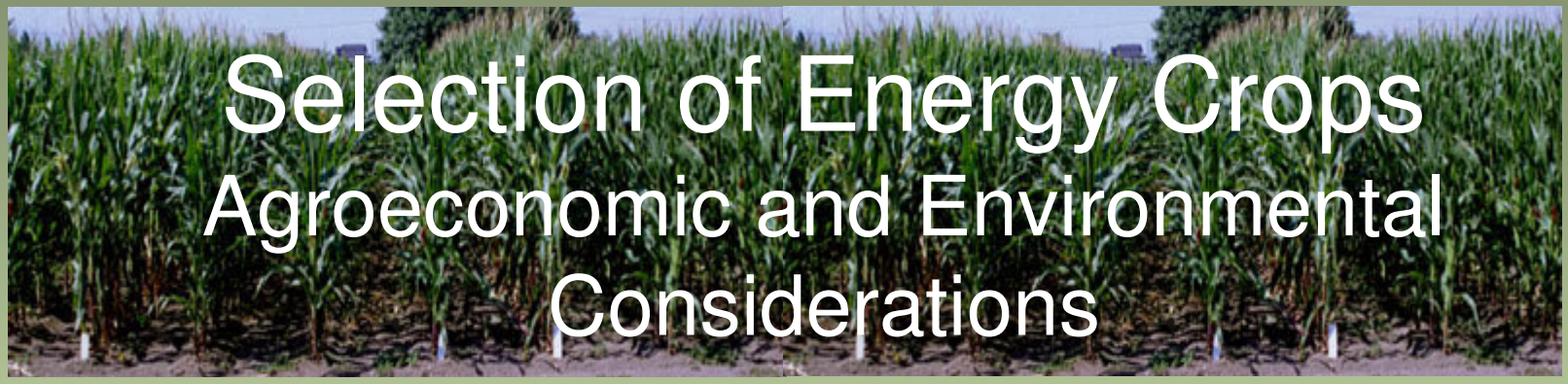

Selection of Energy Crops
Agroeconomic and Environmental Considerations

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cropgen

Outline

- What are energy crops?
  - Different types of energy crops
- Criteria for selection
  - Crop yield
  - Energy efficiency in crop production
  - Secondary/alternative uses of the crop
  - Land use
  - Environmental impacts

What are energy crops?

- “Energy crops are those annual and perennial species which can be cultivated to produce solid, liquid or gaseous energy feedstocks”. (FAO, 1996)
- Energy crops may either be used directly from harvest or stored for later processing.
- All crops have an energy value for burning – can have other uses as well.

Energy crops

- crops for combustion
- crops for oil
- crops for sugar
- crops for starch
- crops for biogas

Crops for combustion

- Short rotation coppice
  - Willow
  - Poplar
- Perennial grasses
  - Miscanthus
  - Reed canary grass
  - Switchgrass

15-20 year stands

Harvested once a year when dry

Uses all above ground plant material

Crops for oil

- Oilseed crops
  - Oilseed rape
  - Sunflower seeds
  - Linseed

- Annual crops (harvest once a year)
- Can be used in crop rotations
- Also food crops
- Does not use all of crop material – only seeds

Crops for ethanol

- Sugar crops
  - Sugar beet
  - Sugar cane
  - Sweet sorghum
- Starch crops
  - Wheat
  - Maize
  - Barley
  - Potatoes
  - Amaranth

- Annual crops (harvest once a year)
- Can be used in crop rotations
- Also food crops
- Does not use all of crop material

Crops for biogas

- Most organic material

- Can use crops
- Crop wastes
- Non-crops i.e weeds
- Verge cuttings etc.

- Can have multiple harvest per year
- Does use all of plant material

- Particularly relevant are forage crops

Advantages & disadvantages of energy crops

Advantages

- Capable of storing energy for use at will.
- Renewable.
- Are dependent on existing technology with minimal capital input.
- Can be developed with existing manpower and resources.
- Are reasonably priced.
- Are ecologically inoffensive and free of hazards (other than fire risk).

Disadvantages

- Land use competition.
- Land areas required.
- Supply uncertainty in initial phases for some fuels.
- Fertiliser and water requirements.

(Hall, 1979)

Criteria for selection of energy crops

1. Crop yield.
2. Input energy requirement.
3. Alternative uses of crops/secondary effects
4. Land use/availability.
5. Environmental impacts.

