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Measuring the environmental sustainability of cities and societies

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Introduction

INTRODUCTION

- Increasing evidence of the negative effects of current human development model on the environment, make clear the *decreasing time our planet [as environment] can sustain human societies.*

- In order **to increase current sustainability, we need to adapt our societies, and transform unsustainable patterns.**

Introduction

- Being able to determine which patterns need to be modified and which patterns should we adopt instead, requires **quantitatively assessing the greater or lesser environmental sustainability of current behaviors** and others which could substitute them.

- Quantitative assessment should provide guidance on which changes are convenient and which are not, and the priority / urgency of each change.

Introduction

- However, different experts propose different procedures for undetaking this quantitative assessment, which leads to different measurements, hence different priorities and set of optimal transformations...
- To better understand the issue, let us review different proposals for undertaking this assessment

Assessing Environmental Sustainability

Assessing Environmental Sustainability

- Currently **we find three approaches for assessing environmental sustainability** of different states/ transformations of society:

1. **Improvement** over current situation.
2. **Comparison/ranking** of cities/societies
3. Comparison of **consumptions against total available resources**

Assessing Environmental Sustainability

- The first approach, **assumes improvement from current status implies advancing towards sustainability.**

- We find many example of indicators/references: Sustainable Development Goals, DNGB Urban Districts, LEED ND, Casbee for Cities, Star Communities….

Assessing Environmental Sustainability

- An example:

  “New buildings must demonstrate an average percentage improvement of 12% (1 point) or 20% (2 points) over …. Standard …” [LEED ND ND 2018. Gib Credit: Optimize Building Energy Performance]

Assessing Environmental Sustainability

- **Drawback: Improving does not ensure sustainability.** A building which uses less energy than a typical building, may be sustainable or not depending on how much energy uses the typical building.

Assessing Environmental Sustainability

- The **comparative approach,** is based on ranking cities/societies so worst ranked societies/cities can copy the practices and methods of best ranked societies/cities.

- A min-max [or 0-max] normalization is used for the indicators, therefore: Best performance city [or 0 consumption] and worst performance city define the top and bottom values of the scale.

Assessing Environmental Sustainability

- **Drawback:** Societies/Cities comparison [ranking] is not a measure of their environmental sustainability /unsustainability:

  - If all societies/cities are highly unsustainable, the comparison does not mean the best cities are sustainable [copying patterns of best ranked cities does not ensure sustainability].
  - If all societies/cities are highly sustainable, the comparison does not mean the worst cities are unsustainable [transformation could actually not be necessary].

