Measuring sustainability – practical techniques

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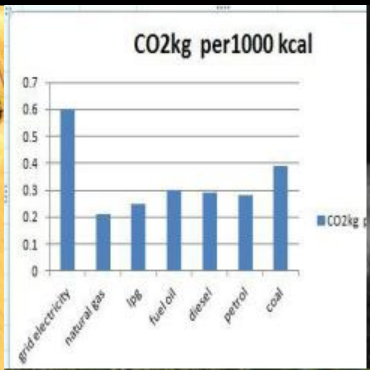


Why measure?

- Permaculture claims more ‘sustainability’ than conventional systems. We should be able to back that up with data

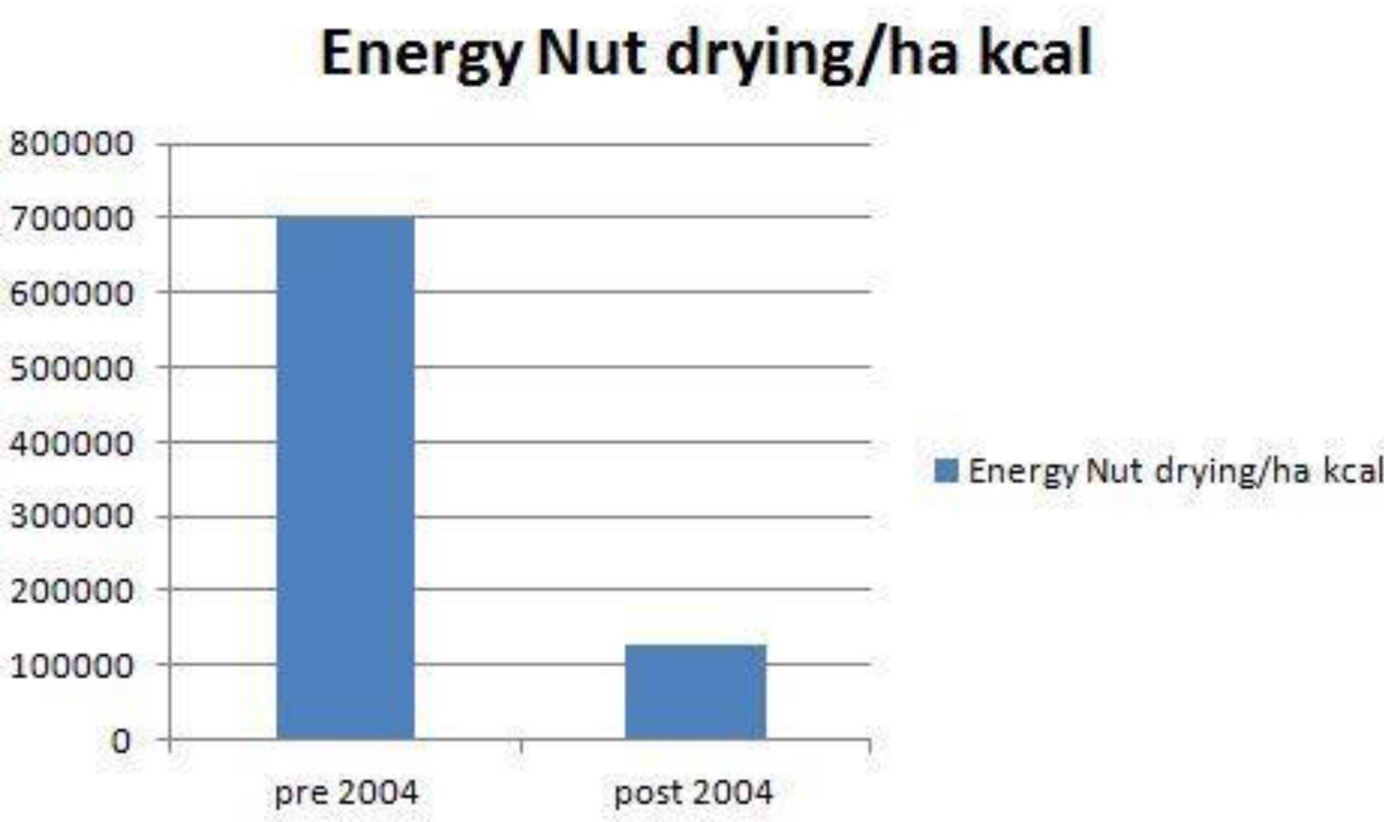
- I’ll be referring to food production systems in this presentation but the same basic measurements can be made for any enterprise

