

Protein production with low environmental impacts

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European agriculture faces numerous challenges

Productivity

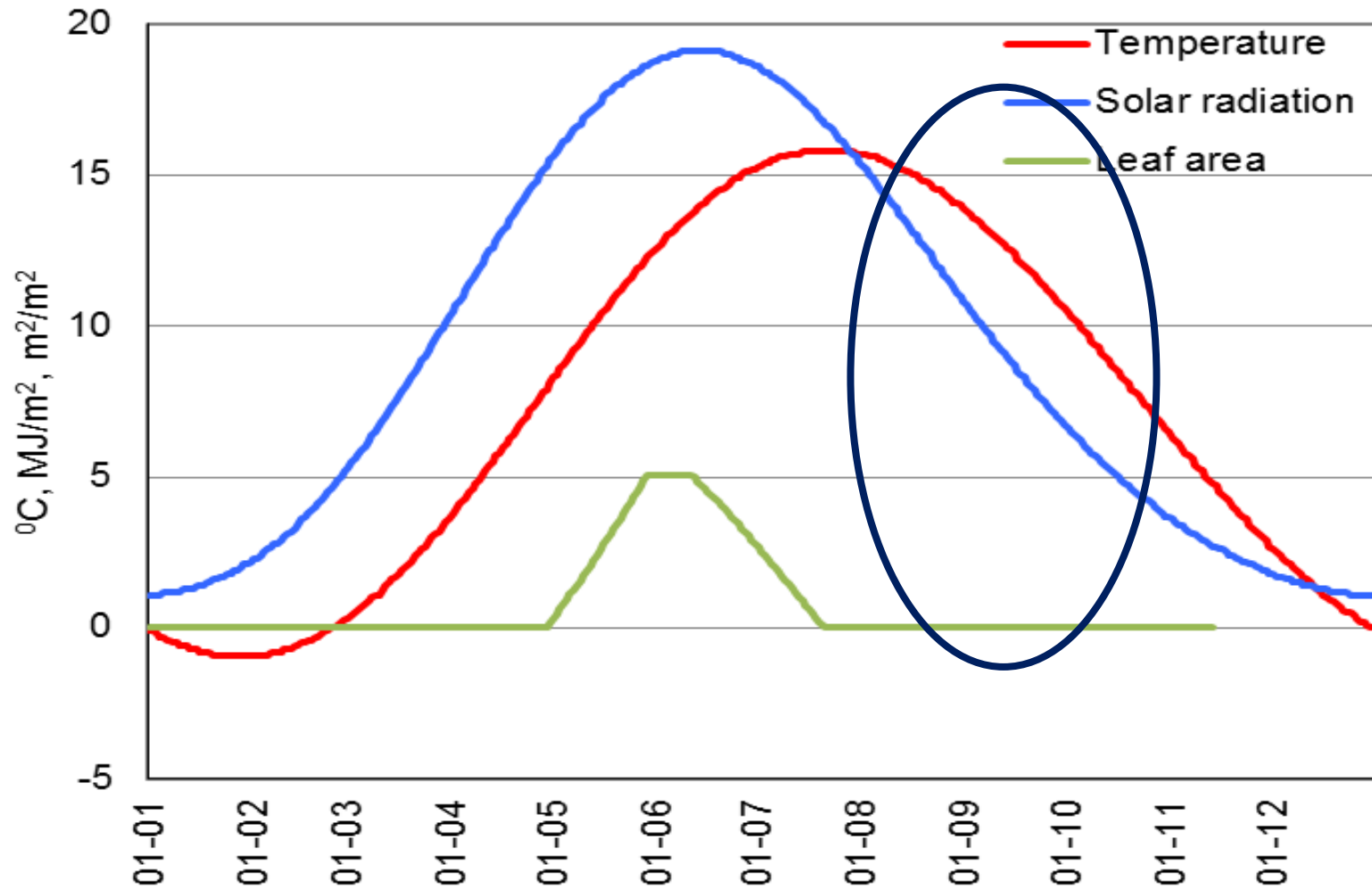
- Biomass for food, feed, material and energy
- Stagnating yields
- Large import of protein feed

Environment

- High nutrient leaching (Nitrate and Water Framework Directives)
- High pesticide use
- Agriculture must contribute to EU climate goals (EU climate policy)

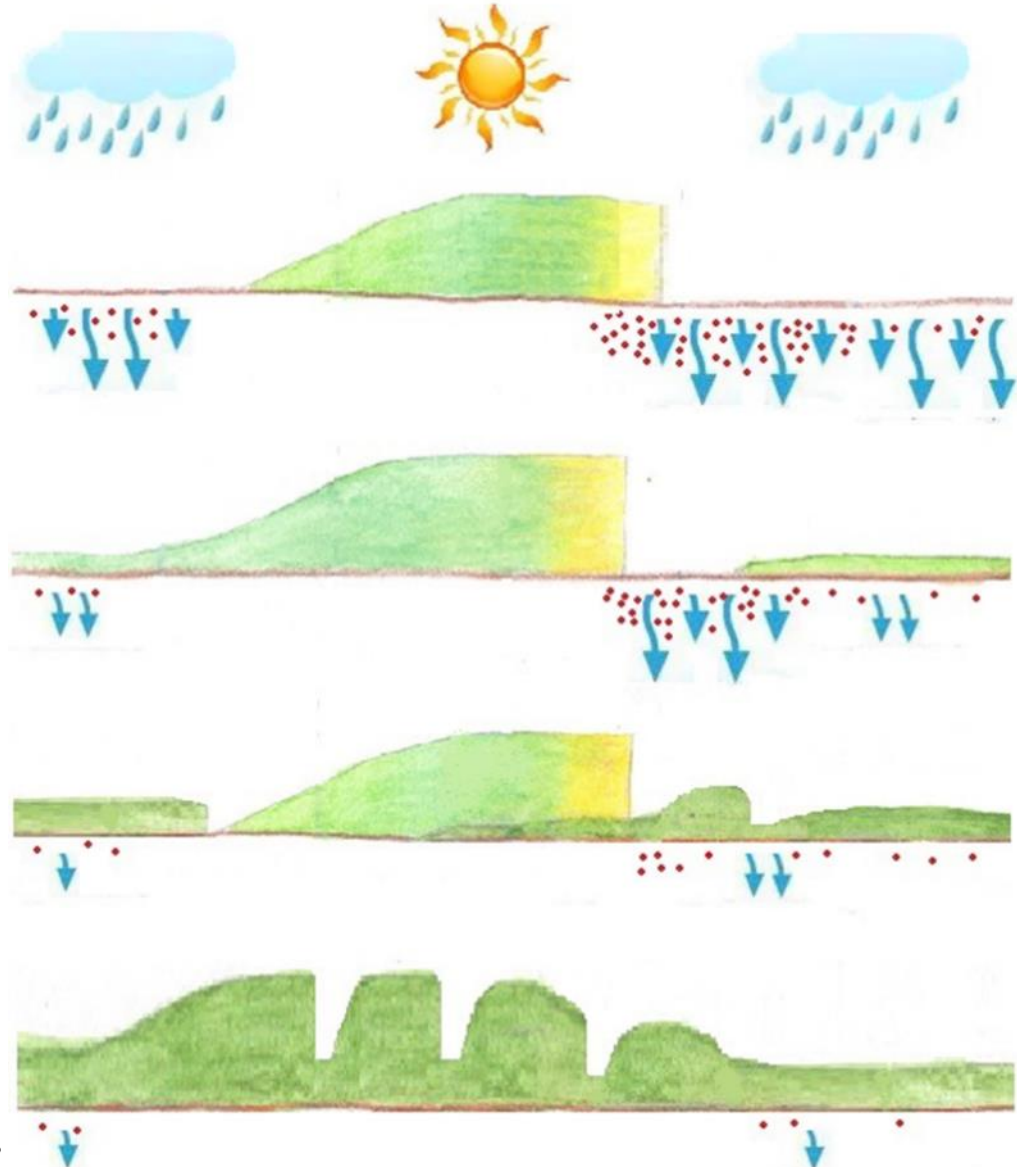
The answer may be sustainable intensification – more with less!

