EMERGY SYNTHESIS 5:
Theory and Applications of the Emergy Methodology

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The Center for Environmental Policy
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Gainesville, FL
The Ranching for Sustainability Club: Grass Roots Change for Dairy Production in Chiapas, Mexico

Rigoberto Alfaro, Stewart Diemont, Bruce Ferguson and Jay Martin

ABSTRACT

Conventional ranching in Chiapas, Mexico includes a yearly pasture burn and agrochemical use that decreases the biodiversity and forest cover of ranch lands. Ranchers, self-described members of a “club” in the Fraylesca region of Chiapas, Mexico, have bucked convention and eliminated burns and agrochemicals from their systems after decades of use because they believed that the land and their production process were growing unhealthy. For this study 25 ranchers were interviewed about their production of dairy cattle, which included seven of these novel silvopostoral systems (holistic) ranches, and 18 conventional ranches. An Emergy Evaluation was conducted to compare the resource use, productivity and sustainability of the conventional and holistic ranches. Conversion to holistic ranching was found to double the Emergy Sustainability Index, increase the Emergy Yield Index, while reducing the Environmental Loading Ratio. Improved emergy sustainability did not decrease milk productivity. Transformities ranged from 0.3 E6 to 12 E6 sej/J of milk in conventional systems and from 0.4 E6 to 1.3 E6 sej/J of milk in holistic systems. Government assistance programs were found to produce a negative impact on ESI. To solve this problem, assistance programs could be re-targeted toward incentive programs for increased forest cover in ranching systems and decreased pasture plowing. The results from this study show that outputs can be maintained as the sustainability of rural dairy ranchers is increased. They also show that positive change can come from the people who work the land, who may recognize what is meant by emergy sustainability in local terms.

INTRODUCTION

Livestock farming in most tropical environments has major impacts on the coverage of forest and grasslands (Nicholson et al. 1995; Dagang & Nair 2003, Pagiola et al. 2004). As cattle increases, the amount of pasture land increases and the forest area shrinks and becomes more fragmented (Kaimowitz, 2001). This kind of tropical cattle farming in Latin America that focuses on extensive areas of grassland, causes reductions in tree coverage, invasion by weeds, and the compaction and loss of soil fertility. Additionally, this farming system causes a decrease in biodiversity, soil erosion, and increased emissions of greenhouse gasses. These impacts are dependent upon the type of farming system; alternative cattle systems appropriate for tropical regions with less environmental impacts are available (Nicholson et al. 2001). “Holistic ranching” techniques have been developed in both temperate and tropical regions to provide similar productivity levels while reducing environmental impacts (Adams 1998, Savory and Butterfield 1999).

The Fraylesca region of the state of Chiapas, Mexico is characterized by many conventional cattle ranches with large areas of pasture. The pasture contains few trees and is seldom divided for managed grazing. Pesticides are used to control pests such as ticks, and herbicides and fire are used for weed control. High rates of animal growth are supported by intensive grazing that provides little time for regeneration of pasture plants (Hernández, 2000). This grazing system and the frequent use of fire
result in low levels of primary production, decreases biodiversity, and cause long-term land degradation. For example, in this region 47% of forest has been degraded by the frequent use of fire as part of conventional cattle systems (Monjaráz, 2002). This land degradation negatively impacts rural development and has been identified as a cause of emigration of Mexican citizens to the United States of America (Howard-Borjas, 1995).

In contrast to these conventional systems, a small group of ranchers in the Fraylesca region have begun practicing “holistic management.” These ranchers, self-described as members of a “club” of holistic manager, have been motivated by the environmental damage of conventional systems to find methods to conserve the soil, water, flora, and fauna (Adams, 1998). Ranchers take courses to learn about “holistic management” and the ensuing environmental, economic and social benefits (Savory & Butterfield, 1999). Each of their ranches has an area of protected forest, for the conservation of flora and fauna, and has a more diverse cattle herd compared to conventional ranches. In addition, the ranchers do not apply, or have sharply reduced the application of agrochemicals.

This study uses Emergy Evaluation to compare the resource use, productivity, and environmental impacts from conventional ranches to those under holistic management in the Fraylesca region of southern Mexico, to better understand how the conversion to holistic management may meet ranchers’ goals for ecosystem health and sustainability.

