Le filiere delle colture da biomassa a scopo energetico: panoramica delle principali colture

Giorgio Ragaglini

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

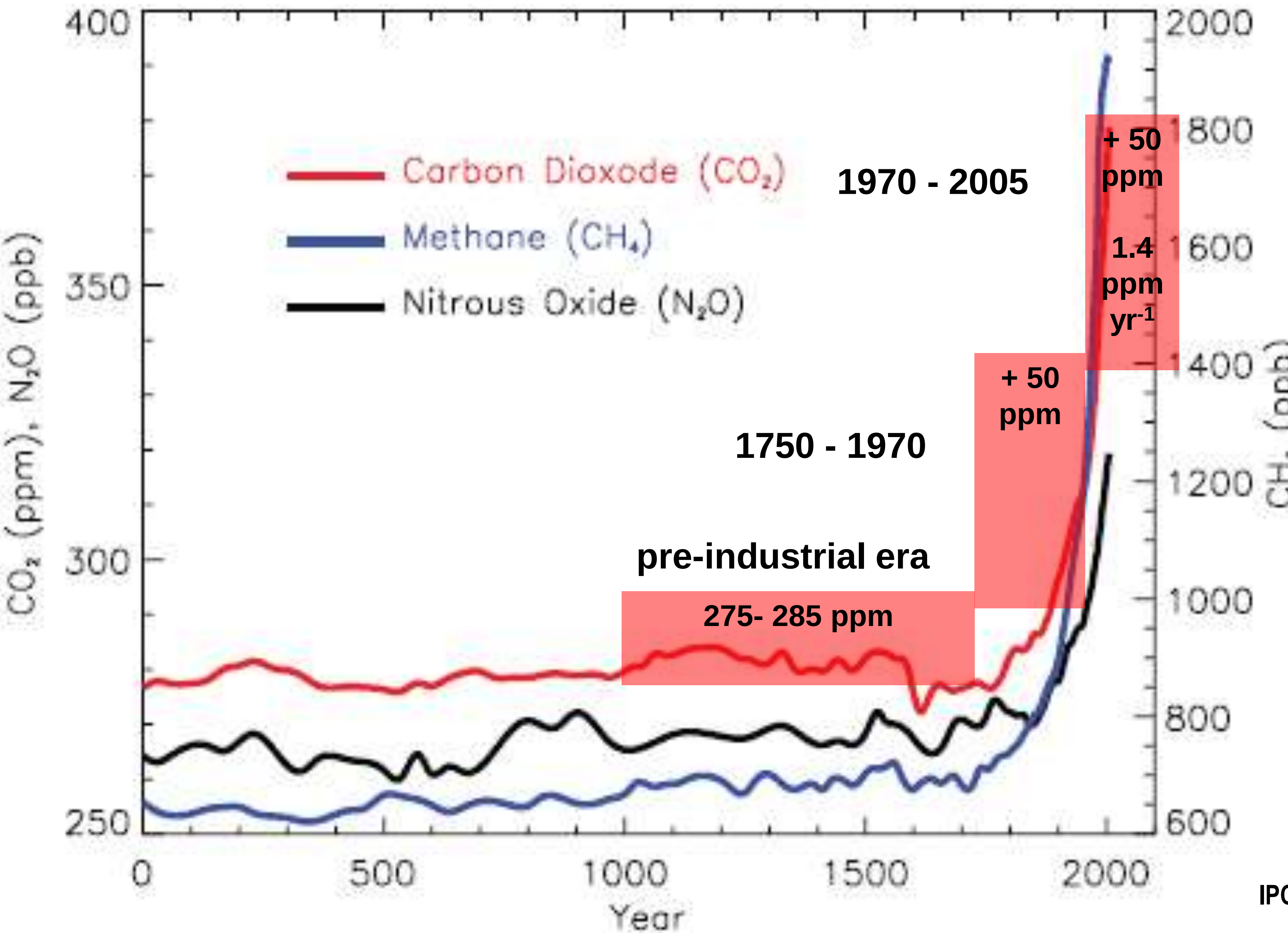
PANACEA
Non Food Crops for a EU Bioeconomy

C.A.I.C.T.
CENTRO ASSISTENZA IMPRESE COLDIRETTI TOSCANA
formazione & sviluppo

Sant'Anna
Scuola Universitaria Superiore Pisa

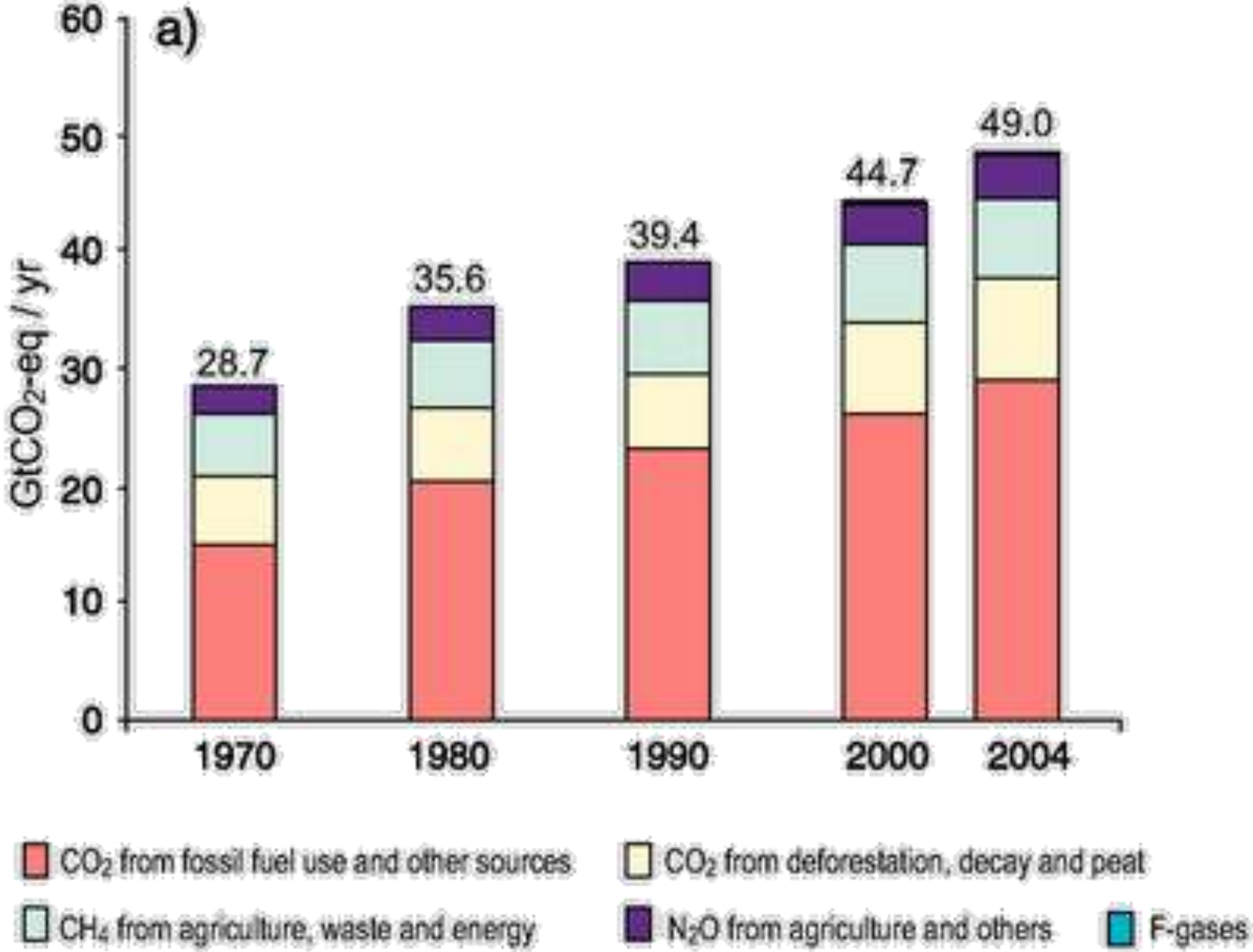
TELLUS
AGRICOLTURA, AMBIENTE, TERRITORIO

GREENHOUSE GASES CONCENTRATION AC



IPCC, 2007

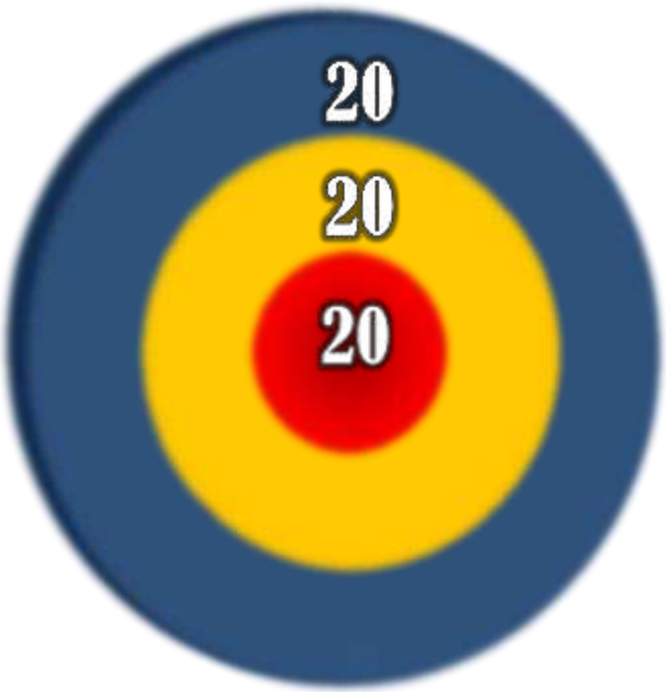
GHG EMISSIONS



CLIMATE AND ENERGY POLICIES

THE CLIMATE AND ENERGY PACKAGE

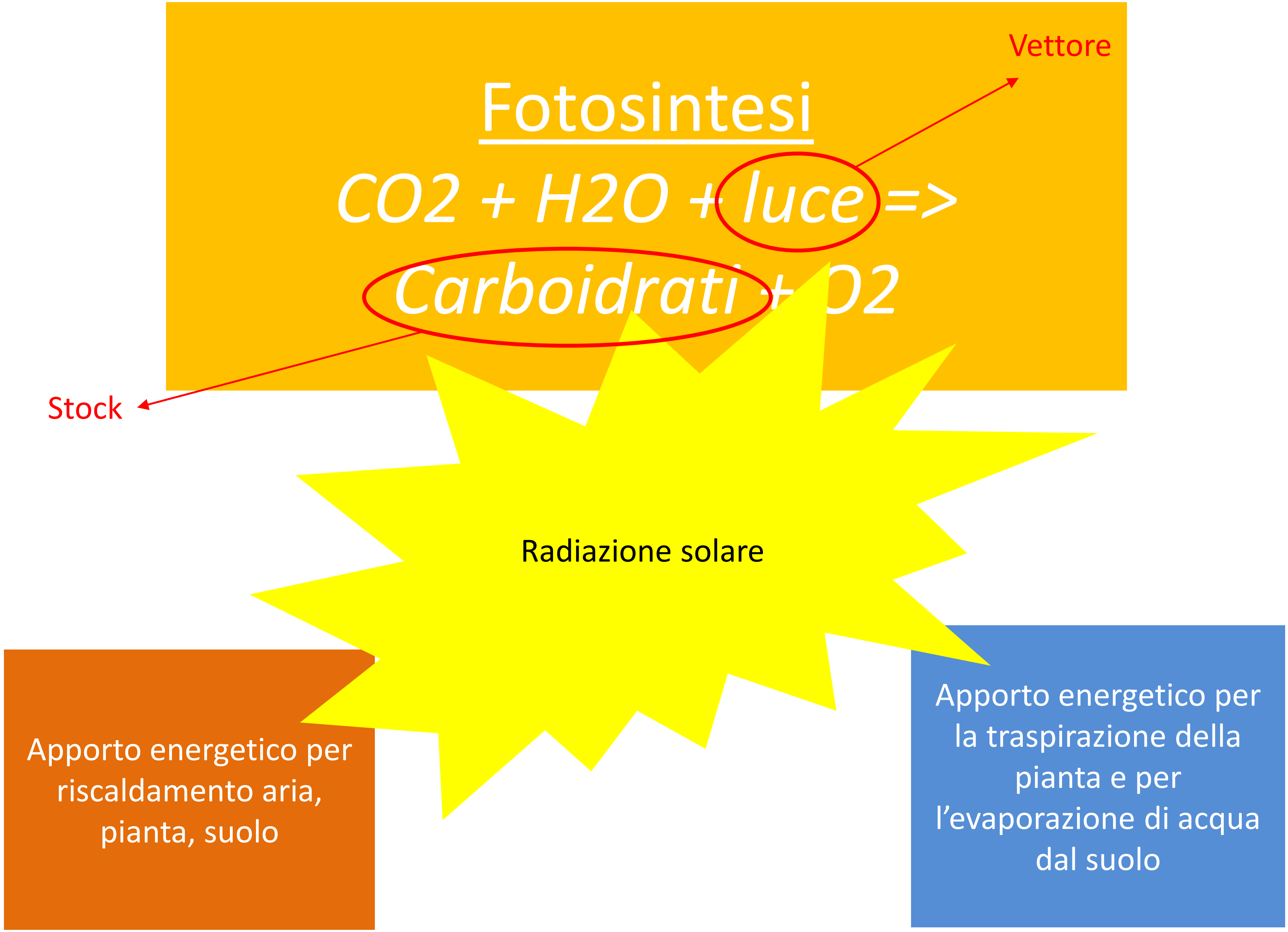
EU TARGETS FOR 2020

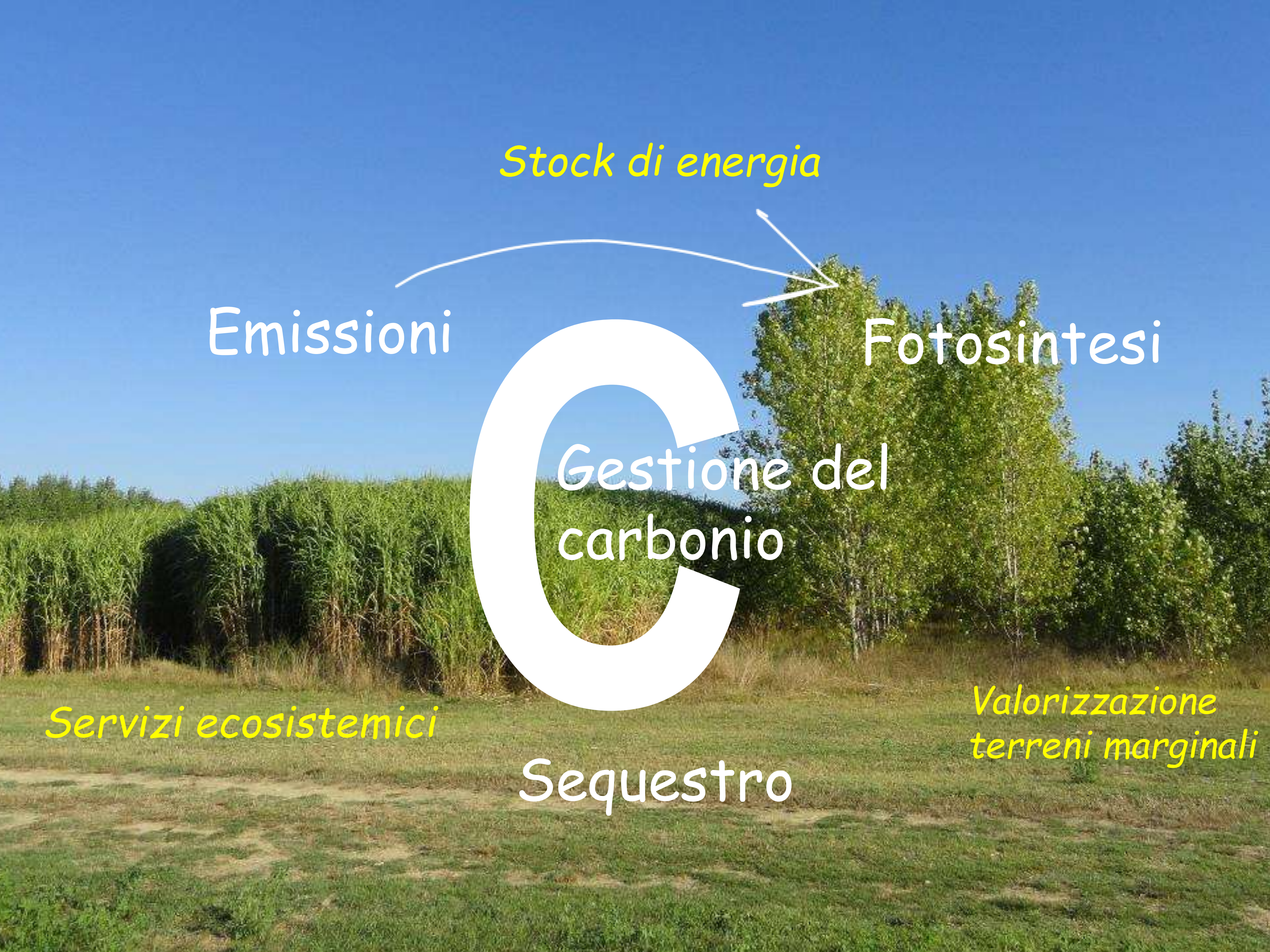


kWh/**kg**

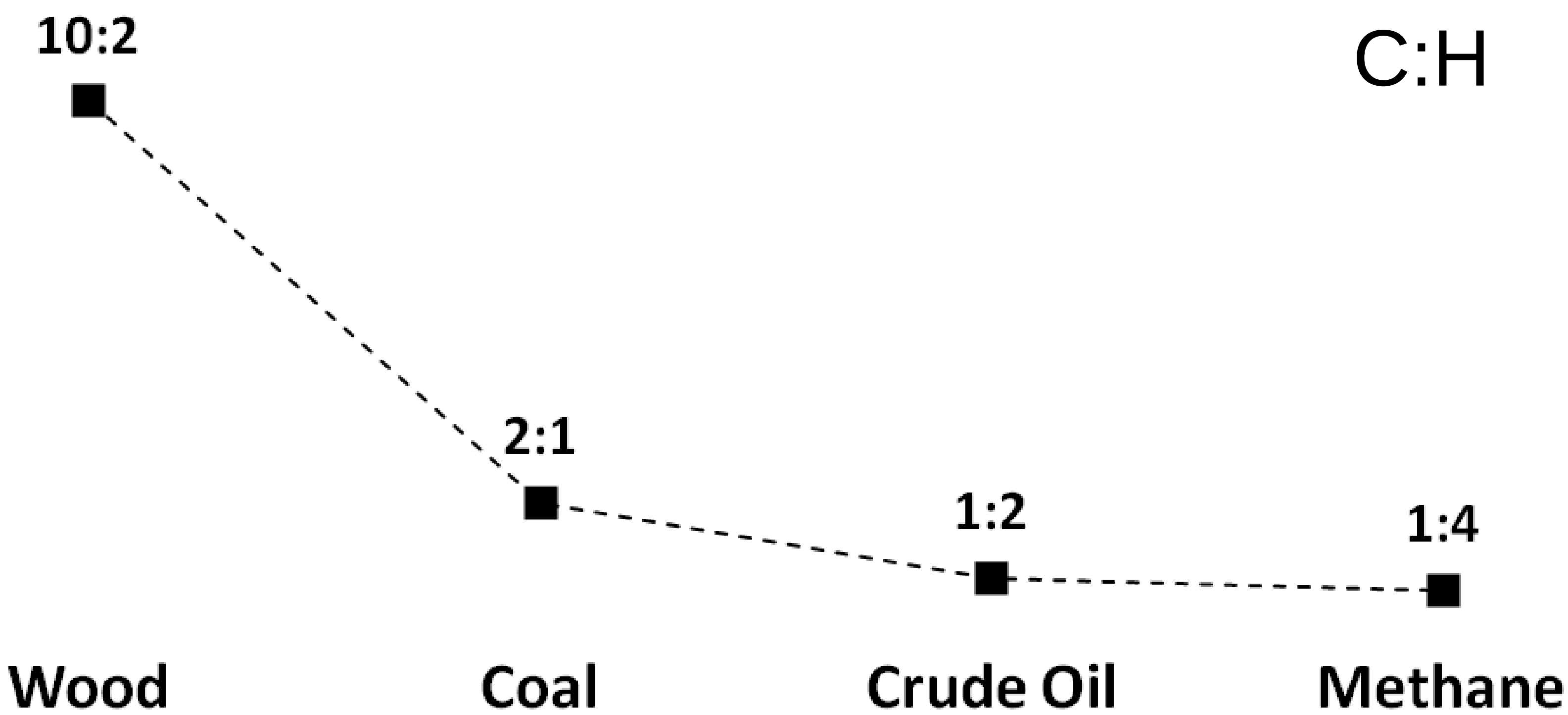
kgCO2eq/**kg**

kWh/kg

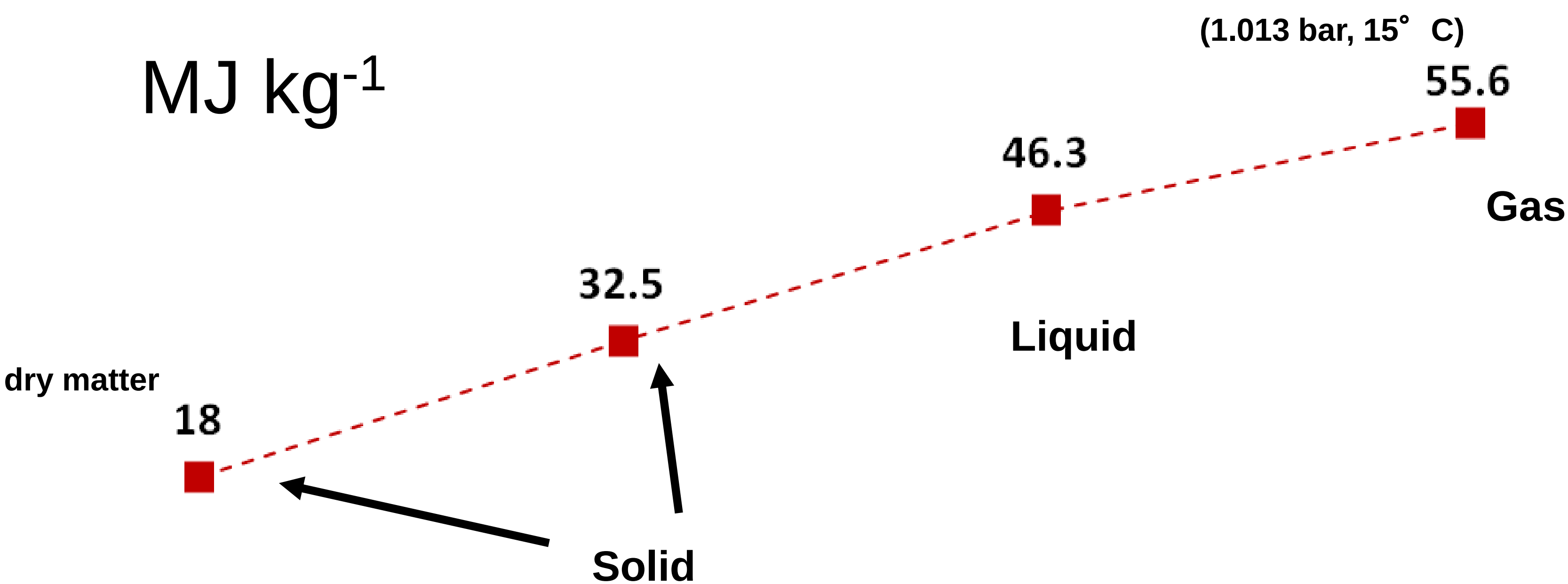

Vettore
Fotosintesi
CO2 + H2O + luce =>
Carboidrati + O2
Stock
Radiazione solare
Apporto energetico per riscaldamento aria, pianta, suolo
Apporto energetico per la traspirazione della pianta e per l’evaporazione di acqua dal suolo


