Consumption based IO analysis: Ecological Footprint application

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OUTLINE

- Ecological Footprint methodology
- National Footprint Accounts
- Data Used
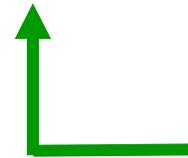- Methodological Improvements

The Ecological Footprint is an environmental accounting tool identifying the extent to which human activities exceed two types of **environmental limits:**

- *resource production*
- *carbon dioxide sequestration*

SUPPLY = BIOCAPACITY
How much bioproductive area is **available to us**?
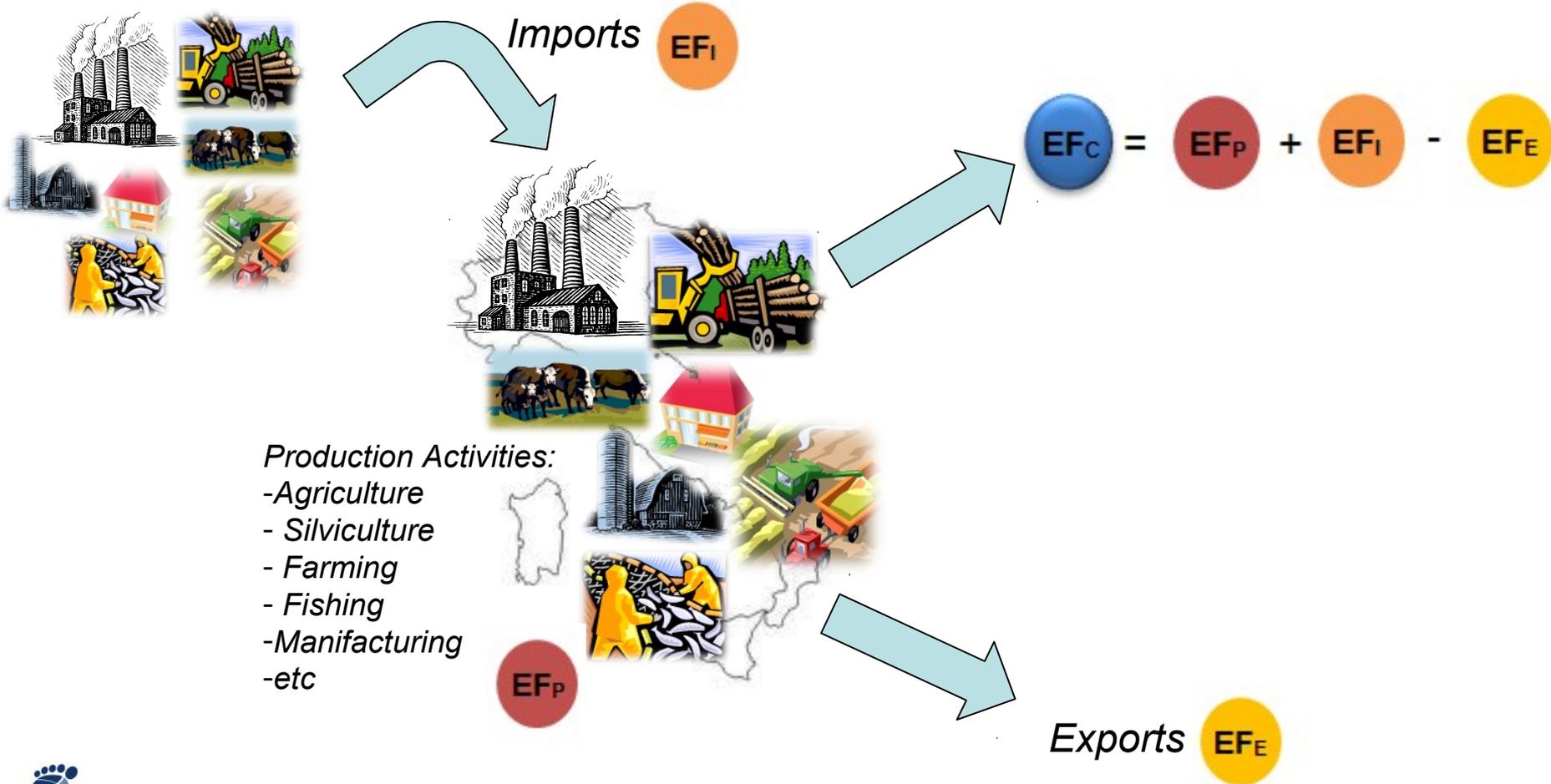

DEMAND = ECOLOGICAL FOOTPRINT
How much bioproductive area do we **use**?

