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1st. Biofuels International Conference

FAAP – São Paulo, May 2010

Measuring the impact of biofuels on climate change

Evaluation of GHG emissions/mitigation in biofuels production/utilization: issues and trends

I C Macedo, NIPE / UNICAMP

Emissions in The Transportation Sector

Global GHG emissions in the transportation sector

6,7 Gt CO_2*e* , 2002 → 11,6 Gt CO_2*e* , 2030 estimate

Increasing (system and components) efficiency and using biofuels (projections) could reduce emissions **2,2 to 4,5 Gt CO_2*e*** (IPCC 2007); but the increasing presence of "new" (fossil) fuels may off set this gain.

→ Transport sector emissions will grow until 2030, even with the use of all mitigation options considered.

→ Biofuels with high potential for GHG mitigation are essential

Avoided emissions, ethanol (+ co-generated electricity) in Brazil

	2006	**2020** (2)
Avoided emissions (M t CO_2 *e*/year) (1)	36	133 (149)
% emissions from (Transportation + Electricity) Sectors	22%	43%
% emissions from all sectors, excluding agriculture, cattle raising and deforestation	10%	18%

(1) 2020: Electricity GHG credits: 260 kg CO_2/MWh, or 570 kgCO_2/MWh

(2) Projected; energy and ethanol use: EPE-2030, UNICA, MAPA, IE-UFRJ, CEPEA

Ethanol emissions: Macedo & Seabra, 2008

Ethanol supplies 50% of all fuel for light duty vehicles.
Sugar cane for ethanol uses ~0.5% of Brazil's area.

GHG accounting: methodologies

The trading of biofuels is leading to the definition of methodologies to evaluate GHG emissions from biofuels, and minimum requirements for GHG mitigation. Examples are:

UE Directive Dec 2008; LCA and LUC (direct)
35% today; 50% in 2017; 60%, new, 2017

CARB includes ILUC (GEM); LCA with "GREET"

EPA includes ILUC (PEM); LCA with "GREET"; ethanol:
20% for corn; 50% for cane; 60% cellulosis

MITE includes LCA (~ RTFO, EU); LUC (direct)
50%

GHG accounting: methodologies

Methodology "harmonization" has been sought (system boundaries, mitigation accounting, by-products allocation, the land use change impacts, N_2O emissions, baselines for electricity production emissions, etc):

GHG Working Group (RSB), EPFL - Switzerland

Global Bioenergy Partnership (GBEP, FAO, G8+5)

Renewable Transport Fuel Obligation, UK (bio-fuels)

NREL/DoE and NIPE/UNICAMP: introducing the ethanol from cane in the GREET model

→*Transparency; adequate simplifications; suitable databases*

GHG accounting: methodologies

Note 1: the need for high quality data base

Some directives indicate default GHG emission values for biofuels with very small (or zero) commercial production such as 2nd. generation ethanol.

Note 2: product diversification → higher complexity

Ethanol and sucrose derived products, electricity, and crop rotation by-products demand more comprehensive analyses

Example: Sugar Cane Ethanol in Brazil

- Emissions in biofuel production / utilization: “conventional” LCA
- Emissions from the land use change (LUC)

