Energy Crops and Carbon Reduction

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Rothamsted Research

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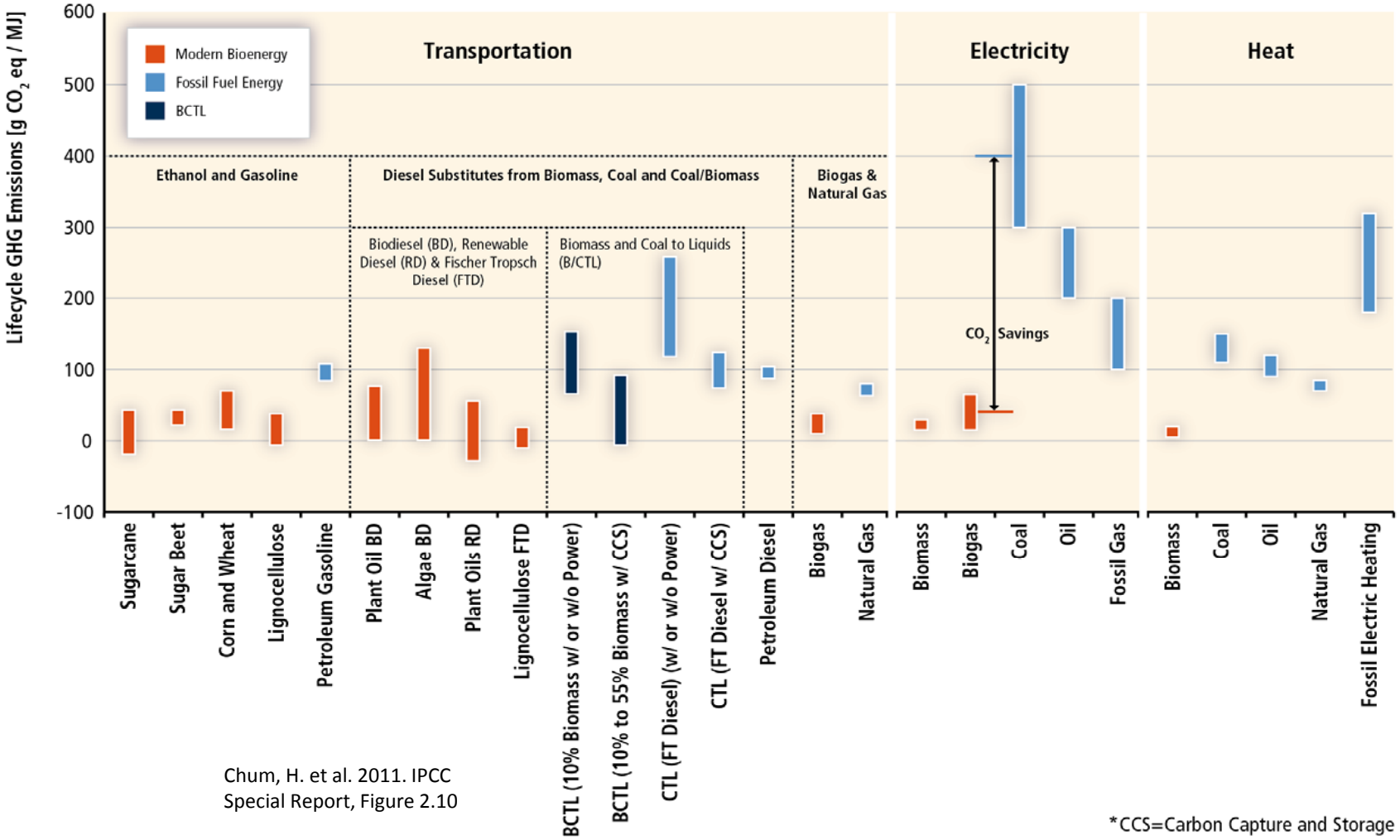
Uncertainties - Ranges of GHG Emissions per Unit Energy Output (MJ)



Chum, H. et al. 2011. IPCC Special Report, Figure 2.10

*CCS=Carbon Capture and Storage

As the UK & much of Europe moves away from coal the life cycle GHG benefits of biomass compared to fossil fuel alternatives diminishes.