- Do permaculture producers use more energy physically controlling weeds than their herbicide spraying neighbours?

- Individual landholders and proponents of land-use systems need to be able to reliably measure performance and to pinpoint weak points for improvement

- When I analysed our operation, I was surprised to see that the energy involved in the processing of pistachio nuts offered the biggest opportunity for increased sustainability

Effect of change to drying on site with locally-built, ultra-efficient electric dehydrator. Figures include the energy cost of transport



Sources of concepts and figures

- Books and papers of American researcher and writer David Pimentel

- ‘Triple Bottom Line Reporting” (Dept Environment and Heritage, Australia, 2003),which subsumes international ‘Global Reporting Initiative’ protocols for the assessment of sustainability and aligns with the Environmental Management System Standard ISO 14001

Indicators of sustainability

- Indicators need to be both physical (positivist) and economic (normative)
- The indicators can be calculated reasonably easily and are expressed in units that we relate-to: weight, volume, energy and money
- Most figures should be available as a normal part of record-keeping processes for tax and for and organic certification if applicable

Overview of key Indicators

1 Product energy/input energy ratio

2 Income/cost of non-renewable inputs ratio

3 Soil nutrient, pH, organic carbon levels and trends

4 Percentage of property given-over to effective biodiversity plantings and reserves

5 Income & yield per kilolitre of water

Indicator 1
Product energy/input energy ratio

- Compares the raw physical energy efficiency of the design and is a key measurement, especially relative to Climate Change or a future shortage of oil
- Does not address product quality or prices; those issues are better dealt with by some of the other indicators.
- Energy values of food, electric power, fuel etc are expressed as kilocalories as the unit in calculations but other units would also work; it is the **ratio** that tells the energy efficiency of a system.
- *Some units 1 Kcal = 4.187Kjoules, 1 Kw = 1 Kjoule per sec, 3600 secs = 1hr, 1KWhr = 863 Kcal*

Energy inputs for maize in the USA David Pimentel

Inputs	Quantity/ha	Kcal/ha
labour	12 hours	7000
machinery	55kg	990000
petrol/oil	26 litres	264000
Diesel	77 l	881500
Gas	80 l	616400
Elect	33.4 Kwhr	95500
Nitrogen	151kg	2220000
Phosphorus	72kg	216000
Potassium	84kg	134000
Lime	426kg	134000
Seeds	18kg	445500
Insecticides	1.4kg	119950
Herbicides	7kg	777500
Drying	of 7000kg	optional
Transport	200kg	51200
Total		**6,958250**
Total yield	**7000**	**25,000000**
Ratio of output to input		**3.5**

Inputs and their energy costs

- Common insecticides per kilo 87000 Kcal
- Common herbicides per kilo 100000 Kcal
- Glyphosate per kilo 110000 Kcal
- Fungicide per kilo 65000 Kcal
- Winter-oil per litre 60000 Kcal
- Petrol per litre 10000 Kcal
- Diesel per litre 11430 Kcal
- Gas per litre 7705 Kcal
- Wood per kilo 4600 Kcal
- Nitrogen per kilo 14700 Kcal
- Phosphorus per kilo 3000 Kcal
- Potassium per kilo 1600 Kcal

