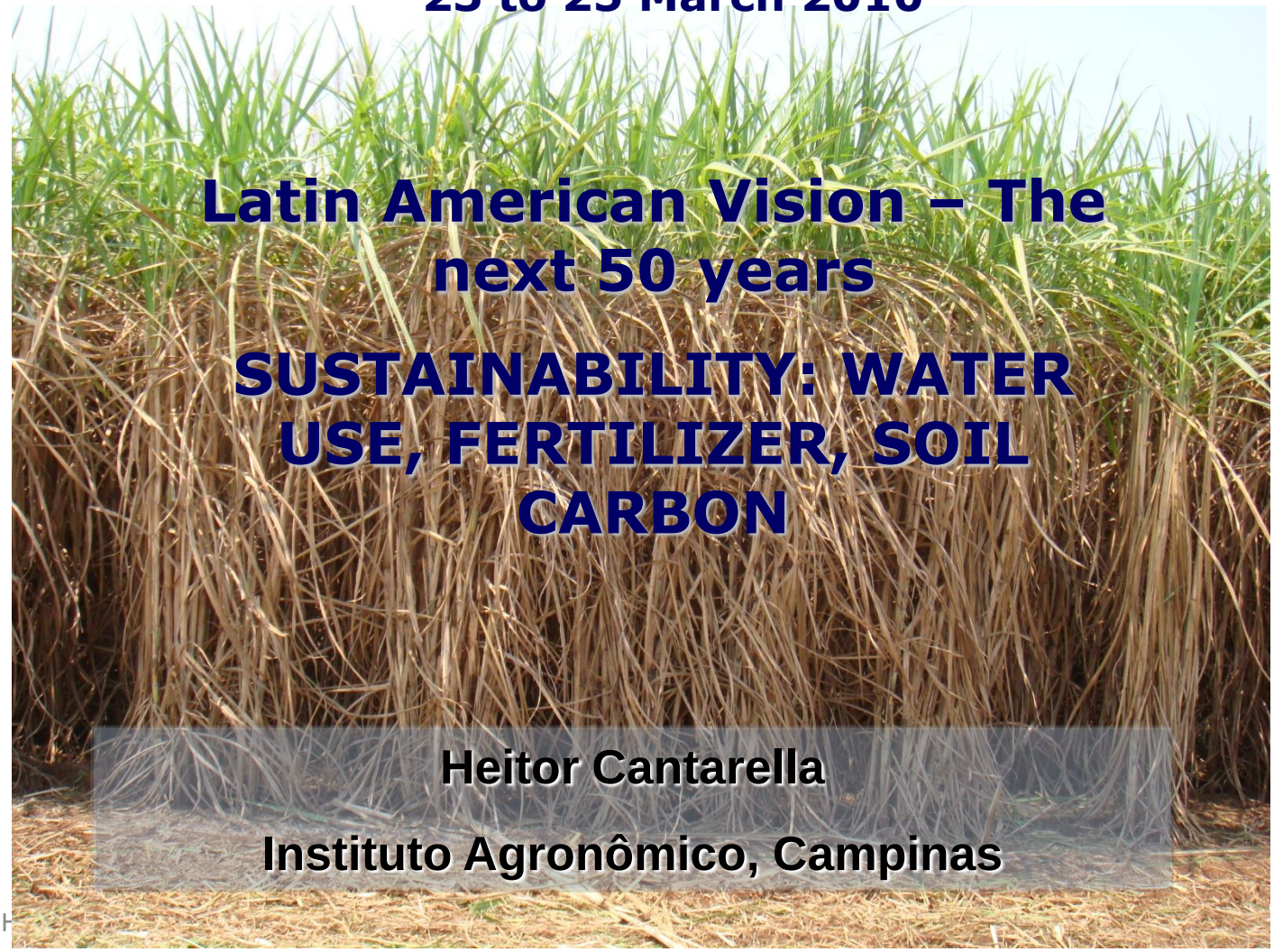
GSB PROJECT

The Latin American Convention of the Global Sustainable Bioenergy Project

23 to 25 March 2010



Latin American Vision – The next 50 years

SUSTAINABILITY: WATER USE, FERTILIZER, SOIL CARBON

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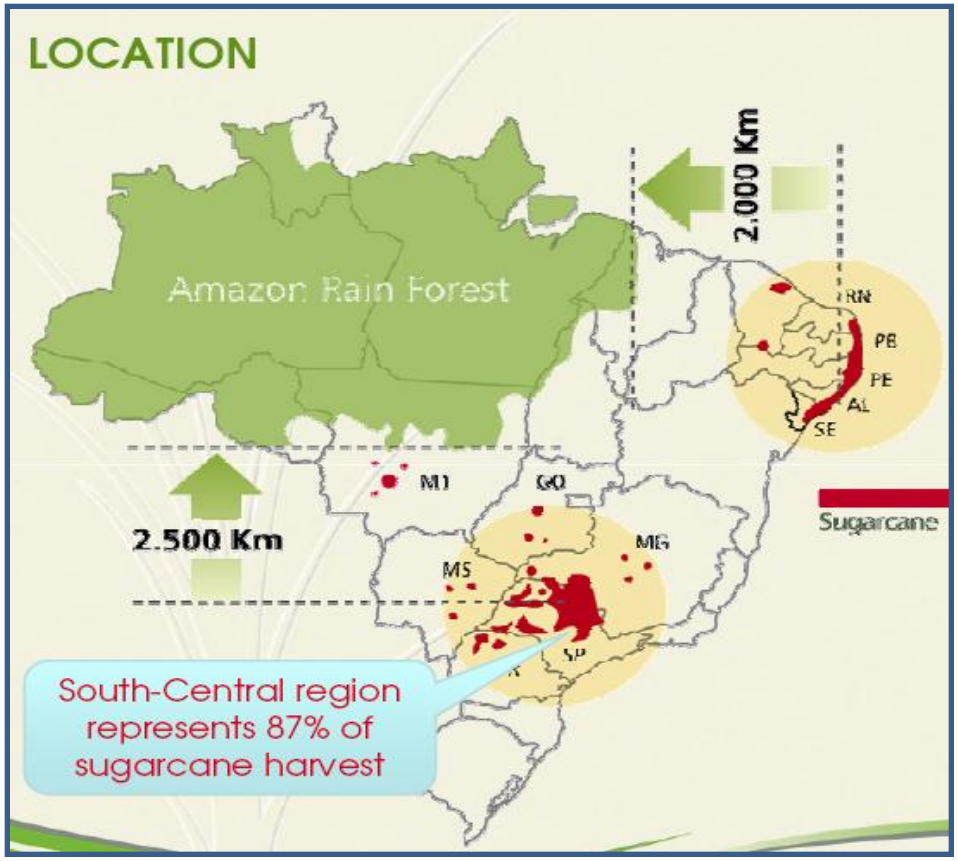
Water use efficiency

- **C-4 species are 2 to 3 times more efficient in water use**
  - **C3: 350 to 100 kg water kg^{-1} synthesized C**
  - **C4: 150 to 300 kg kg^{-1}**