REGENERATE RESOURCES

ABSORB WASTE

Imports EF_I

$$EF_C = EF_P + EF_I - EF_E$$

Production Activities:
-*Agriculture*
- *Silviculture*
- *Farming*
- *Fishing*
-*Manifacturing*
-*etc*

EF_P

Exports EF_E

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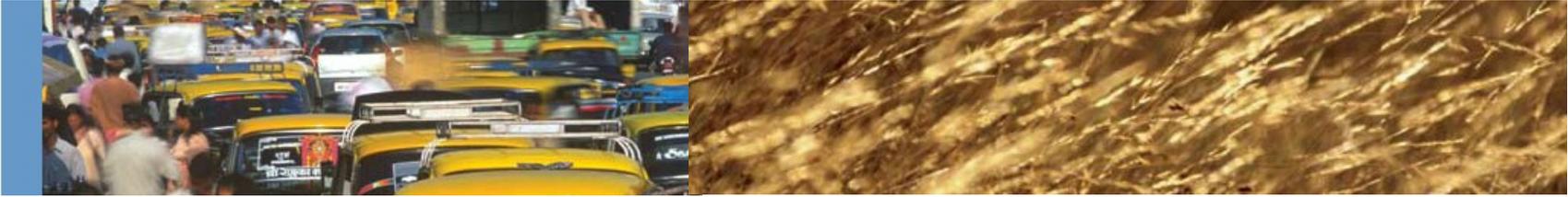
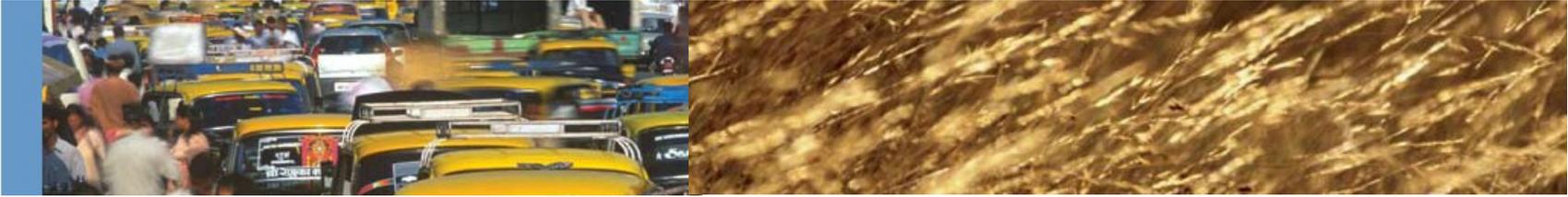The Ecological Footprint is a "resource and energy flows" indicator; however, it is measured in terms of the bioproductive land needed to generate such flows (global hectares - gha).

$EF_C = EF_P + EF_I - EF_E$

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

- **Input variable: flow of physical resources used by humans.**
- **NEED to be aligned with SEEA Chapter 3**

From FLOW to AREA:
- Y_N is used to convert the consumption of a resource flow into the correspondent amount of area locally required to produce that flow
- **YF** is used to scale national to world average productivity for a given land use type
- **EQF** is used to arrive at gha.

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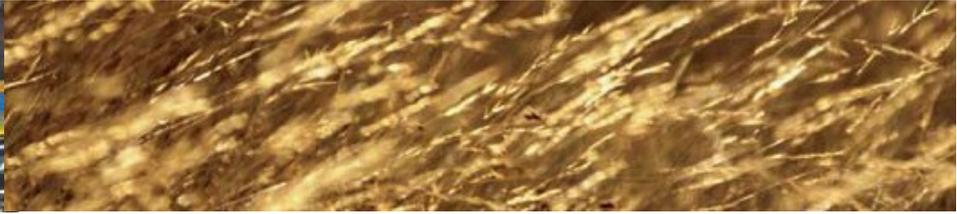
Normalization system: Equivalence Factors

Footprint functional unit is global hectare

EQFs translate the area of a specific land use type into units of world average bioproductive area (gha).

This step is needed to weight different land types according to empirical data on their relative productivity (**Quantity and Quality of production**)

This normalization is based on observable characteristics of the land and sea areas: currently the GAEZ model is used

land type	EQF
Cropland	2.51
Grazing	0.46
Forest	1.26
Fishing	0.37
Carbon	1.26
Built-up	2.51