We must be careful not to lose sight of those benefits and to maximise them.

Energy Crops are very low input. Planting is a major operation, but only once in every 20 years. The two factors of greatest importance to the GHG benefits are;

- Harvesting and post harvest management
- Soil carbon effects

The two most widely grown energy crops in the UK are short rotation willow and miscanthus, work at Rothamsted Research has focussed on these two crops, but has looked at alternative options such as poplar, switchgrass and reed canary grass.

Selected SRC Willow harvesting machines

Bio-baler

Forage harvester, Large, Medium or Small

Sugar cane harvester

Whole rod harvester

<u>Our target is to produce wood chips</u>, the most simple processed form of wide use in industry, by the most efficient method..

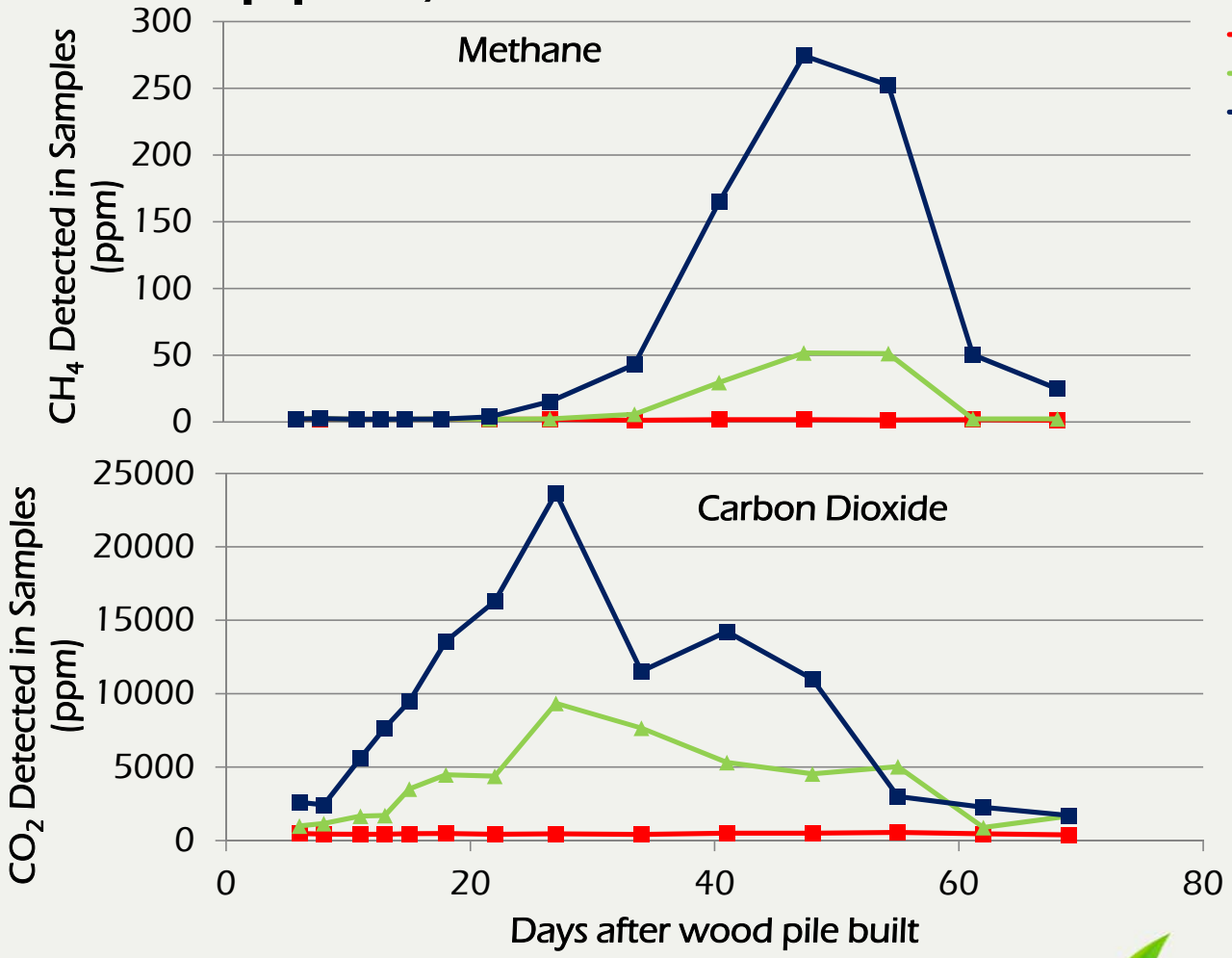
Some buyers take fresh wet wood (50% moisture, ~8 MJ kg^{-1}), others require <30% moisture.
<u>Some storage is necessary, some drying is necessary</u>