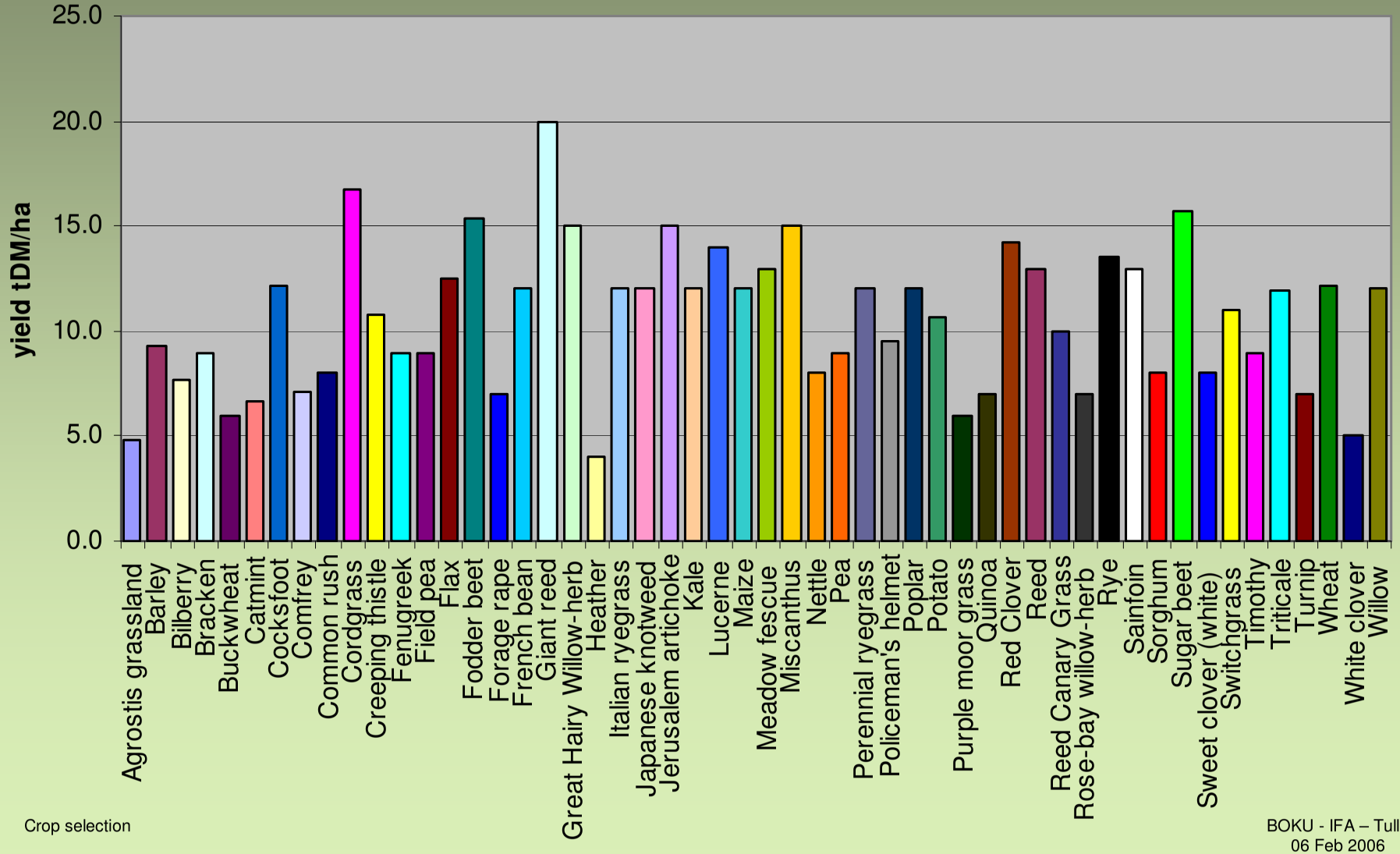
1. Crop yield

Purpose of crop

The yield of a crop depends on the purpose of the crop and the part of the crop that is harvested:

