WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

# Does Organic Farming Use Less Energy?

## … Compared to What ?

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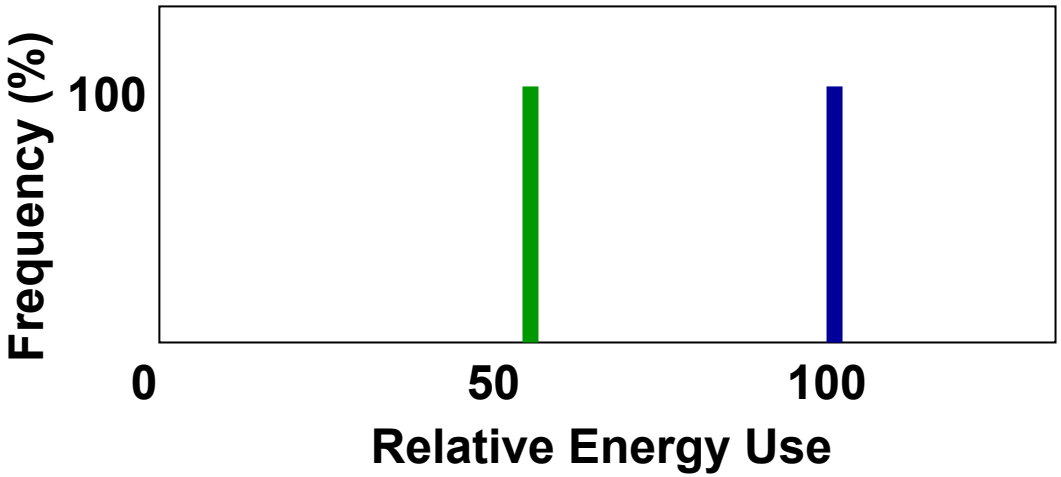
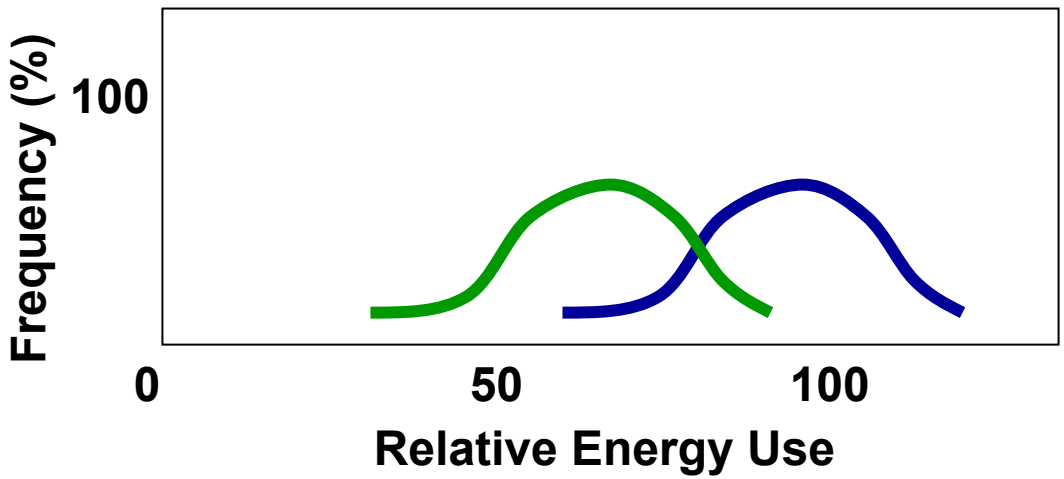
## Challenges:

**How you structure your comparison**

- **Toyotoa Corolla LE 5 sp. vs Honda Civic LX 5 sp**
- **Humvee vs Prius**
- **Organic vs Conventional**

# 'Organic' and 'conventional' – discrete or diverse ?



# Variance in Crop Inputs

**% difference in per acre cost – top 25% farms vs. bottom 25%**

| | KS wheat | MN soy | MN corn |
|---|---|---|---|
| Fertilizer | 8-18 | 1 | 15 |
| Pesticides | 5-13 | 24 | 9 |

| | ------ $/acre ------ | |
|---|---|---|
| SW KS wheat | Top 25 | Bottom 25 |
| Fuel | 6.91 | 9.99 |
| Fertilizer | 2.62 | 10.15 |
| Pesticide | 1.19 | 6.47 |

(NRC, Alternative Agriculture, 1989)

# SAFS Trial – UC Davis

**Conv. 2 yr, Conv. 4 yr, low input, organic – 12 year study**

**Yield difference never more than 10%**

| | N input (kg/ha) | Loss of applied N (%) |
|---|---|---|
| Org | 1924 | 4.6 |
| Conv 2 | 1584 | 28.5 |

