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Energy use, energy efficiency and energy productivity of different intensive rape seed rotations in Lower Saxony, Germany

J. Moerschner and W. Lücke

Int. Conference ‚Sustainable Energy:

New Challenges for Agriculture and Implications for Land Use‘

Wageningen, 18.-20.05.2000

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Topics to be Adressed

- **Introduction**
- **Materials and methods - data base and way of calculation**
  - **Characteristics of the INTEX-Project at Göttingen University**
  - **How the energy analysis was done**
- **Results**
  - **Crop level - mean years of the two investigated project periods**
    - input profiles from location Reinshof for each crop
  - **Rotation level:**
    - mean years of rotations, based on average figures for each crop
    - averages of all crops each year as synthetic ‚rotation‘
- **Summary and some conclusions**

Energy Analysis - Why?

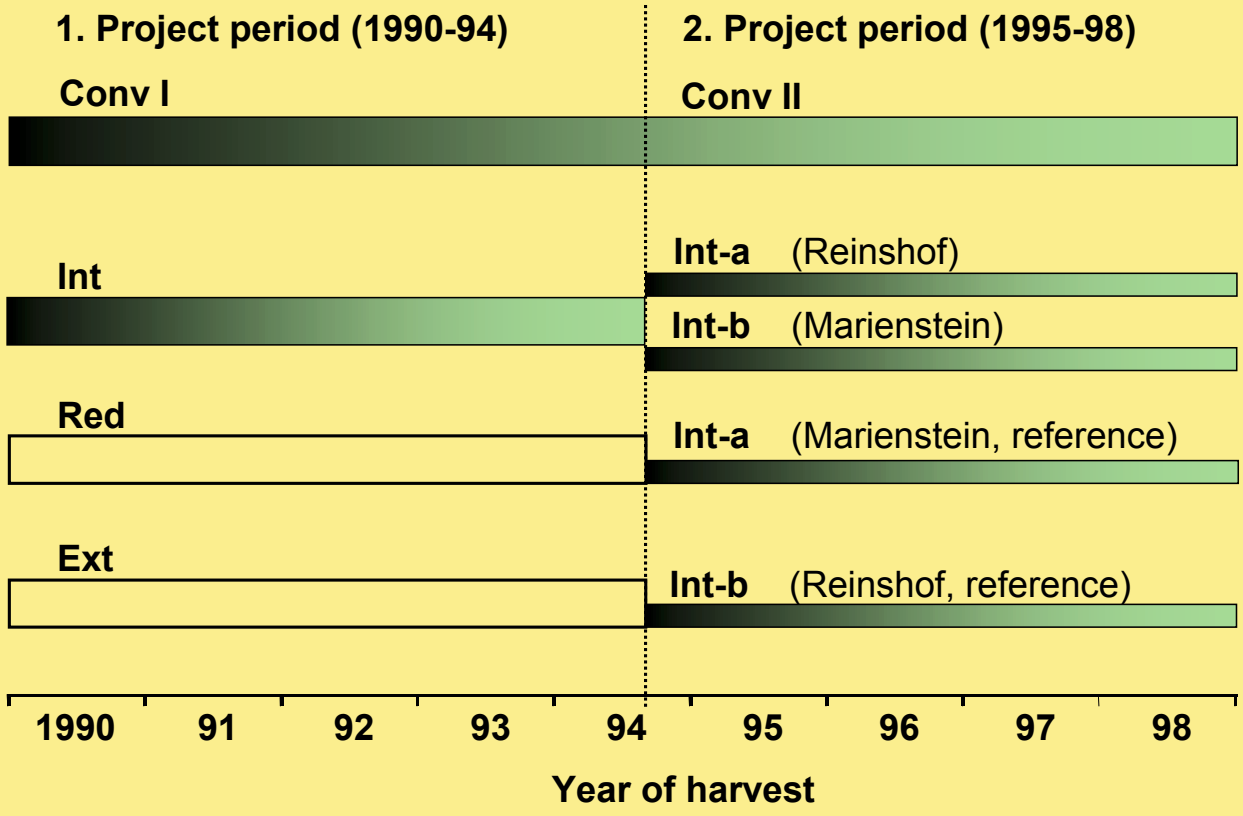
- Completion of ecological indicators investigated before within the INTEX-project
  - Nutrient flows
  - Soil biology
  - Soil physics
  - Herbology
  - Phytopathology
  - Zoology
  - Entomology
- Developement of methods to provide agricultural energy information for downstream applications
  - LCA of food products or renewable energy/raw materials
  - Production chain analysis

Data Background

- INTEX: A large scaled research project on ecological effects of extensivation measures in arable farming -

- Extensified rape seed rotations
  - 9 years of scientific investigation
- Two different locations investigated
  - Reinshof: Good loess soils, near groundwater, high yield potential
  - Marienstein: hilly site, clay soils, lower yield potential
- Infrastructure
  - Size of each plot from 1,1 ha to 4,8 ha; assumed as 5 ha each plot
  - No replications, no randomization
  - Mean assumed farm-to-field-distance: 2 km
  - Used machinery as in practice, assumed to be identical for both sites

The INTEX-Farming Systems



The Farming Systems and their Rotations

1990-1994

- *Conv I* = Conventional
  - Rape seed, Winter wheat, Winter sown barley
- *Int* = Integrated
  - Rape seed, Winter wheat, Field beans, Winter sown barley

1995-1998

- *Conv II* = Conventional
  - Rape seed, Winter wheat, Winter sown barley
- *Int-a* = Integrated flexible
- *Int-b* = Integrated without plough
  - Rape seed, Oats, Winter wheat, Annual fallow

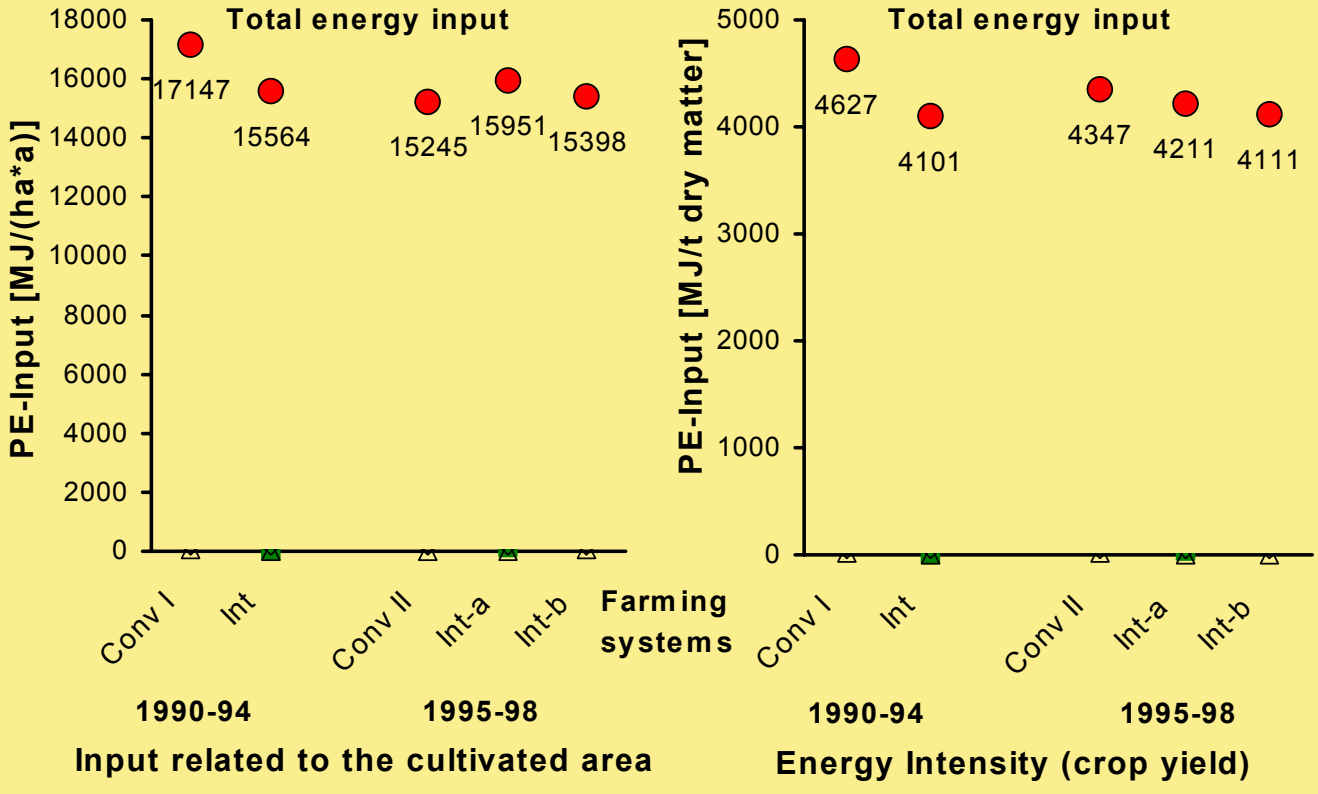
Investigated Energy Indicators

- analysis on single field level -

- **Energy use (Primary energy input)**
  - Total energy use (MJ/ha)
  - Specific energy input by different input groups - energy use profile
- **Energy intensity**
  - Crop level: MJ input per ton of yield (dry matter)
  - Rotation level: MJ input per Grain unit (GU) of yield
- **Energy productivity**
  - Net energy yield (energy input subtracted)
  - Incorporated energy for seeds subtracted
  - Energy yield calculated as Gross energy (MJ GE)
- **Energy Efficiency**
  - Net energy output (seeds subtracted) per MJ energy input