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Raw Input Data

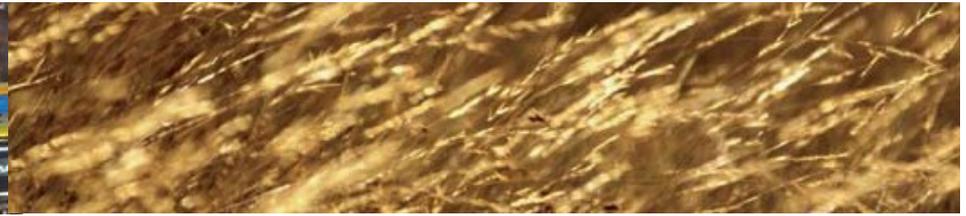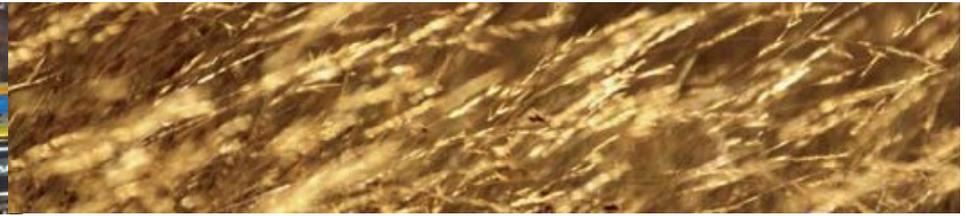| Dataset	Source	Description	Actual completeness and coverage	Action to achieve required dataset
Production of primary agricultural products	FAO ProdSTAT section of the FAOSTAT web-site: http://faostat.fao.org/site/567/default.aspx#ancor	Data on physical quantities (tonnes) of primary products produced in each of the considered countries.	Data are available for almost 229 countries for the period 1961-2009 covering 164 primary crop products. Data coverage and reliability changes depending on the reporting countries.	None
Import and Export of primary agricultural products	FAO TradeSTAT section of the FAOSTAT web-site: http://faostat.fao.org/site/535/default.aspx#ancor Detail trade data obtained from Faostat on special request.	Data on physical quantities (tonnes) of products imported and exported by each of the considered countries.	Data are available for almost 229 countries for the period 1961-2008 covering approximately 570 agricultural and livestock products. Data coverage and reliability changes depending on the reporting countries.	None
Consumption of seeds	Data on crops used as seeds is calculated by Global Footprint Network based on data from the FAO ProdSTAT section of the FAOSTAT web-site: http://faostat.fao.org/site/567/default.aspx#ancor	Data on physical quantities (tonnes) of seed	Data are available for almost 229 countries for the period 1961-2009. Data coverage and reliability changes depending on the reporting countries.	No adjustments needed.
Crop consumption by livestock	This dataset is calculated by GFN by the % feed-mix of crops using market feed supply mapping obtained by GFN; feed demand calculated from the feed efficiency (kg dry matter head^{-1} day^{-1}) (Haberl et al, 2007) and feed intake (tonnes dry matter year^{-1} and finally the total stock of livestock. Based upon the following datasets: - FAO Production for Livestock primary http://faostat.fao.org/site/569/default.aspx	Data on crop-based feed for livestock (tonnes of dry matter per year), split into different crop categories.	Data available for 17 livestock groups and 15 crop categories	None

Raw Input Data

Dataset	Source	Description	Actual completeness and coverage	Action to achieve required dataset
Production, import and export of primary forestry products	FAO ForeSTAT section of the FAOSTAT website: http://faostat.fao.org/site/630/default.aspx	Data on physical quantities (tonnes and m^3) of products (timber and wood fuel[8]) produced, imported and exported in each country.	Data available for 33 forest products for almost 130 countries over the period 1961-2007. Data coverage and reliability changes depending on the reporting country.	None
Production of primary fishery products Import and Export	FAO FishSTAT section of the FAOSTAT website: http://www.fao.org/fishery/statistics/en	Data on physical quantities (tonnes) of marine and inland fish species landed. Import and Export of fish commodities	Data are available for 234 countries and territories for the period 1950-2009. Data coverage and reliability changes depending on the reporting countries. 1439 fish products	None
Carbon dioxide emissions by sector	International Energy Agency – CO_2 sectoral approach database	Data on total amounts of CO_2 emitted by each sector of a country's economy	All sectors	None
Built-up/ infrasturcture areas	A combination of data sources is used, in the following order of preference: 1. CORINE Land Cover. Data can be accessed at: http://terrestrial.eionet.europa.eu/CLC2000/ 2. FAO ResourceSTAT section of the FAOSTAT web-site. Data can be accessed here: http://faostat.fao.org/site/348/default.aspx 3. Global Agro-Ecological Zones (GAEZ) Model. Data can be accessed at: http://www.fao.org/ag/agl/agll/gaez/index.htm 4. Global Land Cover (GLC) 2000. Data can be accessed at http://www-tem.jrc.it/glc2000/ 5. Global Land Use Database from the Center for Sustainability and the Global Environment (SAGE) at	Built-up areas by infrustructure type and country. Except for data drawn from CORINE, all other data sources only provide total area values.	CORINE Land Cover - available only for Europe, year 1990, 2000, and 2006. FAOSTAT - all countries, all years GAEZ - all countries, year 2000 only GLC - all countries, year 2000 only SAGE - all countries, year 1992 only	Data for missing years are approximated using country-specific population and land area data from FAO and interpolated linearly