(Huyck et al., 2003)

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| | N input (kg/ha) | Loss of applied N (%) |
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| Org | 1924 | 4.6 |
| Low | 1550 | 2.4 |
| Conv 4 | 1827 | 22.3 |
| Conv 2 | 1584 | 28.5 |

(Huyck et al., 2003)

**Low input was most energy efficient; high energy costs for organic for hauling fertilizers, mechanical weed control**

# Challenges:

How you structure your comparison

**Units compared – mpg, gal/passenger mile, gal/ton-mile cargo; GJ/ha, GJ/MT DM**

**System boundaries – include fossil, renewable, solar for plants, soil, human labor, …**

# Challenges:

How you structure your comparison

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**How you calculate**

**Assumptions**

# NOP Definition of "Organic Production"

- **Positive definition:** 'A production system that is managed . . . by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity' *(7 CFR 205.2)*

"…maintain or improve soil and water quality…"

- **Negative definition:** Food produced and handled without synthetic substances (with specific, limited, well-defined exceptions), and excludes genetically modified organisms, sewage sludge, and irradiation *(7 CFR 205.105)*

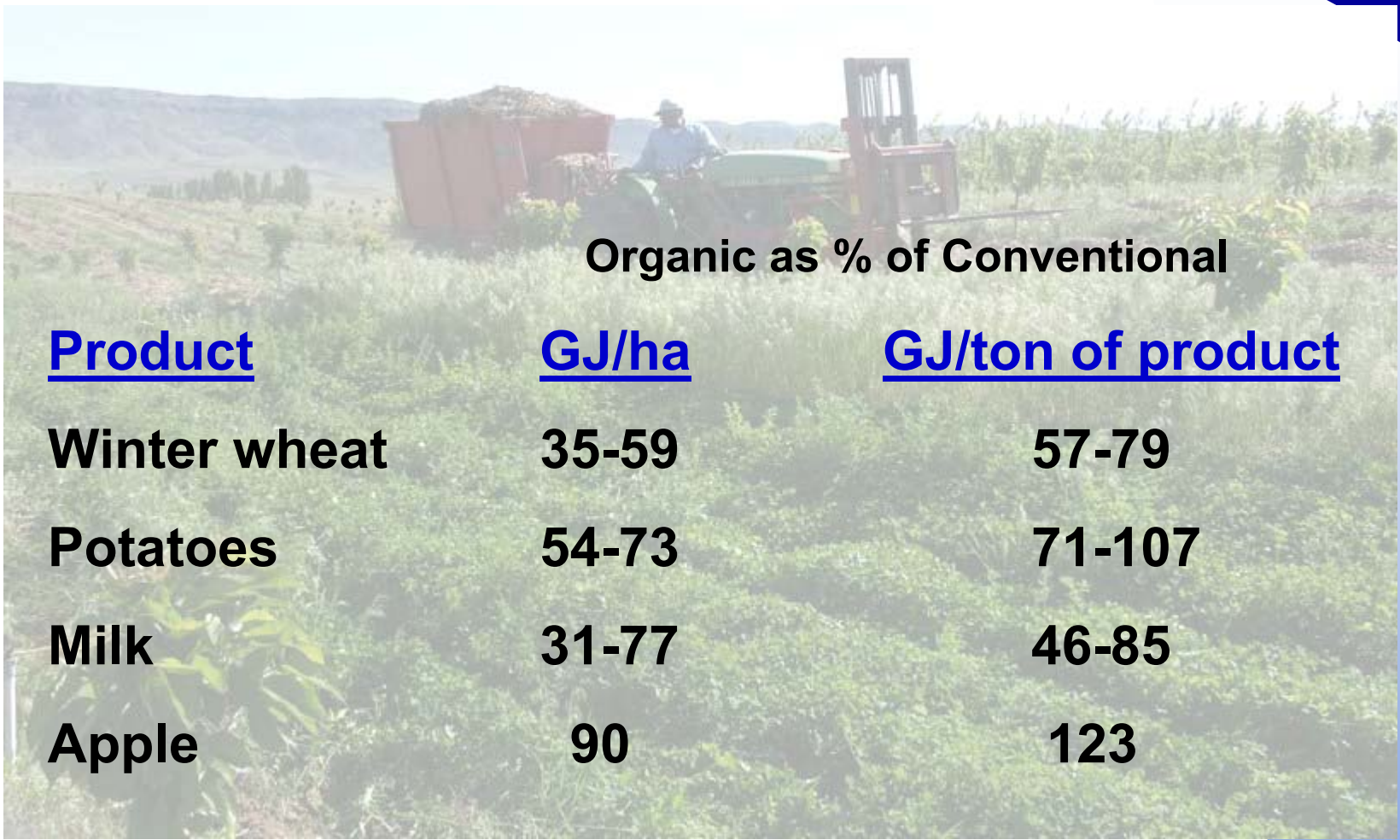
**-- Organic Food Production Act, 1990**