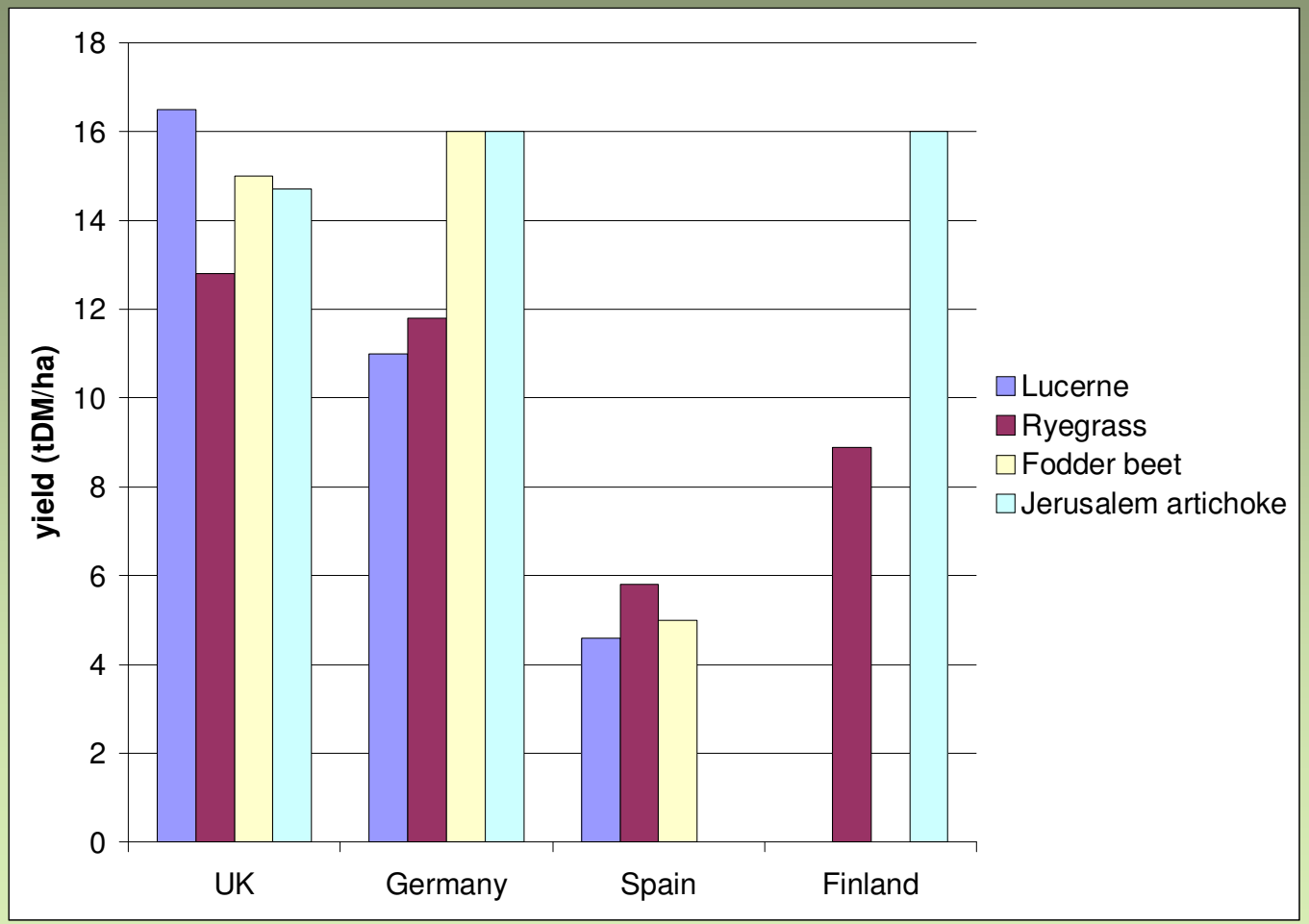
- specific crop part
  - oilseed rape (seed) = 3 tonnes / ha
  - wheat (grain) = 8 tonnes / ha
  - sugarbeet (beets) = 15 tonnes / ha
- wholecrop (dry matter)
  - wheat = 12 tonnes / ha
  - maize = 13 tonnes / ha
  - ryegrass = 15 tonnes / ha
  - miscanthus = 15 tonnes / ha

