JatroMed Project
Evaluation of the energy crop Jatropha curcas as a mean to promote renewable and sustainable energy for the Mediterranean region (JatroMed)

CONSIGLIO PER LA RICERCA E LA SPERIMENTAZIONE IN AGRICOLTURA

Centre de Developpement de la Region de Tensift (CDRT)

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Session 3: Energy crops in the Mediterranean region

Environmental impact assessment of three strategic energy crops for Italy

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INTRODUCTION

Since the 2006 sugar CMO reform, the EU sugar beet sector has undergone a drastic restructuring process. In Italy, the sugar production capacity as well as the sugar beet cultivated area have been reduced by 50%.

Conversion of the Italian sugar beet supply chain, to agro-energy supply chains, with the scope to produce biofuels and electricity: high quantity of lignocellusosic biomass were necessary to supply the energy chains

The ex sugar beet farms started this conversion cultivating herbaceous annual and polyannual crops (e.i. sunflower, rapeseed, cardoon, reed giant) and woody crops(poplar, robinia, eucalipto).

The project SuSCACE funded by the Italian Agricultural Ministry (Mipaaf), and coordinated by CRA-ING, with the collaboration of farmers, sugar beet companies and other research units, collected and elaborated the data field of the most strategic energy crops. The crops have been studied and the economic, logistic as well as environmental evaluations have been carried out to facilitate the conversion and the creation of the new energy supply chains.

GOALOF THE PROGECT

Aim of this study was the evaluation of the enviromental sustainability of three energy crops, considered strategic from the Suscace Project:

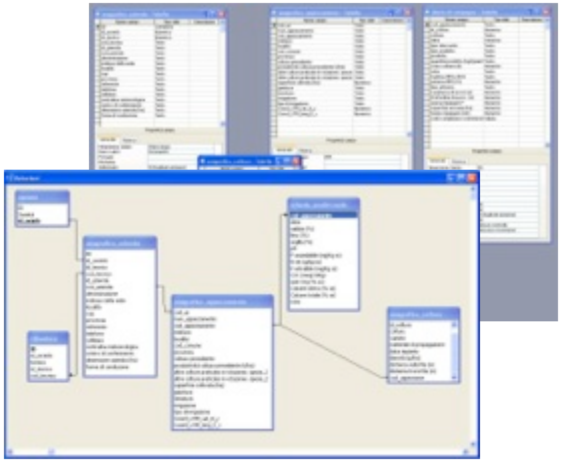
- ✓ Brassica napus, L.: annual herbaceous oil crop
- ✓ Arundo donax, L.: polyannual herbaceous crop for lignocellulosic biomass production
- ✓ Populus spp.: polyannual woody crop for lignocellulosic biomass production

The agricultural phase of each energy crop has been evaluated and compared in order to define the most environmental sustainable crop for the Italian territory, using the Life Cycle Assessment (LCA) research methodology.

MATERIAL AND METHODS

Actual data (2009 – 2010)

Crop		2009	2010
Rapeseed	Farms(n)	111	109
	Sur. (ha)	1234,33	1521,96
Giant reed	Farms(n)	7	7
	Sur. (ha)	7,8	7,8
Poplar	Farms(n)	59	84
	Sur. (ha)	257,5	445,87



Farm data (GPS info, field technician, farm area etc.)

Field data (previous crop, giacitura, irrigation method etc.)

Crop data (cultivar, implantation date, sowing density, field layout ecc.)

Cultivation data (output, inputs and equipment used, work times ecc.)

MATERIAL AND METHODS

Defining of the average farms

Cultivated area (ha);
Yield (t/ha);
Slope (hill or flat);
q.ty of fertilizers (kg/ha);
q.ty of herbicide (kg/ha);
q.ty of pesticide (kg/ha);
Energy applied (kWh);
Previous crop.

“Region”
“Slope”
“Soil texture”
“Clone”
“Geographical position”

Rapeseed
Giant reed
Poplar

Statistical analysis

Average farms (real farms)

Environmental Analysis using the LCA method

From the actual dataset have been chosen the parameters more representatives to define the level of agricultural intensification for each species.

By the ANOVA and MANOVA analysis have been identify the groups of farms statistically homogeneous and the average farms (Good and Bad) of these groups.

FARMS STUDIED

Crop	Field Cod.	Previous crop	Field area (ha)	Variety	Density (p ha^{-1})	Yield (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Herb. (l ha^{-1})	Pest. (l ha^{-1})	Energy (kWh ha^{-1})
Rapeseed (G)	24040001	Wheat	9	PR W 14	740000	2,40	67	-	2.2	0,00	606.14
Rapeseed (B)	24034001	Wheat	34,00	Vectra	740000	1,22	88,00	-	2,2	0,00	491,07

Crop	Field Cod.	Previous crop	Density (p ha^{-1})	Yield (t ha^{-1}anno^{-1})	N (kg ha^{-1}anno^{-1})	Herb. (kg ha^{-1}anno^{-1})	Energy (kWh ha^{-1})
Giant reed (G)	13022002	Wheat	10000	41,9	125.5	0.45	305.5
Giant reed (B)	15027002	Wheat	10000	27,2	83.6	0.99	380,7