Stock di energia
Emissioni
Fotosintesi
C
Gestione del carbonio
Servizi ecosistemici
Valorizzazione terreni marginali
Sequestro

DECARBONIZATION OF ENERGY FUELS



DECARBONIZATION OF ENERGY FUELS



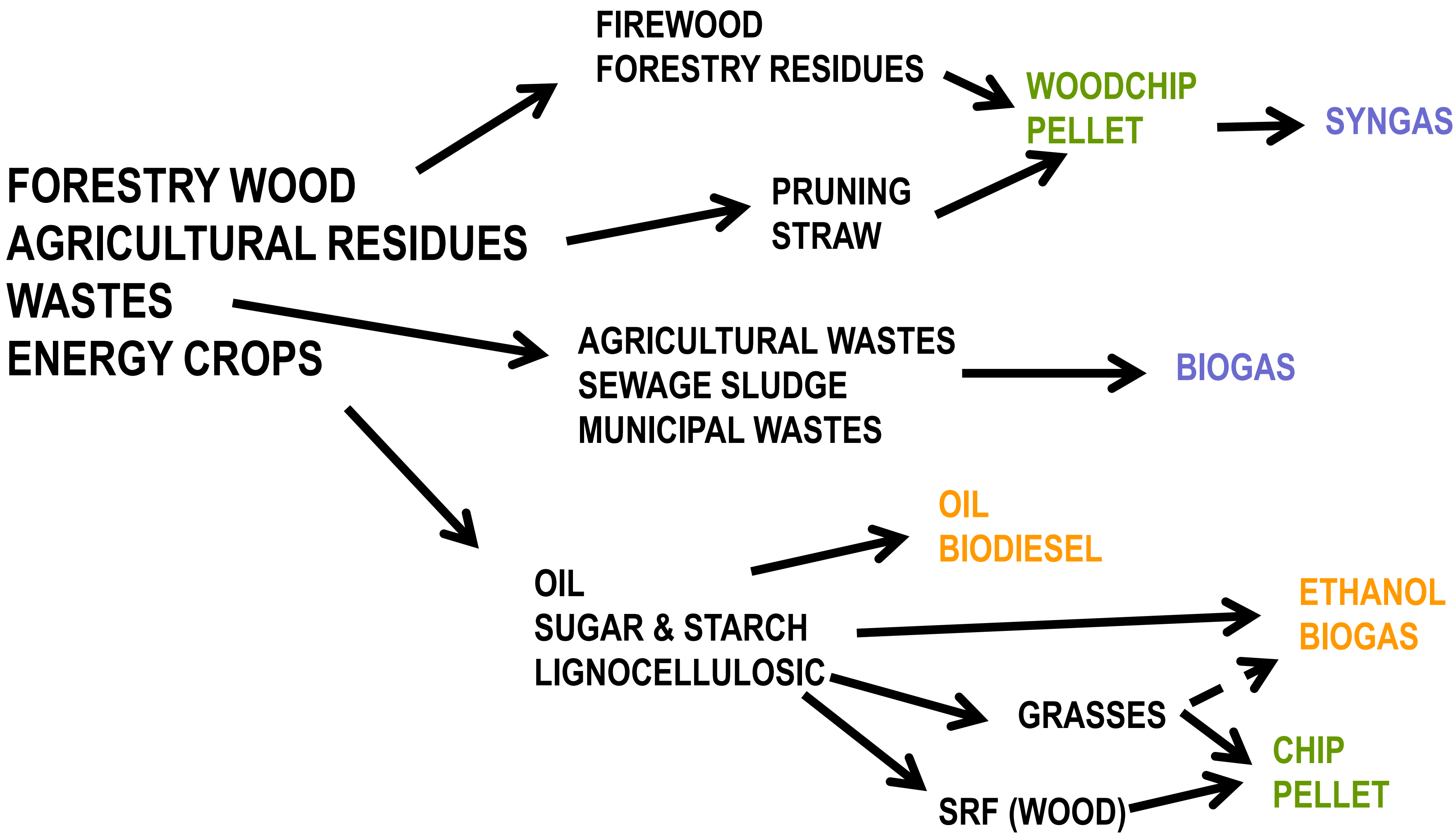
Wood

Coal

Crude Oil

Methane

BIOMASS



FIREWOOD
FORESTRY RESIDUES
WOODCHIP
PELLET
SYNGAS
FORESTRY WOOD
AGRICULTURAL RESIDUES
WASTES
ENERGY CROPS
PRUNING
STRAW
AGRICULTURAL WASTES
SEWAGE SLUDGE
MUNICIPAL WASTES
BIOGAS
OIL
BIODIESEL
OIL
SUGAR & STARCH
LIGNOCELLULOSIC
ETHANOL
BIOGAS
GRASSES
CHIP
PELLET
SRF (WOOD)


Canapa


Cardo


Robinia


Canna comune

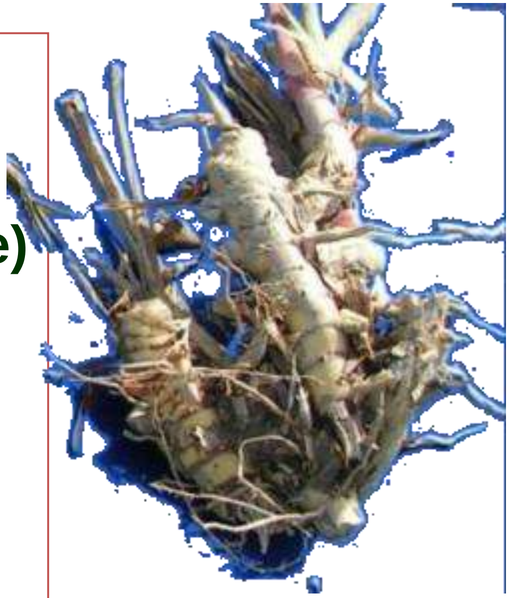

Salice
Pioppo

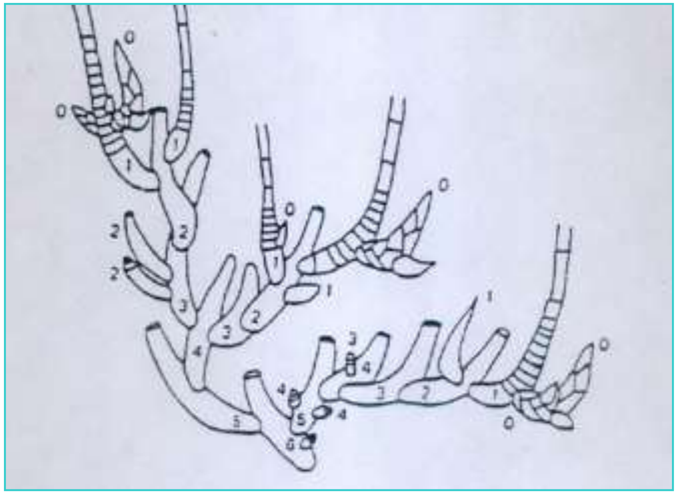

Sorgo


Miscanto

Miscanthus x giganteus

- **Genere: *miscanthus***
- **Specie: *sinensis***
- **Ibrido triploide Miscanthus x Giganteus (sterile)**
- **Famiglia: poaceae**
- **Tribù: andropogoneae**
- **Forma biologica: rizomatosa perenne**
- **Origine: sud est asiatico**





✓ **Pianta: erbacea**

✓ **Ciclo: poliennale**

✓ **Diffusione: introdotta in Europa 65 anni fa come ornamentale.**

✓**Specie C_4 si adatta bene anche ai climi temperati**

Elementi di tecnica colturale

- **Preparazione**: aratura, estirpature invernali, erpicature
- **Impianto:** con rizomi o piantine micropropagate
- **Epoca**: rizomi febb/marzo (10-20 cm prof.);
  piantine maggio
- **Densità**: 2 rizomi/mq, per avere 40 germogli/mq

Anticipata: umidità elevata

Posticipata: riduzione resa

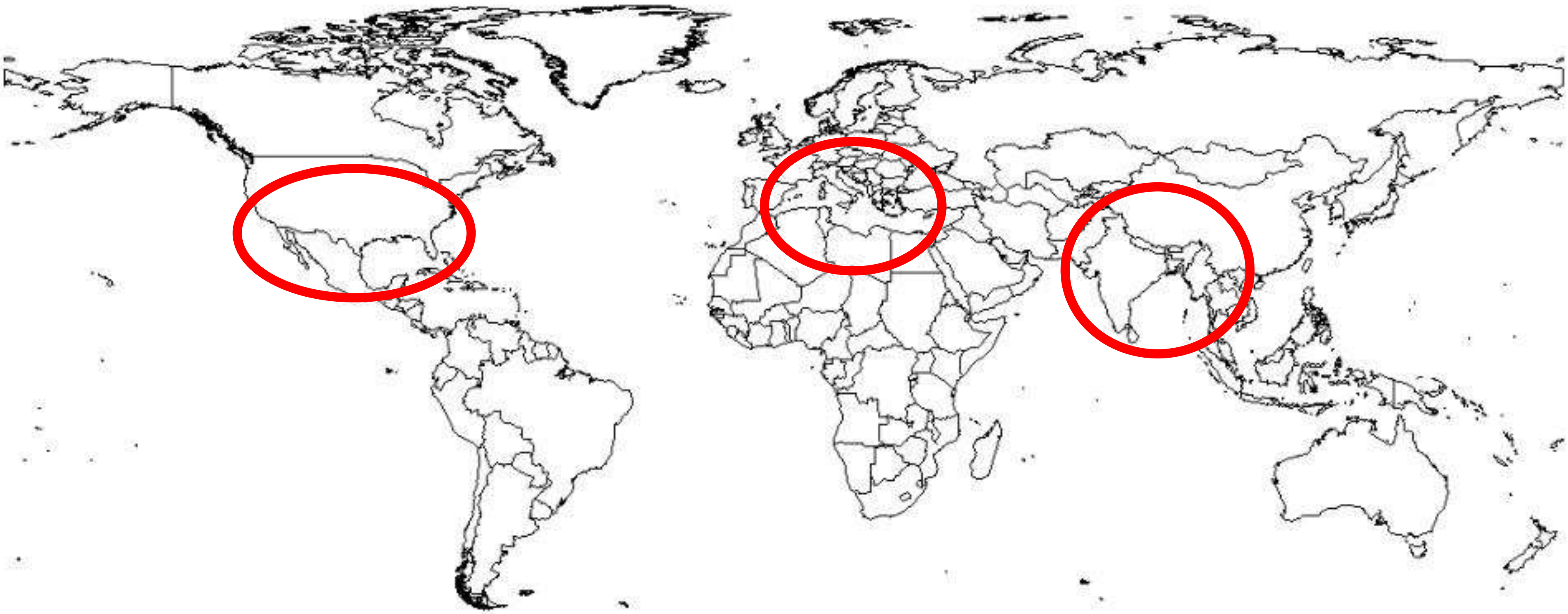
- **Concimazione** alla ripresa vegetativa:
  60 kg/ha N, 25 P_2O_5 e 60 di K_2O
- **Irrigazione**: buona risposta
- **Gestione flora infestante**: solo nell'anno di impianto
  (sarchiatura; erbicidi pre)
- Non esistono **patogeni** noti in ambiente mediterraneo
- **Raccolta**: dicembre–marzo; barra/ranghinatore/
  rotoimballatrice; falcia-trincia-caricatrice e cassone

Punti di forza:
- elevata resa media annua (25–28 t/ha di s.s.)
- poliennale assai longeva

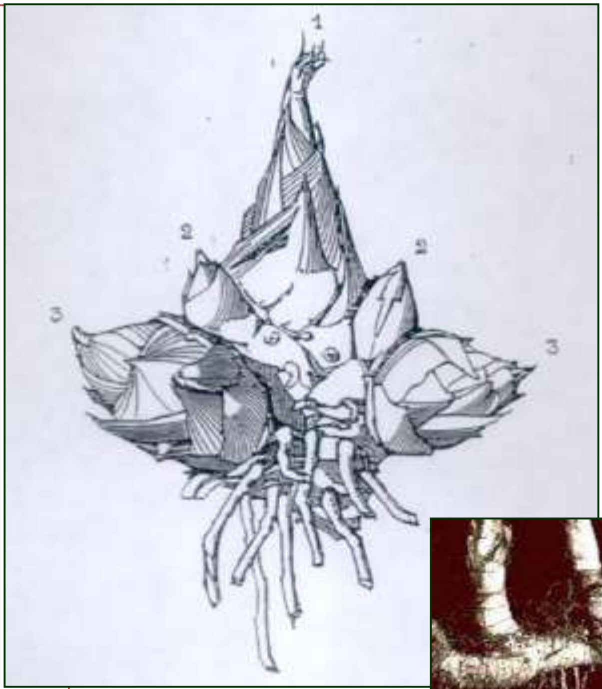
Punti di debolezza:
- esigente in termini di disponibilità idriche
- meccanizzazione delle operazioni di trapianto (costo impianto)
- ripristino del terreno dopo la coltura
- biomassa caratterizzata da un elevato tenore in silice (< ceneri)

GIANT REED *(Arundo donax)*

Giant reed



- **Genere: *arundo***
- **Specie: *donax***
- **Famiglia: poaceae**
- **Tribù: arundinee**
- **Forma biologica: geofita rizomatosa perenne**
- **Origine: mediterraneo – medio oriente, Pakistan**

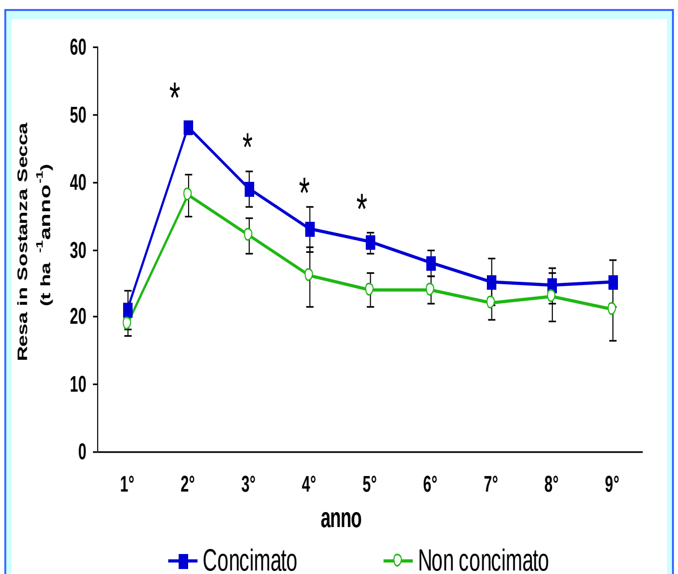


✓ **Pianta: erbacea poliennale**

✓ **Diffusione: vegeta fino agli ambienti submontani, in terreni freschi, lungo i fiumi e fossi, in collina, in prossimità del mare, sui cigli stradali e ferroviari, a formare i tipici "canneti"**

Elementi di tecnica colturale

- **Preparazione**: aratura, estirpature invernali, erpicature
- **Impianto:** con rizomi o fusti (a solchi con piantatuberi)
- **Epoca**: rizomi da febb/marzo (10-20 cm prof.);
  fusti tardo autunno
- **Densità**: 1,0–1,5 rizomi/mqper avere
  a maturità 40 fusti/mq



- **Concimazione** (N-P-K: 200-80-200): risposta variabile
- **Gestione flora infestante**: solo nell'anno di impianto
  (sarchiatura; erbicidi pre)
- Non esistono **patogeni** noti in ambiente mediterraneo
- **Raccolta**: dicembre – marzo; falcia-trincia-caricatrice

PROPAGATION


24.2.2014


25.2.2014


24.2.2014


24.2.2014


25.2.2014


25.2.2014


14.7.2014
10.8.2014

➢Canna comune (*Arundo donax*)

<u>Punti di forza:</u>

- molto produttiva (34-35 t/ha di s.s.)
- specie poliennale assai longeva (12 – 14 anni)
- tipica del nostro paesaggio rurale
- protegge il terreno dall'erosione
- grande adattabilità (terreni e disponibilità idriche) in ambiente mediterraneo

<u>Punti di debolezza</u>:

- costo elevato all'impianto
- specie assai invasiva
- biomassa con elevato contenuto in ceneri (5%) e in silice

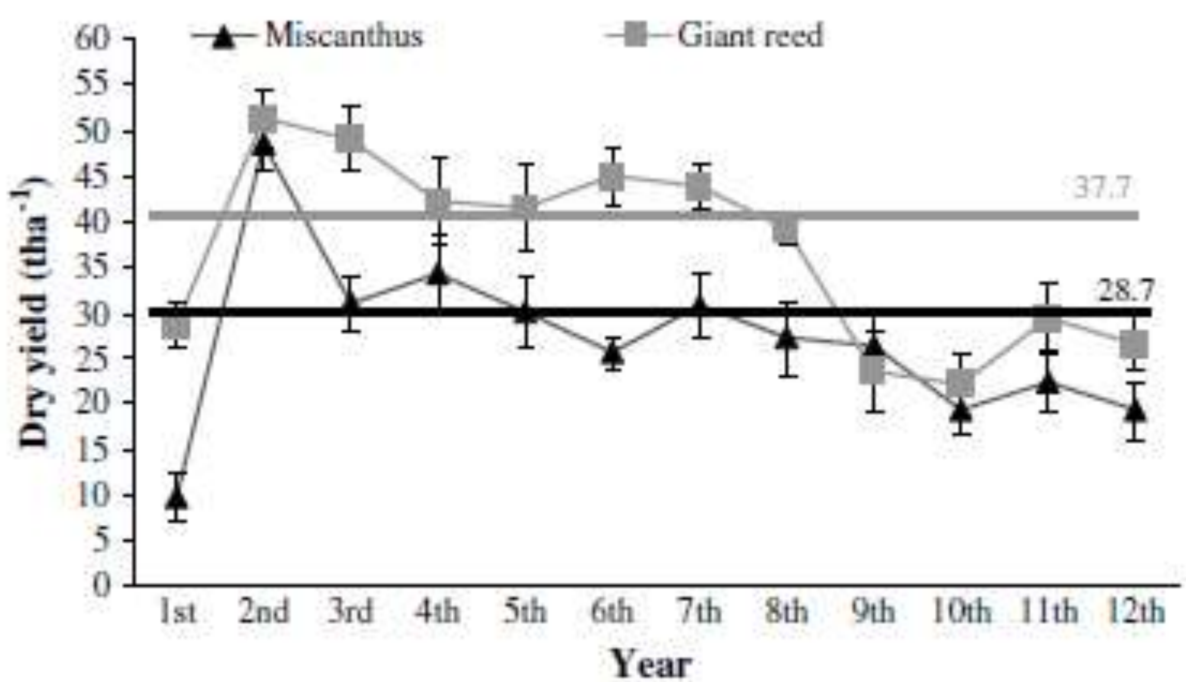


Fig. 1 – Giant reed and miscanthus above-ground dry yield from the crop establishment (1992) to the 12th year of growth in comparison, for each species, with the mean value calculated excluding the yield of the fist year. Vertical bars represent the standard deviation.

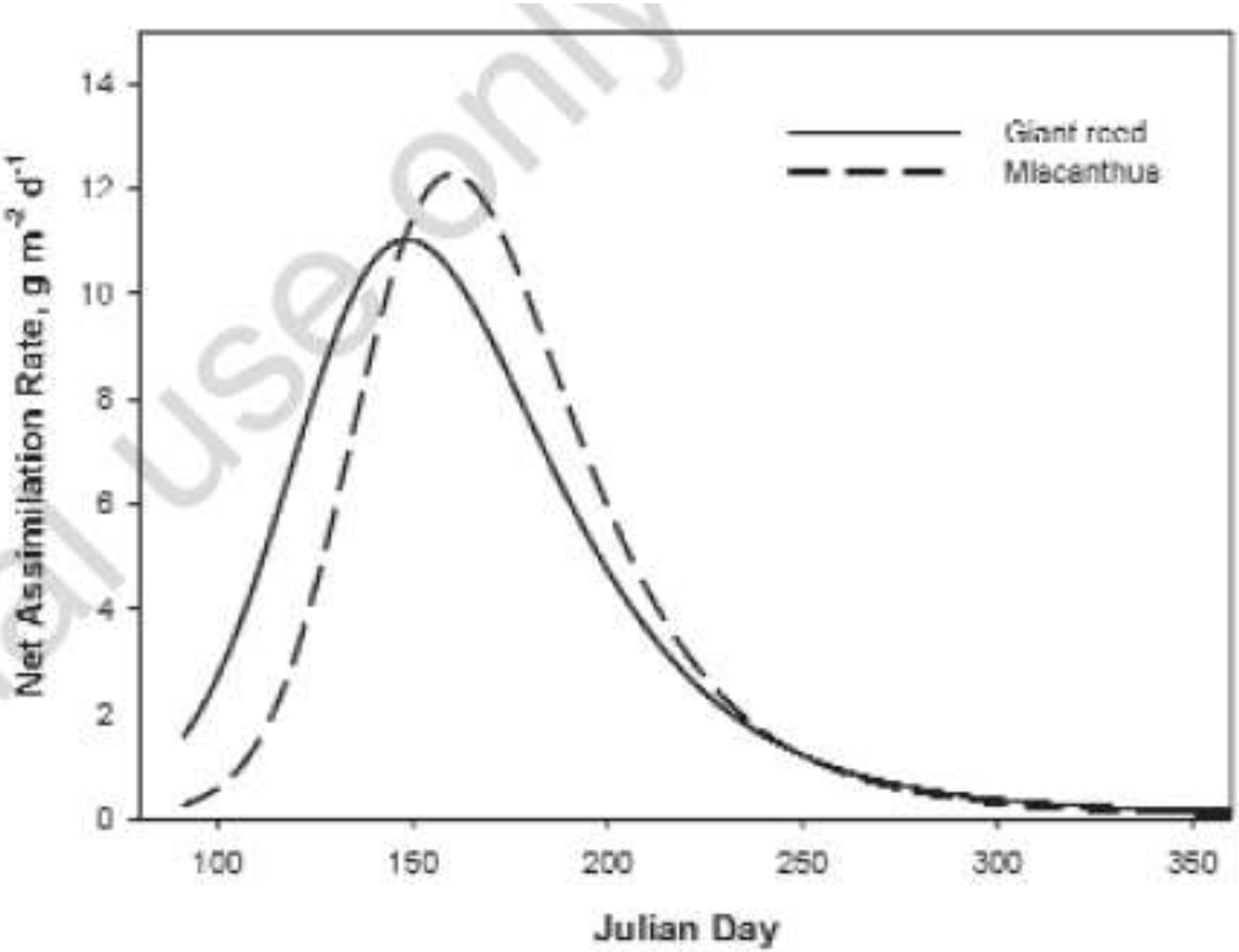
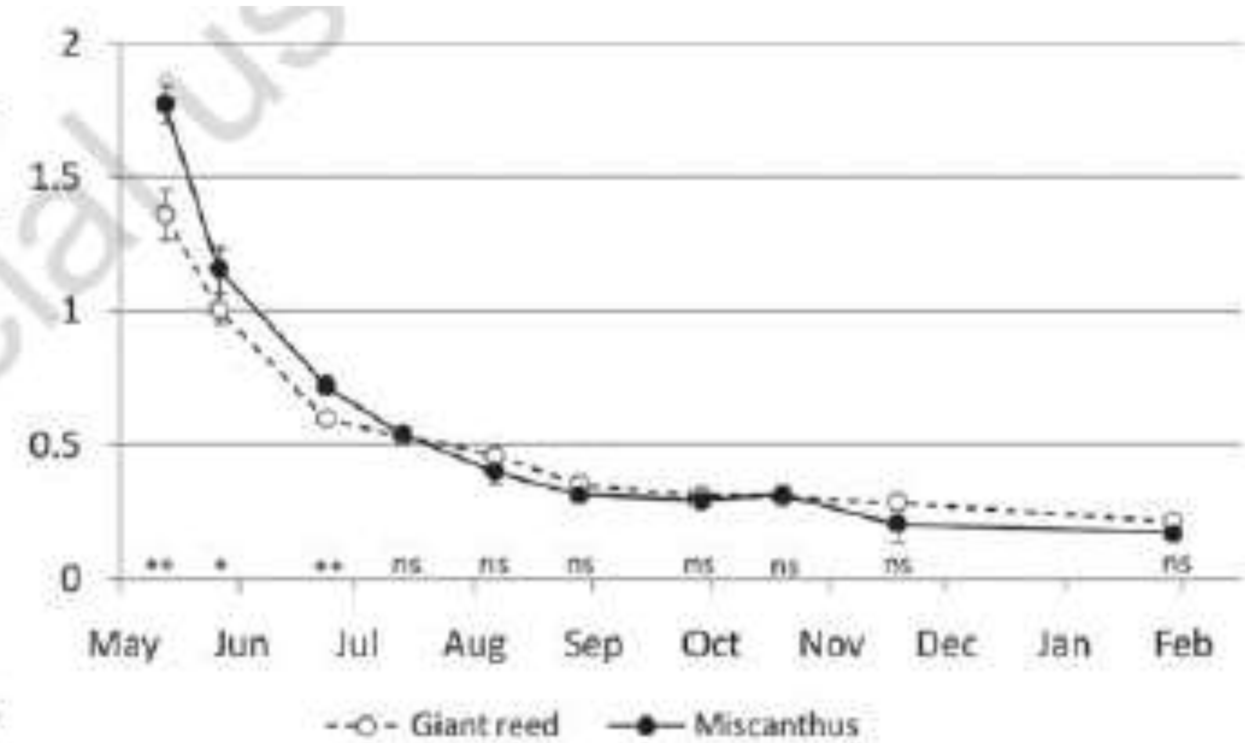
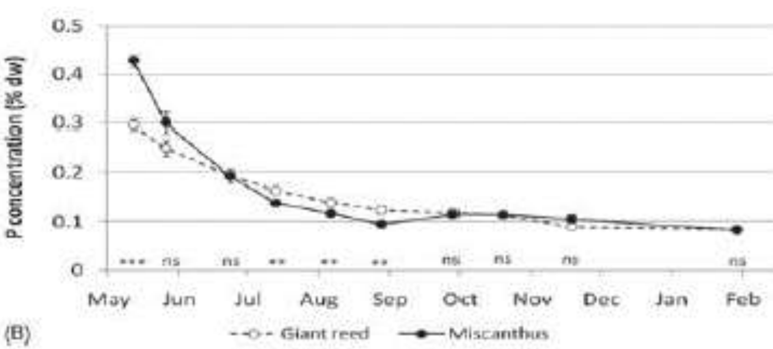


Figure 7. Predicted net assimilation rate of giant reed and miscanthus during the 2009 growing season at Pisa (Central Italy).



