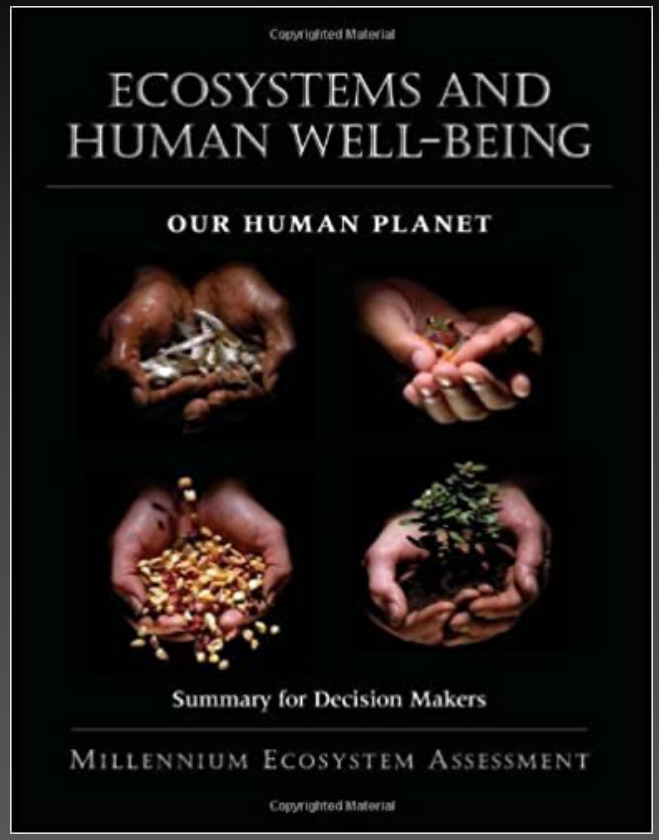
https://wri-indonesia.org/en/blog/forests-and-sdgs-taking-second-look

Part 1

EVOLUTION OF THE ECOSYSTEM SERVICES CONCEPT

Millenium Ecosystem Assemment



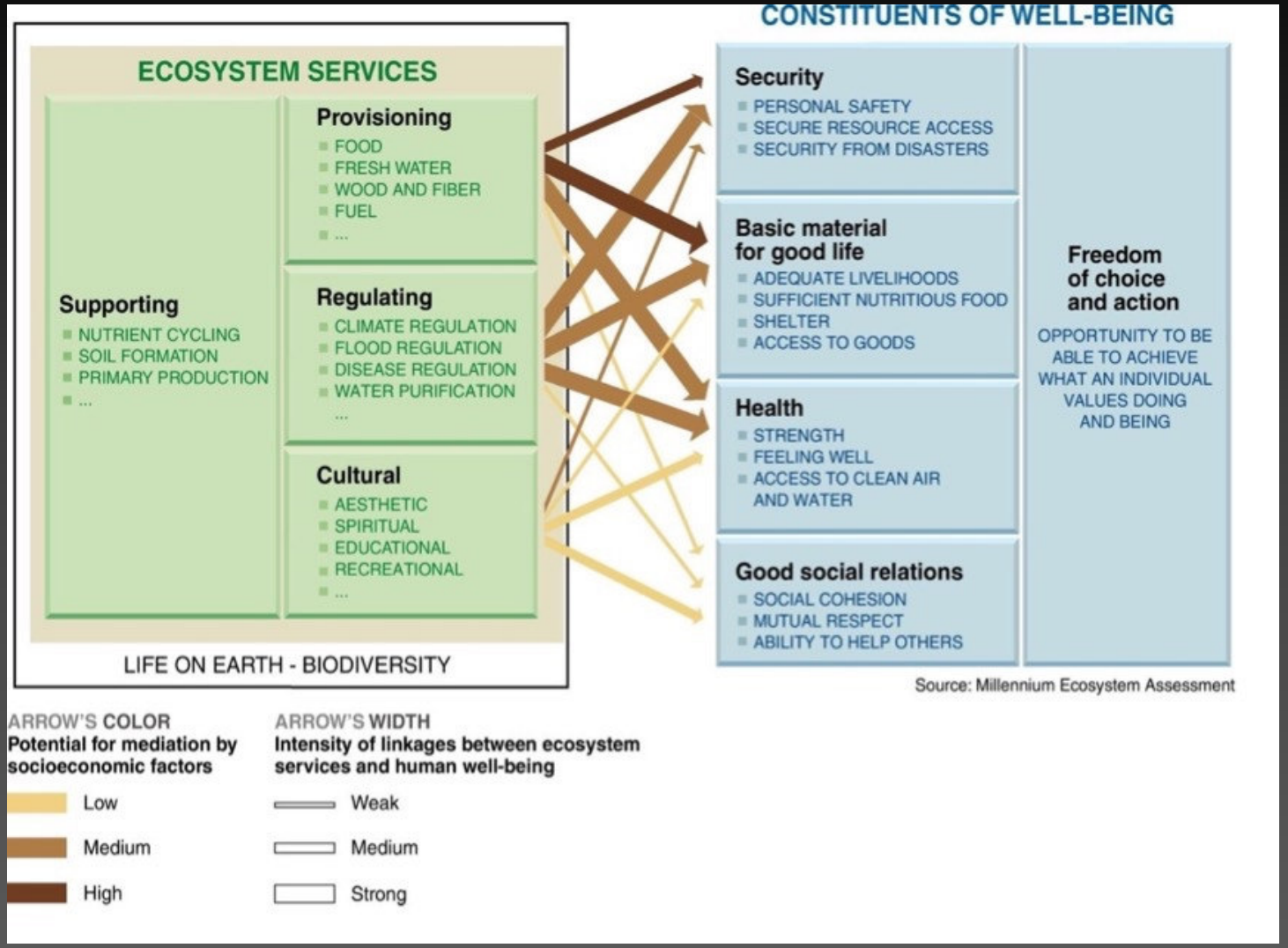


This report widely disseminated the concept of ES with its classification as:

- Support
- Supply
- Regulation
- Cultural

UN, MEA 2005

Millenium Ecosystem Assessment

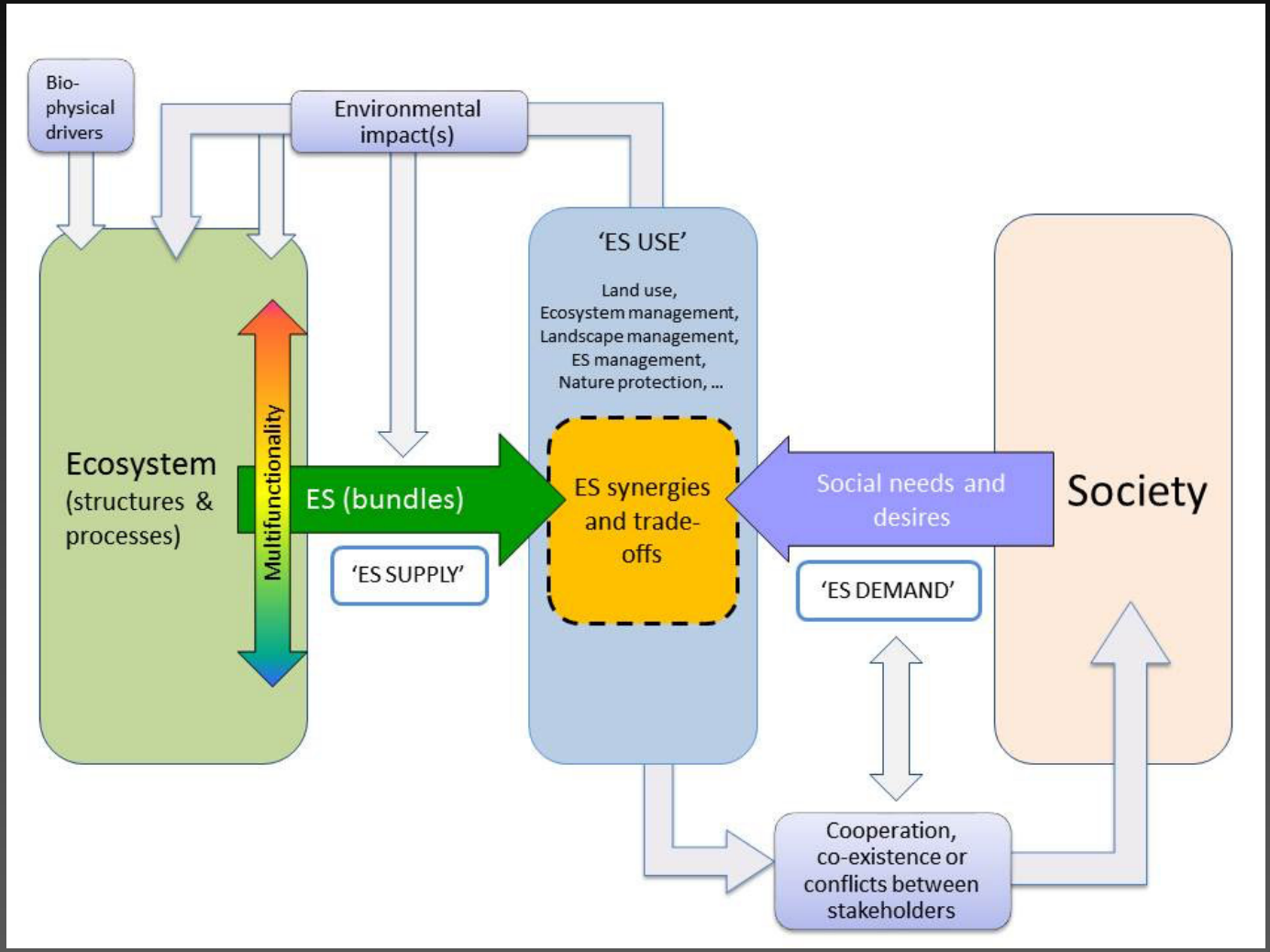


The report also linked ES to the well-being of people

UN, MEA 2005

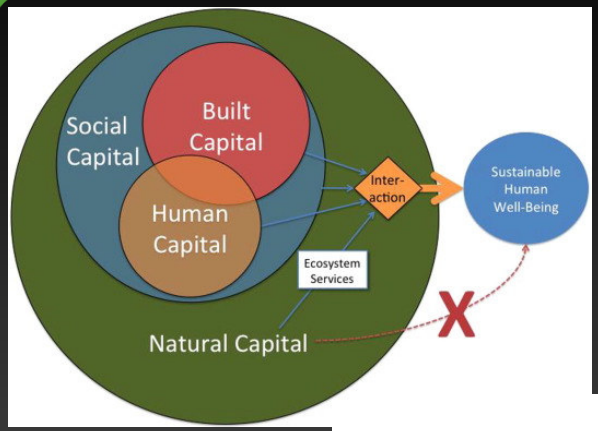
Tradeoffs & Synergies

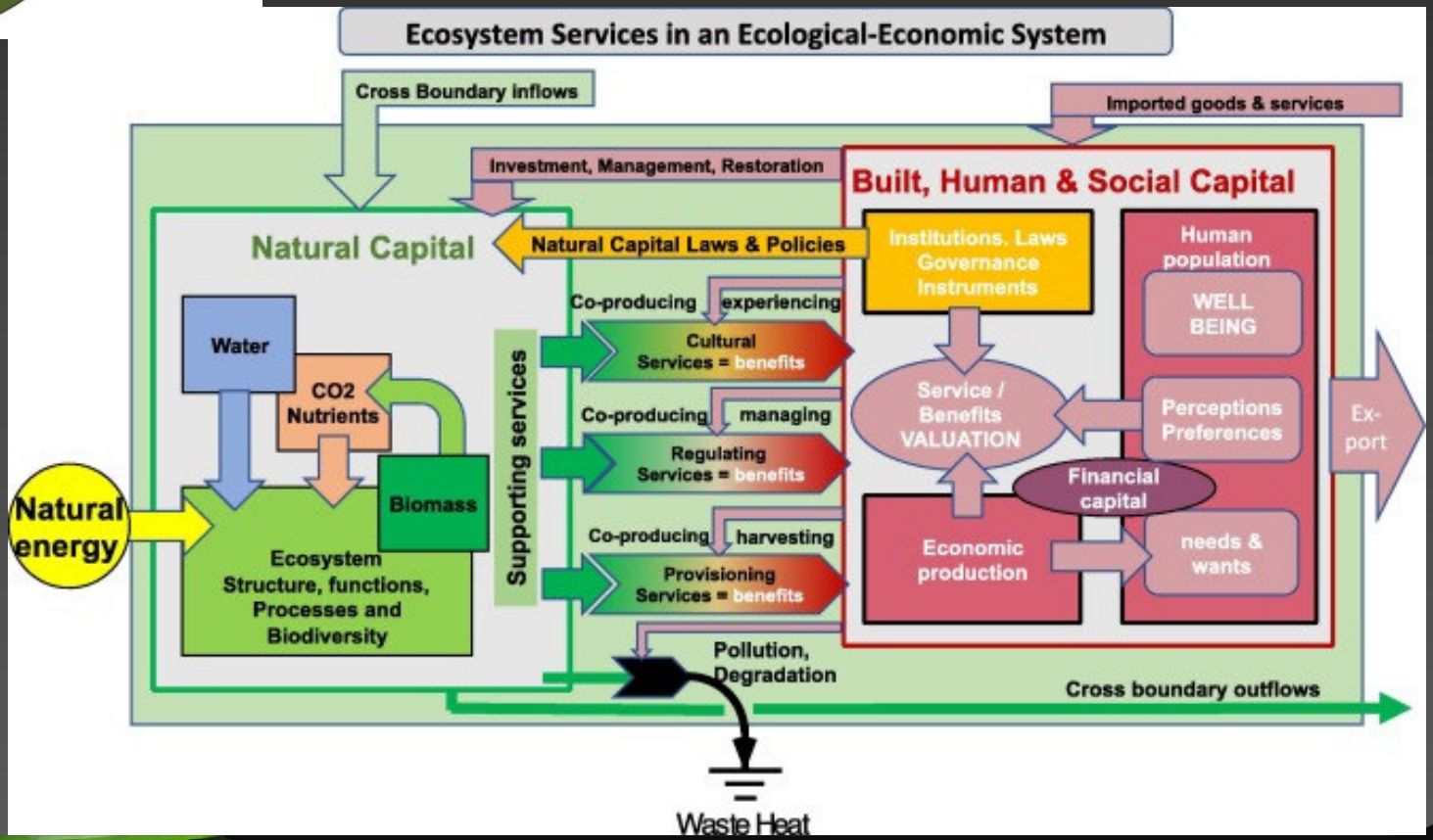
When the supply of ecosystem services meets the demand for synergies are possible and necessary trade-offs



http://www.openness-project.eu/library/reference-book/sp-ecosystem-service-trade-offs-and-synergies