  - **Sugarcane: 500 L kg^{-1} dry matter of stalk**
- **Rainfed sugarcane: 900 to 1000 mm rain needed**
  - **Depends also on rain distribution**

Janssens et al., 2007

Sugarcane crop production

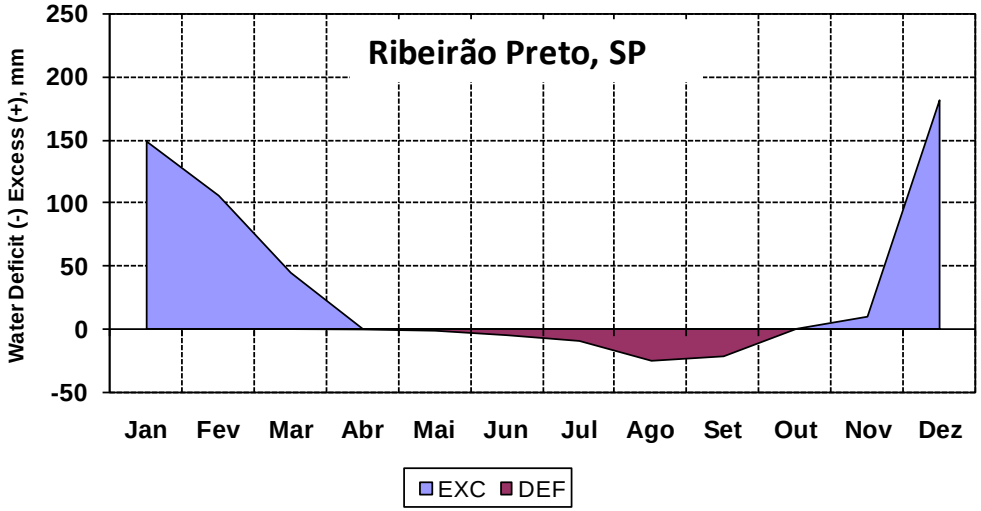
- **Southeastern BR: > 1100 mm rain**
  - **Rainfed**
  - **“Salvage” irrigation to ensure germination in dry periods**
  - **Irrigation is option for higher yields**
- **Northeastern BR: irregular ou insufficient rain**
  - **Part of the area is irrigated**