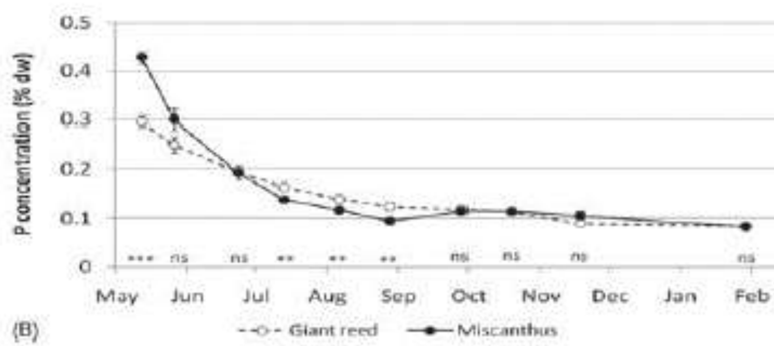
N concentration (% dw)
2
1.5
1
0.5
0
** * ** ns ns ns ns ns ns ns
May Jun Jul Aug Sep Oct Nov Dec Jan Feb
- -○- - Giant reed
—●— Miscanthus

(A)



P concentration (% dw)
0.5
0.4
0.3
0.2
0.1
0
*** ns ns ** ** ** ns ns ns ns
May Jun Jul Aug Sep Oct Nov Dec Jan Feb
- -○- - Giant reed
—●— Miscanthus

(B)



P concentration (% dw)
0.5
0.4
0.3
0.2
0.1
0
*** ns ns ** ** ** ns ns ns ns
May Jun Jul Aug Sep Oct Nov Dec Jan Feb
- -○- - Giant reed
—●— Miscanthus

(B)

Table 1. Nutrient use efficiencies of giant reed and miscanthus crops during 2009 growing season in Pisa (43°40' N, 10°19' E), Italy.

	N_{NUE}, g/g		P_{NUE}, g/g		K_{NUE}, g/g	
Date	Giant reed	Miscanthus	Giant reed	Miscanthus	Giant reed	Miscanthus
19 October	330 a	316 a	884 a	870 a	108 a	150 a
18 November	351 b	489 a	1115 a	952 a	131 b	188 a
23 January	467 b	522 a	1183 a	1073 a	136 b	189 a
Mean	*383 b*	*442 a*	*1061 a*	*965 a*	*125 b*	*176 a*

NUE values, followed by the same letter across species, are not significantly different (P=0.05).

Table 2. Nutrient use efficiencies of some woody and arable crops.

	N_{NUE}, g/g	P_{NUE}, g/g	K_{NUE}, g/g	Source
Poplar	145-370	1000-2000	256-370	Jug *et al.*, 1999
Willow	152-244	909-1429	323-500	Jug *et al.*., 1999
Eucalyptus	219	3477	427	Lodhiyal and Lodhiyal, 1997
Maize	66-111	333-556	86-161	Beale and Long, 1997
Wheat	83-87	-	117-133	Jorgensen, 2000

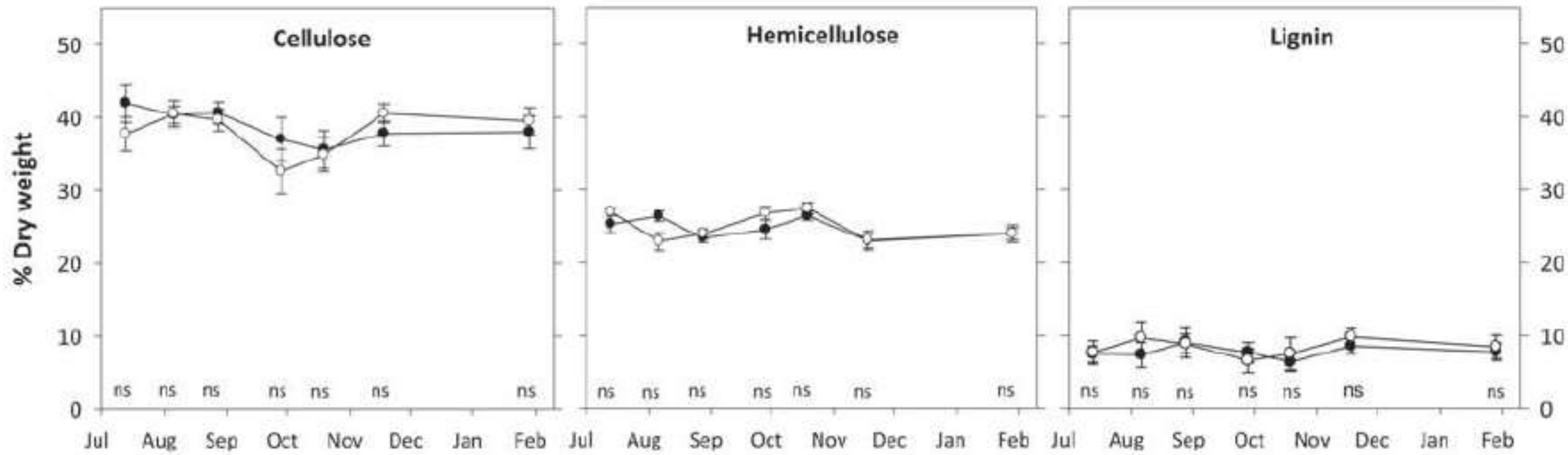


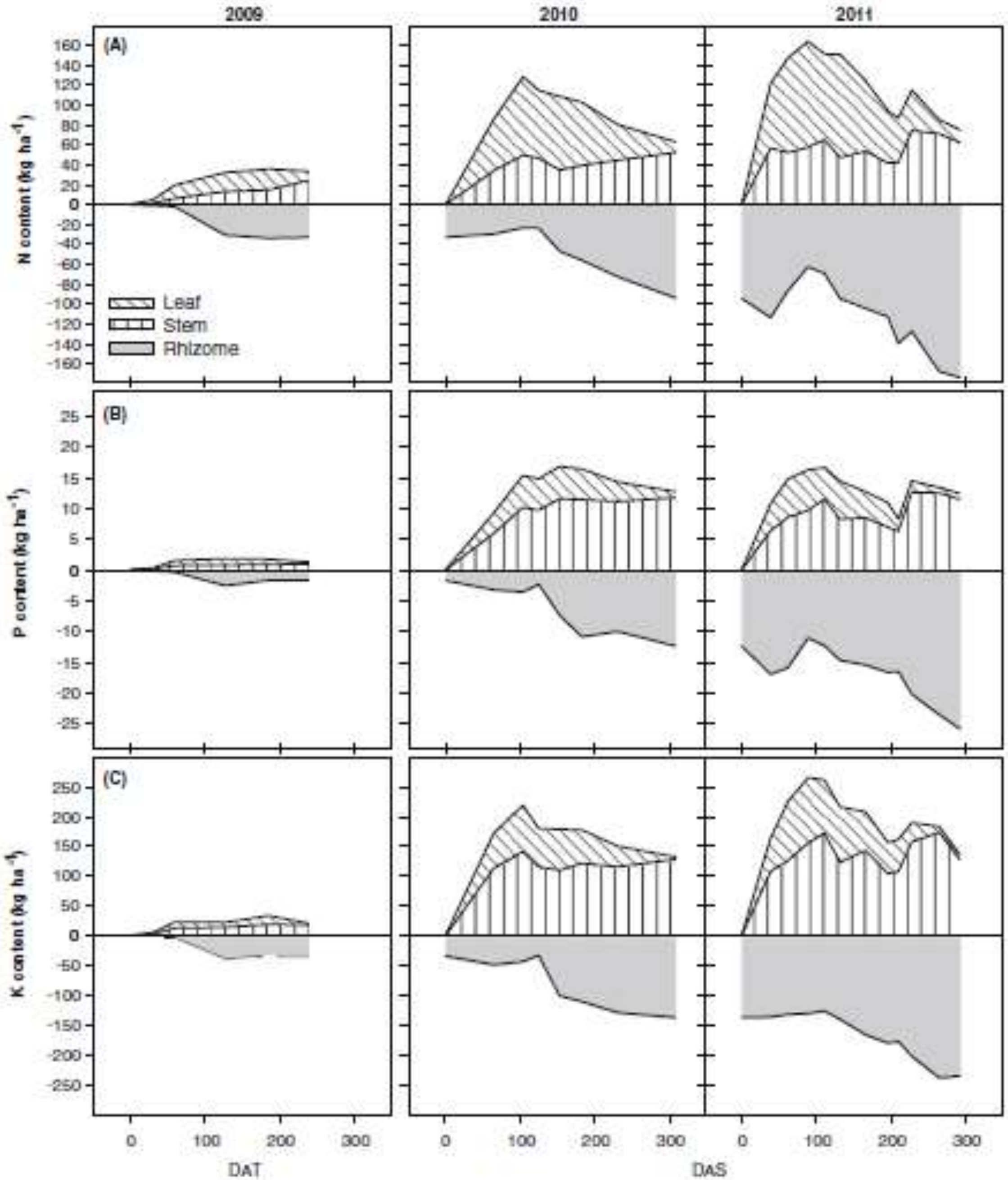
Figure 5. Seasonal variation (2009) in cellulose, hemicellulose and lignin content of giant reed and miscanthus in Pisa, Italy (43°40' N, 10°19' E). ○, giant reed; ●, miscanthus; bars represent the standard deviation; *, **, ***, significant differences at $P<0.05$, $P<0.01$, $P<0.001$, respectively; ns, no significant differences.

Table 3. Cellulose, hemicellulose and lignin contents in common agricultural residues.

Lignocellulosic materials	Cellulose, %	Hemicellulose, %	Lignin, %
Hardwoods stems	40-55	24-40	18-25
Softwood stems	45-50	25-35	25-35
Corn cobs	45	35	15
Wheat straw	30	50	15
Grasses	25-40	35-50	10-30
Leaves	15-20	80-85	0

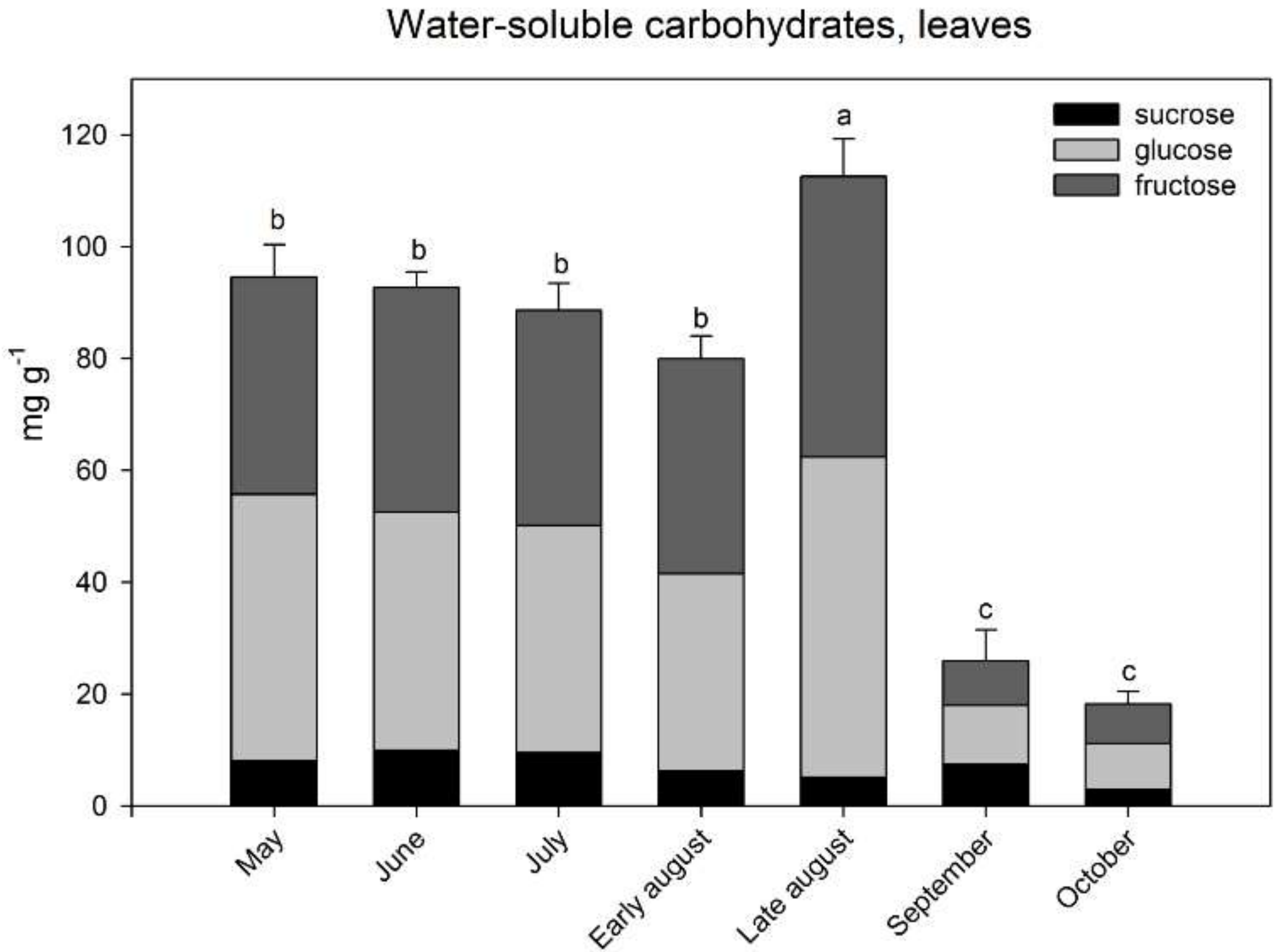
Source: Sun and Cheng, 2002.

Giant reed



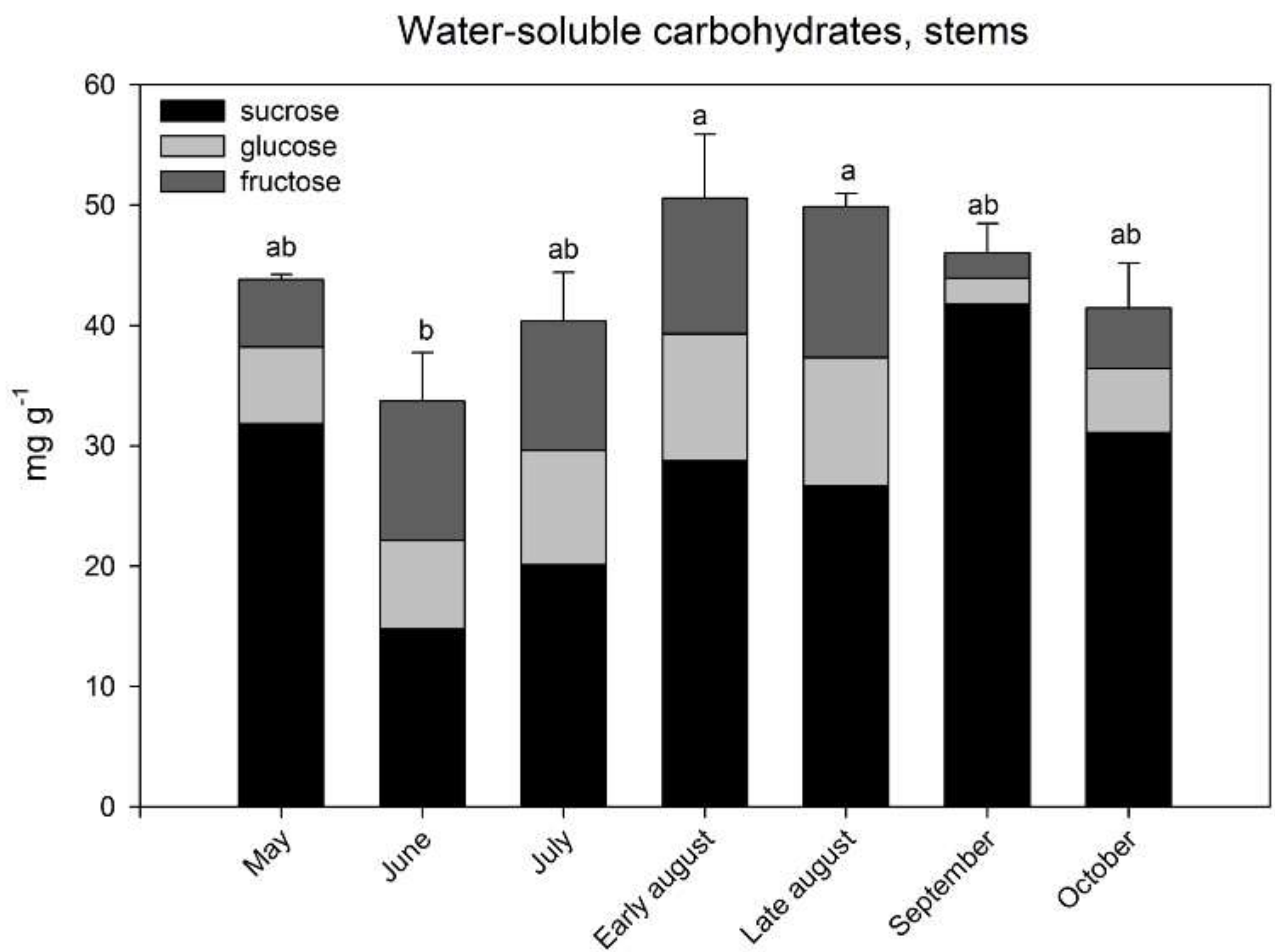
2009
2010
2011
(A)
(B)
(C)
N content (kg ha⁻¹)
P content (kg ha⁻¹)
K content (kg ha⁻¹)
Leaf
Stem
Rhizome
DAT
DAS

Figure 4a



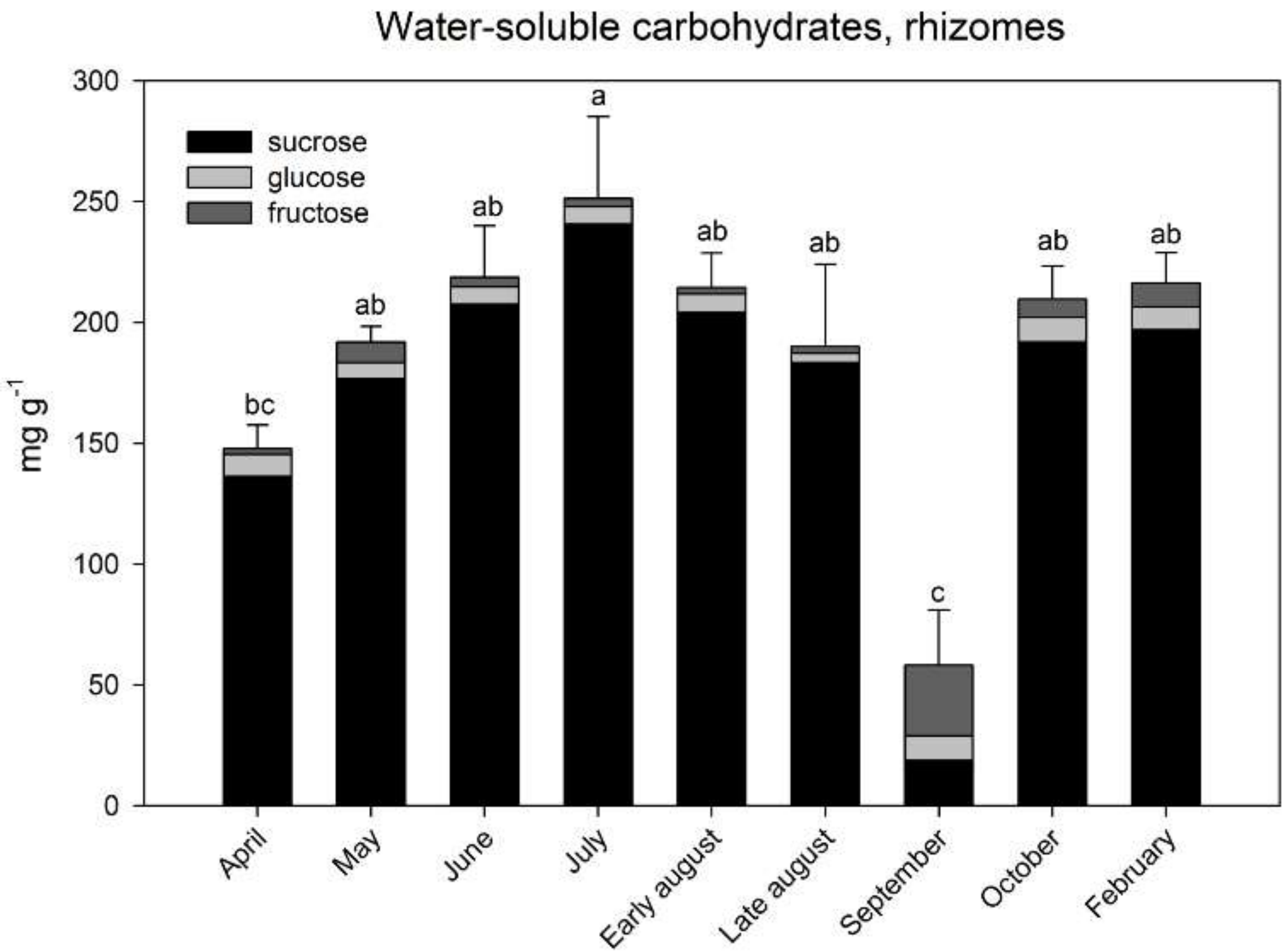
Water-soluble carbohydrates, leaves
mg g-1
0
20
40
60
80
100
120
sucrose
glucose
fructose
b
b
b
b
a
c
c
May
June
July
Early august
Late august
September
October