Inputs and their energy costs

• Guano per kilo	1000 Kcal
• Rock phosphate per kilo	1100 Kcal
• Electricity per Kwhr	860 Kcal
• Compost per kilo (my estimate)	815 Kcal
Embodied energy per kilo	
• Tractors	3500 Kcal
• Harvesters	3100 Kcal
• Tillage equipment & seeders	2000 Kcal
• Sprayers, manure spreaders, mowers	1760 Kcal
• Forage equipment	1400 Kcal

Input energy costs and yields for Pistachios at The Food Forest

Pistachios (Organic) at The Food Forest, ***Product Energy / Input Energy*** **per annum**

Inputs	**Quantity/ha**	**Kcal/ha**
Labour	198 hours	Not allowed for
Light machinery	20 kg	340200
Fuel/oil	15.5 litres	141360
Elect/irrig (notional)	6cm	100000
Phosphorus + Nitrogen etc – composted byproducts	224 kg	182560
Potassium - ash	100kg	byproduct
Insecticides – winter oil	10 kg	600000
Fungicides - Cuprous oxide	0.5kg	50000
Herbicides	-	-
Electricity (drying)	116 kWhr	126133
Total inputs		**1,223762 Kcal inputs**
Total yield	**250kg pistachio nuts**	**1,548250 Kcal (food energy)**
Product Energy / Input Energy Ratio		**1.27**

Energy Efficiency Revealed

- As can be seen the orchard produces 1.27 times more food energy than is applied as inputs.
- Permaculture farms often have better ratios than conventionally managed ones even though yields on conventional farms tend to be higher
- A benchmark conventionally-managed nut farm has a ratio of product energy to input energy of 0.51, ie about twice as much energy went into the production of the crop as was harvested.

Input energy costs and yields for Almonds USA

Almonds (Conventional, America) Benchmark ***Product Energy/Input Energy*** **per annum (Pimentel D, 1984)**

Inputs	**Quantity/ha**	**Kcal/ha**
Labour	198 hours	Not allowed for
Machinery	30kg	540000
Fuel/oil	155 litres	1413600
Elect/ Irrig	301cm	9025000
Nitrogen	224kg	3115000
Phosphorus		
Potassium		
Insecticides	12.2 kg	492800
Fungicides	11.2kg	246400
Herbicides	4.5kg	255400
Gas	37 litres	2331500
Transport	3361kg	373900
Total		**21,150000**
Total yield	**1792 kg almonds**	**10,719000**
Product Energy / Input Energy Ratio		**0.51**



- Whilst the figures are from different environments and nut crops they may demonstrate a significant difference in energy efficiency of the production system. Most importantly, they demonstrate the use of the calculation process for comparative purposes

- If the difference in *Product Energy / Input Energy Ratio* is significant, there are some likely reasons for the relatively higher energy efficiency and low greenhouse impact of the permaculture-designed orchard

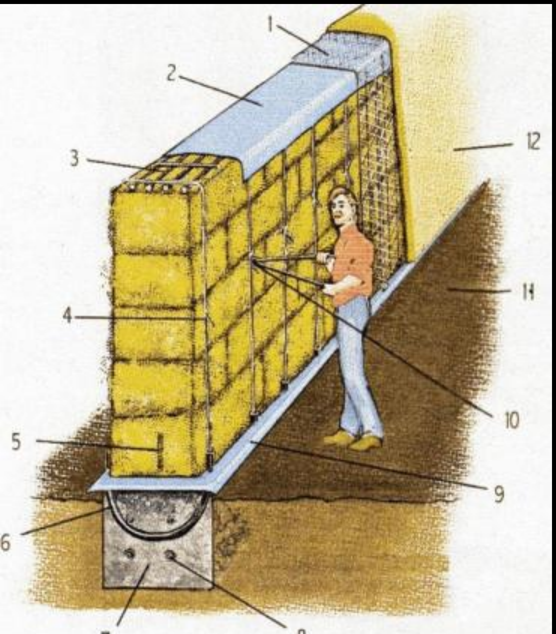
Possible reasons for better sustainability