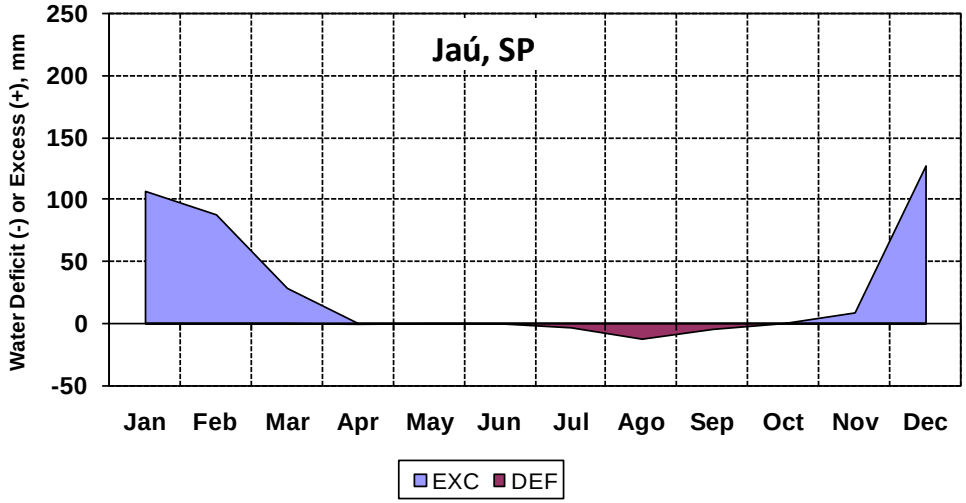


Water balances

Exemples of Goiás and São Paulo

Water Balance: State of São Paulo





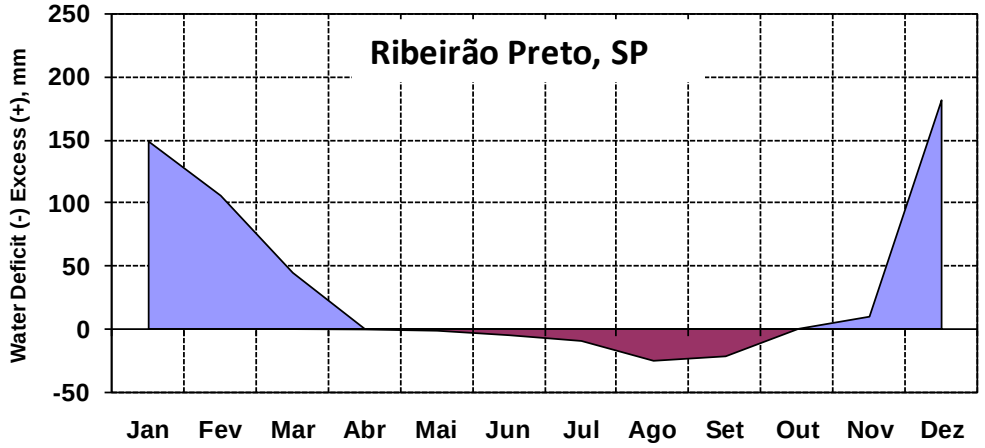
Average annual rain:

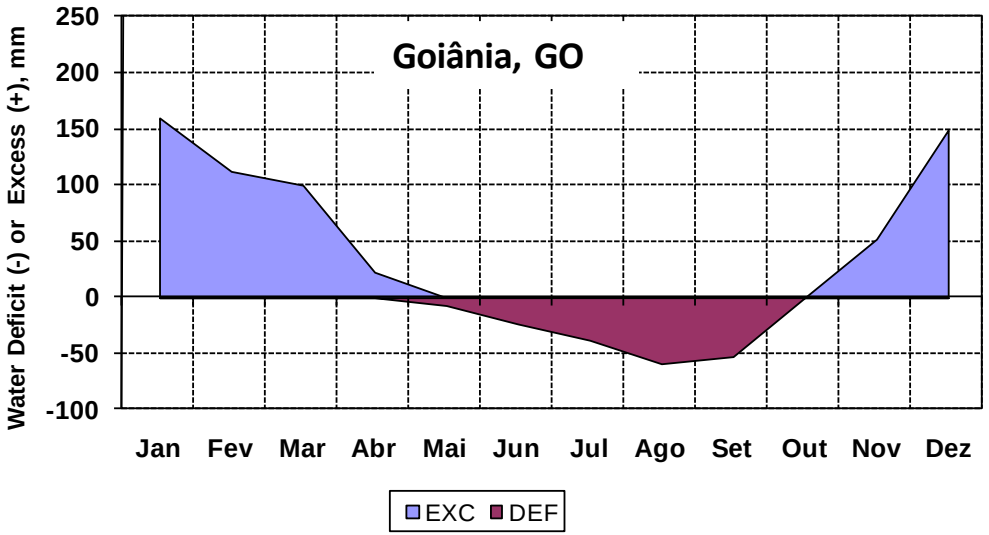
RP: 1529 mm

Jaú: 1417 mm

Dry winter season but mild water deficit

Water Balance: São Paulo X Goiás





Average annual rain:

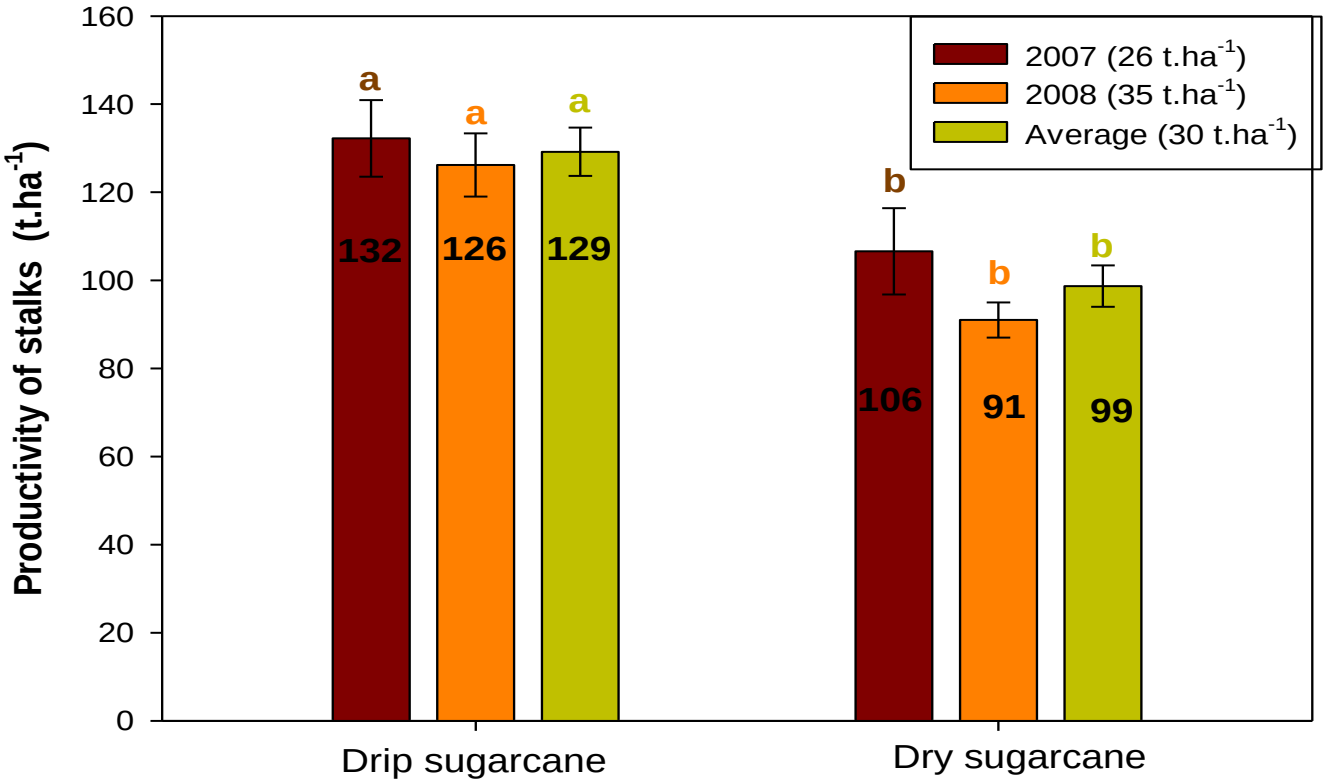
RP: 1529 mm

Goiânia: 1576 mm

Winter season has higher water deficit in Goiás

Central Brazil: salvage irrigation (20 -40 mm) may be necessary

Irrigation increases yields



Irrigation: 400 and 320 mm in 2007 and 2008

Annual rain: 1480 and 1394 mm

Jaú, SP

Average of 3 varieties

Stalk yield: + 30 t ha^{-1}

Sugar yield: + 4.6 t ha^{-1}

Source: Gava et al. (2009)

Sugarcane plant irrigated and fertilized to show potential of variety

Sugarcane yielding 346 t/ha at IAC

Water use in sugarcane in Brazil

- **In most regions irrigation is not necessary**
  (except salvage irrigation in some areas)
- **Breeding programs: search for drought tolerant varieties: dry winter and soils with low water holding capacity**
- **Industry: Legislation restricts water use in new projects to maximum 1 m^3/t cane.**
  - **Great water use efficient improvements in the last 20 years (5.6 to 1.8 m^3/t cane)**
  - **Model mill: 0.46 m^3/t**
- **More strict laws for surface water protection**