METHODS

Interviews were conducted with 25 ranchers in the Fraylesca region of Chiapas, Mexico to determine resource use, productivity, and management techniques within their dairy cattle production systems. Ranchers were interviewed between June and September 2007 and were asked information specific to the previous calendar year. Seven of the ranchers were pre-selected as participants in the study based upon self-identification as members of a “club,” farmers striving to convert their systems to “holistic” ranches. The remaining 18 ranchers, owners of “conventional” ranches were selected due

Figure 1. Generalized diagram of ranching systems in the Fraylesca region of Chiapas, Mexico.
Table 1. Emergy evaluation example from 80 hectare holistic ranching system in Fraylesca Region, Chiapas, Mexico.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Data (units/yr)</th>
<th>Unit Solar EMERGY (sej/unit)</th>
<th>Solar EMERGY (E13 sej/yr)</th>
<th>Solar EMERGY/area (E13 sej/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RENEWABLE INPUTS (R)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Sun</td>
<td>J</td>
<td>4.75E+15</td>
<td>1</td>
<td>475</td>
<td>5.9</td>
</tr>
<tr>
<td>2 Rain</td>
<td>J</td>
<td>4.54E+12</td>
<td>1.80E+04</td>
<td>8167</td>
<td>102.1</td>
</tr>
<tr>
<td>3 Wind</td>
<td>J</td>
<td>8.43E+10</td>
<td>1.50E+03</td>
<td>13</td>
<td>0.2</td>
</tr>
<tr>
<td>4 Labor (renewable)</td>
<td>hr</td>
<td>4.44E+03</td>
<td>6.99E+12</td>
<td>3100</td>
<td>38.8</td>
</tr>
<tr>
<td>5 Workshops (renewable)</td>
<td>hr</td>
<td>4.95E+01</td>
<td>6.99E+12</td>
<td>34</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>NONRENEWABLE INPUTS (N)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Net Topsoil Loss</td>
<td>J</td>
<td>3.01E+11</td>
<td>6.25E+04</td>
<td>1884</td>
<td>23.5</td>
</tr>
<tr>
<td><strong>PURCHASED INPUTS (F)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Labor (purchased)</td>
<td>hr</td>
<td>6.64E+03</td>
<td>6.99E+12</td>
<td>4644</td>
<td>58.0</td>
</tr>
<tr>
<td>8 Workshops (purchased)</td>
<td>hr</td>
<td>4.93E+01</td>
<td>6.99E+12</td>
<td>34</td>
<td>0.4</td>
</tr>
<tr>
<td>9 Electricity</td>
<td>J</td>
<td>1.08E+10</td>
<td>1.60E+05</td>
<td>173</td>
<td>2.2</td>
</tr>
<tr>
<td>10 Herbicides</td>
<td>g</td>
<td>0.00E+00</td>
<td>1.48E+10</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>11 Materials</td>
<td>US$</td>
<td>1.40E+04</td>
<td>1.88E+12</td>
<td>2623</td>
<td>32.8</td>
</tr>
<tr>
<td>12 Feed</td>
<td>g</td>
<td>0.00E+00</td>
<td>1.82E+09</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>13 Vaccinations</td>
<td>g</td>
<td>9.64E+02</td>
<td>3.06E+09</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>14 Nutritional Blocks</td>
<td>g</td>
<td>0.00E+00</td>
<td>1.82E+09</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>15a Government Assistance, monetary</td>
<td>US$</td>
<td>2.27E+03</td>
<td>1.88E+12</td>
<td>427</td>
<td>5.3</td>
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<tr>
<td>15b Government Assistance, calves</td>
<td>J</td>
<td>0.00E+00</td>
<td>1.73E+06</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>15c Government Assistance, machinery</td>
<td>g</td>
<td>2.99E+03</td>
<td>1.25E+10</td>
<td>4</td>
<td>0.0</td>
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<tr>
<td>16 Calves</td>
<td>J</td>
<td>0.00E+00</td>
<td>1.73E+06</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>17 Pesticides</td>
<td>g</td>
<td>4.00E+03</td>
<td>1.48E+10</td>
<td>6</td>
<td>0.1</td>
</tr>
<tr>
<td>18 Nitrogen Fertilizer</td>
<td>g</td>
<td>0.00E+00</td>
<td>2.41E+10</td>
<td>0</td>
<td>0.0</td>
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<tr>
<td><strong>TOTAL INPUTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7911</td>
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RESULTS

