

Students' Teaching Module

Unit 4. (Optional topic)- Ecological Footprint and biocapacity: Equations



EUSTEPs

Enhancing Universities' Sustainability Teaching
and Practices through Ecological Footprint

KA 203, Strategic Partnership in Higher Education 2019-2022, Agreement No. 2019-1-
EL01-KA203-062941

Co-funded by the
Erasmus+ Programme
of the European Union



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HOW TO CITE THIS MATERIAL

- Galli, A., Patrizi, N., Niccolucci, V., Bacelar-Nicolau, P., Caeiro, S., Malandrakis, G., Moreno Pires, S., Nicolau, M., Papadopoulou, A., Mapar, M., Pulselli, F.M., Theodosiou, N., Zachos, D. (2020). EUSTEPs Students' teaching module. Unit 4 - Optional: "Ecological Footprint and biocapacity: Equations"

Unit 4 (Optional topic). Ecological Footprint and biocapacity: Equations

Ecological Footprint main equations

a- slides

Ecological Footprint and biocapacity definitions

THE ECOLOGICAL FOOTPRINT

The Ecological Footprint measures the amount of biologically productive land and water (fishing grounds) area required to:

- produce all the resources an individual, population or activity consumed
- to absorb the wastes they generated, given prevailing technology and resources management practices.

The final Ecological Footprint of an individual or a country is the sum of all these different types of land, irrespective of where they are located.



BIOCAPACITY

- measures the amount of biologically productive land and sea area available to provide the ecosystem services that humanity consumes.
- The biocapacity represents the natural capital that provides the basic life-support services, expressed as the available regenerative capacity of the biosphere.
- The biocapacity represents the ability of the biosphere to produce crops, timber, livestock as well as to absorb carbon dioxide.
- The total biocapacity of a Nation (or planet) is calculated as the sum of the biocapacity supplied by each land type.
- It depends on natural conditions but also on dominant agriculture and forestry practices.



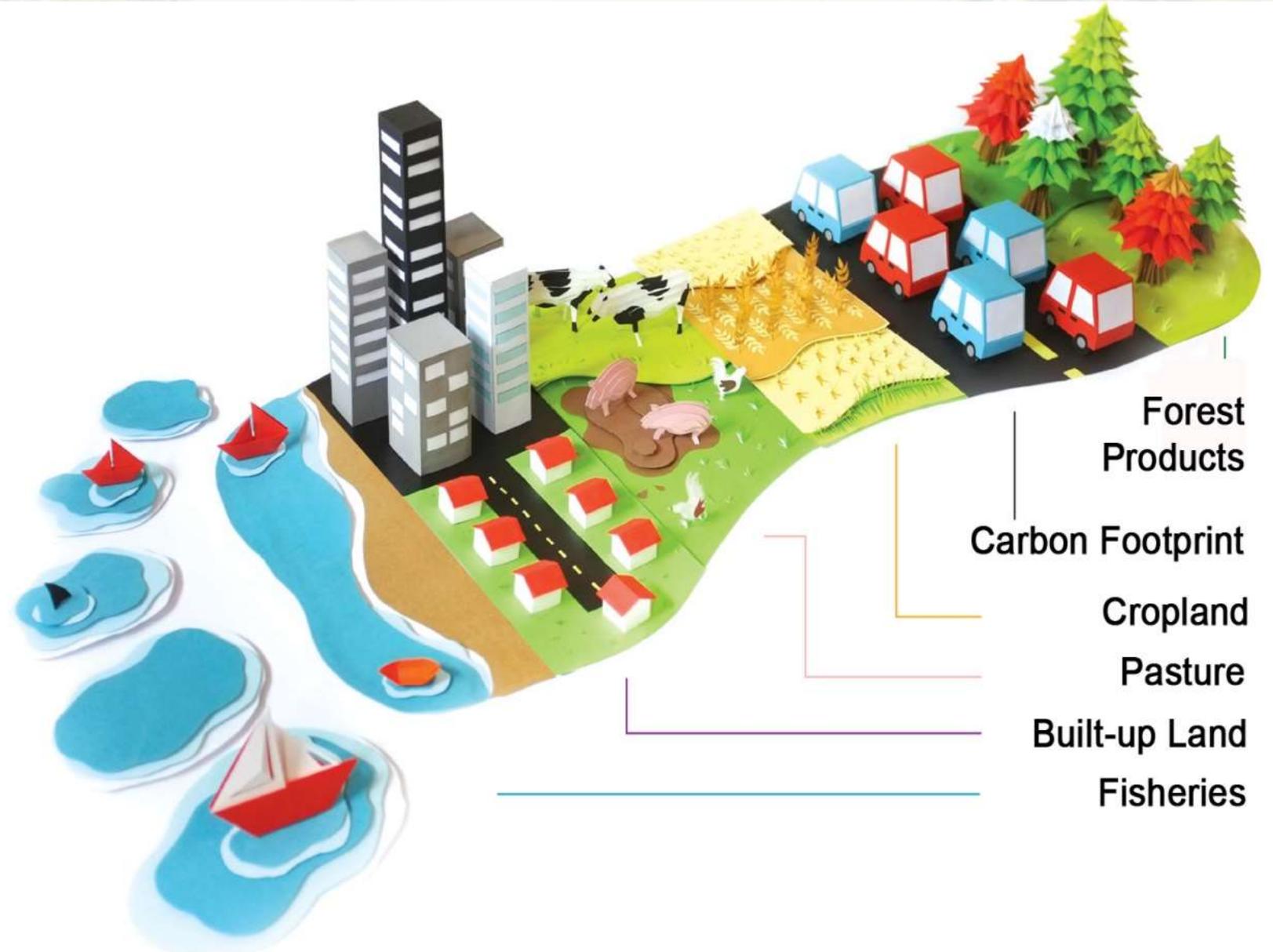
EF Methodology: assumptions, components and unit