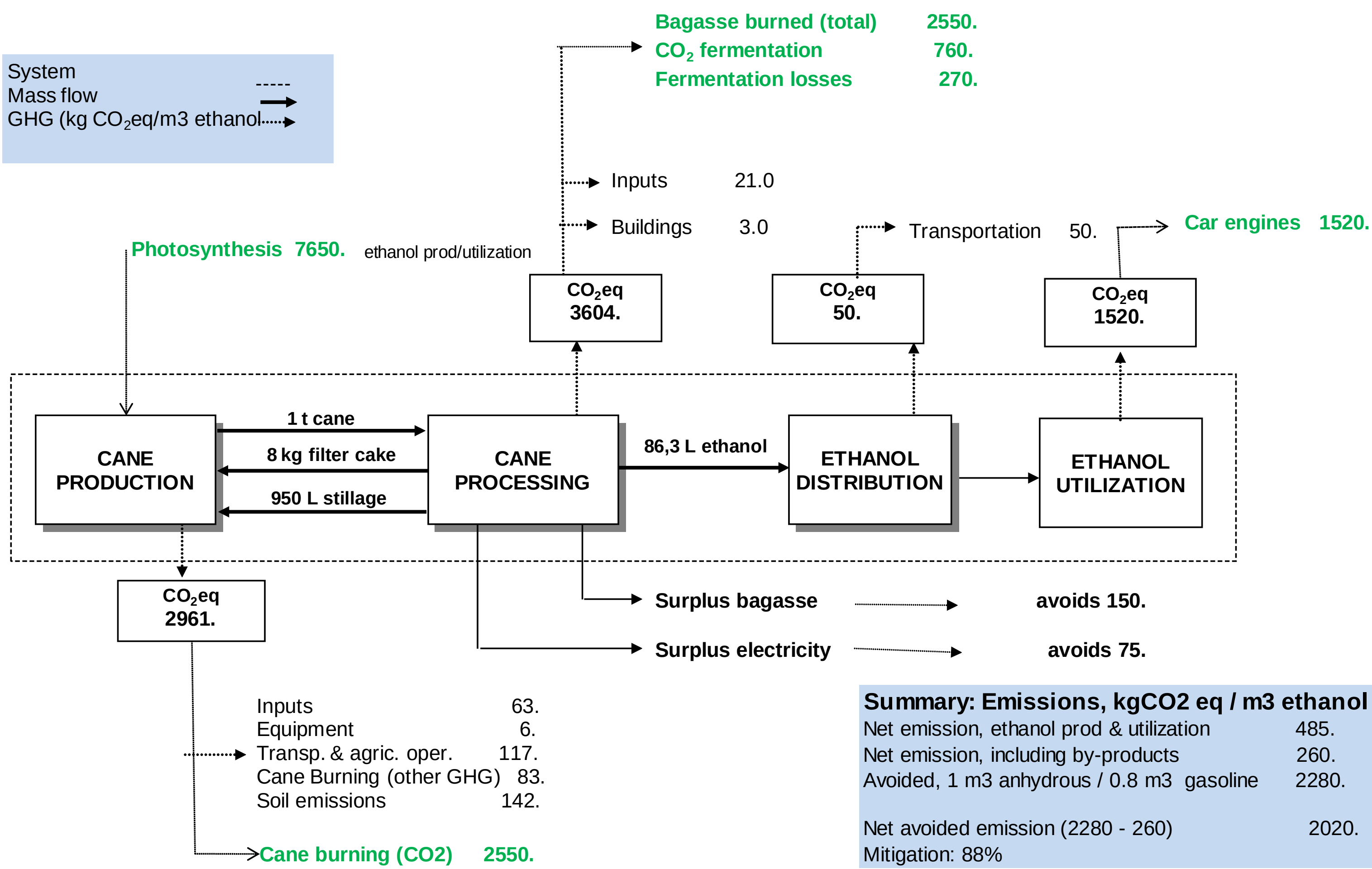
Direct: from 2002 to 2008, sugar cane expanded in croplands and pasture lands, with < 2% in native vegetation areas (ICONE/INPE, 2008; CONAB 2008). This led most probably to an *increase* in SOC stocks.

Indirect: still no consensual criterion for evaluation; ICONE studies indicate very small effects.

Environmental legislation, economics

Land availability: cattle raising “intensification”

“Conventional” LCA



Summary: Emissions, kgCO2 eq / m3 ethanol

Net emission, ethanol prod & utilization	485.
Net emission, including by-products	260.
Avoided, 1 m3 anhydrous / 0.8 m3 gasoline	2280.
Net avoided emission (2280 - 260)	2020.