Why do we mainly grow grain crops that utilize only part of the growing season? Case: spring barley in Denmark



Tightening the nitrogen (N) cycle

- ↓ Soil water (drainage)
- Soil nitrate (leaching)



Production systems designed to cover the whole year investigated

Optimized Crop Rotation

- Energy maize + Winter rye (direct sowing end October)
- Energy beets
- Hemp + Triticale
- Triticale early harvest (10-15 July) + undersown grass clover (two cuts: autumn and spring)

Conventional crop rotation

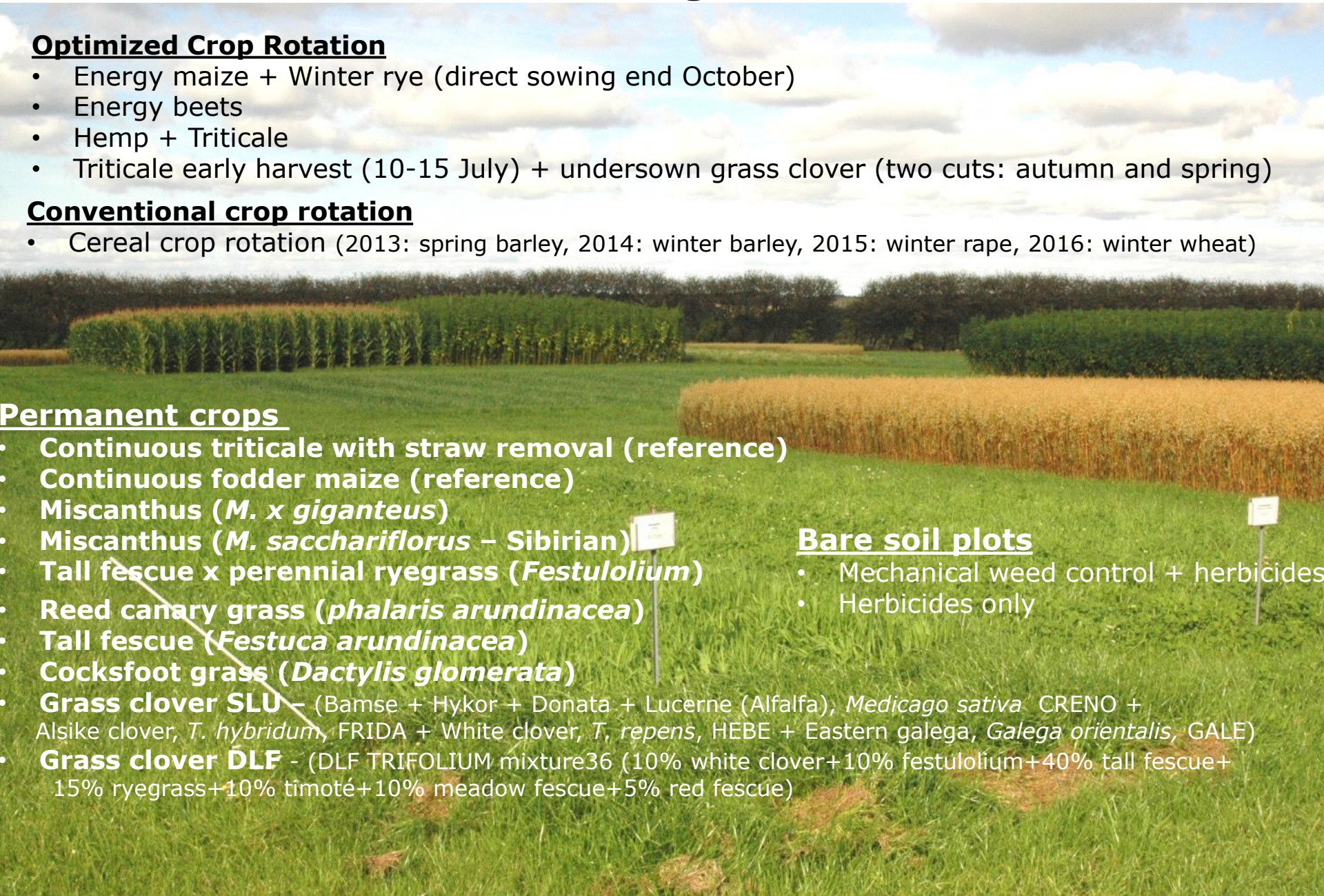
- Cereal crop rotation (2013: spring barley, 2014: winter barley, 2015: winter rape, 2016: winter wheat)

Permanent crops

- Continuous triticale with straw removal (reference)
- Continuous fodder maize (reference)
- Miscanthus (*M. x giganteus*)
- Miscanthus (*M. sacchariflorus* – Sibirian)
- Tall fescue x perennial ryegrass (*Festulolium*)
- Reed canary grass (*phalaris arundinacea*)
- Tall fescue (*Festuca arundinacea*)
- Cocksfoot grass (*Dactylis glomerata*)
- Grass clover SLU – (Bamse + Hykor + Donata + Lucerne (Alfalfa), *Medicago sativa* CRENO + Alsike clover, *T. hybridum*, FRIDA + White clover, *T. repens*, HEBE + Eastern galega, *Galega orientalis*, GALE)
- Grass clover DLF - (DLF TRIFOLIUM mixture36 (10% white clover+10% festulolium+40% tall fescue+15% ryegrass+10% timoté+10% meadow fescue+5% red fescue)