Crop	Field Cod.	Density (p ha^{-1})	Yield (t ha^{-1} anno^{-1})	N (kg ha^{-1} anno^{-1})	P_2O_5 (kg ha^{-1} anno^{-1})	Herb. (kg ha^{-1} anno^{-1})	Energy (kWh ha^{-1})
Poplar (G)	15028001	5700	16,4	34.2	0	2.02	179
Poplar (B)	14005001	5700	4,8	20.5	40.9	1.36	209

MATERIAL AND METHODS

Software: SimaPro 7.3.3 (Prè Consultants, Amersfoort, NL)

Impact method: Recipe 2008

Functional unit: 1 Gj of biomass produced and 1 ha of cultivated land (sensitivity analysis)

System boundaries: Agricultural production phase (input, output), including the inputs production chains.

Models to evaluate the nitrogen and phosforic fertilizers emissions

NH_3, N_2O on the air and NO_3 on the water (Brentrup F. et. al., 2000).
The emissions on the water caused by P_2O_2 fertilization (Nemecek T & Kagi T , 2007).

Brentrup, F. Kiisters, J. Lammel, J. and Kuhlmann, H. (2000). Methods to Estimate On-Field Nitrogen Emissions from Crop Production as an Input to LCA Studies in the Agricultural Sector. *International Journal of Life Cycle Assessment* 5 (6): 349 – 357.

Nemecek T & Kagi T. (2007). Life Cycle Inventories of Swiss and European Agricultural Production System. Final report ecoinvent V.2.0 No. 15a. Agroscope Reckenholz-Taenikon Research Station ART, Swiss Centre for Life Cycle Inventories, Zurich and Dubendorf, CH

Assessment of the herbicides and pesticides fractions on the ground, air and water

It was adopted the model proposed by Hauschild (2000).

Hauschild M. (2000). Estimating pesticide emissions for LCA of agricultural products. In. Weidema, B.P. and Meeusen M.J.G. Agricultural data for Life Cycle Assessments. Vol.2. The Hague, The Nederlands. LCA net food, pp. 64-72 (Chapter 22). Report 2.00.01; ISBN 90-5242-563-9

Equipments

It was considered the emissions generated by the use of the equipments as proposed by Monti et al. (2009)

Monti A, Fazio S, Venturi G. 2009. Cradle-to-farm gate Life Cycle Assessment in perennial energy crops. Europ, J. Agronomy. 31:77-84.

ENVIRONMENTAL IMPACT ASSESSMENT: METHODOLOGY USED

The impact generated by 1 GJ of biomass produced has been assessed by the **ReCiPe Endpoint 2008** method, that consists of two groups of impact chategories:

“midpoint level”

“endpoint level”

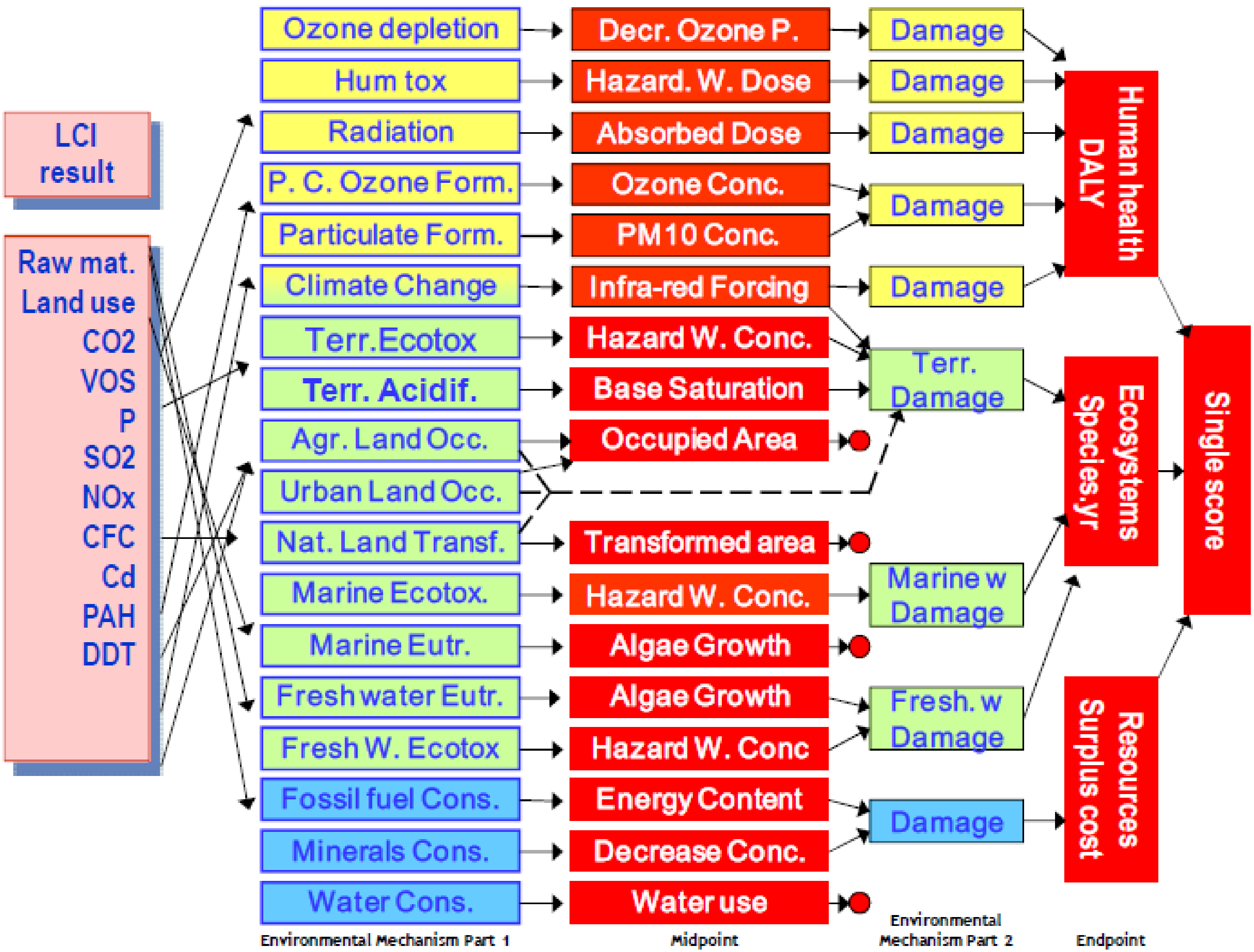
Inventory data is associated with impact chategories at the “midpoint” level by characterization factors. The impact categories are converted and aggregated to three damage chategories by weighing factors at “endpoint” level :