Energy Use for Rape Seed

- Input groups, mean figures at Reinshof -



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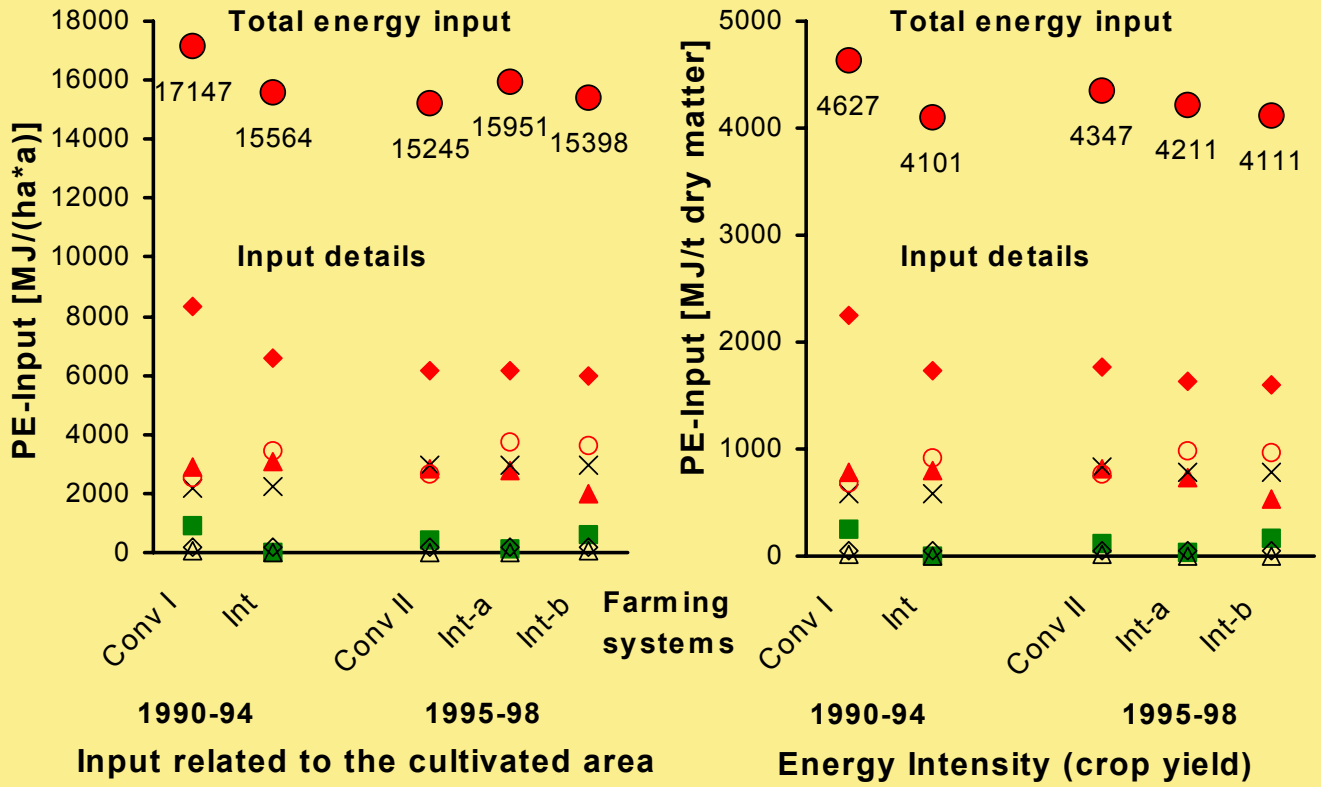
Energy Use for Rape Seed

- Input groups, mean figures at Reinshof -



● Total ◆ N-fertiliser ▲ Fuel × Basic fertiliser ○ Machinery ■ Pesticides ◇ Electricity △ Seeds

Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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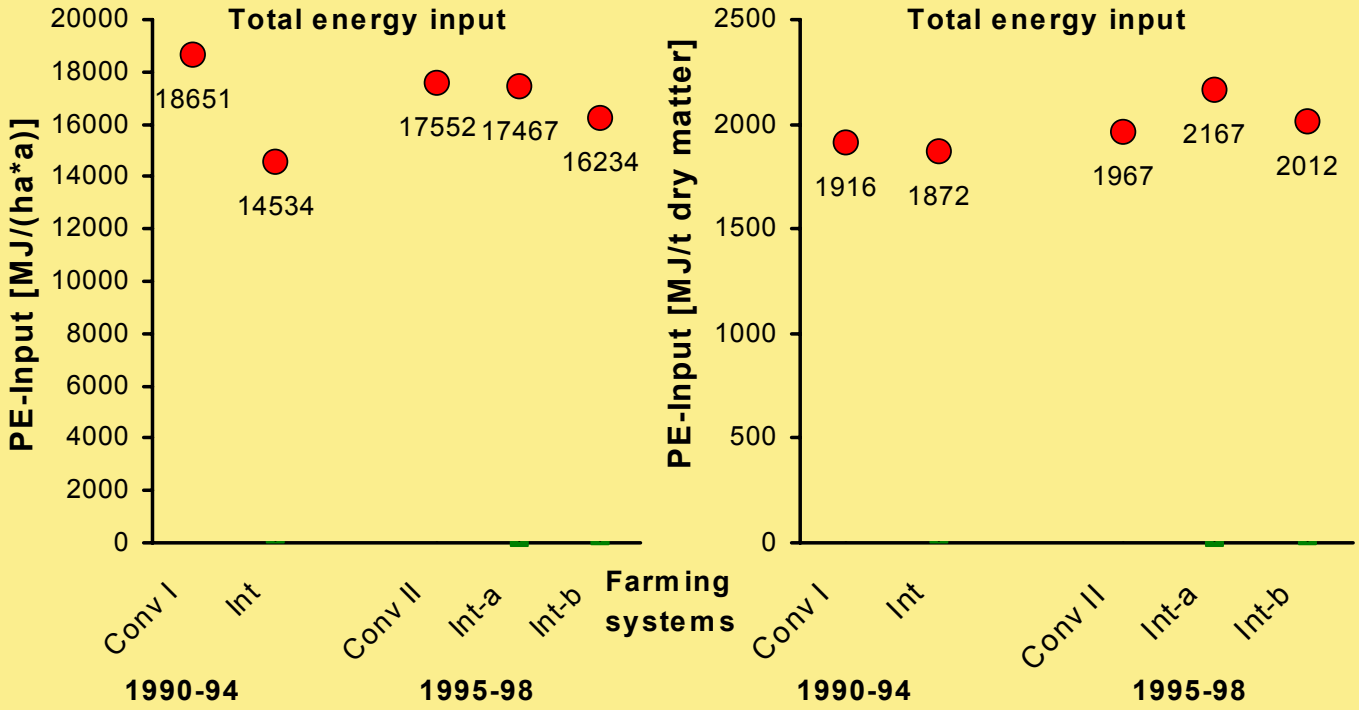
Energy Use for Winter Wheat

- Input groups, mean figures at Reinshof -



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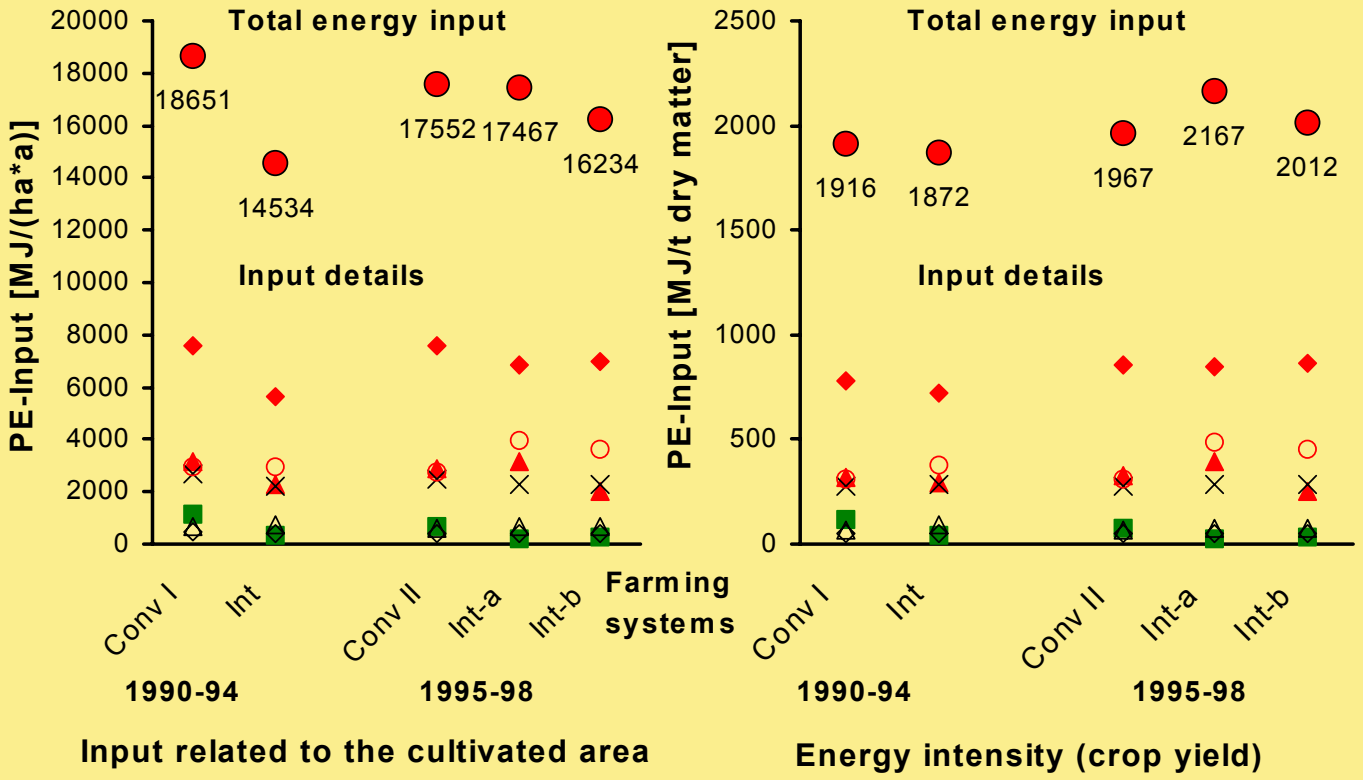
Energy Use for Winter Wheat