Bare soil plots

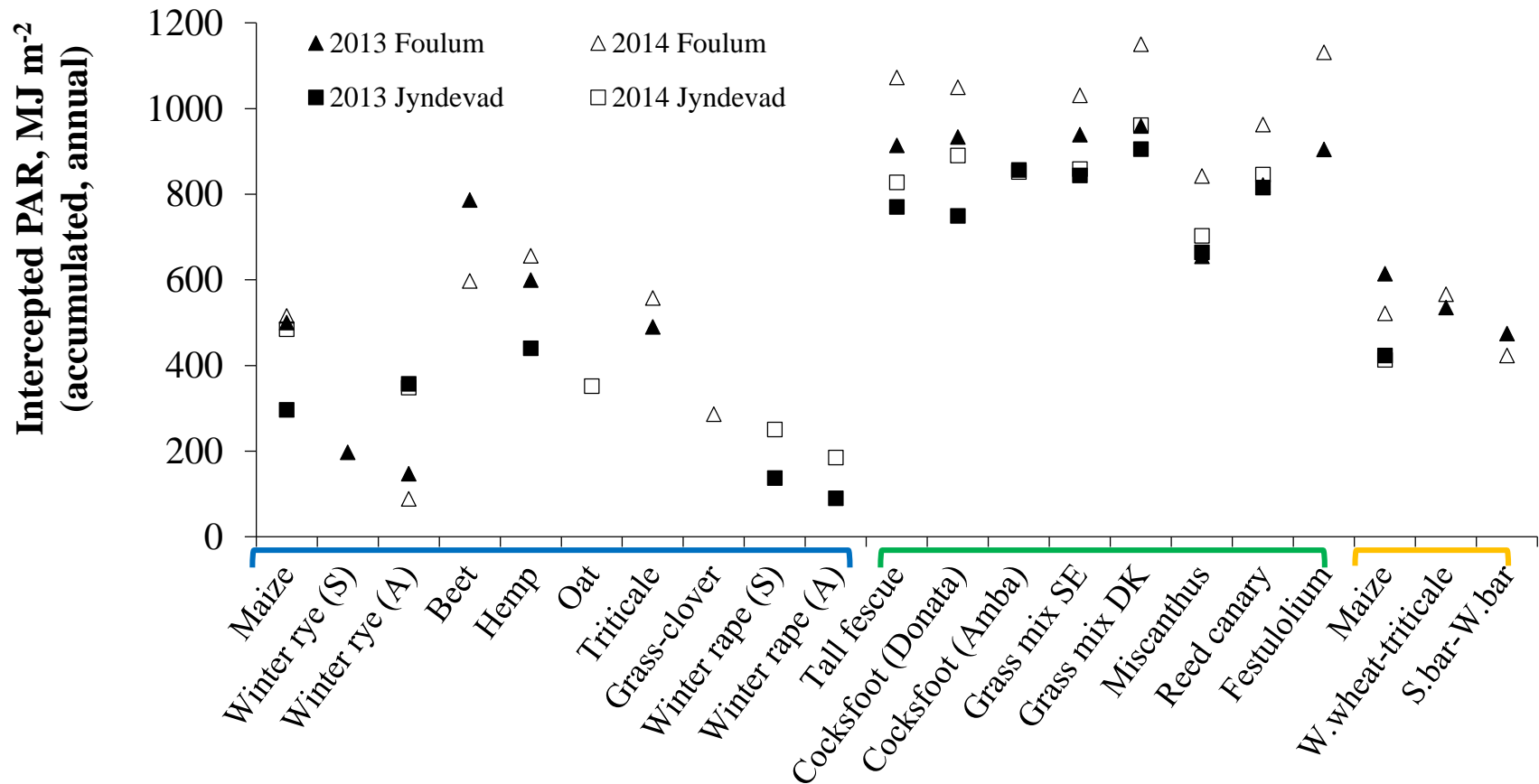
- Mechanical weed control + herbicides
- Herbicides only