Figure 4b

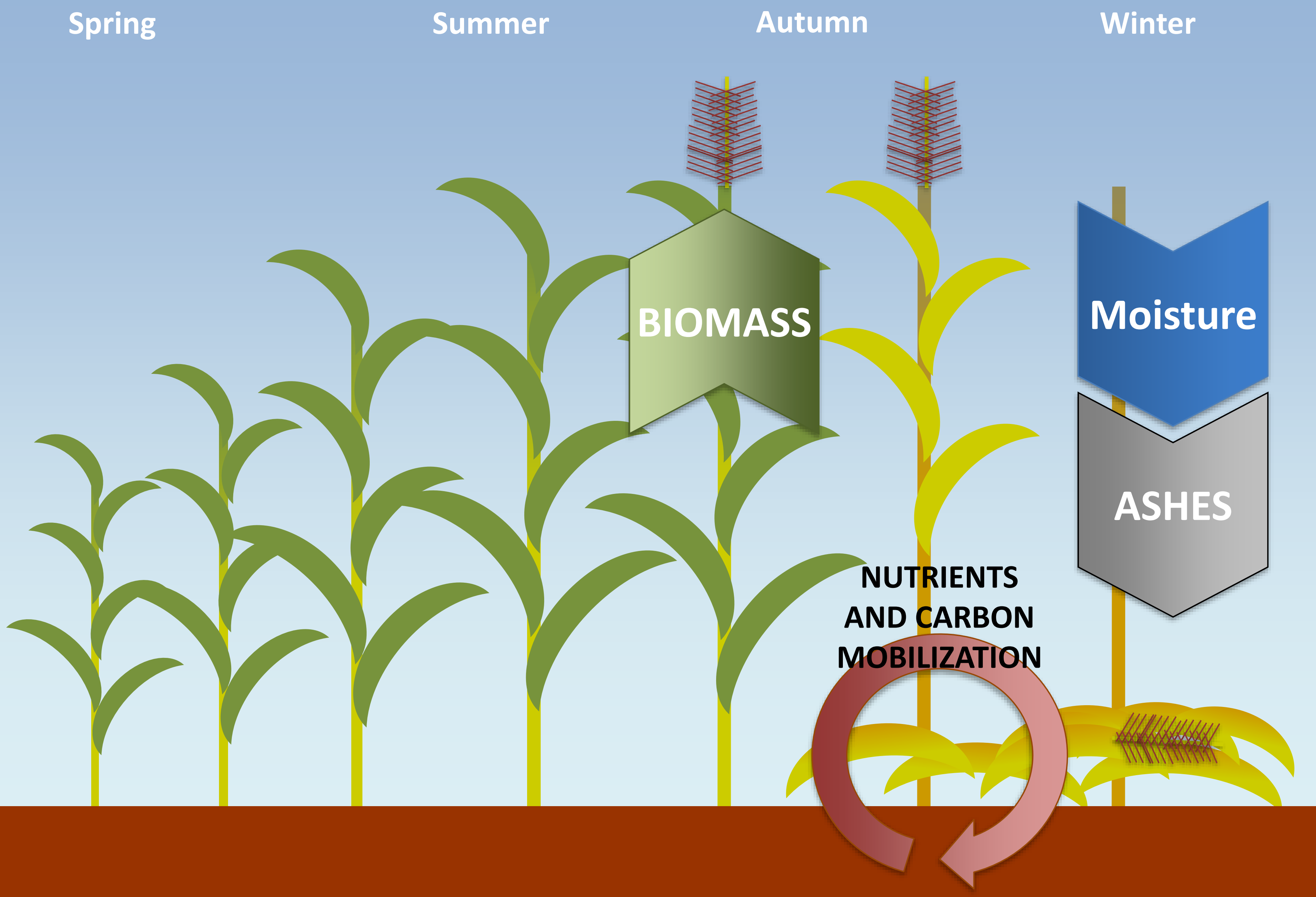


Water-soluble carbohydrates, stems
sucrose
glucose
fructose
mg g⁻¹
60
50
40
30
20
10
0
ab
b
ab
a
a
ab
ab
May
June
July
Early august
Late august
September
October

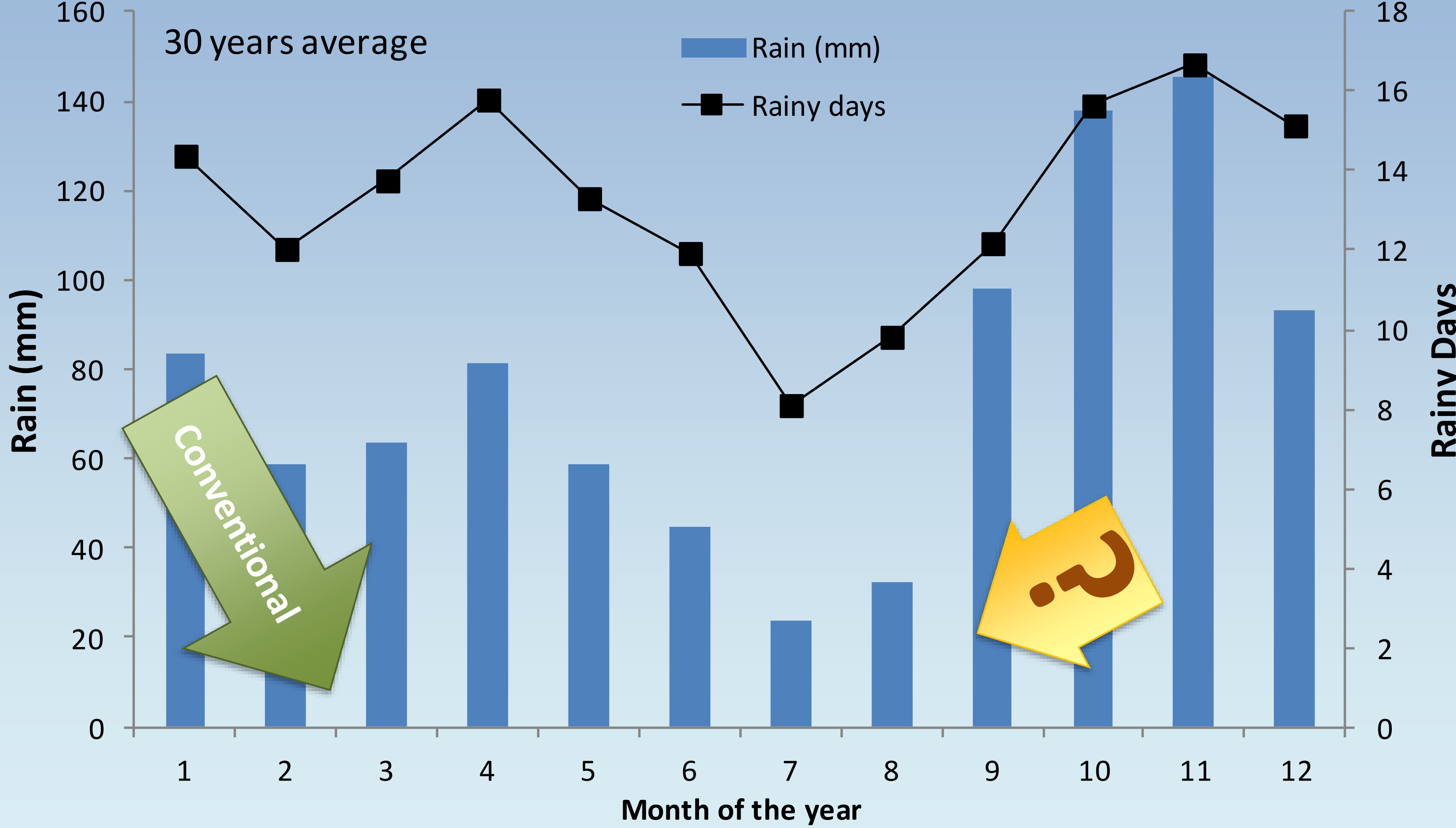
Figure 4c


Water-soluble carbohydrates, rhizomes
sucrose
glucose
fructose
mg g-1
0
50
100
150
200
250
300
bc
ab
ab
a
ab
ab
c
ab
ab
April
May
June
July
Early august
Late august
September
October
February

When to harvest?



When to harvest?

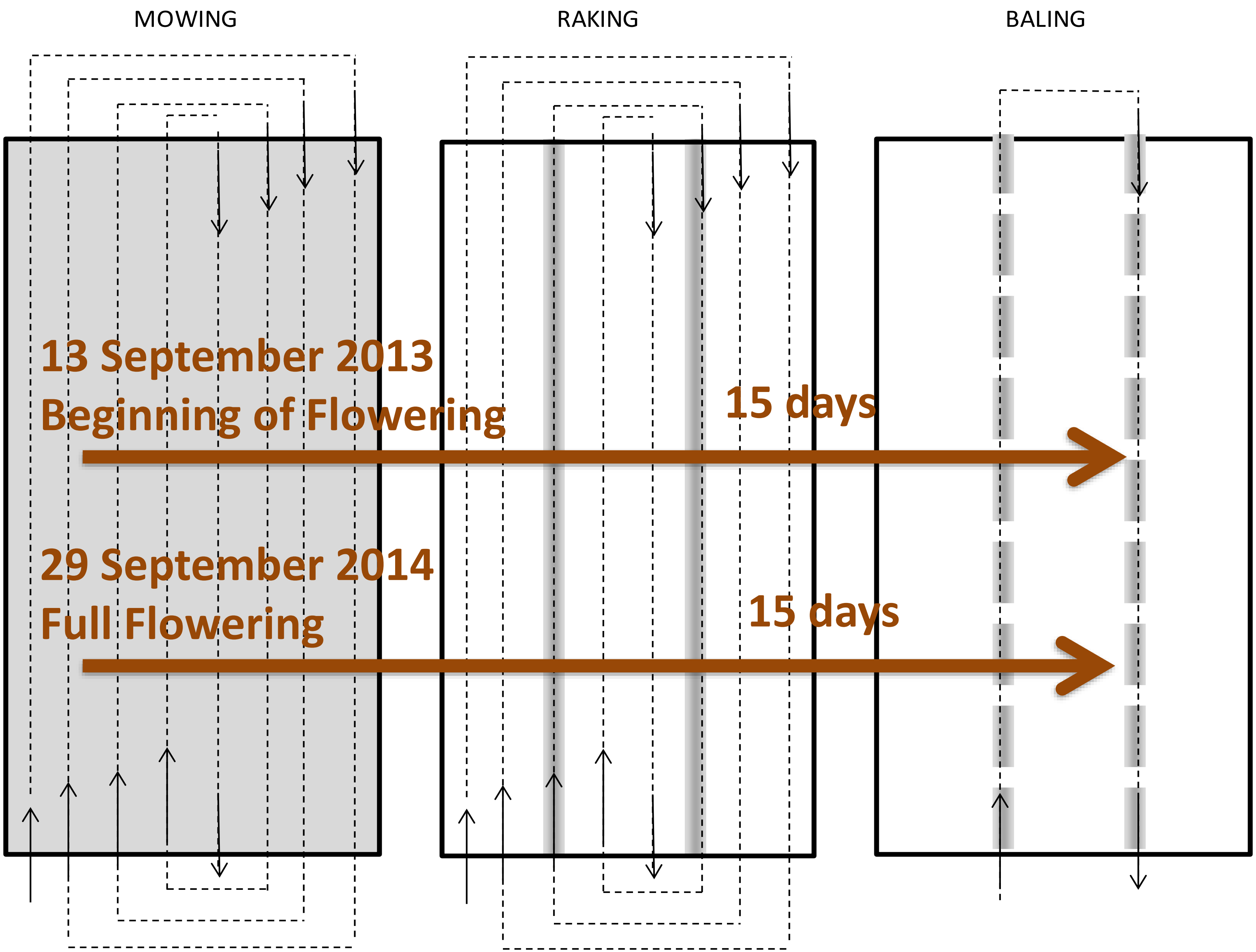


THREE-PASSAGE SYSTEM AT FLOWERING STAGE (EARLY AUTUMN)

EARLY HARVESTING OF MISCANTHUS IN ITALY

Machine	Company	Model	Tractor	Fitting
Shredder	NOBILI	WS 320 BIO	Case IH CVX 195 - 192 Hp	Back - Reverse Drive
Rotary Rake	KUHN	GA 3502	New Holland TN75S - 75 Hp	Back
High density square baler	KUHN	LSB 1290	Case IH CVX 195 - 192 Hp	Back

EARLY HARVESTING OF MISCANTHUS IN ITALY

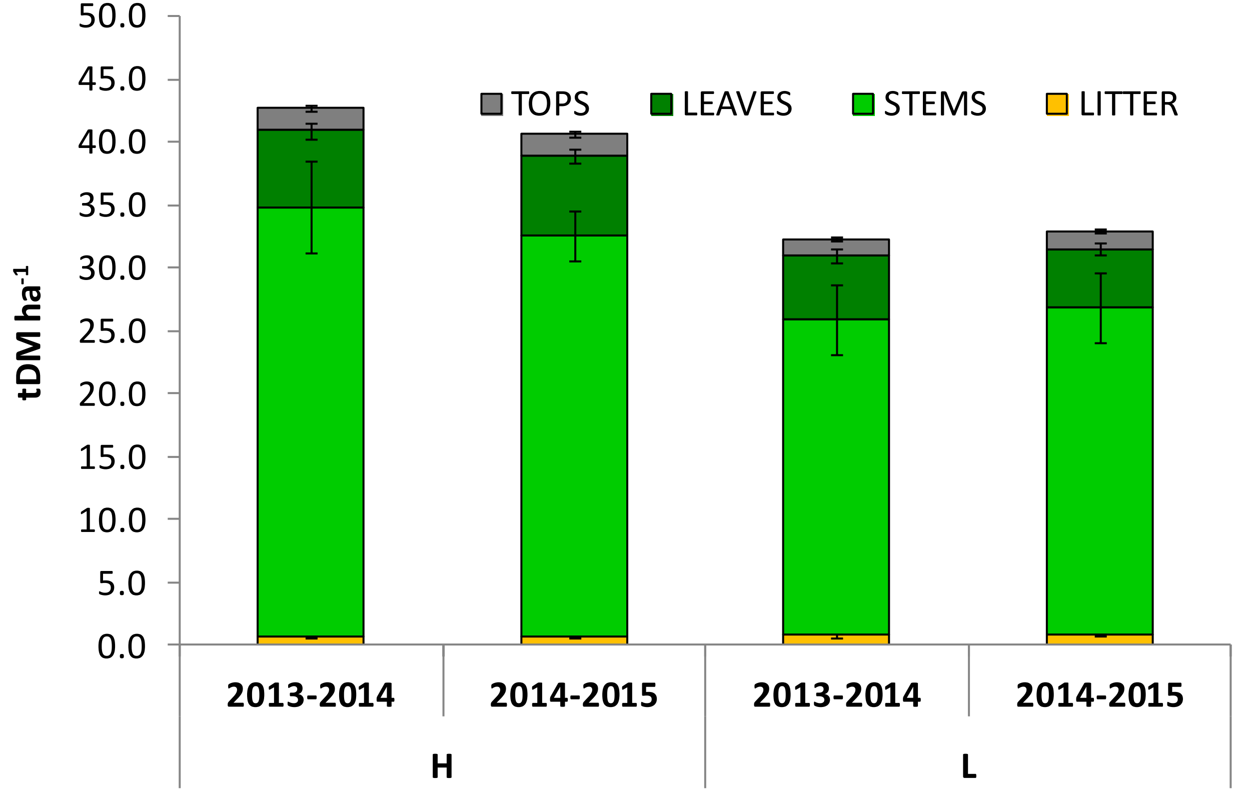


SINGLE-PASSAGE SYSTEM AT FULL SENESCENCE (LATE WINTER)

LATE HARVESTING OF MISCANTHUS IN ITALY

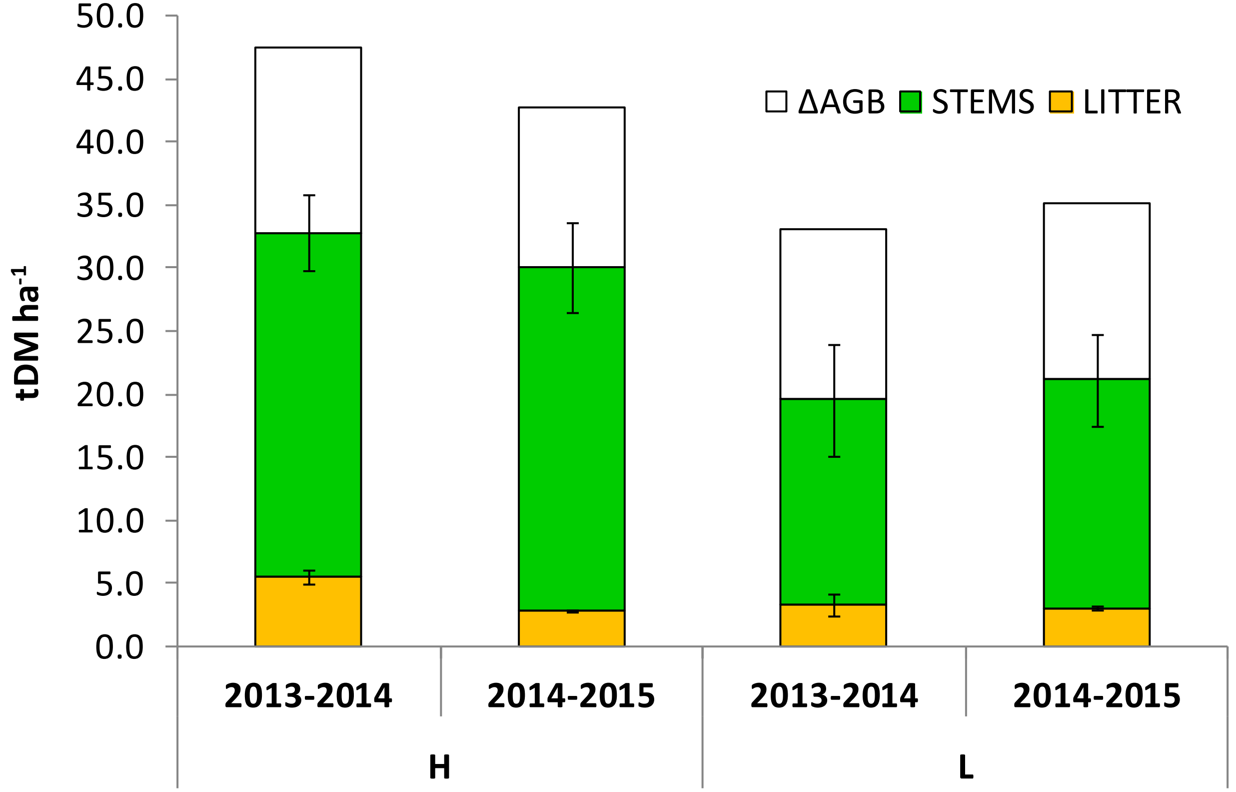
Machine	Company	Model	Tractor	Fitting
Shredder	NOBILI	WS 320 BIO	Case IH puma 155 - 155 Hp	Front
High density square baler	KUHN	LSB 1290		Back