- Input groups, mean figures at Reinshof -



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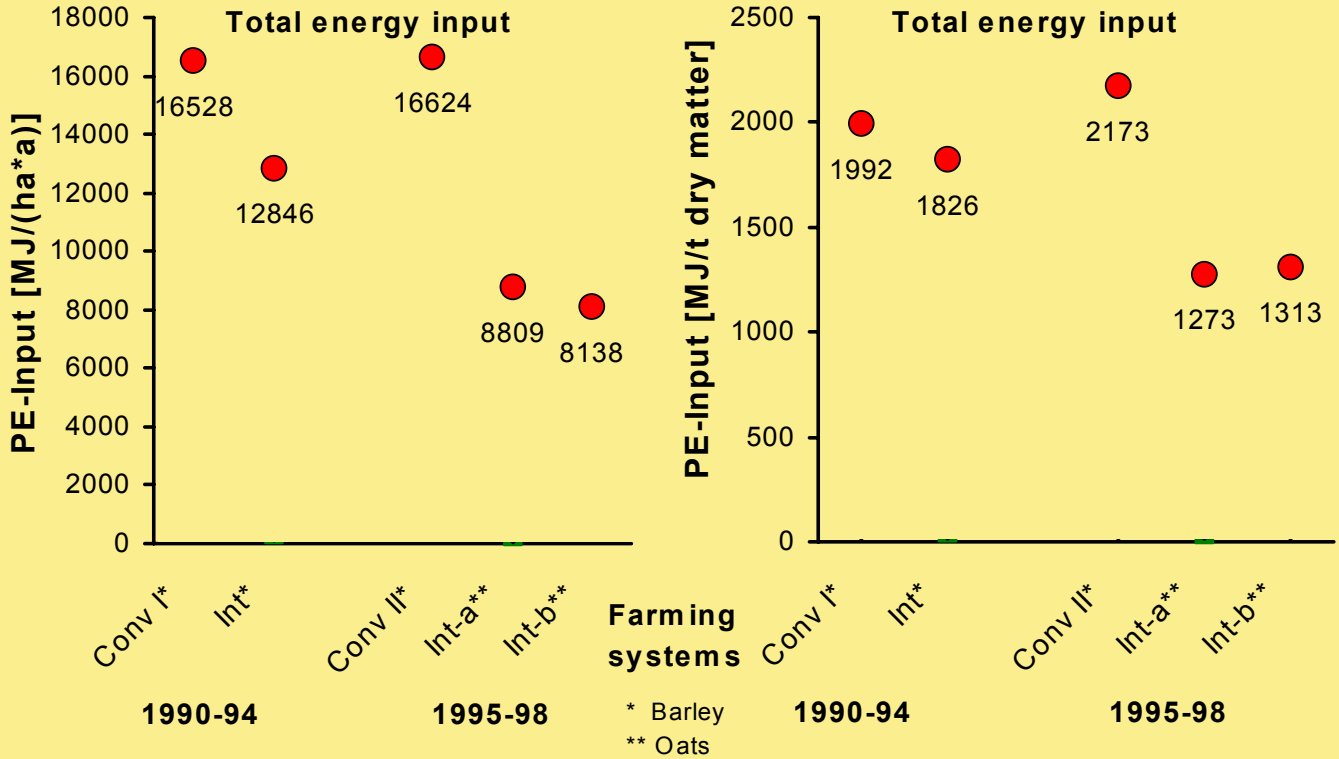
Energy Use for Barley and Oats

- Input groups, mean figures at Reinshof -



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Energy Use for Barley and Oats

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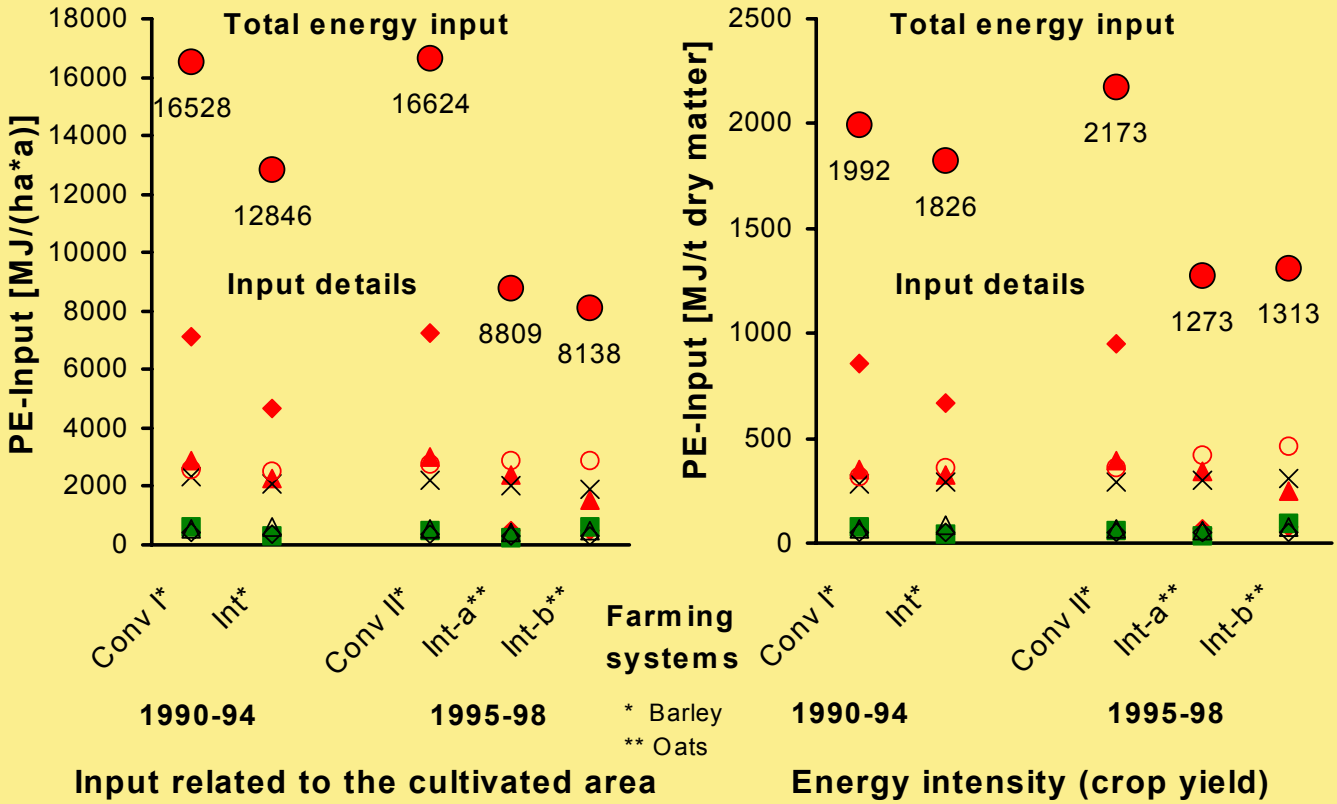

* Barley
** Oats

Input related to the cultivated area | **Energy intensity (crop yield)**

Total ◆ N-fertiliser ▲ Fuel × Basic fertiliser ○ Machinery ■ Pesticides ◇ Electricity △ Seeds

Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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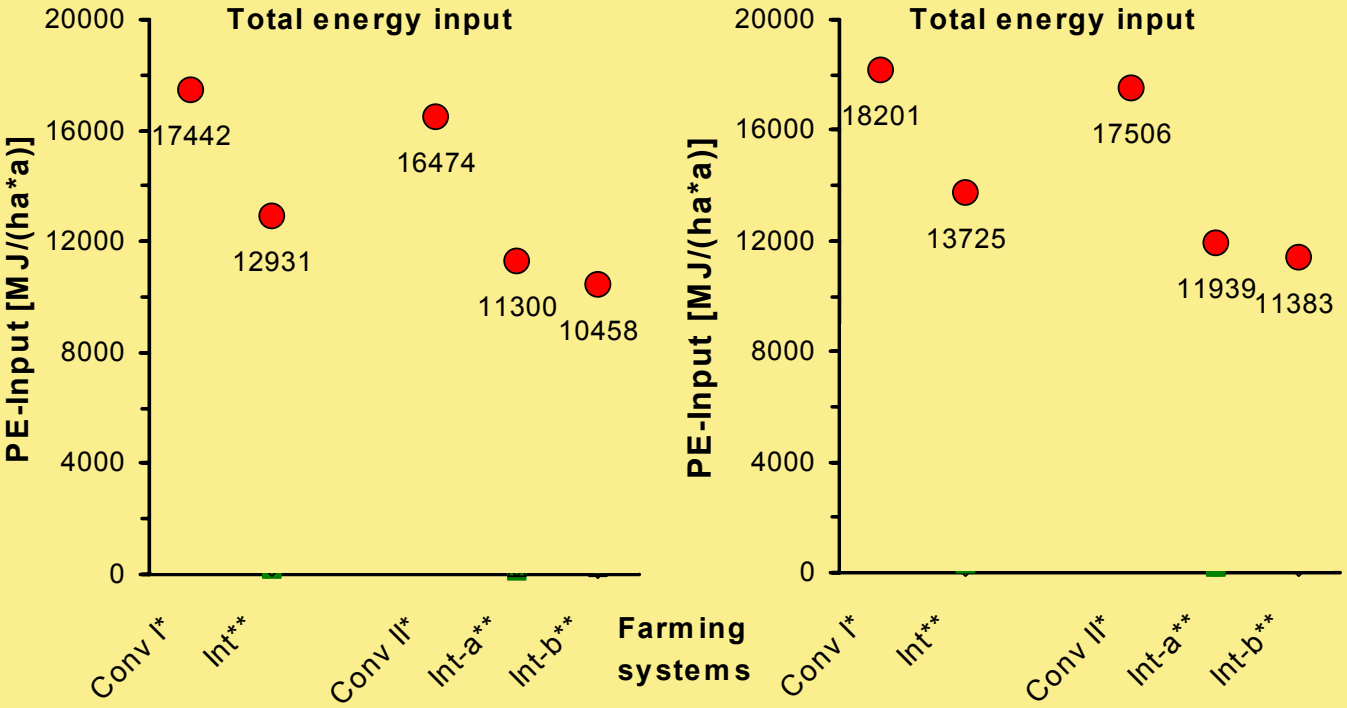
Energy use at Crop Rotation Level (area)

- mean years of rotation, annual fallow included -



* n=3
** n=4

Location Reinshof | **Location Marienstein**

Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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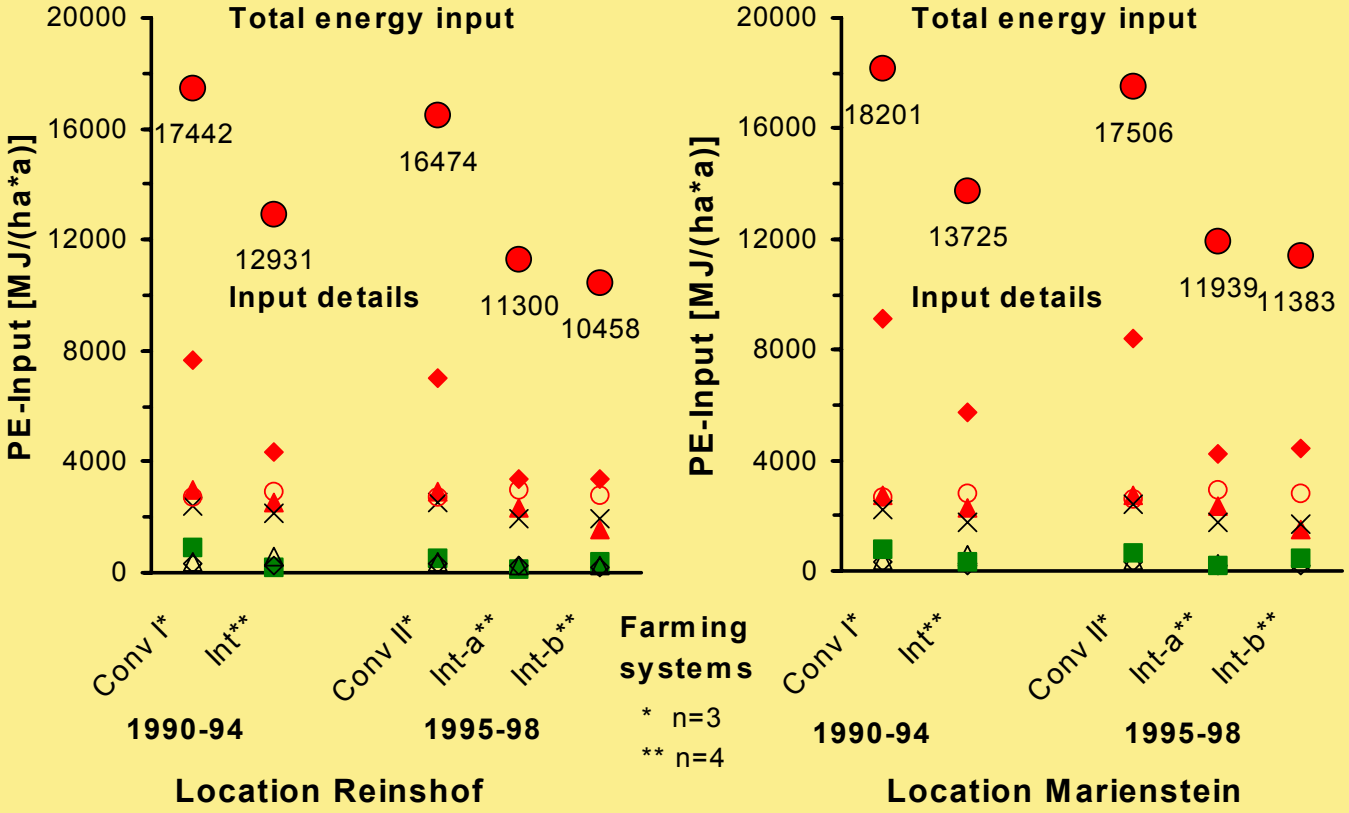
Energy use at Crop Rotation Level (area)

- mean years of rotation, annual fallow included -



Total ◆ N-fertiliser ▲ Fuel × Basic fertiliser ○ Machinery ■ Pesticides ◇ Electricity △ Seeds

Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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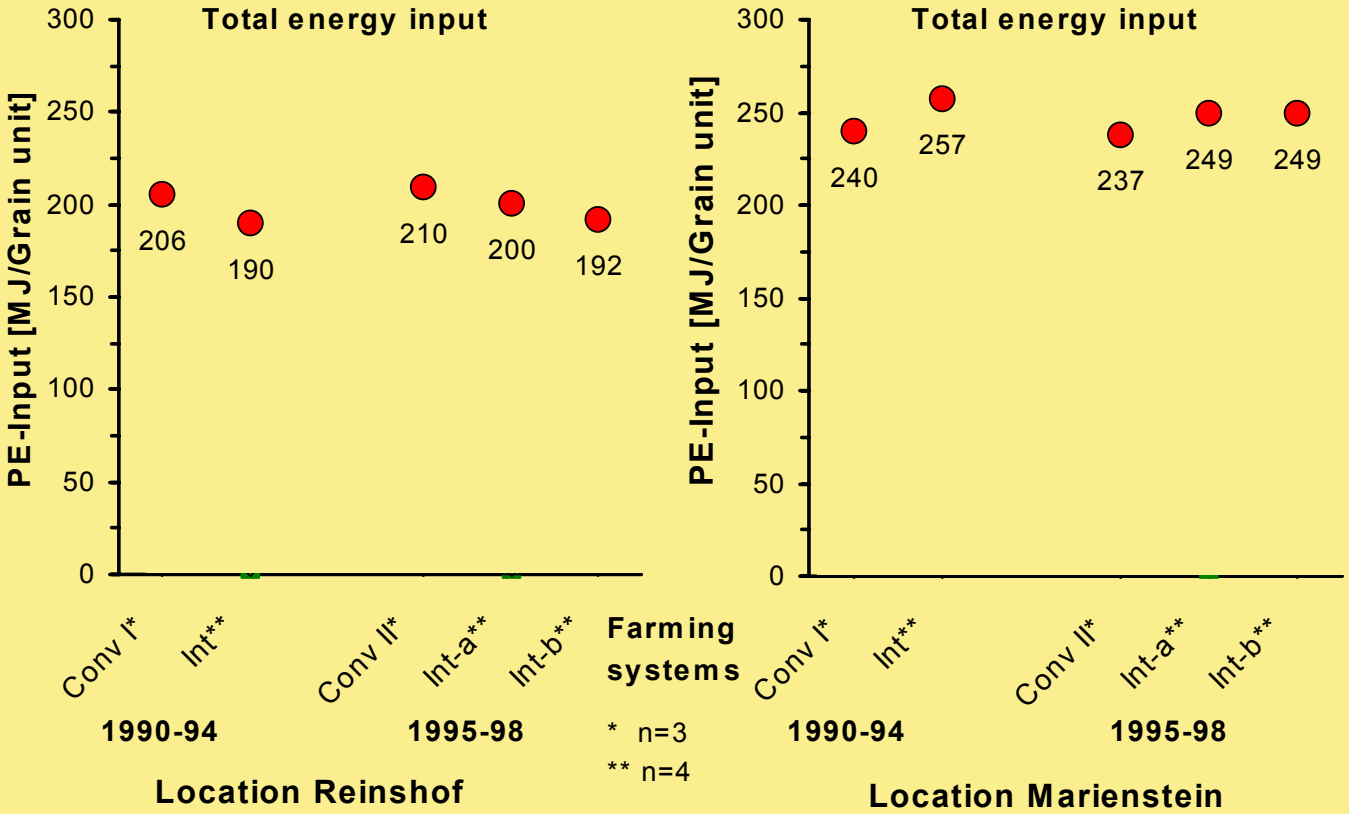
Energy Intensity at Crop Rotation Level (GU)

