

ACCOUNTING LAND AS NATURAL RESOURCE FOR ENERGETIC AND EXERGETIC LCA: A NEW METHOD

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Introduction

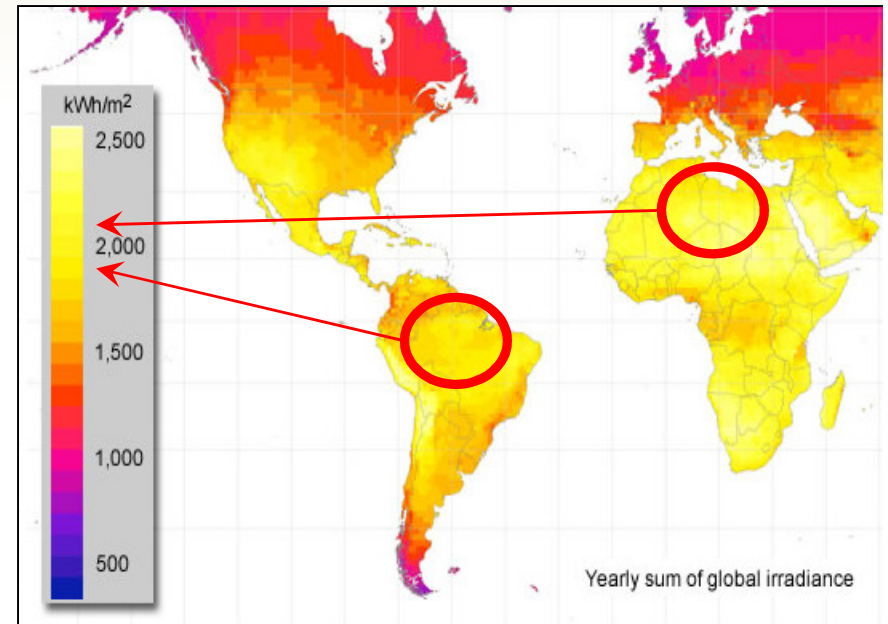
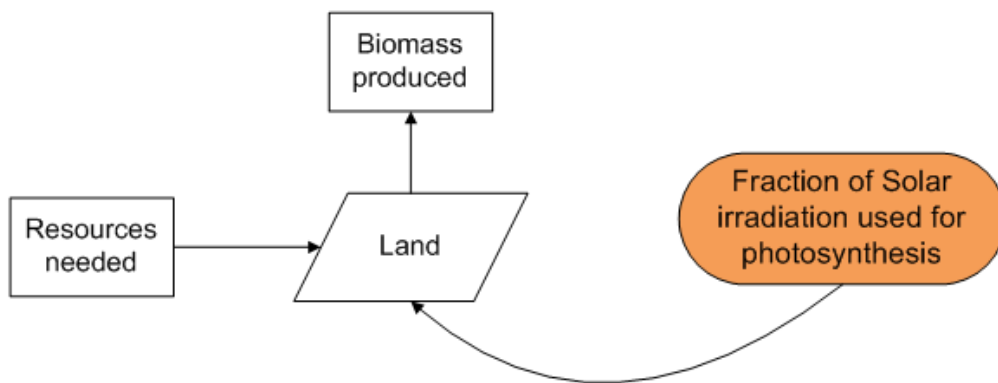
- Life Cycle Assessment (LCA)
 - Environmental impact assessment methodology for:
 - Assessing products
 - Life-cycle perspective
 - Divided in 4 stages => It is in 3rd stage (LCIA) where the impacts are considered
- Other methods
 - Exergy analysis, Energy analysis
 - When life cycle of the product is taken into consideration, they can be considered as LCIA methods
 - Often called “Exergetic LCA” and “Energetic LCA”

Introduction

- In energetic or exergetic LCA, all resources consumed during the life cycle of the product shall be accounted
 - In terms of energy (MJ) or exergy (MJ_{ex})
- Most studies, when analyzing the production of biomass, consider only the consumption of non-renewable resources
 - “*Energy ratio*” = (Biotic energy output) / (Non-renewable energy input)
- Although, land play an important role in biomass production, and should be accounted as well.
- But how to account land, in energy and exergy terms?