ABOVE GROUND BIOMASS PARTITIONING AT FLOWERING STAGE



H = high yielding plantation
L = low yielding plantation

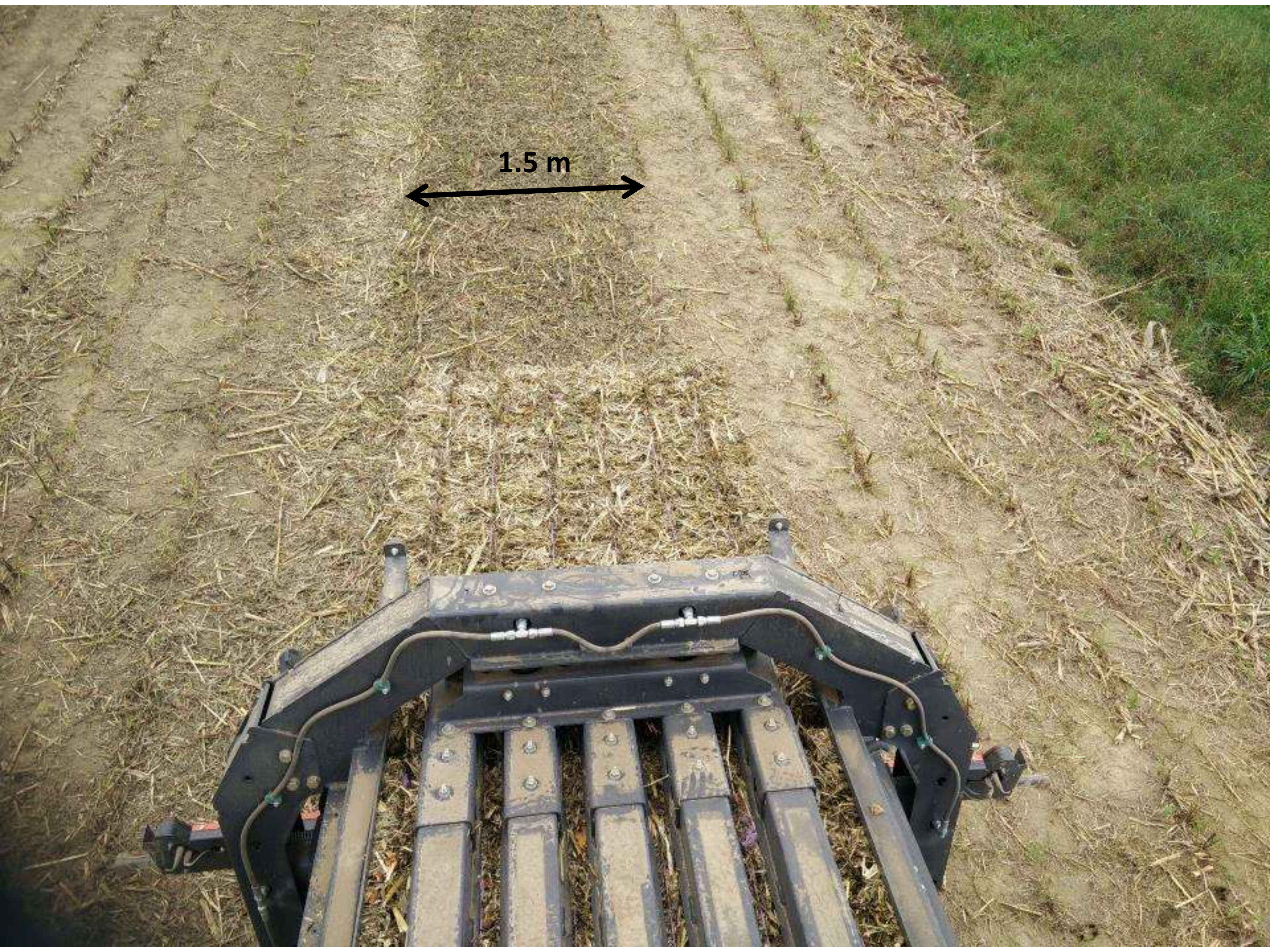
ABOVE GROUND BIOMASS PARTITIONING AT FULL SENESCENCE



H = high yielding plantation
L = low yielding plantation

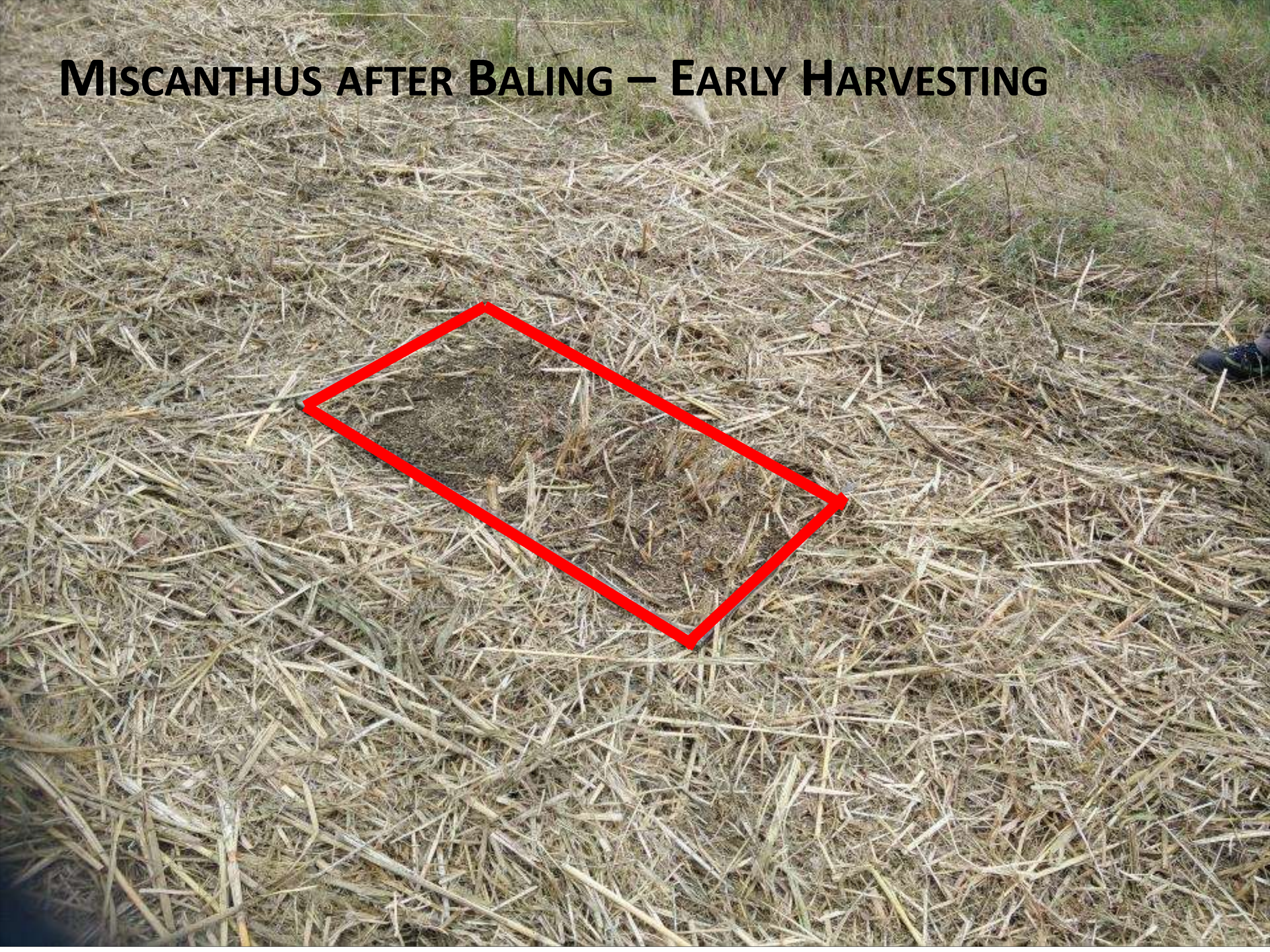
Miscanthus after Mowing

MISCANTHUS AFTER RAKING


1.5 m

Miscanthus after Baling – Early Harvesting

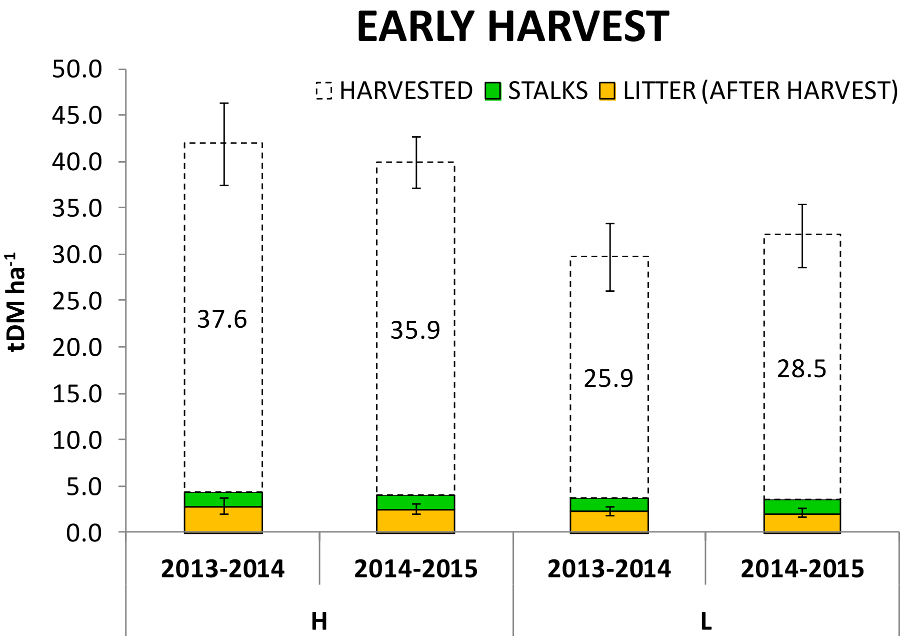
Miscanthus after Baling – Early Harvesting

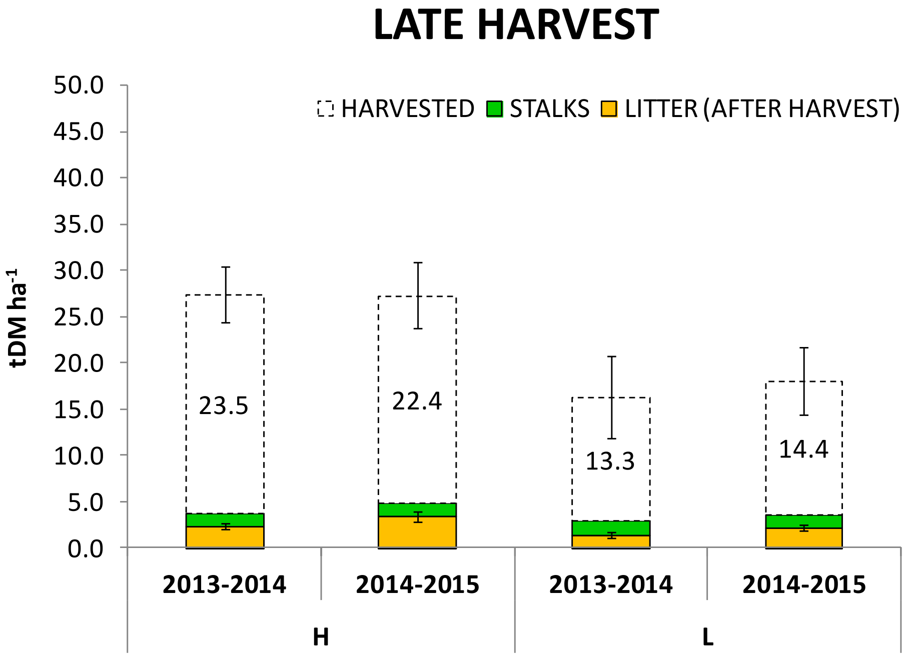


Miscanthus after Baling – Late Harvesting

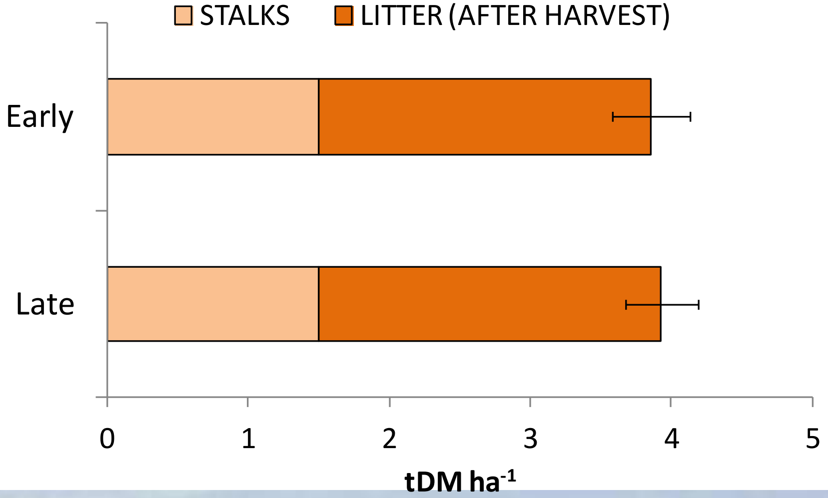

30 cm
15 cm ~ 1.5 tDM ha-1

HARVESTED BIOMASS



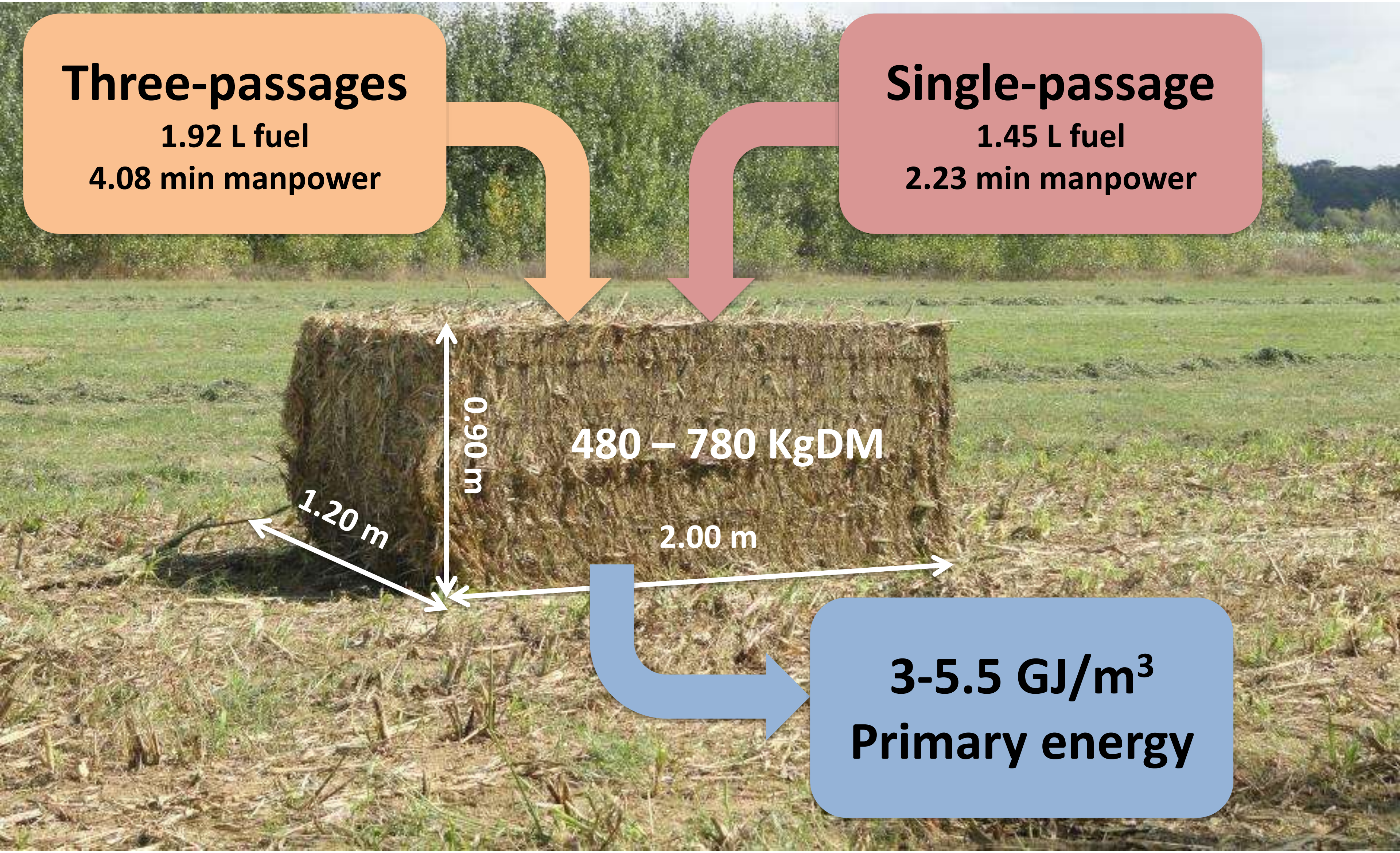


FIELD LOSSES AND OVERALL EFFICIENCY



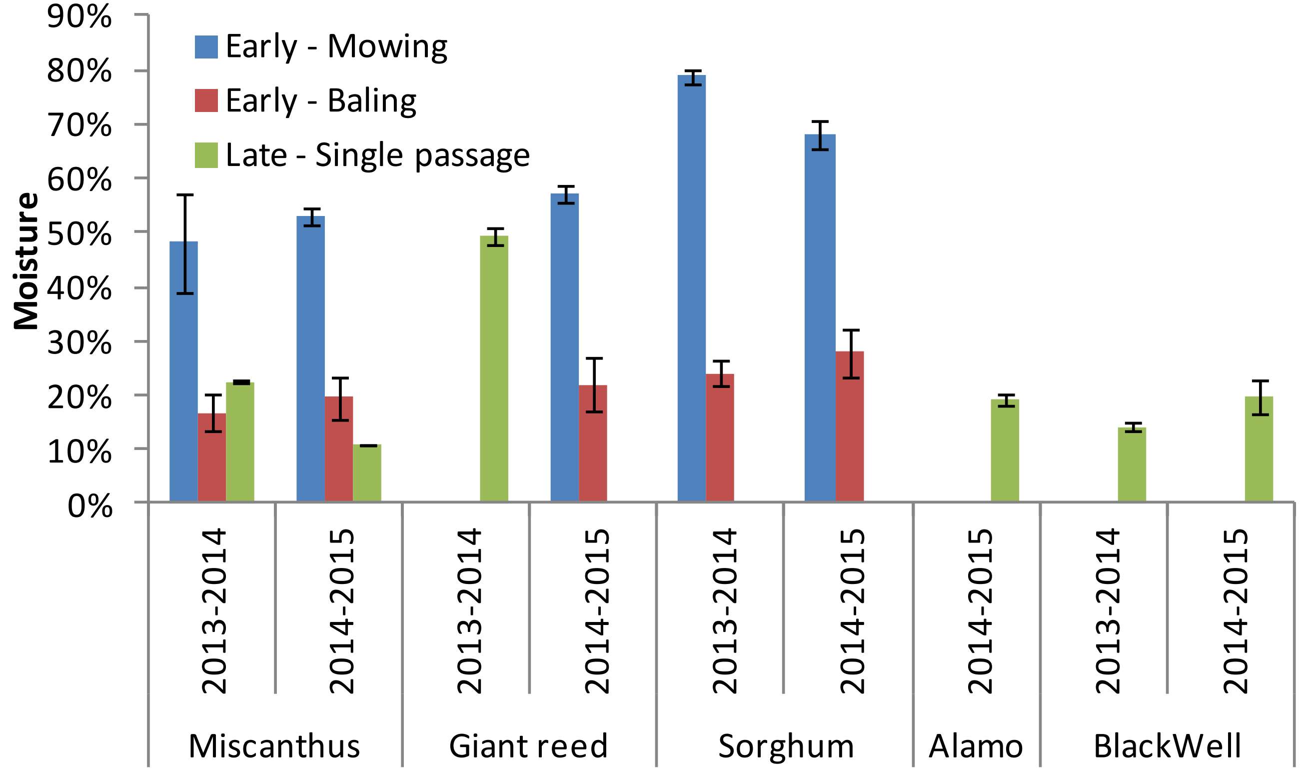
vs Harvestable	*vs* max AGB
87%	*87%*
70%	*50%*

Bales


Three-passages
1.92 L fuel
4.08 min manpower
Single-passage
1.45 L fuel
2.23 min manpower
0.90 m
480 – 780 KgDM
1.20 m
2.00 m
3-5.5 GJ/m^3
Primary energy

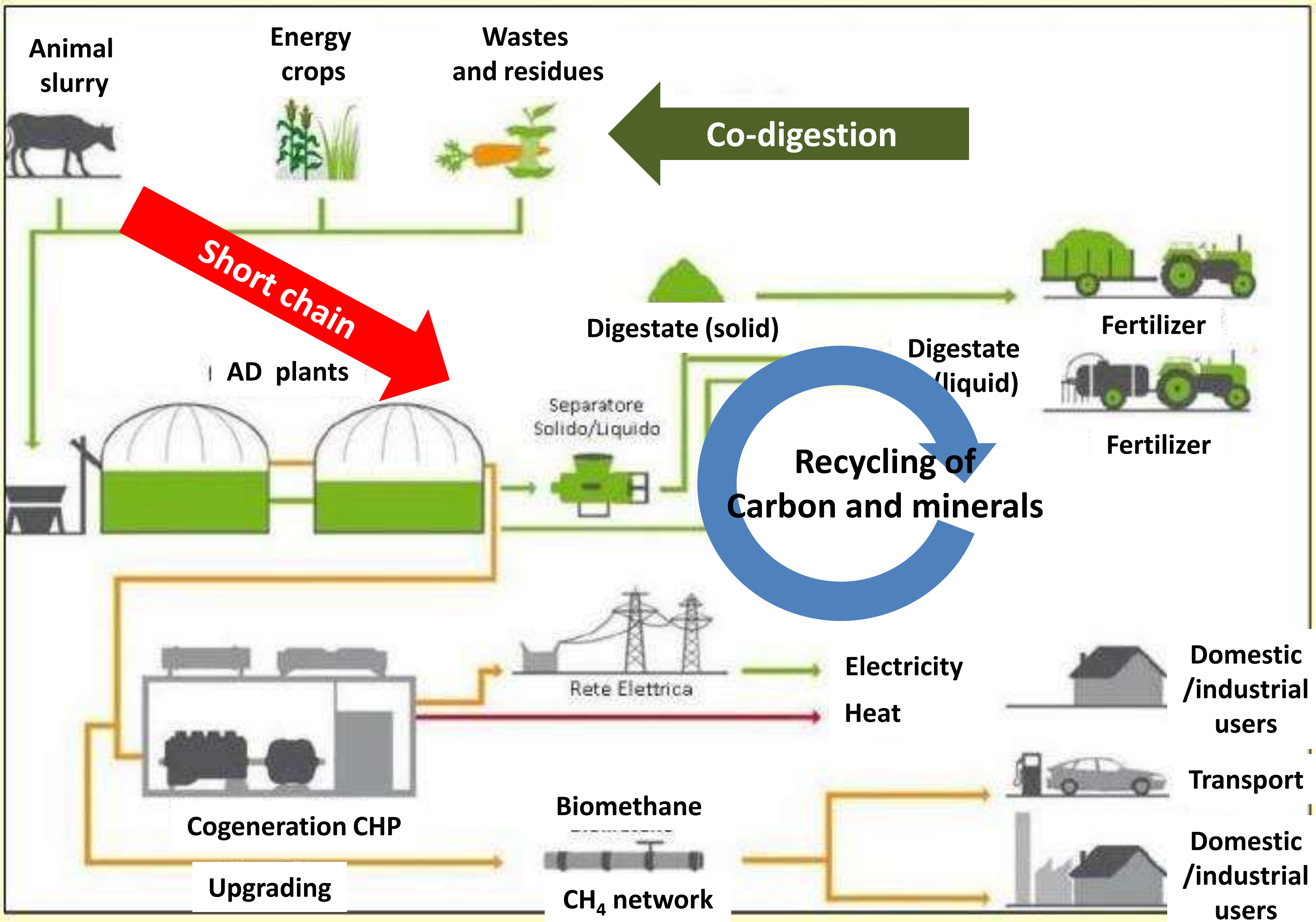

LSB 1290

MOISTURE CONTENT



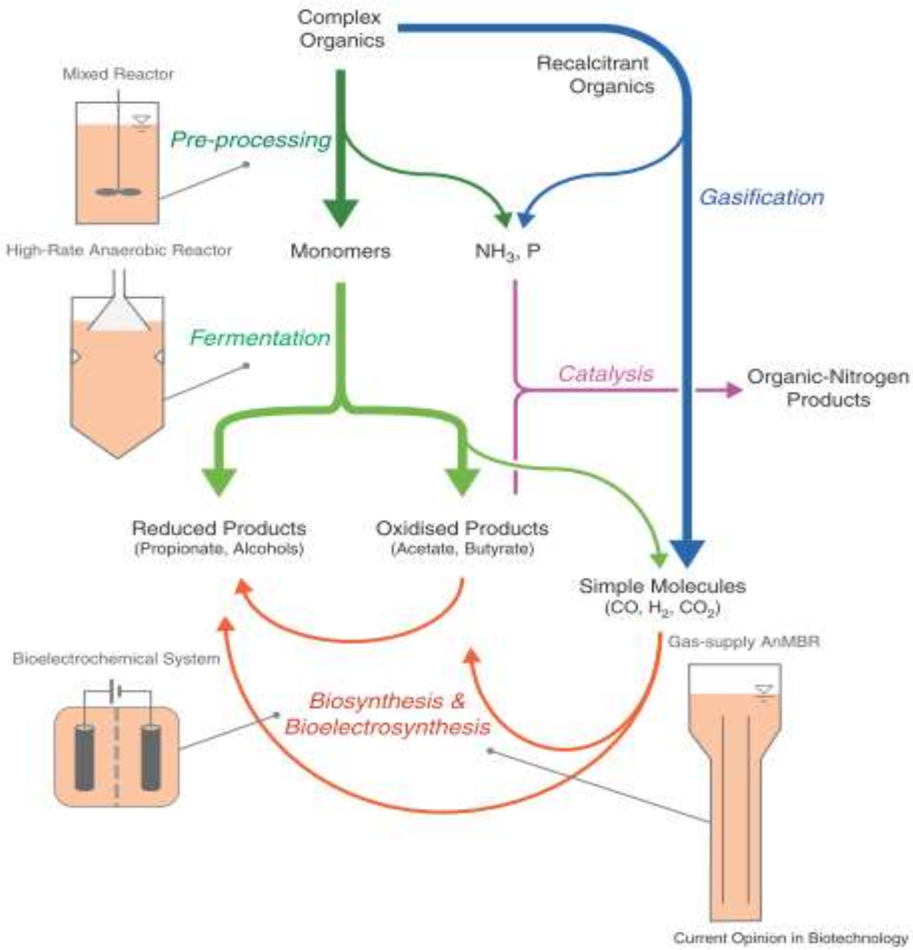

CHUCHI

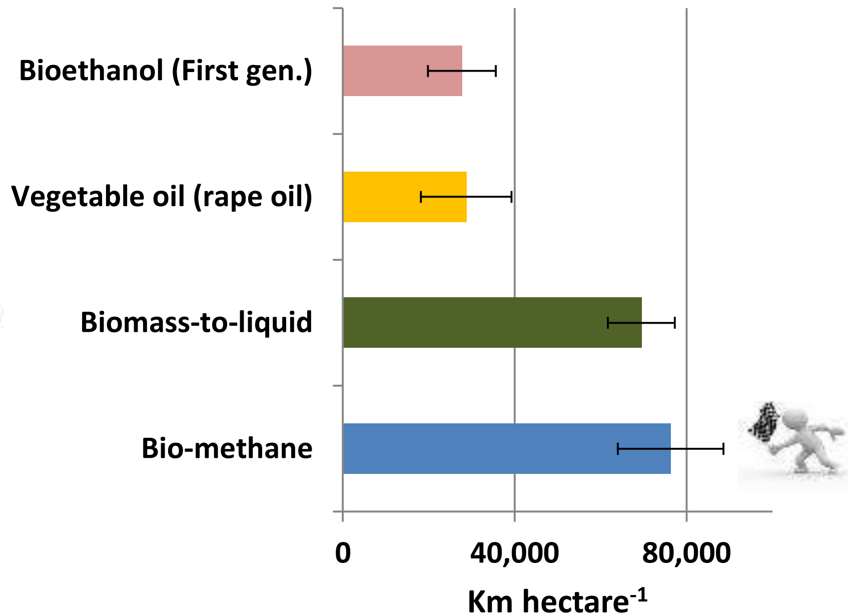
Reasons behind the success of AD



i. Introduction

Biogas production: the anaerobic digestion pathway





Biomethane showed good performances as a biofuel for transportation

Anaerobic digestion can be integrated with several bioenergy supply chains and in a ***biorefinery*** approach

Existing and new technologies can be applied to anaerobic digestion for energy recovery and chemicals production.