- mean years of rotation, annual fallow included -



Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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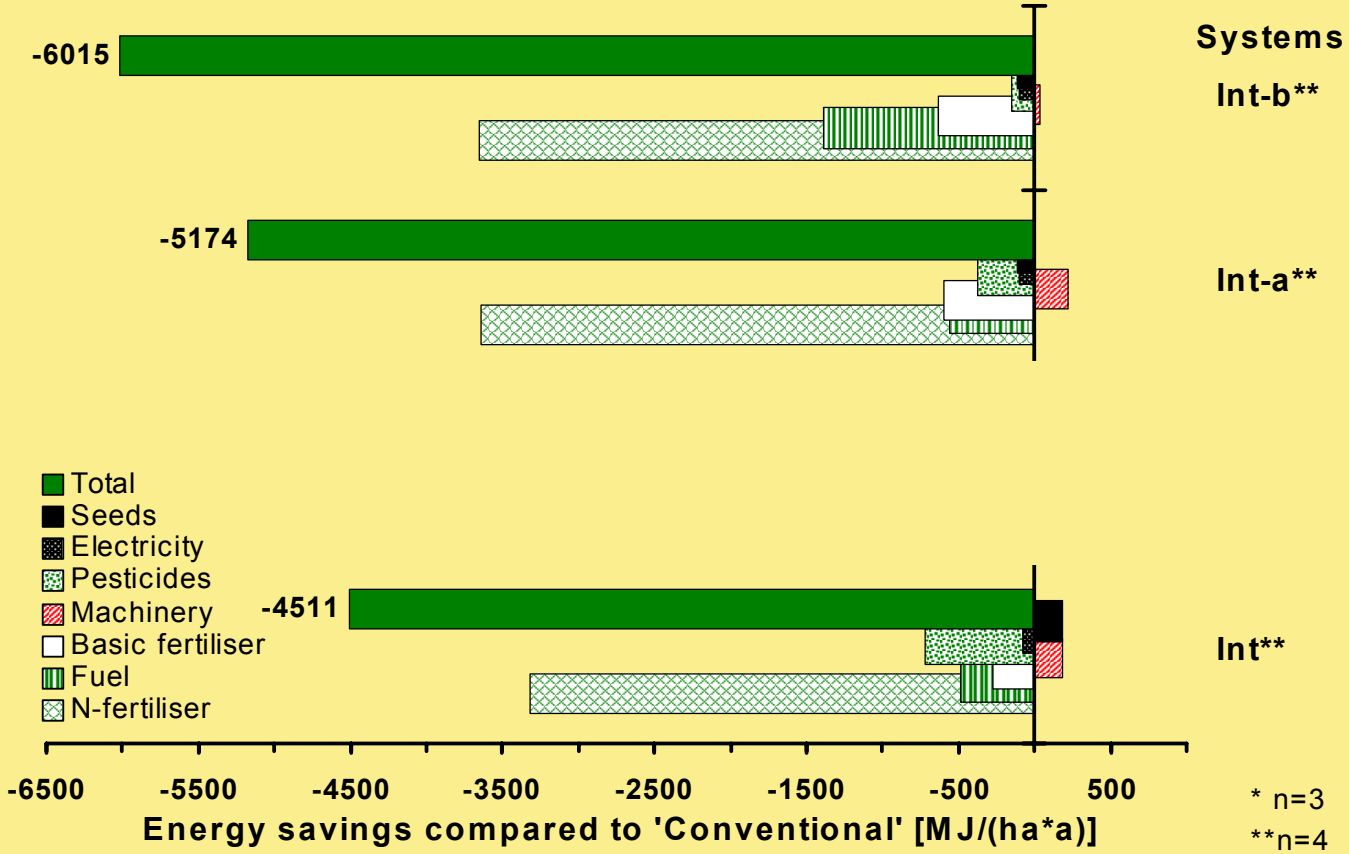
Energy Savings in the Crop Rotations

- mean years of rotation, Reinshof, annual fallow included -



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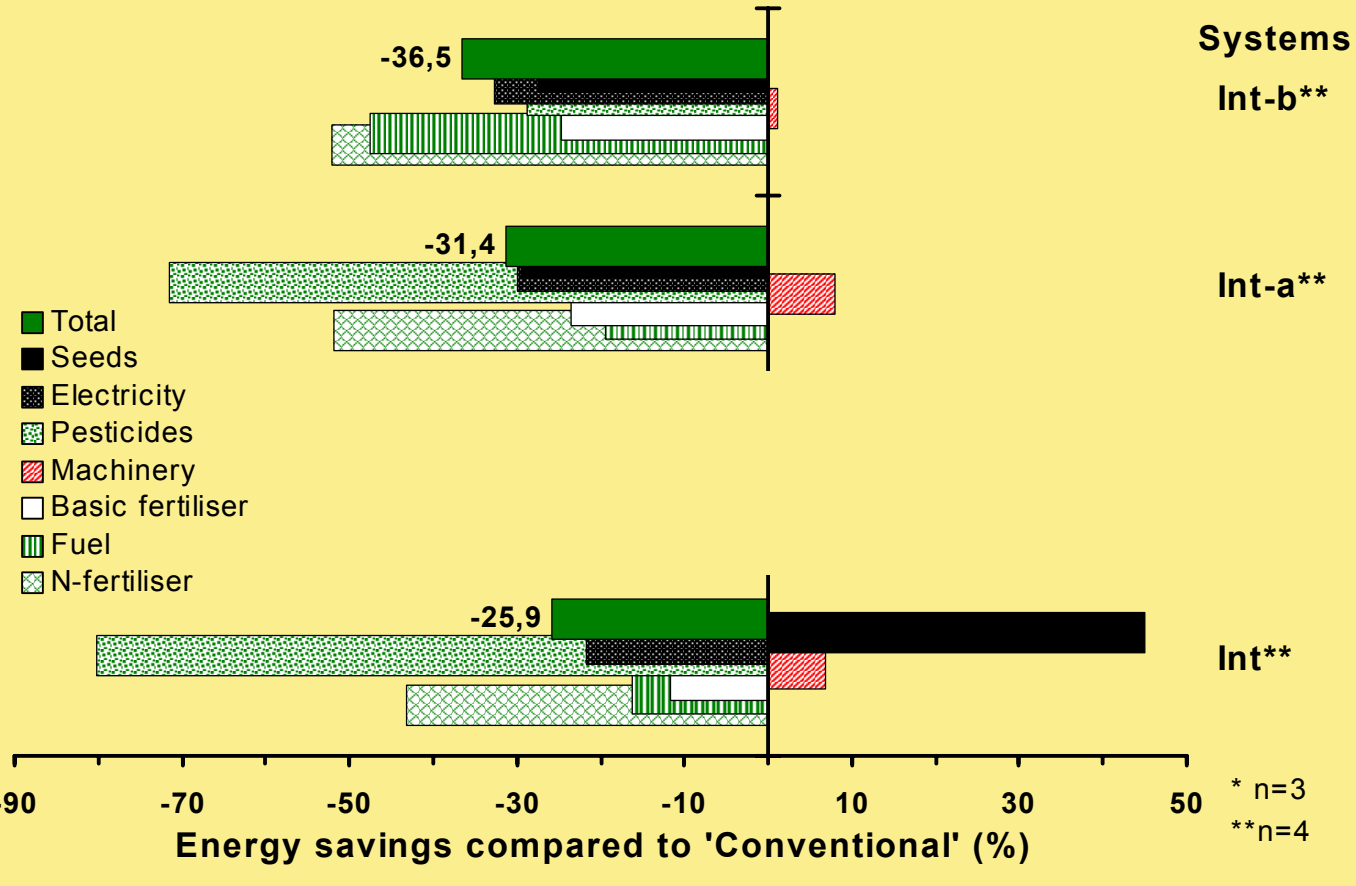
Relative Energy Savings in the Crop Rotations