(Courtesy: B. Baker, OMRI)

# Energy Used in Agricultural Production U.S., 1977

| | % of total |
|---|---|
| Field machinery | 18 |
| Transport | 15 |
| Irrigation | 12 |
| Livestock | 10 |
| Crop Drying | 5 |
| Misc. | 3 |
| Fertilizer | 31 |
| Pesticides | 5 |

# Energy Use

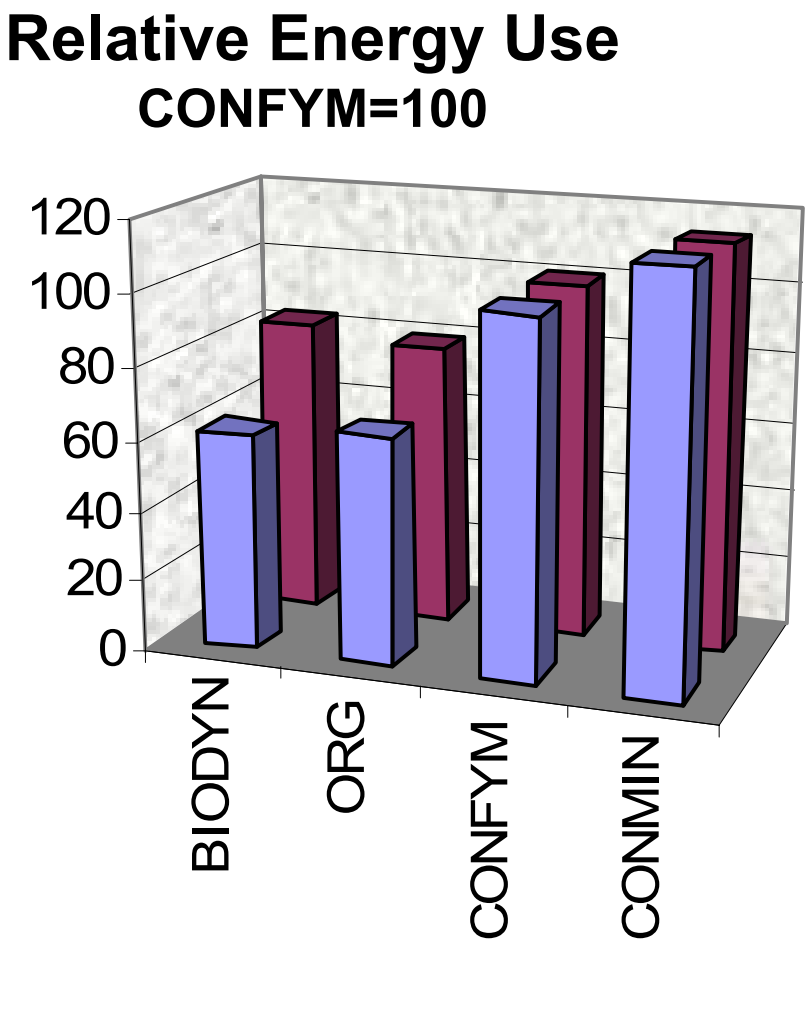


Organic as % of Conventional

| Product | GJ/ha | GJ/ton of product |
|---|---|---|
| Winter wheat | 35-59 | 57-79 |
| Potatoes | 54-73 | 71-107 |
| Milk | 31-77 | 46-85 |
| Apple | 90 | 123 |