D J Batstone, B Virdis (2014). The role of anaerobic digestion in the emerging energy economy, Current Opinion in Biotechnology, 27:142-149

i. Introduction

Perennial grasses have been acknowledged as high-yielding, low input crops, very promising for their GHG and energy balance

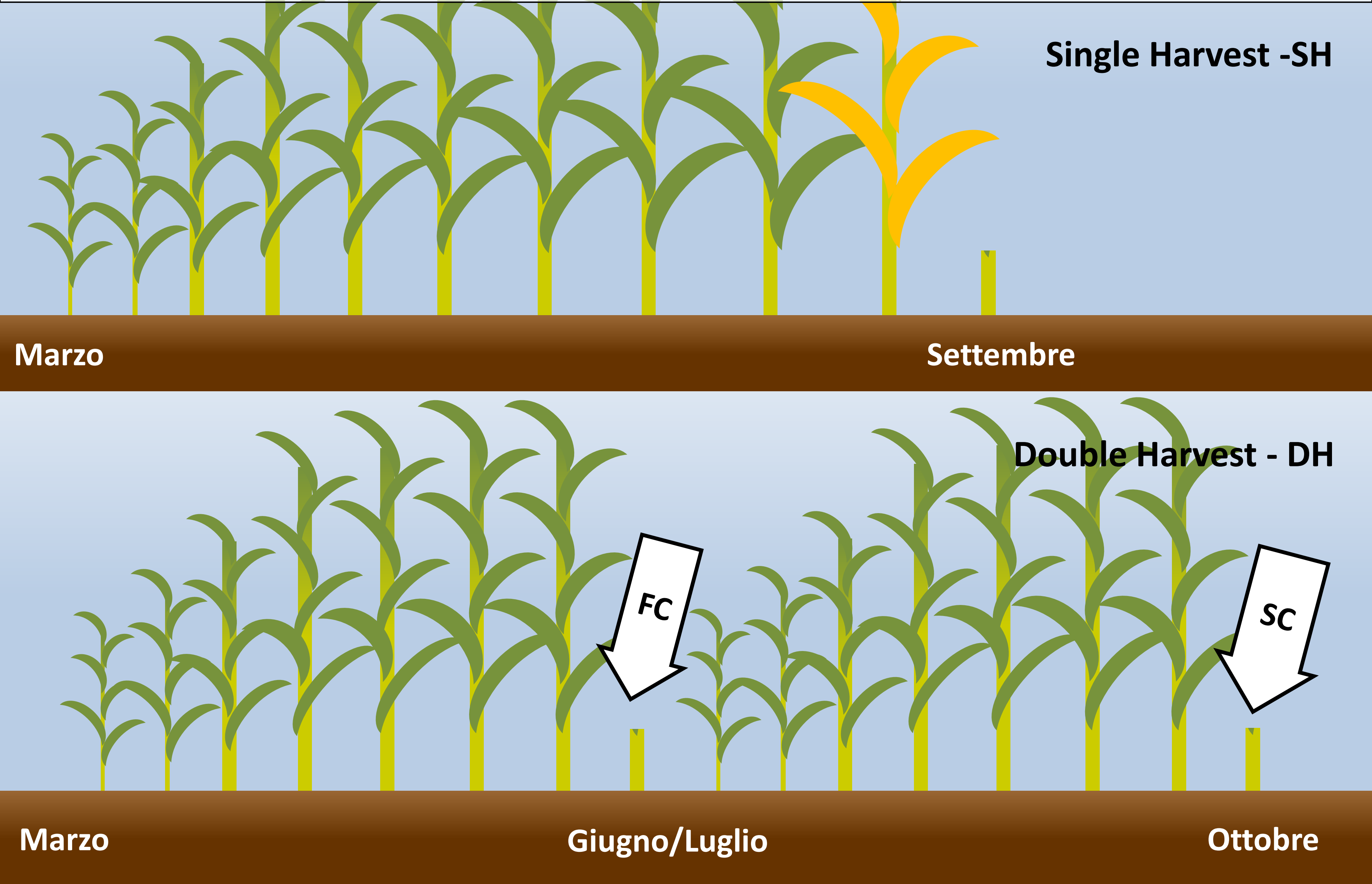
At the same time, annual crops (e.g. maize) have been increasingly used (and criticized) as substrates for biogas production.

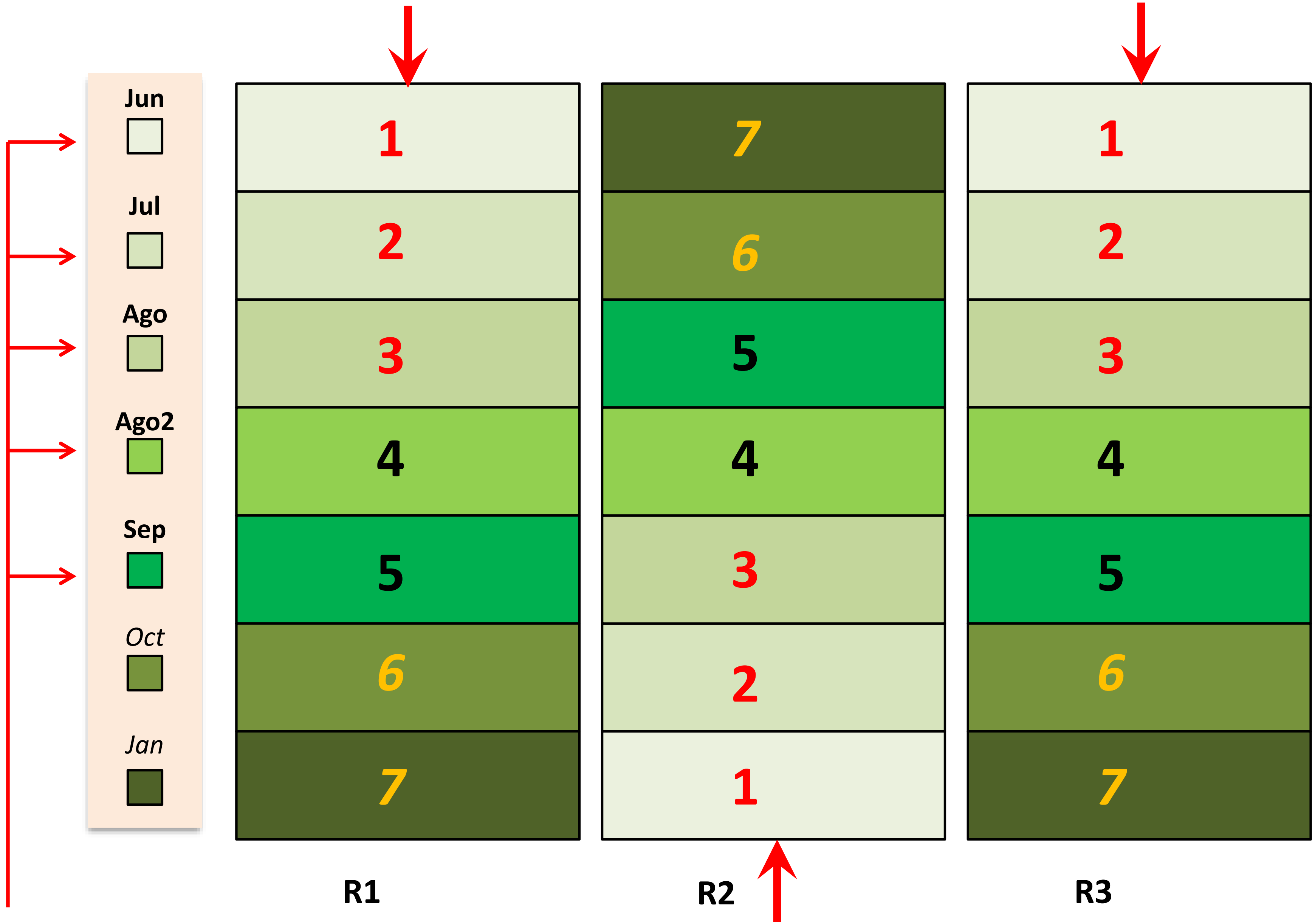
In the last few years, perennial grasses gained interests as potential feedstock for anaerobic digestion.

Crop		Biochemical Methane Potential (BMP)	
Maize	*Zea mais* L.*	312-365 NL $kgVS^{-1}$	Amon et al., 2007
Hemp	*Cannabis sativa* L.	234 NL $kgVS^{-1}$	Kreuger et al., 2011
Switchgrass	*Panicum virgatum* L.	191-309 NL $kgVS^{-1}$	Massé et al., 2010
Reed canary grass	*Phalaris arundinacea* L.	283-315 NL $kgVS^{-1}$	Kandel et al., 2013
Giant reed	*Arundo donax* L.	273 NL $kgVS^{-1}$	Di Gregorio et al., 2013

* FAO 600, milk ripeness

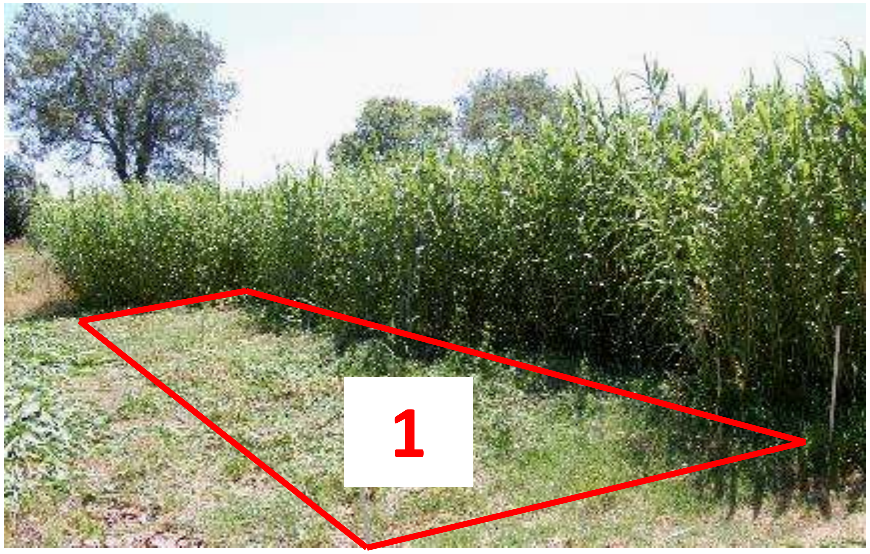
Uno Scenario Alternativo chiamato Giant Reed




Jun
Jul
Ago
Ago2
Sep
Oct
Jan
1
2
3
4
5
6
7
7
6
5
4
3
2
1
1
2
3
4
5
6
7
R1
R2
R3

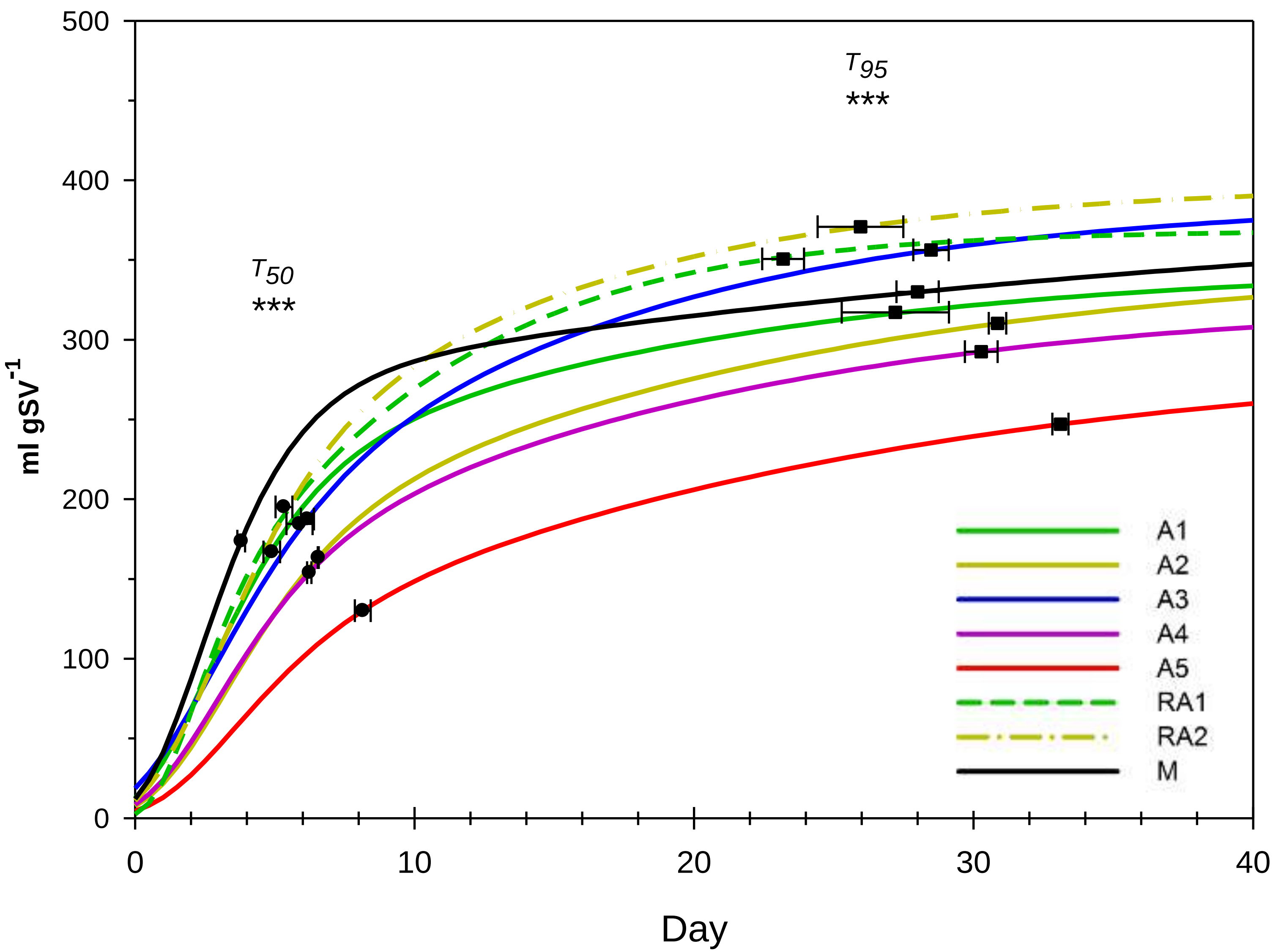
1. 1 Materials and methods

June, after FC



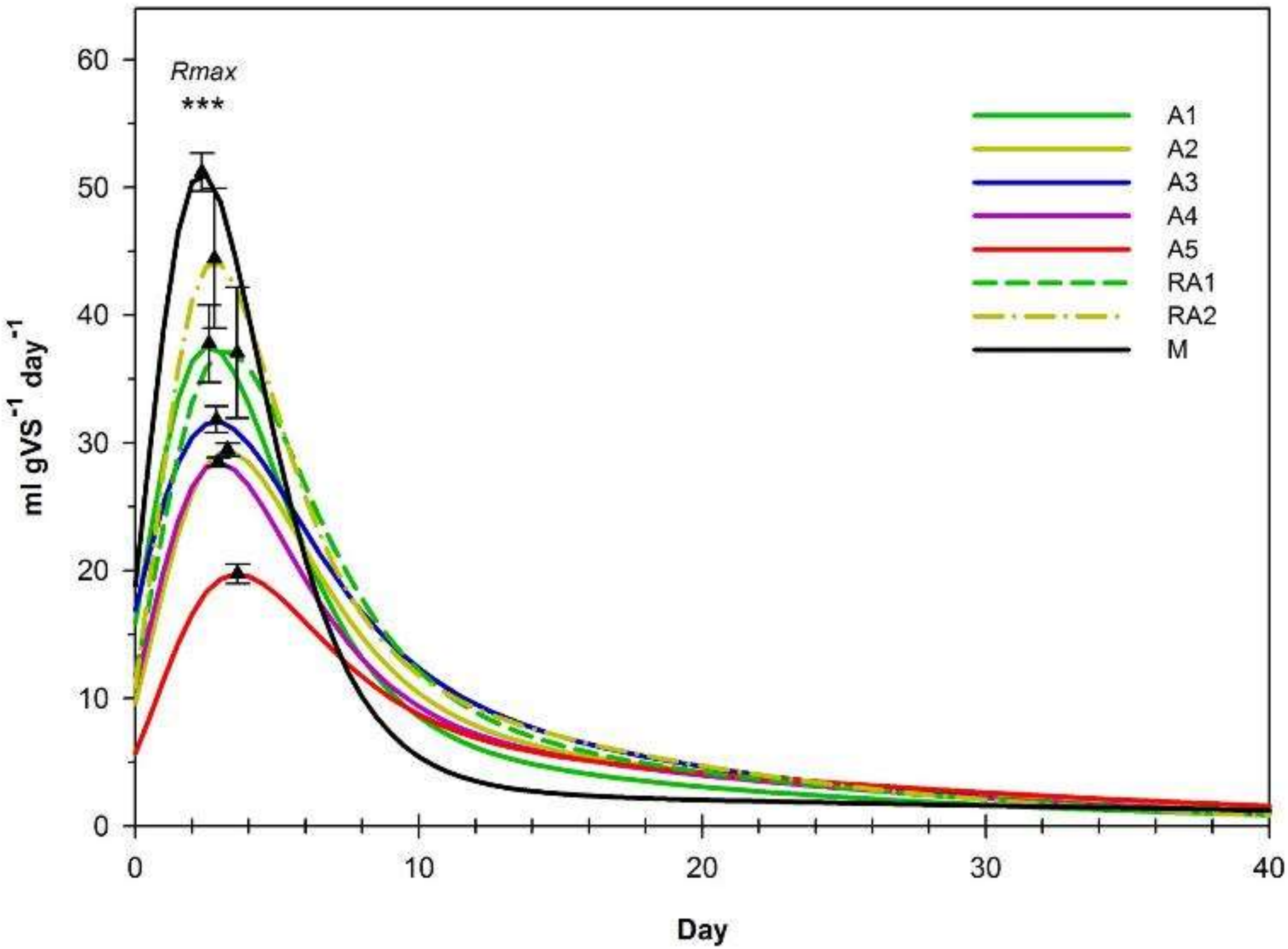
August, crop regrowth before SC

September, crop regrowth before SC

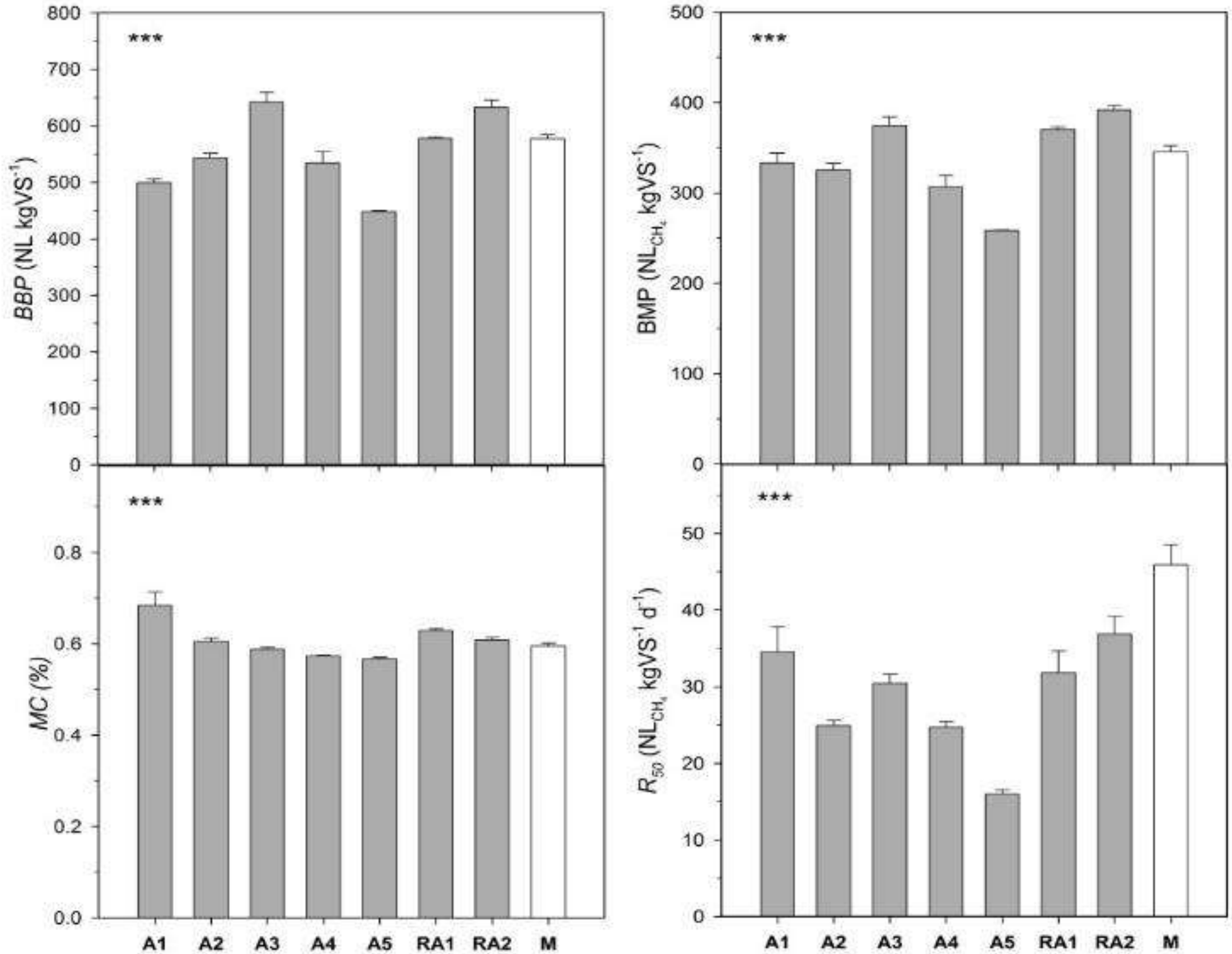


The highest Biochemical Methane Potential (390 NL CH_4 $kgVS^{-1}$) was achieved by RA2, while the lowest was that of A5 (280 NL $kgVS^{-1}$).