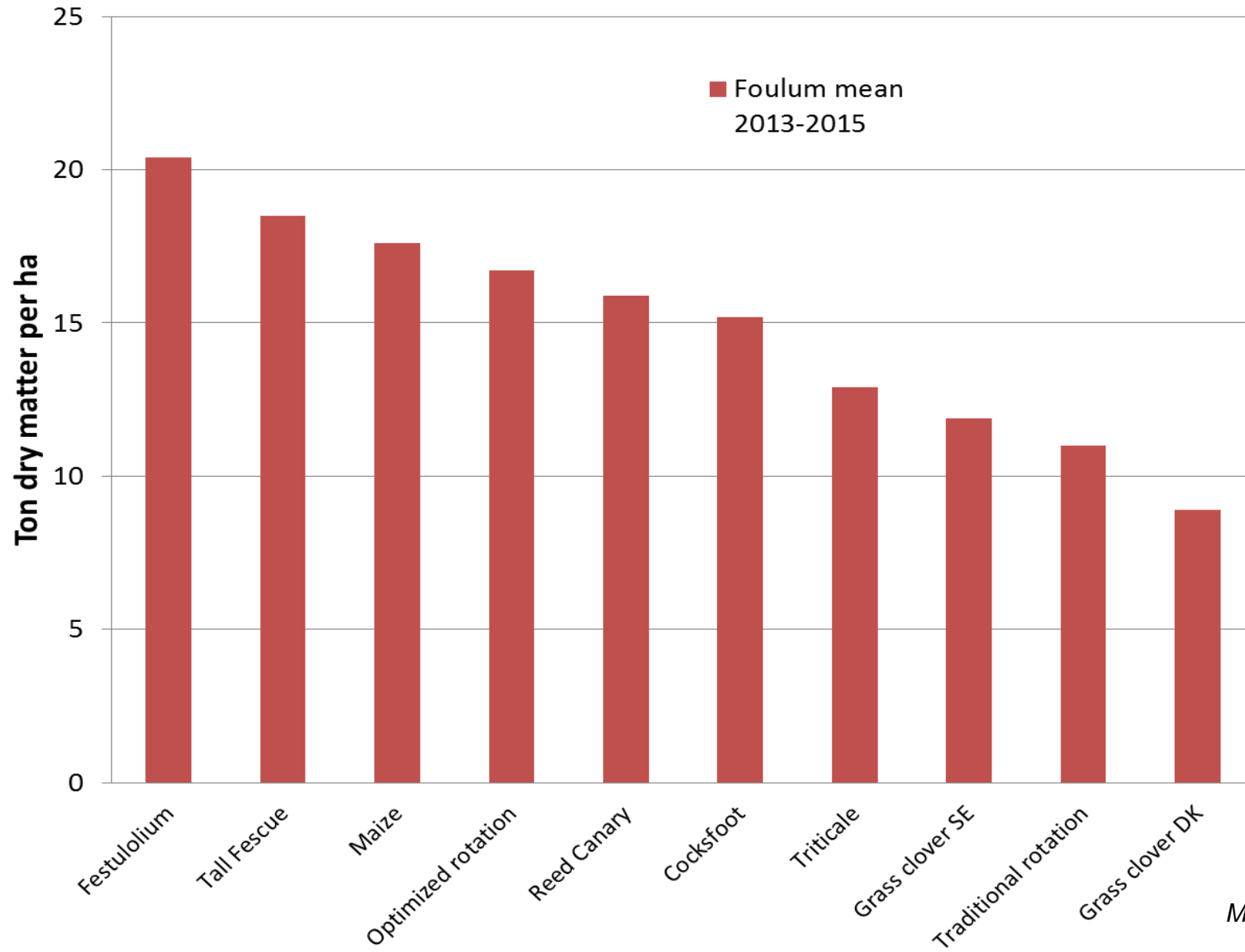




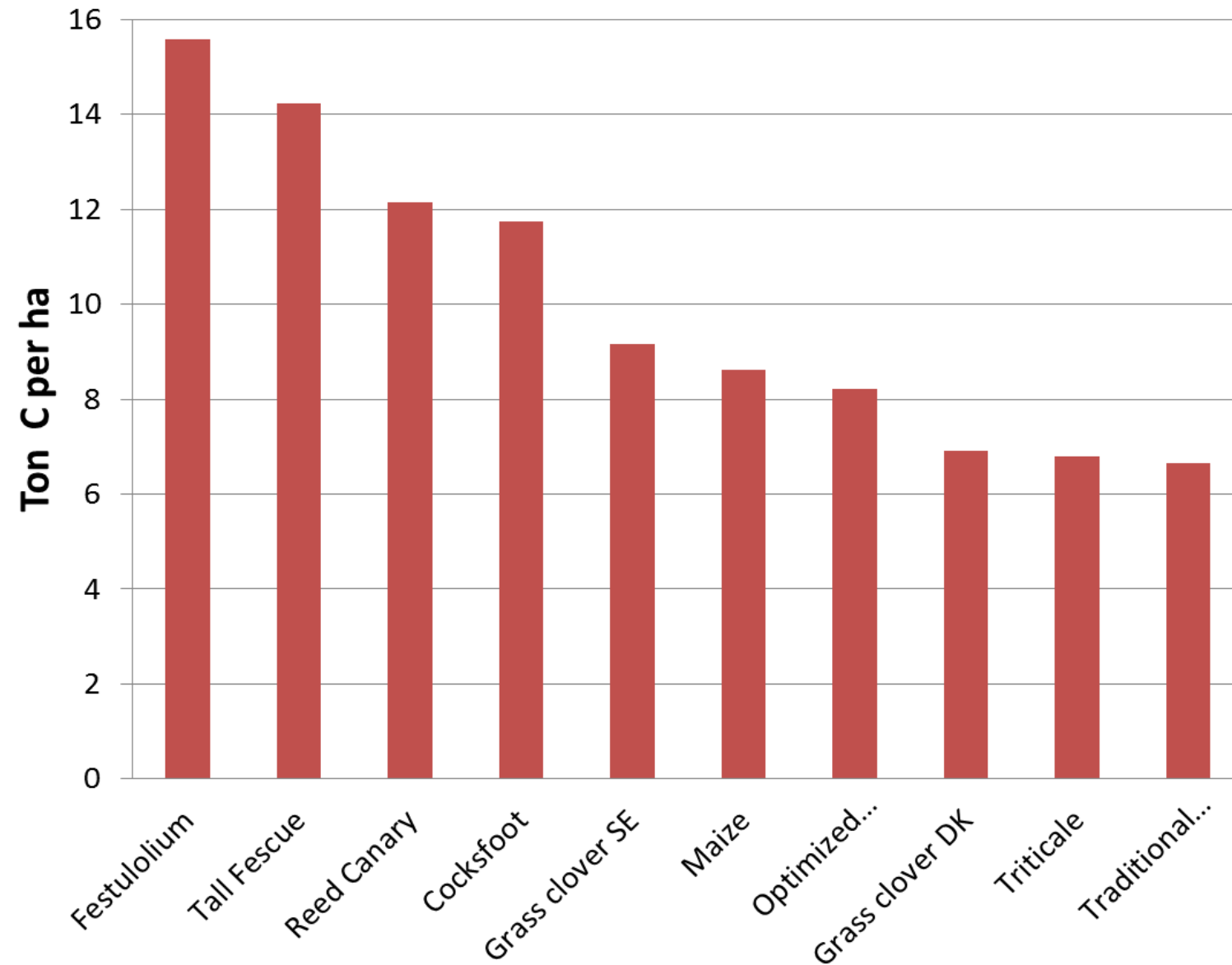
Perennial crops intercept approx. double as much solar radiation as do annual crops



