Switchgrass in Europe and a comparison to Miscanthus

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Bioenergy at WAGENINGEN UR

Agenda

- What is switchgrass?
- How to grow switchgrass?
- Delayed harvest system
- Comparison to Miscanthus x giganteus

What is switchgrass?

- Perennial C_4 grass
- Tall grass
- Native to American prairie
- Seed propagated
- Deep roots (2m)
- Adapted to dry and wet conditions
- Low input
- 15 year cycle
- Yields 6 to 25 tonnes/ha

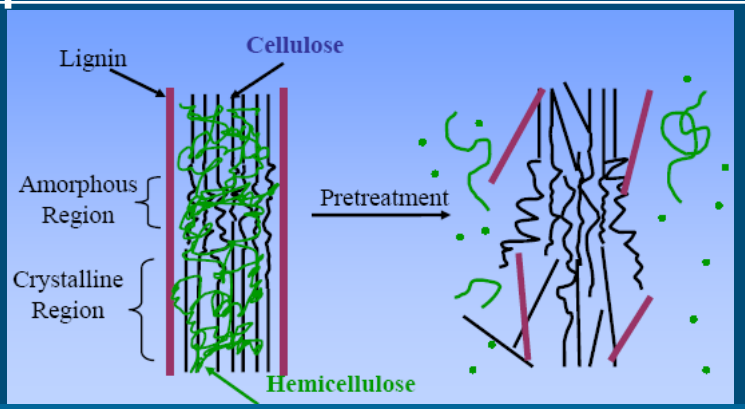
Applications:

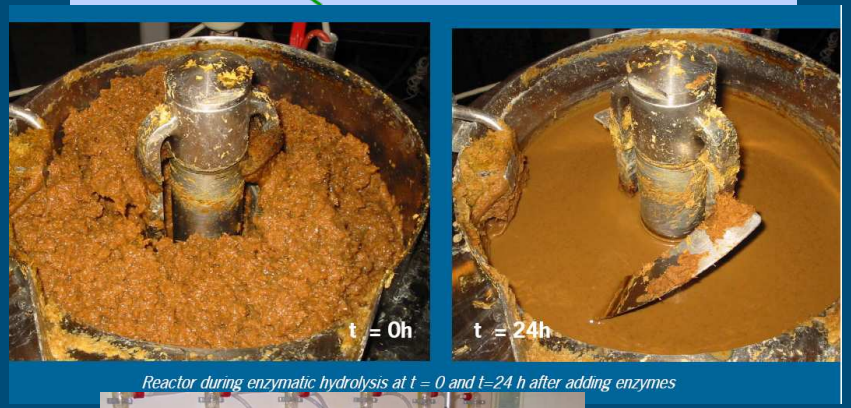
- Erosion control
- Fodder
- Power/heat
- Ethanol/butanol
- Fibre/pulp

Second generation biofuel production

Second generation biofuel production

- Thermochemical path (FT – BTL)
- Biochemical path
  - Pre-treatment
  - Enzymatic hydrolysis
  - Fermentation