Raw Input Data

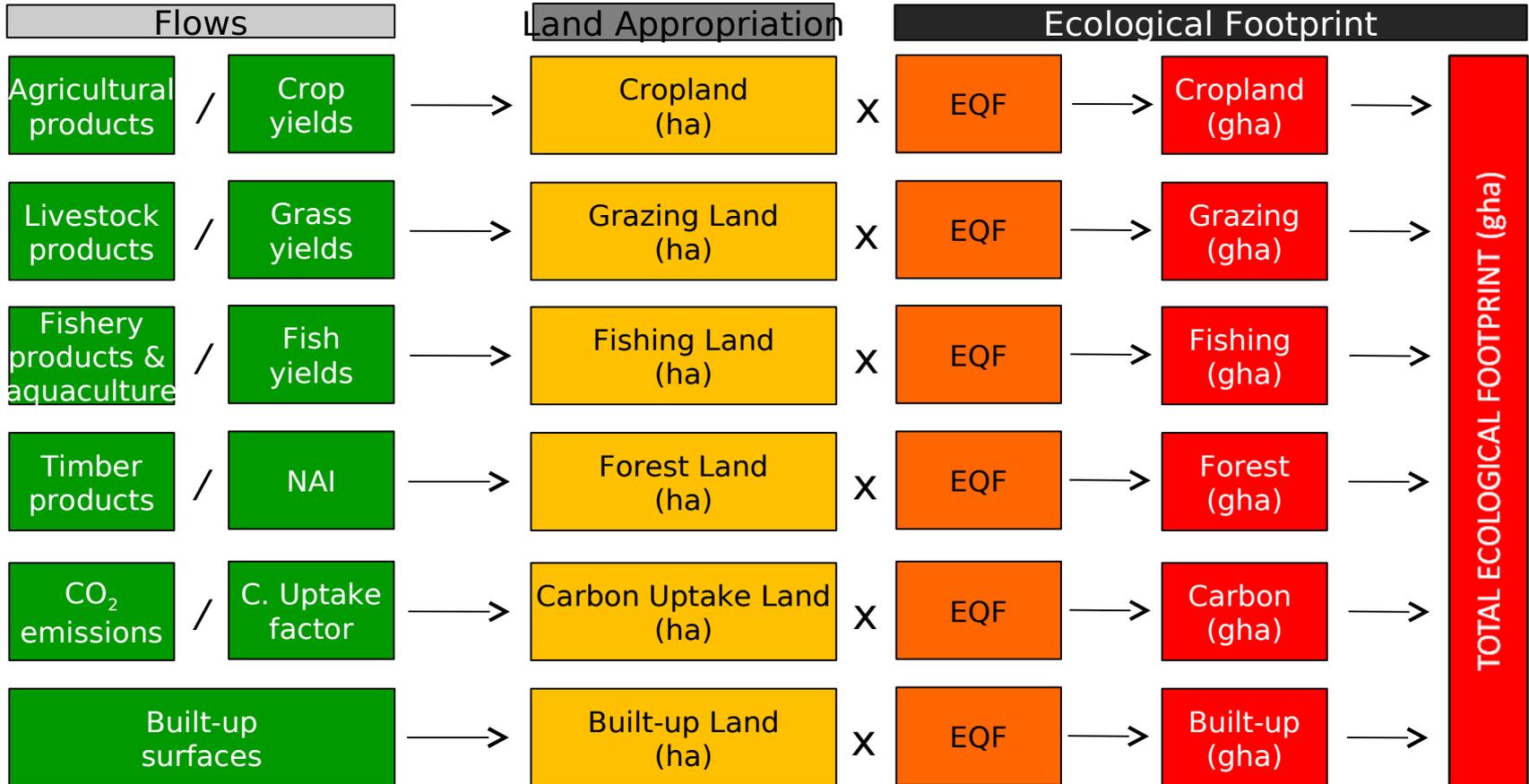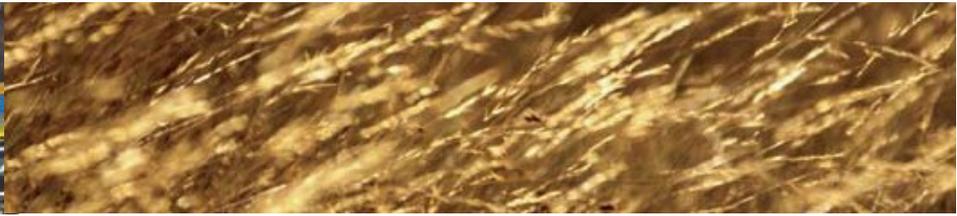| Dataset	Source	Description	Actual completeness and coverage	Action to achieve required dataset
Cropland yields	Data drawn directly from FAO ProdSTAT section of FAOSTAT web-site: http://faostat.fao.org/site/567/default.aspx#ancor	World average yield for 164 primary crop products	Data is available for the period 1961-2009.	None
National yield factors for cropland	Calculated by Global Footprint Network based on cropland yields and Country specific un-harvested percentages.	Country specific yield factors for cropland	All countries	None
Grazing land yields	Chad Monfreda (personal communication). 2008. SAGE, University of Wisconsin, Madison.	World average yield for grass production. It represents the average above-ground edible net primary production for grassland available for consumption by ruminants.	A single world average yield for grass production is available.	None
Fish yields	Calculated by Global Footprint Network based on several data including: • Sustainable catch value (Gulland 1971) • Trophic levels of fish species (Froese and Pauly 2008) Data can be accessed here: http://www.fishbase.org • Data on discard factors, efficiency transfer, and carbon content of fish per tonne wet weight (Pauly and Christensen 1995).	World-average yields for fish species. They are based on the annual marine primary production equivalent.	Yields calculated for 1439 fish species for the 1961-2007 period.	An estimate of global total sustainable catch is converted to primary production equivalent, and this is divided by global total continental shelf areas to obtain an estimate of available primary production (see (Kitzes et al. 2009; Ewing et al. 2010) for an in-depth description).
Forest yields	World average forest yield calculated by Global Footprint Network based on national Net Annual Increment (NAI) of biomass. NAI data is drawn from two sources: Temperate and Boreal Forest Resource Assessment – TBFRA (UNECE and FAO 2000). Data can be accessed here: http://www.unece.org/trade/timber/fra/welcome.htm Global Fiber Supply Model – GFSM (FAO 1998). Data	World average forest yield. It is based on the forests' Net Annual Increment of biomass. NAI is defined as the average annual volume over a given reference period of gross increment less that of neutral losses on all trees to a minimum diameter of 0 cm (d.b.h.).	TBFRA – data available for 55 countries. GFSM – data available for 67 countries.	Word-average forest yield value is calculated as weighted average of national values. Minor estimates are required for missing countries as reported by Ewing et al. (2010)

