The New Zealand Institute for Plant & Food Research Limited

Plant & Food RESEARCH
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Closed-loop nitrogen cropping for biogas energy

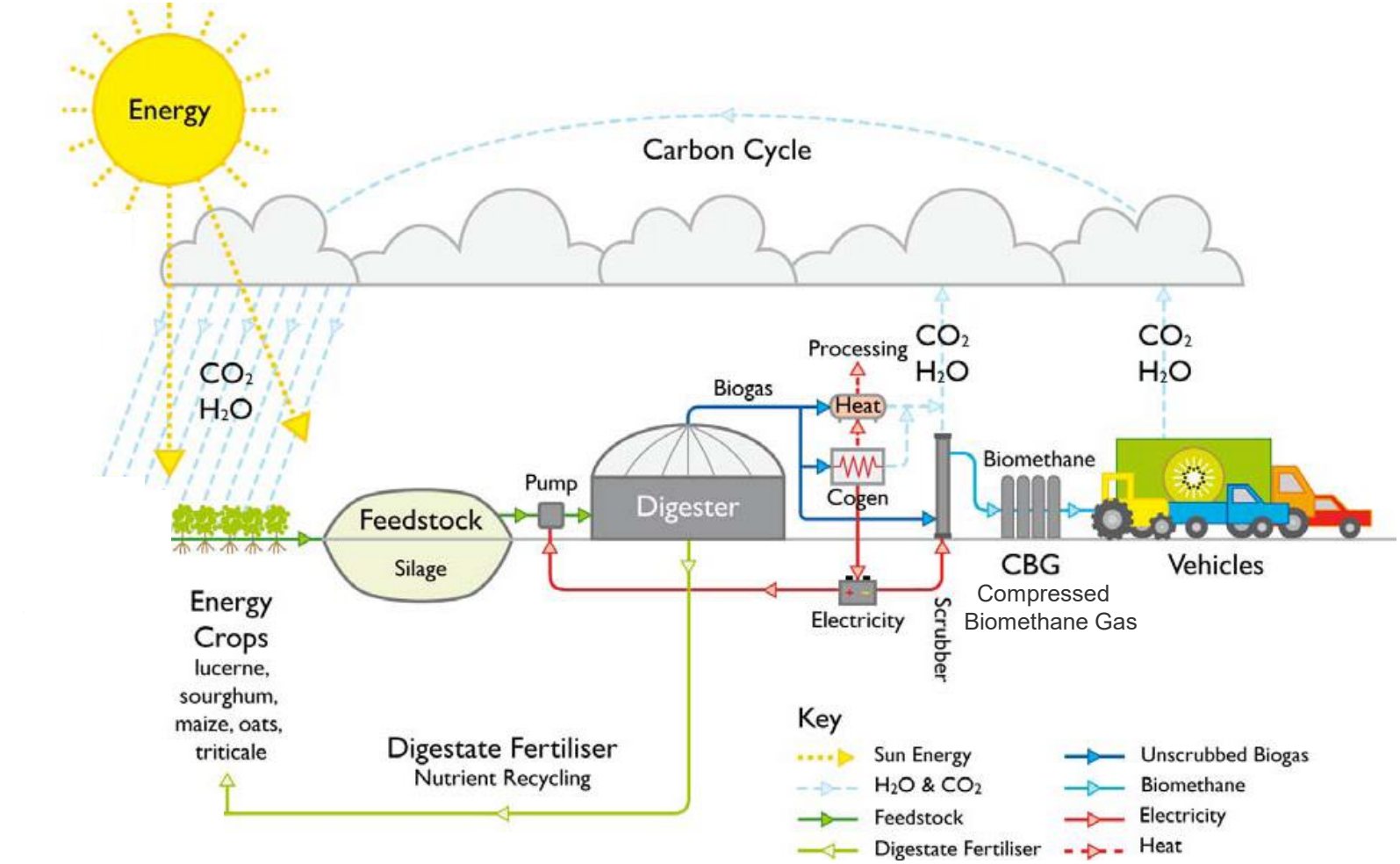
Huub Kerckhoffs & Stephen Trolove

Closed-loop nitrogen cropping system

Grow biomass for fuel without external N fertiliser input (closed-loop N concept, CLN):

- conversion of biomass into biogas using anaerobic digestion.
- target one category of marginal land: sites where crops are susceptible to moderate drought stress.
- crops with high nitrogen-use efficiency, plus use of legumes.
- return biogas digestate to the field to grow energy crops (plus a surplus to use for food/feed crops).