Assumptions

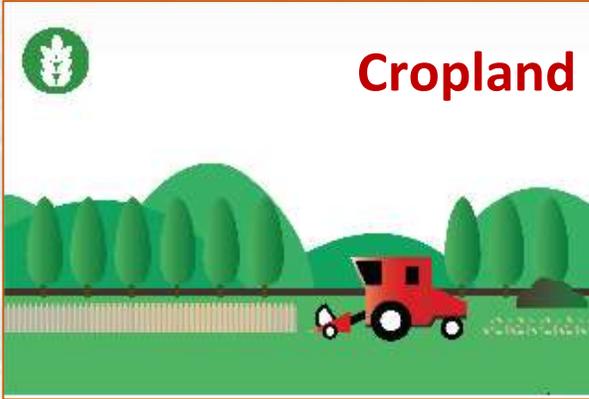
The Footprint methodology is based on six assumptions :

- 1) It is possible to track the annual amounts of resources consumed and wastes generated by countries.
- 2) the majority of these resource flows can be related to the bioproductive area necessary for their regeneration and the assimilation of their waste.
- 3) by weighting each area in proportion to its usable biomass productivity (annual production of usable biomass), the different areas can be expressed in terms of a standardized average productive hectare. They are called 'global hectares'.
- 4) the overall demand can be aggregated by adding all mutually exclusive resource-providing and waste-assimilating areas;
- 5) the aggregate Ecological Footprint and biocapacity can be directly compared to each other;
- 6) area demanded can exceed area supply.

ECOLOGICAL FOOTPRINT components



Ecological Footprint components



Cropland

areas used to produce food and fiber for human consumption, feed for livestock, oil crops, and rubber.

It is calculated by using data on production, import and export of ≈ 400 primary and derived agricultural products.

Source data is FAO

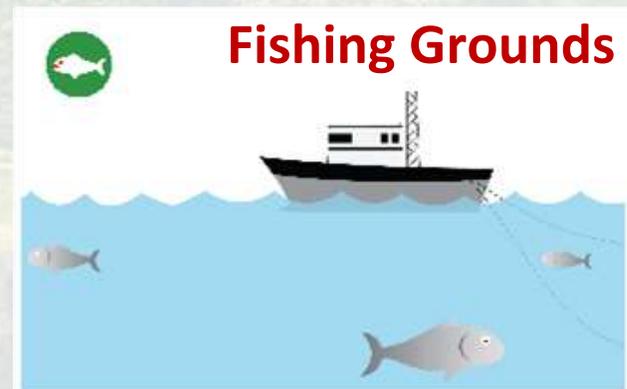
Grazing land is used to raise livestock for meat, dairy, hide, and wool products.

It is calculated by using data on production, import and export of ≈ 150 animal and dairy products (including live animals).

Source data is FAO



Grazing Land



Fishing Grounds

Measures the area of marine and inland water used to provide the primary production needed to sustain aquatic species (including fish meals).

It is calculated by using data on production, import and export of ≈ 1500 fish products.