Chip wet (forage harvester) or chip dry (rod harvester) ?

Measure losses during storage / drying and energy required to create chip

Losses of 20% of initial DM from 4 full scale wood chip piles, some of it as methane.

Don't compact the heap !



Water vapour, but what else ? CO_2, CH_4 ?

Force dry wood chips ?

Has required emptying and refilling shed to mix chip

Continuous flow dryer is an option where available, but must be able to cope with chip sizes.

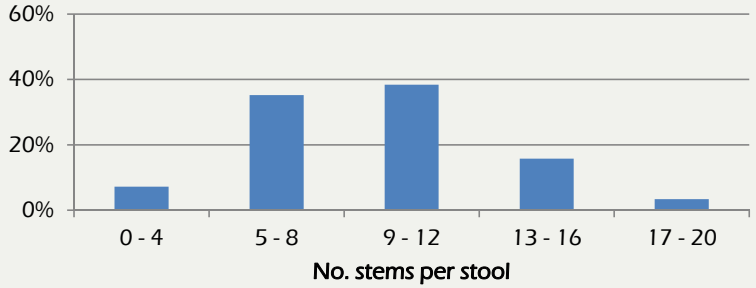
Drying in winter, low ambient temperatures, high humidity, more energy required per kg water removed than grain drying in late summer

Energy required to chip wet and part dried willow rods of different diameters.

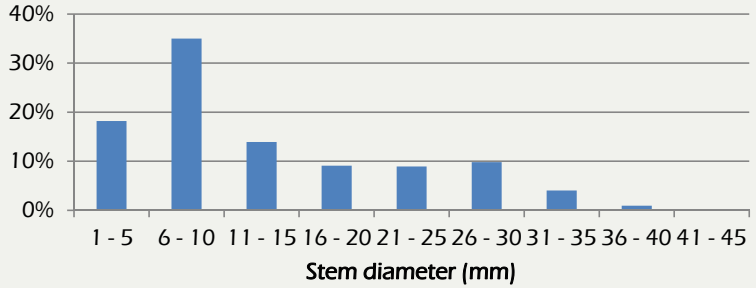
Stem diameter (mm)	Moisture content (%)	Energy to chip (kWh / fresh tonne)	200 tonnes harvested, energy to chip, kWh
10 – 30	45.2	1.48	134
20 – 40	44.8	2.21	198
10 – 30	23.7	4.43	164
20 – 40	26.5	4.19	181