Emergy Evaluation revealed numerous differences between holistic and conventional ranching systems. Mean Emergy Sustainability Index (ESI) of holistic systems was nearly twice that of...
Table 2. T-tests comparing means of emergy indices of ranches in the Fraylesca region of Chiapas, Mexico. Conventional and Holistic ranching were compared for all systems, as well as larger systems (≥ 40 hectares) and systems after eliminating government assistance.

<table>
<thead>
<tr>
<th></th>
<th>EYR n</th>
<th>mean (sd)</th>
<th>P value</th>
<th>ELR n</th>
<th>mean (sd)</th>
<th>P value</th>
<th>ESI n</th>
<th>mean (sd)</th>
<th>P value</th>
</tr>
</thead>
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<td>Conventional</td>
<td>18</td>
<td>1.7 (0.4)</td>
<td>0.032</td>
<td>2.4 (1.6)</td>
<td>0.263</td>
<td>1.1 (0.78)</td>
<td>0.026</td>
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</tr>
<tr>
<td>Holistic</td>
<td>7</td>
<td>2.2 (0.59)</td>
<td></td>
<td>1.6 (1.2)</td>
<td></td>
<td>2.1 (1.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional (≥ 40 ha.)</td>
<td>9</td>
<td>1.6 (0.25)</td>
<td>0.049</td>
<td>2.4 (1.2)</td>
<td>0.229</td>
<td>0.86 (0.42)</td>
<td>0.044</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holistic (≥ 40 ha.)</td>
<td>7</td>
<td>2.2 (0.6)</td>
<td></td>
<td>1.6 (1.2)</td>
<td></td>
<td>2.1 (1.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional (no govt. assis.)</td>
<td>18</td>
<td>1.8 (0.4)</td>
<td>&lt;0.001</td>
<td>1.9 (1.2)</td>
<td>0.054</td>
<td>1.3 (0.85)</td>
<td>&lt;0.001</td>
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<tr>
<td>Holistic (no govt. assis.)</td>
<td>7</td>
<td>2.6 (0.57)</td>
<td></td>
<td>0.96 (0.28)</td>
<td></td>
<td>3 (1.3)</td>
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<td></td>
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<tr>
<td>Fire</td>
<td>10</td>
<td>1.7 (0.24)</td>
<td>0.211</td>
<td>2 (1.2)</td>
<td>0.699</td>
<td>1.1 (0.43)</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Fire</td>
<td>15</td>
<td>1.9 (0.59)</td>
<td></td>
<td>2.2 (1.8)</td>
<td></td>
<td>1.6 (1.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>19</td>
<td>2 (0.49)</td>
<td>0.058</td>
<td>1.8 (1.3)</td>
<td>0.077</td>
<td>1.6 (1.1)</td>
<td>0.063</td>
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<tr>
<td>No Forest</td>
<td>6</td>
<td>1.5 (0.29)</td>
<td></td>
<td>3.1 (1.9)</td>
<td></td>
<td>0.71 (0.47)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Coyotes</td>
<td>5</td>
<td>2 (0.61)</td>
<td>0.46</td>
<td>1.9 (1.3)</td>
<td>0.662</td>
<td>1.7 (1.4)</td>
<td>0.4</td>
<td></td>
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<tr>
<td>No Coyotes</td>
<td>20</td>
<td>1.8 (0.46)</td>
<td></td>
<td>2.2 (1.6)</td>
<td></td>
<td>1.3 (0.95)</td>
<td></td>
<td></td>
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<tr>
<td>Cuban Grass 115</td>
<td>11</td>
<td>2 (0.56)</td>
<td>0.34</td>
<td>1.8 (1.1)</td>
<td>0.38</td>
<td>1.6 (1.2)</td>
<td>0.32</td>
<td></td>
<td></td>
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<tr>
<td>No Cuban Grass 115</td>
<td>14</td>
<td>1.8 (0.42)</td>
<td></td>
<td>2.4 (1.8)</td>
<td></td>
<td>1.2 (0.86)</td>
<td></td>
<td></td>
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<tr>
<td>Electric Fence</td>
<td>14</td>
<td>1.9 (0.54)</td>
<td>0.63</td>
<td>2.2 (1.7)</td>
<td>0.85</td>
<td>1.5 (1.1)</td>
<td>0.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Electric Fence</td>
<td>11</td>
<td>1.8 (0.42)</td>
<td></td>
<td>2.1 (1.4)</td>
<td></td>
<td>1.3 (0.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide Use</td>
<td>19</td>
<td>1.8 (0.45)</td>
<td>0.19</td>
<td>2.3 (1.6)</td>
<td>0.45</td>
<td>1.2 (0.97)</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Pesticide Use</td>
<td>6</td>
<td>2.1 (0.57)</td>
<td></td>
<td>1.7 (1.2)</td>
<td></td>
<td>1.8 (1.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goldfinch</td>
<td>6</td>
<td>2.3 (0.47)</td>
<td>0.003</td>
<td>1.2 (0.59)</td>
<td>0.009</td>
<td>2.4 (1.1)</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Goldfinch</td>
<td>19</td>
<td>1.7 (0.39)</td>
<td></td>
<td>2.5 (1.6)</td>
<td></td>
<td>1.1 (0.78)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