Reactor during enzymatic hydrolysis at t = 0 and t=24 h after adding enzymes

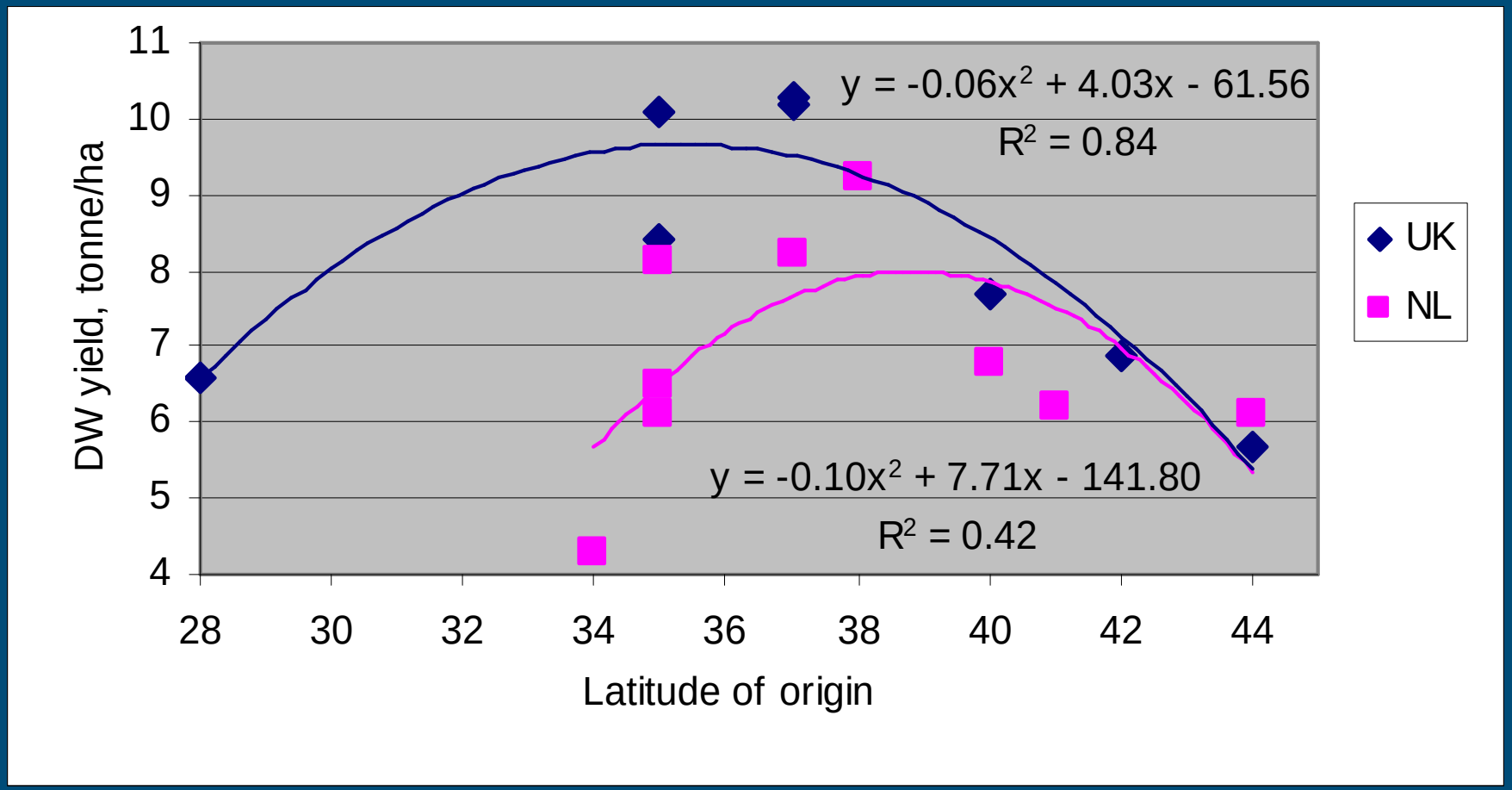
Critical elements in switchgrass field production