Biogas System Overview



(redrawn from Loren Pole, Bioform Ltd)

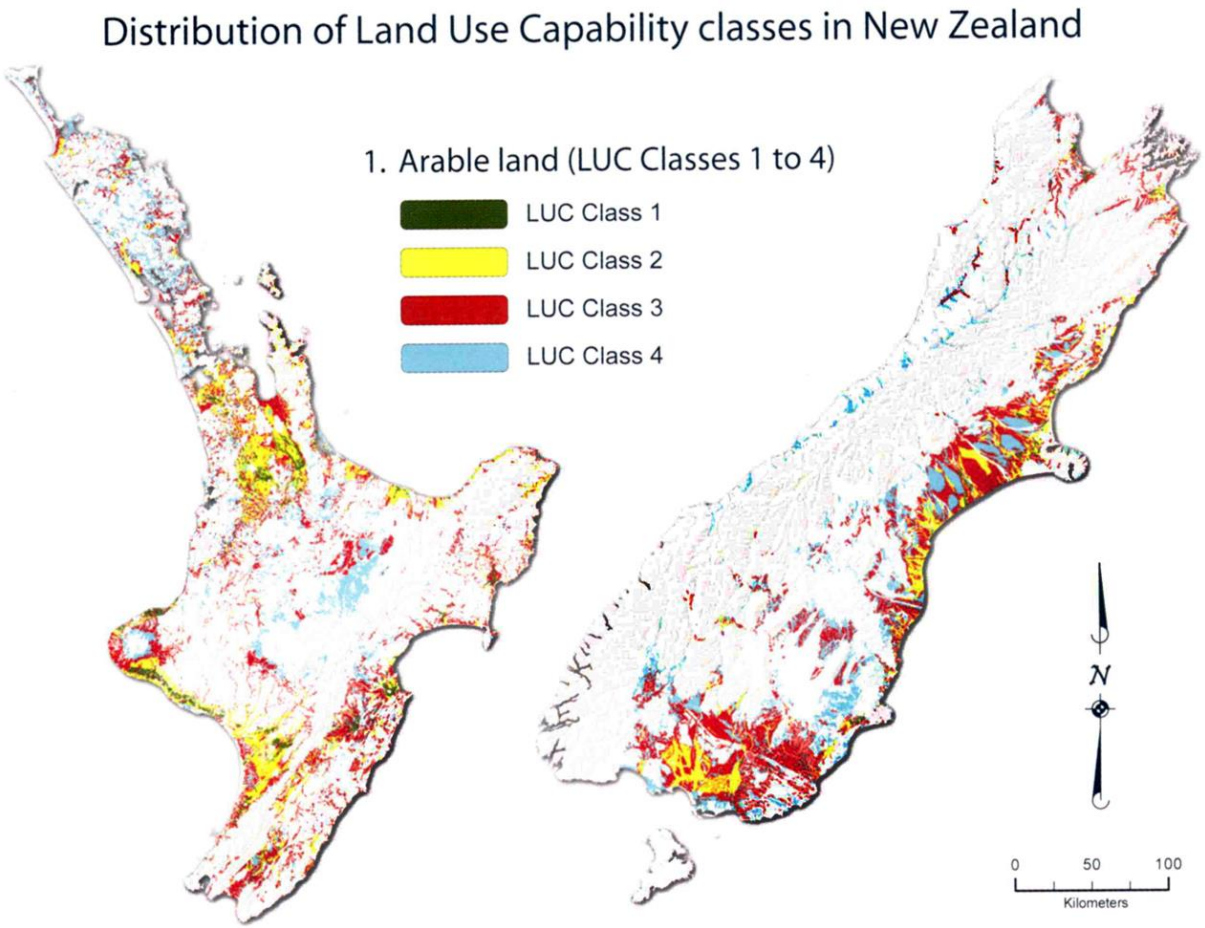
Biogas System Overview


SCANIA


LONG
VEHICLE


fiorino
QUBO

Defining marginal land



Mapped LUC classes 3 & 4 in red and blue

Arable land affected by moisture stress

Sites vulnerable to moderate water stress are defined as those with annual soil moisture deficit > 50mm

Our focus is on land with inconsistent rainfall for high DM yield and to identify adapted crops able to grow there for a dual market: biofuel and/or forage

Closed Loop Nitrogen Supply Cropping

Jerusalem artichoke

(Forage) sunflower

Millet

Forage sorghum

Maize

Luzerne (alfalfa)