20 years of Ecosystem Services: synthesis



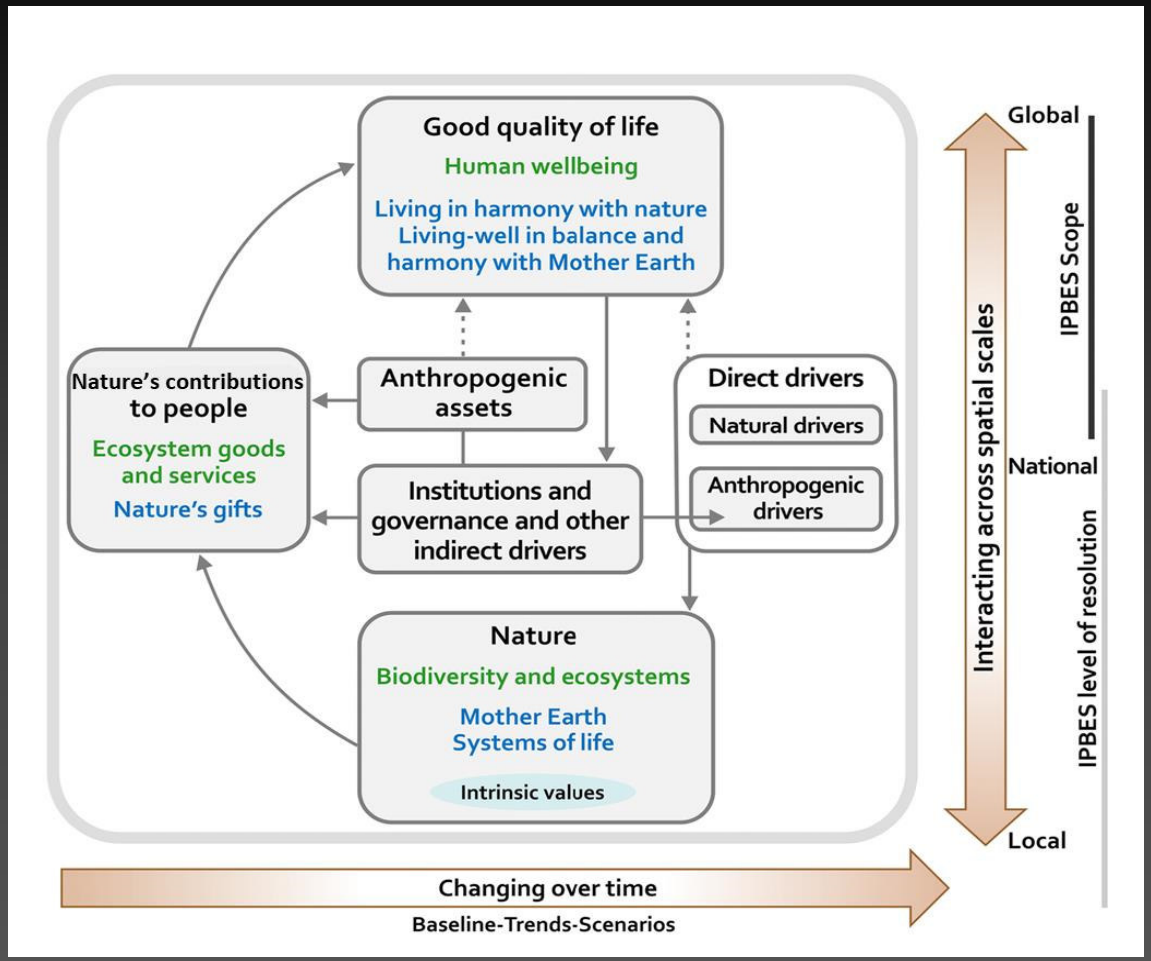


Costanza et al. 2017: https://doi.org/10.1016/j.ecoser.2017.09.008

Part 2

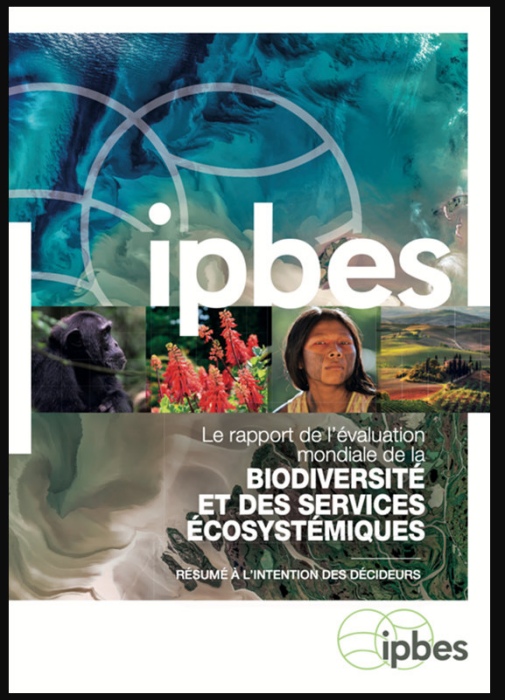
EVALUATION OF ECOSYSTEM SERVICES

IBPES Conceptual Framework



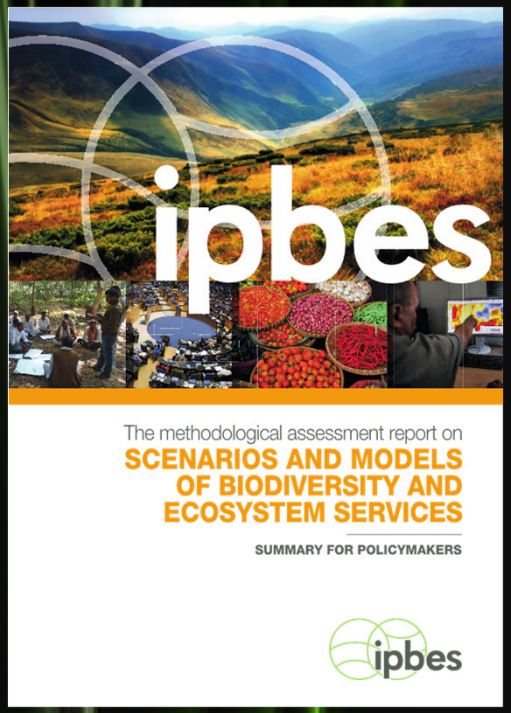
Concepts de la science

Autres systèmes de connaissance

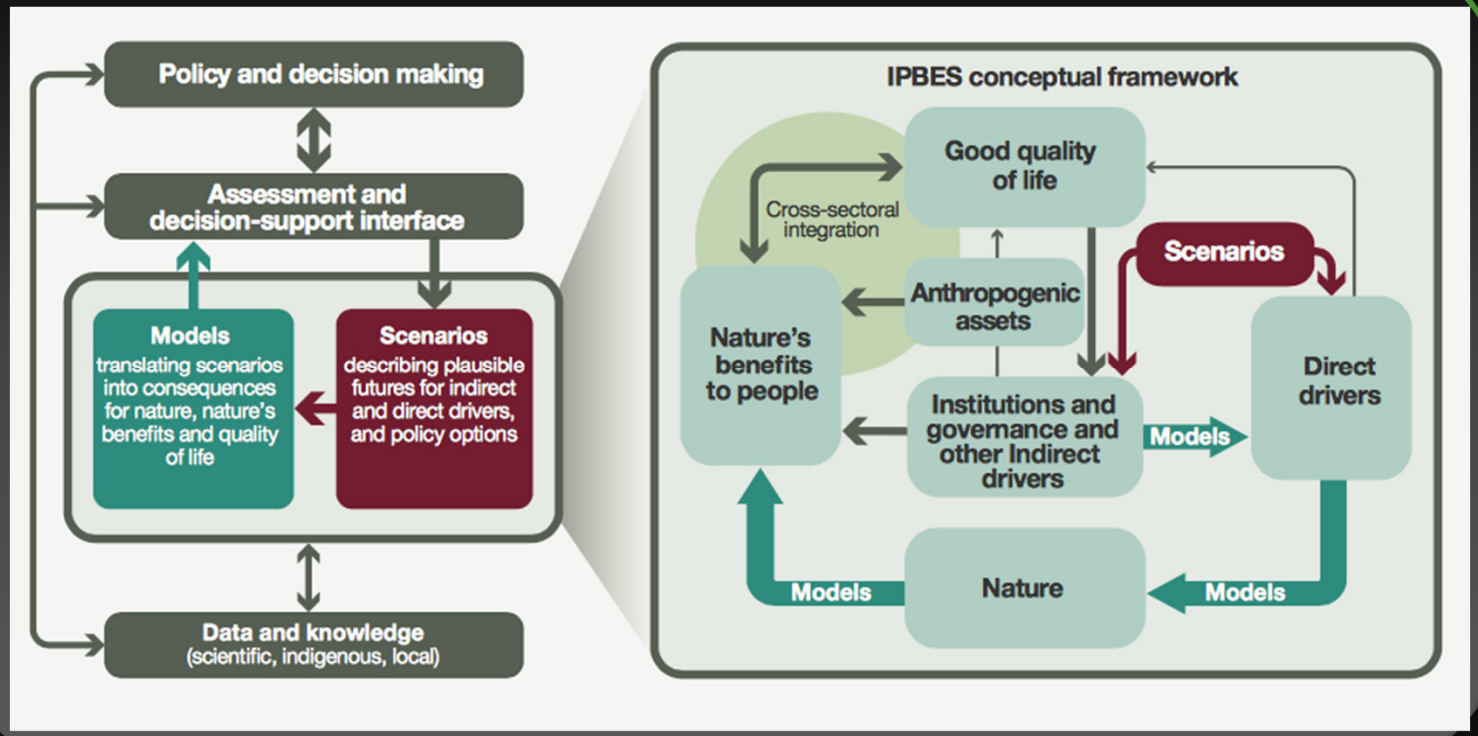


- "Nature," "nature's contributions to people" and "good quality of life" are inclusive categories that have been identified in a participatory process.
- This includes other knowledge systems, such as those of indigenous peoples and local communities.

https://ipbes.net/global-assessment



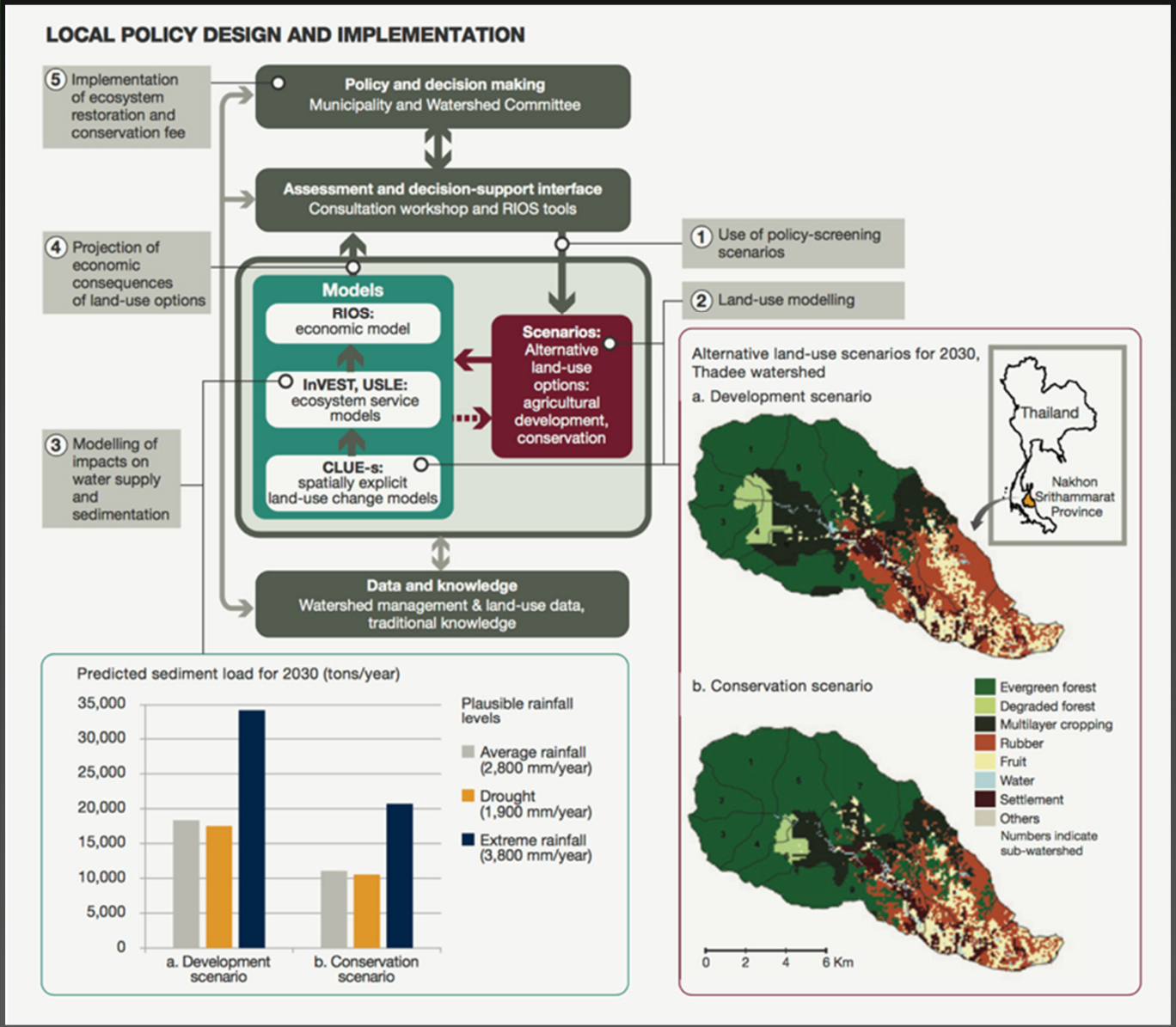
Scenarios and models



The panel on the left points out that scenarios and models are directly dependent on data and knowledge for their construction and testing and add value by synthesizing and organizing knowledge.
The right panel provides a detailed view of the relationships between scenarios, models and key elements of the platform's conceptual framework

https://www.ipbes.net/document-library-categories/assessment-reports-and-outputs

Scenarios and models



Thadee watershed, Thailand, where farmers' water supply and household consumption have been degraded by the conversion of natural forests to rubber plantations.

Part 3

TOOLS AND DATA FOR THE EVALUATION OF ES

Data and Tools

The data and models used are intimately linked to the biodiversity and ecosystem services assessment process.

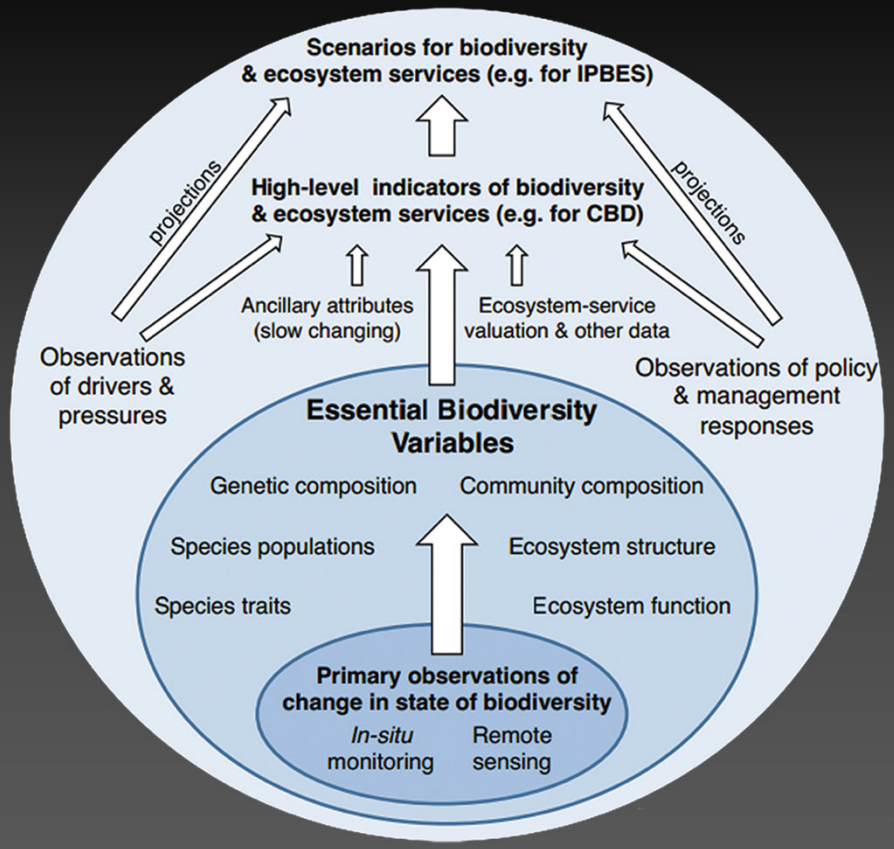
Specific tools have been developed at different scales with varying degrees of complexity.