- Variety choice
- Establishment
- Fertilisation
- Harvest management

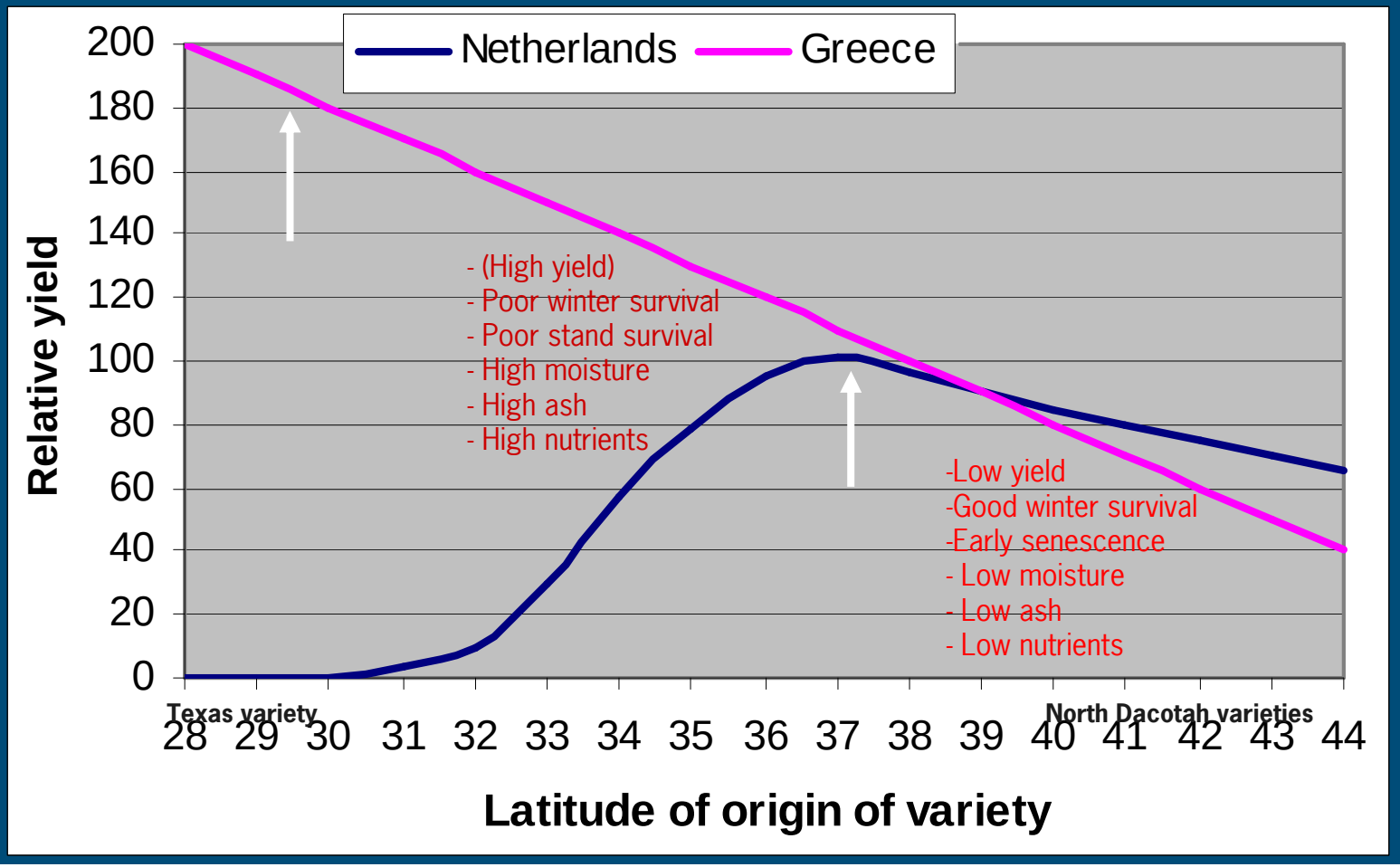
Variety choice

Variety	Ecotype	Ploidy level	Origin
Alamo	lowland	Tetraploid	South Texas 28°
Blackwell	upland	Octoploid	Northern Oklahoma 37°
Caddo	upland	Octoploid	South Great plains 35°
Carthage = NJ-50	?	?	North Carolina 35°
Cave-in-Rock	Intermediate?	Octoploid	Southern Illinois 38°
Dacotah	upland	Tetraploid?	North Dakota 46°
Forestburg	upland	Tetraploid?	South Dakota 44°
Kanlow	lowland	Tetraploid	Central Oklahoma 35°
Nebraska 28	upland	?	Northern Nebraska 42°
Pangburn	lowland	Tetraploid	Arkansas 34°
Pathfinder	upland	Octoploid	Nebraska / Kansas 40°
REAP 921	upland	Tetraploid	Southern Nebraska 41°
Shelter = NY4006	mixed?	Octoploid?	West Virginia 40°
Summer	upland	Tetraploid	South Nebraska 41°
Sunburst	upland	?	South Dakota 44°
Trailblazer	upland	Octoploid	Nebraska 40°