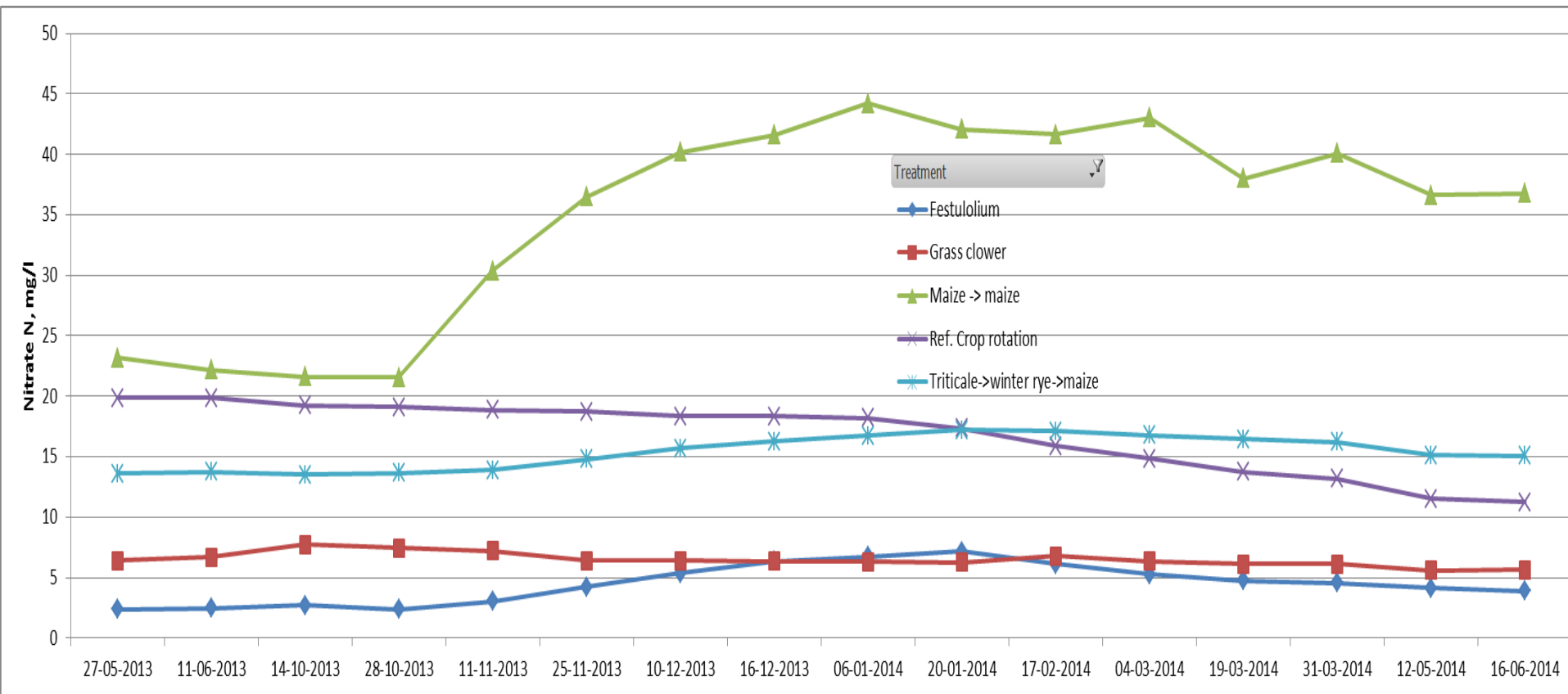
High variation in total biomass yield



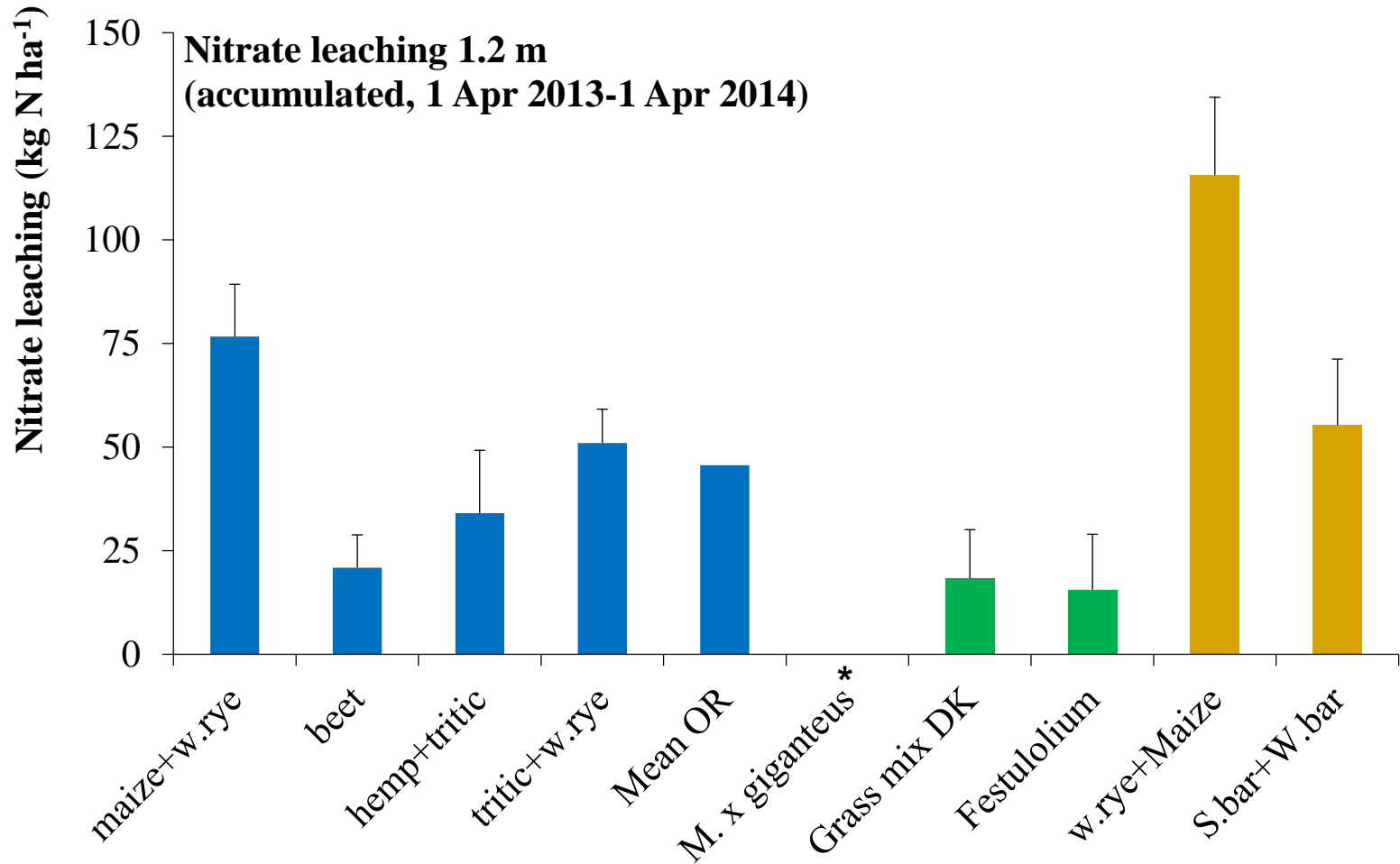
Maize moves down the range of carbon uptake when roots are included (preliminary data)



Nitrate leaching much lower from grass than from maize and barley – irrespective if fertilized or not