Introduction

- Through the land occupation (or *Land use*)
 - *Area* and *time* needed to produce the biomass
 - No direct value => Indicator needed => Solar irradiation available for photosynthesis at land, e.g.: CEENE (Dewulf et al., 2007)
 - Possible bad estimations (share for photosynthesis not well known) and is not applicable worldwide (solar irradiation is only one of the several factors)

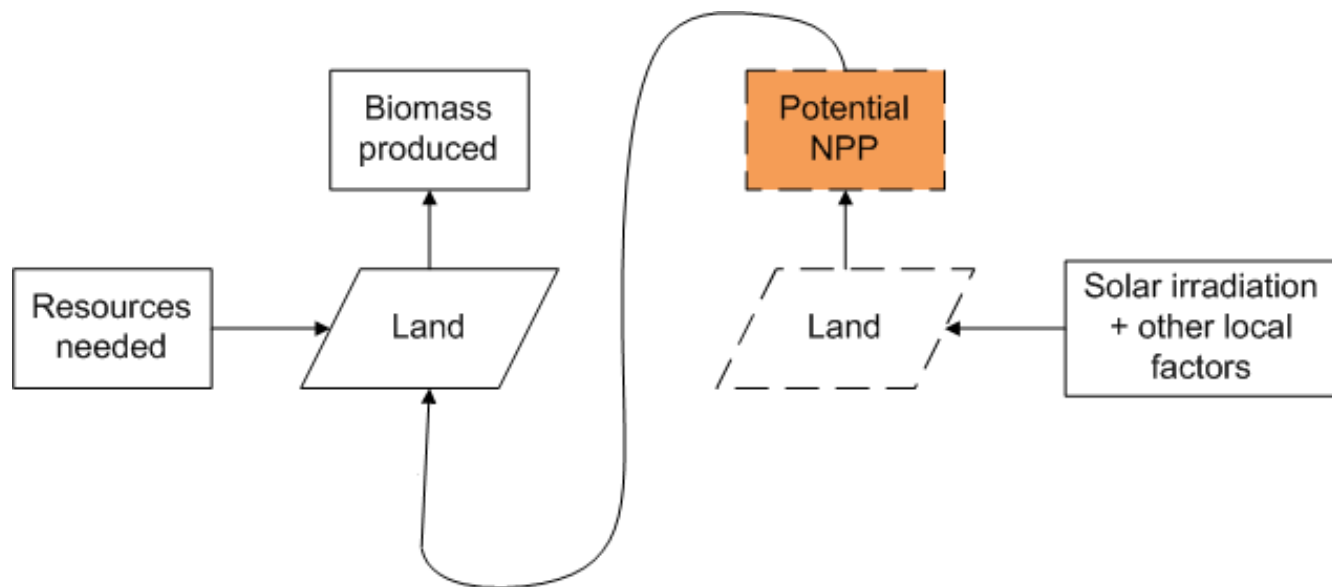


The method

- Land occupation => Net Primary Production (NPP)
 - The NPP is the amount of biomass produced through photosynthesis in a certain *area* and *time*;
 - It is an output indicator, that takes into account several factors as water availability, soil quality, temperature, among others;
 - The potential NPP is the amount of natural biomass production in a certain *area* and *time*.

The method

- This approach for LCA
 - In case of an area occupied by men (e.g. crop production), the potential NPP is the biomass production that would exist if land was not being used by men.
 - Thus, it is the resource deprived from nature due to land use.