Human health,

Ecosystems,

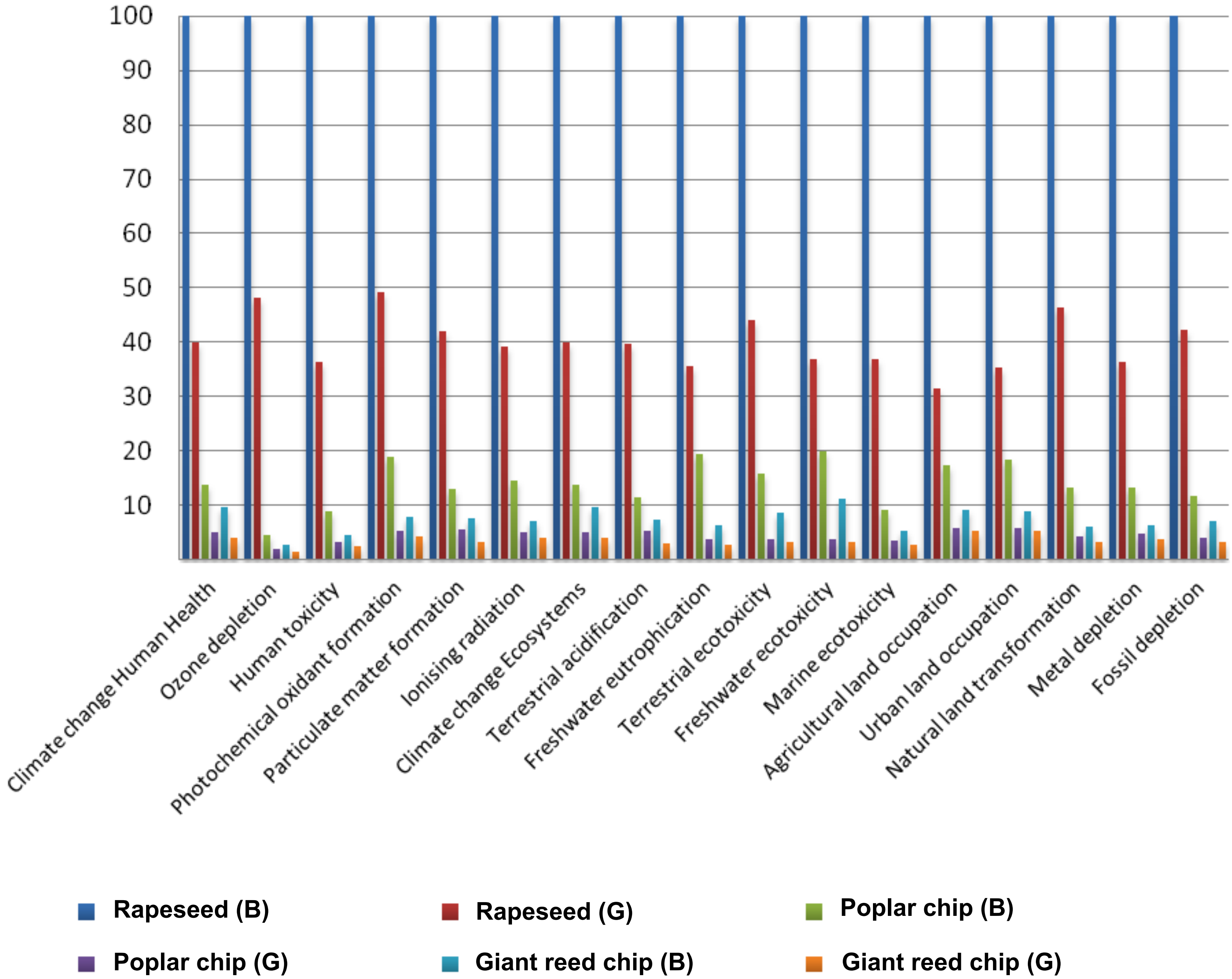
Resources.