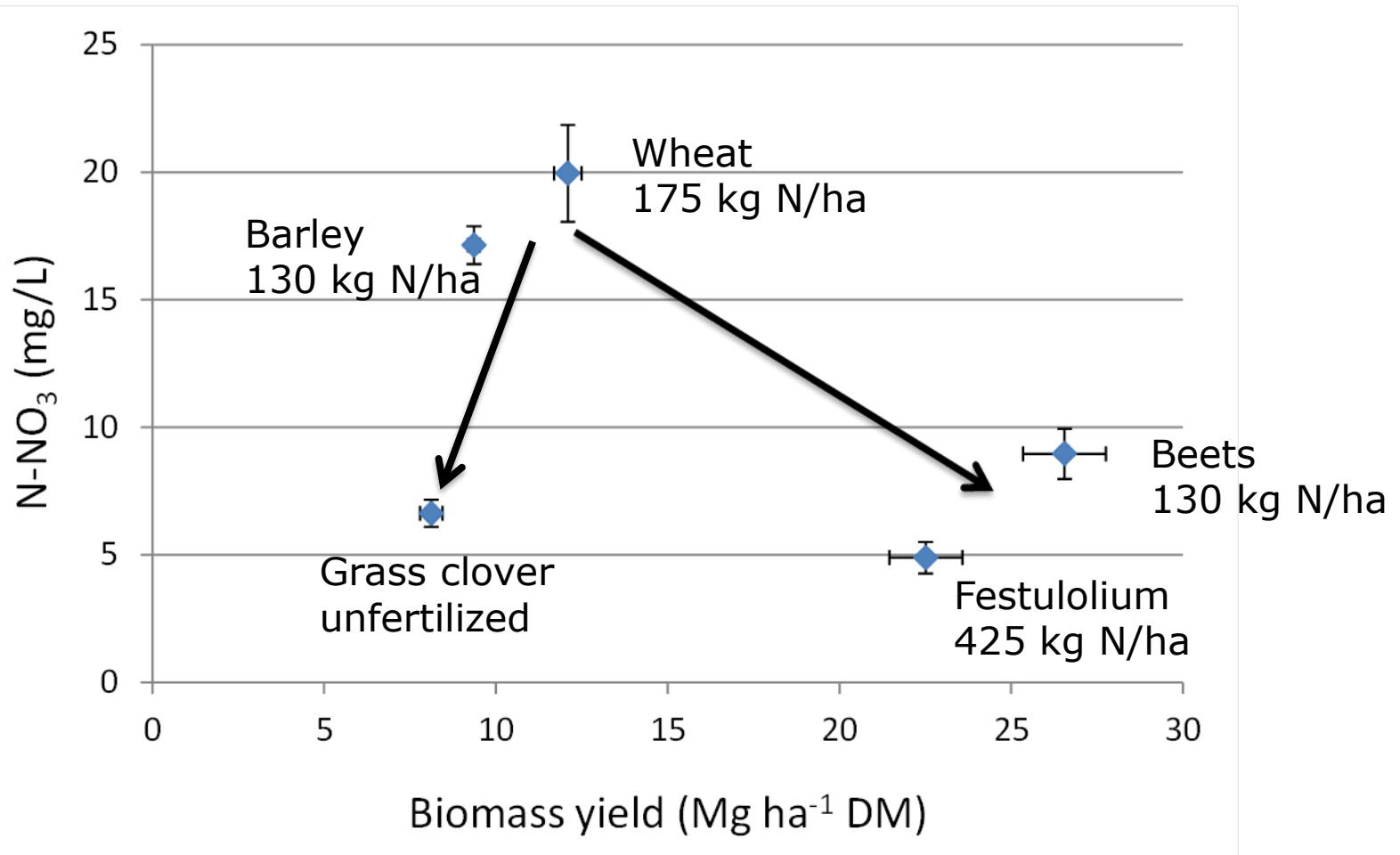


Cumulated leaching is up to six times higher in annual crops than in grasses



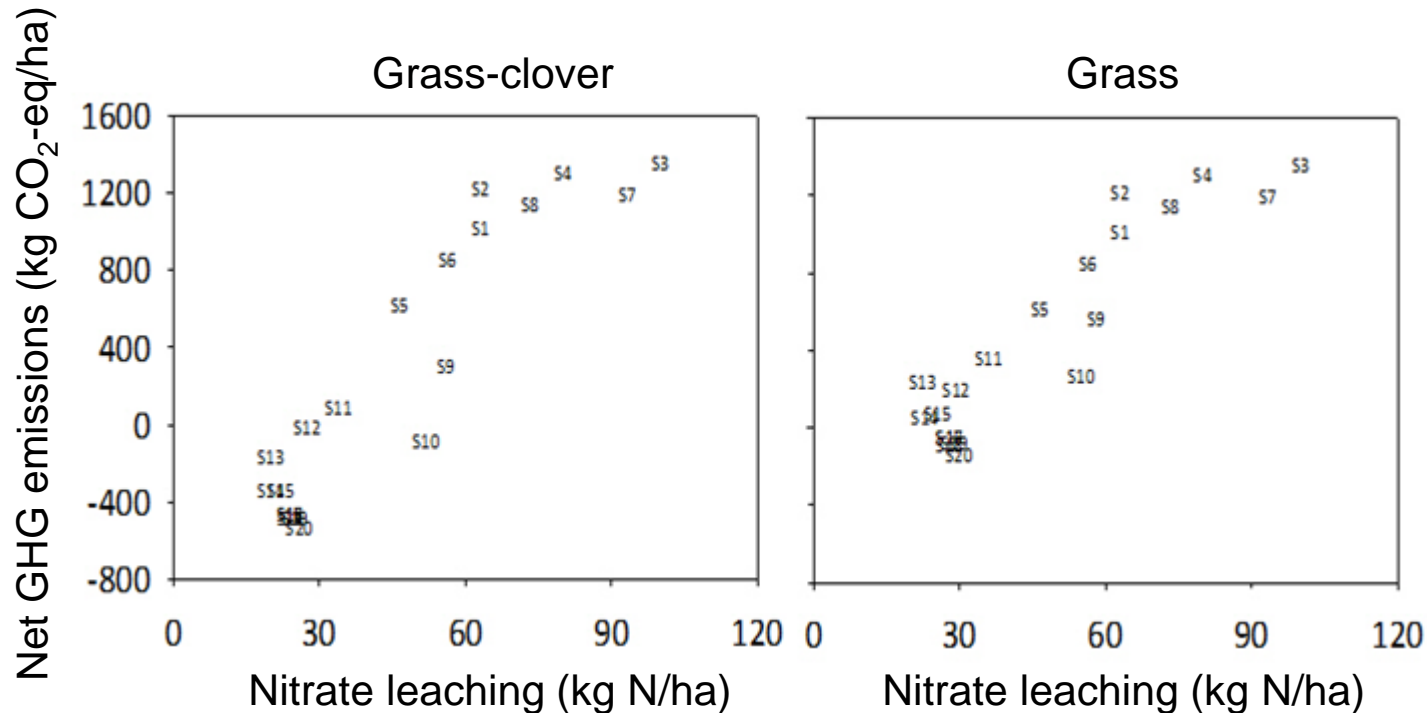
* Not calculated yet

It is possible to increase yield and decrease nitrate leaching



Synergy between GHG and nitrate leaching

Comparison of rotations with varying proportion of grass



So, what to do with all that grass?