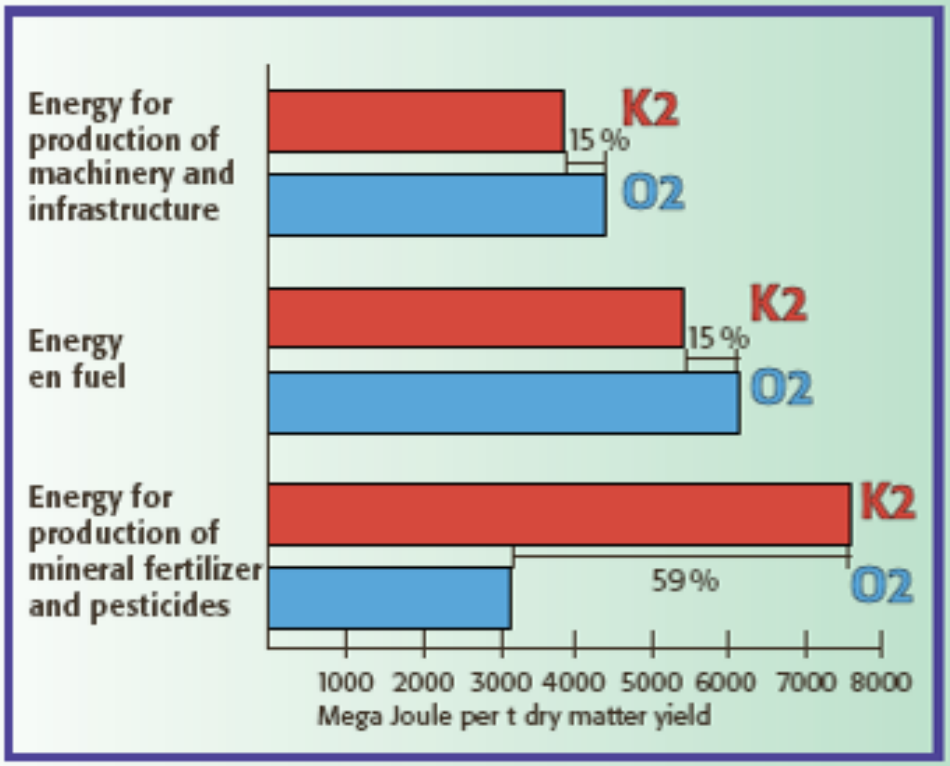
(Scialabba and Hattam, 2002)

# DOK Study, Switzerland




(Mäder et al., 2002, *Science)*

# Is organic farming energetically sound?




*Organic farming needs only slightly more energy for infrastructure and machinery as well as for fuel, whilst markedly lower energy input for the production of fertilizers and pesticides.*

## DOK Study, Switzerland

**Organic yields 80% of conventional**

**Organic 19% less energy per unit crop output, 30-50% less per unit land**

(from FiBL Dossier, No. 1, 2000)

# Netherlands Survey Study
## Crop, Dairy

Dairy farms

| | |
|---|---|
| Total energy use | 30-116 GJ |
| Conventional (ave.) | 75 GJ/ha |
| Organic (ave.) | 39 GJ/ha |
| Conventional | 4.3-5.5 GJ/MT milk |
| Organic (19% less) | 3.6-4.5 GJ/MT milk |

Crop farms

Ave. energy use in plant production **higher** on organic (per MT product)

- Difference varies among crops
- Organic carrots 2x energy of conventional (flaming weeds)

(Bos et al., 2007)

# ‘Model’ Corn production - USA

| Input | CONV | ORG |
|---|---|---|
| | kcal x106/ha | |
| Labor | 462 | 600 |
| Fuel | 1408 | 1431 |
| Machinery | 1018 | 1018 |
| Nitrogen | 2448 | -- |
| P & K | 521 | 386 |
| Lime | 315 | 315 |
| Seed, corn | 520 | 520 |
| Seed, vetch | -- | 930 |
| Herbicides | 620 | -- |
| Insecticides | 280 | -- |
| Electricity | 34 | 34 |
| Transport | 169 | 169 |
| Total | 7795 | 5377 |

**Organic corn uses 31% less energy; similar to Rodale results; equals 64 gal diesel per ha**

**Soybean 17% less for organic**

(Pimentel, SSR, 2006)

# Rodale Farming Systems Trial 1981-1995 - PA

| | CONV | LEG |
|---|---|---|
| Maize yield (kg/ha) | 7170 | 7100 |
| Cum. NPP (MT/ha) | 75 b | 68 a |
| Plant residues returned | 43 b | 39 a |
| Soil C change (MT/ha) | 2.2 ns | 6.6* |
| **Energy input (Mil kcal/ha)** | | |
| corn | 5.2 | 3.6 |
| soybean | 2.1 | 2.3 |

Soil C storage in organic ~70 gal DFE/ha/yr

(Drinkwater et al., 1998; Pimentel et al., 2005)