Water Quality & Sugarcane production

Vinasse: liquid by-product
800 - 1000 L/t cane
10-13 L/L ethanol
Fertilizer 2% K_2O
High BOD

Rate of application: 90 to 200 m^3/ha
Excess may seep into surface waters

2005: State law (SP) limits rate of application

Surface and Ground Water Quality: Fertilizer

- **Research data show negligeable NO_3^- losses in Brazil**
  - **Rates of N fertilizer applied to sugarcane are low**
- **Euthrophication by excess P**
  - **Rates and form of P application decrease chance of runoff losses**

Use of fertilizers for sugarcane production

Nutrient	Consumption in sugarcane (1000 t)	Percentage of fertilizer used in Brazil	% imported in 2008
N	535	23.3	73
P_2O_5	274	8.7	46
K_2O	713	20.6	92
Total	1.522	17.1	83

Biofuel in the world: 2.4 % of NPK

Brazil: 13 to 17% of NPK consumption

Estimated fertilizers used for biofuel crops 2007/2008 (Million t N, P_2O_5, K_2O).

Data from BR and USA are for ethanol

Fertilizer consumption	World	Brazil (Cane)	EUA (Corn)
N	2,1	0,32	1,57
P_2O_5	0,8	0,16	0,58
K_2O	1,2	0,43	0,65
Total	**4,1**	**0,91**	**2,80**
Ethanol Production (billion L)		22,5	24,7

Source: Heffer & Prud'homme. IFA 2008

Life of World's P and K Reserves

Nutrient	Life of Reserve	Life of Base Reserve	Main producing countries
	----- Years ----		
P	93	291	Marrocco & West. Saara (37%) China (27%) USA (8%) Brazil (2%)
K	235	510	Canada (53%) Russia (22%) Biolorussia (9%) Germany (9%) Brazil (4%)???

Source: USGS 2009; Fixen, 2009

Scenario: Dependence on Imported Fertilizer

- High dependence in Brazil: N: 75%, P: 50%, K: 92%
- All countries that are large producers are also large importers (reserves are distributed across the world)
- Risks are lowered by international trade intensity and interdependence among nations
- Biofuels use only 2.4% of world's fertilizers
- Price increases are very likely
- Scarcity scenario: protectionist barriers to guarantee internal supply (2007: fertilizers - China).

Biological N Fixation in sugarcane

- Several microorganisms with BNF capability have been identified in sugarcane
- Evidences that BNF can contribute with N nutrition of sugarcane
  - Controversy over the importance and magnitude of BNF
  - Inoculant launched in the marked but effectiveness still to be proven
    - Embrapa: inoculant = 30 kg/ha N.
- Strong research effort in Brazil

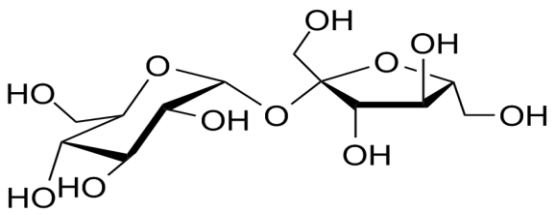
GHG and fertilizers

- **Fertilizer production and transport:**
  - **N: 2,6 to 9,7 kg CO_2-eq/kg; P_2O_5: 1,0; K_2O: 0,7**
- **Fertilizer use: IPCC: 1% of N-fertilizer is released as N_2O**
  - Highly uncertain
    - **0,3 to 3% of fertilizer N**
    - **Davidson et al (2009): 2,5%**
    - **Crutzen et al (2007): 4%**
    - **Keeney (1997): 1 a 7%**

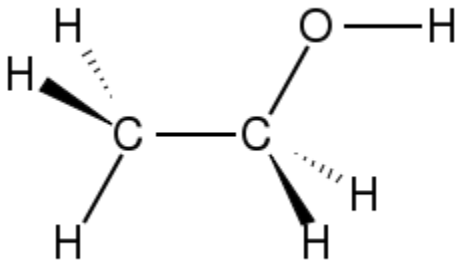
N_2O and other GHG need to be better assessed in sugarcane, especially in green cane

Nutrient recycling

- **Exported products contain only C, H, and O**
  - **Minerals in sugarcane can be recycled back to the field**