Reported wholecrop plant yields in the UK

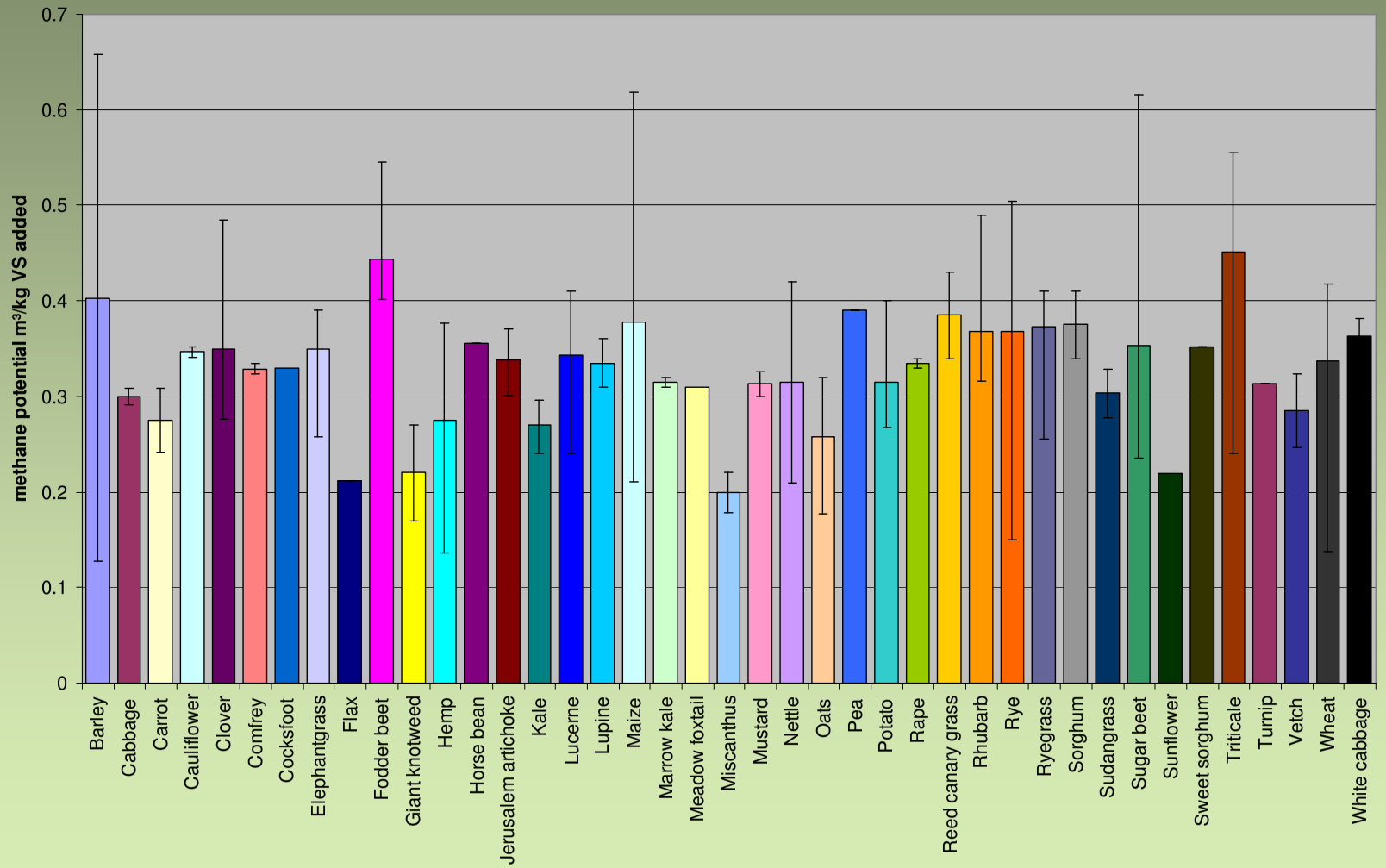


Crop selection

European yields



Methane potentials

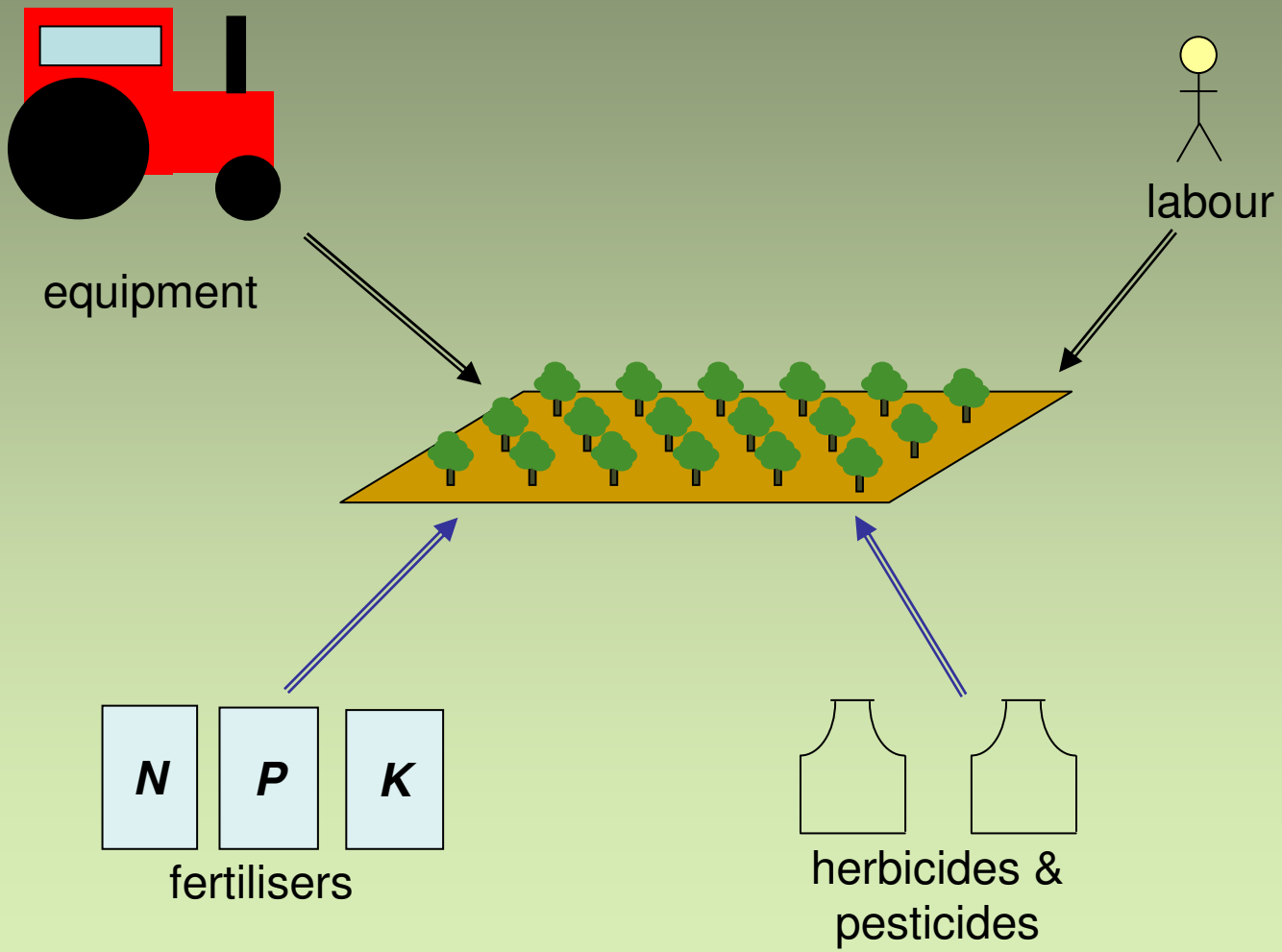


2. Production efficiency

Agro-energetics/economics

- It is possible to calculate the average energy required to produce a crop.
- Using these values we can:
  - Make a comparison of crops and farming systems.
  - Identify the most ‘energy efficient’ crops.

Energy requirements in crop production



Fuel energy requirements

operation	energy requirement (MJ/ha)	average energy requirement (MJ/ha)
ploughing	624-1160	800
seedbed cultivations	138-278	160
fertiliser applications	59-88	81
combine harvesting	568-617	598

Indirect energy requirements

	Average energy requirement
NH_4NO_3	40.6 MJ/kg
P_2O_5	15.8 MJ/kg
K_2O	9.3 MJ/kg
herbicides	264 MJ/kg a.i. *(active ingredient)*
fungicides	168 MJ/kg a.i.
insecticides	214 MJ/kg a.i.
machinery	

Energy requirements example – wheat

	energy requirement (MJ/ha/yr)
fuel total	2218
machinery	3332
fertiliser	7596
pesticides	1922
labour	16
transport (on farm)	52
Total	**15,136**