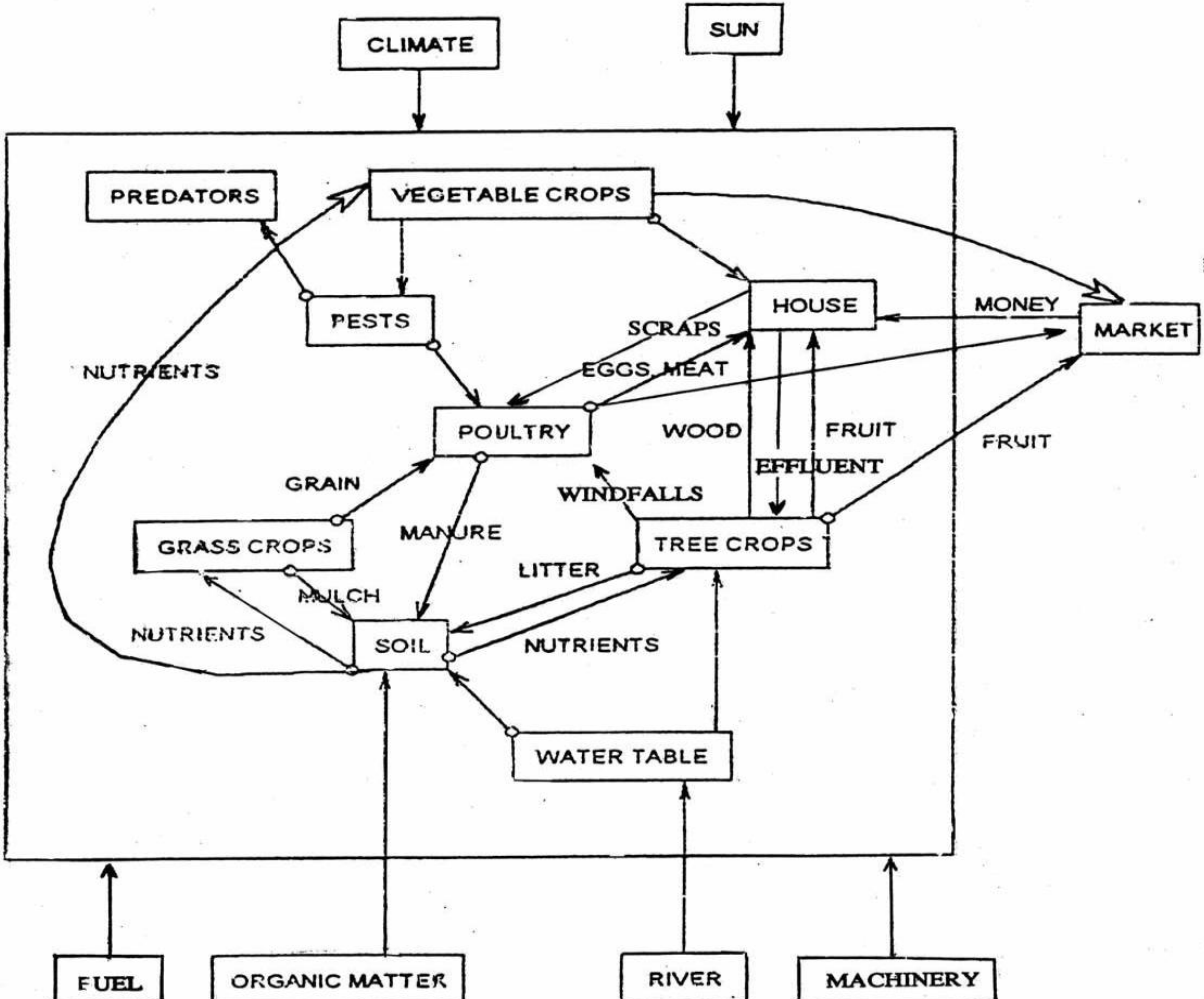
- Fuel use is low due to under-tree grazing rather than herbicides or mowing
- Biocide use is low as part of the biodiverse, organic system
- Fertilizer use is low as legumes provide nutrients and yields are limited by rainfall and available irrigation water anyway