Mitigation: 88%

Comments: “Conventional” LCA

- EU, CARB and EPA do not compute the energy used in the production of equipment and buildings
- Energy use in the production of some inputs (mainly fertilizers) is considered by EPA
- EPA does not compute agricultural fuel utilization for the specific biomass (the total agricultural fuel use in the country was allocated in an area basis).
- The larger differences are in the co-poducts credits

Comments: “Conventional” LCA

The initial evaluations of sugar cane ethanol made by EPA, CARB e EU had some mistakes and methodology differences:

- Energy in fertilizer and lime production
- Efficiency of trucks for cane and ethanol transportation
- Values for trash% cane and fraction of burned cane
- CARB and EU consider a two-way trip for the fuel consumption of tankers for the exported ethanol
- The analysis was WTTank, not WTW.
- Most important differences are in the computation of credits for the surplus electricity:

- CARB utilizes the GREET (1.8b) model and considers the total energy sold, in displacement, substituting for NG based thermoelectric power stations (operational margin)
- EPA: also using the GREET (1.8b), and also displacement, but changing the concept and substituting for the energy production "mix" . This is being re-considered.
- EU: only considers for replacement the surplus energy strictly co-generated (with the steam needed for the ethanol production); any energy from the condensing portion of the cycle may be (???) allocated.

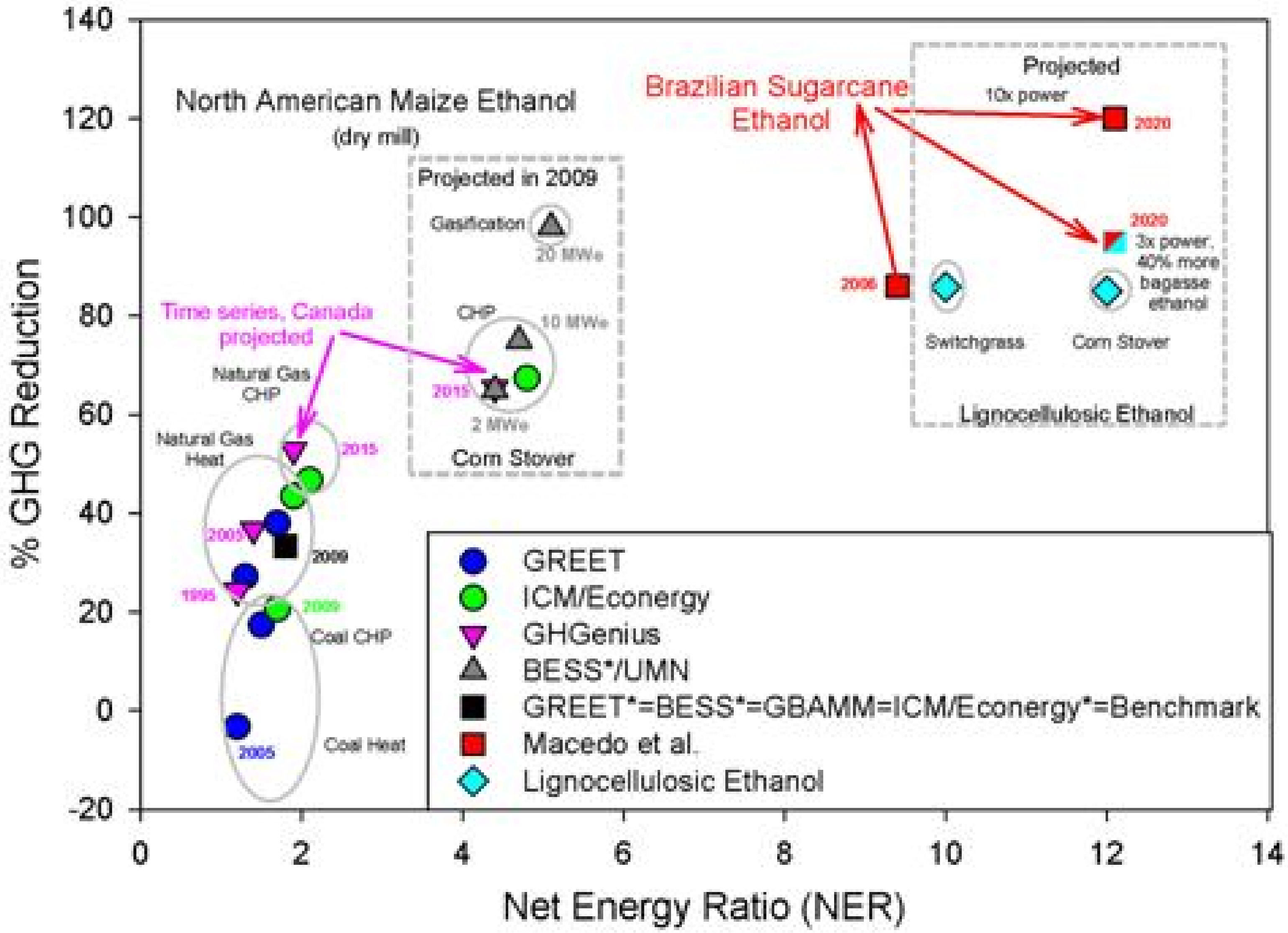
Each 10 kwh / t cane sold to the grid avoids the emission of 3.5 g C /MJ ethanol (computed against a NG power plant).