Source data is FAO

Ecological Footprint components



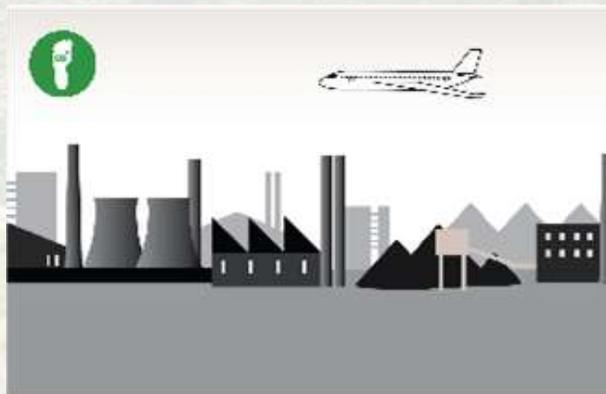
Represents the amount of forest required to supply timber products, pulp and fuel wood. It is calculated by using data on production, import and export of ≈ 30 in between timber and wood fuel products.
Source data is FAO

Represents the amount of land covered by human infrastructure, including transportation, housing, industrial structures and reservoirs for hydropower.

Source data is CORINE, GLC, SAGE, etc



**Carbon
Footprint or
"uptake"
Footprint**



Represents the amount of forest land that could sequester CO₂ emissions from the burning of fossil fuels, excluding the fraction absorbed by the oceans which leads to acidification. It is calculated by using data on emissions from ≈ 45 industrial sectors as well as import and export of ≈ 625 manufactured commodities.

Source data is IEA and UN COMTRADE

Unit of measurement

- Ecological Footprint and biocapacity are usually expressed in **global hectare** (gha).
- Each **global hectare** is defined as hectares of land or sea area normalized to the world average productivity of all biologically productive land and water area in a given year.
- each global hectare represents an equal amount of biological productivity.
- **Yields Factors** (YF) and **Equivalence Factors** (EQF) are the two scaling factors used to “convert” physical hectares to global hectares.

Unit: hectare-equivalent or **Global hectare**

The Ecological Footprint is an indicator of human appropriation of Earth's photosynthetic capacity, although expressed in hectare-equivalents.



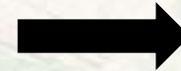
The release of 1 t of CO_{2eq} does not mean that this amount has actually been released (no molecule called CO_{2eq}). Rather, it means that various GHGs with the equivalent global warming potential of 1 t of CO₂ have been released.

Similarly, having a per capita Ecological Footprint of 1 gha doesn't mean that 1 ha of physical land is used. It rather means that the capacity of 1 hectare-equivalents (or gha) is needed to produce (via photosynthesis) the renewable resource provisioning services consumed and to sequester the carbon dioxide emitted

Unit: hectare-equivalent or **global hectare**

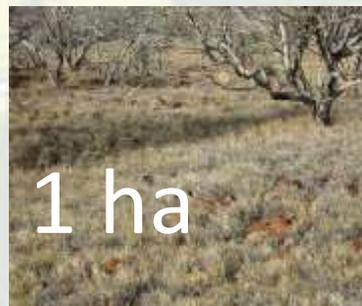
Because different land types have different productivity, a global hectare of, for example, cropland, would occupy a smaller physical area than the much less biologically productive pasture land, as more pasture would be needed to provide the same biocapacity as one hectare of cropland.

For example, if this hectare is twice as productive as a world average, biologically productive hectare. Then it is worth 2 gha.



2 gha

For example, if this hectare is half as productive as a world average, biologically productive hectare. Then it is worth $\frac{1}{2}$ a gha.



$\frac{1}{2}$ gha

Conversion factors and equations

Yield Factors (YF)

- YFs account for countries' differing levels of productivity for particular land use types.
- YF reflects the difference between the national productivity and the world average hectares of a given land use type.
- YF is the ratio of national average to world average yields.
- It is calculated in terms of the annual availability of usable products.
- YFs are country-specific and vary by land use type and year.

$$YF = \frac{Y_N}{Y_W}$$

$$\text{UNIT: } \left[\frac{\cancel{t} / \text{ha}_N}{\cancel{t} / \text{ha}_W} = \frac{\text{ha}_W}{\text{ha}_N} \right]$$



DIMENSIONLESS

Equivalence Factors (EQF)

- EQFs convert the areas of different land use types, at their respective world average productivities, into their equivalent areas at global average bioproductivity across all land use types.
- EQFs vary by land use type as well as by year.
- The rationale behind the EQF calculation is to weight different land areas in terms of their inherent capacity to produce human useful biological resources.
- The weighting criterion is not the actual quantity of biomass produced, but what each hectare would be able to inherently deliver.

$$\text{EQF} = \text{gha}/\text{ha}_w$$

$$\text{UNIT} : \left[\frac{\text{gha}}{\text{ha}_w} \right]$$



DIMENSIONLESS

Table 1: Yield and Equivalence factors, per land type and Nation.