# Cumulative Energy
## (6-yr apple orchard, Zillah, WA)

| (MJ/ha) | Org | Int | Conv | |
|---|---|---|---|---|
| Fertilizer | 311* | 8,901* | 16,255 | 0.1-3% |
| Insecticide | 22,159 | 40,375 | 42,313 | 4-8% |
| Fungicide | 18,023 | 12,855 | 12,922 | 2-3% |
| Weed control | 141 | 13,350 | 31,931 | 0-6% |
| Labor | 2,337 | 1,718 | 1,607 | 0.4% |
| Machine | 73,974 | 73,560 | 73,560 | 14% |
| Fuel | 173,400 | 182,919 | 182,919 | 35% |
| | | | | |
| Electricity | 10,794 | 10,794 | 10,794 | 2% |
| Infrastructure | 144,188 | 144,188 | 144,188 | 28% |
| Total input | 445,328 | 488,661 | 516,489 | Org 14%↓ |

*energy for compost charged to poultry farm

(Reganold et al., *Nature*, 2001)

# Weed Control - Apples

## Conventional

| | | |
|---|---|---|
| Yr 1 – spray 2x + hand | | 1,070 |
| Glyphosate | 272 | |
| Tractor + sprayer | 241 | |
| Hand weed (20 h) | 44 | |
| Yr 2 – spray 2x + hand | | 1,070 |
| Yr 3 – spray 5x | | 2,565 |
| Yr 4-6 – spray 5x/yr | | 7,695 |
| **Total (no embedded energy)** | | **12,400** |
| From Reganold study | | 31,931 |

# Weed Control - Apples

| Organic | | MJ/ha | CONV |
|---|---|---|---|
| Yr 1 – mulch + hand | | 1,403 | 1,070 |
| Labor | 34 | | |
| Tractor | 1,206 | | |
| Hand weed (30 h) | 163 | | |
| Yr 2 – fabric + hand | | 1,423 | 1,070 |
| Tractor | 1,206 | | |
| Labor (40 h) | 217 | | |
| Yr 3 – hand hoe 8x | | 260 | 2,565 |
| Yr 4 – cultivate + hand | | 4,726 | 2,565 |
| Remove fabric | 1,336 | | |
| Cult. 8x | 3,216 | | |
| Hoe 8x | 174 | | |
| Yr 5-6 – cult. + hand | | 6,780 | 5,130 |
| Total (no embedded energy) | | 14,592 | 12,400 |
| From Reganold study | | 141 | 31,931 |

# Weed Control - Apples

| Organic | MJ/ha |
|---|---|
| Yr 1 – mulch + hand | |
| Labor | 34 |
| Tractor | 1,206 |
| Hand weed (30 h) | 163 |
| Total | 1,403 |
| Trucking for mulch (20 mi RT) | 1,627 |

# Nitrogen Fertilizer

## Energy for Nitrogen Fertilizer Production (MJ/kg)

(Leach, 1976)

| | %N | Factory | Delivered, farm Product | Element |
|---|---|---|---|---|
| $NH_4NO_3$ | 34.5 | 25.4-25.9 | 26.2 | 76.0 |
| Urea | 46.6 | 36.8-38.6 | 38.9 | 83.5 |
| Anhydrous | 82.4 | 50.5-51.2 | 51.5 | 62.5 |

100 lb N/ac = 2,812 - 3,757 MJ

= 19 – 26 gal gasoline

# Organic N

Chicken manure (broiler) 3.3% N, 37% moisture

For 100 lb PAN/ac, need 5 T/ac chicken compost

To get 5 T compost, need 7.6 T litter (50% manure);
75 bu corn to produce manure (4,125 MJ)

Making compost
- Machine fuel turner 22 MJ/ac
- Other machines, loaders 28 MJ/ac

Trucking per 100 mi RT 542 MJ/ac

Spreader 54 MJ/ac ?

| | Org | Conv |
|---|---|---|
| | - - - - - MJ/ha - - - - - | |
| For 100 lb N | 11,784 | 8,111 |
| Reganold (6 yr) | 311 (100 lb N) | 16,255 (182 lb N) |

# Germany
## 32-year field study

| Treatment | Yield MT DM/ha | Energy input GJ/ha | GJ/MT |
|---|---|---|---|
| FYM0/MIN0 | 6.86 | 11.17 | 1.63 |
| FYM0/MIN3 | 12.01 | 17.39 | 1.45 |
| FYM2/MIN2 | 12.87 | 20.96 | 1.63 |
| FYM3/MIN0 | 10.20 | 19.51 | 1.91 |
| FYM3/MIN3 | 13.00 | 25.27 | 1.94 |

**No legume in rotation !**

(Hülsbergen et al., 2001)