- Drying is efficient due to dehydrator design

- Geese & sheep exploit inter-row space in the orchard in spring and early summer. They provide a bonus a gourmet food product

- Water use is low due to the choice of deep-rooted, well adapted species such as carob and pistachio




CLIMATE
SUN
PREDATORS
VEGETABLE CROPS
PESTS
HOUSE
MONEY
MARKET
SCRAPS
EGGS, MEAT
NUTRIENTS
POULTRY
WOOD
FRUIT
FRUIT
EFFLUENT
WINDFALLS
GRAIN
MANURE
GRASS CROPS
TREE CROPS
LITTER
MULCH
NUTRIENTS
SOIL
NUTRIENTS
WATER TABLE
FUEL
ORGANIC MATTER
RIVER
MACHINERY

4. Performance of various crops per hectare

crop	Crop yield kg	Protein kg	Food energy Million Kcal	Fossil fuel costs in Million Kcal	Energy output/ fossil fuel input	Labour in man hours
maize grain	7000	630	25	7	3.5	12
wheat	2022	283	6.7	2.5	2.7	6
oats	2869	423	10.9	2.1	5.1	3
apples	41546	83	23.3	26	0.9	176
potato	34468	539	21.1	15.5	1.4	35
lucerne	11800 dry	1845	47.2	3.6	13.1	12
maize silage	9400 dry	753	29	5.2	5.6	15
almonds	1792		10.719	21.151	0.51	200
walnuts	1136	170	7.395	16.858	0.4	100
walnuts	454	68	2.955	2.413	1.2	40

Indicator 2 Income/cost of non-renewable inputs ratio

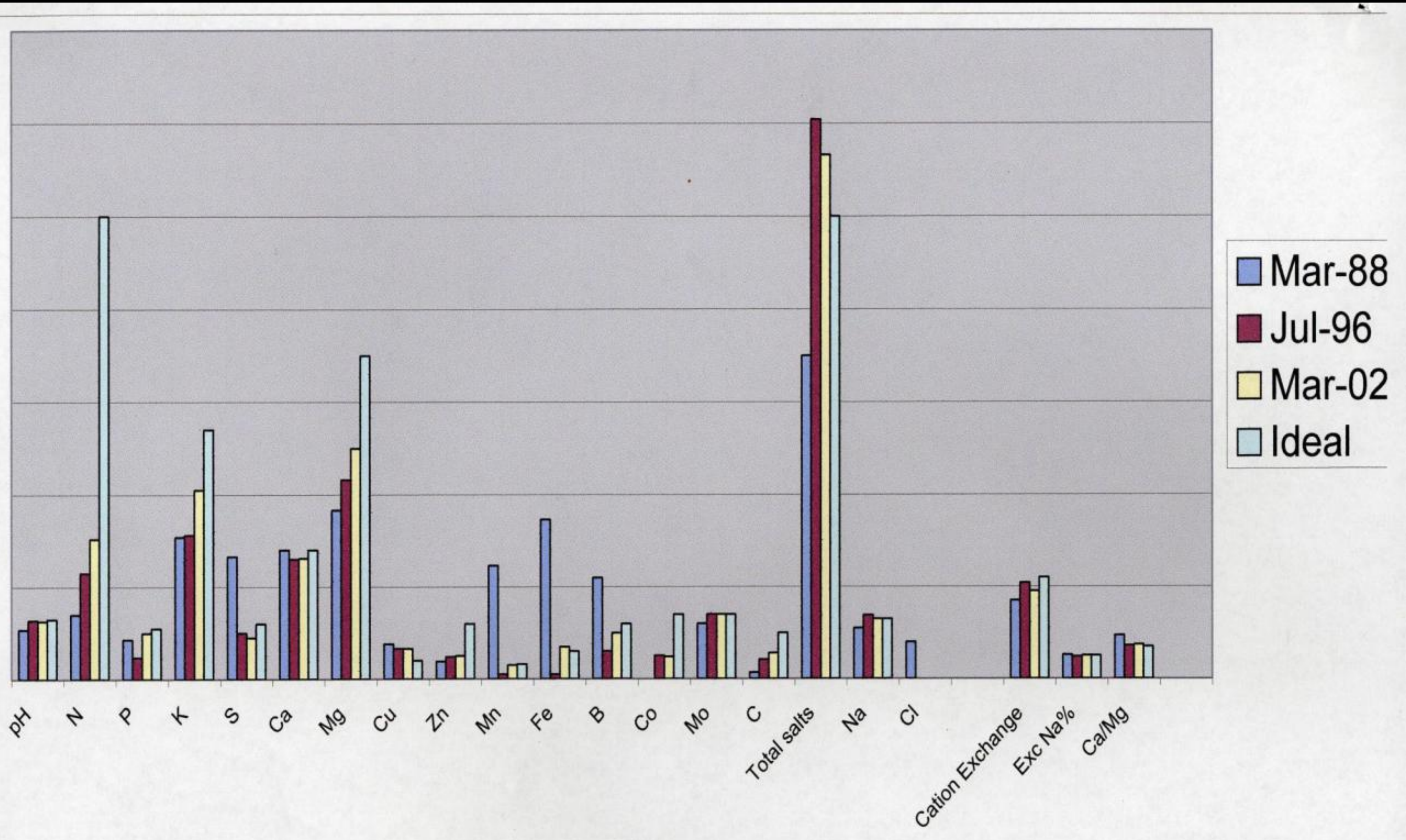
- This ratio shows the environmental footprint of each dollar you earn. Inputs that are not products or by-products of the production system on the property must be costed. Examples: A wind turbine purchased for the farm is costed but the electricity produced by it is not

