Machinery efficiency effects in the energy performance of an orange production system

N. C. Franco Junior, T. L. Romanelli, M. Milan

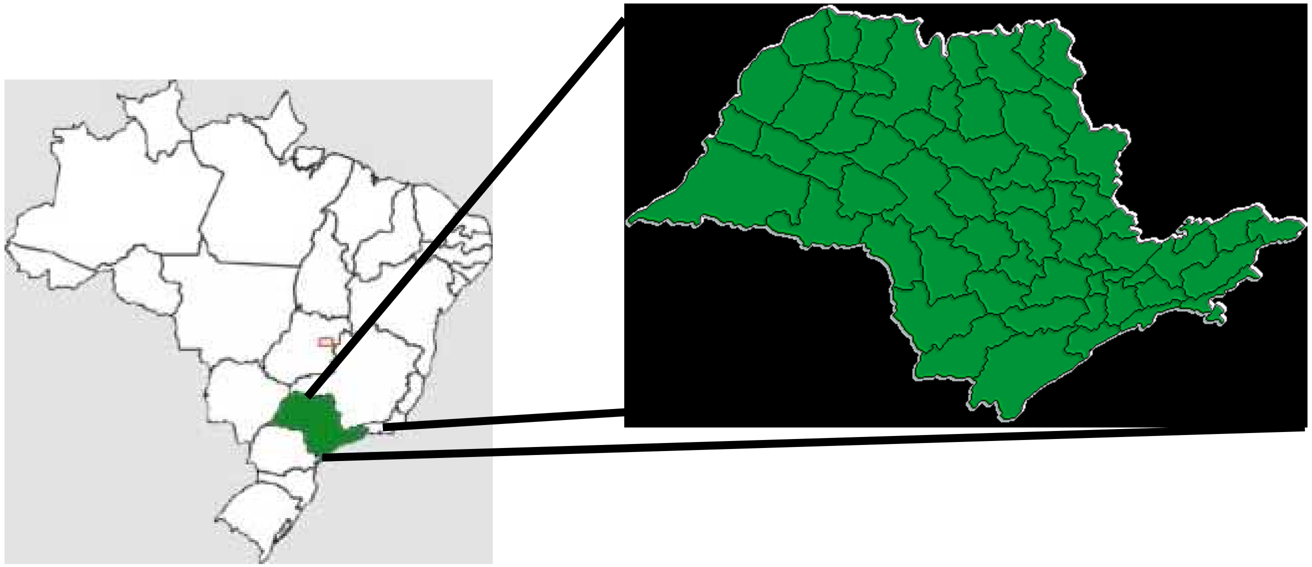
"Luiz de Queiroz" College of Agriculture –Univesity of Sao Paulo

romanelli@usp.br

Efficient and safe production processes in sustainable agriculture and forestry
XXXIV CIOSTA CIGR V Conference 2011

Introduction

- BR – 20% of the world orange production
  i.e., 18 million t and 840,000 ha
- São Paulo state – 80% of the Brazilian production



Introduction

- Between 1999 and 2009, profitability decreased
  - ⇧ land prices (+130%)
  - ⇧ production cost (+32%)
  - ⇩ orange price (–20%)
  - although yields ⇧ (25%)

Introduction

- ⇧production costs regards the insect and disease controls
  - *greening* (HLB), a disease caused by *Candidatus liberibacter*, transmitted by the species *Diaphorina citri*.

Introduction

- Global market - increasing competitiveness
-
- Organizations more efficient about resource use
- Waste reduction and sustainability improvement
- Energy analysis is a tool to evaluate the sustainability degree, although it has been little used by agricultural sector as a decision-making tool

Introduction

- Energy flow evaluation demands the determination of the material flows
  - Direct inputs (fertilizers, pesticides etc.)
  - Indirectly used (machinery, labor, fuel)
- For the inputs indirectly used, efficiency of is vital

Objective

- To establish the energy flows in the orange production and to monitor how efficiency of mechanized operations affects the energy indicator

Material and Methods – Material flow

Field Capacity = (speed * width * Efficiency) / 10

Machine Depreciation =

$$[(mass_{tr}/life_{tr}) + (mass_{impl}/life_{impl})] / FC$$

Fuel Cons = (Power * Specific cons) / FC

Labor = Number of workers / FC

Material and Methods

$$\text{Input Energy}_{indirect} = (MD * EC_{MD}) + (Cons * EC_{CONS}) + (LB * EC_{LB})$$