conventional systems (Table 2). Emergy Yield Ratio (EYR) was 30% greater in holistic compared to conventional systems. Although the mean Emergy Loading Ratio (ELR) was 50% greater in conventional systems, that difference was not significant (alpha = 0.05) due to a high variance of the ELR data. The largest source of variance that appears to have affected ELR comes from purchased resources (F), which dominated the variance in system yield (Y) (Figure 2). Standard deviation of Y in the holistic system was over twice that of the conventional system, 553 E13 sej/ha/yr compared to 268 E13 sej/ha/yr. This variance is largely due to high standard deviation of the purchased resources (F) in holistic systems, over twice that the conventional systems, 471 E13 sej/ha/yr compared to 241 E13 sej/ha/yr. An assessment of specific resource use indicated that government assistance to ranchers though machinery dominated the purchased resources (F) in holistic systems (Figure 3).

Communication with holistic ranchers revealed that some holistic ranchers received preferential treatment in receiving government assistance during the year from which results were collected (Efrain Coutiño Velasco, Adrian Antonio Castillejos Constantino, and others, pers. comm.). In order to assess how the account of resource use in the systems would change without this additional government assistance, government assistance was removed from the calculations. Without government assistance the ELR in holistic systems dropped to half the ELR of conventional systems (P=0.054) (Table 2). The
level of significance of the differences in ESI and EYR decreased to less than 0.001, indicating that government assistance appears to be decreasing the relative sustainability in terms of emergy for holistic systems. F in conventional and holistic systems was statistically equivalent before the removal of government assistance (Figure 3). Furthermore standard deviation of purchased resources in holistic systems dropped from 471 E13 sej/ha/yr to 132 E13 sej/ha/yr without government assistance. When government assistance is removed, purchased labor dominates the purchased resources in conventional systems. In conventional systems, purchased labor, nitrogen fertilizer, and cattle feed play somewhat equal roles in the purchased components of the system (Figure 4).

System size positively correlated with higher ESI (Coeff. = 0.012, R= 0.41, P = 0.044) and EYR (Coeff. = 0.007, R = 0.45, P = 0.023) and negatively correlated with ELR (Coeff. = -0.02, R = 0.43, P = 0.034 ). Holistic systems relied upon a larger land area (mean = 82 hectares, sd = 44 ha.) compared to conventional systems (mean = 38 ha., sd = 18 ha.) (P = 0.04). To ensure that the differences noted in emergy indices between holistic and conventional systems were not due only to the land area utilized by the systems, holistic and conventional systems greater than or equal to 40 hectares in size were compared. When smaller systems were removed from the analysis (≥40 hectares), the remaining nine conventional and seven holistic systems displayed the same tendencies in emergy indices (Table 2) as when all systems were incorporated in the analysis. Mean land area of the holistic and conventional systems ≥40 hectares were not statistically different (P = 0.11).