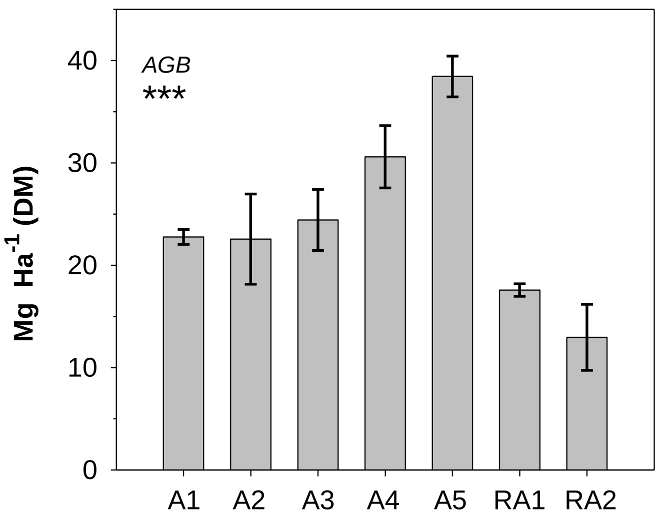
2.2 Results

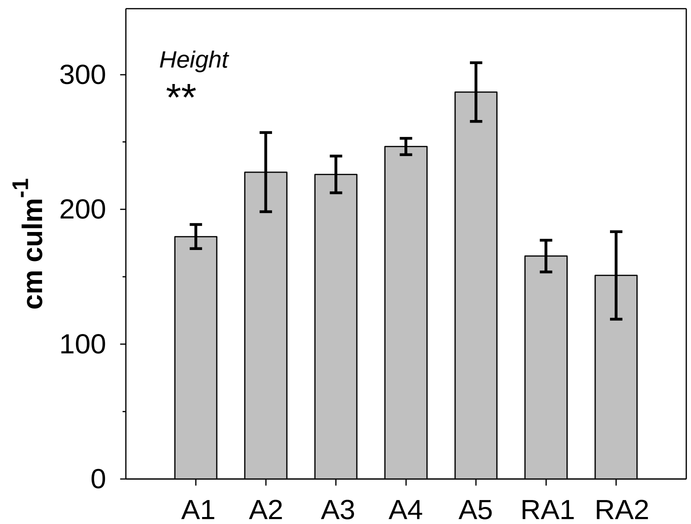


The maximum digestion rate (Rmax) ranged from 51 NL CH_4 kg VS^{-1} (maize) to 20 NL CH_4 kg VS^{-1} day^{-1} (A5).



BBP, BMP, MC and digestion rate (R_{50}) varied significantly between different cuts.



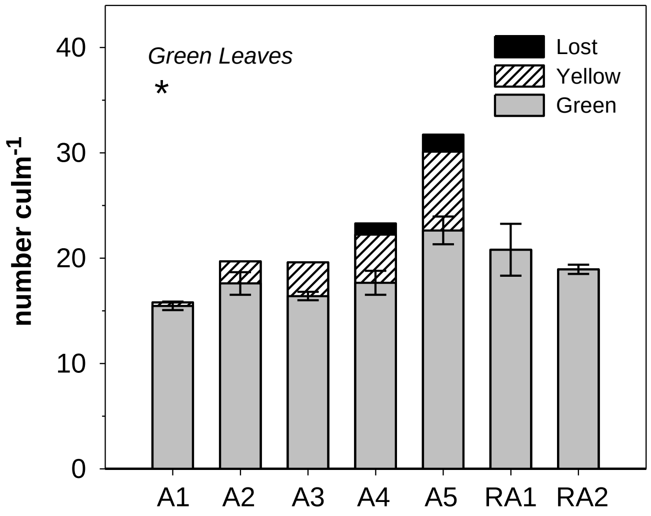


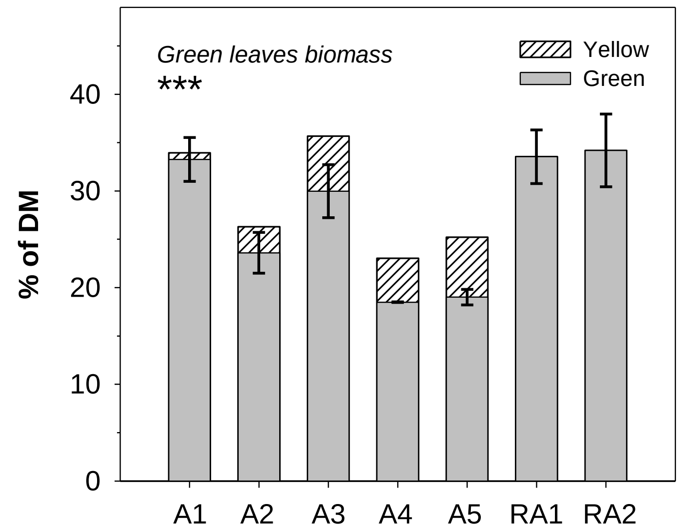
Correlation matrix between anaerobic digestion parameters and biomass/crop characteristics

	Height		Leaves (%)		Green Leaves (%)		TKN (%)		Carbon (%)		C/N		Lignin (%)		NSC (mg g^{-1})	
BMP	-0.84	*	0.82	*	0.84	*	0.78	*	-0.53	ns	-0.83	*	0.49	ns	0.44	ns
BBP	-0.58	ns	0.64	ns	0.58	ns	0.51	ns	-0.16	ns	-0.56	ns	0.48	ns	0.43	ns
MC	-0.69	ns	0.57	ns	0.72	ns	0.76	*	-0.9	**	-0.77	*	0.06	ns	-0.16	ns
T_{50}	0.87	*	-0.65	ns	-0.78	*	-0.85	*	0.75	ns	0.86	*	-0.16	ns	-0.09	ns
T_{95}	0.92	***	-0.75	ns	-0.87	*	-0.75	*	0.71	ns	0.78	*	-0.53	ns	-0.47	ns
R_{max}	-0.98	***	0.74	ns	0.88	**	0.93	***	-0.79	*	-0.92	***	0.18	ns	0.42	ns
R_{50}	-0.94	***	0.82	*	0.91	***	0.93	***	-0.75	ns	-0.94	***	0.23	ns	0.33	ns

Plant height increased along the seasons, thus being an indicator of crop maturity

2.2 Results





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R_{max}	-0.98 ***	0.74 ns	0.88 **	0.93 ***	-0.79 *	-0.92 ***	0.18 ns	0.42 ns
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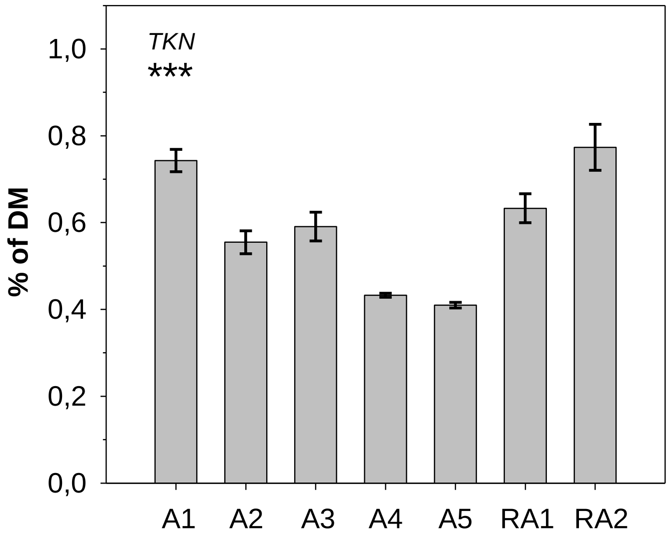

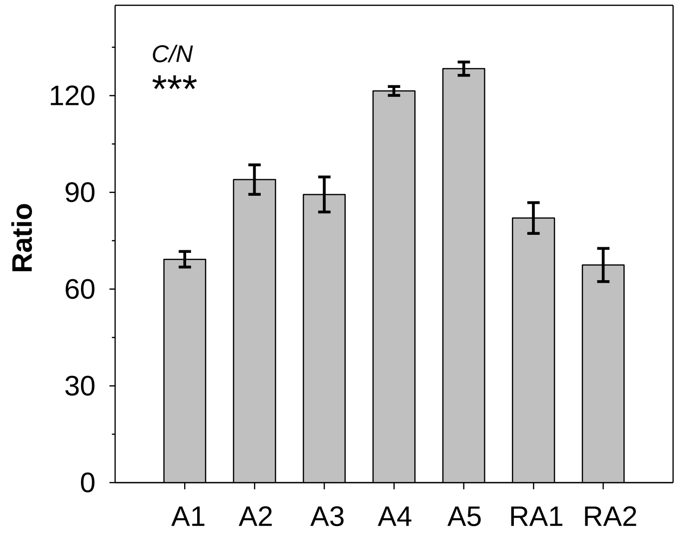

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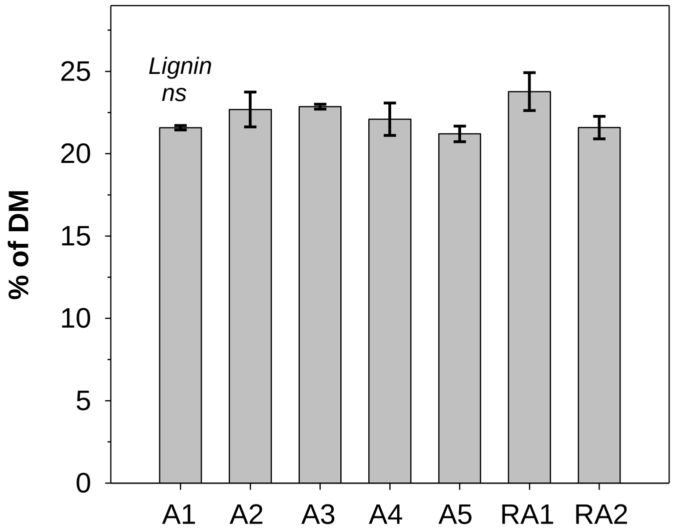

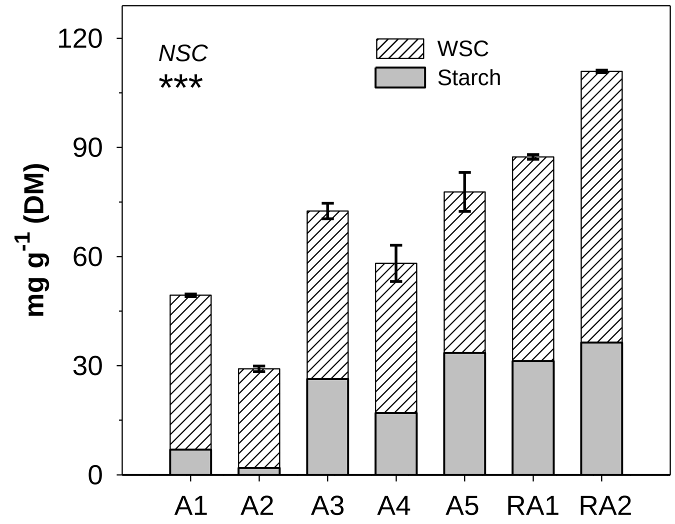

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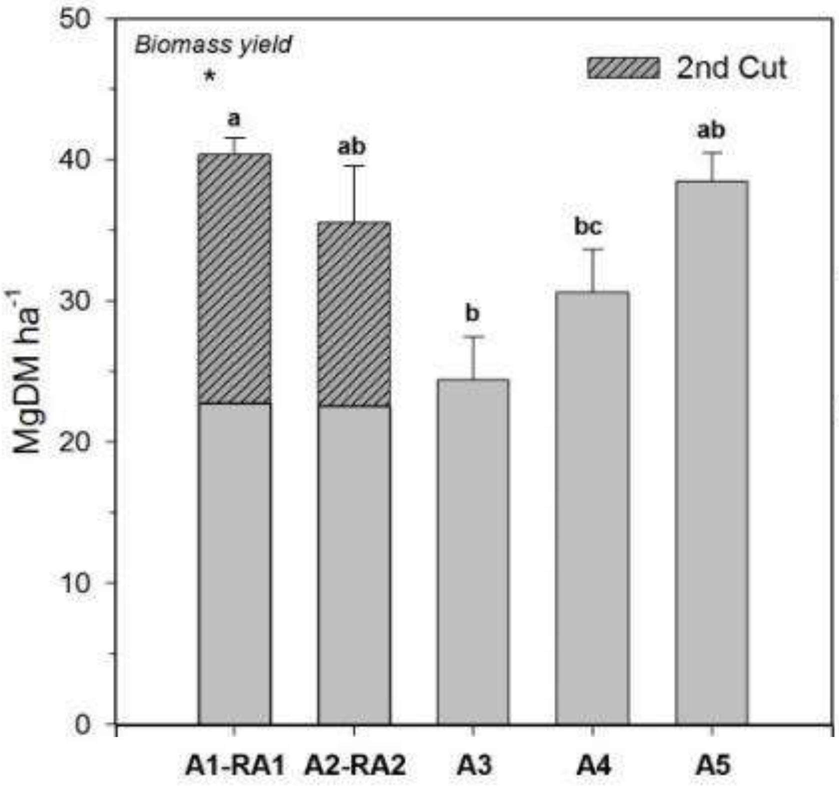
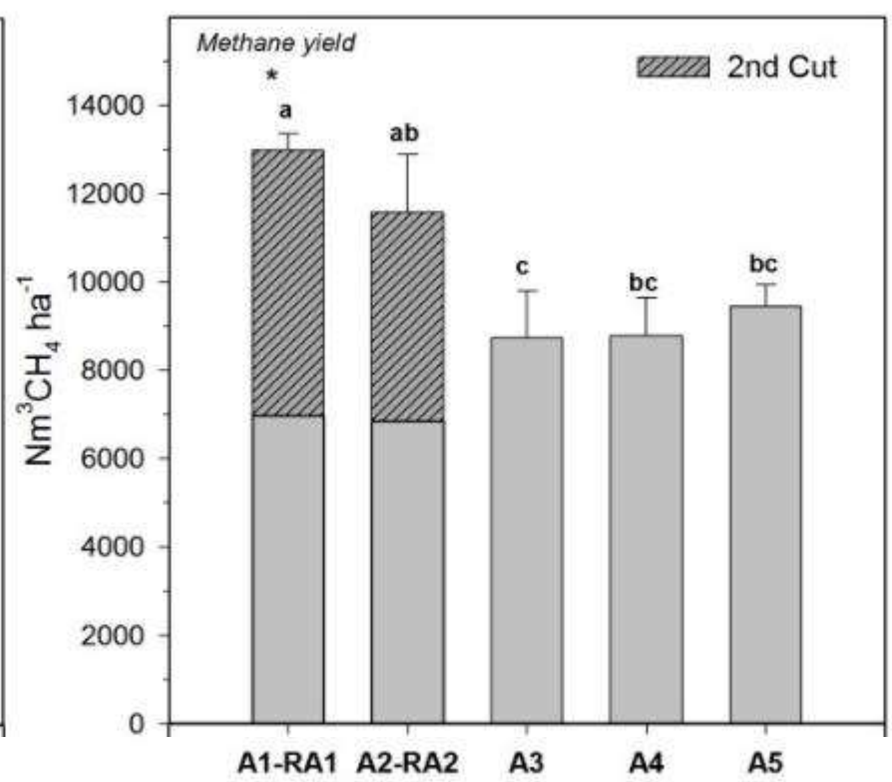




A1+RA1, based on first cut in *June* and second cut in *October*, showed the highest methane yield per hectare, as a result of high yields and high digestibility.

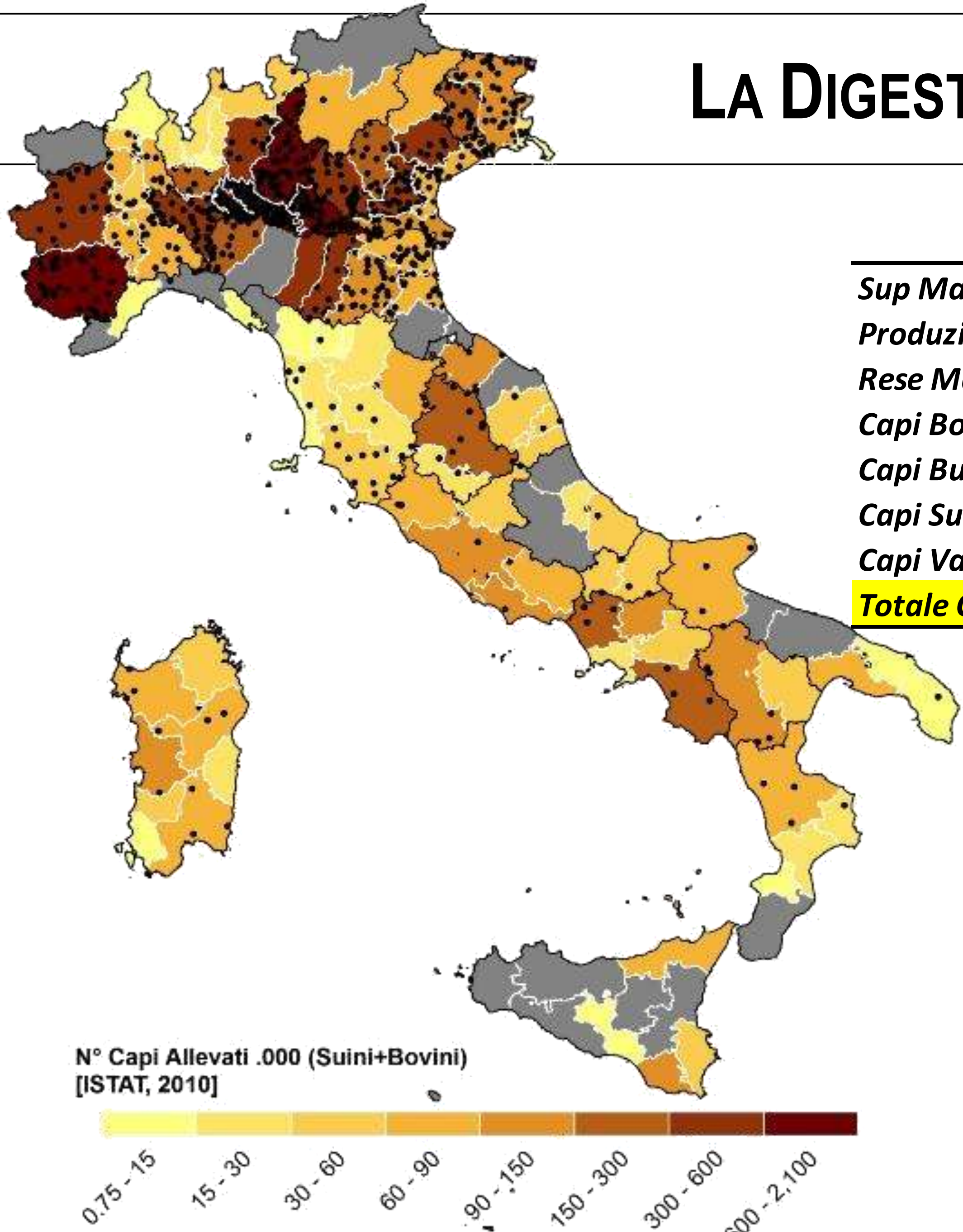
M: ~6500 Nm^3 CH_4 ha^{-1} (considering 20 Mg ha^{-1} dm)

A1+RA1: ~13000 Nm^3 CH_4 ha^{-1} (about 50% at FC)

A2+RA2: ~11500 Nm^3 CH_4 ha^{-1} (about 50% at FC)

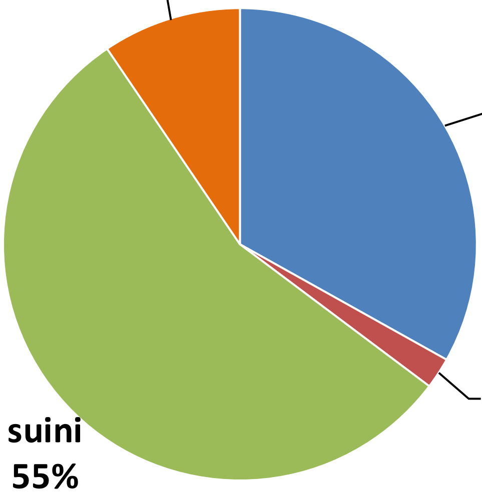
A5: ~9000 Nm^3 CH_4 ha^{-1}

La Digestione Anaerobica in Italia

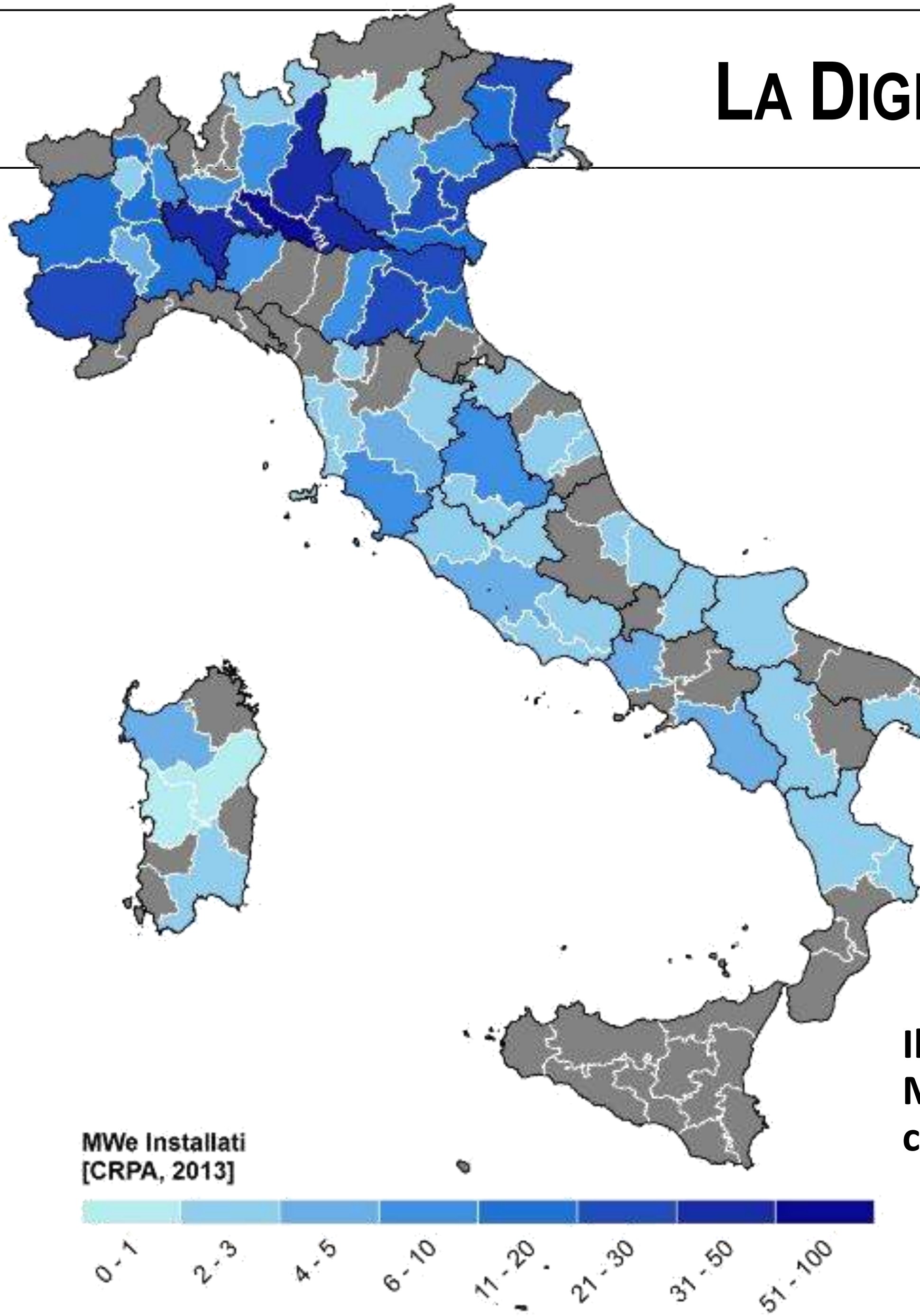


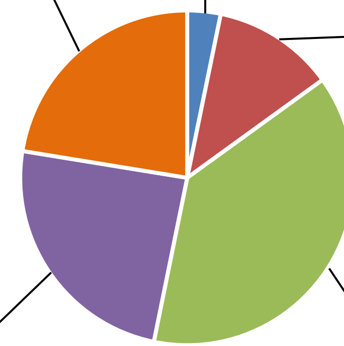
	N° Impianti DA	Potenze kWe
	r (spearman)	r (spearman)
Sup Mais Ceroso	0.56 ***	0.54 ***
Produzione Mais Ceroso	0.56 ***	0.55 ***
Rese Mais Ceroso	0.33 **	0.36 **
Capi Bovini	0.55 ***	0.45 ***
Capi Bufalini	0.11 *ns*	0.12 *ns*
Capi Suini	0.74 ***	0.72 ***
Capi Vacche Latte	0.54 ***	0.47 ***
Totale Capi	0.71 ***	0.63 ***