# Farming Systems Study
## South Dakota, 1985-1992

| | Alt. | Conv. | RT |
|---|---|---|---|
| **Direct costs** (not labor) ($/ac) | 45 | 62 | 69 |
| **Net income 1986-92** (not mgt.) ($/ac) | 37 | 23 | 6 |
| **Surface residue** in spring (%) | 43 | 22 | 42 |
| **$NO_3$-N (lb/ac)** 30-60 cm depth | 26 | 88 | 36 |
| **Herbicides applied** (lb a.i. whole farm) | 0 | 459 | 595 |
| **Whole farm energy** inputs (DFE) | 2657 | 8275 | 9024 |

Based on a 500 acre farm. *(Smolik et al., 1993)*

# The Future…


**Energy saving potential: N source, less tillage, weed suppression,**

*Source: Iowa State University*

# No-till Organic Systems

## Cover crops, killed by rolling – 70% energy reduction


*Source: New Farm, Rodale Institute*

# My Conclusions

Question numbers !

Organic generally less energy – fertilizer, pesticides

Reducing tillage is important

Where do you credit embedded energy, N in amendments?

Less inputs from off-farm, less energy; transport

Low energy – human labor, legumes; impact on productive land base, ability to farm

Something on rotation, how more land would go to N production, impact on whole system

C-S-O-H-H-H vs. C-S

| | ave MJ/ha/yr |
|---|---|
| C-S | 13,000 |
| C-S-O-H-H-H | 11,300 |

| Lockeretz 1983 | energy consumption per unit area MJ/ha |
|---|---|
| Corn | 20,000 |
| Soybean | 6,000 |
| Alfalfa | 12,000 |

# Energy to Produce Wheat

| Crop-fallow zone, WA | MJ/ha | MJ/kg wheat | |
|---|---|---|---|
| Conv. Till | 10,381 | 2.80 | |
| No Till | 10,065 | 2.72 | 3% savings |
| | | | |
| Annual crop zone, WA | | | |
| Conv. pea - WW | 9,156 | 1.66 | |
| Cook Farm SW - WW NT | 15,558 | 2.82 | |
| PCF SW NT Org | 3,870 | 3.20 | |
| Boyd WW Org | 2,840 | -- | |

- Lockeretz, 1983; 4x more fuel for conv. Till

(Courtesy: K. Painter)