	Yield Factors			EQFs
Land Use type	GREECE	ITALY	PORTUGAL	
Crop Land	1.01	0.79	0.34	2.50
Grazing Land	1.00	1.91	1.92	0.46
Marine Fishing Grounds	0.76	0.90	0.79	0.37
Inland Fishing Grounds	1.00	1.00	1.00	0.37
Forest Land	0.49	1.68	2.05	1.28
Infrastructure	1.01	0.79	0.34	2.50

Source: Global Footprint Network

Ecological Footprint Equations

P is the amount of each primary product that is harvested (or carbon dioxide emitted) in the nation (in tones yr⁻¹);

YF is the country specific yield factor for the production of each product

Y_N is the annual national average yield for the production of commodity (or its carbon uptake capacity in cases where P is CO₂) (t ha_N⁻¹ yr⁻¹).

$$EF = \frac{P}{Y_N} \times YF \times EQF$$

EQF is the equivalence factor for the land use type considered

$$YF = \frac{Y_N}{Y_W}$$

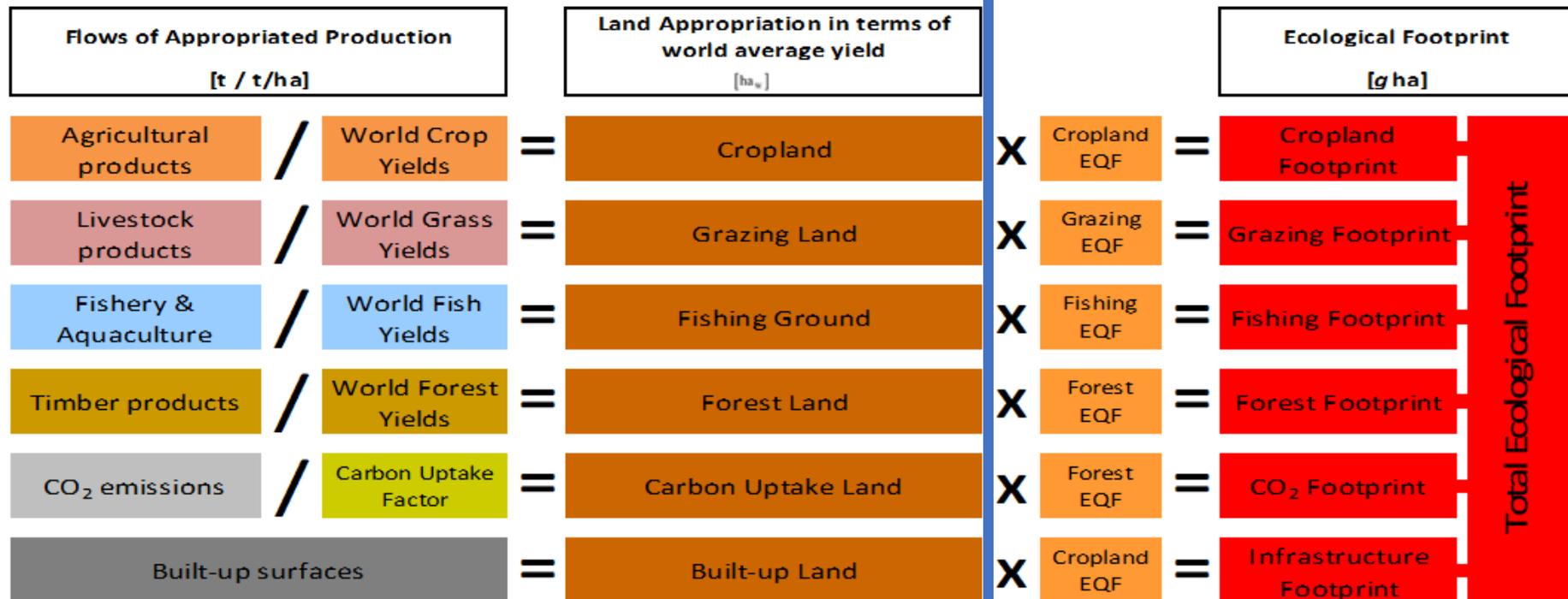
$$EF = \frac{P}{\cancel{Y_N}} \times \frac{\cancel{Y_N}}{Y_W} \times EQF$$

$$EF_P = \frac{P}{Y_W} \times EQF$$

$$\text{UNIT: } \left[\frac{\cancel{t} / \cancel{yr}^{-1}}{\left[\cancel{t} \times (\cancel{ha}_W)^{-1} \times \cancel{yr}^{-1} \right]} \right] \times \left[\text{gha} \times (\cancel{ha}_W)^{-1} \right] = \text{gha}$$