Recipe 2008 method scheme

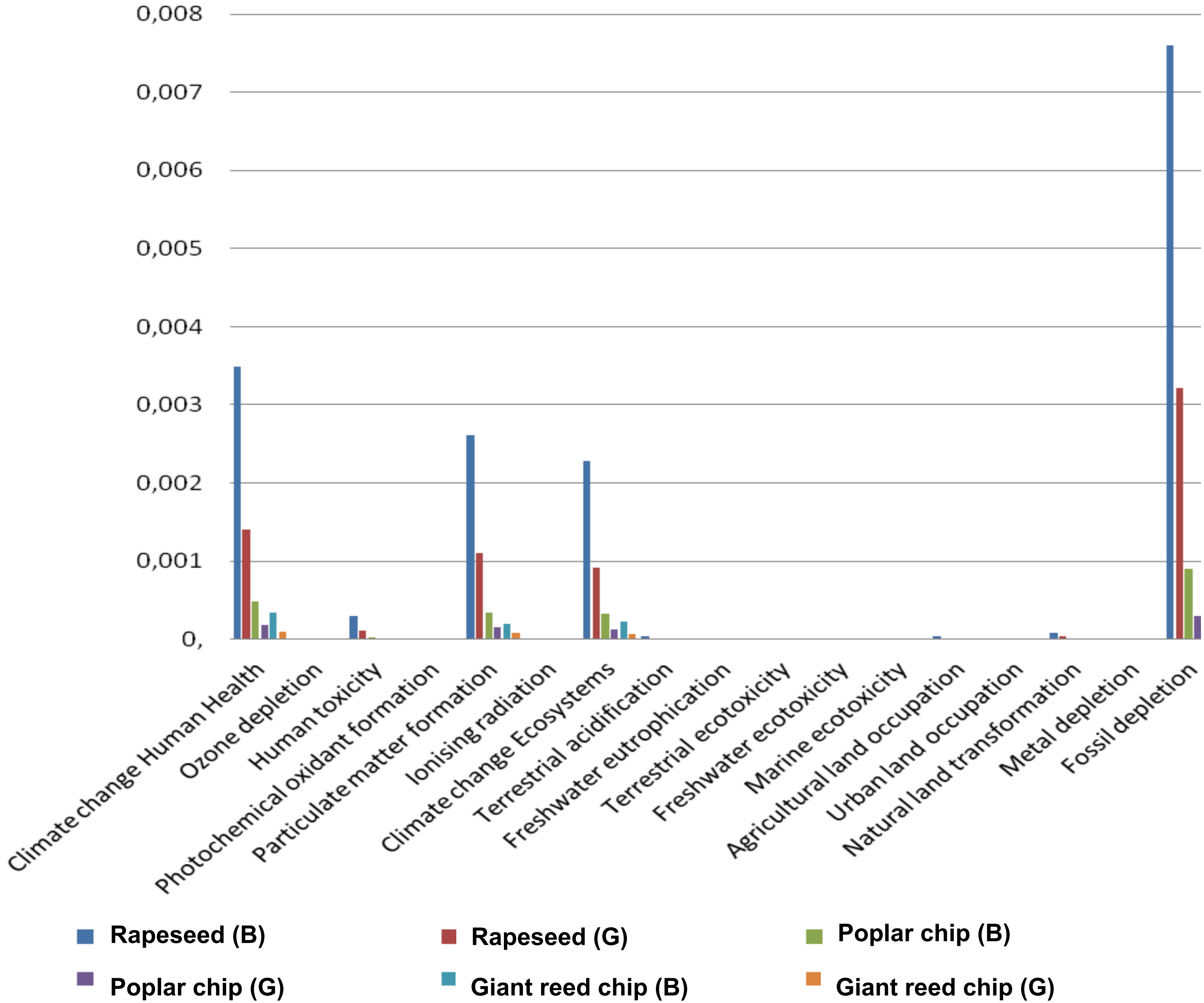


ReCiPe 2008 : relation among the inventary data - LCI (on the left), midpoint factors (in the middle) and endpoint factors (on the right) (Source: Goedkoop, 2009)

CHARACTERIZATION – Energy based comparison (1 GJ)