TOOL	MODEL TYPE	SPATIAL AND TEMPORAL EXTENT	EASE OF USE	COMMUNITY OF PRACTICE	FLEXIBILITY	REFERENCE
IMAGE	Process	Global, dynamic	Difficult	Small	Low	Stehfest *et al.*, 2014
EcoPath with EcoSim	Process	Regional, dynamic	Medium	Large	High	Christensen *et al.*, 2005
ARIES	Expert	Regional, dynamic	Difficult	Small	High	Villa *et al.*, 2014
InVEST	Process and correlative	Regional, static	Medium	Large	Medium	Sharp *et al.*, 2014
TESSA	Expert	Local, static	Easy	Small	Low	Peh *et al.*, 2014

https://www.ipbes.net/document-library-categories/assessment-reports-and-outputs

Essential Biodiversity Variables (EBVs)

EBV classes	Candidates
Genetic composition	Co-ancenstry Allelic diversity Population genetic differentiation Breed and variety diversity
Species populations	Species distribution Population abundance Population structure
Species traits	Phenology Body mass Natal dispersion distance Migratory behavior Demographic traits Physiological traits
Community composition	Species richness Species interactions
Ecosystem function	Net primary productivity Secondary productivity Nutrient retention Disturbance regime
Ecosystem structure	Habitat structure Ecosystem extent and fragmentation Ecosystem composition by functional type

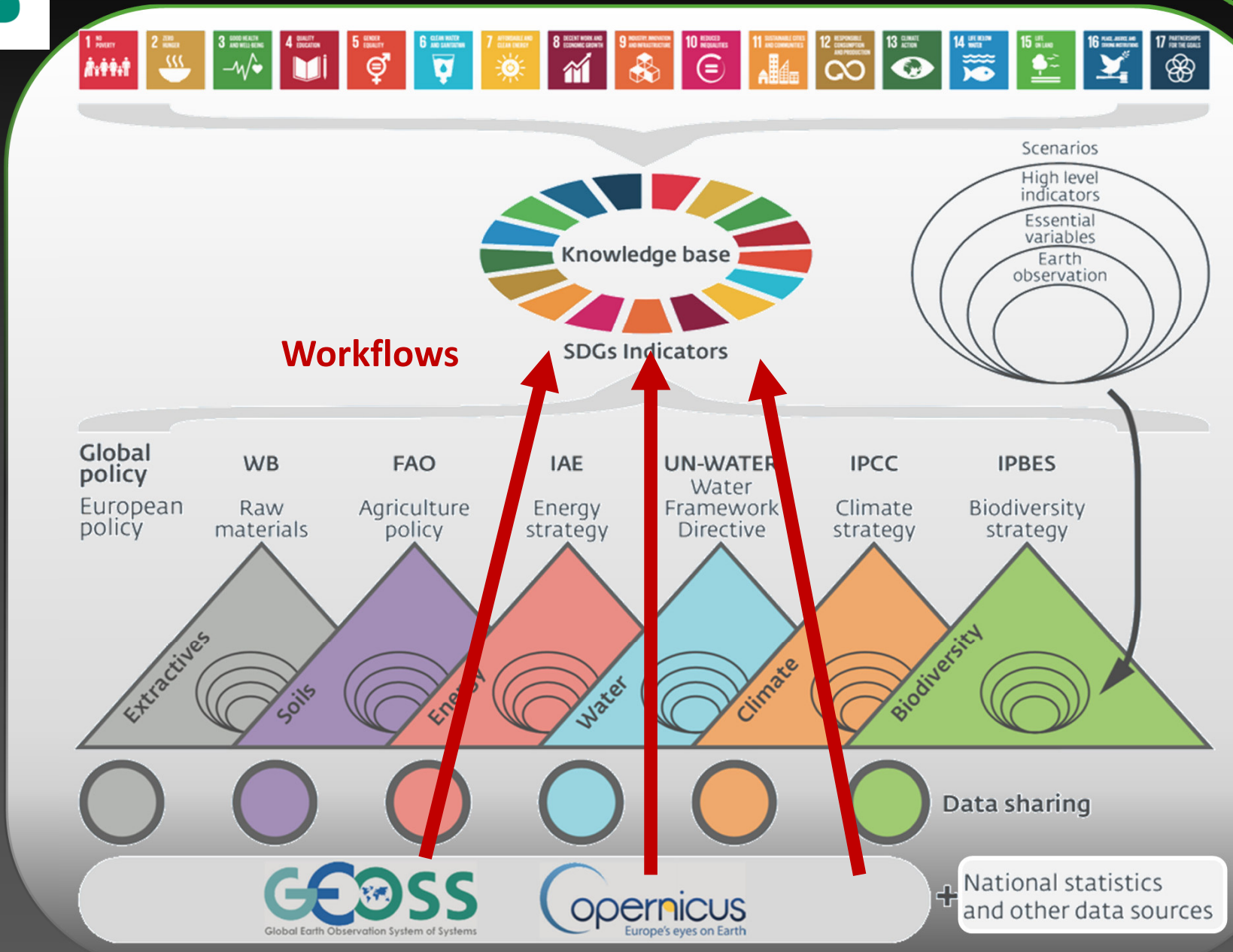


Essential variables of biodiversity are defined as the derived measures needed to study, report and manage changes in biodiversity, focusing on the state and trend of biodiversity elements. They provide the first level of abstraction between low-level primary observations and high-level biodiversity indicators.

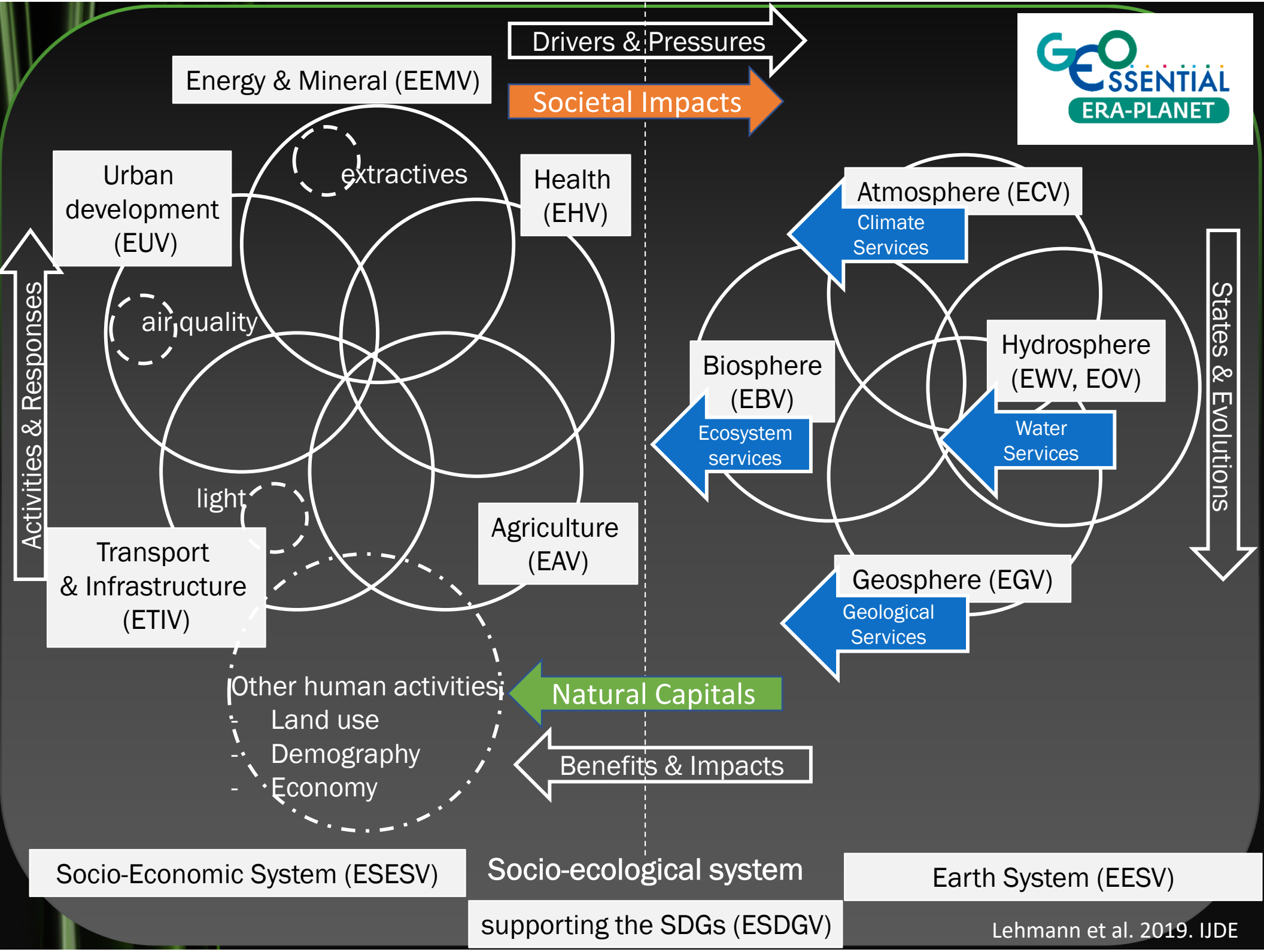
https://geobon.org/ebvs/what-are-ebvs/

GEOEssential project

GEOEssential general framework linking data sources to policy indicators through Essential Variables



Lehmann et al. 2019. IJDE


Drivers & Pressures
Societal Impacts
Energy & Mineral (EEMV)
Urban development (EUV)
extractives
Health (EHV)
air quality
light
Transport & Infrastructure (ETIV)
Agriculture (EAV)
Other human activities
- Land use
- Demography
- Economy
Activities & Responses
Natural Capitals
Benefits & Impacts
Atmosphere (ECV)
Climate Services
Biosphere (EBV)
Ecosystem services
Hydrosphere (EWV, EOV)
Water Services
Geosphere (EGV)
Geological Services
States & Evolutions
Socio-Economic System (ESESV)
Socio-ecological system
supporting the SDGs (ESDGV)
Earth System (EESV)
GEOESSENTIAL
ERA-PLANET
Lehmann et al. 2019. IJDE

Part 4

GLOBAL IPBES ASSESSMENT

To reconcile the global visions around the concept, the IPBES now proposes to talk about Nature's Contributions to Populations, and has made a first comprehensive assessment of it.

https://ipbes.net/global-assessment

Figure SPM 1 **Tendances mondiales de la capacité de la nature à maintenir ses contributions à une bonne qualité de vie, de 1970 à aujourd'hui, illustrant un déclin pour 14 des 18 catégories de contributions analysées.**

IPBES Global Assessment

Impacts of land use and climate change on biodiversity and material and regulatory NCPs between 2015 and 2050.

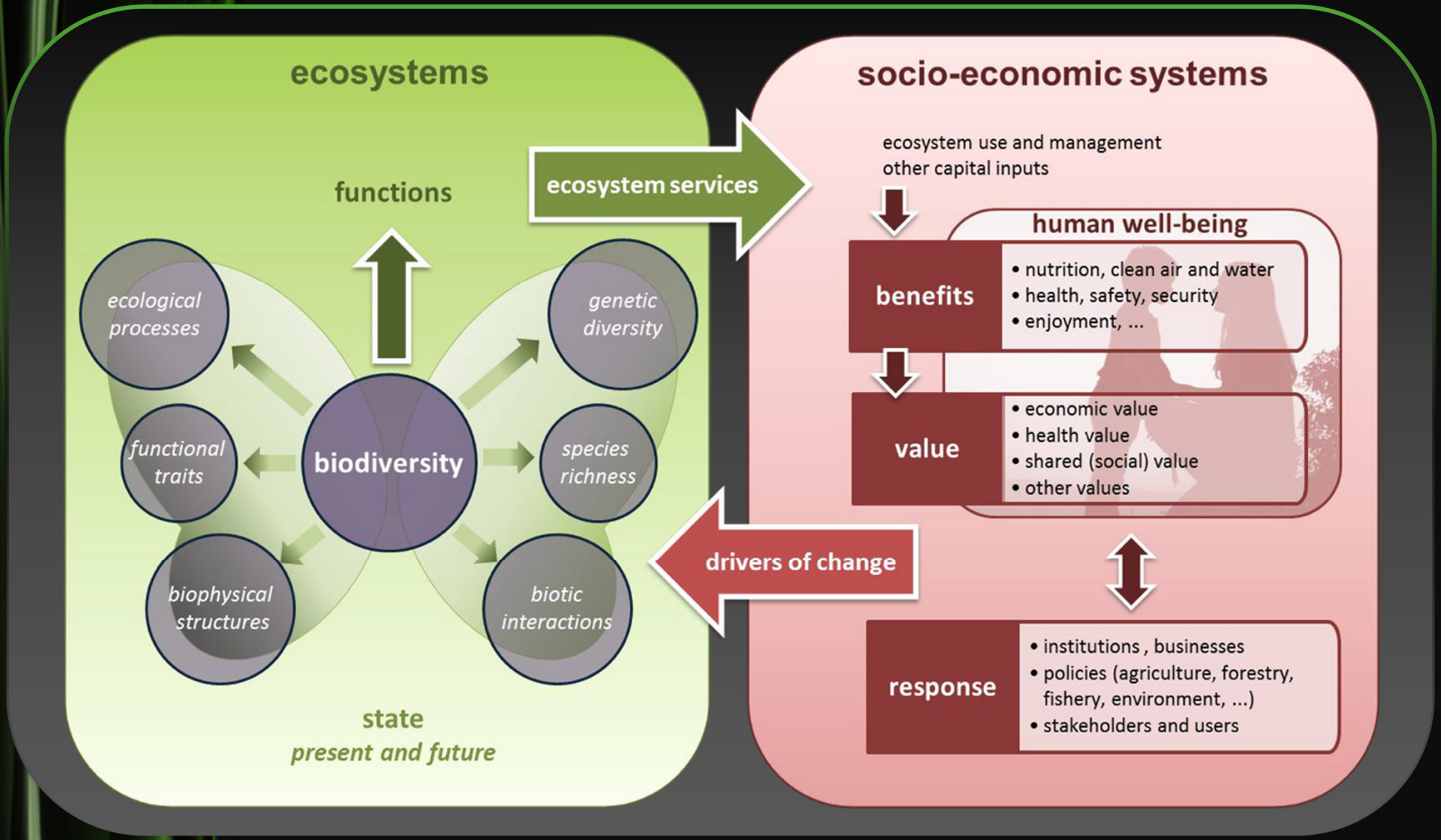
https://ipbes.net/global-assessment

(i) impacts are lowest in the global sustainability scenario in almost all sub-regions, (ii) regional impact differences are high in the regional competition and economic optimism scenario and (iii) material ASCs increase the most in regional competition and economic optimism scenarios, but this is at the expense of biodiversity and ASC regulation.