16,883,750 capi



LA DIGESTIONE ANAEROBICA IN ITALIA

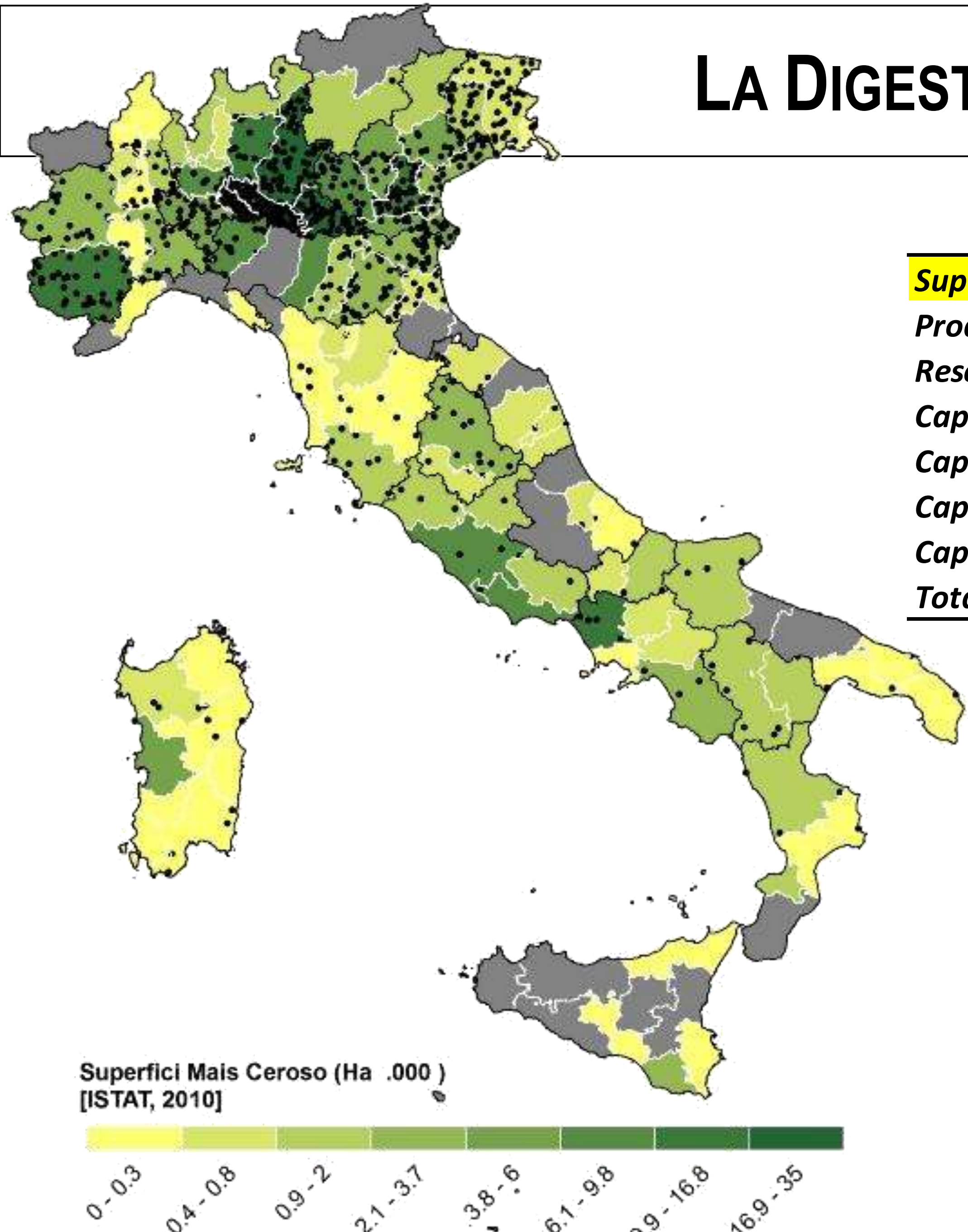




Il 72% della potenza elettrica installata (653 MWe) basa il proprio approvvigionamento su **colture da biomassa**

Fabbri et al., 2013

LA DIGESTIONE ANAEROBICA IN ITALIA



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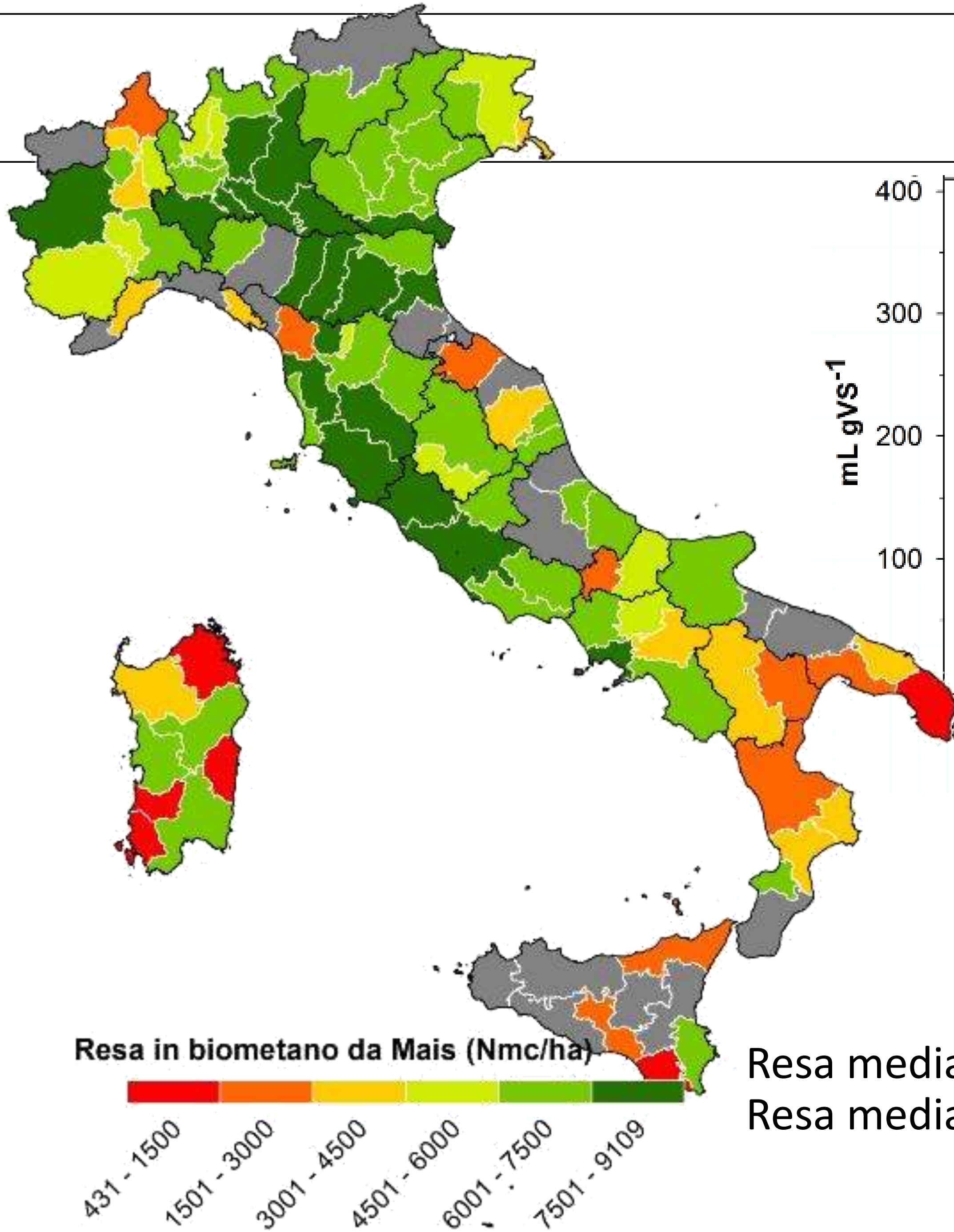
Capi Bufalini	0.11	*ns*	0.12	*ns*
Capi Suini	0.74	***	0.72	***
Capi Vacche Latte	0.54	***	0.47	***
Totale Capi	0.71	***	0.63	***

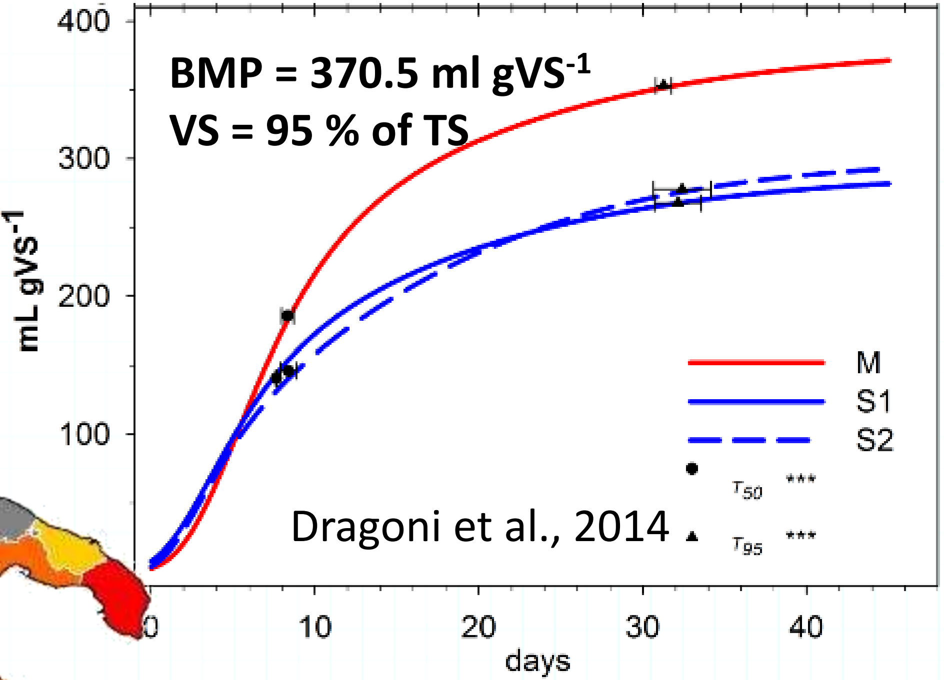
Superficie: 290,700 ha

Produzione: 16,635,000 t FM

Resa media: 570 qli ha^{-1}

Potenzialità del Mais

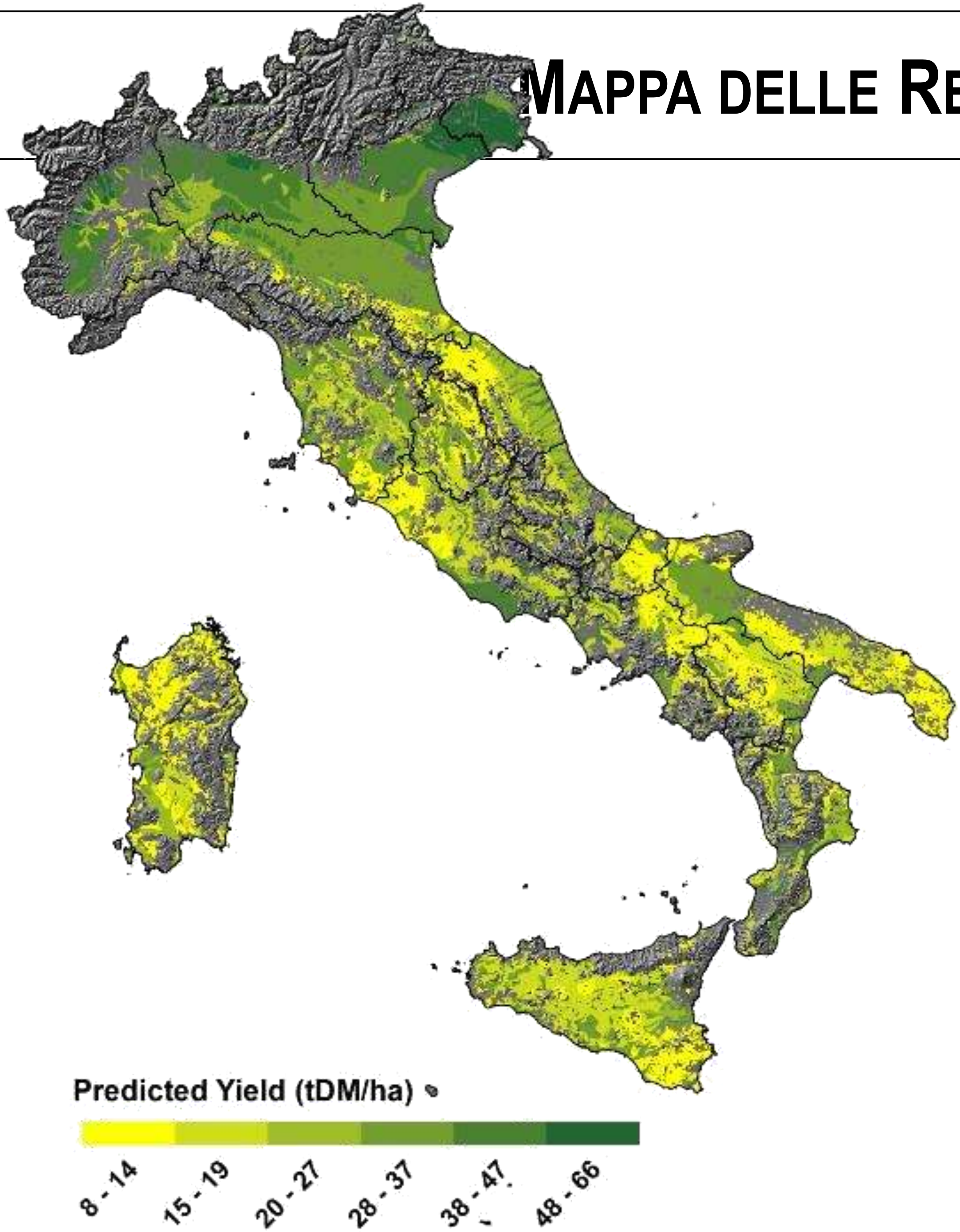




Resa media mais = **18.3 (±4.4) tDM**

Resa media biometano = **6434 (±1554) Nm ha^{-1}**

Mappa delle Rese Potenziali di Arundo



CROP

RUE = 5.74 g MJ^{-1} (Ceotto et al., 2013)
avgLAI = 3.5 > 0.85 *f*_IPAR
WUE = 3.2 g L^{-1} (Triana et al., 2014)
Tb = 6 °C (Nassi o Di Nasso et al., 2012)
ΣHU – vegetative season

CLIMATE (15 year data UCEA)

RAD
Tmed
Ptot

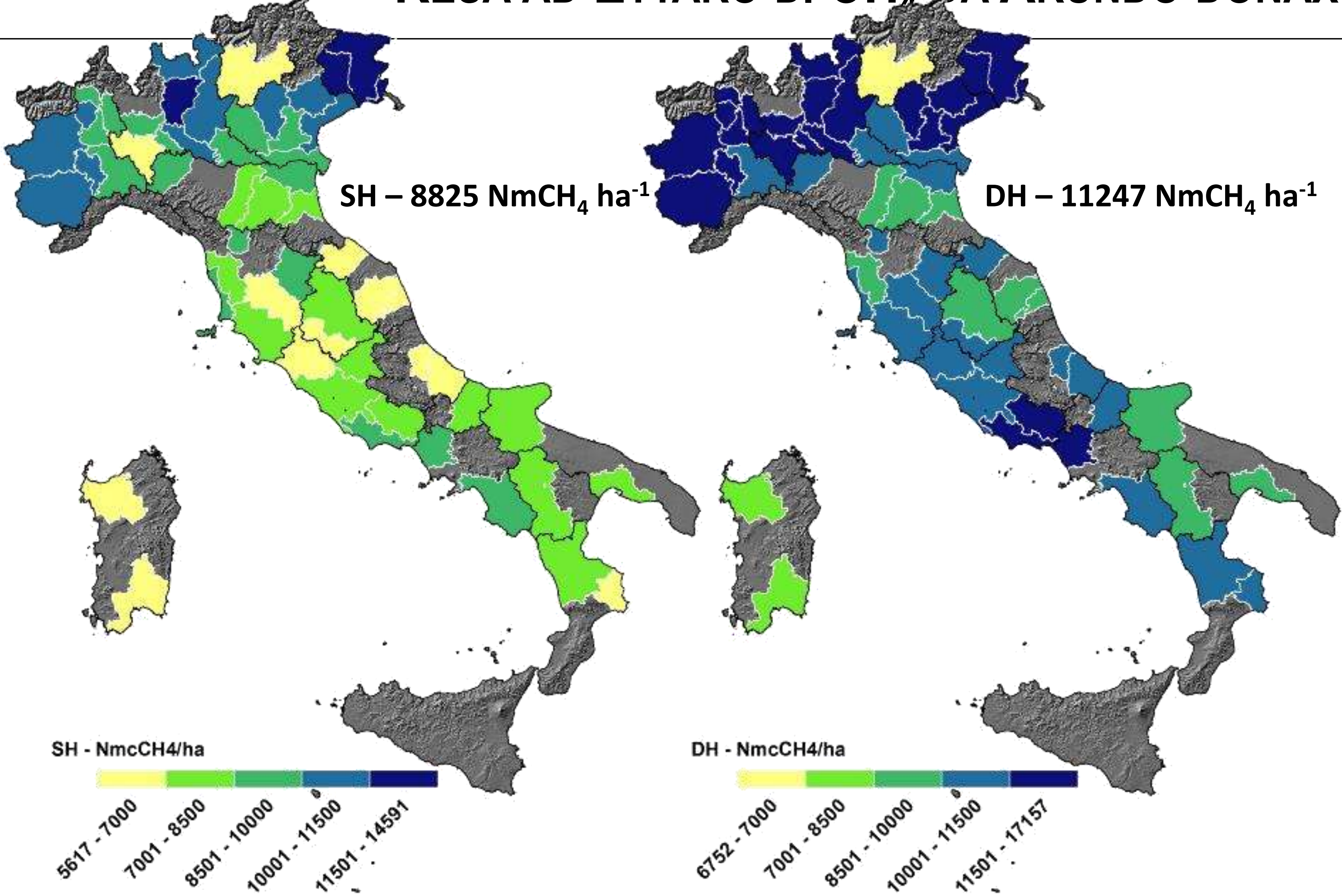
SOIL (ESDB)

Texture
Bulk Density
OM
Depth
Pedotransfert function
Ground Water Level

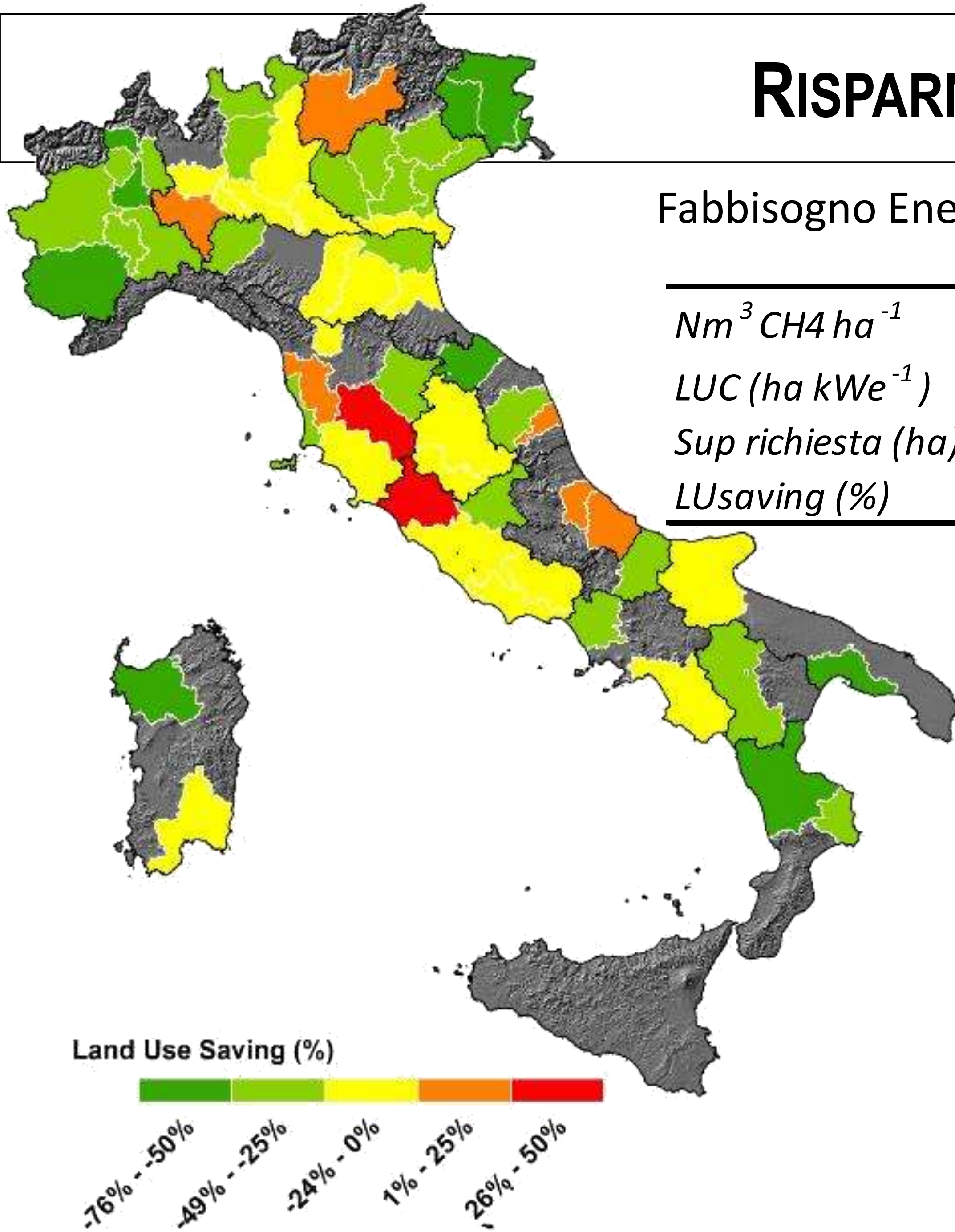
GEOGRAPHICAL CONSTRAINTS

Soil Use (211 of CORINE 2006)
Slope (DTM 75m)

RESA AD ETTARO DI CH_4 DA ARUNDO DONAX



RISPARMIO DI SUOLO – SH VS MAIS



Fabbisogno Energia primaria **= 22.514.150 GJ anno^{-1}**

	Mais	**Arundo SH**
Nm^3 CH4 ha^{-1}	6434 (± 1554)	8825 (± 1956)
LUC (ha kWe^{-1})	0.45 (±0.16)	0.32 (±0.07)
Sup richiesta (ha)	92,143	66,645
LUsaving (%)		-28

RISPARMIO DI SUOLO – SH VS MAIS

Fabbisogno Energia primaria **= 22.514.150 GJ anno^{-1}**

	Mais	**Arundo DH**
Nm^3 CH4 ha^{-1}	6434 (± 1554)	11247 (± 1932)
LUC (ha kWe^{-1})	0.45 (±0.16)	0.24 (±0.04)
Sup richiesta (ha)	92,143	53,804
LUsaving (%)		-42