- Waste organic material that would have gone to land-fill is not costed but its transport to the farm and composting is. Inputs can be amortised where required eg. gypsum may be applied in one year but lasts for (say) five, so can be charged-for in 5 yearly instalments just as equipment would be depreciated.

Indicator 3 Soil nutrient, pH, organic carbon levels and trends

- This indicator is to show that you are not degrading soil through your growing system and also to enables you to track benefits that result from investments in nutrients through husbandry or fertiliser imports.
- Regular soil tests will provide all the data required. Results can also be indexed against recognised optimal values for growing a range of crops (obtainable from soil testing labs) as below.

Tracking soil fertility



Indicator 4 Percentage of area utilized for biodiversity plantings and reserves

- It is generally regarded as appropriate to have at least 15% of a farm given over to plantings or remnant vegetation to enhance biodiversity, protect waterways and other fragile elements of the landscape

- The ideal percentage will depend on the particularities of the site and its surroundings.

Indicator 5 Income & yield per kilolitre of irrigation water

- This indicator is easy to derive from water consumption records and tax returns and shows how well one is using water drawn from the environment.
- The monetary figure reflects the value society places on the product. For organic producers this is significant as consumers are often prepared to pay a premium for certified organic produce.

Water and the two example properties

- Water use at The Food Forest is low due to the choice of crop optimisation rather than maximisation. The benchmark property uses 50 times as much water, achieving just over 7 times the yield