- mean years of rotation, Reinshof, annual fallow included -



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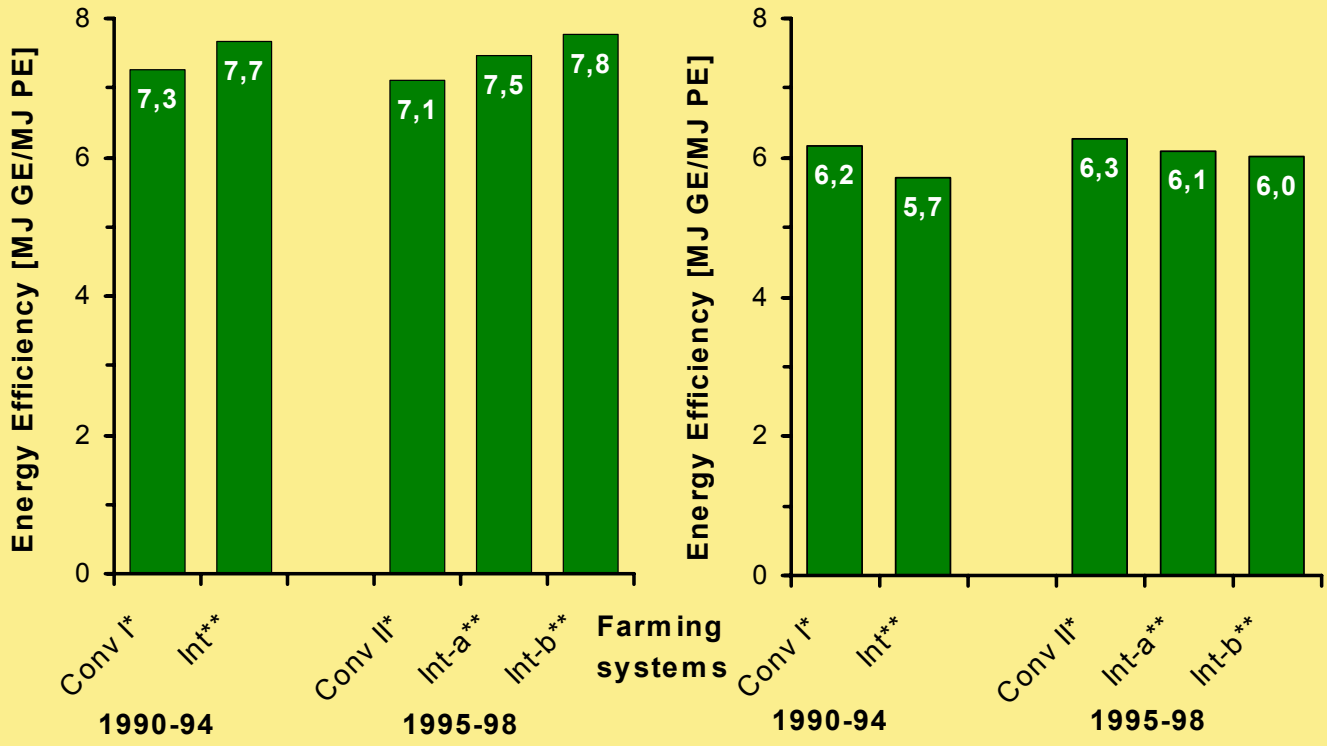
Mean Energy Efficiency in the Crop Rotations

- mean years of rotations, annual fallow included -



* n=3 ** n=4 GE=Gross energy PE=Primary energy

Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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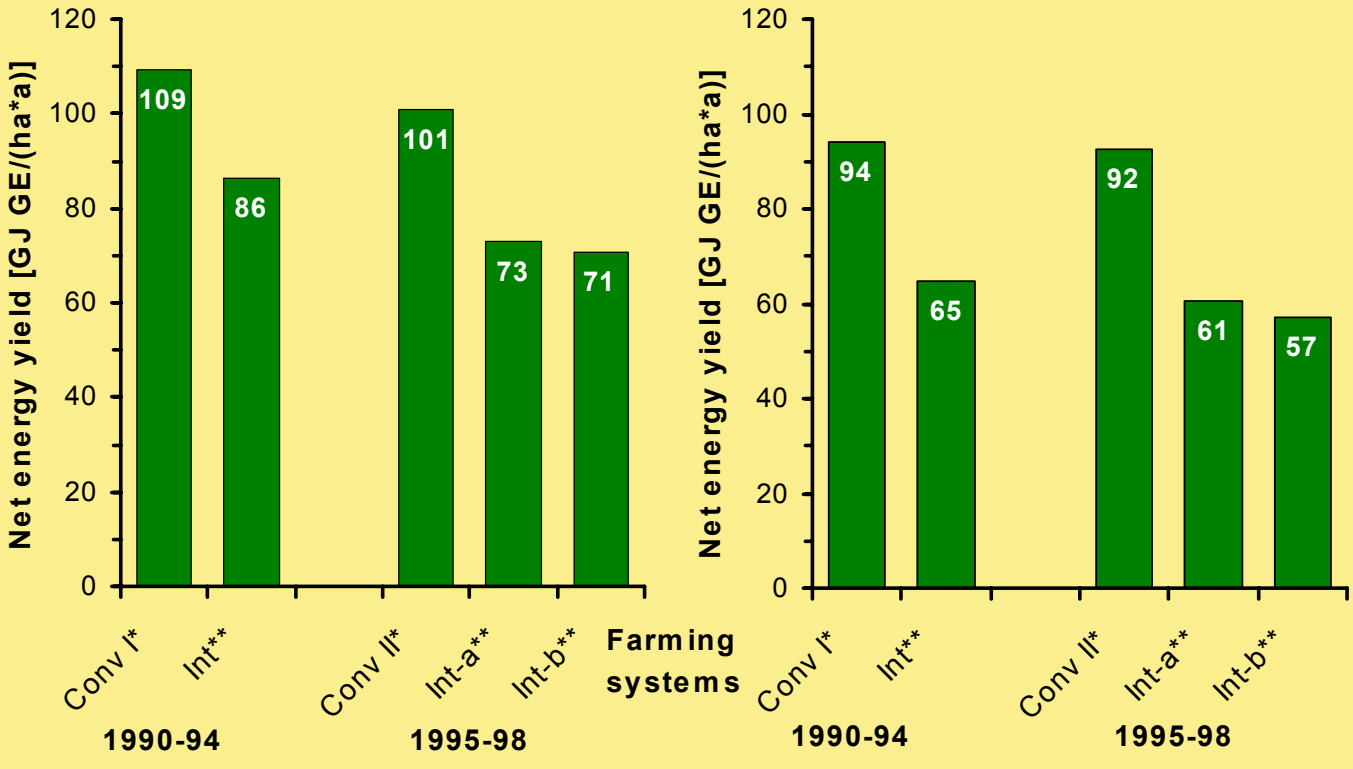
Mean Energy Productivity in the Crop Rotations

- mean years of rotations, annual fallow included -



* n=3 ** n=4 GE=Gross energy

Conv = Conventional Int = Integrated Int-a = Integrated flexible Int-b = Integrated without plough

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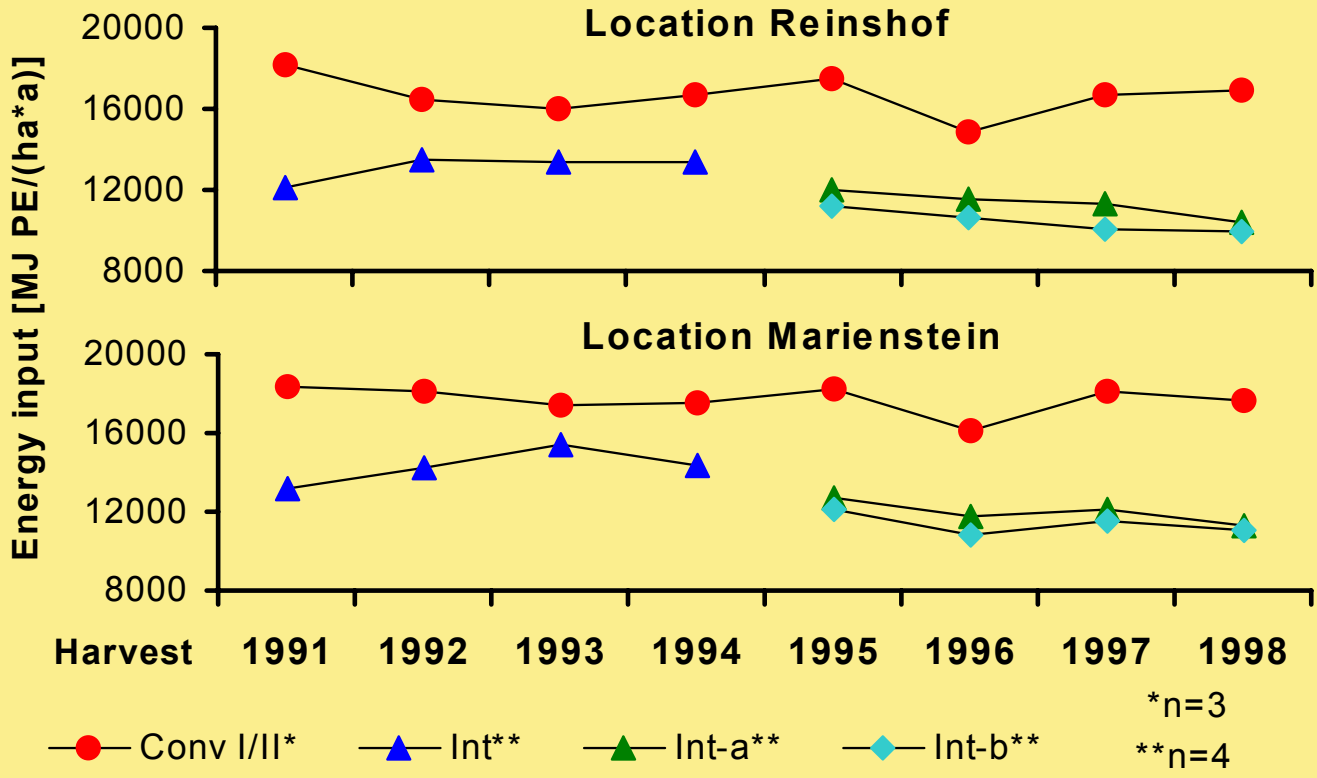
Mean Energy Input in the Crop Rotations (related to area)