# Netherlands

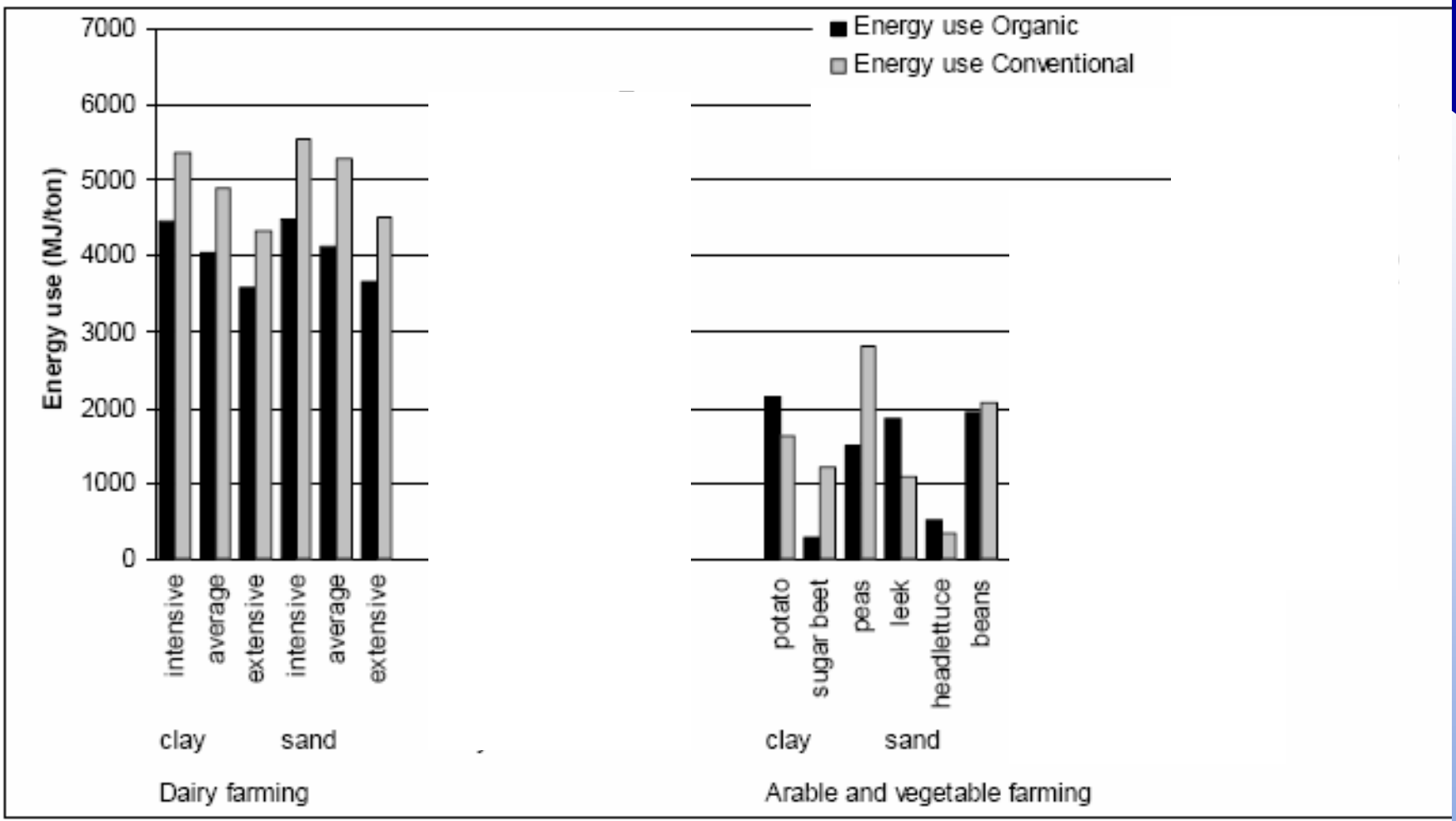



**Figure 2: Energy use and GHG emissions per Mg of product on organic and conventional model farms.**

(Bos et al., 2007)

**Table S4.** Energy input per unit land area (GJ $ha^{-1}$) in the 2nd crop rotation ($n$ = 3) Difference BIOORG and CONFYM = 36%, Difference between BIODYN and CONMIN = 53%. Note: grass-clover sawing in the year of barley cultivation. Source: T. Alföldi, Research Institute of Organic Agriculture [Forschungsinstitut für biologischen Landbau (FiBL)], internal report.

| Crop | BIODYN | BIOORG | CONFYM | CONMIN |
|---|---|---|---|---|
| Potatoes | 26.39 | 28.42 | 39.85 | 40.69 |
| Winter wheat 1 | 12.52 | 11.56 | 18.88 | 19.74 |
| Beetroots | 16.31 | 15.14 | 28.53 | 31.56 |
| Winter wheat 2 | 10.31 | 9.79 | 20.49 | 21.81 |
| Barley | 8.82 | 9.62 | 16.29 | 15.78 |
| Grass-clover sawing year | 6.43 | 7.63 | 6.78 | 6.75 |
| Grass-clover 1st year | 3.91 | 4.27 | 5.22 | 11.75 |
| Grass-clover 2nd year | 4.86 | 6.48 | 9.98 | 20.47 |
| Sum | 89.55 | 92.91 | 146.02 | 168.55 |
| Mean (energy input per year, sum/7) | **12.79** | **13.27** | **20.86** | **24.08** |
| Mean% (CONFYM = 100%) | 61 | 64 | 100 | 115 |

Web support material for Mader et al, 2002 Science article

**Table S5.** Energy input per unit crop yield (GJ/metric tons dry matter) in the 2nd crop rotation ($n$ = 3).

| Crop | BIODYN | BIOORG | CONFYM | CONMIN |
|---|---|---|---|---|
| Potatoes | 4.23 | 3.70 | 3.81 | 3.98 |
| Winter wheat 1 | 3.51 | 2.93 | 4.01 | 4.22 |
| Beetroots | 1.91 | 1.75 | 2.48 | 3.67 |
| Winter wheat 2 | 2.60 | 2.35 | 3.90 | 3.88 |
| Barley | 2.46 | 2.68 | 3.39 | 3.19 |
| Grass-clover sawing year | 2.83 | 3.35 | 3.44 | 3.92 |
| Grass-clover 1st year | 0.27 | 0.29 | 0.34 | 0.83 |
| Grass-clover 2nd year | 0.42 | 0.53 | 0.70 | 1.62 |

## Summarised DOK results

**Organic farming enhances soil fertility and biodiversity and exerted a higher energy and nutrient efficiency than conventional**