CRL Medium scale header

Frequency distribution of stem number per stool. Rothamsted, winter 2012-13



Frequency distribution of stem diameters. Rothamsted, winter 2012-13



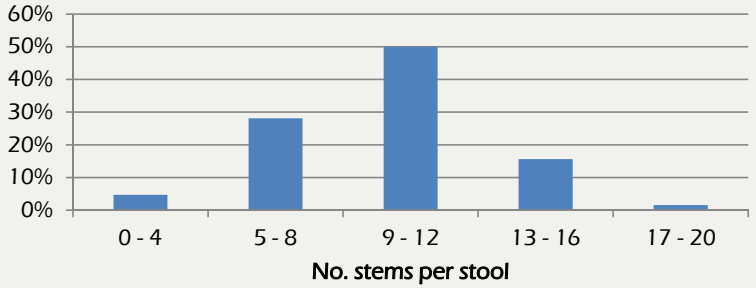
47.1 t ha^{-1} @ ~50% moisture

Cheaper to own and run, but slower 4.5 km h^{-1}

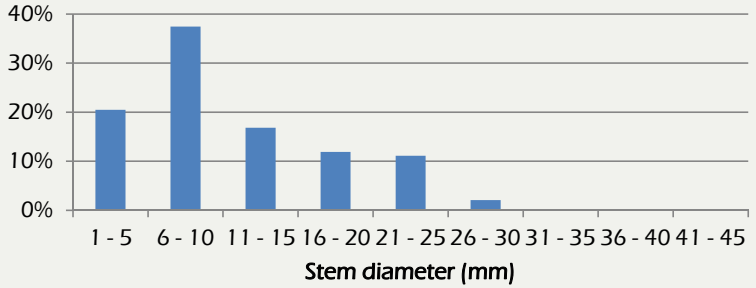
Owner operator

CRL Large scale header

Frequency distribution of stem number per stool. Rothamsted, winter 2013-14



Frequency distribution of stem diameters. Rothamsted, winter 2013-14



54.8 t ha^{-1} @ 52.3% moisture

More expensive, but quicker, 5.6 km h^{-1}

Contractor

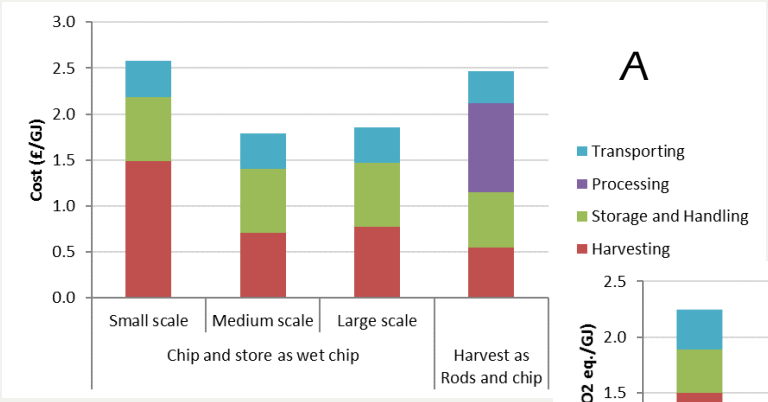
Moisture and dry matter losses during storage of src willow chips and whole stems (rods).

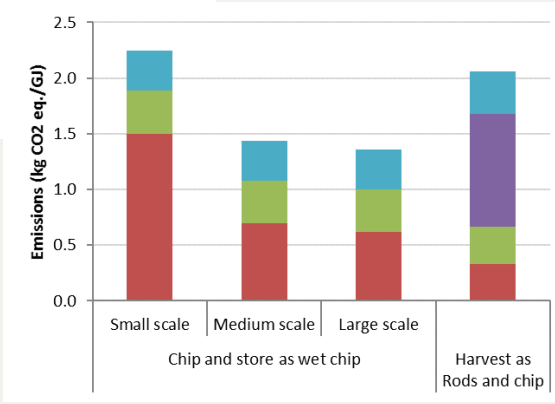
	Storage period (days)		Moisture content (%) when cut		Moisture content after storage, %		Dry matter loss in storage, %		Loss in handling, % DM	
	Chip	Rod	Chip	Rod	Chip	Rod	Chip	Rod	Chip	Rod
2014	97	156	50.0	53.2	42.8	21.8	18.6	1.9	2.9	5.4
2015	208	192	56.4	53.1	44.4	23.8	21.4	6.6	1.6	-