ECOLOGICAL FOOTPRINT

$$EF_P = \sum_{i=1}^6 \frac{P_i}{Y_{W,i}} \times EQF_i$$



Biocapacity equation

For any given land type, biocapacity represents the bioproductive area expressed in nation-specific hectares that is available for the production of each primary product at national level

$$BC = A \times YF \times EQF$$

EQF is the equivalence factor for the land use type considered

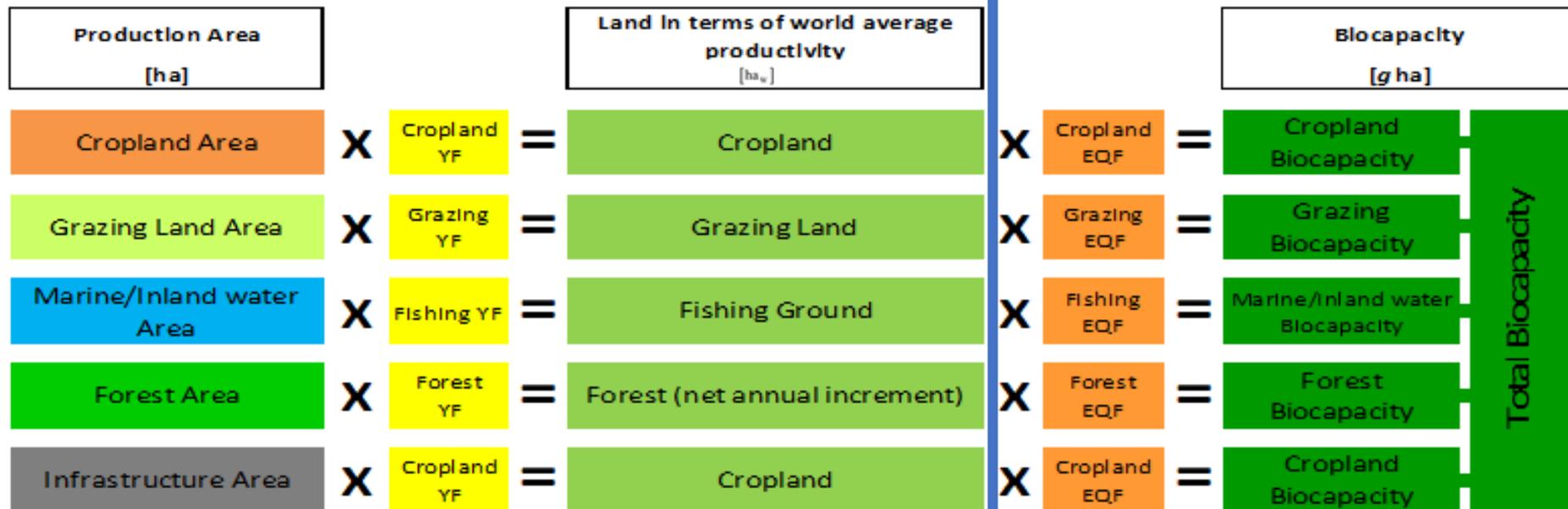
YF is the country specific yield factor for the production of each product

A is area of the nation considered

$$\text{UNIT: } \left[\cancel{\text{ha}}_N \times \frac{\cancel{\text{ha}}_w}{\cancel{\text{ha}}_N} \times \frac{\text{gha}}{\cancel{\text{ha}}_w} = \text{gha} \right]$$

BIOCAPACITY

$$BC_N = \sum_{i=1}^6 A_N \times YF_{N,i} \times EQF_i$$



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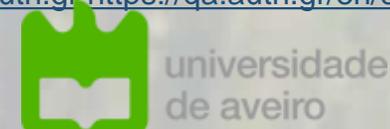
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Thank you!

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"The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflect the views of the authors only. The Commission, along with the National Authority (IKY), cannot be held responsible for any use which may be made of the information contained therein."

Co-funded by the
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