Numerous management strategies that come to define the differences between holistic and conventional systems were noted from the interviews. Holistic systems conserved numerous animals in their systems, including: wild boars, deer, ocelots, and anteaters. Holistic systems also use and conserve certain trees in their systems that conventional systems do not utilize, such as: guanacaste, guava, and espino blanco (Acacia farnesiana). Furthermore holistic ranchers, unlike conventional ranchers, are interested in general in the forest being available for productive use.

Other management strategies, animals, and plants noted in the systems did not align completely into holistic and conventional management. Of these factors, only forest cover and the presence of goldfinches appeared to correlate with higher ESI, lower ELR, and higher EYR (Table 2). Although

![Figure 2. Yield (Y), Renewable resources (R), Non-renewable local resources (N), and Purchased Resources (F) in conventional and holistic ranching systems.](image-url)
not significant at alpha = 0.05, differences were noted at alpha = 0.08 in indices related to the presence of forest. At this limit ESI was over twice as high where forest was present in systems, EYR was 33% higher, and ELR was over 40% lower. The groups with forest and without forest were very different from the holistic and conventional management groups; 12 conventional ranches joined the holistic ranches as having forest.

Relationship between forest cover and ESI were partially offset by the higher non-renewable local resources (N) found in holistic systems compared to conventional systems (P = 0.038). These differences related to the division made between natural pasture and plowed pasture, where holistic systems utilized a greater proportion of plowed pasture than conventional systems.

Differences were also noted where Carduelis tristis (goldfinch) were present. However, in the case of goldfinch, the group divisions are similar to those for holistic and conventional, but for the removal of one holistic ranch. The rancher removed from the group (who did not note the presence of goldfinch) received a tractor the previous year from the government and thus had a high F in his system.

Other continuous data that appeared to affect emergy indices and differed between holistic and conventional systems included quantity of forest, most recent fire event, land divisions, and calf mortality (Table 3). EYR and ESI appeared to positively correlate with number of amount of forest, most recent fire, and number of divisions, and negatively correlate with mortality rate of calves. ELR, on the other hand, only appeared to decrease with amount of forest cover and increase with calf mortality.

Keeping additional land in forest, reducing or removing fires, and dividing land with electric fences to permit selected grazing are all part of the holistic ranching systems utilized by club members.

So, it is not surprising that these management strategies are found to a much larger degree in holistic systems (Table 4). Holistic systems have an order of magnitude higher forest cover and number of years since the most recent fire than conventional systems. The number of land divisions in holistic systems is seven times greater than in conventional systems. Holistic systems also have lower calf mortality, 66% lower than that in conventional systems.
Figure 4. Purchased resources (F) in conventional and holistic ranching systems when government assistance in terms of cattle, money, and equipment is removed from the analysis. Error bars equal ± 1 standard error.

Table 3. Emergy Indices (dependent variable) as they relate through Pearson's linear regression to quantity of forest, most recent fire, land divisions, and calf mortality. Statistically significant P values (alpha = 0.05) are displayed in bold. Marginal statistical significance (alpha = 0.08) is displayed in italics.

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Holistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity of Forest (ha.)</strong></td>
<td>Coeff.</td>
<td>R</td>
</tr>
<tr>
<td>EYR</td>
<td>0.43</td>
<td>0.38</td>
</tr>
<tr>
<td>ELR</td>
<td>-1.3</td>
<td>0.36</td>
</tr>
<tr>
<td>ESI</td>
<td>0.89</td>
<td>0.38</td>
</tr>
</tbody>
</table>

| **Most Recent Fire (yr.)** | Coeff. | R | P value | Coeff. | R | P value |
| EYR                  | 0.43 | 0.38 | 0.058 | 0.02 | 0.38 | 0.059 |
| ELR                  | -1.3 | 0.36 | 0.077 | -0.036 | 0.22 | 0.291 |
| ESI                  | 0.89 | 0.38 | 0.063 | 0.042 | 0.38 | 0.063 |