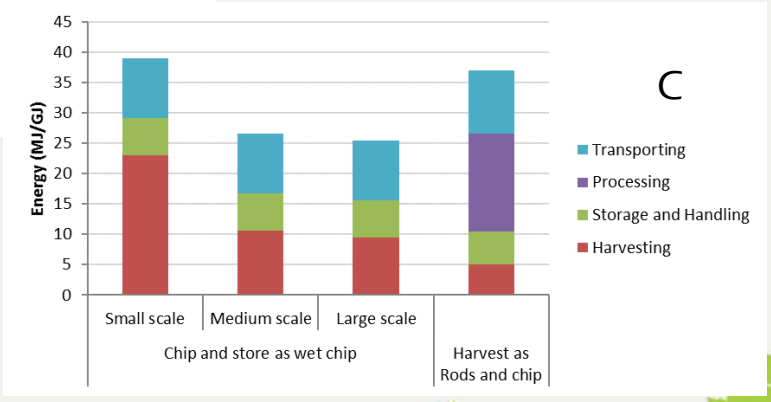
Particle size distribution (% by mass) of src willow chipped fresh by a forager and then stored for 208 days and chipped fresh and part dried (after storage as rods) by a wood chipper.

	Chipped fresh by forage harvester		Rods chipped fresh by wood chipper	Rods chipped part dried (23.8% moisture)
Particle size	Pre-storage	Post storage	Pre-storage	Post storage
16-45mm	15.5	6.7	6.6	6.0
3.15-16mm	78.4	89.2	87.5	82.8
<3.15mm	5.7	4.1	5.4	10.9

THE FINANCIAL (A), GREENHOUSE GAS (B) AND ENERGY (C) COST OF THE ALTERNATIVE METHODS OF HARVESTING SRC WILLOW.







Selected Miscanthus harvesting machines

Forage harvester, high density rectangular baler

Mulching mower high density rectangular baler. 1 or 2 pass

Disc mower, round baler

Forage harvester, loose chip

Our target is to produce high density bales with a moisture content <22% by the most efficient method. The most simple processed form of wide use in industry.

However, Bourgogne Pellets introduced us to the concept of miscanthus chip and the conditions under which it may be viable.

Miscanthus must be cut into short lengths (50 cm) before baling.

or you spend a lot of time unblocking the pick up reel

NOBILI WS 320 BIO

£29k mulcher or £250k forage harvester ?

Can spread for drying or swath for immediate baling

"Y" shaped blades for greater chopping, straight blades for less aggressive chopping

LOGISTEC
Logistics for Energy Crops Biomass

Now sold
as Kuhn

Still need to fully evaluate the one pass system.
Looks promising for southern and central Europe where the standing crop in spring is dry.

Blowing chopped miscanthus straight into the bale chamber ?

How short should the chop length be ?

Increased bale density (marginal ?) vs bale integrity (begins to fall apart when handled)

8m³ per tonne, 8 tonnes on 65 m³ lorry, but quick to load and unload.

5.5m³ per tonne, 72 bales, 26 tonnes on standard lorry, slightly slower to load and unload.