Part 5

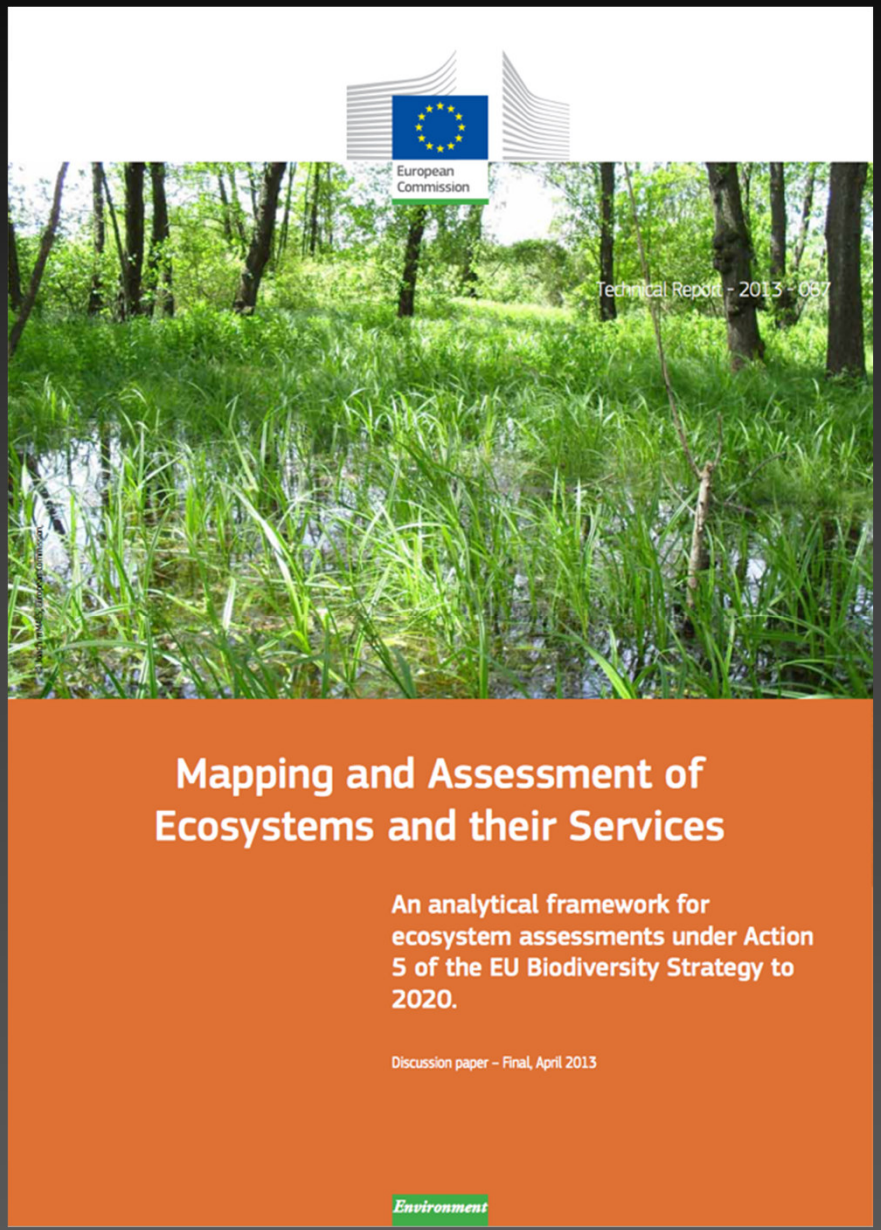
ECOLOGICAL INFRASTRUCTURES

European conceptual framework for SE

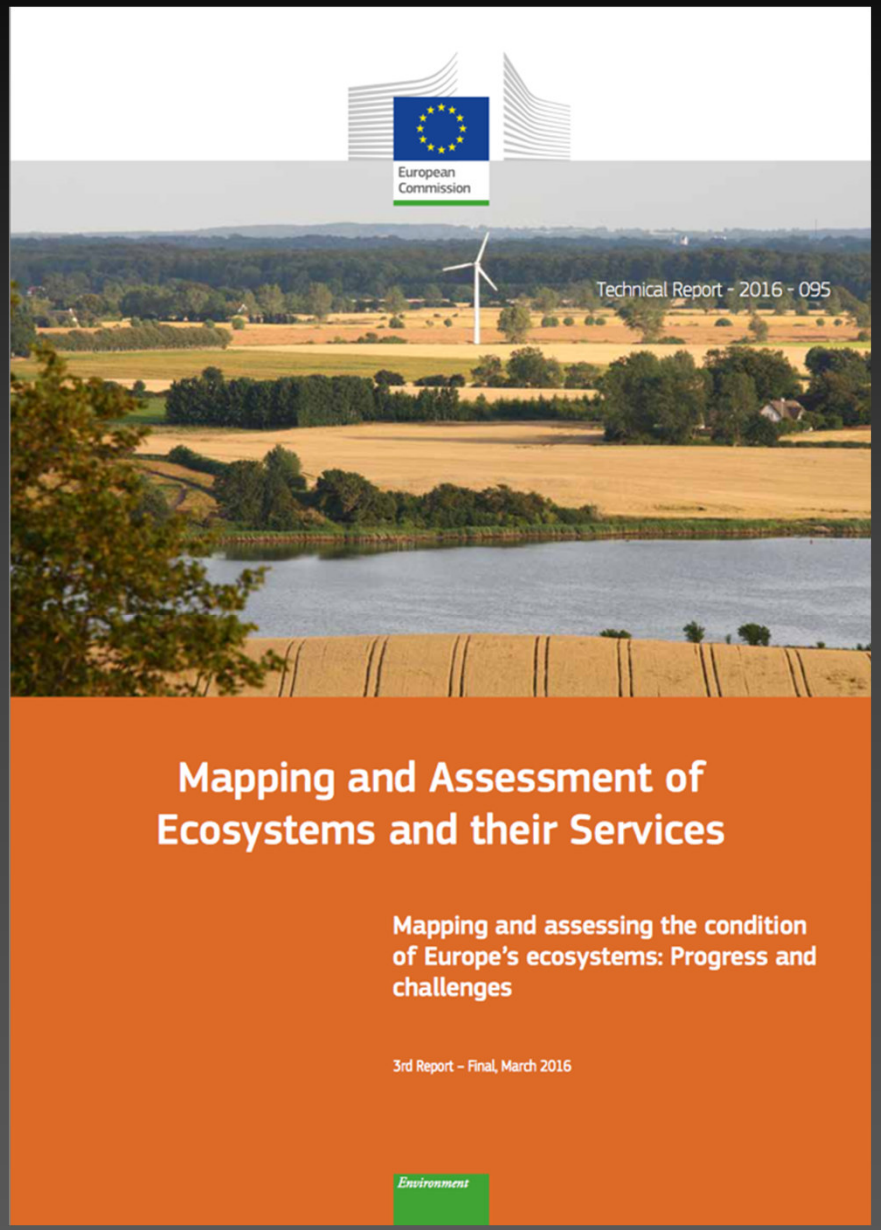


http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

Mapping ecosystem services

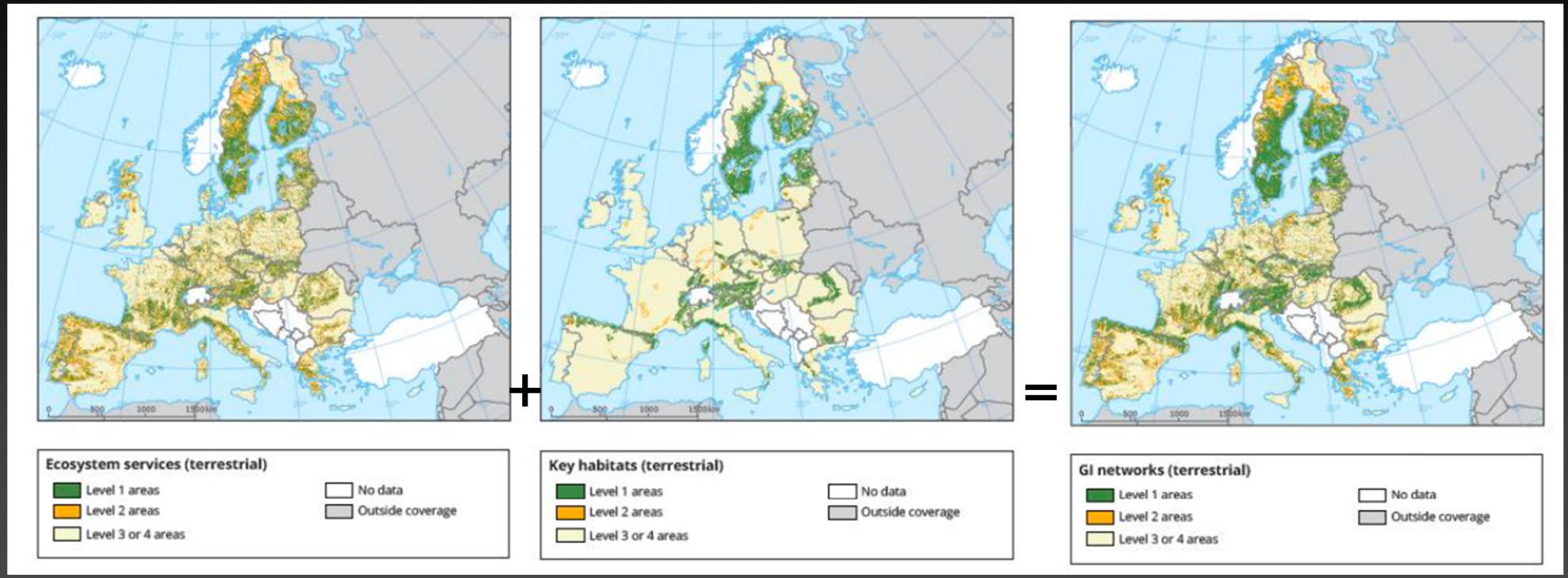


http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf



http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/3rdMAESReport_Condition.pdf

European scale: Ecological infrastructure



27% of EU-27s could be part of the IE "C" network, the largest contribution from regions with the greatest capacity to provide ecosystem services.

17% of the EU's territory could correspond to EI's 'R', mainly defined by limited service areas.