| **Land Divisions (#/ha.)** | Coeff. | R | P value | Coeff. | R | P value |
| EYR                  | 0.43 | 0.38 | 0.058 | 0.02 | 0.38 | 0.059 |
| ELR                  | -1.3 | 0.36 | 0.077 | -0.036 | 0.22 | 0.291 |
| ESI                  | 0.89 | 0.38 | 0.063 | 0.042 | 0.38 | 0.063 |

| **Calf Mortality (%/yr.)** | Coeff. | R | P value | Coeff. | R | P value |
| EYR                  | 0.43 | 0.38 | 0.058 | 0.02 | 0.38 | 0.059 |
| ELR                  | -1.3 | 0.36 | 0.077 | -0.036 | 0.22 | 0.291 |
| ESI                  | 0.89 | 0.38 | 0.063 | 0.042 | 0.38 | 0.063 |

Table 4. t-tests comparing means of quantity of forest, most recent fire, land divisions, and calf mortality in conventional and holistic systems. The Student t-test was used to compare means unless F-test revealed unequal variance, in which case the unequal variance t-test was used.

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Holistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity of Forest (hectares)</strong></td>
<td>n</td>
<td>mean (sd)</td>
</tr>
<tr>
<td>EYR</td>
<td>18</td>
<td>2.8 (3.1)</td>
</tr>
<tr>
<td>ELR</td>
<td>18</td>
<td>2 (1.6)</td>
</tr>
<tr>
<td>ESI</td>
<td>18</td>
<td>0.32 (0.18)</td>
</tr>
<tr>
<td><strong>Most Recent Fire (years)</strong></td>
<td>18</td>
<td>7 (2.9)</td>
</tr>
<tr>
<td><strong>Land Divisions (#/hectare)</strong></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td><strong>Calf Mortality (%/year)</strong></td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>
Differences in ESI between holistic and conventional systems did not appear to affect production, or transformities. Holistic milk production was 2713 (543 sd) liters/hectare/year, whereas conventional systems milk production was 1536 (1980 sd) L/ha/yr (P = 0.21). The transformity of the holistic systems ranged from 0.4 E6 to 1.3 E6 sej/J milk, a mean of 0.65 E6 (0.36 E6 sd) sej/J milk. Conventional systems ranged from 0.3 E6 to 12 E 6 sej/J of milk, a mean of 2.4 E6 (2.5 E6 sd) sej/J milk produced. Nonetheless, these differences where not significant (P = 0.14), and the overall mean transformity of milk production in the Fraylesca region of Chiapas, Mexico was 2.0 E6 (2.4 E6 sd) sej/J milk produced.

DISCUSSION

Conversion from conventional ranching to holistic ranching in the Fraylesca region of Chiapas, Mexico appeared to have a positive impact on emergy resource use indices, while not decreasing milk production, nor decreasing quality or efficiency of the systems, as measured by emergy transformity. Specific factors that appeared to relate to higher ESI included: increased forest land, decreased fire in the systems, a greater amount of land divisions, and decreased calf mortality. The first two factors, increased forest land and decreased fire, are interrelated. Ranchers who have removed yearly pasture burns from their systems are regenerating forest (Table 4). The increased forest would likely result in a lower soil runoff in their systems (decreased N), but it is unclear if these factors are simply indicators of conversion to holistic systems or actually result directly in a higher ESI. In these systems conversion to holistic systems did not result in a lower N, but a higher N due to a higher proportion of plowed pasture compared to natural pasture, and thus higher runoff. Consequently fire suppression did not result in lower ELR. Thus holistic ranchers could improve overall sustainability if changed plowing methodology where greater incorporated into holistic ranching methods; a decrease in plowing would improve ESI and decrease ELR.

No decrease in milk production in holistic systems and low relative calf mortality are both important indicators that conversion to holistic ranching should not decrease a ranch’s productivity, but may actually increase the overall health of the ranch. Savory and Butterfield (1999) contend that holistic management will increase the overall health of a production system. While not entirely the same, Hermansen (2003) found that organic ranching systems did not result in lower cattle health compared to conventional systems. Results from this study appear to support those findings. These results are particularly important for ranchers operating at a low profit margin who may consider converting to holistic ranching in the Fraylesca region of Mexico. Low calf mortality appeared to be the single best indicator of higher ESI and EYR, and low ELR. Calf mortality rates may capture sustainable ranching in conventional systems, as well as inconsistencies within holistic systems, but rates do not appear to correlate with any specific characteristic in either system.