Variety choice depends on latitude



Variety choice depends on latitude

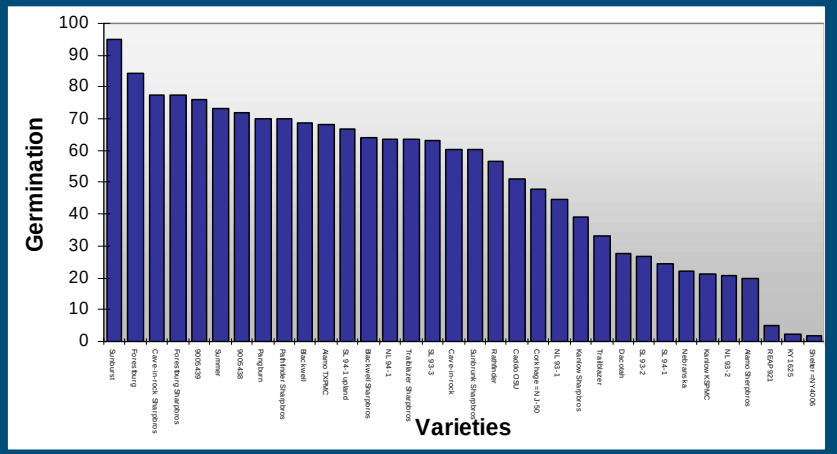


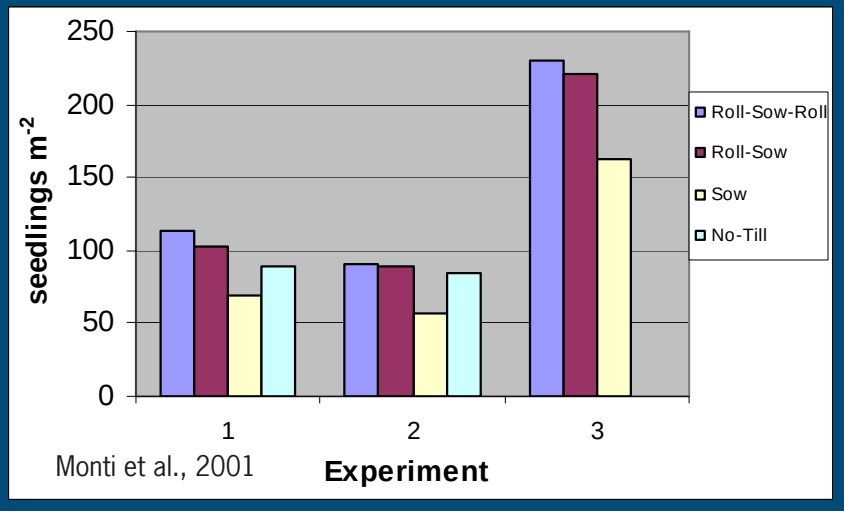
Variety Choice

- Switchgrass varieties grown too far north will have:
  - Later or no flowering and maturity
  - High yields in first year
  - Lower yield in later years
  - Decreased winter survival
  - High moisture content at harvest
  - Higher nutrient contents at harvest
  - Decreased stand survival in long term?
- Switchgrass varieties grown too far south will have:
  - Early flowering and maturity
  - Lower yields
  - Good winter survival
  - Low moisture content at harvest
  - Good stand maintenance

Establishment: Follow the rules and it will work!

- Establishment takes > 1 year
- Site selection
  - Best is deep soil, good water holding capacity and drainage, but
  - Shallow, stony, accasionally waterlogged, Low fertilile, low pH will do
- Site preparation – Roll!!!!
- Germination test !!!
- Time of planting = Maize
  - Too early –> weeds
  - Too late –> moisture problems
- Mowing + herbicide against weeds





Monti et al., 2001

Delayed harvest system:

Harvest in winter /spring

Delayed harvest system advantages

- If you let the plant mature it will re-grow better in spring
- Translocation of nutrients to below ground
- Low nutrient off take
- Good re-growth in spring
- Good stand management
- Dry biomass
- Lower transport cost
- No drying
- Easy storability
- Low ash
- Low free sugars
- High fibre/ lignocellulose content

	Yield on 1 November 1994 (ton/ha)		
Harvest date	Location 1	Location 2	Location 3
1 September 1993	7.6	8.4	8.0
1 October 1993	7.4	8.4	7.9
1 November 1993	8.8	9.4	9.1

Harvest time	N	P	K
Fall	0,46	0,12	0,95
Winter/Spring	0,33	0,04	0,06

Christian et al., 1999)

Delayed harvest system disadvantages

- Yield losses due to winter losses (20 to 40%?)
  - breeding should help to reduce losses
- Low biomass digestibility
- Not good for biogas

	Yield (ton/ha)	
Harvest date	93/94	94/95
1 September	13.6	
1 November	11.1	8.6
13 January	10.2	8.3
1 April	10.0	7.8

Christian et al., 1999)