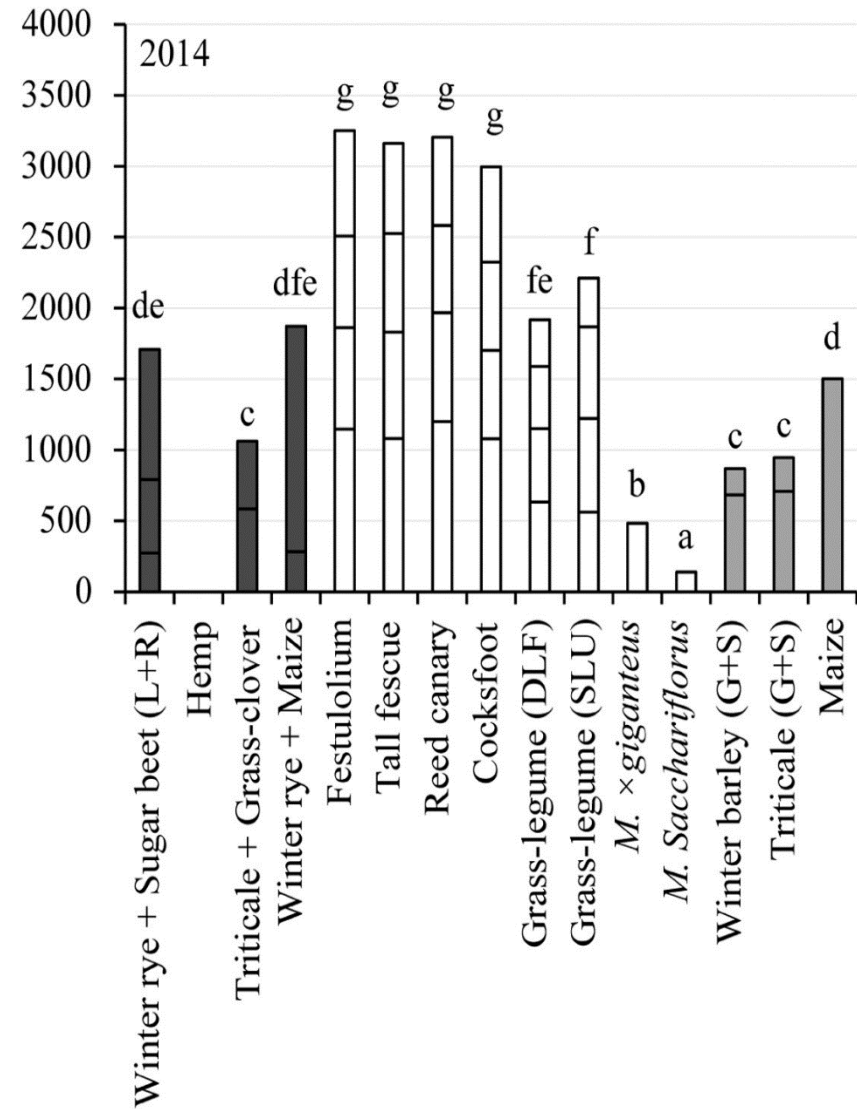
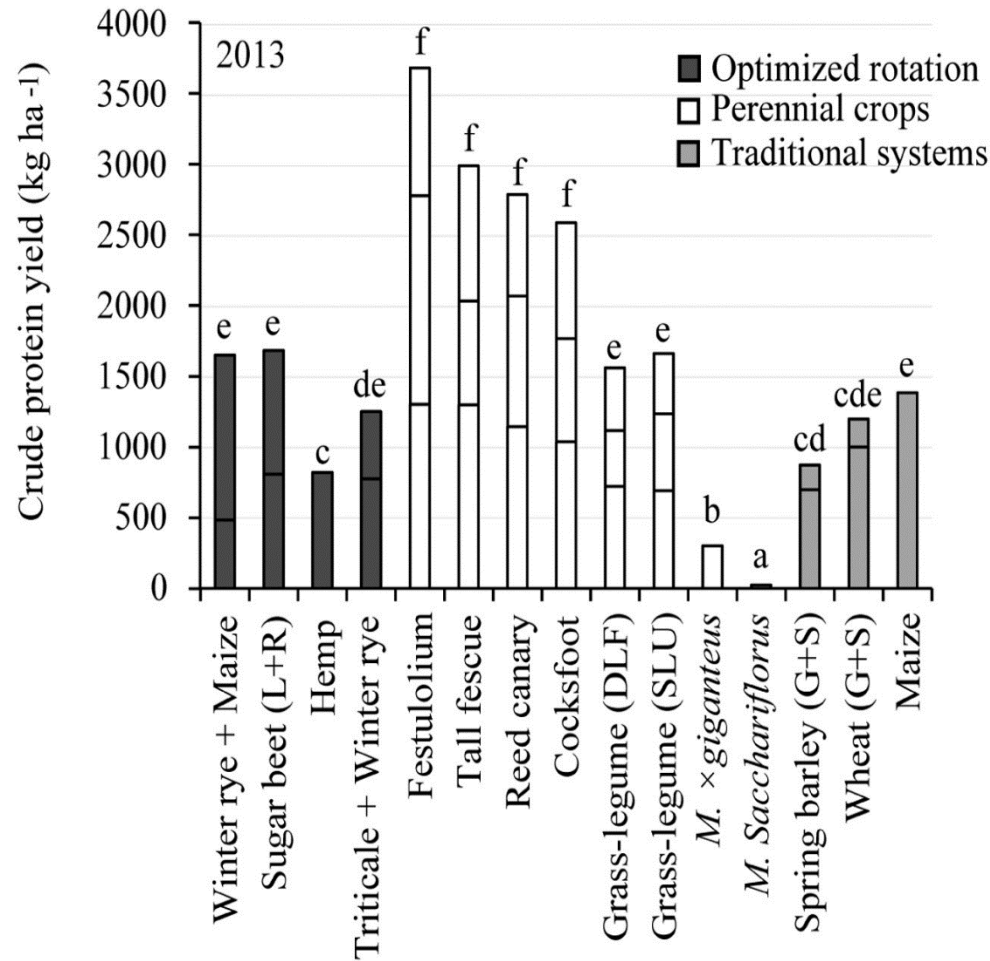


Current crop and protein yields under good DK conditions

	Total yield, t/ha	Protein %	Protein, kg/ha	Lysin, kg/ha	Methionin, kg/ha	Vitamin E, g/ha
Soy	2	35	700	43	9	30
Rape seed	5	20	1000	60	20	75
Peas	6	22	1300	92	13	50
Winter wheat	9	11	1000	30	16	90
Grass clover	13	12	1500	120	52	600
Red clover	12	21	2600	200	90	600