EEA, 2014

REPUBLIQUE ET CANTON DE GENEVE

POST TENEBRAS LUX

Biodivesity Strategy - Geneva

1. Infrastructure Ecologique

2. Aires protégées

5. Rivières et lacs

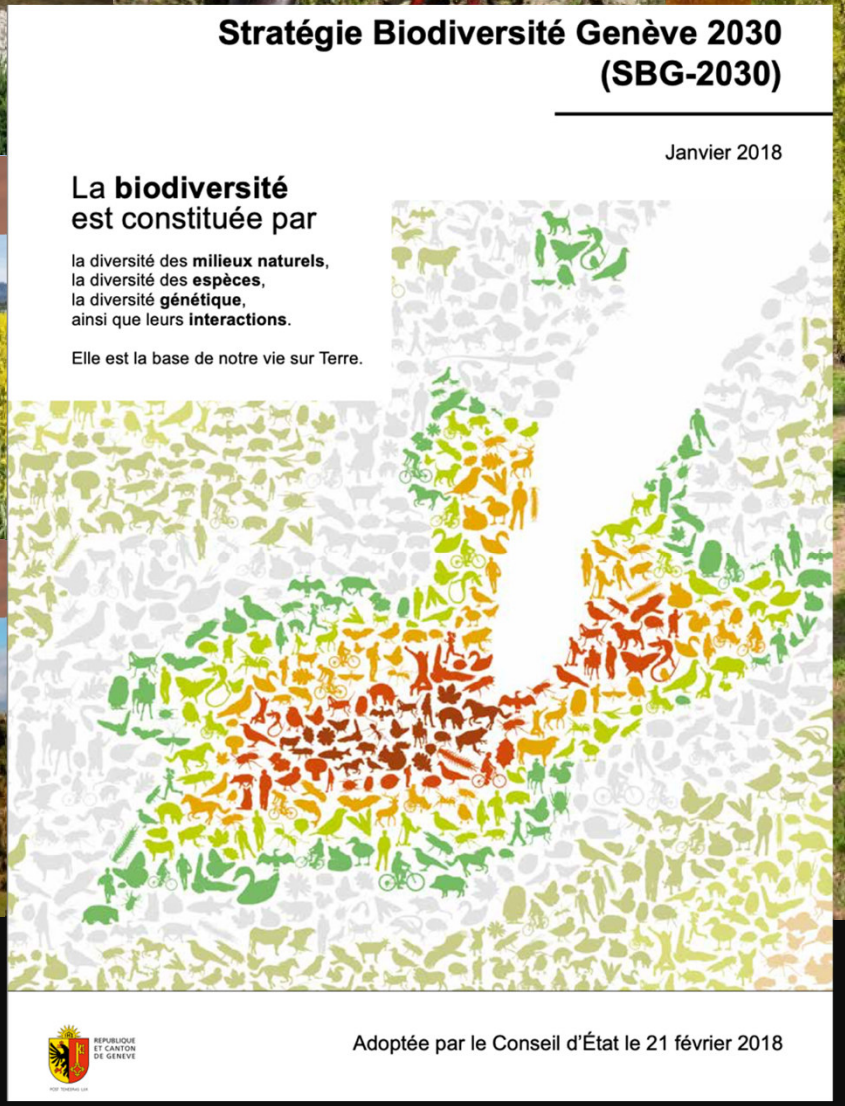
8. Faune et Flore

3. Forêt

6. Agriculture

4. Arbres

7. Zones urbaines



REPUBLIQUE ET CANTON DE GENEVE

Conservatoire et Jardin botaniques Genève

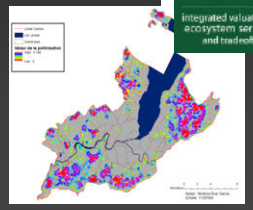
UNIVERSITÉ DE GENÈVE

hepia
Haute école du paysage, d'ingénierie et d'architecture de Genève

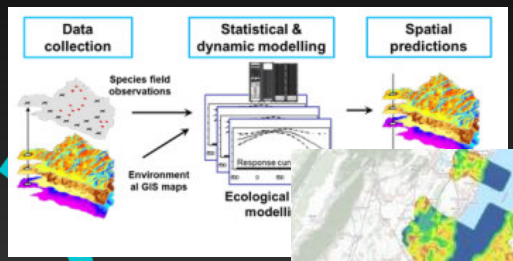
GE-21

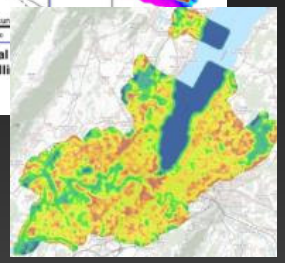
Geneva Ecological Infrastructure

4. Ecosystem Services



1. Composition





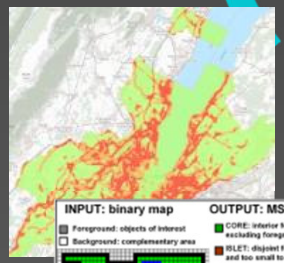
?%

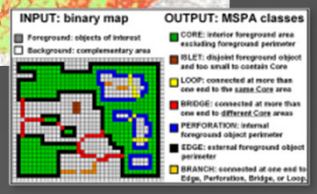
?%

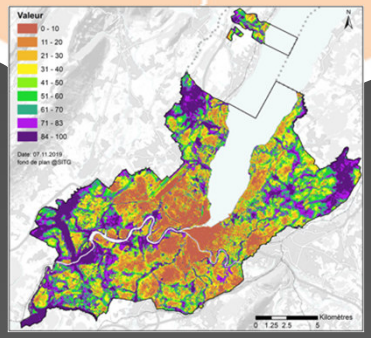
?%

?%

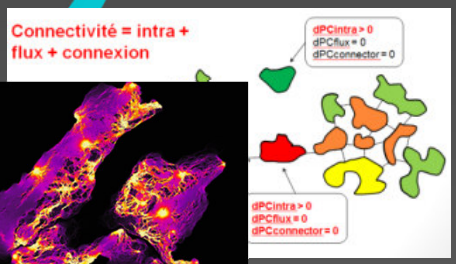
2. Structures







3. Functions

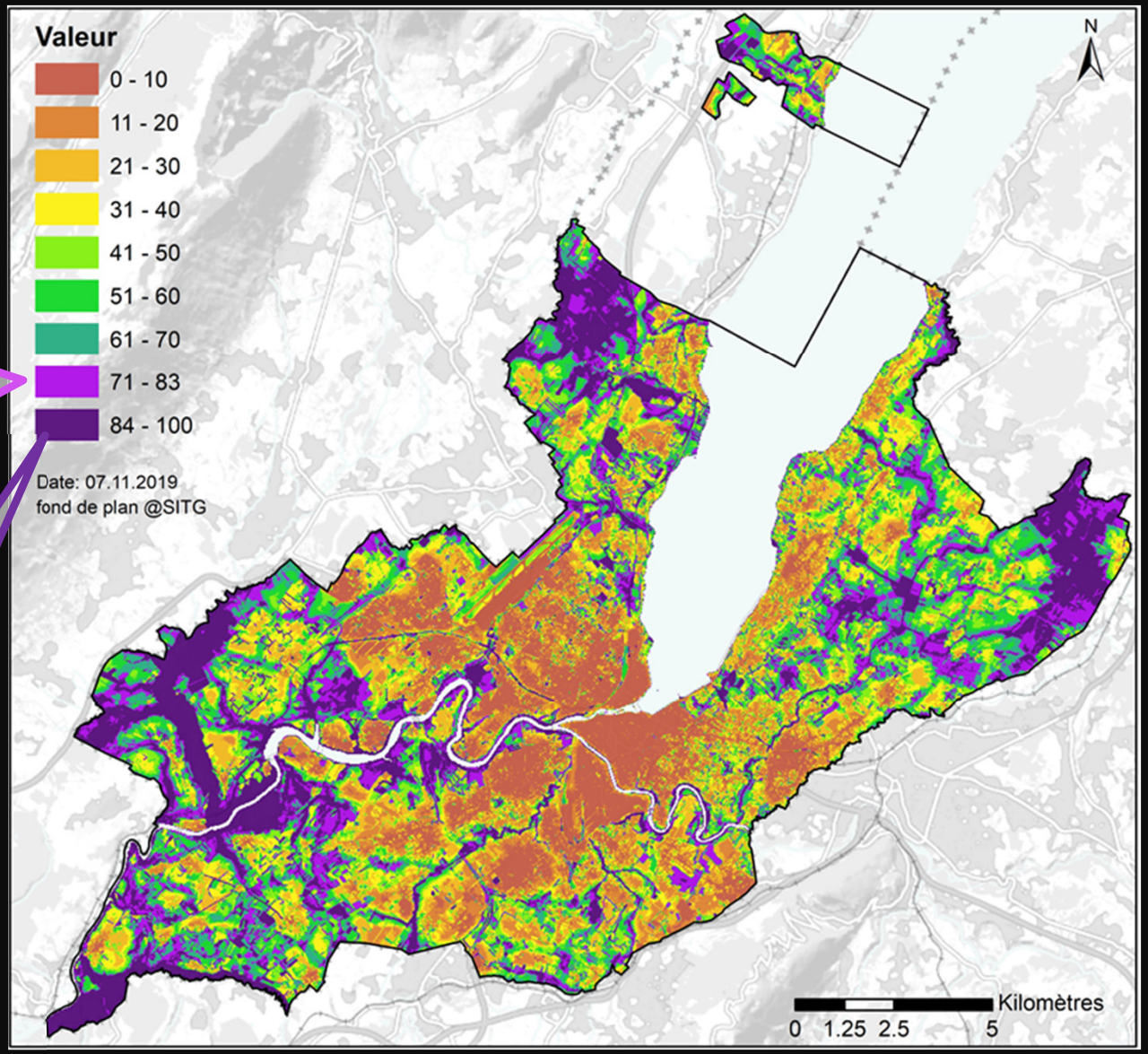


Infrastructure Ecologique de Genève

GE-21

13% additional networking of main habitats

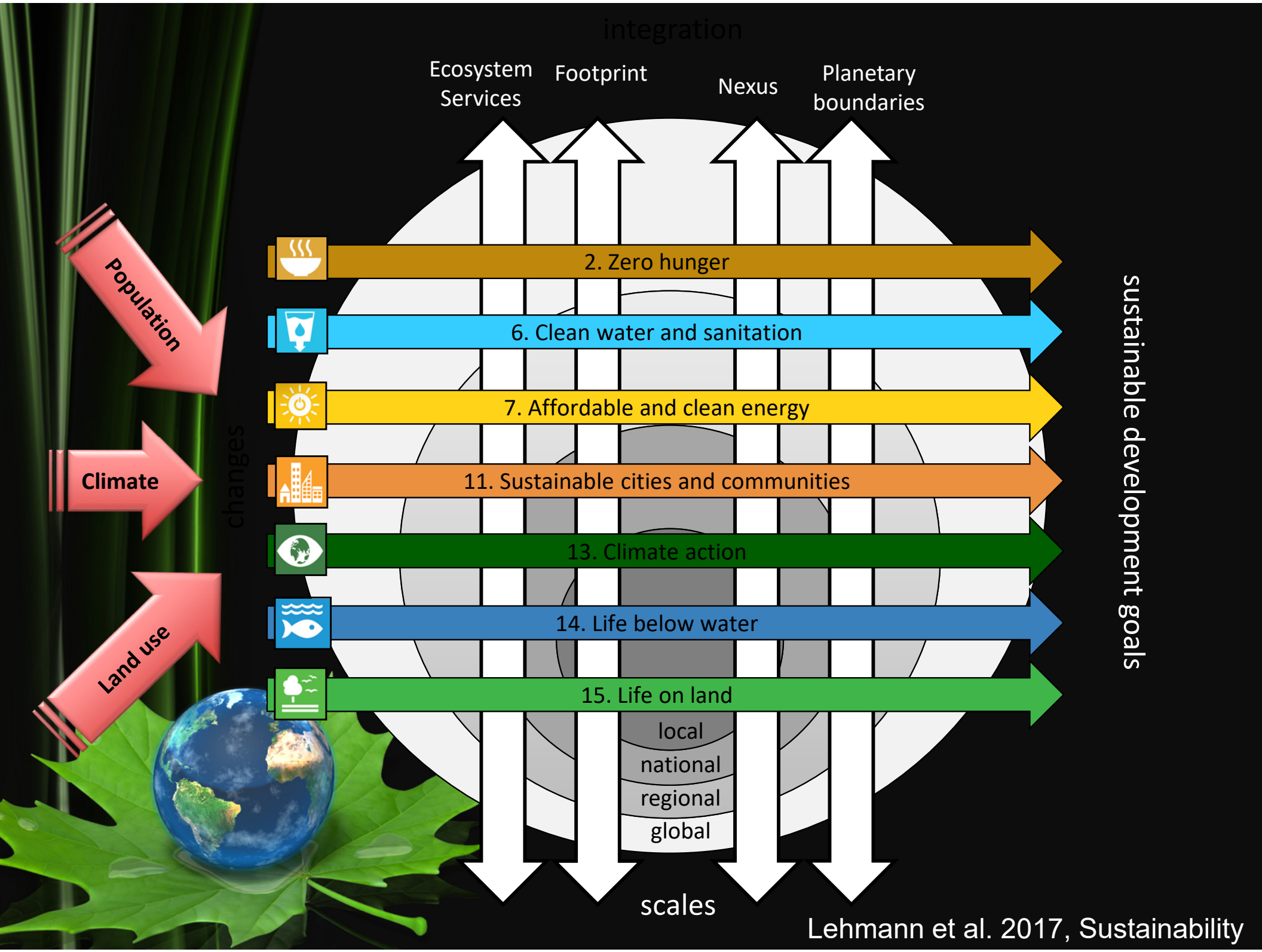
17% of the most interesting areas including existing protected areas. This correpsond to the main habitats and the CBD Aichi Object



Honeck et al. 2020: doi:10.3390/su12041387

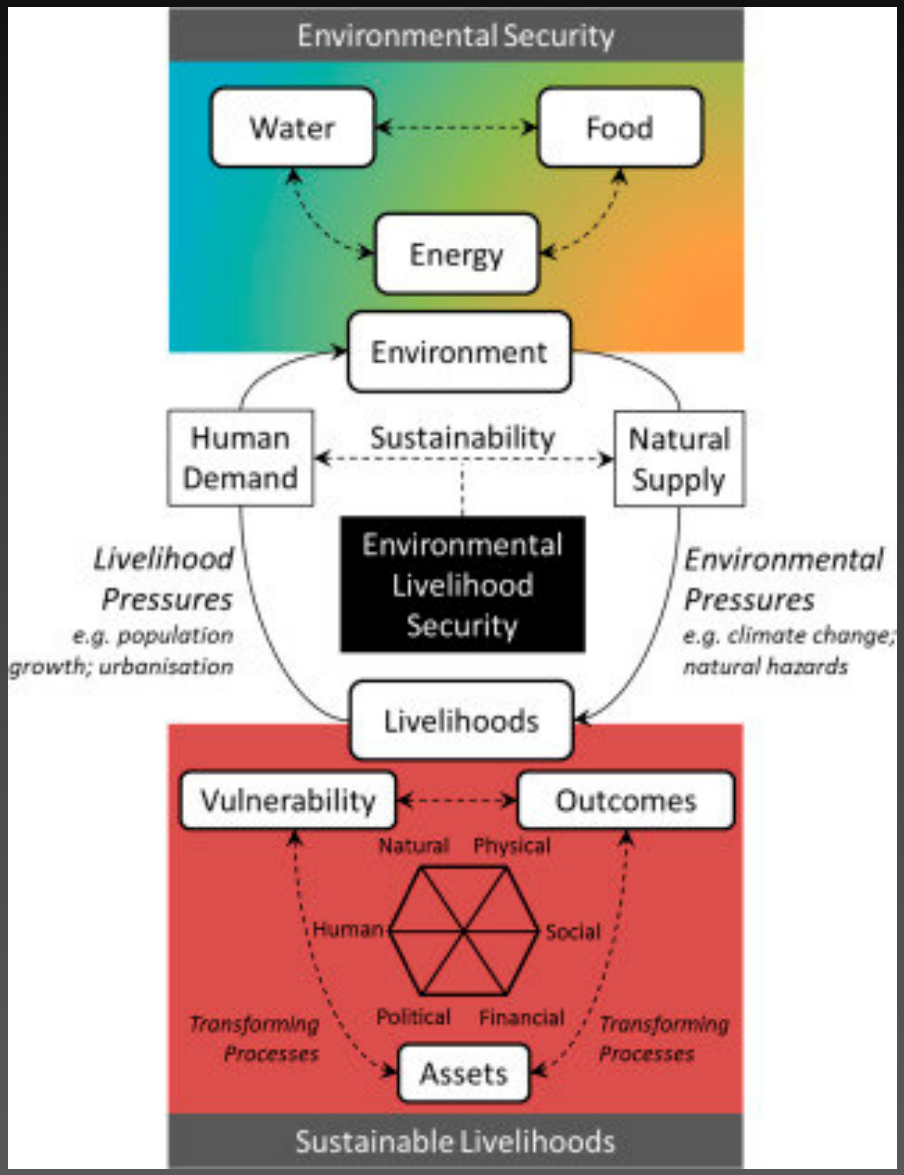
Part 6

NEXUS: FROM ES TO SDG



Lehmann et al. 2017, Sustainability

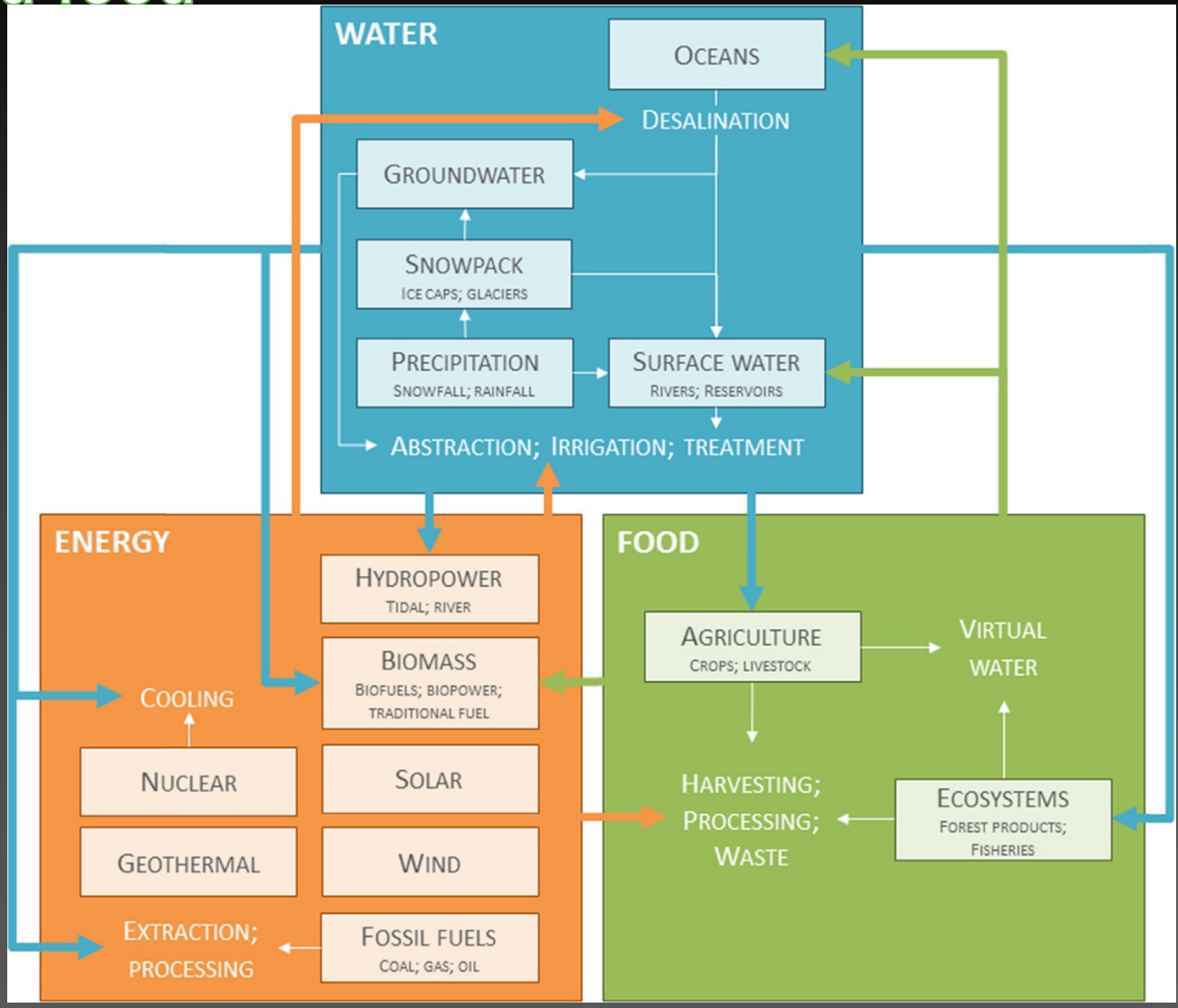
Sustainable development and the link between water and energy and food: a perspective on livelihoods