Total emissions in the ethanol production / use cycle correspond to ~ 20 g C / MJ ethanol.

⟶ *an ethanol plant selling 60 kWh / t cane has zero net emissions, or 100% mitigation of gasoline emissions.*

Some mills already reach 60 kWh / t cane exported energy, with bagasse. New plants (using some trash) will produce much more.

Maize, Sugar cane, Cellulosic Ethanol; NREL/NIPE evaluation, 2009; excluding LUC emissions; co-products displacement



Comments on LUC (direct) evaluation

- EU estimates direct LUC emissions as the difference between the equilibrium values of soil carbon (from cane to the substituted biomass) divided by 20 years.
- EPA considers a peak emission (~80%) in the first year and distributes the remaining for up to 100 years; the present value , with 2% per year discount, is used. Also considers 30 years, zero discount.
- The “average” above ground Carbon in the sugar cane plant was not initially considered.

Soil Organic Carbon – Sugar Cane

1. Expansion areas, Center-South: keeping the trend (over annual *crops and pasture, not native vegetation*)
    The Agro-Ecological Zoning for Sugar Cane
    Economics
2. Soil / Crop considerations
    Cane is a perennial or annual crop?
    Use of default values or actual data?
    (the Winrock 2009 report)

Soils in the expansion areas: almost all LAC; texture variation
Harvesting in the expansion areas: green cane

Soil Organic Carbon – Sugar cane

- IPCC 2006 (30 cm depth)
  LAC soils, tropical moist climate: SOC_{REF} = 47 t C/ha
  Green cane, high residues:
  Annual: 29 t C/ ha
  Perennial: 52 t C / ha
- Winrock 2009 (updated); (EPA); **perennial; average 41**
  SOC_{REF}: 28 to 41 t C/ha S Paulo, MS
  41 to 66 t C/ha MG, GO, MT, Parana

	CWCerr DF	CWCerr GO	CWCerr MT-CW	CWCerr MT-S	SE MG	SE SP	N-NE Cerr TO
Sugar Cane (2), SOC_{EQ}	**50**	**43**	**58**	**41**	**46**	**38**	**49**

- 2008 data survey (Amaral 2008)
  44 t C/ha (green) and **35 t C ha** (burned), in São Paulo.