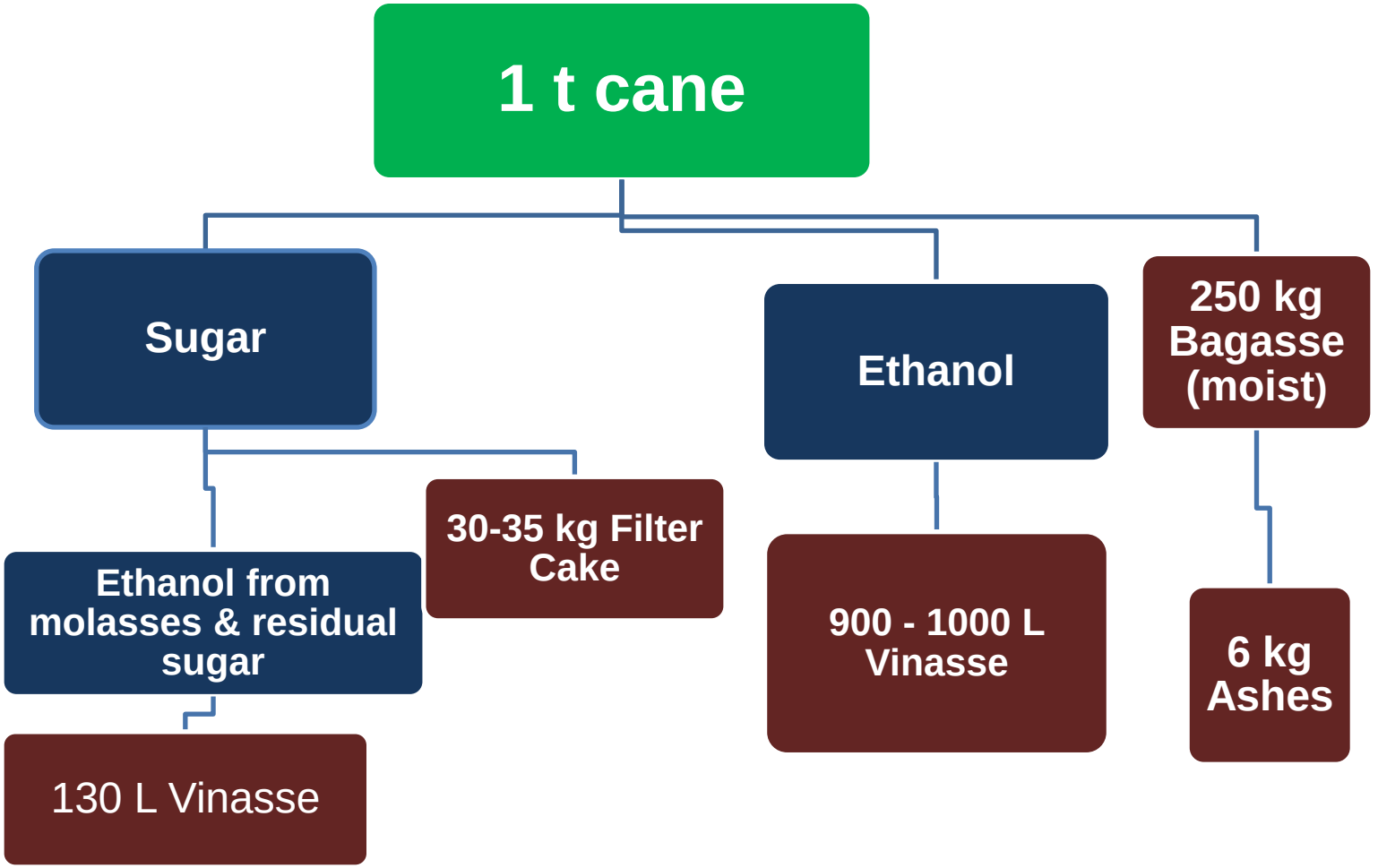


Sucrose: $C_{12}H_{22}O_{11}$

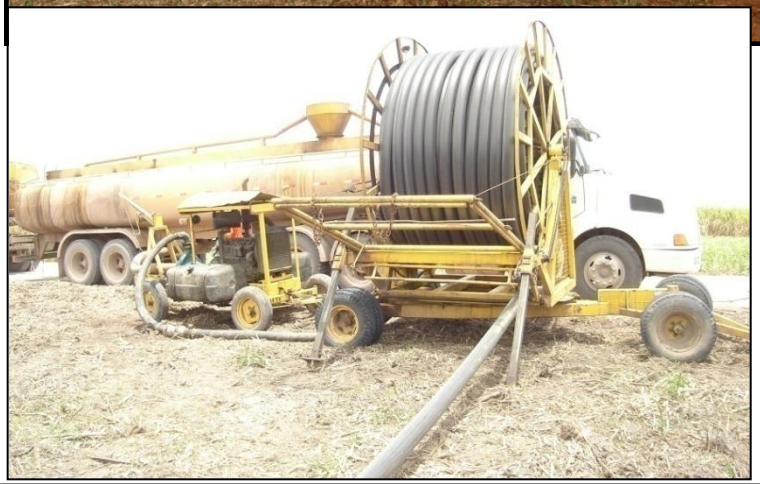


Ethanol: C_2H_5OH

Sugarcane residues



Filter cake and vinasse are regularly applied to the field



Potential of recycling residues in sugarcane

Residues	Volume of residues	Nutrient recycled (t/year)		
		N	P_2O_5	K_2O
Filter cake	6.8 Mt dry filter cake/year	47,690	64,723	14,306
Trash	40.9 Mt dry matter /year	20,499	12,300	163,990
Vinasse	351.4 billion L/year	131,760	21,082	825,696
Total		199,949	98,105	1,003,992