Raw Input Data

Dataset	Source	Description	Actual completeness and coverage	Action to achieve required dataset
Carbon Uptake land yield	Calculated by Global Footprint Network based on data on terrestrial carbon sequestration (IPCC 2006) and the ocean sequestration percentage (IPCC 2001). Further details can be found in (Kitzes et al. 2009), page 69.	World average carbon uptake capacity. Though different ecosystems have the capacity to sequester CO_2, carbon uptake land is currently assumed to be forest land only by the Ecological Footprint methodology.	A single world-average value is available.	Calculated as the weighted-average sequestration potential of world forests (IPCC 2006) by ecological zones, adjusted for the fraction of emissions sequestered by oceans.
Equivalence Factors (EQF)	Calculated by Global Footprint Network based on data on land cover and agricultural suitability. Data on agricultural suitability is obtained from Global Agro-Ecological Zones (GAEZ). FAO and International Institute for Applied Systems Analysis 2000. http://www.fao.org/ag/agl/agll/gaez/index.htm. Land cover data are drawn from the ResourceSTAT section of the FAOSTAT website. Data can be accessed here: http://faostat.fao.org/site/377/default.aspx#ancor	EQF for crop, grazing, forest and marine land. Based upon the suitability of land as measured by the Global Agro-Ecological Zones model (FAO 2000b).	Equivalence factors are available for each land type tracked by the Ecological Footprint methodology, for the period 1961-2007.	GAEZ evaluates the biophysical limitations and potential for crop production using global terrain, soil and climate data. The results from GAEZ are utilized along with land cover data for crops, pasture and forest areas.

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Source: OPEN:EU WP2 Report, 2010.
http://www.oneplaneteconomynetwork.org/

Outcomes: National Footprint Accounts - NFA

$$EF_C = EF_P + EF_I - EF_E$$

- **Every year** Global Footprint Network releases an updated version of the NFA, which is based on the most up-to-date Footprint methodology
- **Each edition** of the NFA tracks EF and BC values for almost 200 countries (and the World), over about 5 decades (1961-2008) and with different level of aggregation:
  1. Aggregate national EF and BC values (*most known*)
  2. EF and BC values by land type
  3. EF values by variable
  4. EF values for all individual products
  5. Values are provided both per capita and total
  6. Results in both ha and gha (not for totals)

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Flows		Land Appropriation		Ecological Footprint		
Agricultural products / Crop yields	→	Cropland (ha)	X	EQF	→ Cropland (gha)	→
Livestock products / Grass yields	→	Grazing Land (ha)	X	EQF	→ Grazing (gha)	→
Fishery products & aquaculture / Fish yields	→	Fishing Land (ha)	X	EQF	→ Fishing (gha)	→
Timber products / NAI	→	Forest Land (ha)	X	EQF	→ Forest (gha)	→
CO_2 emissions / C. Uptake factor	→	Carbon Uptake Land (ha)	X	EQF	→ Carbon (gha)	→
Built-up surfaces	→	Built-up Land (ha)	X	EQF	→ Built-up (gha)	→

TOTAL ECOLOGICAL FOOTPRINT (gha)

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products	/	Yields			X	EQF		

Fishery & Aquaculture / World Fish Yields = Fishing Ground X Fishing EQF = Fishing Footprint

Timber products / World Forest Yields = Forest Land X Forest EQF = Forest Footprint

CO_2 emissions / Carbon Uptake Factor = Carbon Uptake Land X Forest EQF = CO_2 Footprint