Government assistance had a negative impact on ESI, ELR, and EYR in holistic systems. Some holistic ranchers received unusually large assistance packages from government in the year used for this analysis. This assistance was both because government is cognizant of the positive change that ranchers appear to be undertaking and because government agents have had closer relationships with some holistic farmers than they have with some conventional ranchers (Efrain Coutiño Velasco, Adrian Antonio Castillejos Constantino, and others, pers. comm.). As government is interested in the positive environmental impact of holistic ranching relative to conventional ranching, assistance could use emergy indices as a guide for appropriate assistance measures that do not decrease overall sustainability. The difficulty is in providing a government assistance program that would encourage R, while not increasing F. Because government assistance by nature defined as F, the solution may not lie with government, unless it came in the form of decreased spending toward government for ranch operation (lower taxes), a change that could be argued is simply externalizing the F within the system to the larger system that includes the government, a change that would result in no net regional change in ESI, ELR, or EYR. Nonetheless, improving government assistance efforts to ranchers in terms of sustainability may be possible. Forest cover appears to have a positive correlation with ESI and negative correlation with ELR. An assistance program with a small F, that decreases soil erosion (N),
through increased forest cover, would have a positive impact on ESI and decrease ELR. In other words, ranchers could be paid to convert some of their land to forest, at a rate such that the decrease in N through the forest conversion would be marginally higher than the increase in F from the payout. Because holistic ranchers did not exhibit a lower milk production than conventional ranchers, this conversion should not come at a financial hardship to the rancher, but in contrast should yield them a net increase in both financial input to the ranch, in terms of the government financial incentive, and higher sustainability in terms of the ESI of their ranch. Furthermore, as noted earlier, ranchland plowing had a negative impact on ESI and increased ELR. Government technical education programs could improve education about alternatives to plowing or natural grass recovery in holistic systems. This method would not increase F in the systems because of time partitioning in human labor and education in Chiapas (Table 1, Appendix A and Martin et al. 2006, Diemont et al. 2006); this would not be the case in a region or country with lower individual renewable consumption.

Larger ranches have a higher ESI, regardless of adherence to holistic or conventional ranching practices. These results are consistent with the results for indigenous swidden systems in Chiapas (Diemont et al. 2006, Martin et al. 2006), where larger systems permitted a higher proportion of land that could be devoted to forest. This is a likely reason why a greater number of large ranches are holistic. Because no holistic ranches were among the smallest ranches in this study, it remains unclear whether very small ranches (i.e., < 15 ha.) can maintain the same level of milk production without the input of agrochemicals and fertilizers to their systems. Furthermore, because Chiapas ranches operate at a very low profit margin (Hernández 2000), a conversion from conventional to holistic is likely easier for larger ranches, where the annual profit margin may be larger, and land area can be converted in portions. Thus a rancher does not risk losing an entire year’s production during conversion to holistic if the “new” system were to fail.

Transformities of milk production in the Fraylesca region ranged over two orders of magnitude. This high variance is likely due to size and management differences among the systems, but may also be due to the degree to which farmers have reached a steady state with their systems. Because holistic ranchers are in the process of converting their systems, and are at different stages of that conversion, annual material costs may not yet be stable. Nonetheless results from Fraylesca region, Mexico, are comparable to milk production in Florida, US. Brandt-Williams (2002) calculated a transformity of 1.3 \( E^6 \) for milk production in Florida. Mexico milk production in the Fraylesca region averaged 2 \( E^6 \) sej/J.