SINTEF, INRA, CENER and Bourgogne Pellets

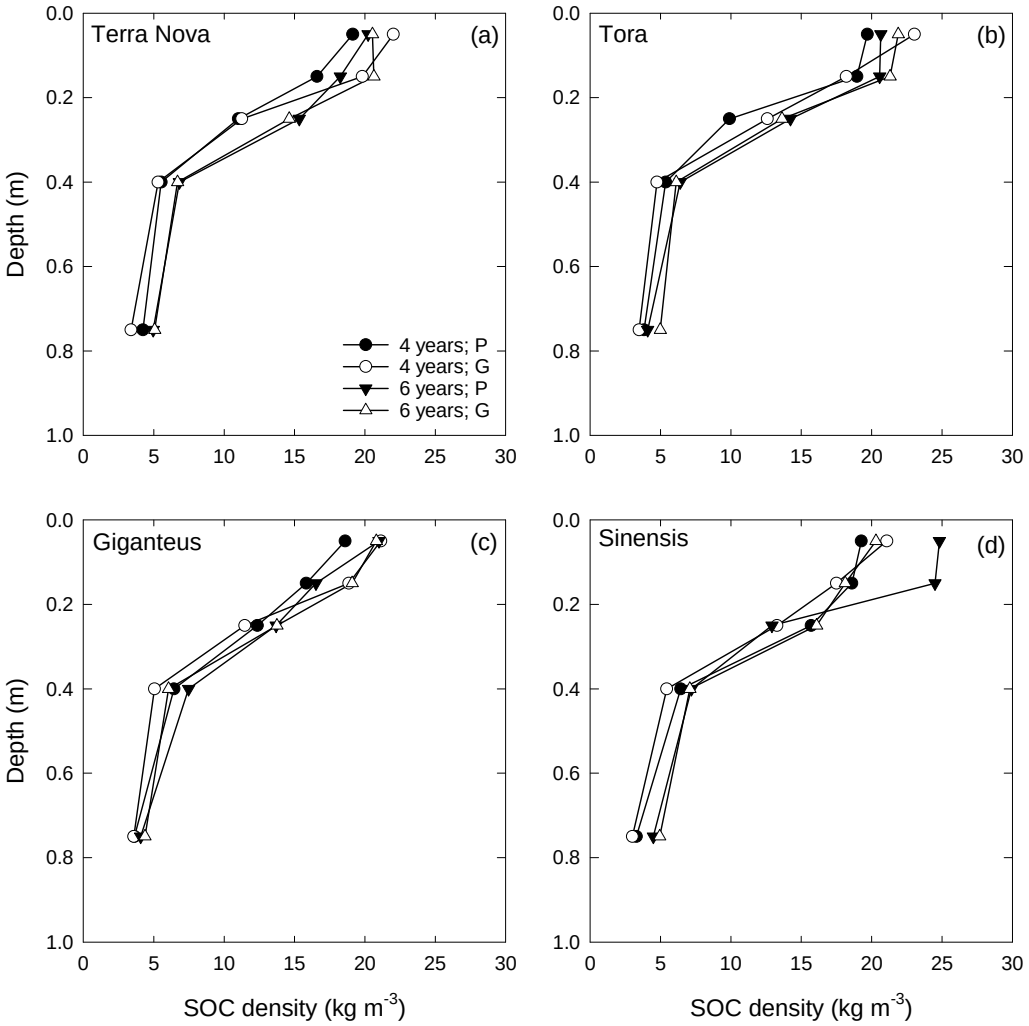
LogistEC

Rothamsted energy crops, silty clay loam

Period (years)	Genotype	SOC stock change (Mg ha^{-1} year^{-1}) total			*Miscanthus*-derived		
		0-0.3 m	0.3-1.0 m	0-1.0 m	0-0.3 m	0.3-1.0 m	0-1.0 m
0-4	Terra Nova	1.44	–3.50	–2.06	–	–	–
	Tora	1.72	–3.99	–2.27	–	–	–
	Giganteus	1.12	–3.33	–2.21	1.08	0.22	1.31
	Sinensis	1.50	–4.26	–2.76	0.76	0.09	0.85
4-6	Terra Nova	1.98	4.46	6.44	–	–	–
	Tora	2.27	5.15	7.42	–	–	–
	Giganteus	0.31	2.78	3.09	1.52	1.58	3.10
	Sinensis	3.02	5.82	8.84	3.30	2.11	5.40

Terra Nova and Tora are willow cultivars,
Giganteues and Sinensis are representative genotypes of *Miscanthus* species.