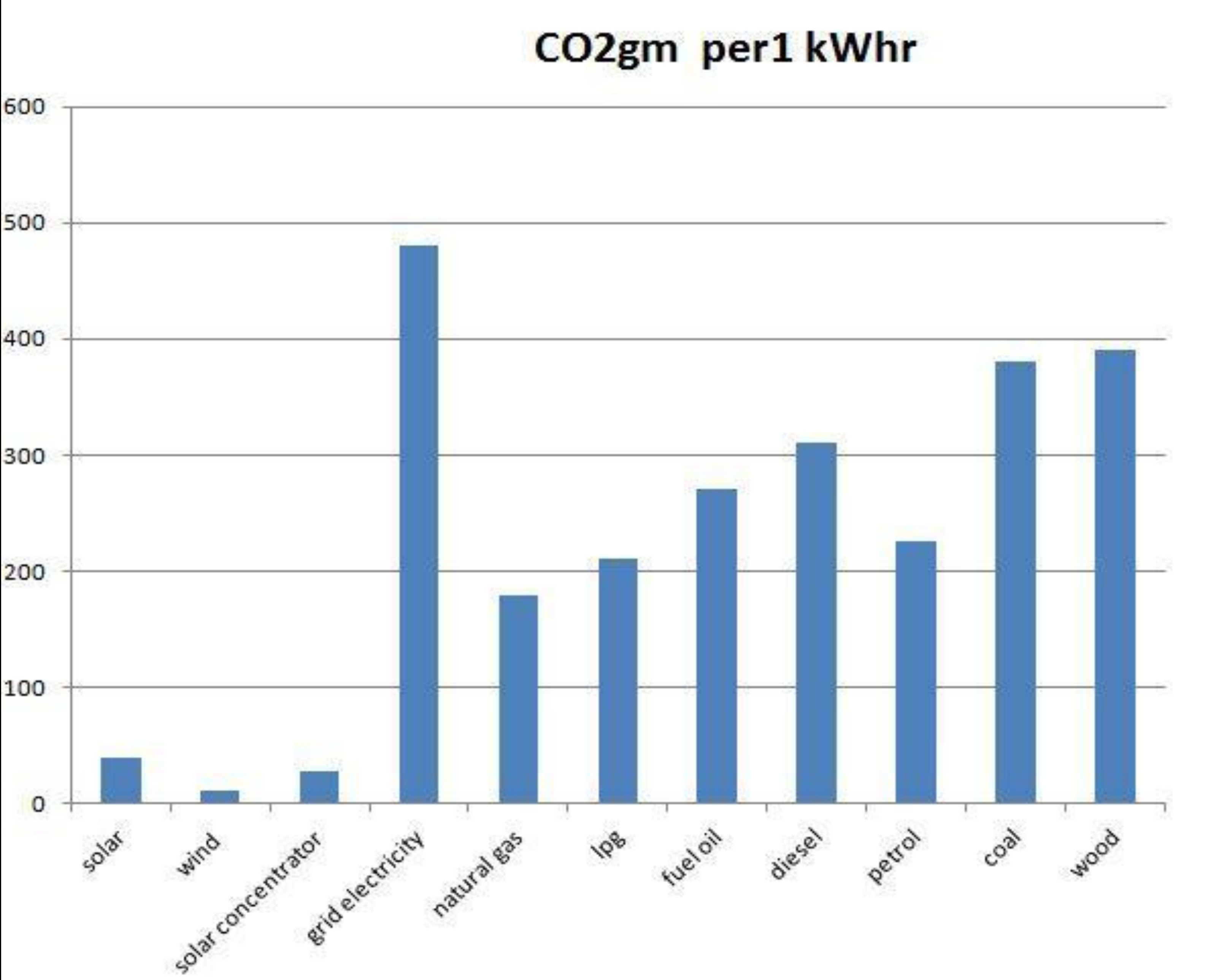
- Income per kilolitre of water used is about $5 compared with the benchmark property's 36 cents. (incorporating a 100% premium for certified nuts)

Conclusion

- Sustainability is becoming an important issue in food production and environmental management
- The indicators proposed are in line with international conventions and provide a simple means for collecting data.
- The indicators combine physical and monetary values that provide trend information and allow comparison with benchmarks
- Are there jobs in this area of expertise?

Jake Bugden

- Chemical Engineering graduate
- Undertook PDC, built own composting toilet changed track into sustainable engineering
- Founded ‘Sustainable Focus’ – projects saving millions of kWhs of electricity annually. Created large photovoltaic projects
- Organised ‘Permaculture Street’ (Gething Cres)
- Past President Wilderness Society
- Undertook water audit of million-person city which showed the potential for it to catch all the water it needs
- New company – ‘The Energy Project’
- Young Australian of the Year Environmental Award



1 kWhr = 863kcal