**Input**

Organic farming uses

- 34 to 53 % less fertiliser and fossil energy
- 97 % less pesticides

than conventional

**Output**

- Organic farming produces 80 % of conventional yields

FiBL

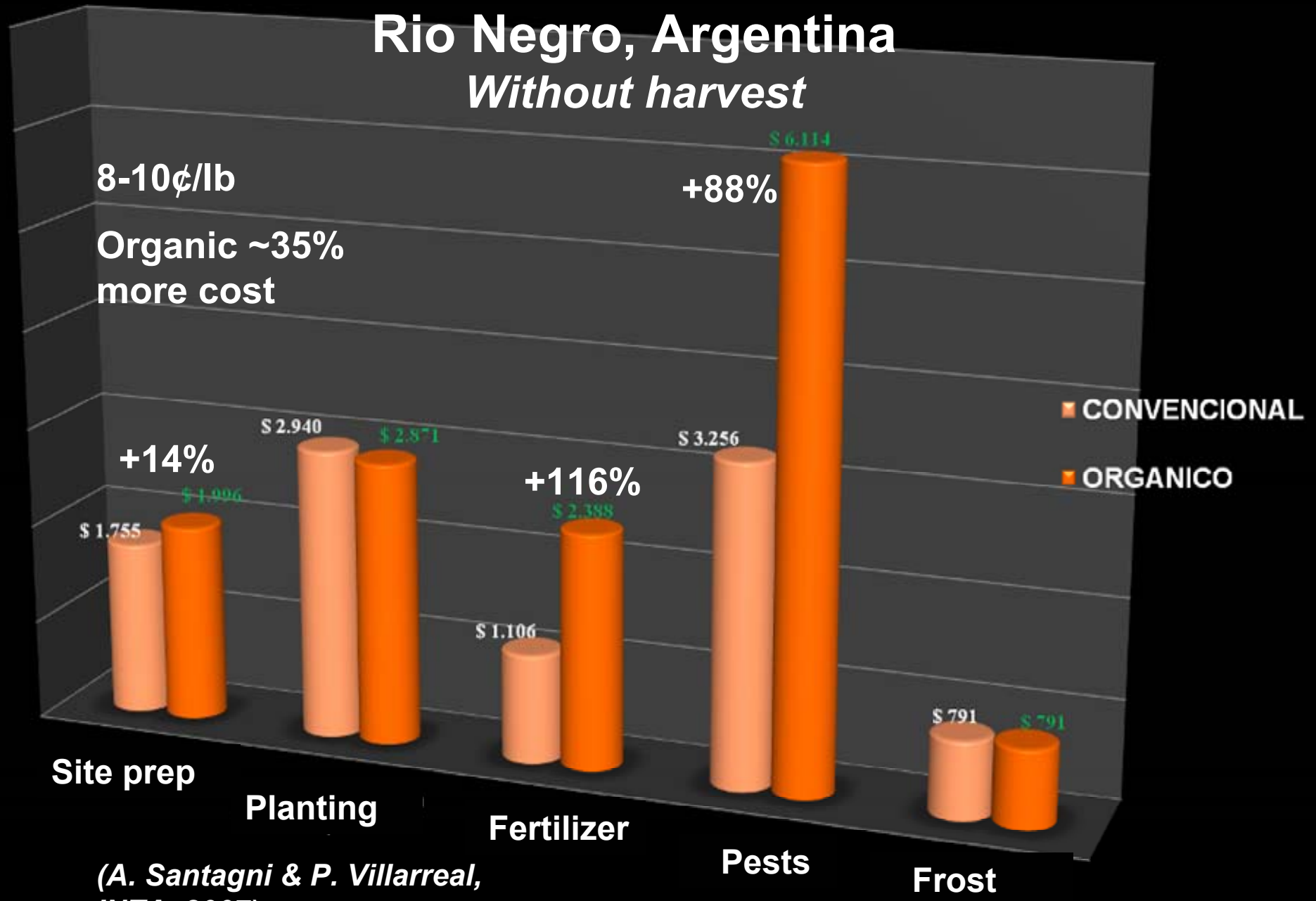
FiBL Frick

P. mader, Bertabos conference

# Cost of Production – Bartlett Pear

## Rio Negro, Argentina

*Without harvest*




*(A. Santagni & P. Villarreal, INTA, 2007)*

Rotary Harrow

Pre-plant

Post-plant

Rotary Hoe

# Weed Control in Organic Wheat

## Pullman, WA

# SAFS Trial – UC Davis

Conv. 2 yr, Conv. 4 yr, low input, organic – 12 year study

Yield difference never more than 10%

Cover crop – increased summer infiltration 2x, decreased winter runoff >10x

Conv. Lost 10x more applied N than low input, 5x more than organic

| | N input (kg/ha) | Loss of applied N (%) |
|---|---|---|
| Org | 1924 | 4.6 |
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