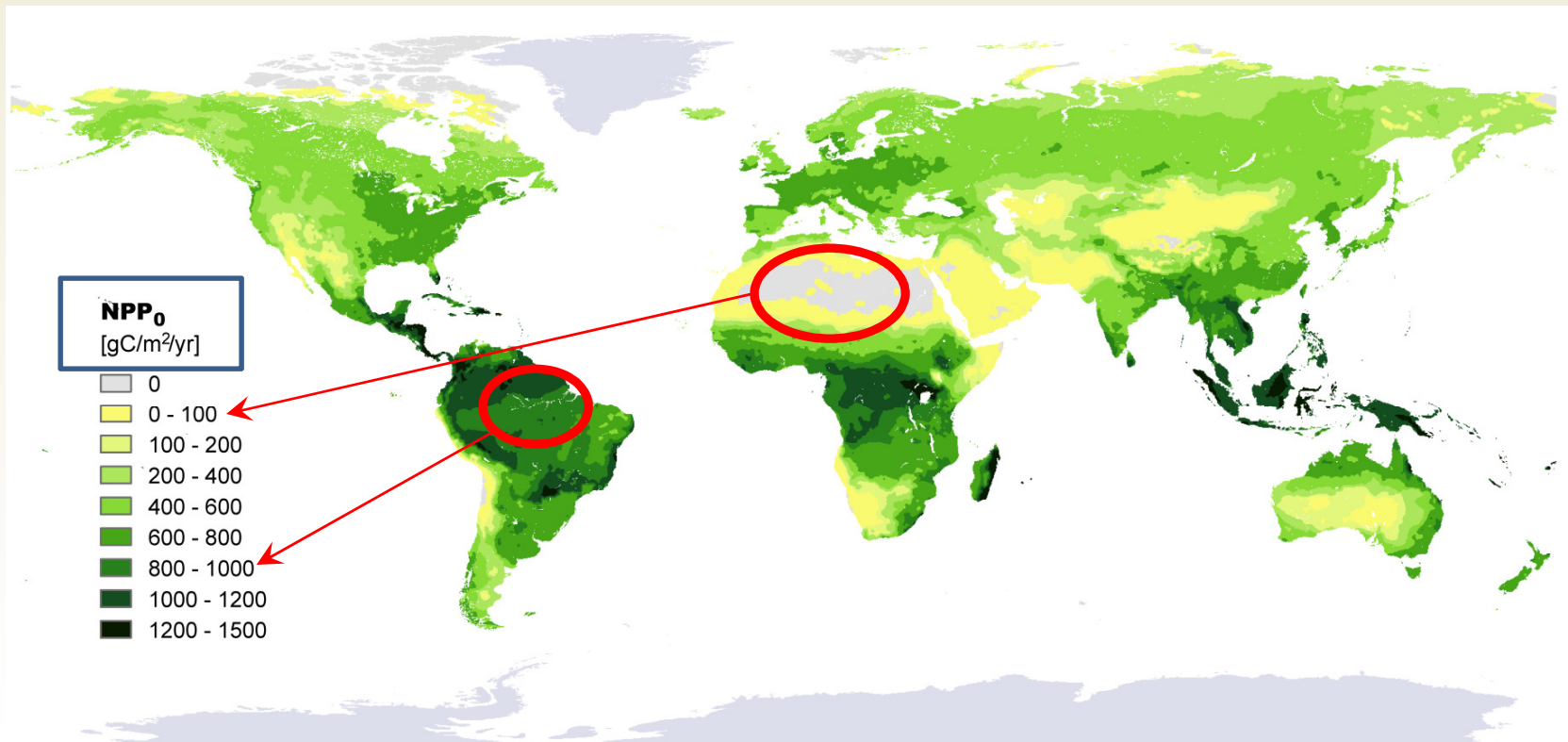


The method

- World map on potential NPP
 - Haberl et al (2007) modeled a map, considering hydrology, concentration of CO₂, climate, and soil quality => resulting in average values of 20th century.