Soil Organic Carbon – Sugar Cane

- CTC (1990 – 2009) data bank: sugar cane areas in C-S

  Measurements:

  Soil Carbon, **Texture:** 27.5 thousand locations, 5 states (C-South)

  Depths: 0-25 cm; 25-50 cm

  Total area: 1.1 million ha

  Soil density, Texture: 290 locations, SP – Parana – MG

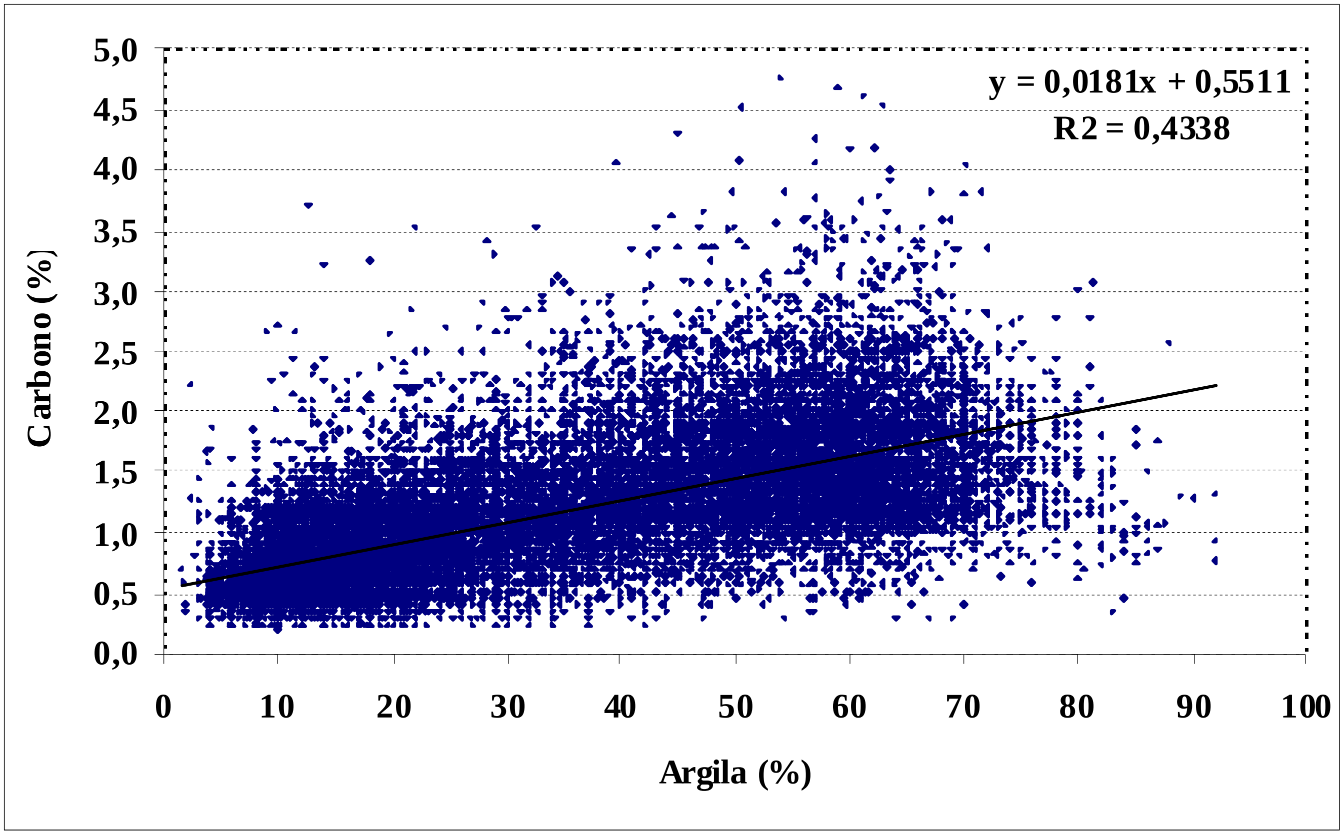
  Depths: 0-25 cm; 25-50 cm

  Results: Each State, Regions in S Paulo

  Soil Carbon Stock: 0-25;25-50; calculated for 0-30

Soil Organic Carbon – Sugar Cane

- Carbon (g/g soil) X Texture, C-S, 0-25 cm; 1.1 million ha



Soil Organic Carbon – Sugar Cane

- Carbon Stock, C-S, 0-25 cm

faixa de textura (%)	nº de pontos	média de argila (%)	média de carbono (%)	Densidade média (g/cm^3)	toneladas de carbono/ha	% de representatividade	Área estimada (ha)*
0 a 10	2.577	8,1	0,67	1,63	27,31	9,4	103.080
10,1 a 20	8.297	15,1	0,79	1,59	31,54	30,1	331.880
20,1 a 30	4.125	24,6	1,02	1,53	38,78	15,0	165.000
30,1 a 40	2.758	35,4	1,25	1,46	45,47	10,0	110.320
40,1 a 50	2.870	45,4	1,45	1,40	50,62	10,4	114.800
50,1 a 60	3.751	55,5	1,60	1,34	53,41	13,6	150.040