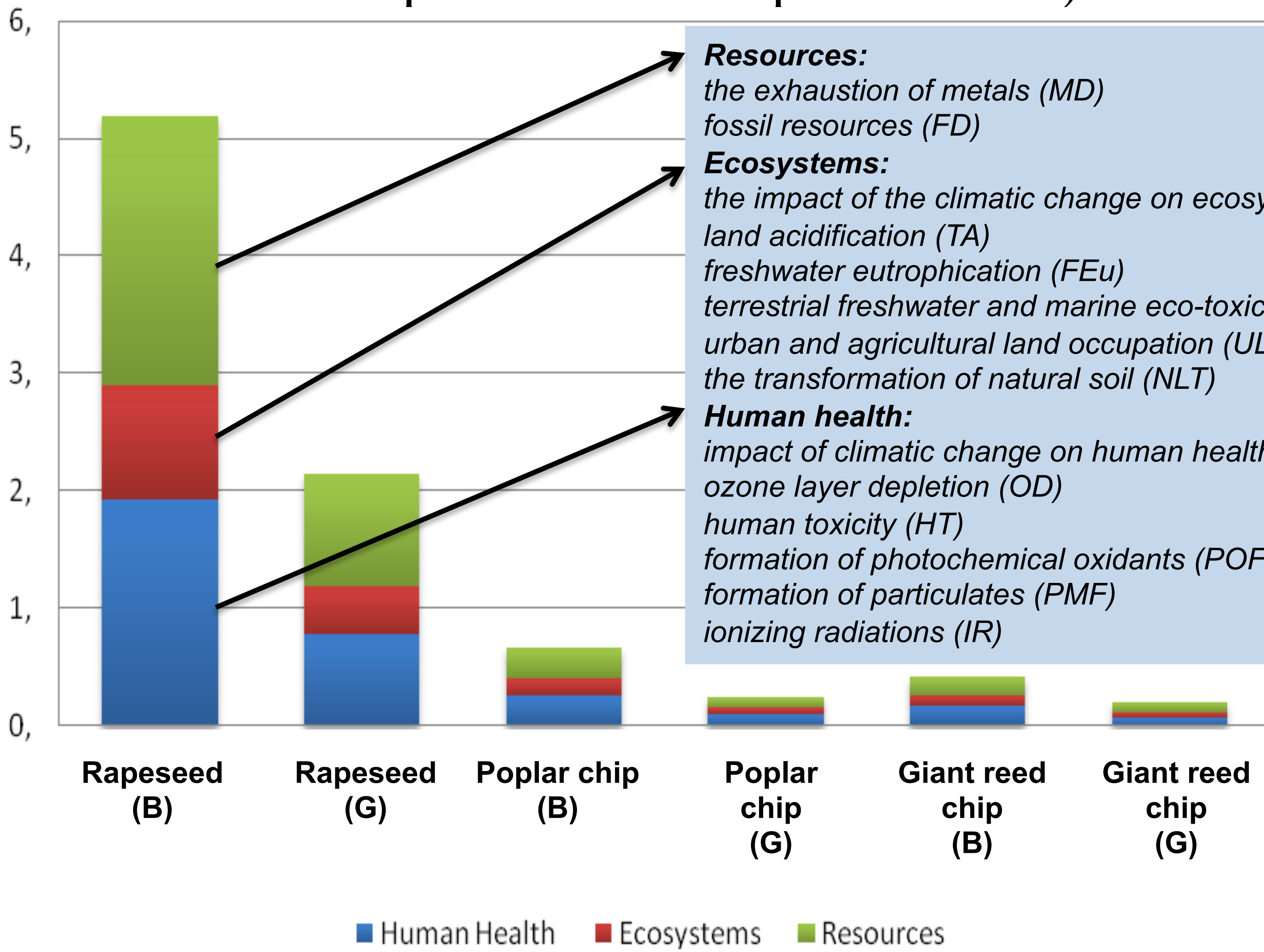


NORMALIZATION – Energy based comparison (1 GJ)



SINGLE SCORE – Energy based comparison (1 GJ)

Through the Recipe 2008 methodology, all the emissions have been sorted into three macro-categories and the global impact for each process has been evaluated by assigning eco-scores (1/1000 of the annual environmental impact of an European citizen).

