Energy return on energy invested (EROEI) empirical model of an organic integrated animal and vegetable farm in Kentucky

Matthew S. Deason, John R. Schramski, and Krista L. Jacobsen
International Society for BioPhysical Econoics (ISBPE)
University of D.C.

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The Farm

- 375 acre farm in Scott County Kentucky
- Generations of the same family
- Community Supported Agriculture (CSA)
- Certified Organic (USDA designation)
- Integrated Farm
  - Vegetables (wide variety)
  - Eggs and Meat (Beef, Lamb, Turkey, Chicken)
Farm Philosophy

- Livestock and crop recycling of nutrients
- 10 year rotation of production and fallows
- Humane nurture and care for livestock
- Diversity in Product Offering
- Serve the Community

“We use many conservation practices to ensure better soil and water for future generations . . .”
• Vegetables
  • Sweet Corn, Potatoes, Sweet Potatoes, Beans, and Broccoli
  • Squash and Eggplant, Root Vegetables, Herbs, Tomatoes and Peppers, Exotics (bok choy and ginger), etc.

• Fruits (blackberries, raspberries, strawberries, watermelon, etc.)

• Processed (dried herbs, salsa, ketchup, and cornmeal)

• Meat (eggs, chicken, lamb, turkey, beef)

• Tobacco

• Direct
  • Human Labor
  • Gasoline and Diesel
  • Electricity
  • LP Gas

• Indirect
  • Associated with direct inputs
  • Feed and feed products
  • Live animals
  • Water
  • Seed (vegetables, grains, and grasses)
  • Plastic products
  • Fertilizer
  • Egg cartons
  • Pine shavings and wheat straw
  • Pesticides
  • Gravel and agricultural lime
  • Equipment (Amortized)
Input Coefficients

- Literature searches
- Combined estimates
- Actual conditions representing the farm

Model Boundary

- Farm Gate
- Given this is a CSA, Farm to household energy very low
Vegetables, Fruits, and Finished Products

- Weights taken prior to distribution
- USDA established values for kcals
- Monthly totals recorded

Eggs and Meat

- Eggs were counted in dozens
- Live weights were recorded prior to processing
- Live weights were discounted
- USDA kcal values to discounted weights

<table>
<thead>
<tr>
<th>Species</th>
<th>Carcass %</th>
<th>Bone %</th>
<th>Total Discount (Carcass – Bone)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>60 %</td>
<td>10%</td>
<td>50%</td>
<td>1</td>
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<tr>
<td>Lamb</td>
<td>50 %</td>
<td>7%</td>
<td>43%</td>
<td>1</td>
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<tr>
<td>Turkey</td>
<td>76.4%</td>
<td>-</td>
<td>76.4%</td>
<td>2</td>
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<tr>
<td>Hens</td>
<td>73.8%</td>
<td>-</td>
<td>73.8%</td>
<td>3</td>
</tr>
<tr>
<td>Broilers</td>
<td>74%</td>
<td>-</td>
<td>74%</td>
<td>2</td>
</tr>
</tbody>
</table>

1. Darre et al., 1991; Table 13
2. Darre et al., 1991; Table 14 (averaged male and female)
3. Darre et al., 1991; Table 14 (female)
Equipment

Motorized Equipment
• 24 individual pieces
  • 10 pieces 12 years old or less
  • 14 pieces older than 12 years
• Amortized 12 years when less than 12 years old
• Rest amortized by age of equipment
  • 1970 Gleaner Combine
  • 1966 Farmall 140
  • 1963 Ford 500

Non-Motorized Equipment
• 38 individual Pieces
• 33 pieces amortized 20 years
• 5 pieces amortized 30 years
Model Results

Direct and Indirect
7.8 to 1.0

Direct only
2.8 to 1.0

Values in GJ
## Input References

<table>
<thead>
<tr>
<th>Input</th>
<th>Reference</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor (Direct)</td>
<td>Cox and Atkins, 1979; Pimentel, 1984; Duhon, 1985; SFNB, 1989; Zhengfang, 1994; Tharion et al., 2005; Smil, 2008; Schramski et al., 2013</td>
<td></td>
</tr>
<tr>
<td>Labor (Indirect)</td>
<td>Schramski et al., 2013</td>
<td>Upstream energy used to supply the labor and to maintain laborer’s physiology</td>
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<tr>
<td>Gasoline and Diesel (Direct)</td>
<td>US Department of Energy values for each fuel</td>
<td><a href="http://www.afdc.energy.gov/fuels/fuel_properties.php">http://www.afdc.energy.gov/fuels/fuel_properties.php</a></td>
</tr>
<tr>
<td>Gasoline and Diesel (Indirect)</td>
<td>Hall et al., 2014</td>
<td></td>
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<tr>
<td>Gravel and Ag Lime</td>
<td>Venkatarama Reddy and Jagadish, 2003</td>
<td>Local Quarry</td>
</tr>
<tr>
<td>Seed (all)</td>
<td>Gliessman, 1998</td>
<td>“Local seed”</td>
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<tr>
<td>Fertilizer</td>
<td>Spångberg et al., 2011</td>
<td></td>
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<tr>
<td>Feed and Trace Minerals</td>
<td>Pelletier, 2008</td>
<td></td>
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<tr>
<td>Roasted Soybeans</td>
<td>Pradhan et al., 2009 and manufacturing data from Dilts-Wetzel</td>
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<tr>
<td>Shavings</td>
<td>M. dos Santos et al., 2015</td>
<td></td>
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<tr>
<td>Electricity</td>
<td>WeiBback et al., 2013</td>
<td>Formula by probability of generation</td>
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<td>Water</td>
<td>Mo et al., 2010</td>
<td></td>
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<tr>
<td>Pesticides</td>
<td>Leach and Slessor, 1973 and Green, 1987</td>
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<tr>
<td>Paper Egg Cartons</td>
<td>Manda et al., 2012</td>
<td>Kraft paper values</td>
</tr>
<tr>
<td>Plastic and Styrofoam</td>
<td>Lawson and Rudder, 1996</td>
<td></td>
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<tr>
<td>Wheat Straw</td>
<td>Nilsson, 1997 (for production) and Eom et al., 2012 (for transportation)</td>
<td>Based on top five wheat producing states.</td>
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<td>Live birds</td>
<td>Pelletier, 2008</td>
<td></td>
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<tr>
<td>Whole Corn</td>
<td>Pelletier, 2008</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>Smil et al., 1983</td>
<td>Amortization based on age</td>
</tr>
</tbody>
</table>
Conclusion

- Integrated animal/vegetable farms have lower EROEI
  - 40:1 UKY CAS (Shramski et al., 2013)
  - 40:1 or 20:1 for cattle (Pimentel and Pimentel, 2008) (32.6:1 or 16.3:1)
  - Lime only soil amendment (local quarry)
  - Low animal inputs

- Equipment (capital) energy investments very low
- Farm is building soil organic matter
- Studies needed
  - Organic Certified pesticides
  - Organic Fertilizer
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