Il s'agit de parvenir à un équilibre durable entre l'approvisionnement naturel et la demande humaine afin d'assurer la sécurité des moyens de subsistance environnementaux

Environmental Science & Policy, Volume 54, 2015, 389–397

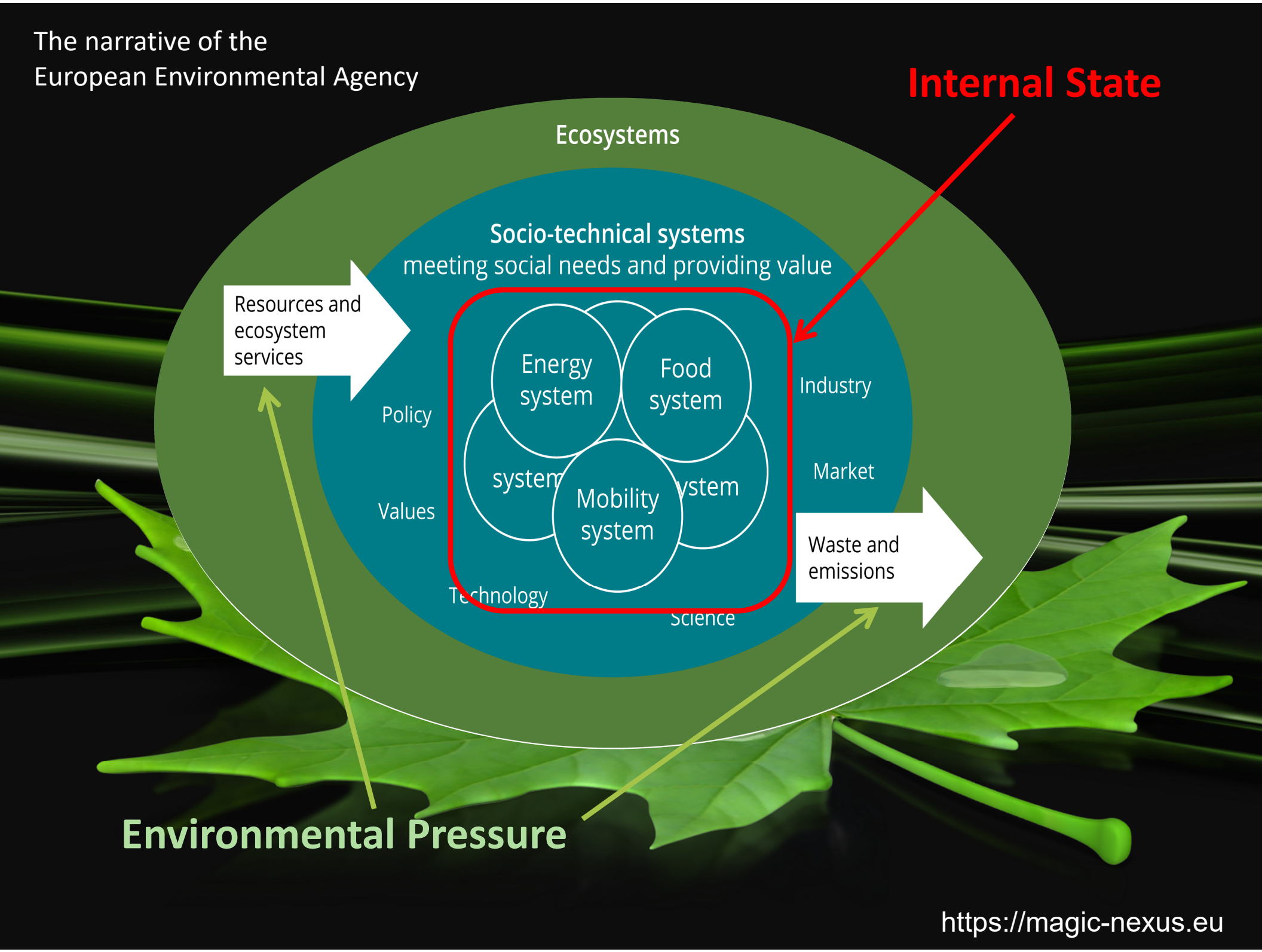
Sustainable development and the link between water and energy and food



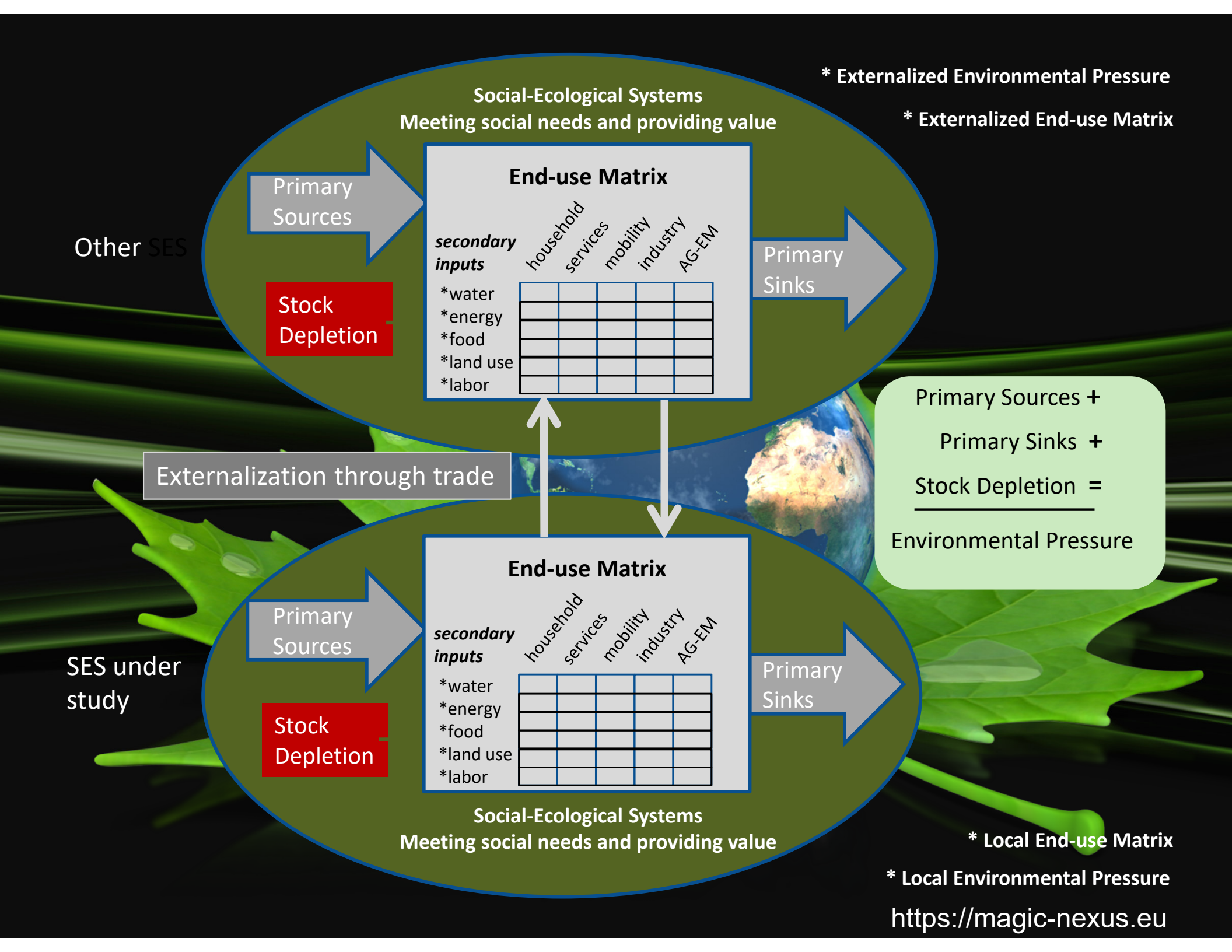
The environmental link system defines the main flows within and between water, energy and power systems.

Environmental Science & Policy, Volume 54, 2015, 389–397

The narrative of the
European Environmental Agency

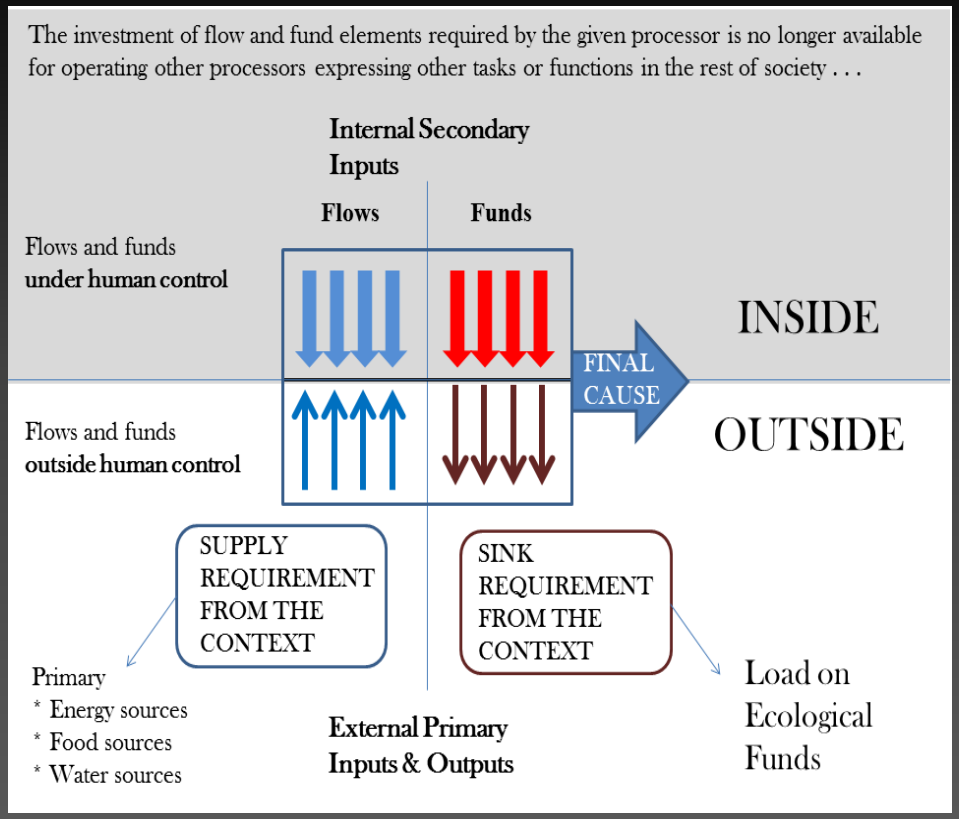


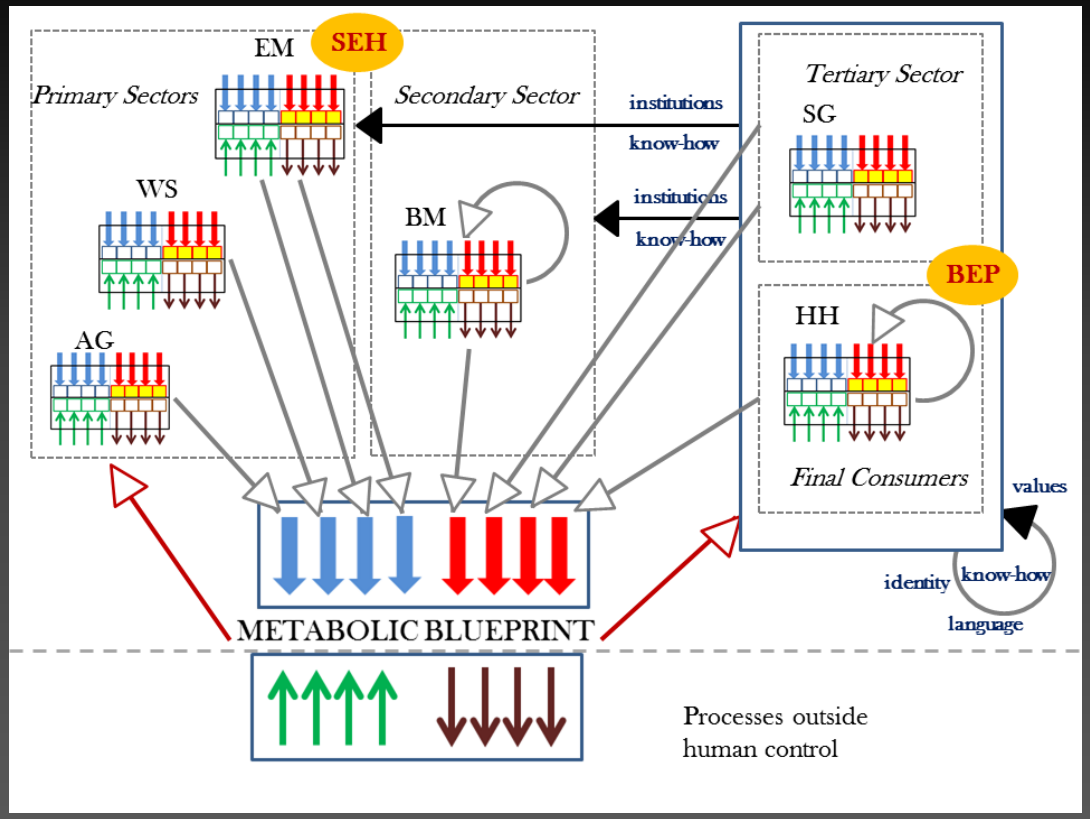
https://magic-nexus.eu


* Externalized Environmental Pressure
* Externalized End-use Matrix
Social-Ecological Systems
Meeting social needs and providing value
Other SES
Primary Sources
Stock Depletion
End-use Matrix
secondary inputs
household
services
mobility
industry
AG-EM
*water
*energy
*food
*land use
*labor
Primary Sinks
Externalization through trade
Primary Sources +
Primary Sinks +
Stock Depletion =
Environmental Pressure
SES under study
Primary Sources
Stock Depletion
End-use Matrix
secondary inputs
household
services
mobility
industry
AG-EM
*water
*energy
*food
*land use
*labor
Primary Sinks
Social-Ecological Systems
Meeting social needs and providing value
* Local End-use Matrix
* Local Environmental Pressure
https://magic-nexus.eu