Gregory et al. in review



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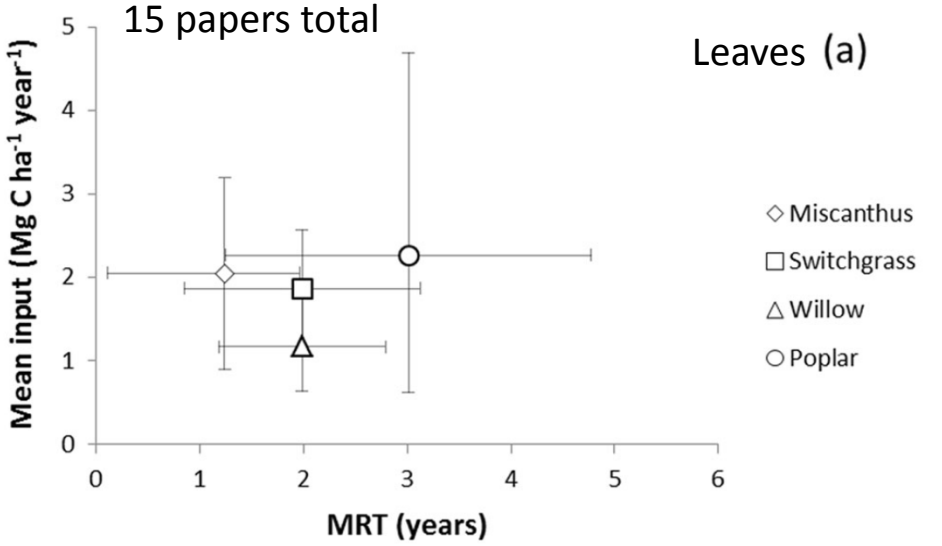
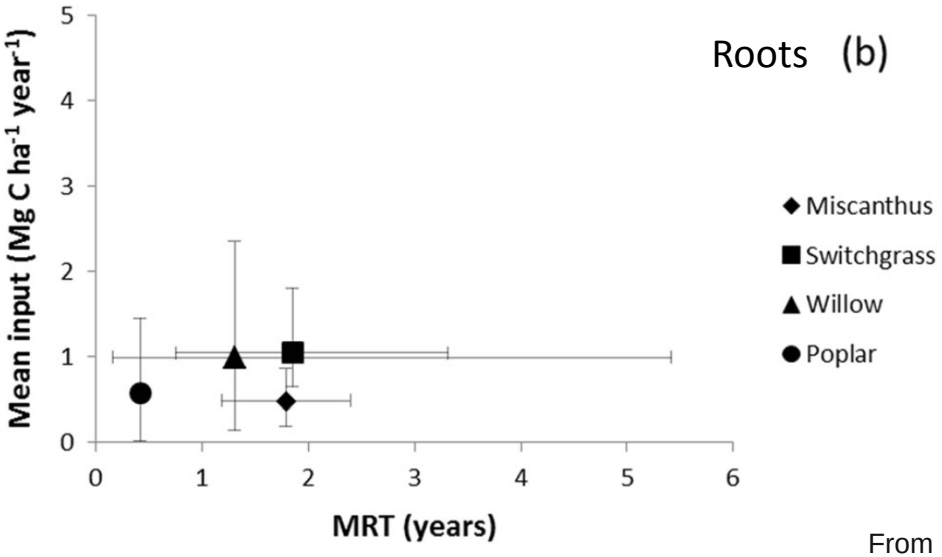
MRT = Mean Residence Time
15 papers total





Few time series, many more single time point measurements.

Fine roots and root exudates difficult to quantify.

Variable results reported for factors such as priming effects of soil C additions. Method variation plus natural variation.