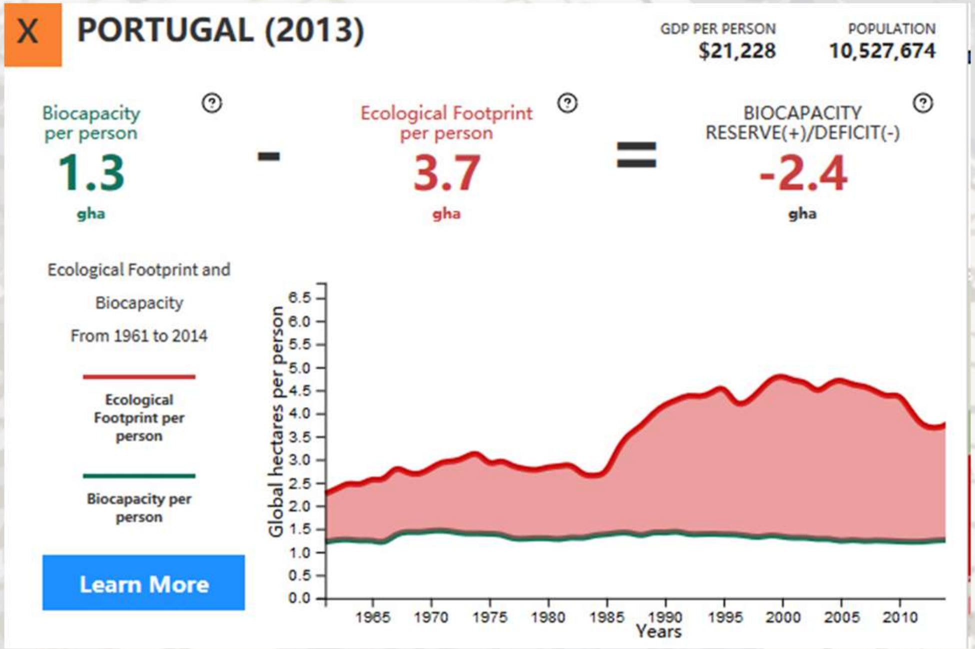
Assessing Environmental Sustainability

- The third approach, **Comparing consumptions against earth Biocapacity,** is the only approach that actually informs of environmental sustainability.

- A first group of indicators set one boundary and check whether consumptions are below or above said boundary. E, g. Planetary Boundaries [Rockstrom et Al, 2009]; Ecological Deficit,…

Assessing Environmental Sustainability

- For instance: in Portugal 2013, Ecological Footprint per person was higher than Biocapacity per person, implying an Ecological Deficit:



- Source: http://data.footprintnetwork.org/#/

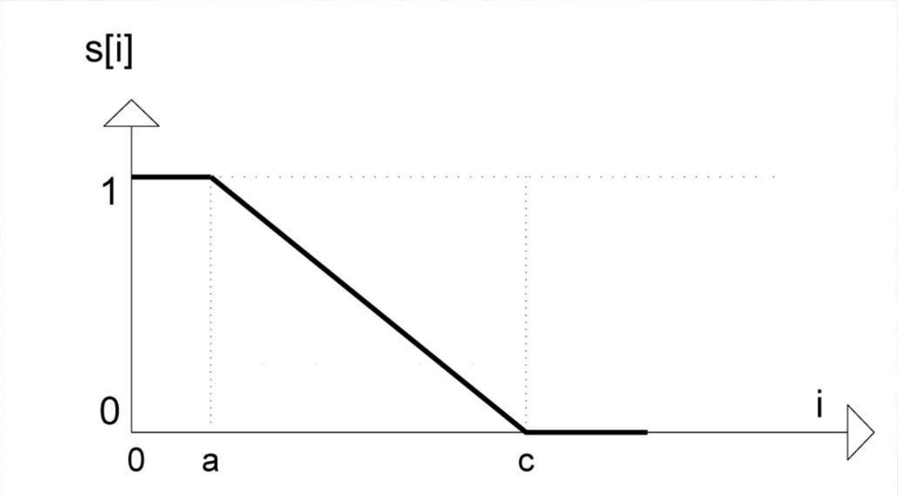
Assessing Environmental Sustainability

- **Drawback:** *Societies deficit/surplus is not a measure of their unsustainability.*

  - A society which uses **little biocapacity** is far more environmentally sustainable than another which uses almost all its share of biocapacity, even if both have no deficit…. *How much sustainable is each of them?*
  - A society with a smaller **ecological deficit** is less environmentally unsustainable than another with higher ecological deficit, but .. *How much unsustainable is each of them?*

Assessing Environmental Sustainability

- **In order to answer above questions, we need continuous measuring, which requires defining fuzzy functions.** An example of linear fuzzy function is [Zadeh, 1965]:



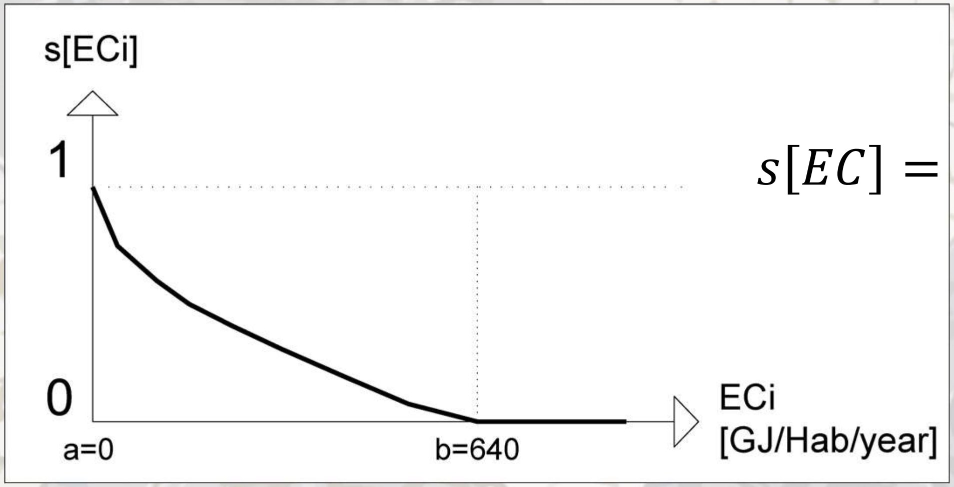
- For such function, not one but two thresholds must be set.

Assessing Environmental Sustainability

- Some authors have already –explicitly or not- built on this conceptualization, e.g.:
  - Prescott Allen, 2001
  - Sustainable Cities Index, 2004
  - Rueda et Al, 2007 & 2012
  - Graymore et Al, 2010
  - …

Assessing Environmental Sustainability

- For instance, the assessment of Energy Consumption [Prescott Allen, 2001:95] can be modelled as a fuzzy function, approximately described by the equation:



$$s[EC] = \max\left[\min\left[1 - \frac{\sqrt{EC_i}}{\sqrt{640}}; 1\right]; 0\right]$$

Assessing Environmental Sustainability

- However, while conceptually correct, we find some drawbacks in most above indicators:
  - Most of them only take into account direct consumptions, yet in developed societies most consumptions are indirect.
  - There is some lack of consistency in chosen thresholds [which usually do not fit to Earth thresholds] and functions [e.g., according to above function, linearly increasing consumption, increases unsustainability with decreasing marginality, a relation which intuitively should be linear or the opposite]

Assessing Environmental Sustainability

- So let us a explain an easy procedure that can be used for assessing environmental sustainability/ unsustainability.
- This procedure, relates sustainability to Earth renewable resources/assimilation capacity.

EARTH CAPACITY/CONSUMPTION THRESHOLDS

Planetary vs Individual Thresholds

Planetary vs individual thresholds

- In order to simplify the problem, we focus on six human processes considered by most experts [e.g.: Wolman, 1965] as currently most important for environmental sustainability :

  - Water Use/Water contamination
  - Resources/Solid Waste
  - Energy consumption/gas emissions

Planetary vs individual thresholds

- First of all, **we define a hierarchy structuring different dimensions of these six cycles.**

Planetary vs individual thresholds

TABLE: INDICATORS FOR ASSESSING ENVIRONMENTAL SUSTAINABILITY			
E. Environmental Sustainability	M1. Water Resources Use [Blue Footprint Consumption]		
	M2. Water Contamination [Grey Footprint]		
	M3. Use Of Bioproductive Land (1)	Cropland	
		Grazing Land	
		Forest Land	
		Fishing Ground	
		Built-up Land	
	M4. Use Of Materials/ Solid Waste	Biotic Resources	Organic waste
			Paper
			Wood and Textiles
		Abiotic Resources	Glass
			Metal
			Pllastics
			Construction and Demolition
	M5. Energy Consumption	Non Renewable Energy Consumption	
		Renewable energy consumption	
	M6. Ghg Consumption		

Source: Alvira, 2017

(1) Ecological Footprint excluding CO2 emissions, which are included in M6

PLANETARY VS INDIVIDUAL THRESHOLDS

- We need calculate two consumption thresholds for each indicator. These thresholds must relate to actual Earth capacity
- Currently we can make a sufficiently accurately estimate of Earth renewable capacity for most of these cycles. But …
- …the issue comes when reviewing how such renewable capacity is distributed among its potential users.