Consumption of mineral fertilizer: 1.5 Mt NPK per year (2008)

Fertilizer: summary and prospects

- Sugarcane uses 13-17% of NPK in Brazil
- World reserves are adequate
- Dependence on imports is of concern
- BNF has potential
- Sugarcane industry recycles residues
  - Space for improvements
- GHG is an issue:
  - Best practices in industry and field can reduce GHG

Does sugarcane deplete or enhance soil C?

- **Depends on the reference**
  - **Forest ⟶ sugarcane: loss of soil C**
  - **Degraded pasture, row crops ⟶ sugarcane: soil accumulates C**

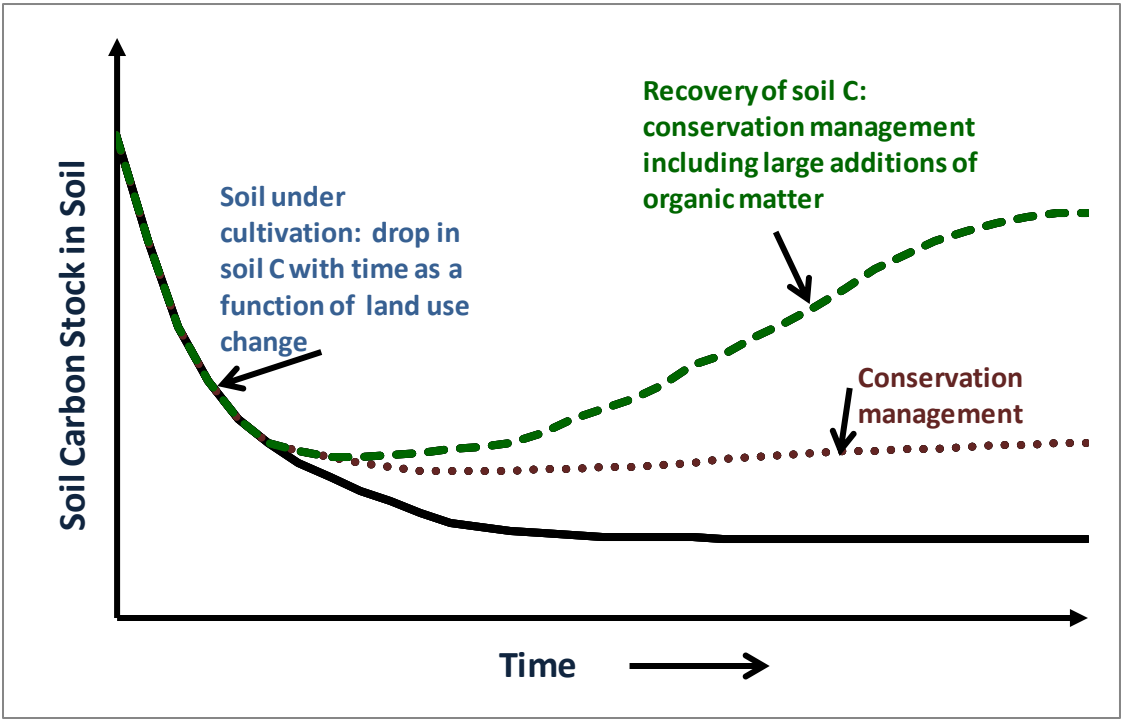
- **Limited data available in Brazil**
- **Research needed to obtain field data under various vegetation sequences/soil types**

Sugarcane: Soil C

Unburned sugarcane (green cane)

- +50% of sugarcane area (and increasing)
- Deposition of large amounts of plant material on soil surface (8 to 16 t/ha DM)
- Large root system
- Soil and water conservation
- Potential to increase soil C

Soil C accumulation: variables



There is a limit to C accumulation in soils:

Soil type (clay)
Climate
Soil management
OM addition
Caracteristics of OM
Soil organic C:
C:N ~ 10-12:1

Sugarcane trash: 80 to 100:1

Trash: preserve soil or use for co-generation and 2nd. generation ethanol?

Constant addition of OM needed to maintain soil chemical and biological quality

Is all the trash necessary to maintain soil fertility?