Attribute↓	Miscanthus	Switchgrass
Latin Name	Miscanthusxgiganteus	Panicum virgatum L.
Native Range	South East Asia, Japan	North America
Yields tons DM per year	12 to 35 tons DM	10 to 30 tons DM
Photosynthesis system	C4	C4
Height	Up to 4 m	Up to 2,5 m
Rotation time	15 years	15 years
Propagation method	Rhizomes	Seed
Adaptation	Moderate winters, sufficient/low moisture	Moderate winters, sufficient/low moisture
Adaptation range in Europe	Cool and warm region of Europe	Cool and warm region of Europe
Harvest time	Fall to early spring	Fall to early spring
Energy output/input	20 to 30	20 to 30
Fertiliser input	In northern EU 0 to 50 kg N. In south 50 to 100 kg N	In northern EU 0 to 50 kg N. In south 50 to 100 kg N
Water use	Rel. Low	Rel. Low
Erosion control	Rel. Good	Very good

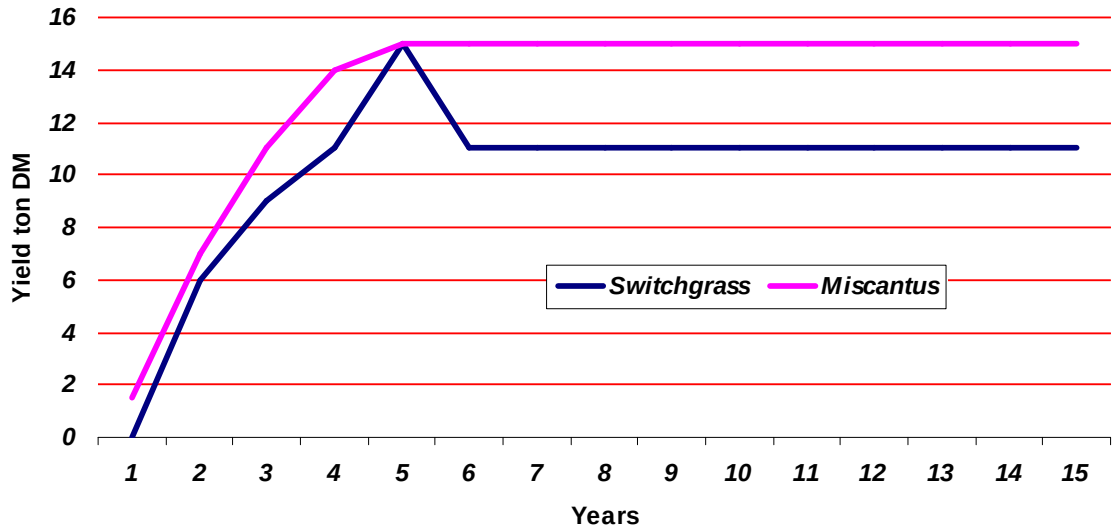
Estimated dry (spring!) yields in Europe

Crop	Environmental zone	Highest experimental yields = 100%	Low yielding soils = 45%	Average soils = 55%	Good soils = 70%
Switchgrass	Atlantic Central	14.8	6.7	8.1	10.4
	Atlantic North	11.3	5.1	6.2	7.9
	Mediterranean North	23.0	10.4	12.7	16.1
Miscanthus gigantheus	Atlantic Central	17.2	7.7	9.5	12.0
	Atlantic North	16.0	7.2	8.8	11.2
	Continental	22.8	10.3	12.5	16.0
	Mediterranean North	30.0	13.5	16.5	21.0

Expect a steep learning curve (2% = 37% yield increase 2004- 2020)

Yields?

- Switchgrass yields are lower than for Miscanthus
- Cost of establishment is lower fro switchgrass
- Establishment risk is higher for Miscanthus!
- Does higher yield of Miscanthus compensate for higher cost of establishment??
- If no, what about land use efficiency? Which may be higher for Miscanthus



	Miscanthus	switchgrass
	Euro/ha/year	
annuity returns	6517	5101
annuity cost	8540	5054
annuity total	-2023	46
per year	-135	3

Van der Hilst et al in preparation

Comparison *Miscanthus* and switchgrass

Attribute	*Miscanthus gigantheus*	Switchgrass
Establishment cost	4346 €	440€
Establishment risk	Higher	Lower
Yield	Higher	Lower
Break even	50 years	6 years
Quality	Lower ash melting point?	Higher ash melting point?
Fertilization response	Low	Low

Van der Hilst et al in preparation

Christian et al., (1999)

When to use Miscanthus? When to use switchgrass?

Do higher Miscanthus yields compensate for higher investment costs?