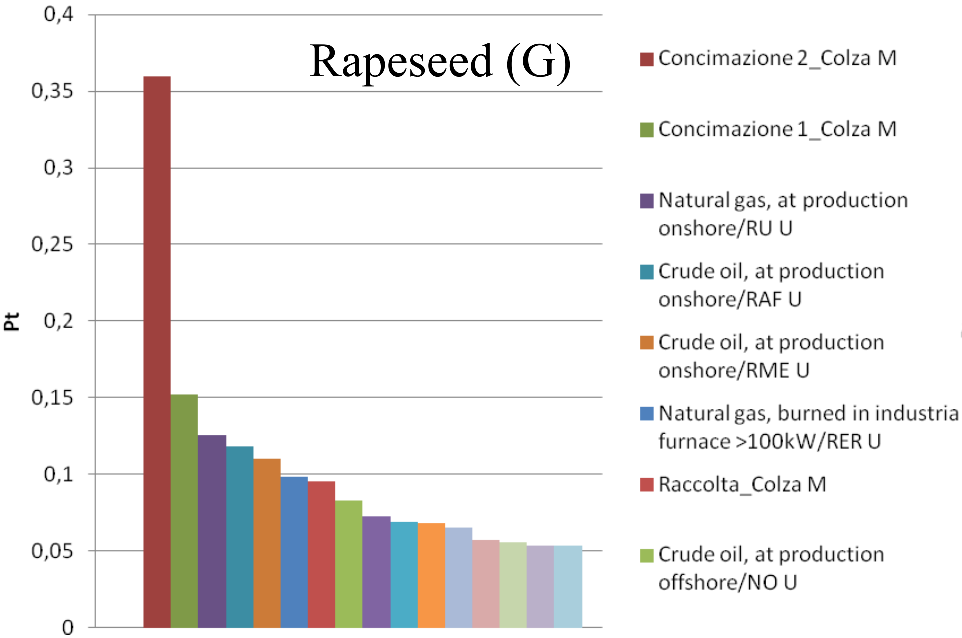


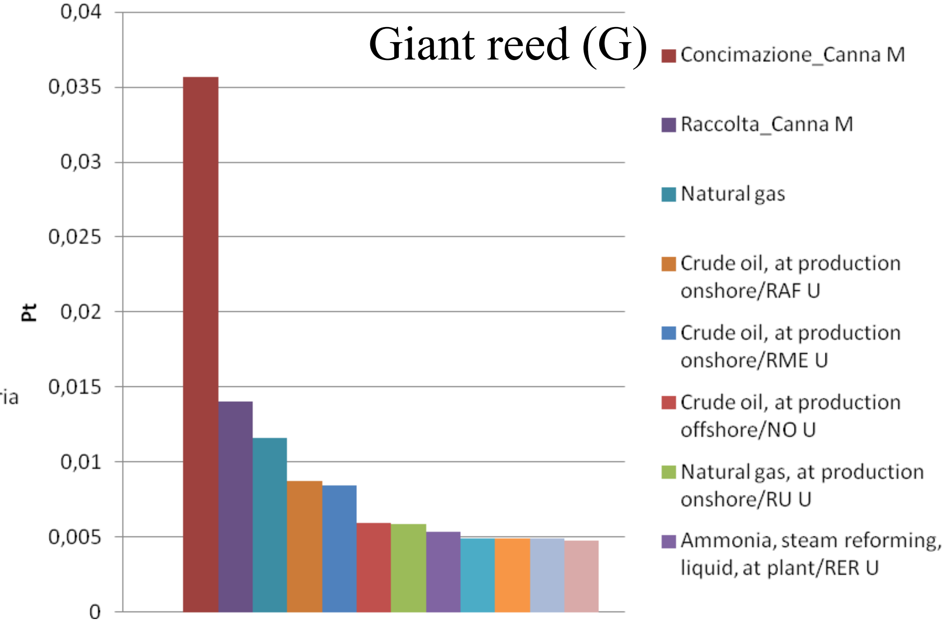
Resources:
the exhaustion of metals (MD)
fossil resources (FD)

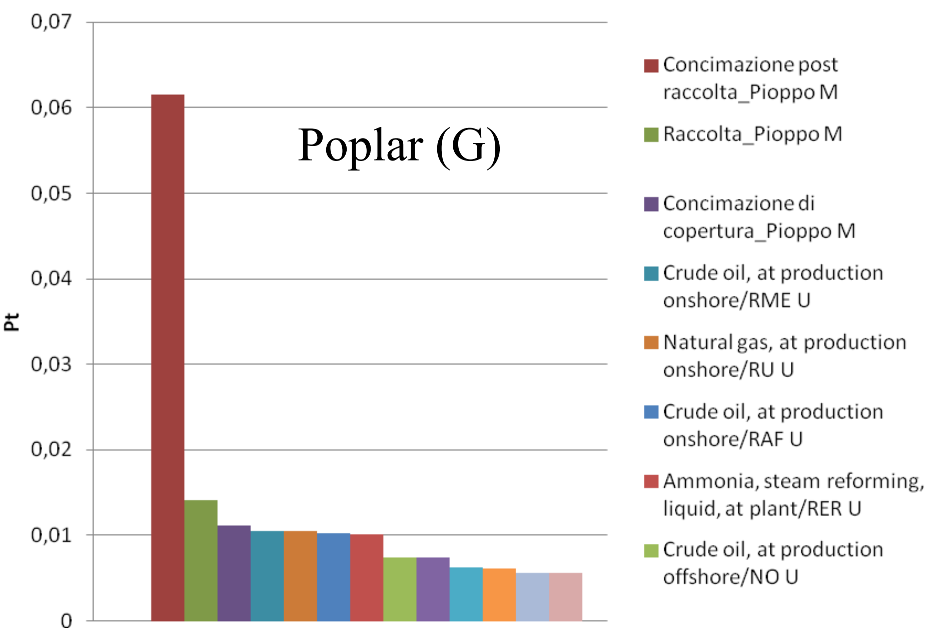
Ecosystems:
the impact of the climatic change on ecosystems (CCE)
land acidification (TA)
freshwater eutrophication (FEu)
terrestrial freshwater and marine eco-toxicity (TE, FEc, ME)
urban and agricultural land occupation (ULO, ALO)
the transformation of natural soil (NLT)

Human health:
impact of climatic change on human health (CCHH),
ozone layer depletion (OD)
human toxicity (HT)
formation of photochemical oxidants (POF)
formation of particulates (PMF)
ionizing radiations (IR)

CONTRIBUTION ANALYSIS







GOOD AGRICULTURAL PRACTICES

Rapeseed:

Good management of the fertilization: it is possible a reduction of fertilizers > 50% (Rathkea et al. 2006)

Minimum tillage or direct seeding when possible (to evaluate case by case)

Sowing period- It is critical for the drastical reduction of the emissions. Infact, an early sowing permit to reduce the N losses caused by the leaching.