PLANETARY VS INDIVIDUAL THRESHOLDS

- It is mostly **a distribution problem**. We can estimate how much total resource can be used by all individuals, but we must decide how should this amount be actually distributed among individuals:
  - Should we consider the biocapacity of the Earth must be equally distributed among [used by] all its inhabitants?
  - Or should we accept some inequality on the distribution/use?
  - If we accept inequality… How much inequality in the distribution/use should be accepted?

PLANETARY VS INDIVIDUAL THRESHOLDS

- Building on our economic paradigm, *it could be argued that since there is no limit for economic inequality, there should be no restriction on individual biocapacity use/consumption.*

Planetary vs individual thresholds

- The drawback of this approach is many of the above cycles are public goods; i.e., which access can not be prevented. Furthermore, individuals can use greater amount of resources/ assimilation capacity that which use can be sustained over time [i.e., they can use ‘savings’].

- And imposing no limits on individual use of biocapacity is most likely the main reason which has taken to our actual situation; **allowing every individual use as much biocapacity as he wants has proven to lead to excessive consumption patterns.**

Planetary vs individual thresholds

- Therefore, **the only acceptable approach is to set limits to maximum individuals admissible biocapacity use.**

- But, … which should these limits be?.

PLANETARY VS INDIVIDUAL THRESHOLDS

- **Plato suggested no person should benefit of more than 5 times** the goods than the person with less goods in the community [ib., 349 BC]

- Let **us increase such limit up to 7 times,** and consider this stands as a type of 'social contract' for the preservation of global environment.

Planetary vs individual thresholds

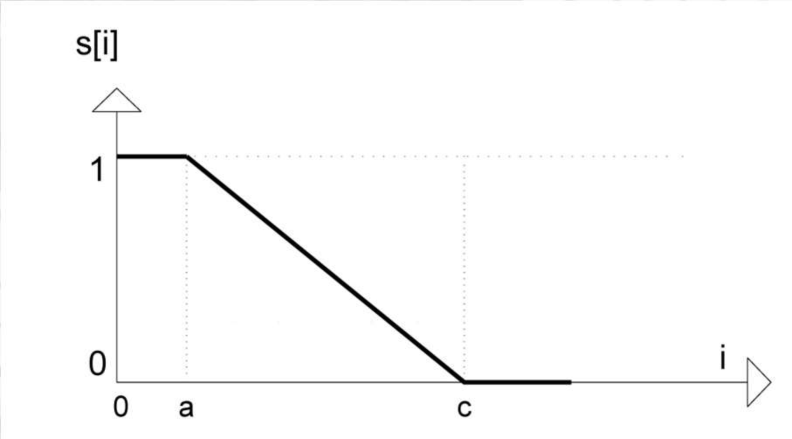
- Therefore, we assess the environmental sustainability of the society as a 'social contract'; i.e., **as if all Earth inhabitants agree to limit their total consumption below global threshold, yet admitting some inequality in the distribution of resources.**

- Let us review the design of the indicators building on above paradigm.

DESIGNING SUSTAINABILITY INDICATORS

DESIGNING SUSTAINABILITY INDICATORS

- We use the procedure explained in Alvira [2014& 2018 based on Zadeh, 1965], so we need to set two thresholds and the equations describing the curve between the thresholds:



$$s[i] = \max\left[\min\left[1 - \frac{i-a}{c-a}; 1\right]; 0\right]$$

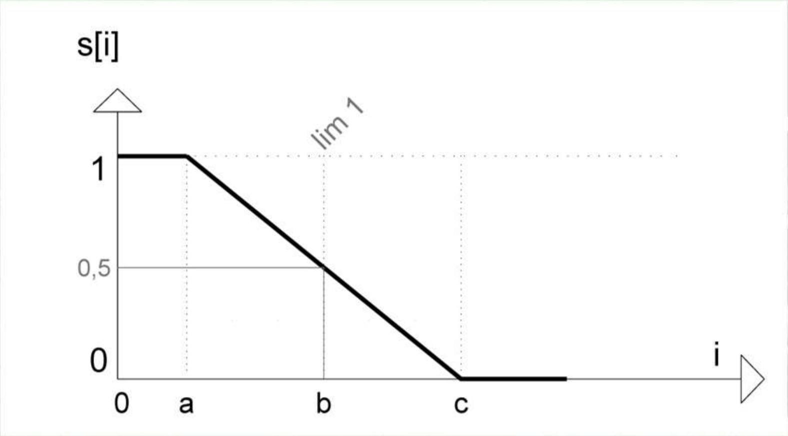
- Where 'i' is biocapacity consumption per inhab, and a,c are the two thresholds

Designing sustainability indicators

- Above function states as our consumption increases, our unsustainability increases [and our sustainability decreases].
- Every use of biocapacity implies some impact on the environment; if every individual uses his biocapacity share, it already has a considerable impact on the environment.

Designing sustainability indicators

- Therefore, for the situation where total available resources are used for sustaining human society, we set the indicator value equal to 0,5, i.e.:



- Where lim 1 is total Earth available [renewable] resources divided by the number of inhabitants

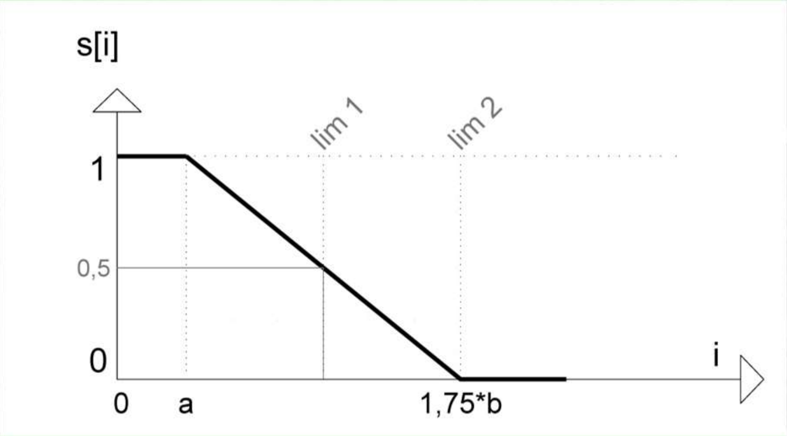
Designing sustainability indicators

- We have also stated some inequality in the use of available capacity should be allowed.

- The maximum admissible inequality is when someone needs to use his own share and ¾ parts of someone else's share, implying as top threshold the use of 1,75 times the individuals' available biocapacity.

DESIGNING SUSTAINABILITY INDICATORS

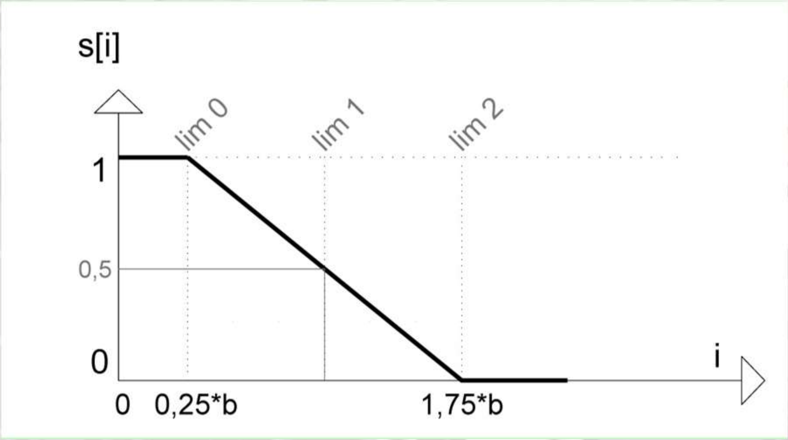
- This can be represented as:



- Where lim2=1,75*lim1 is defined as unsustainability threshold

Designing sustainability indicators

- Lastly, since we have no reason to assume a non linear equation, we calculate lim0 using a linear equation so:



- Lim0 is 0,25*lim1

DESIGNING SUSTAINABILITY INDICATORS

- Then, the complete formulation of each indicator is:

$$\mathrm{S[i]} = max\left[min\left[1 - \frac{i - 0{,}25 * lim1}{1{,}50\ * \mathrm{lim1}}; 1\right]; 0\right]$$

Designing sustainability indicators

- This formulation provides a
  - 1 value when less than 0,25 renewable resources/ available capacity are used
  - a 0,5 value when all renewable resources/available capacity are used
  - and a 0 value when sustaining consumption requires an inequality ratio higher than 7:1

DESIGNING SUSTAINABILITY INDICATORS

- The estimated thresholds for some cycles are [considering footprints]:

SUSTAINABILITY/UNSUSTAINABILITY THRESHOLDS			
	Lim0	Lim1	Lim2
Water use (1)	50,3 m3/inhab/year	204,93 m3/inhab./year	376 m3/inhab/year
Bioproductive Land (2)	20% m2 Bioproductive Land/inhab	80% m2 Bioproductive Land/inhab	131% m2 Bioproductive Land/inhab
Energy consumption (3)	ER = 4 MWh/inhab/year	16 MWh/ inhab /year.	28 MWh/inhab/year
GHG emissions (4)	Emissions=Absorptions	1,27 TmCO2 /inhab/year	2,22 TmCO2 /inhab/year
SOURCE: Alvira, 2017: 311. Own calculation based on estimated population of 8250 MM people in 2050. For detailed sources and assumptions, refer to original source. (1) Based on data of Water Footprint Network (2) Based on data of Global Footprint Network, 2015 (3) Based on data suggested by several experts (4) Own calculation building on global agreements and several experts.			

So, according to this criteria … How much can the environment sustain our current model?

The environmental sustainability of the population of a typical compact city area in Europe

The environmental Sustainability of our current model

- In Alvira [2017] an assessment was undertook of the environmental sustainability of a 65 Ha neighbourhood in Madrid city, Spain.
- It is one of the ten most dense neighbourhoods in Madrid city [120 neighbourhoods]. Area is 65 Ha, with a population around 30.000 people.
- The area was planned by mid XIX century and built along XIX and XX centuries.

The environmental Sustainability of our current model

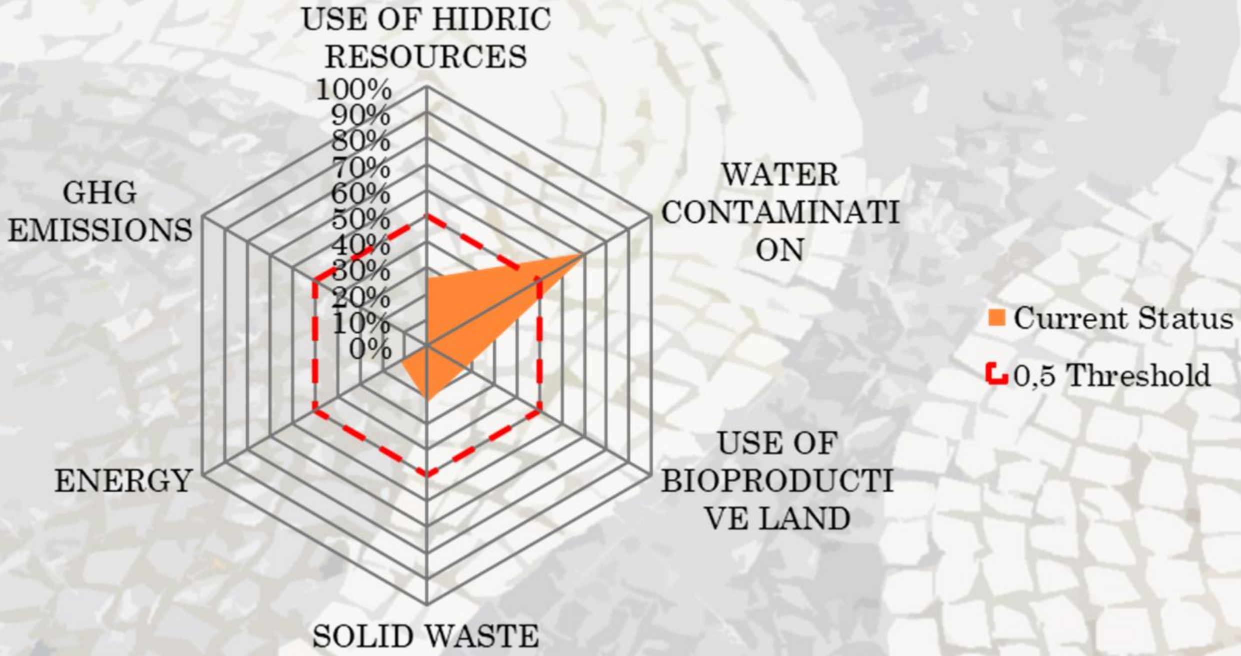
- Assessed area: Palos de Moguer, Madrid