60,1 a 70	2.579	64,3	1,68	1,28	53,72	9,4	103.160
70,1 a 80	530	73,9	1,61	1,22	49,10	1,9	21.200
80,1 a 90	62	83,6	1,27	1,16	37,04	0,2	2.480
90,1 a 100	3	92,0	1,01	1,11	28,12	0,0	120
total/ média ponderada	27.552	32,5	1,14	1,46	41,53	100,0	1.102.080

0 – 30 cm average: ***47.6 t C / ha*** **Texture: 0.33** **Density: 1.46**
0 – 50 cm: **71.8 t C / ha**

Soil organic Carbon – Pastures, Annual Crops

Winrock 2009:

- Annual Crops: average SOC in the expansion areas: 20 t C/ha
- Native grasslands: 41 t C / ha

IPCC 2006:

- Degraded pastures: 33 t C / ha
- Non degraded, equilibrium: 47
- Improved: 55

The available experiments (not enough) seem to confirm the values for crops, native grasslands, and non degraded pastures; but they do not show that much difference (as IPCC 2006) from non degraded to degraded pastures.

Cane Biomass – Above Ground

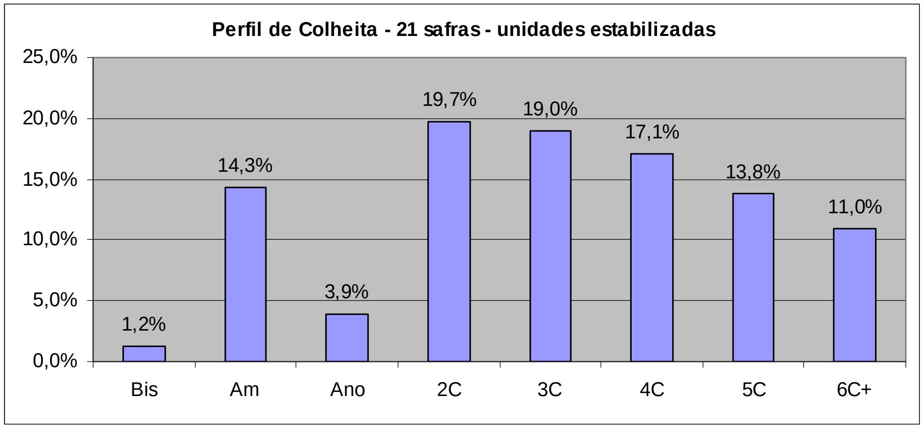
- Plant development Model, C-S : Averages, 21 year stabilized cane plantations, C-S
- Cane stocks (t stalks green / total ha) in April 1 (beginning harvesting):

Cane Stalks (t/ha)