Index	Energy content	Unit	Source
EC_{MD}	68.9	kg	Ulbanere & Ferreira (1989)
EC_{CONS}	38.6	L	Ulbanere & Ferreira (1989)
EC_{LB}	2.2	h	Serra et al (1979)

$$\text{Input Eenergy}_{direct} = Qty_i * EC_i$$

Material and Methods

Total Input Energy = $IE_{indirect} + IE_{direct}$

Output Energy = Yield * EC_{orange} (1.9 MJ/kg)

Indicators

Energy Balance = OE – IE	(MJ/ha)
EROI = OE/IE	(adimensional)
Embodied Energy = IE/Y	(MJ/kg)

Material and Methods

Efficiency range of mechanized operations (ASABE, 2009)

Operations	Field Efficiency (%)		
	Minimum	Typical	Maximum
Limestone application	60	70	80
Terracing	70	80	85
Harrowing	70	80	90
Fertilizer application	60	70	80
Furrowing	70	75	85
...			

Results and Discussion

Material flow by operation groups (18-yr life cycle, 15-yr production)

Mechanized operations	**Machine depreciation** **kg ha^{-1}**	**Fuel** **L ha^{-1}**	**Labor** **h ha^{-1}**
Soil tillage	*15.24*	*142.29*	*15.65*
Planting	*14.60*	*257.85*	*28.65*
Conduction	*486.11*	*5830.65*	*647.85*
Harvesting	40.62	652.50	72.50
Total	556.58	6883.29	764.65

Spraying uses 338.5 kg/ha of machinery
3348.1 L/ha of diesel
372.5 h/ha of labor

Results and Discussion

Material and Energy flows on directly applied inputs

Input	Unit	Material flow	Energy content	Input energy	
		Qty ha^{-1}	MJ unit^{-1}	MJ ha^{-1}	%
Fertilizer					***44.11***
Limestone	kg	20350.0	1.7	33984.50	8.95
KCl	kg	3160.0	7.2	22720.40	5.98
$(NH4)_2SO_4$	kg	14780.0	22.0	32368.20	8.52
$MnSO_4$	kg	81.6	1.7	136.27	0.04
$ZnSO_4$	kg	122.4	1.7	204.41	0.05
S. S. phosphate	kg	5510.0	9.8	53942.90	14.20
Urea	kg	310.0	78.0	24192.40	6.37
Pesticide					***55.79***
Acaricide	L	103.3	184.7	19082.39	5.02
Formicide	kg	12.0	97.1	1165.56	0.31
Fungicide	kg	195.4	97.1	18975.32	5.00
Herbicide	L	54.3	254.6	13828.24	3.64
Insecticide	L	715.8	184.7	132209.88	34.81
Fly trap	L	48.0	97.1	4662.24	1.23
Mineral oil	L	511.8	38.6	19755.87	5.20
Sticker	kg	41.2	38.6	1589.93	0.42
Seedling					***0.10***
Grevillea SP	Unit	30.0	0.8	24.00	0.01
Orange	Unit	408.0	0.8	326.40	0.09

Results and Discussion

Input energy for orange production

Input	Energy flow GJ ha^{-1}	%
Indirect energy	***305.72***	***44.6***
Fuel	265.69	38.76
Machine Depreciation	38.35	5.59
Labor	1.68	0.25
Indirect energy	***379.81***	***55.4***
Fertilizers	168.19	24.53
Pesticides	211.27	30.82
Seedlings	0.35	0.05
Total	***685.53***	***100.00***

Results and Discussion

Energy indicators of the studied scenario

Indicator	*Value*	*Unit*
Yield (orange)	612587.52	kg ha^{-1}
Yield (vit.C)	328.96	kg ha^{-1}
Output Energy	1163,92	GJ ha^{-1}
Input Energy	*685.53*	GJ ha^{-1}
Energy Balance yr^{-1}	26.58	GJ ha^{-1} yr^{-1}
Energy Balance	478.38	GJ ha^{-1}
EROI	1.70	-
Emb. Energy (orange)	1.12	MJ kg^{-1}
Emb. Energy(vit. C)	2083.95	MJ kg^{-1}