Type of fertilizer: Ammonia + denitrification inhibitors

Good soil drainage: reduction of the denitrification (Brentrup et al., 2000).

Presence of Sulfur in the soil – improved used of N

Poplar and Giant reed:

Optimize the fertilization (Arundo d.)– to evaluate case by case (reduction of ash content <20% in autumn harvesting (m.c. <10%)

Biofilter– (Perttu 1998; Karacic 2005; Dickmann 2006; Bisoffi et al. 2009).

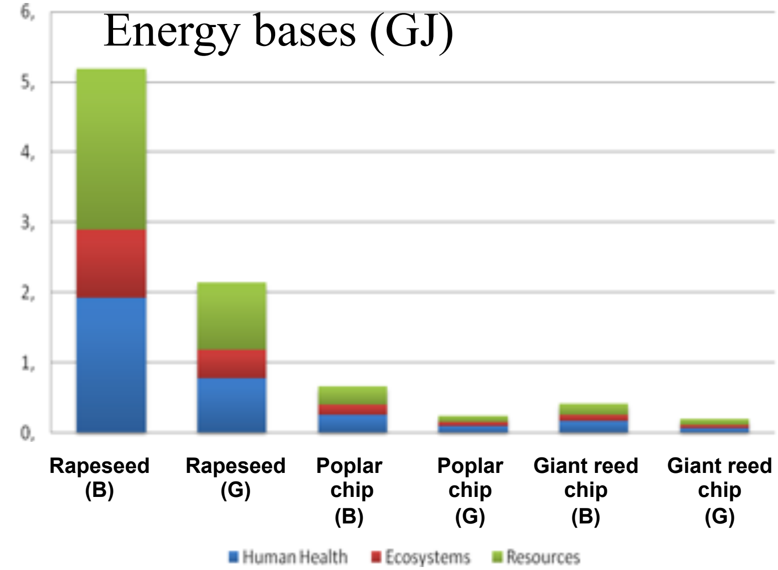
Choice of the best harvesting logistics – one or two times; Chipping or baling

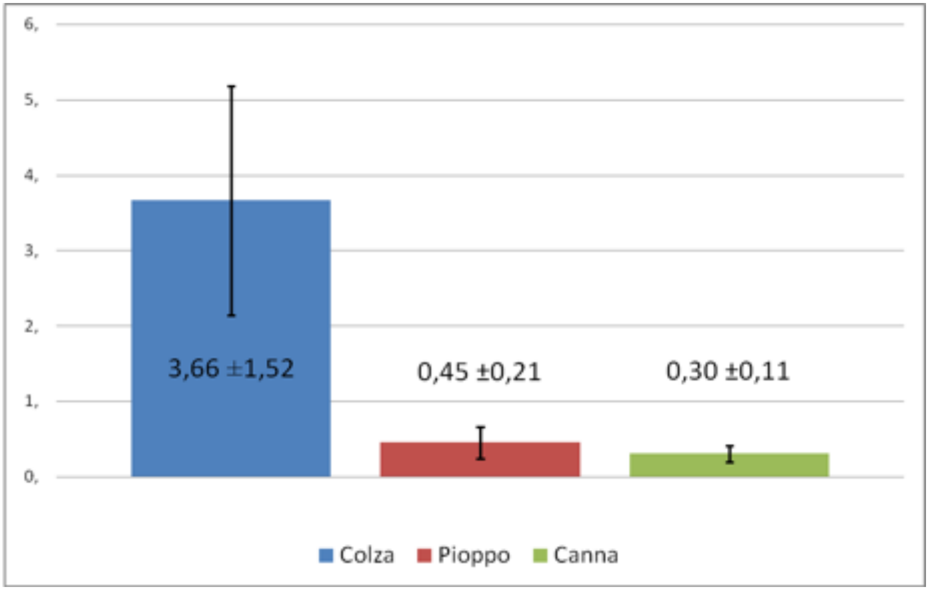
Correct sizing of tractors and equipment: reduction of direct (fuel consumption) and indirect emission (materials used for the construction)