Energy requirements for a range of crops

crop	total energy input (GJ/ha)	*reference*
Oilseed rape	17.0	
Sugar beet	20.3	
Maize	15.6	*calculated*
Potatoes	24.22	
Winter wheat	19.12	
Winter barley	16.97	
Sugar beet	29.49	
Spring barley	14.45	*(Hülsbergen and Kalk 2001)*
spring sown grain	9.98-12.1	
Fodder beet	16.8-20.48	*(Refsgaard et al. 1998)*
Sugar beet	23.88	*(Tzilivakis et al. 2005)*
Maize	18.71	*(Shapouri et al. 2002)*
Oilseed rape	13.8	*(Elsayed et al. 2003)*

Fertiliser

- Fossil fuel based fertiliser inputs have very high energy requirements

  wheat
  - total energy requirement 15,136 MJ/ha
  - fertiliser energy requirement 7,596 MJ/ha

- Alternatives
  - Use digestate as a fertiliser
  - Use legumes to provide nitrogen

Digestate

- Digestate contains most of the nutrients that were in the original feedstock.
- Can be applied directly or separated into:
  - a liquid slurry containing most of the nitrogen
  - a fibrous residue containing most of the phosphate and potassium.
- These can be applied to the land at the required time.
- Restrictions may be applied to the use of digestate from wastes other than crops.

Legumes

- Legume crops interact with bacteria to fix nitrogen from the air and soil.
- Include crops such as:
  - lupins
  - beans
  - clovers
  - lucerne
- Can be grown as part of a rotation system.
- Can be combined with other crops.
  - undersown
  - in grass leys

Energy balance for a lucerne crop

	energy requirement (MJ/ha/yr)	
	first year	**second year on**
fuel	2475	3851
machinery	1283	929
fertiliser	2326	2326
labour	13	23
transport (on farm)	56	223
Total	**6,153**	**7,352**
wheat	15,136	

3. Multiple uses of a crop

Crop use

- Crops can have more than a single use:
  - nitrogen fixation
  - cover/catch crops
  - soil enhancement
- Crops have multiple parts which can be harvested for alternate uses
  - sugar beet tops
  - green pea waste

4. Land availability

Where to grow energy crops

- As part of the crop rotation.
- As replacements for food crops.
- On set-aside land.
- Fallow ground.
- Verges.
- Underutilised ‘waste’ ground.
- Reclaimed land.

5. Environmental impacts

Mono-crops

Perennial

- Disadvantages
  - establishment
  - harvest times
  - duration
  - diversity
- Advantages
  - duration
  - low input requirements
  - carbon sequestration

Annual

- Disadvantages
  - high input requirements
  - disease resistance
  - diversity
- Advantages
  - yields

Mixed crops

- Advantages
  - crop rotations for soil benefits
  - crop rotations for farm and food benefits
    - pest control
    - plant and animal diversity
    - legumes for nitrogen fixing, catch crops, cover crops
- Disadvantages
  - lower yield over the whole farm
  - lower carbon sequestration

How Much Biomass can Europe Use Without Harming the Environment?

European Environment Agency (2005)

- *Maintain extensively cultivated agricultural areas.*
  - existing grasslands can be used for providing a feedstock. This agrees with the cross-compliance requirement which requires grassland to not be transformed.
- *At least 30% of the agricultural land dedicated to 'environmentally-oriented farming in 2030 in the member states*.
  - AD links comprehensively into organic farming and crops can be chosen which maintain biodiversity.
- *The introduction of new cropping systems can combine high yields with little fertiliser and pesticide input .*
  - Reuse of digestate as a fertiliser, the use of legumes and cover crops .

The selection of crops for biogas production

- A number of factors can be considered:
  - low input crops e.g. grass – good carbon sequestration, low fertiliser input if combined with legumes or use digestate
  - high yield crops e.g. fodder beet
  - underused crops e.g. Jerusalem artichoke
  - cover and catch crops, harvest and digest before ploughing in and use as fertiliser.
  - crops with multiple uses e.g. sugar beet (for beet & leaves for digestion)
  - crops with good storage abilities e.g. maize, grass
  - crops that will grow on a wide range of soil types
  - market for biomass produced

Conclusion

- Anaerobic digestion can make use any crop – effectiveness dependent on the stage of harvest
- Crops can be chosen to fit in with existing farming systems
  - Farmers know what grows best on their land
- Crops can be chosen to fit best with EU legislation
- The energy difference between annuals and perennials is small compared to the difference between mineral and organic fertilisers
- Crops can be selected which have multiple uses
- For biogas production forage crops are a good start
  - need breeding programmes to increase biomass yields and exploit the benefits of crops for energy.

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