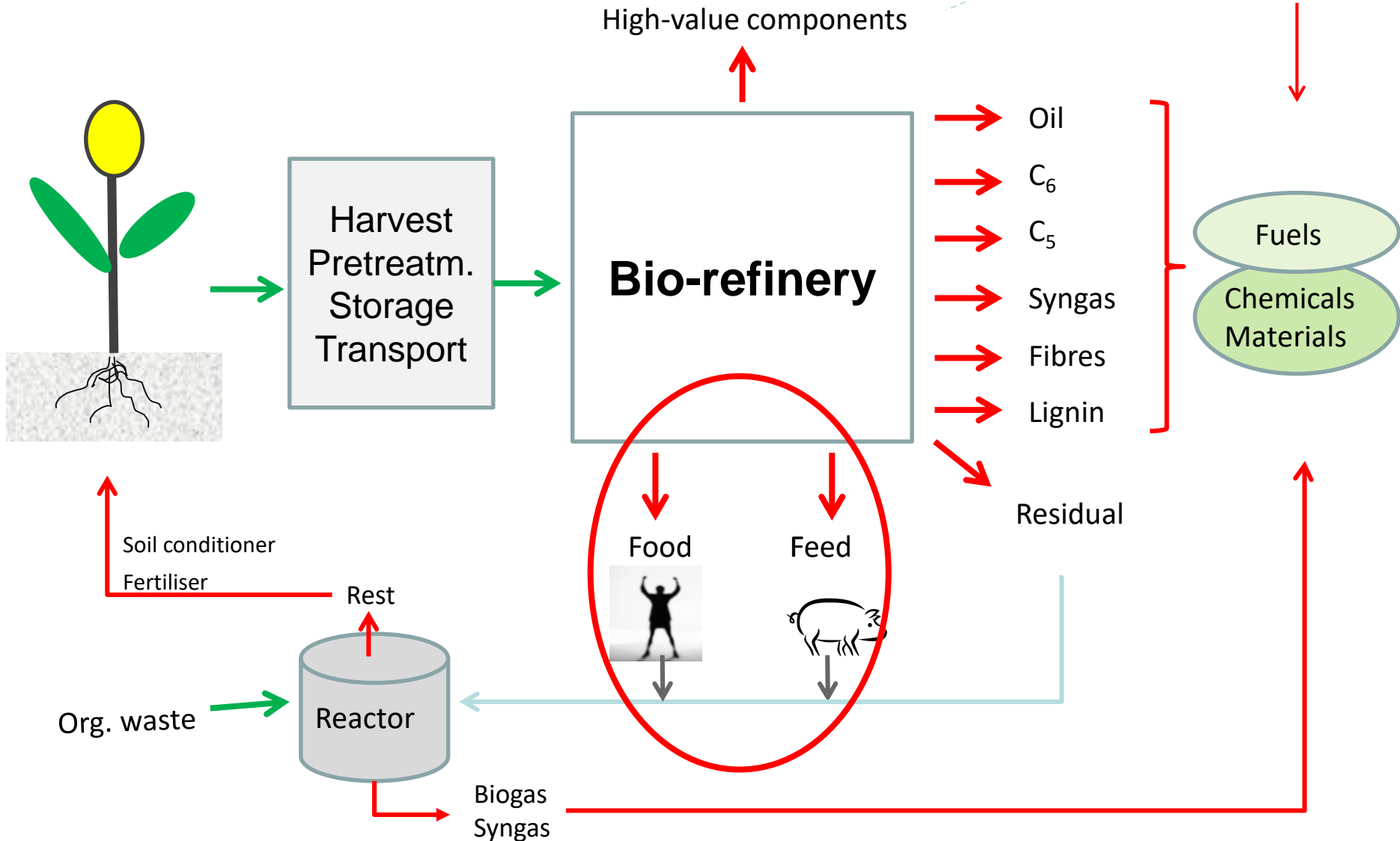
Total crude protein yield in Foulum biomass

Solati et al., 2018

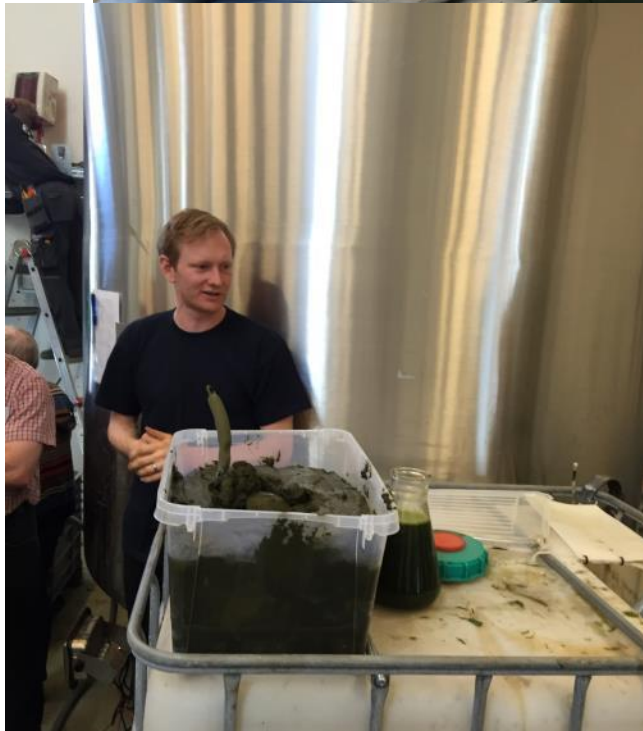
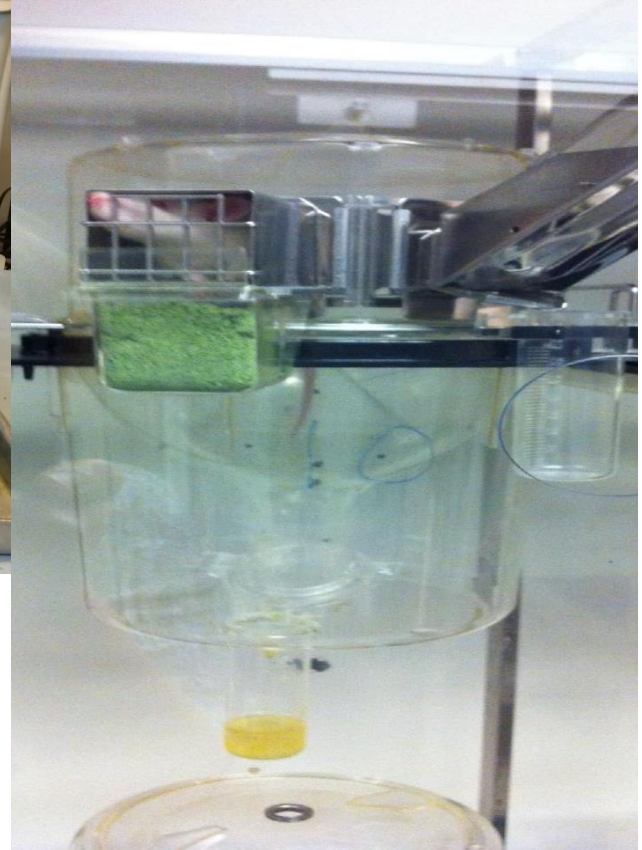


Implementation of a radical new crop production paradigm is conditional to development of green biorefineries

Colours
Flavors
Medicin
Other chemicals



Crops are separated, protein precipitated and animals fed to determine feeding value in current projects



BioValue (www.biovalue.dk)

Biobase (www.dca.au.dk/en/research/bioeconomy-and-biobased-production/biobase)



Some conclusions

- Grasses are more efficient than annual crops in intercepting radiation
- Maize and beets have high above-ground Radiation Use Efficiency
- However, if roots are included grasses have as high RUE (probably)
- Grasses can produce much product and soil carbon (if water is not limiting)
- Extract the high protein content in grass & legumes
- Nitrate losses can be kept low even at high input

Farmers are eager to produce grass – if
there is a market