Probably not

Research data in Brazil (CTC) shows that leaving 40% of trash is enough

Amounts may vary with soil type and region/climate

More research needed

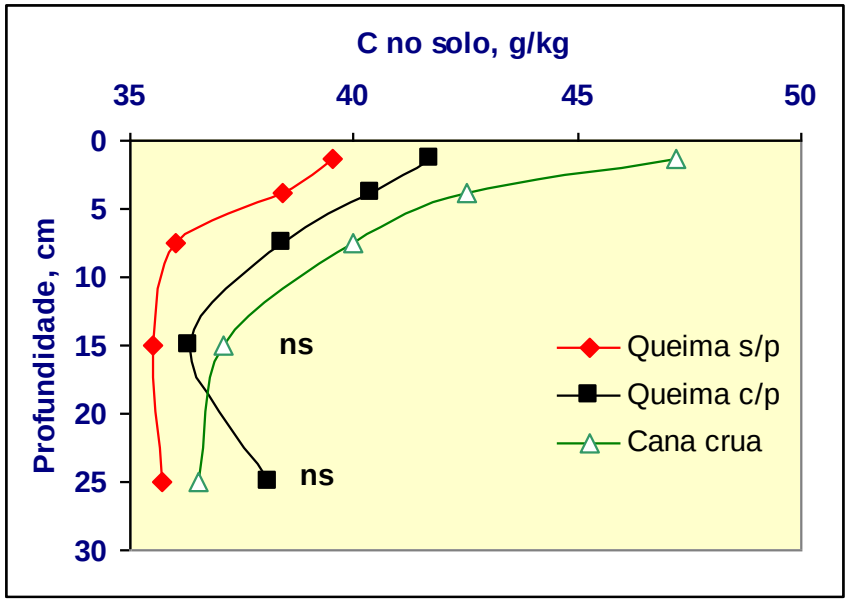
(Penatti, 2004)

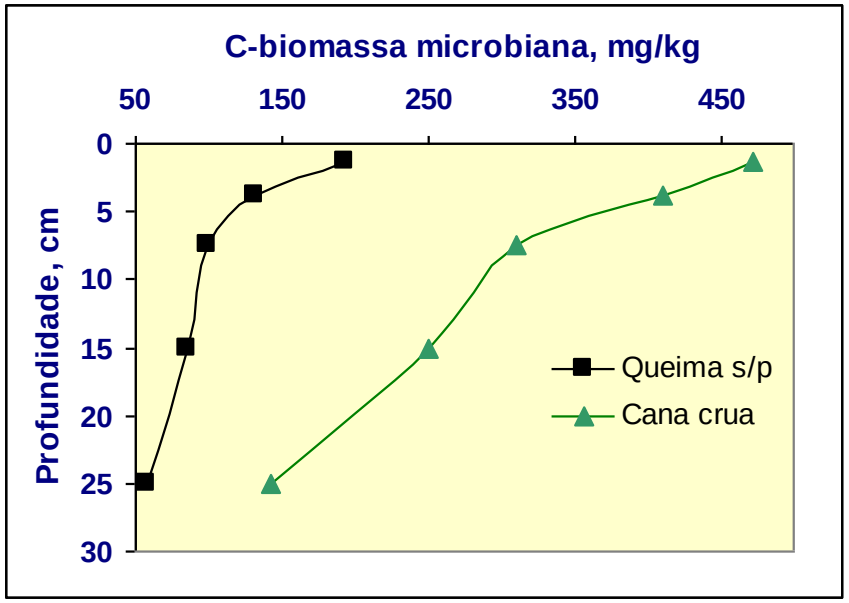
Green cane favors soil C accumulation (Green X Burned)

Soil layer (m)	Range of C accumulation t ha^{-1} yr^{-1}	Soil (Number of years)	Reference
0-0.05	2.0 to 3.1	Oxisol (4)	Luca (2002)
0-0.40	4.8 to 7.8	Oxisol (4)	Luca (2002)
0-0.20	0.32	Oxisol (12)	Feller (2001)
0-0.40	0.30	Ultisol (16)	Resende et al (2006)

Cerri et al. (2009);
Resende et al. (2006)

Data from South Africa: 59 years of green cane X burned cane





Soil: Vertissol ; Rain: 950 mm/yr

Graham et al., 1999

C: significantly higher only in the 0-0.1 m layer

Brazil: 8 years in clayey Oxisol
Soil C: +30%
Microbial biomass: + 250%
Particulate matter: + 380%

Galdos et al (2009)

Sugarcane & Soil C

- **Conclusion:**
  - **In general: good crop for soil conservation**
    - **Long cycle**
    - **Little soil mechanical disturbance**
      - **Even less with no-till**
    - **Presence of mulch in green cane**