NEXUS avec MuSIASEM

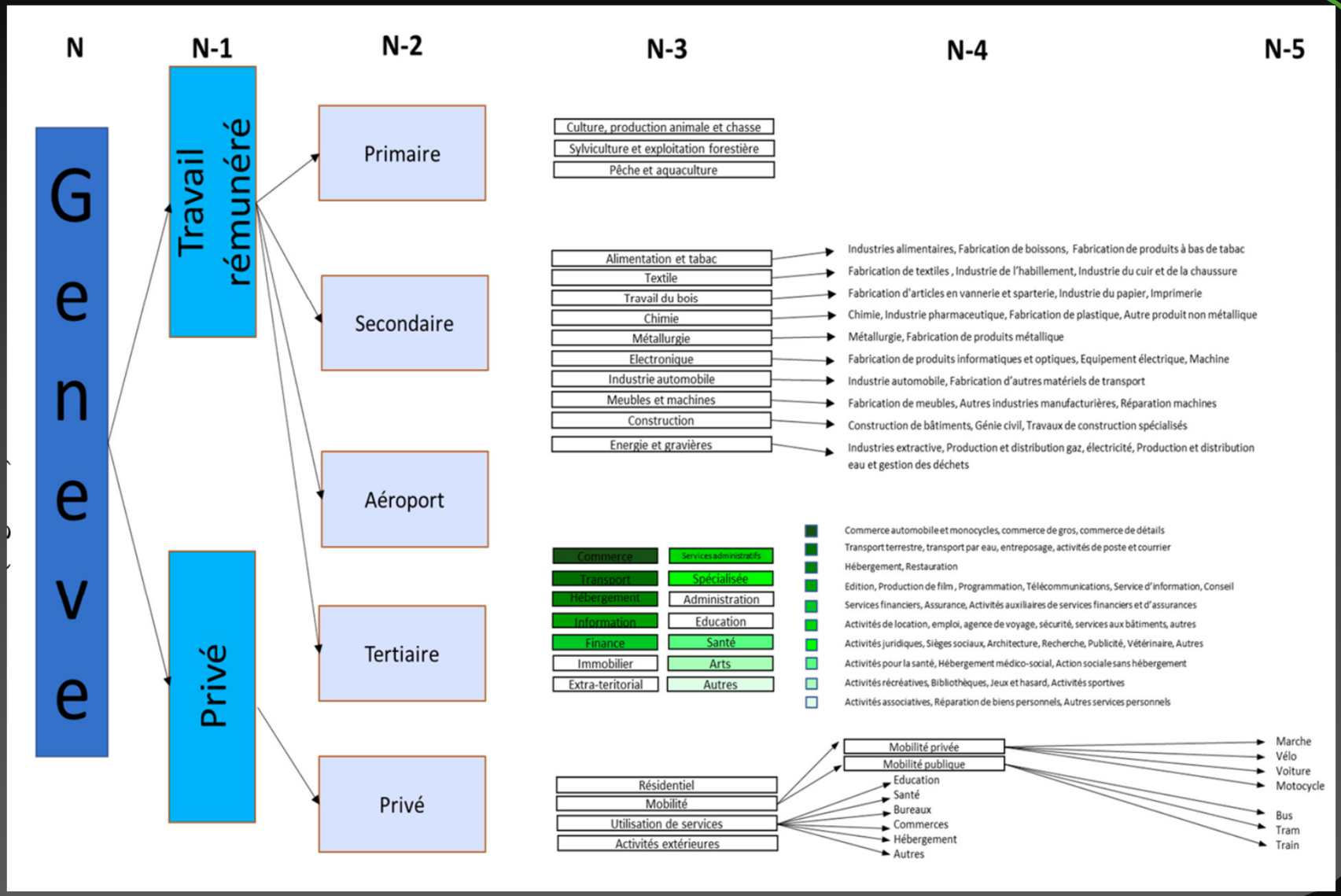
Multi-Scale Integrated Analysis of
Societal and Ecosystem Metabolism





https://en.wikipedia.org/wiki/MuSIASEM

MuSIASEM: Genève



MuSIASEM: Genève

Selected funds and flows variables

Flow / Fund	fund	flow	flow	flow	flow	flow	flow	flow
Internal / External	internal / external	internal / external	external	external	external	external	internal/ external	external
intensive / extensive	extensive	extensive	extensive	extensive	extensive	extensive	extensive	extensive
Input / output	Input	Input	Input	Input	Input	Input	Input	Output	Output
Name of variable	**Human activity**	**Electricity**	**Gaz**	**Oil**	**Mazout**	**Total Petrol**	**Water**	**GDP**	**CO_2**
Unit	h	GW/h	TJ	TJ	TJ	TJ	m3	CHF	T
Year of data	2015	2016	2016	2016	2016	2016	2016	2015	2016
N-2	**Private**								
N-3	**Residential**								
N-3	**Mobility**								
N-4	Proivate mobility								
N-5	Cars								
N-5	Motos								
N-5	Active mobility								
N-4	Public mobility								
N-5	Bus								
N-5	Tramway								
N-5	Train								
N-3	**Service use**								
N-4	Education								
N-4	Health								
N-4	Office								
N-4	Commercial								
N-4	Bar / restaurant / hotel								
N-4	Others								
N-3	**Outdoor activities**								

Hierarchical levels

End use matrix

Intensive Variables - Variables Extensives /Human Activity (HA):

1. **Majority of human activity (HA) in the private sector**
2. **Majority heavy consumption in the residential and tertiary sectors**
3. **Intensive consumption dominated by economic sectors**

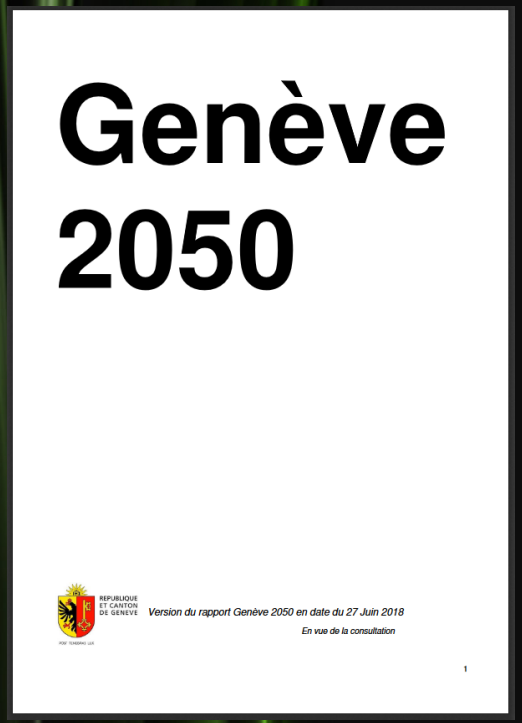
		Intensive					Extensif				
	HA	EMR				EJP	ET				GDP
		Electricity	Gaz	Petrol	Water		Electricity	Gaz	Petrol	Eau	
	Mh	kWh/h	MJ/h	MJ/h	L/h	CHF/h	GWh	TJ	TJ	dam3	M€
Geneva	**4'680**	**0.5**	**2.7**	**6.4**	**11**	**9.3**	**2'412**	**12'691**	**30'088**	**49'697**	**43'303**
Private	**4'060**	**0.2**	**2.3**	**2.3**	**8**	**0.0**	**697**	**9'507**	**9'208**	**32'531**	**0**
Residential	3'448	0.2	2.8	1.4	9	0.0	676	9'496	4'779	32'529	0
Mobility	210	0.1	0.1	21.1	0	0.0	21	11	4'427	0	0
service use	169	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Outdoor activities	89	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Paid work	**620**	**2.8**	**5.1**	**33.7**	**28**	**69.9**	**1'715**	**3'184**	**20'880**	**17'167**	**43'303**
Primary	18	0.5	11.8	4.1	110	7.1	8	207	72	1'933	125
Secondary	85	4.6	23.8	2.4	26	87.2	389	2'019	201	2'238	7'391
Airport	3	1.2	0.0	6'229	72	557	3	0	17'442	202	1'561
Tertiary	514	2.6	1.9	6.2	25	66.5	1'314	958	3'165	12'794	34'226

1

2

3

Report «Genève 2050»



Scénario de type « Continuation » :
les tendances déjà observables au présent se poursuivent

Scénario de type « Limites et discipline » :
les comportements doivent s'adapter pour faire face aux contraintes environnementales ou aux limites du monde physique.

Scénario de type « Effondrement » :
des dégradations systémiques et l'échec des tentatives de régulation provoquent un recul significatif du niveau de vie, qui peut aller jusqu'à un effondrement civilisationnel.

Scénario de type « Transformation » :
la combinaison de nouvelles formes d'organisations et d'échanges commerciaux, de nouvelles technologies et d'une dynamique de transformations socioculturelles permettent à la société de se transformer, et ce faisant, d'accroître significativement sa capacité d'action.

(République et canton de Genève, 2018)

Gonzales, 2020, MUSE

Scenarios

Genève 2050

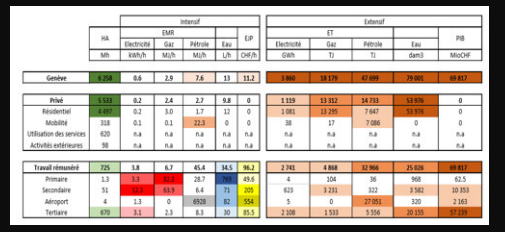
RÉPUBLIQUE ET CANTON DE GENÈVE *Version du rapport Genève 2050 en date du 27 Juin 2018*

En vue de la consultation

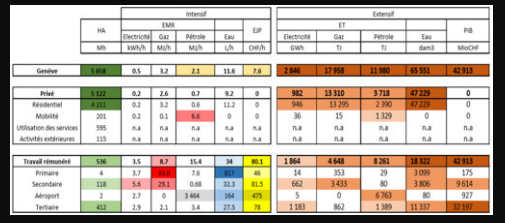
X

	HA	Intensif EMR Electricité	Gaz	Pétrole	Eau	EJP	Extensif ET Electricité	Gaz	Pétrole	Eau	GDP
	Mh	kWh/h	MJ/h	MJ/h	L/h	CHF/h	GWh	TJ	TJ	dam3	M€
Genève	4 665	0.5	2.7	6.5	11	9.3	2 411	12 691	30 088	49 698	43 303
Privé	4 060	0.2	2.3	2.3	8	0.0	697	9 507	9 208	32 531	0
Résidentiel	3 448	0.2	2.8	1.4	9	0.0	676	9 496	4 779	32 529	0
Mobilité	210	0.1	0.1	21.1	0	0.0	21	11	4 427	0	0
Utilisation de services	169	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Activités extérieures	89	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Travail rémunéré	605	2.8	5.3	34.5	28	71.6	1 715	3 183	20 880	17 167	43 303
Primaire	2.5	3.3	82.4	28.7	769	50.0	8	207	72	1 933	125
Secondaire	85	4.6	23.8	2.4	26	87.2	389	2 019	201	2 238	7 391
Aéroport	3	1.2	0.0	6 229	72	557	3	0	17 442	202	1 561
Tertiaire	514	2.6	1.9	6.2	25	66.5	1 314	958	3 165	12 794	34 226