- Average of all crops each year, annual fallow included -



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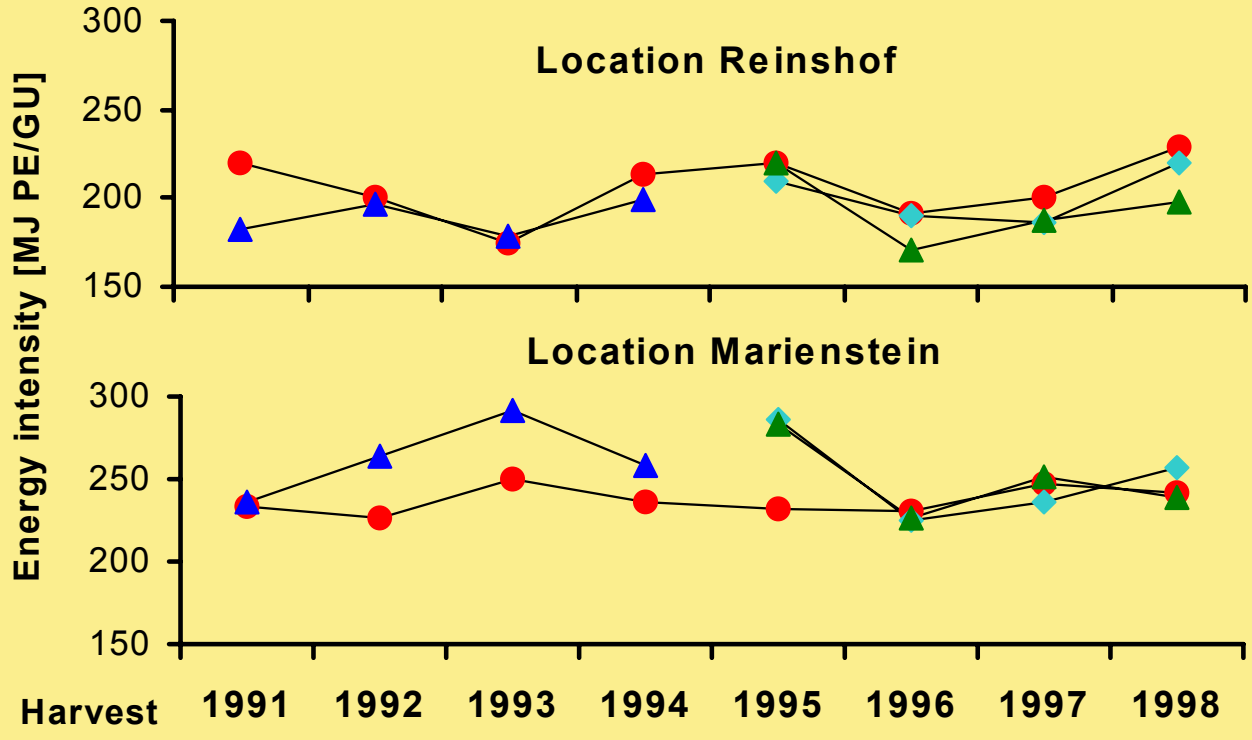
Mean Energy Intensity in the Crop Rotations (GU)

- Average of all crops each year, annual fallow included -



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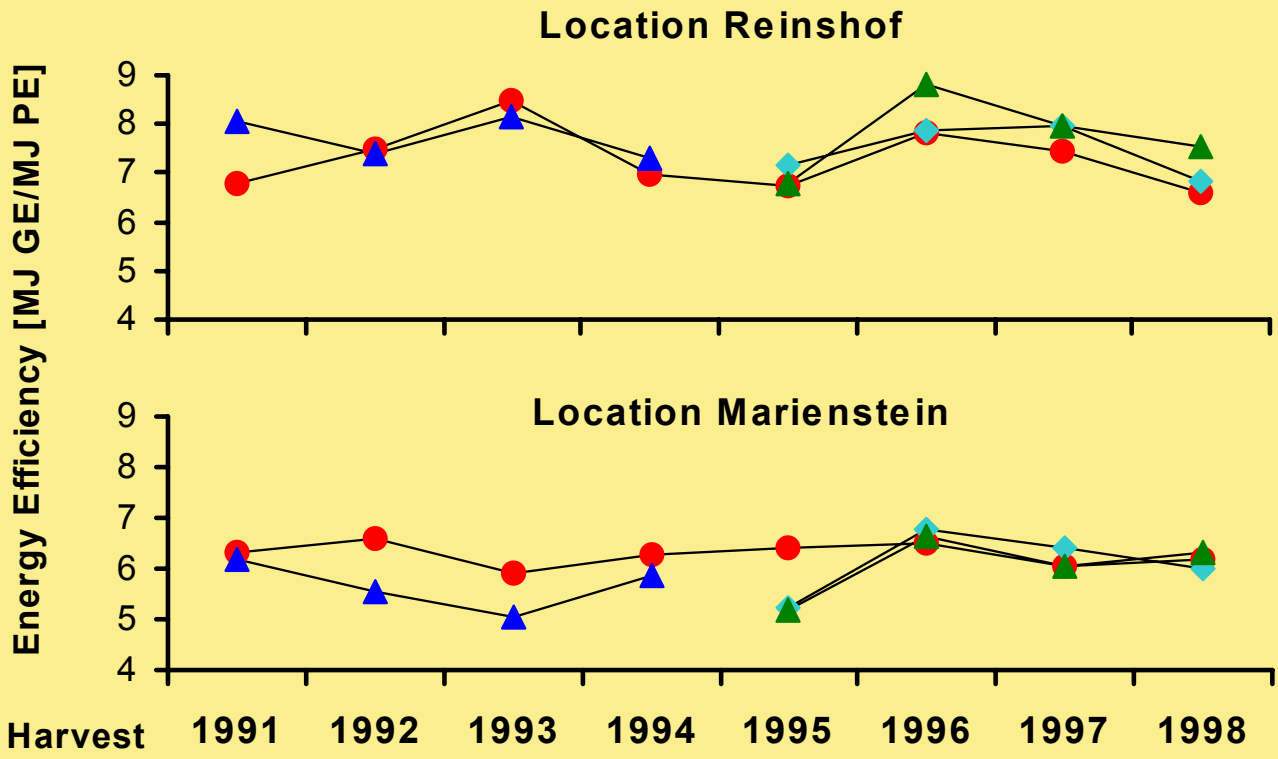
Mean Energy Efficiency in the Crop Rotations

- Average of all crops each year, annual fallow included -



Conv I/II* Int** *n=3 GE=Gross energy

Int-a** Int-b** **n=4 PE=Primary energy

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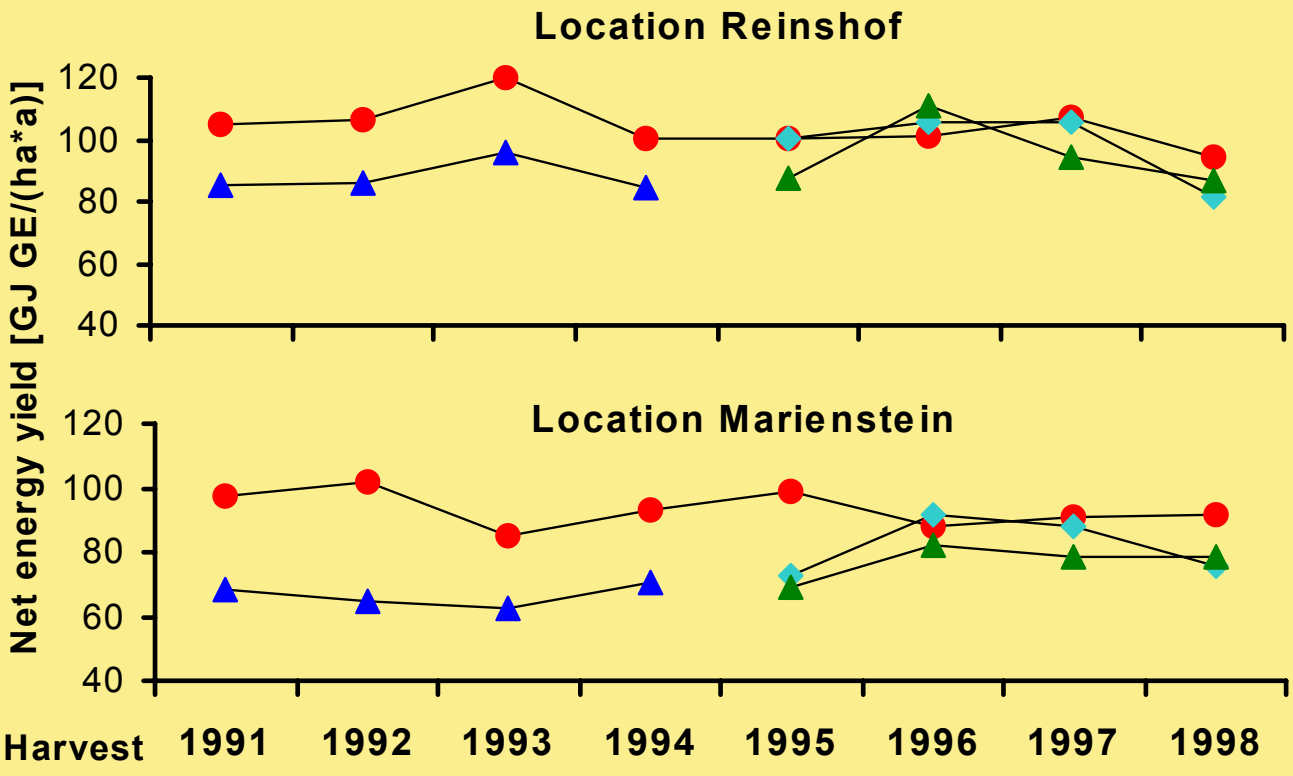
Mean Energy Productivity in the Crop Rotations