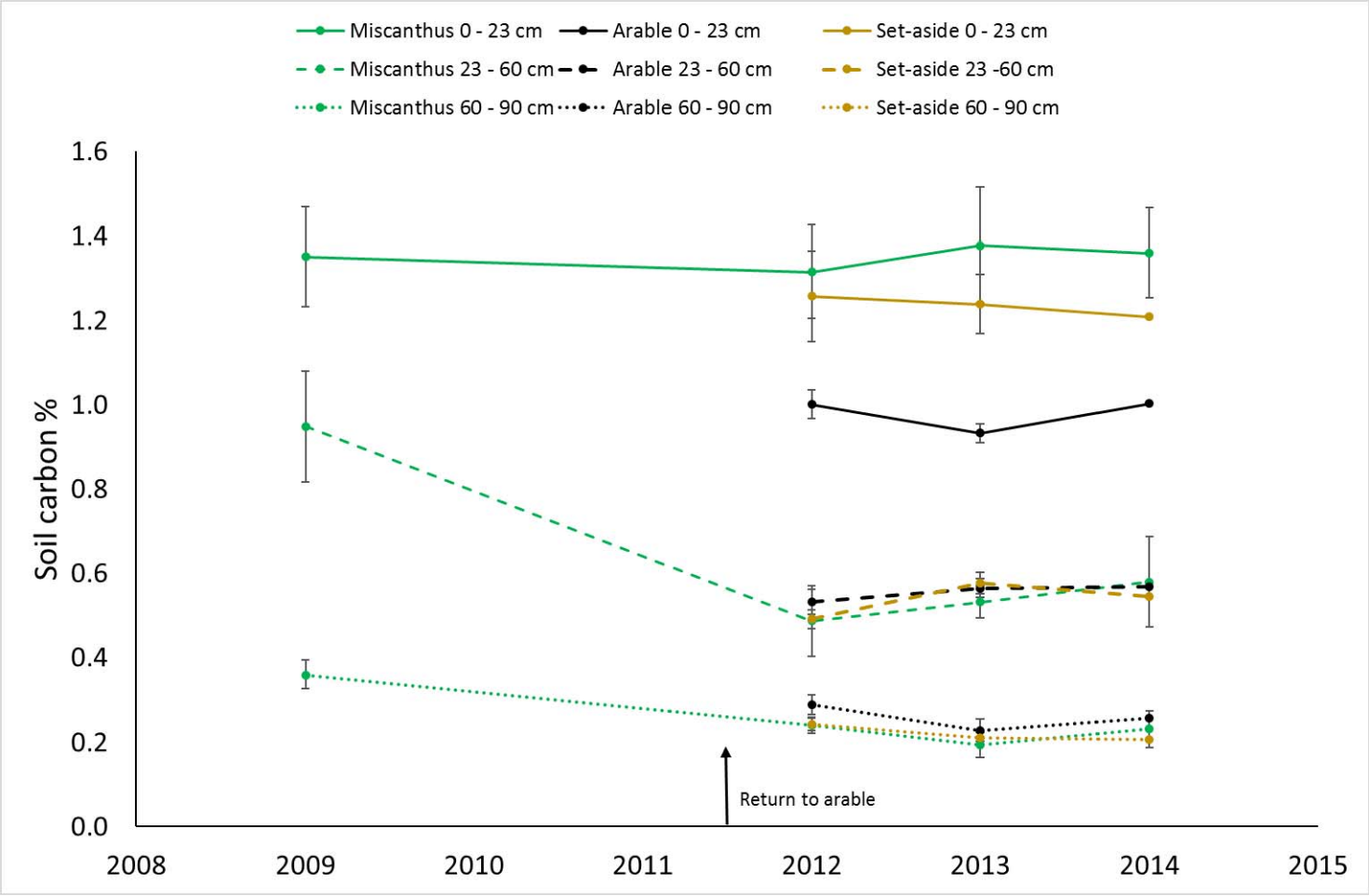
Do litter bags represent the real situation ? Carbon isotope ratio from C4 crop very valuable.

Different soil types have different ultimate C capacity. Much published work is NOT on the target soil types for these crops.

Differential effects of temperature etc. on decomposition rates of different plant parts. What C compounds are present ? C:N ratio ?

From a review by Agostini et al. *Bioenerg. Res.* (2015) **8**:1057–1080 DOI 10.1007/s12155-014-9571-0

Soil carbon changes following reversion to arable after 10 years of miscanthus, sandy loam soil, Woburn



Thank You, Any Questions ?