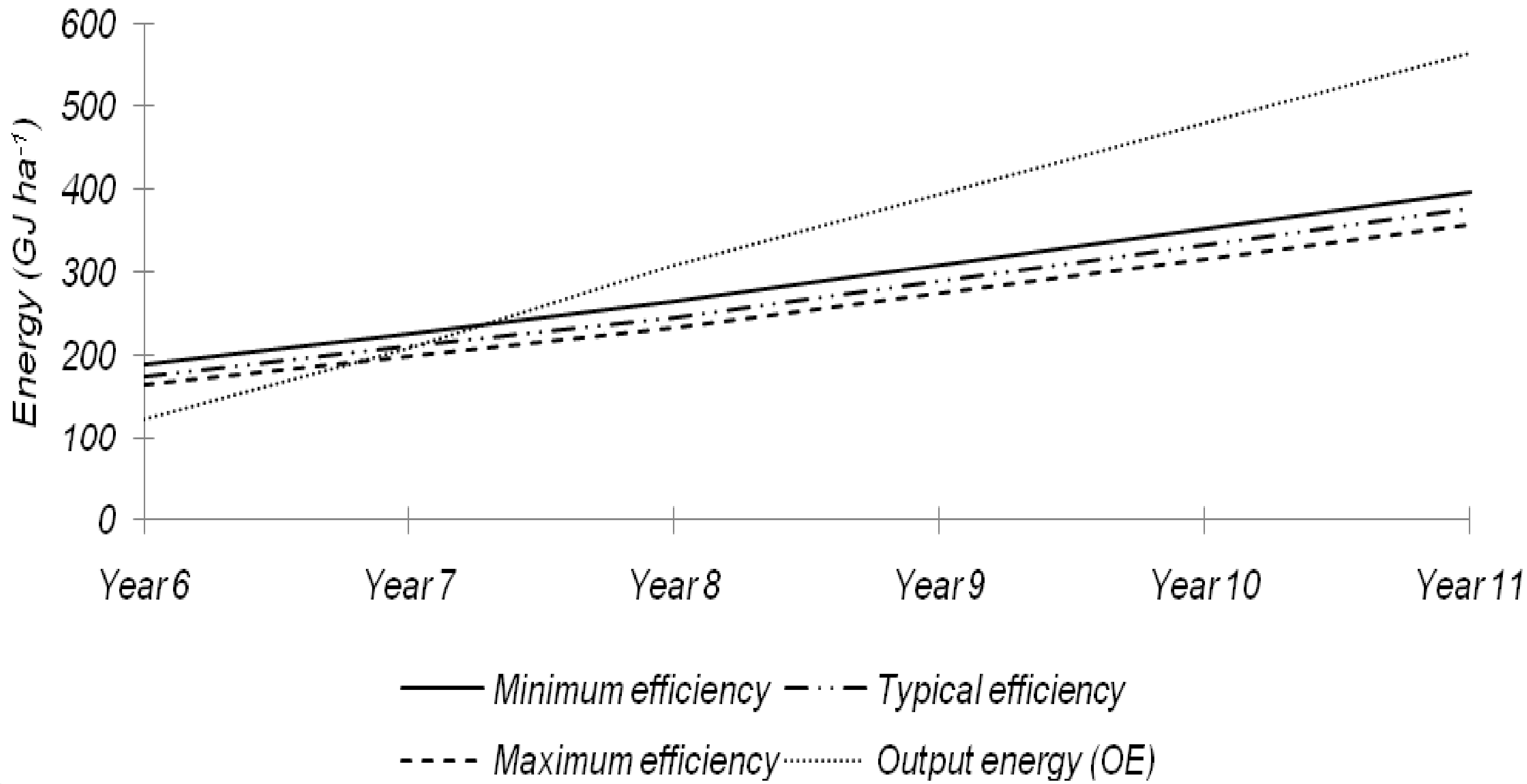
Compared to Ozkan et al. (2004) and Pimentel (2009)

Results and Discussion

Energy demand for orange production under field efficiency scenarios

Input	Typical Eff.	Minimum eff.		Maximum eff.	
	IE (GJ ha^{-1})	IE (GJ ha^{-1})	**Δ%**	IE (GJ ha^{-1})	**Δ%**
Fuel	265.7	285.1	**7.3**	235.3	**-11.4**
Mach. Depreciation	38.3	41.9	**9.4**	34.0	**-11.2**
Labor	1.7	1.8	**5.9**	1.5	**-11.8**
Total	305.7	328.8	**7.6**	270.8	**-11.4**

Results and Discussion



Results and Discussion

Effects in the indicators under field efficiency scenarios

Indicators	Vartiation (%)	
	Minimum Eff.	Maximum Eff.
EROI	-3,53	5,29
EB	-4,81	7,29
EE (orange)	3,57	-5,35

Conclusions

- Varieties resistant to diseases are key for increasing orange sustainability

- Labor and seedlings can be ommited for further studies with oranges and for perennial crops.

- Management of agricultural machinery plays an important role on decreasing the environmental impact of orange production.