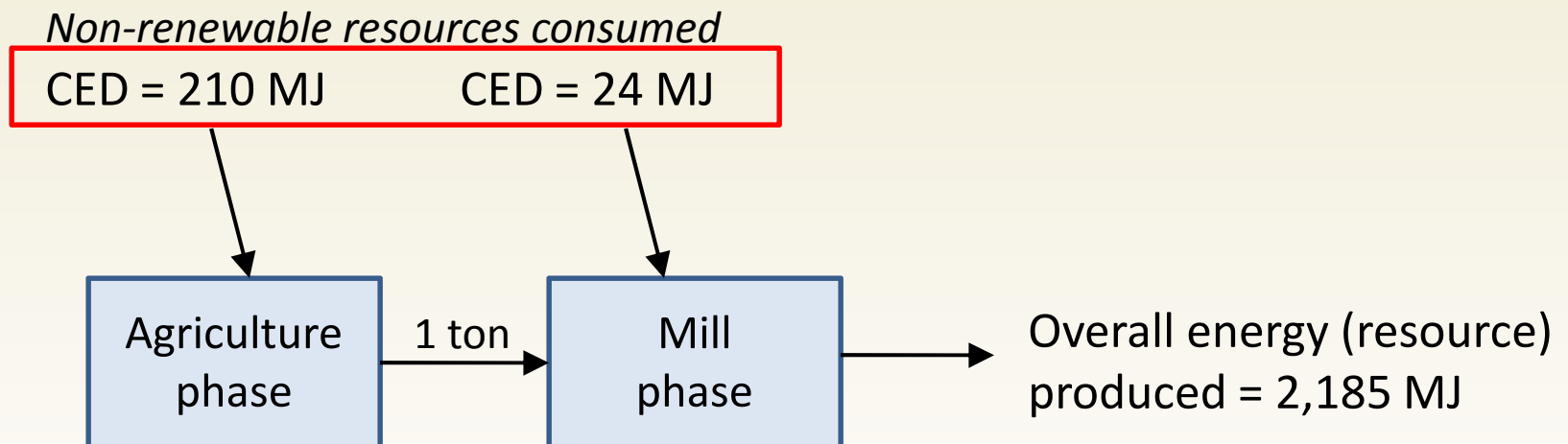
Need for unit conversion:

gC
↓
kgDM
↓
MJ or MJ_{ex}



Applying the new method

- Case where land is not considered in the energy balance.
- Ethanol (from sugarcane) energy balance, from Macedo et al. (2008), for the year 2005/2006.



Energy ratio = 9.3

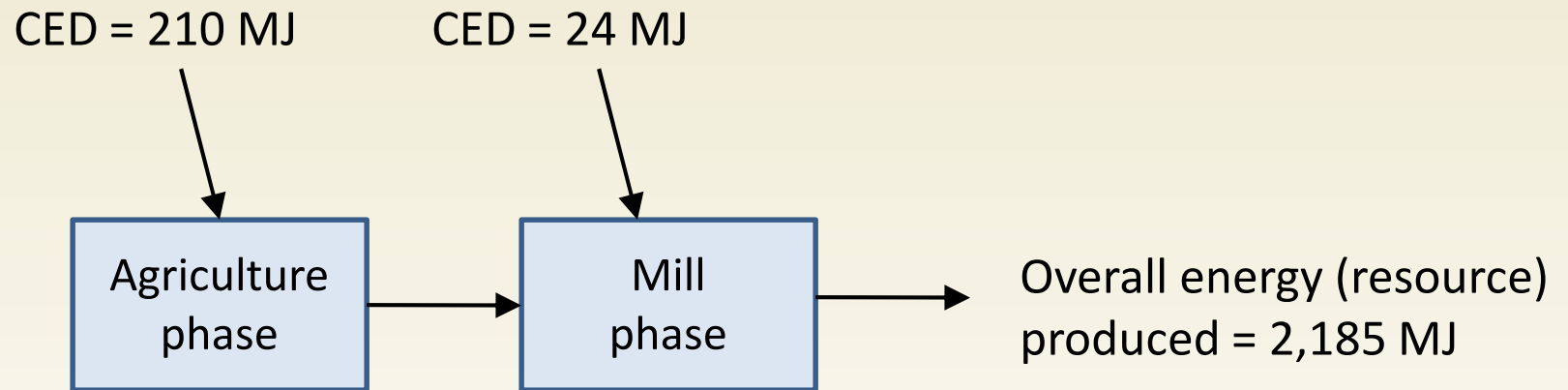
Applying the new method

- If we consider this method in the energy balance from Macedo et al. (2008), for the same year:
 - Considering the production occurs in Sao Paulo state:



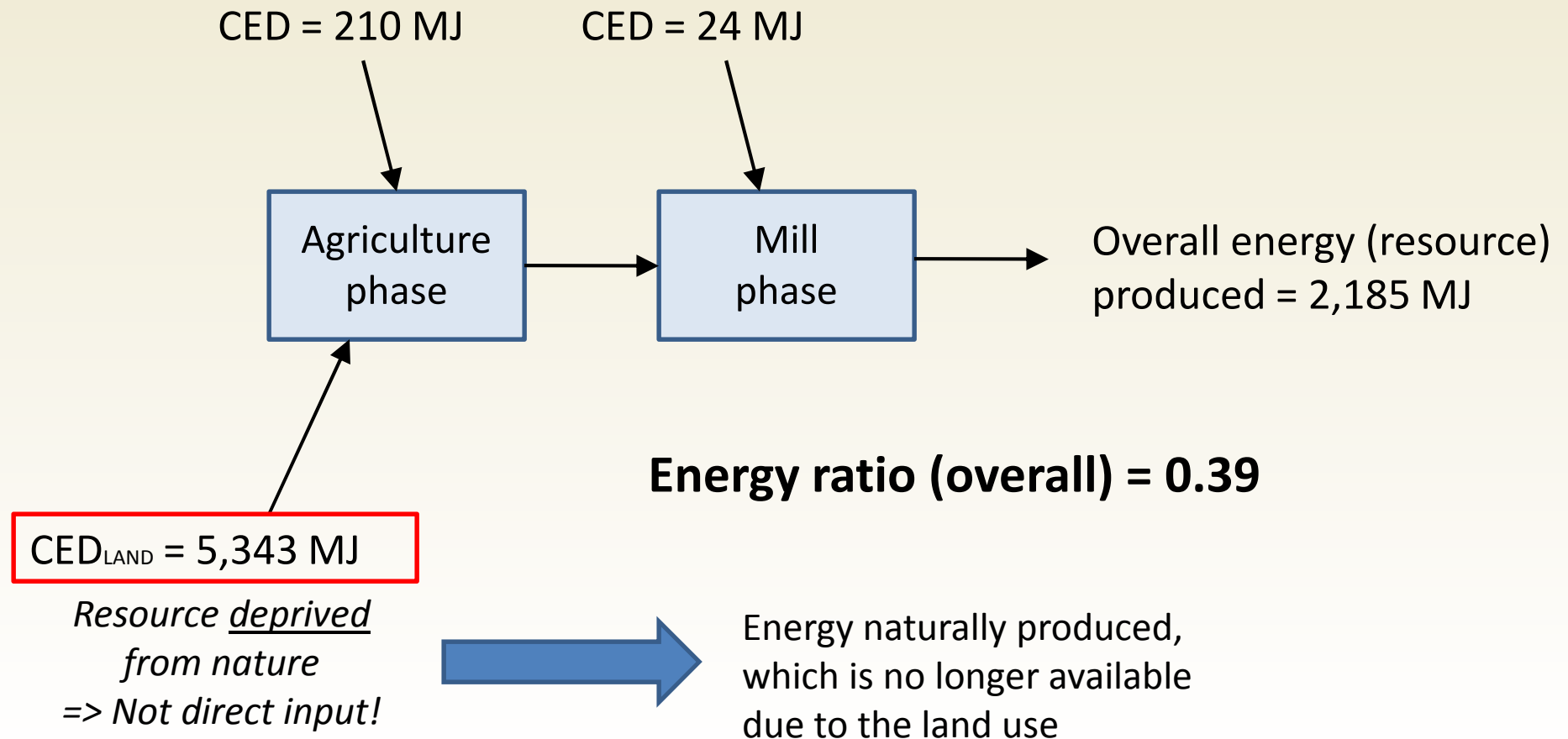
- Considering 0.5kgC/kgDM and 20 MJ/kgDM
 - Potential NPP = 970gC/m²a = **38.8 MJ/m²a**.
- For 1 ton of sugarcane => 137.7 m²a => this is equal to **5,343 MJ**.