Type	Area (%)	Development (%)	Full Productivity (t/ha)	Cane Stalks (t/ha)
18 month Plant Cane (from two seasons ago)	11.3%	100%	120	13.6
18 month Plant Cane (planted two months ago: Jan-Mar)	**7.9%**	10%	120	0.9
18 month Plant Cane (to be planted in next Apr-May)	**3.4%**	0%	120	0.0
Seed cane, for 18 month plant cane (Jan-Mar)	**1.1%**	10%	90	0.1
Seed Cane to be harvested for 18 month Plant Cane (Apr-May)	**0.5%**	100%	90	0.4
12 month Plant Cane (planted last season)	4.3%	100%	100	4.3
Ratoon, harvested in the start of last season (Apr-Jun)	21.5%	100%	80	17.2
Ratoon, harvested in the middle of last season (Jul-Sep)	32.2%	85%	80	21.9
Ratoon, harvested in the end of last season (Oct-Dec)	17.9%	75%	80	10.7
Total	100.0%		86	69.1
Area to be harvested in this season	87.1%			

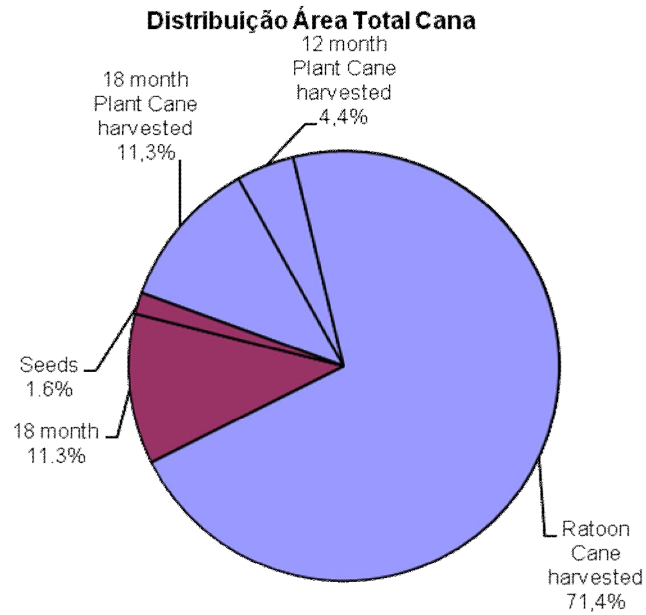
Cane Biomass – Above Ground

- Model Parameters (harvesting)



Average, 21 year harvesting profile - Stablized

	Start	Middle	End	Total
Bis	0.9%	0.2%	0.1%	1.2%
18 month	6.7%	5.8%	1.8%	14.3%
12 month	0.4%	1.4%	2.1%	3.9%
Ratoon	23.5%	35.6%	21.4%	80.5%
Total	**31.6%**	**43.0%**	**25.4%**	**100.0%**



Cane Biomass – Above Ground

- Simulation of stocks at the end of harvesting (Month 7) indicate 19 t stalks / ha total.
- The biomass above ground / ha total varies along the season from 69 t to 19.6 t stalks; average is 44.3 t stalks / total ha.
- 1 t green stalks = 0.425 t dry mass = 0.212 t Carbon

⟹ Time averaged above ground biomass is **9.4 t Carbon / ha (t)**

- Root system biomass (live roots) must be added; some results are being compared (~4 t C/ ha).

Conclusions

- It is important to establish the local (national) values for the main parameters involved, rather than relying on “default” parameters. This is particularly true for the agronomic data, since the diversity of conditions and processes is much larger than in the conversion (industrial) phase.
- In the agronomic area, this will lead to long term experiments (> 20 year); however the results will be important when concepts like the ILUC become sounder, to be used by all agriculture / cattle / forestry system (not only biofuels)
- In the conversion area (industry) the increasing (and desirable) presence of by products demands a broader, more flexible methodology for credits; focus must be in the main objective (global GHG emissions mitigation).