Built-up surfaces = Built-up Land X Cropland EQF = Infrastructure Footprint

Total Ecological Footprint

Production Area [ha]			Land in terms of world average productivity [w ha]			Biocapacity [g ha]	
Cropland Area	X Cropland YF	=	Cropland	X Cropland EQF	=	Cropland Biocapacity	
Grazing Land Area	X Grazing YF	=	Grazing Land	X Grazing EQF	=	Grazing Biocapacity	
Marine/Inland water Area	X Fishing YF	=	Fishing Ground	X Fishing EQF	=	Marine/Inland water Biocapacity	Total Biocapacity
Forest Area	X Forest YF	=	Forest (net annual increment)	X Forest EQF	=	Forest Biocapacity	
Infrastructure Area	X Cropland YF	=	Cropland	X Cropland EQF	=	Cropland Biocapacity	

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1.5

World Ecological Footprint

1 World Biocapacity

Carbon

Fishing Grounds

Cropland

Built-Up Land

0.5 Forest Land

Grazing Land

0

Improvements

MOTIVATION:

- Adapt to changes in the organization of the source data;

- Respond to issues raised in outside reviews (e.g., DG Environment, 2008; Stiglitz et al., 2009; and the like);

- Increase the specificity and accuracy of the NFA calculations;

- Move towards harmonization with SEEA.

RECENT:

- Revised ocean uptake factor for anthropogenic CO_2 in NFA 2011 Ed.

- Beta Version of MRIO-based NFA

FUTURE:

- Full review of Carbon Cycle / new terrestrial uptake factor for anthropogenic CO_2.

- Ongoing research on EQF (GAEZ, NPP, etc)

- Full MRIO framework into NFA

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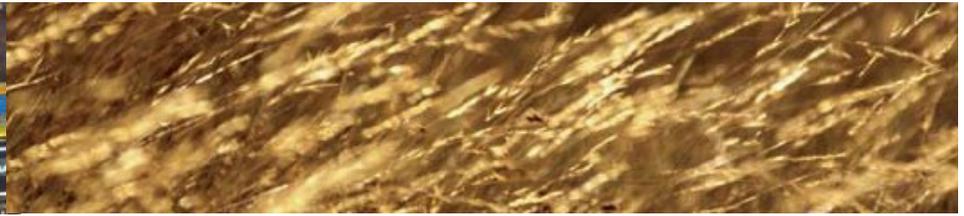
NFA Land Use Type	Component	NFA Source Data	NFA Classification	SEEA Classification
Cropland	Production	FAO ProdSTAT	FAO	CPC v. 2
	Trade	FAO TradeSTAT	FAO	CPC v. 2
	Yield	FAO ProdSTAT	FAO	CPC v. 2
	Biocapacity	CLC, GLC, SAGE, or FAO	CLC or FAO	FAO LCCS
Grazing Land	Production	FAO ProdSTAT	FAO	CPC v. 2
	Trade	FAO TradeSTAT	FAO	CPC v. 2
	Yield	GFN Derived	-	-
	Biocapacity	CLC, GLC, SAGE, or FAO	CLC or FAO	FAO LCCS
Forest Land	Production	FAO ForesSTAT	FAO	CPC v. 2
	Trade	FAO ForesSTAT	FAO	CPC v. 2
	Yield	UN TBFRA & UN GFSM	FAO	CPC v. 2
	Biocapacity	CLC, GLC, SAGE, or FAO	CLC or FAO	FAO LCCS
Fishing Grounds	Production	FishSTAT	Species	?
	Trade	FishSTAT	Species	?
	Yield	GFN Derived	Species	?
	Biocapacity	CLC, GLC, SAGE, or FAO	-	FAO LCCS
Built-up Land	Production	CLC, GLC, SAGE, or FAO	CLC, GAEZ, GLC, or SAGE	FAO LCCS
	Biocapacity	CLC, GLC, SAGE, or FAO	CLC, GAEZ, GLC, or SAGE	FAO LCCS
Carbon Footprint	Production	IEA Fossil Fuel Emissions	IEA	?
	Trade	UN Comtrade	SITC rev. 1	?
	Yield	IPCC	-	?

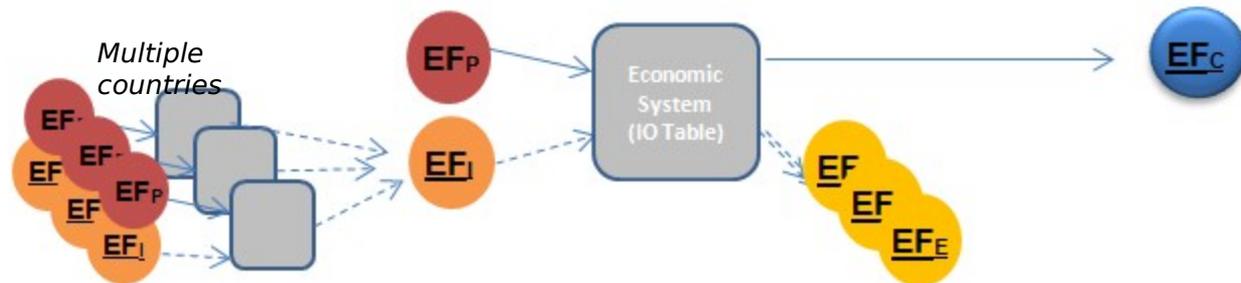*Table 1: Sample list of correspondence between the National Footprint Accounts and the SEEA*