Under good conditions use Miscanthus, else use switchgrass

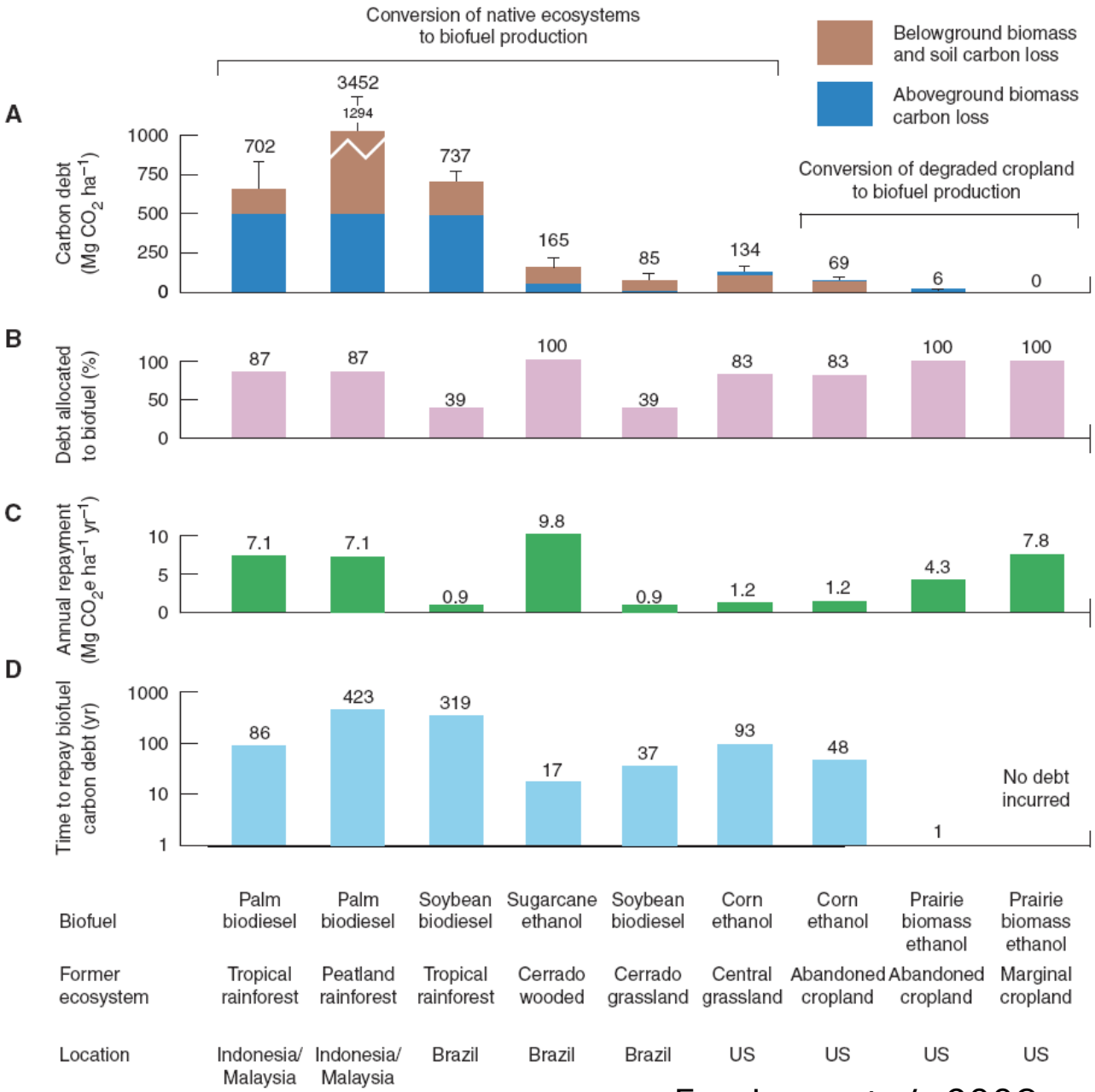
Carbon Debt

- A = 'carbon debt' by LUC
- B = biofuel share (compared to co-products)
- C = annual CO_2 repayment
- D = time to repay carbon debt

$$D = \frac{A \times B/100}{C}$$

If land is scarce competition for land creates a CO2 debt

Use underutilized land



Fargione *et al.*, 2008

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