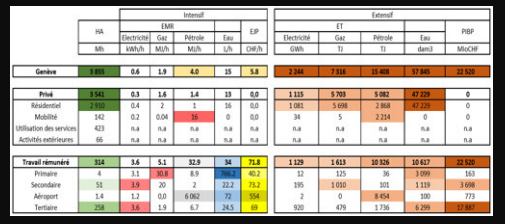
Scénario 1



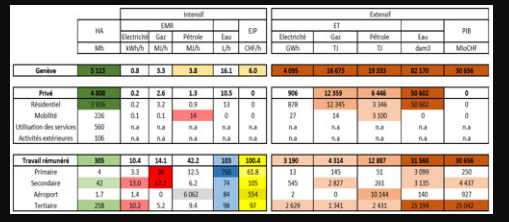
Scénario 2



Scénario 3



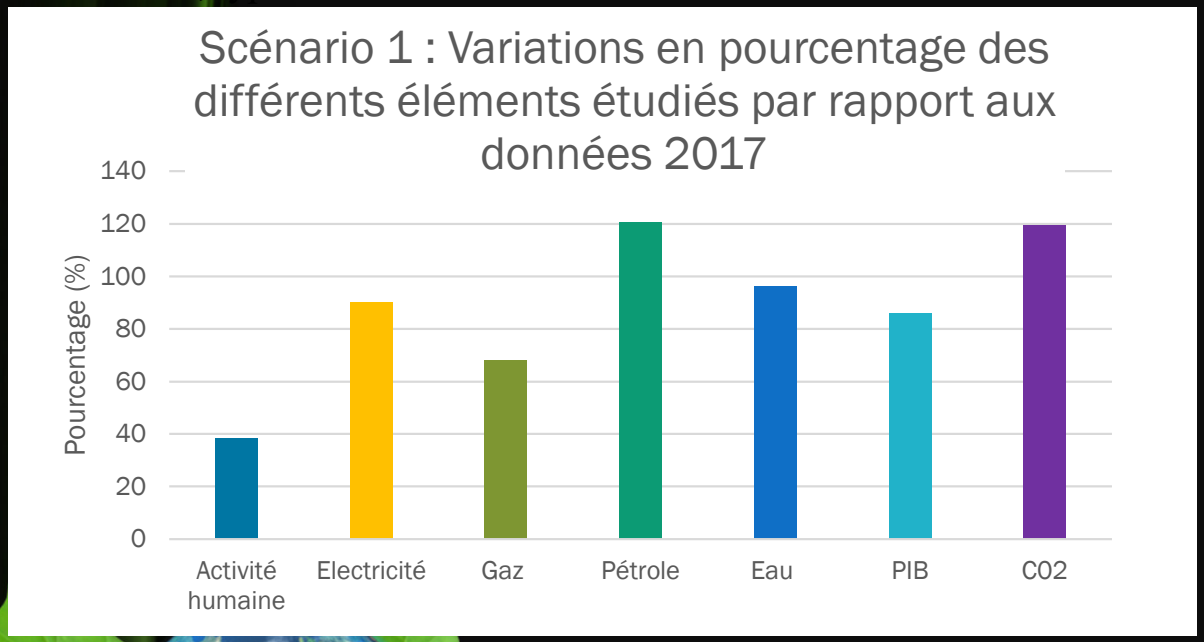
Scénario 4

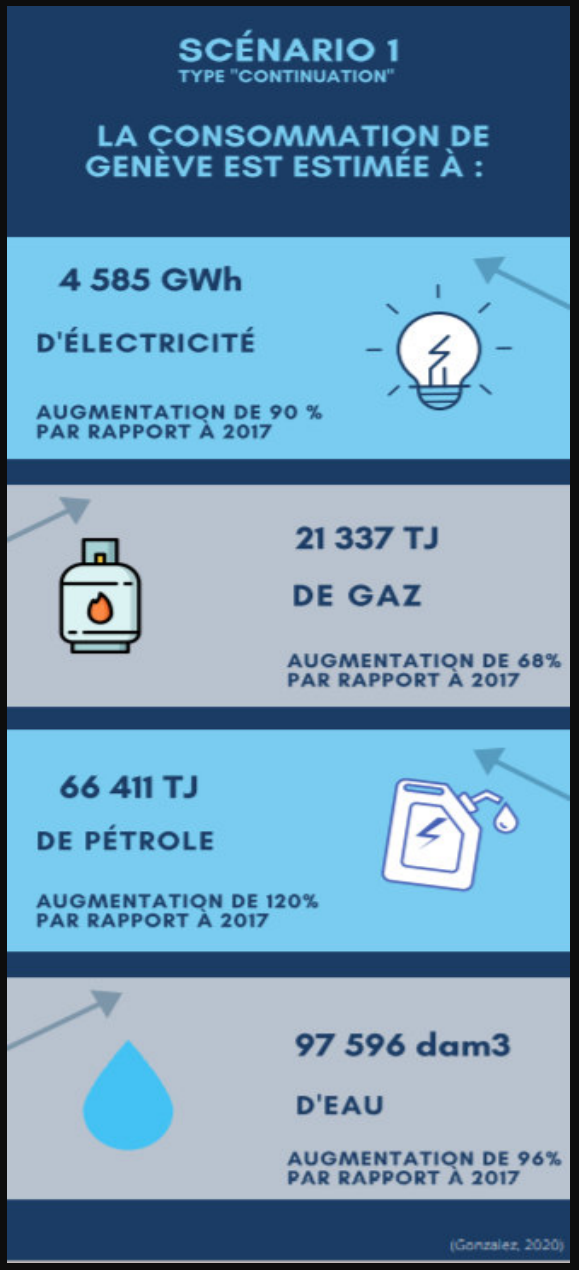


Gonzales, 2020, MUSE

Scenario 1

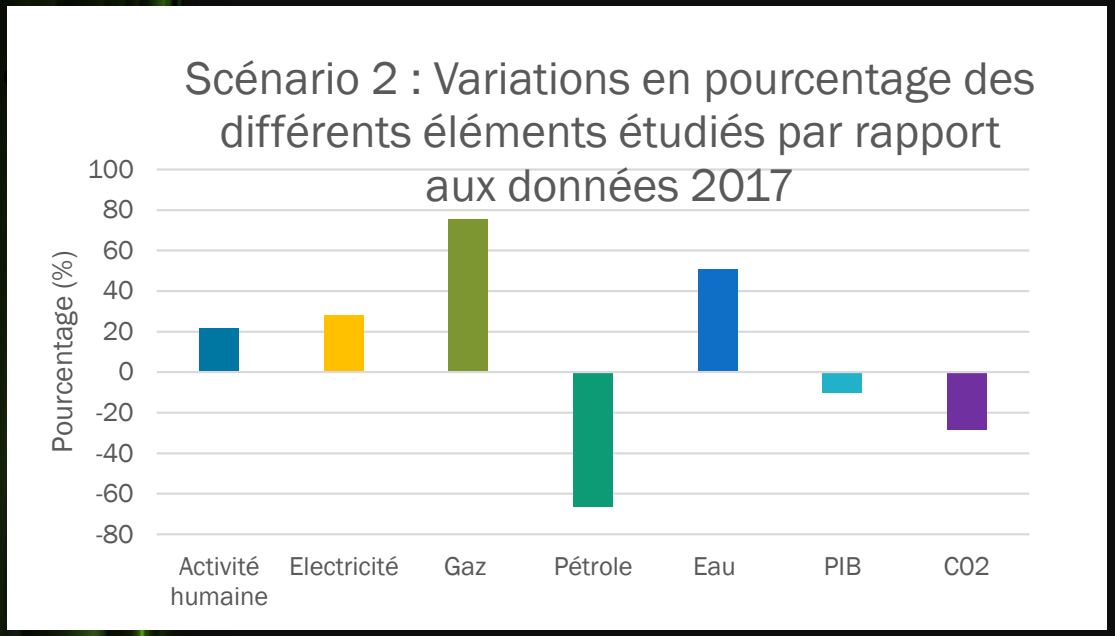
Scénario 1, type «continuation» :

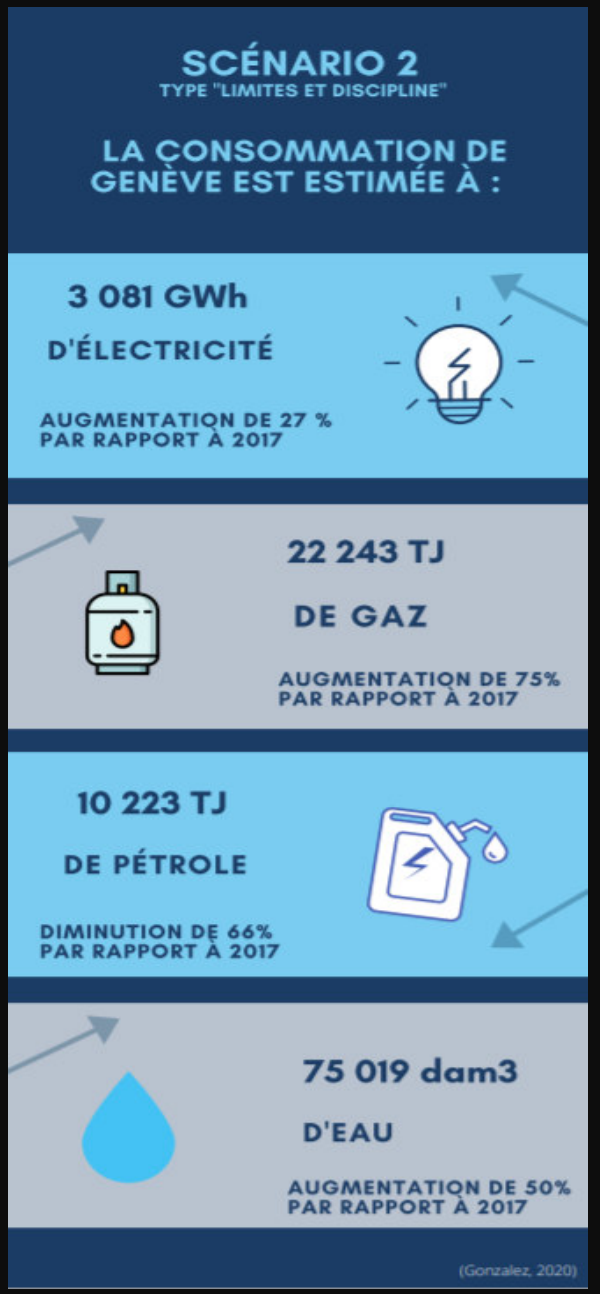




Gonzales, 2020, MUSE

Scenario 2

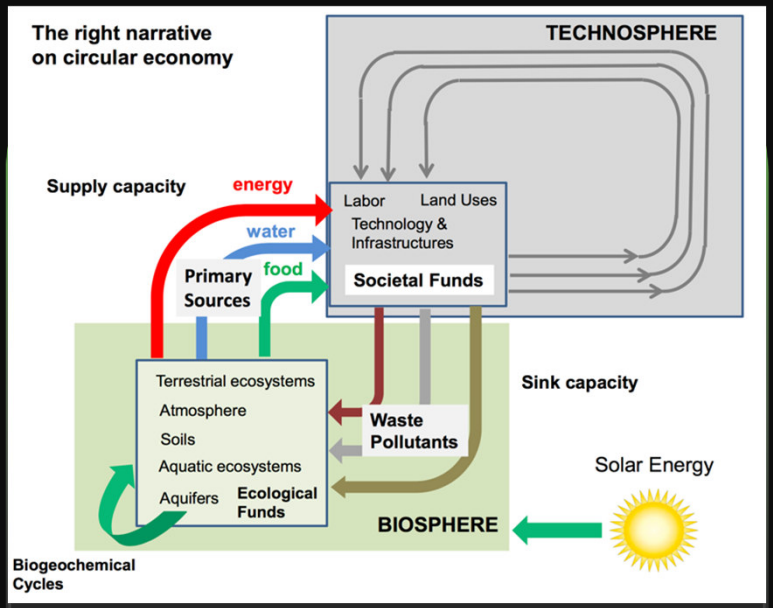




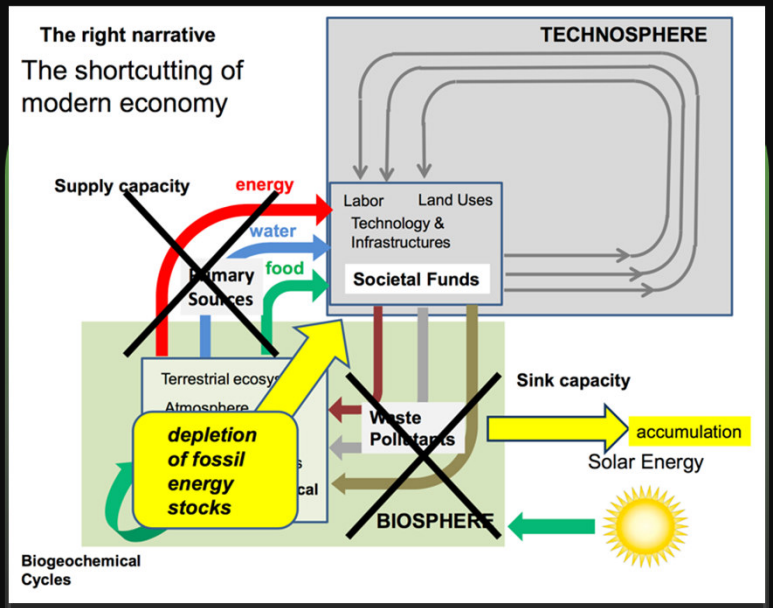
Gonzales, 2020, MUSE


CONCLUSIONS

Circular economy?



Before the industrial revolution and access to fossil fuel sources the economy could still be considered circular, with a possible recycling of all waste and pollutants



The modern economy has completely crowned the natural metabolism of our societies and causes the reduction of fossil energy stocks and the accumulation of pollutants (e.g. CO2)

Giampietro et al. 2020, in press

Is there a pilot on the plane?

The current level of control around sustainable development issues

Giampietros' slides

Is there a pilot on the plane?

Le niveau de contrôle que nous souhaiterions voir partout

Giampietros' slides

Is there a pilot on the plane?

Avec un véritable tableau de bord des ODD

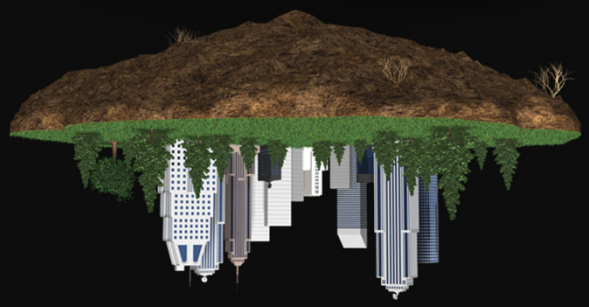
Giampietros' slides

Conclusions

Ecosystem Services (ES): anthropocentric concept

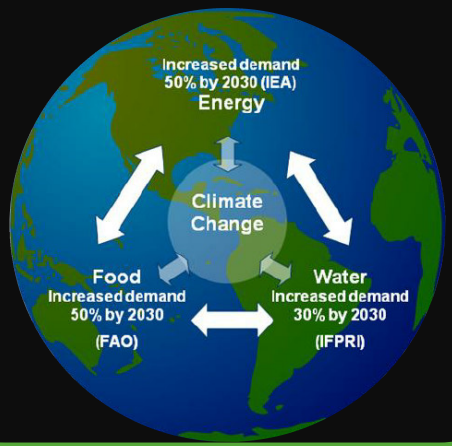
We have the data and tools to evaluate ES

Whatever the approach, we exceed the planet's natural ability to regenerate the natural capital we need!



The Nexus is a political and scientific approach aimed at integrating the objectives of the different sectors

The complexity of the SDGs requires an integrated Nexus-type approach



https://www.naturebasedsolutionsinitiative.org

Some references

Costanza, R. et al. Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals. Ecological Economics 130, 350-355 (2016).

Fischer, J. et al. Advancing sustainability through mainstreaming a social–ecological systems perspective. Current Opinion in Environmental Sustainability 14, 144-149 (2015).

Biggs, E.M. et al. Sustainable development and the water-energy-food nexus: A perspective on livelihoods. Environmental Science & Policy 54, 389-397 (2015).

Gallagher, L. et al. The critical role of risk in setting directions for water, food and energy policy and research. Current Opinion in Environmental Sustainability 23, 12-16 (2016).

Honeck, E.C. et al. Implementing Green Infrastructure for the Spatial Planning of Peri-Urban Areas in Geneva, Switzerland: Sustainability (2020)

Giuliani, G. et al. Knowledge generation using satellite earth observations to support sustainable development goals (SDG): A use case on Land degradation: International Journal of Applied Earth Observation and Geoinformation (2020).

Lehmann, A. et al. Lifting the Information Barriers to Address Sustainability Challenges with Data from Physical Geography and Earth Observation. Sustainability 9 (2017).

Lehmann, A. et al. GEOEssential – mainstreaming workflows from data sources to environment policy indicators with essential variables: International Journal of Digital Earth (2019).

Lehmann, A., et al. Towards integrated essential variables for sustainability. International Journal of Digital Earth (2020).

Lu, Y.L., Nakicenovic, N., Visbeck, M. & Stevance, A.S. Five priorities for the UN Sustainable Development Goals. Nature 520, 432-433 (2015).

Reyers, B., Stafford-Smith, M., Erb, K.-H., Scholes, R.J. & Selomane, O. Essential Variables help to focus Sustainable Development Goals monitoring. Current Opinion in Environmental Sustainability 26–27, 97-105 (2017).

Saltelli, A. & Giampietro, M. What is wrong with evidence based policy, and how can it be improved? Futures (2017).

Wood et al. Distilling the role of ecosystem services in the Sustainable Development Goals. Ecosystem services (2018).

Internet links

Vidéos:

- ✓ Nexus: https://www.coursera.org/learn/sustainability-social-ecological-systems/lecture/WLFIa/welcome-to-our-course-on-sustainability
- ✓ Ecosystem services: https://www.youtube.com/watch?v=Cr1wn4Do7gE
- ✓ Story of stuffs: http://storyofstuff.org/movies/story-of-stuff/

Présentations recommandées:

- ✓ Georgina Mace: https://www.youtube.com/watch?v=Cr1wn4Do7gE
- ✓ Camino Liquete: https://mediaserver.unige.ch/play/100389
- ✓ Alessandro Gimona: https://mediaserver.unige.ch/play/102254
- ✓ https://www.ted.com/talks/johan_rockstrom_let_the_environment_guide_our_development
- ✓ https://www.ted.com/talks/pavan_sukhdev_what_s_the_price_of_nature

MOOCs:

- ✓ https://www.coursera.org/learn/sustainable-development
- ✓ https://www.coursera.org/learn/sustainability-social-ecological-systems
- ✓ https://www.coursera.org/learn/ecosystem-services/home/welcome

Livres:

- ✓ http://ab.pensoft.net/article/12837

Université de Genève:

- ✓ https://www.unige.ch/environnement
- ✓ https://www.unige.ch/envirospace

Thank you for your attention

UNIVERSITÉ
DE GENÈVE
INSTITUT DES SCIENCES
DE L'ENVIRONNEMENT