The environmental Sustainability of our current model

- The impact of ***a set of 'best practices'*** was assessed. Said practices were grouped into three areas:
  - ***Mobility***, increasing bicycle share use up to 15%; improving public transport, reducing car use, substituting fuel by electric vehicles.
  - ***Solid Waste***, reuse of 90% of solid waste
  - ***Rooftops,*** improving thermal insulation, installing PV panels, rooftop orchards,…

The environmental Sustainability of our current model

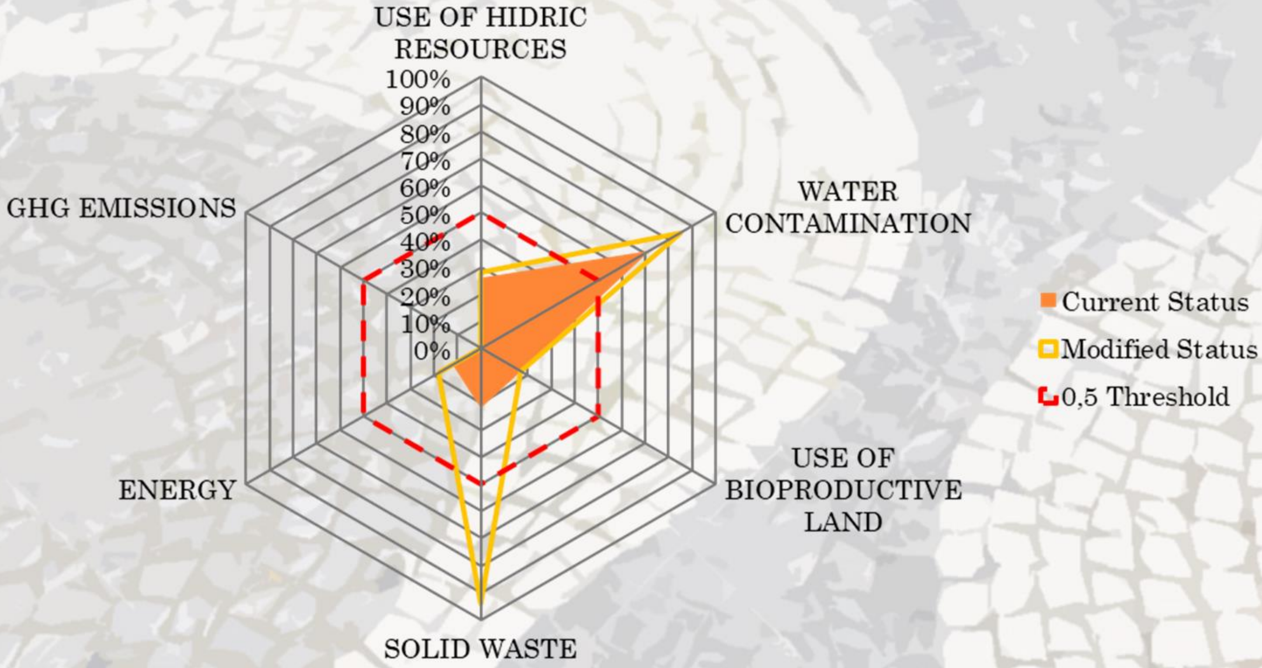
- Current status assessment [environmental sustainability overall value =0,13 or 13%]:



Note: 100% implies complete sustainability; 0% implies complete unsustainability

The environmental Sustainability of our current model

- Assessment after implementing 'best practices' [environmental sustainability = 0,197 or 19,7%]



Note: 100% implies complete sustainability; 0% implies complete unsustainability

The environmental Sustainability of our current model

- The assessment showed two important issues:
  - the *minimal reduction of the high environmental unsustainability achieved via the implementation of these 'best practices'*.
  - technological solutions have lower impact than behavioural patterns change.

CONCLUSIONS

Conclusions

- In order to transform our current society into a sustainable one, we need to identify unsustainable patterns, and formulate alternative sustainable ones.
- Quantitatively assessing the environmental sustainability of different patterns is key in the process.

Conclusions

- An easy procedure for designing indicators for assessing environmental sustainability has been explained.

- For this assessment, an inequality ratio needs to be decided *in the use of Earth [common good] renewable resources / assimilation capacity*.

- A *maximum inequality ratio [1:7] has been proposed/used.*

CONCLUSIONS

- Assessment of a neighbourhood in a *typical European compact city*, shows that
  - *Its environmental unsustainability is much higher than usually assumed.*
  - *The implementation of a set of so –called best practices, only slightly increases the environmental sustainability of the area, which remains greatly unsustainable.*

Conclusions

- This raises a most fundamental issue; sustaining our society and our environment needs *far more transformation of our 'developed' societies, than it is currently assumed…*

- *…and this transformation cannot be expected to be achieved only by technological change. We need to modify current behaviours, i.e.,* ***we need to greatly decrease our total consumption.***

CONCLUSIONS

- Herein procedure for quantitatively assessing environmental sustainability can help designing the optimum transformations of society, as well as measuring actual progress towards an environmentally sustainable model.

THANK YOU !

References

References

- Alvira Baeza, R. (2014). *A Mathematical Theory of Sustainability and Sustainable Development*.

- Alvira Baeza, R. (2017). Un modelo y una metodología para la transformación de ciudades hacia la sostenibilidad (Doctoral dissertation).

- Alvira Baeza, R. (2018). A Methodology for Urban Sustainability Indicator Design. Tema. Journal of Land Use, Mobility and Environment, 11(3), 285-303.

References

- Graymore, M. et Al [2010]. Sustaining Human Carrying Capacity: A tool for regional sustain-ability assessment. Economics & Ecology, 69: 459-468
- Observatorio de la Sostenibilidad, OS [2018] Ciudades Sostenibles En España 2018
- Plato [349 AC] The laws. Translated by Benjamin Jowett

References

- Prescott-Allen, R. [2001] The Wellbeing of Nations A Country-by-Country Index of Quality of Life and the Environment
- Rueda, S. [2007]. Plan Especial de Indicadores de Sostenibilidad Ambiental de la Actividad Urbanística de Sevilla.
- Rockström, J. et Al [2009]. Planetary boundaries: exploring the safe operating space for humanity. Ecological Society, 14 (2): 32

References

- Sustainable Cities International (2012). 'Indicators for Sustainability. How cities are monitoring and evaluating their success'

- United States Green Building Council, USGBC (2018). LEED v4 for Neighborhood Development. Rating System. Updated July 2, 2018.

- Wolman, A. [1965] The metabolism of Cities. *Scientific American*, September 1965:179-190

References

- Zadeh, L. A. [1965]. Fuzzy Sets, *Information and Command*, 8: 338-353