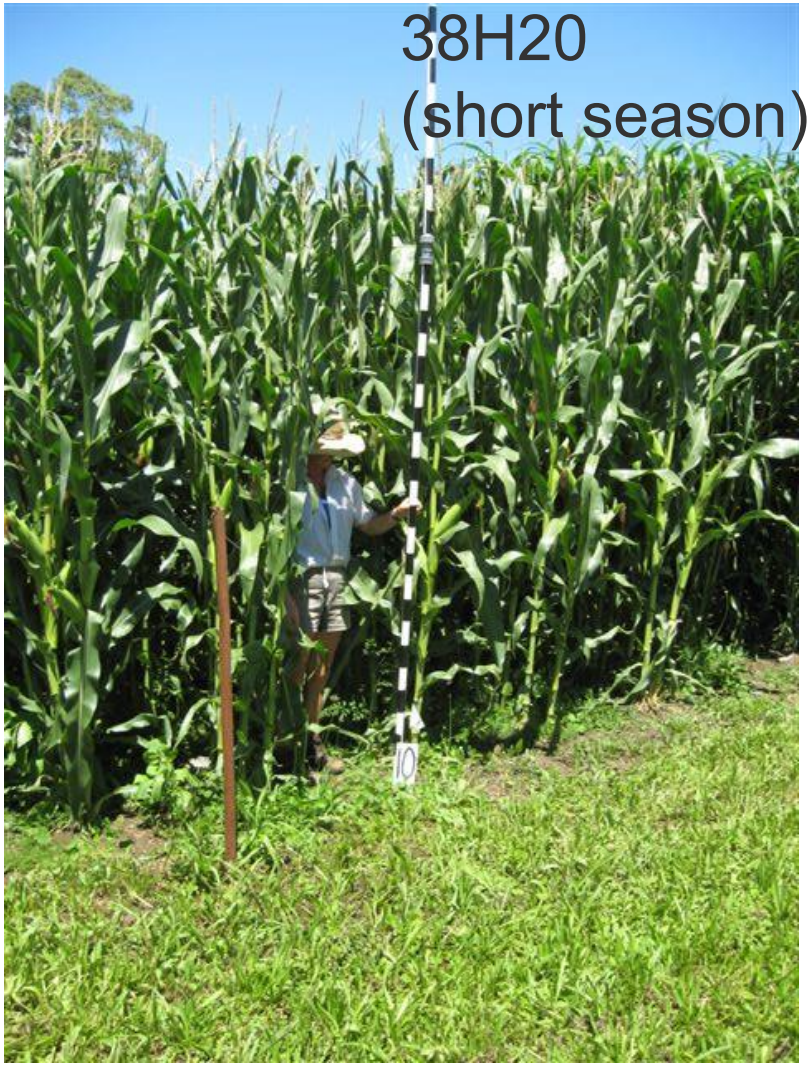
Selection criteria for biomass crops

- Ability to produce moderate to high DM in marginal conditions and with minimal tillage (perennials).
- Very high DM yield in years when rainfall is adequate. Can be annual crops with a high N requirement (annuals/perennials).
- General traits:
  - high biogas yield per kg DM;
  - minimal pest control requirements;
  - easy to establish and harvest;
  - able to be stored or ensiled; and
  - don’t make viable seed but lots of vegetative DM (biomass).

Crops screened for CLN system

Common name	Species
Annual:	
Maize	*Zea mays*
Sorghum	*Sorghum bicolor*
Pearl millet	*Pennisetum glaucum*
Forage sunflower	*Helianthus annuus*
Perennial:	
Jerusalem artichoke	*Helianthus tuberosum*
Lucerne	*Medicago sativa*

Yr 1 screening: Maize



Yr 1 sreening: Sorghum

Yr 1 screening: Jerusalem artichoke

Yr 1 screening: Nutrifeed (millet)

Yr 1 screening: Nutrifeed (millet)

Yr 1 screening: Jerusalem artichoke (JA)