- Average of all crops each year, annual fallow excluded -



Conv I/II* Int** *n=3 **n=4

Int-a** Int-b** GE=Gross energy

Summary and Conclusions (I)

- **Primary energy use** (related to cultivated area)
  - **system ranking on crop level differs between crops (and locations)**
  - **usually contradiction between energy use and energy intensity in the system ranking**
  - **on rotation level the system ranking is identical for both locations**
  - **Influence of machinery use depends on the used depreciation model**
  - **Input for machinery is often higher in the Integrated systems**
- **Energy savings compared to Conventional**
  - **highest potential on rotation level: Barley replaced by oats**
  - **reduction of mineral N-fertiliser as main advantage**
  - **further savings by - reduction of cultivation intensity (fuel use) or**
    - reduction of pesticide use
  - **annual fallow causes considerable effects on rotation level**

Summary and Conclusions (II)

- **Energy intensity** [MJ/t dry matter; MJ/Grain unit]
  - **is higher at ‚Marienstein' than at ‚Reinshof'**
  - **system ranking differs considerably between crops and locations**
- **Energy efficiency** [MJ Gross energy/MJ Primary energy]
  - **farming intensity cannot be really expressed by this indicator**
- **Energy productivity** [MJ Gross energy/(ha*a)]
  - **system ranking on mean rotation level:**
    - Integrated always lower than Conventional (both locations)
    - Int-b slightly lower than Int-a
    - difference increases in second period when annual fallow included
- **Reliability of results**
  - **No clear tendencies of system ranking for most investigated critera on rotation level when results of single years are compared**

Used Energy Coefficients (Inputs)

Supplies		Energy coefficients
Direct Energy	- Diesel fuel, Motor oil (2 % of fuel)	47,82 MJ/kg
	- Electricity	11,39 MJ/kWh
Seeds	- Field beans	3,55 MJ/kg
	- Grass, Clover and other fine seeds	12,21 MJ/kg
	- Oats	3,28 MJ/kg
	- Rape seed	8,43 MJ/kg
	- Sunflowers	3,55 MJ/kg
	- Winter sown barley	3,45 MJ/kg
	- Winter wheat	3,02 MJ/kg
Mineral fertilisers	- Urea	59,07 MJ/kg N
Nitrogen	- Urea ammonium nitrate (UAN, liqu.)	52,33 MJ/kg N
	- Calcium ammonium nitrate (CAN)	47,18 MJ/kg N
	- Ammonium sulphate (AS)	17,41 MJ/kg N
Phosphate	- Triple-Superphosphate (TSP)	18,79 MJ/kg P_2O_5
Potash	- MOP, 40 % K_2O	10,73 MJ/kg K_2O
Limestone	- Calcium carbonate	1,72 MJ/kg CaO
Sulfur	- Ammonium sulphate (AS)	17,41 MJ/kg S
Pesticides	- Active substance	274,46 MJ/kg AS
Farm machinery	- Tractors	122,45 MJ/kg
	- Self propelled harvesters	112,88 MJ/kg
	- Cultivation machinery	109,75 MJ/kg
	- Other machinery and trailers	101,25 MJ/kg

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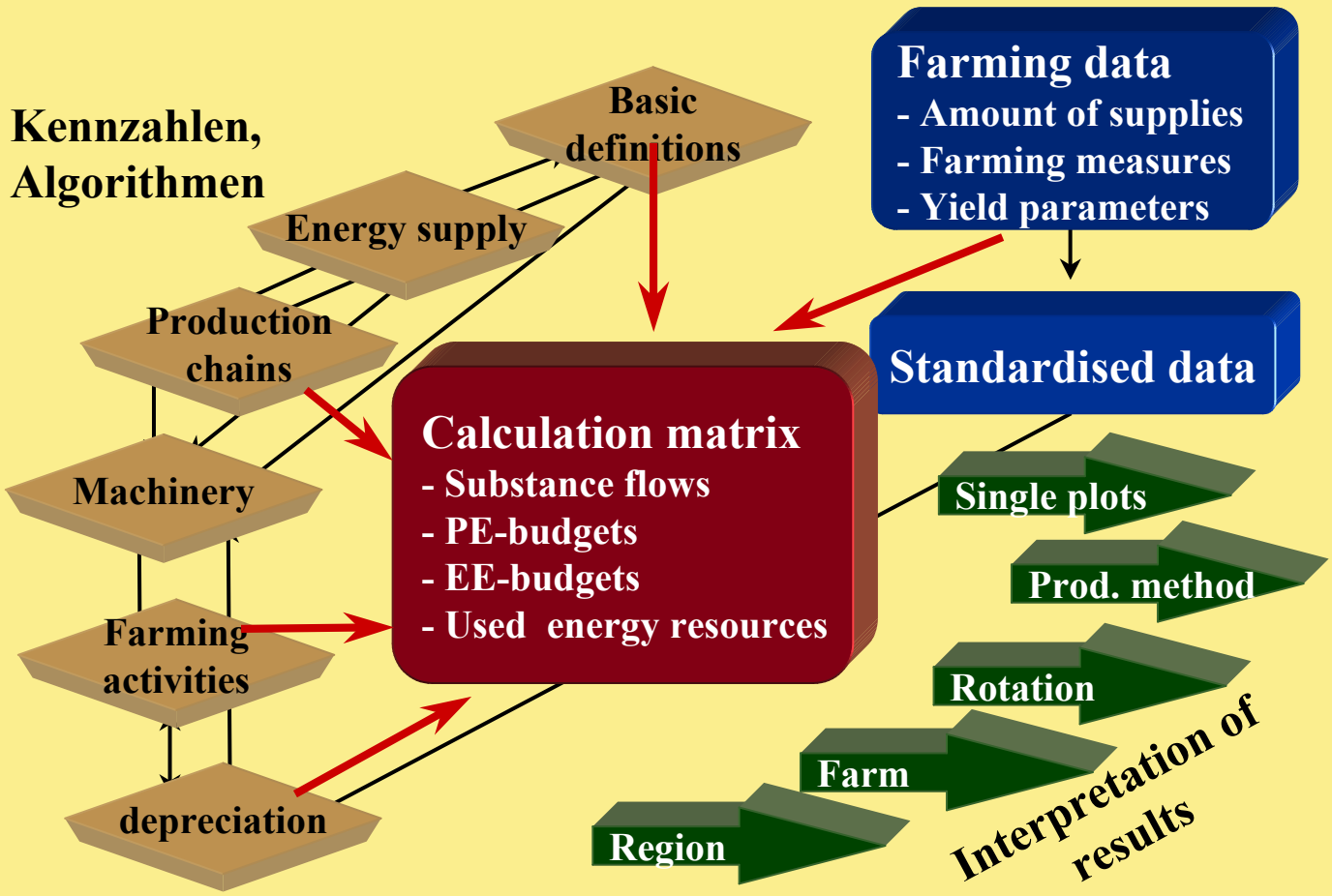
Used Energy Coefficients (Gross energy)

- incorporated energy of seeds and kernel yield -

Product		Gross Energy (GE)
Seeds and kernel yield identical	- Field beans	16,42 MJ/kg
	- Oats	16,30 MJ/kg
	- Rape seed	25,72 MJ/kg
	- Winter sown barley	15,79 MJ/kg
	- Winter wheat	15,79 MJ/kg
Other seeds	- Grass, clover and other fine seeds	16,40 MJ/kg
	- Sunflowers	25,12 MJ/kg

Modules of the Calculation Programme



Dependency of Factor use in Arable Farming

- **Input factors dependent on the cultivated area**
  - Amount of seeds
  - Amount of fuel use
  - Application of Ca-fertiliser
  - Mechanisation
  - Amount of pesticides
- **Input factors dependent on the amount of yield**
  - Amount of N-fertiliser
  - Amount of basic fertilisers P, K, Mg
  - Electricity, (and moisture content of yield)
- **Dependencies on farming system intensity**
  - Amount of fuel use
  - Mechanisation and energetical depreciation rate of machinery
  - Pesticides: Number of applications and amount of pesticides