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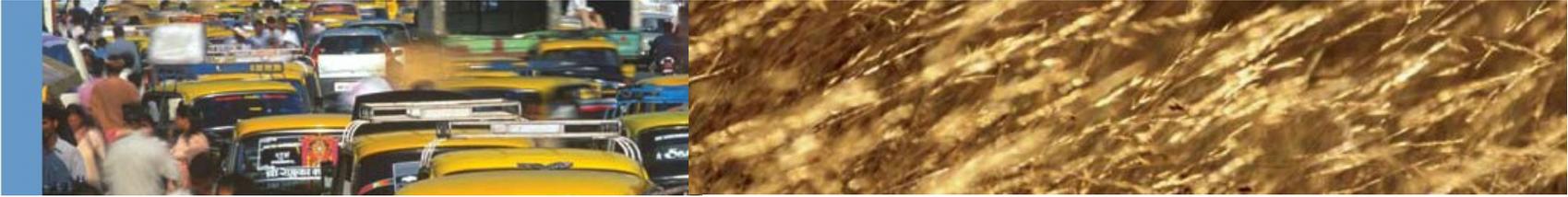
NFA vs. MRIO models

1. National Footprint Account (NFA)

$$EF_C = EF_P + EF_I - EF_E$$

2. MRIO-based EF model

Need to ensure consistency with SEEA chapter 3 on physical flows

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EF by final demand

GFCF 26%
Gov 10%
HH 64%

EF by household consumption

Legend: Built-up Land, Forest Land, Fishing Grounds, Grazing Land, Cropland, Carbon
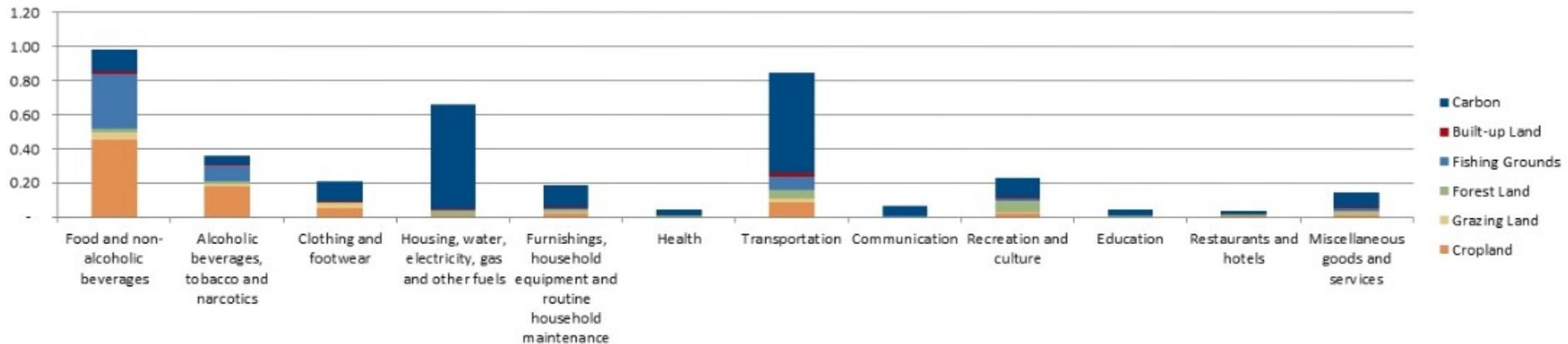
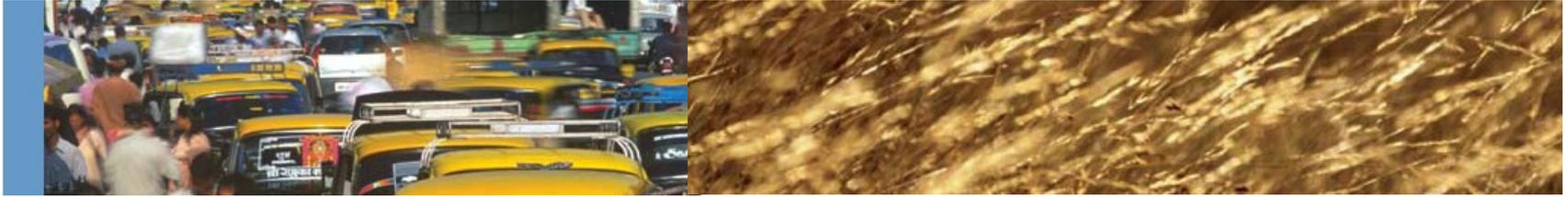Categories: Food, Housing, Transportation, Goods, Services
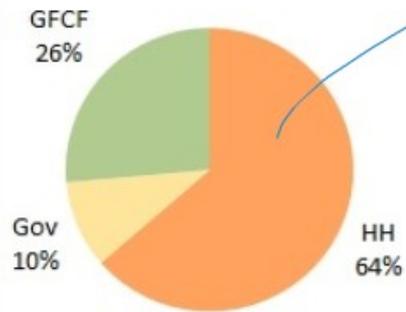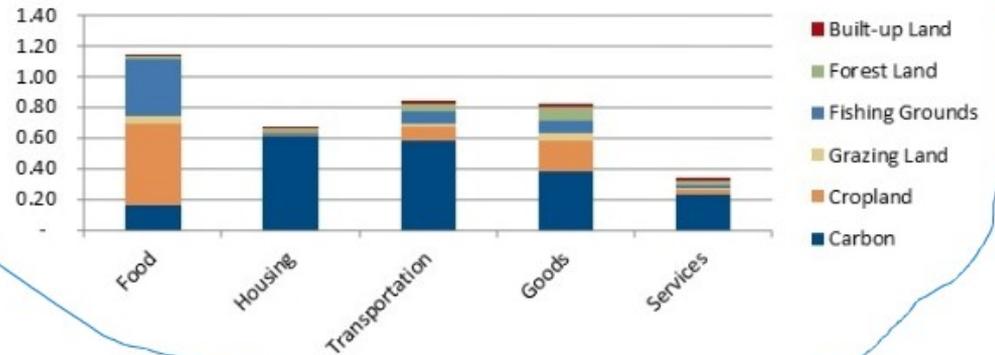
Using input-output techniques, the total Ecological Footprint of a country may be broken down into the Ecological Footprint associated with the final demand for goods and services that are directly purchased from each sector.