2nd year trials: Digestate application

2nd year trials: JA and sorghum

2nd year trials: JA and sorghum

Yr 2: Sorghum

Yr 2 Jerusalem artichoke

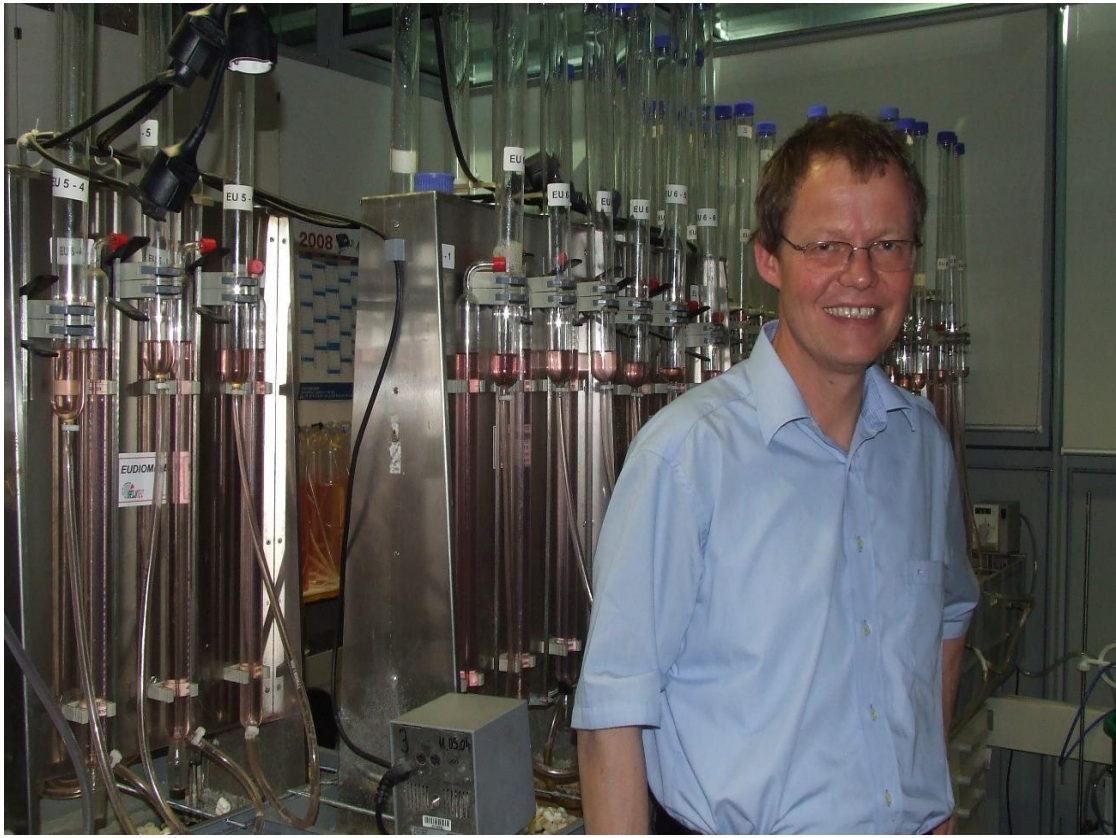
Kerikeri
(low latitude, longer frost-free season)

Flaxmere (Hawke's Bay) (shallow soil, early drought; no irrigation)

Crop yields

		Year 1		Year 2	
		Kerikeri	Flaxmere	Hastings	
Crop	Cultivar	Yield (t DM ha^{-1})	Yield (t DM ha^{-1})	Yield (t DM ha^{-1})	
Maize	33M54	33.7	13.2		
Maize	38H20	26.0	12.0		
Sorghum	Bettagraze	19.5	11.0		
Sunflower	Hysun 38	10.4	8.1		
Sorghum	Jumbo	30.3	20.6	27.0	
Pearl millet	Nutrifeed	31.2	13.3		
Sorghum	Speedfeed	21.8	12.2		
Sorghum	Sugargraze	28.1	17.7	22.1	
Jerusalem artichoke	Inulinz	15.3	-	16.3	excl. tubers
Crimson clover	King Seeds			9.6	
White clover				5.3	

Biogas yield assessment



Methane yield

Methane yield parameters for the biomass feedstock crops.

Crop	Site	Total yield (m^3 CH_4 ha^{-1})
Maize	Kerikeri	8928
Maize	Flaxmere	3651
Sorghum	Kerikeri	6946
Sorghum	Flaxmere	4377
Sunflower	Flaxmere	1815
Jerusalem Artichoke	Hastings	3672

Is there a net energy gain?

'Crops to transport fuel' production from maize / sorghum

gross methane yield: 8000 m^3 biogas per hectare
(equivalent to approx 8000 litres of diesel)
gross energy yield: 300 GJ per hectare (NZ Energy Data File, 2011)

subtracting 30% for combined energy input (Stewart, 1983)
to grow the crops (~5%)
to produce compressed biogas (~25%)

net energy yield: 210 GJ per hectare
(equivalent to approx 5600 litres of diesel)

positive net energy gain:
energy invested (input) / energy output ratio exceeding 3

Summary

The CLN supply concept is very much an integrated system:

- crops with moderately high DM yield on marginal land: the screening trials confirmed good options for NZ
- a biomass crop ‘rotation’ that is integrated by means of a shared biogas digester rather than as a crop sequence in a single planting site
- crops that need no on-going N fertiliser: the use of *lucerne* and *crimson clover* is well suited to supplement the N recycled from digester to field

Summary

- Two rotation types:

  (1) annual sorghum (Jumbo/Sugargraze) + crimson clover / tickbeans

  (2) perennials in long rotation or merely adjacent: Jerusalem artichoke + lucerne

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