Applying the new method



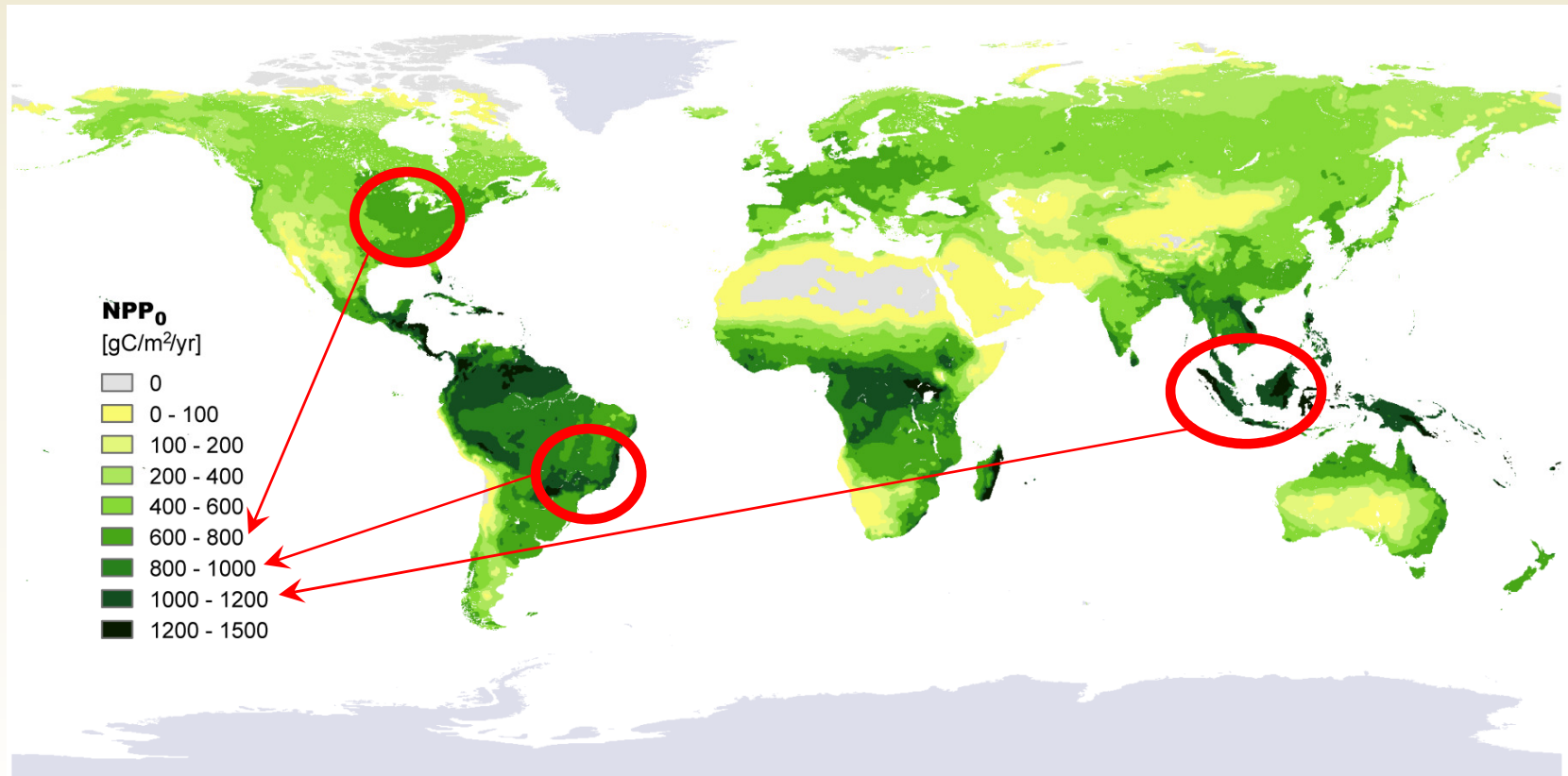
Energy ratio = 9.3

Applying the new method



Applying the new method

- Applying it in other studies on biofuels where land is also not considered



Applying the new method

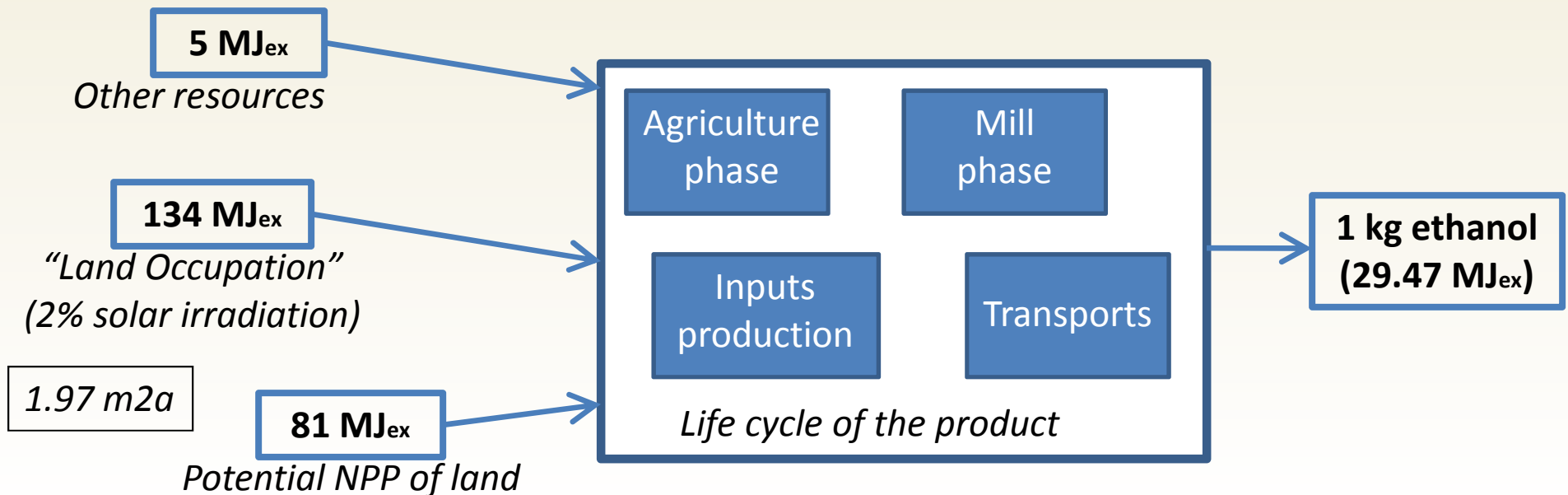
- Applying it in other studies on biofuels where land is also not considered

	Ethanol (Corn)	Biodiesel (Palm fruit)
Country	USA	Indonesia
Energy ratio	1.34	3.10
Yield (ton/ha.year)	8.1	15.5
Source	Shapouri et al. (2002); FAOSTAT	Kamahara et al. (2010)
Potential NPP (gC/m ² a)	650 (average value)	1,130 (average value)
Energy ratio (overall)	0.23	0.27

Applying the new method

- Case where land is considered, but through solar irradiation
- Exergetic LCA => CEENE => ethanol (from ecoinvent database)
- Potential NPP (Sao Paulo) = 970 gC/m²a
 - 970 gC => 1.94 kgDM => **41.01 MJ_{ex}**

Considering (for biomass):
500 gC = 1 kg DM
1kg DM = 21.14 MJ_{ex}



Conclusions

- Land is a crucial aspect for biomass production, as Sun, water, CO₂, and other resources. Therefore, when land use is not accounted in energetic and exergetic LCA, they may be considered as incomplete studies.
- The existing way to account for land (solar irradiation) is subject to non-realistic estimations and is not applicable worldwide.
- The potential NPP approach is able to overcome the weaknesses presented in the solar irradiation approach.

Conclusions

- It is operational for LCA, since worldwide data is already available (at Haberl et al., 2007).
- Through unit transformations it is possible to include it on energetic and exergetic LCA, giving more completeness into the analysis (in a resource point of view).
- By considering the potential NPP of the land, we account for the biotic resources that are deprived from nature due to land use (for LCA) OR even use it as basis of comparison with the actual land use productivity (Is men doing “better” than nature?).

Thank you for your attention!

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