Since, for example, household typically purshase their food after processing from the retail sector, the Ecological Footprint of these sectors is much greater than the agriculture sector.

EF by household consumption in COICOP

Legend: Carbon, Built-up Land, Fishing Grounds, Forest Land, Grazing Land, Cropland

Categories: Food and non-alcoholic beverages, Alcoholic beverages, tobacco and narcotics, Clothing and footwear, Housing, water, electricity, gas and other fuels, Furnishings, household equipment and routine household maintenance, Health, Transportation, Communication, Recreation and culture, Education, Restaurants and hotels, Miscellaneous goods and services

Further reading on EF-MRIO

- Weinzettel, J., Steen-Olsen, K., Galli, A., Cranston, G., Ercin, E., Hawkins, T., Wiedmann, T., Hertwich, E., 2011. **Footprint Family Technical Report: Integration into MRIO model**. http://www.oneplaneteconomynetwork.org/

- Weinzettel, J., Steen-Olsen, K., Cranston, G., Galli, A., Ercin, E., Roelich, K., Hertwich, E., 2011. **Benchmarking, analysis and Visualization Technical Report: Testing and validating EE-MRIOM**. http://www.oneplaneteconomynetwork.org/

- Galli, A., Weinzettel, J., Cranston, G., Ercin, E., 2011. **A Footprint Family extended MRIO model to support Europe's transition to a One Planet Economy**. Accepted for Oral Presentation at World Resources Forum 2011, Davos, Switzerland, 19-21 September, 2011

- Hawkins, T., Wiedmann, T., Ewing, B., Galli, A., Ercin, E., Weinzettel, J., Steen-Olsen, K., forthcoming. **Integrating Ecological and Water Footprint Accounting in a Multi-Regional Input-Output Framework**

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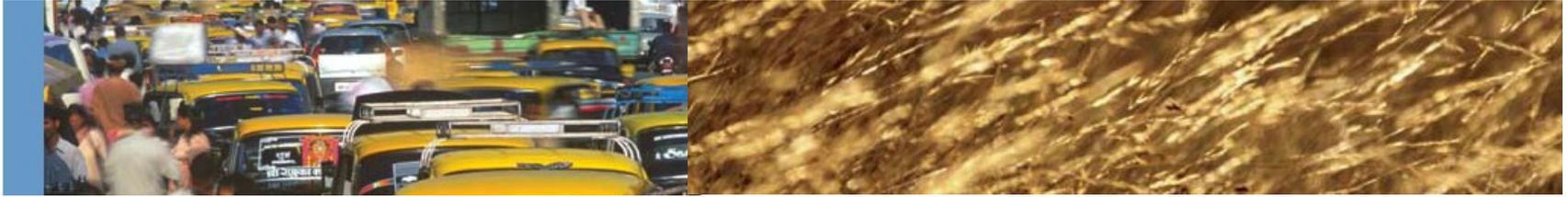
Final Remarks

- Harmonizing the National Footprint Accounts with the SEEA will enable the Ecological Footprint and biocapacity indicators to follow internationally agreed practices.
  - EFp – SEEA Chapter 3 alignment
  - MRIO for calculation of Footprint embedded in trade flows
- Ecological Footprint within an input-output model based on SNA provides useful information on the economy-environment interactions.
- Work together with LG on:
  - Methodology review
  - Development of bridge tables and harmonization issues

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Thank You

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