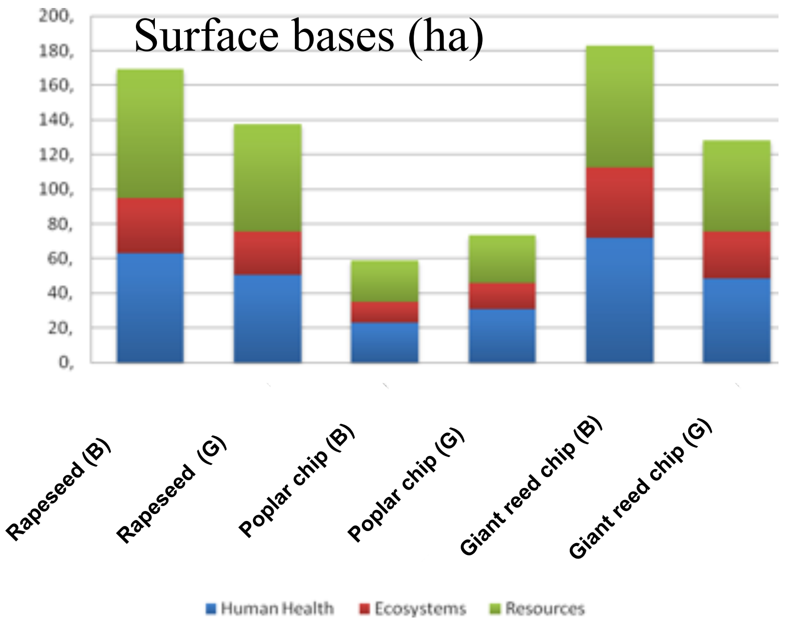
Use clones of more productive

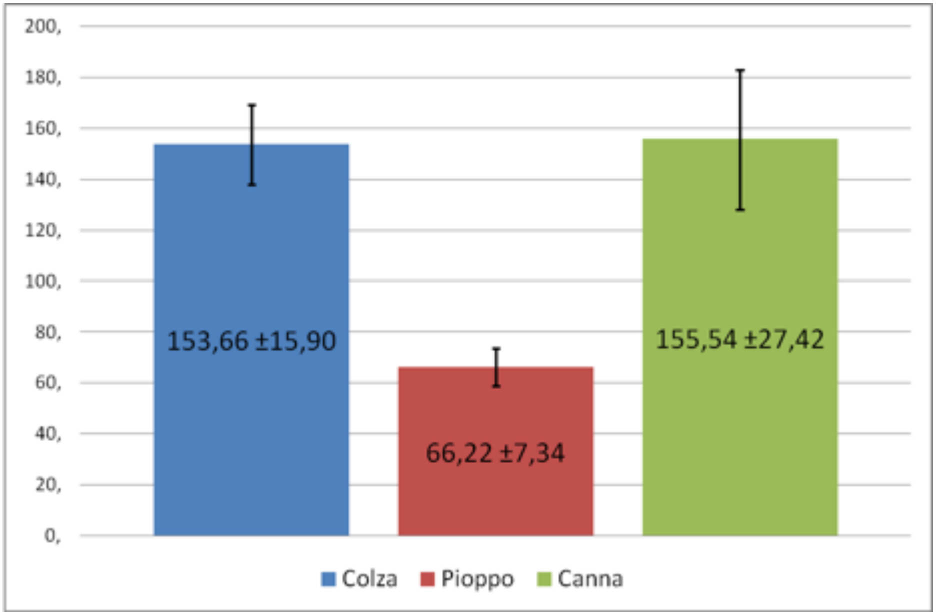
SENSITIVITY ANALYSIS

Energy bases (GJ) Vs surface bases(ha)





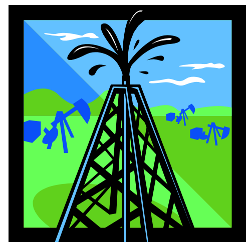




CONCLUSION

1- Agricultural phases: the most critical impact category

"Fossil depletion"



"Climate change"

2- Rapeseed resulted the most impactful crop on energy bases (GJ)

-Low yield (even with high LHV)
-The poliannual crops resulted more sustainable.
-It is more convenient to use the whole plant than the seeds
-Arundo donax represent the best solution as well as Poplar, on energy bases, because the high productivity.

CONCLUSION

3- On the surface bases (ha) – Arundo donax is most impactful crop

-Cause the annual fertilization and harvesting with selfpropelled harvesters

-Poplar resulted the best solution also on the surface bases because the fertilizations and harvesting every two years.

Poplar resulted the energy crop more environmental sustainable for the Italian territory, as substitute of the sugar beet, and in the geographical area more adapt for its grown.

CONCLUSION

- The LCA methodology, presents criticity due to lack of methodologies and impact models designed specifically for the agricultural sector.
- However It is still considered as an effective comparative method of the environmental sustainability of systems and supply chains.
- In a comparison of different energy crops, assuming the cultivation in the same areal and with the same environmental variables, it is conceivable that the real environmental impact generated will be different from that produced by the model, but proportionally wrong in different scenarios. So, the problem results marginal in a relative comparison.



Thank you for your attention





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MATERIAL AND METHODS

Crops	LHV (MJ kg^{-1})	Yield (kg ha^{-1})	Energy Output (GJ ha^{-1})
Rapeseed (G)	26,8*	2400	64,32
Rapeseed (B)	26,8*	1220	32,70
Giant reed (G)	16,0**	41900	670,40
Giant reed (B)	16,0**	27200	435,20
Poplar (G)	18,5***	16400	303,40
Poplar (B)	18,5***	4800	88,80

* The rapeseed's LHV has been calculated considering an oil content of 34% and a press cake of 63% and multiplying the quantity with the corresponding LHV , and then summed (LHV of oil 37,4 MJ/kg (AAVV, 2007) and LHV of press cake 21,2 MJ/kg (Fonte AIEL, 2009a). (0,34 kg *37,4 MJ) + (0,63 kg *21,2 MJ).

** Source: ENAMA, (2010)

*** Source: AIEL, (2009)