The conversion to holistic ranching analyzed in this study was grassroots change brought about by ranchers who believed that their land was being degraded by conventional ranching practices. Ranchers did not have access to soil, plant community, or sustainability studies which supported their belief before undertaking this large change. This study appears to support the conversion that they made. Although, changes and adjustments could be recommended from this study, ranchers appear to have converted their system to one that is more sustainable in emergy terms. Nonetheless, it is not clear from this study that conversion to holistic ranching is universally more sustainable. Because family labor was partitioned between renewable and purchased, according to current resource use in Chiapas, this study is best viewed as a regional appraisal. It does, however, suggest that ranchers had a clear idea of the ecological and economical conditions in their own region and were able to utilize resources accordingly to make their own systems more sustainable in emergy terms.

ACKNOWLEDGMENTS

We wish to thank the help of the ranchers we interviewed in the Fraylesca Region of Chiapas, Mexico, who donated their time to the completion of this project.

REFERENCES

APPENDIX A. DETAILED CALCULATIONS FOR TABLE 1.

1 Sun
Annual energy = (Avg. Total Annual Insolation J/yr)(Area)(1-albedo)
Insolation: 6.63E+09 J/m2/yr
Area: 80 ha
Area, m²: 8.00E+05 m²
Albedo: 0.105
Annual energy: 4.75E+15 J
Emergy per unit input = 1 sej/J (Odum 1996)

Rain, Chemical
Annual energy = (in/yr)(Area)(0.0254 m/in)(1E6g/m3)(4.94J/g)(1 - runoff)
in/yr: 48.6
Area: 80 ha
Area, m²: 8.00E+05
runoff coefficient: 7.00E-02
Annual energy: 4.54E+12 J
Emergy per unit input = 1.80E+04 sej/J (Odum 1996)

Wind
Area: 80 ha
Area, m²: 8.00E+05 m²
Density of Air: 1.3 kg m⁻³
Wind Velocity - Average 10 m: 2.58 m/s
Geostrophic wind: 2.32 m s⁻¹
Drag coefficient: 0.001
8 E5 m² * 1.3 kg m⁻³ * 0.001 * (2.58 m s⁻¹)³ * 3.14E7 sec yr⁻¹ = 8.43E+10 J yr⁻¹
Emergy per unit input: 1.50 E3 sej J⁻¹ (Odum 1996)

Labor (renewable)
Family: 3840 hr/yr
% R: 77 % (Guillen Trujillo 1998)
Total: 2956.8 hr/yr
Emergy/ unit: 6.99E+12 sej hr⁻¹ (Guillen Trujillo 1998)

Workshops (renewable)
Time: 64 hr/yr
% R: 77 % (Guillen Trujillo 1998)
Total: 49.28 hr/yr
Emergy unit input: 6.99E+12 sej hr⁻¹ (Guillen Trujillo 1998)

Net Topsoil Loss
Erosion rate = 2 t/ha/yr natural pasture (Rotolo et al. 2006)
Erosion rate = 10 t/ha/yr sowed pasture (Rotolo et al. 2006)
Natural pasture: 55 ha
Sowed pasture: 25 ha
Soil loss: 360 t/yr
Soil loss: 36000000 g/yr
Energy cont./g organic = 5.00kcal/g (Ulgiati et al. 1994)
4186 J/kcal
Annual energy: 3.01E+11 J
Emergy per unit input = 6.25E+04 sej/J (Ulgiati et al. 1994)

Labor (purchased)
Family: 3840 hr/yr
Purchased: 5760 hr/yr
% F: 23 % (Guillen Trujillo 1998)
Total: 6643.2 h
Emergy per unit input: 6.99E+12 sej/ hr (Guillen Trujillo 1998)
Workshops (purchased)
Time: 270 hr/yr
% F: 23 % (Guillen Trujillo 1998)
Total: 62.1 hr/yr
Emergy per unit input: 6.99E+12 sej hr⁻¹

9 Electricity
Annual energy = KWh*3.6E6 J/KWh
Energy: 3.00E+03 KWh/yr
Annual energy: 1.08E+10 J
Emergy per unit input = 1.60E+05 sej/J (Odum 1996)

10 Herbicides
Annual consumption: 0 L
density 1.24 g/ml
Annual consumption: 0.00E+00 g
Emergy per unit input = 1.48E+10 sej/g (Brandt-Williams 2002)

11 Materials
Annual consumption: 1.40E+04 US$
Emergy per unit input = 1.88E+12 sej/US$ (Guillen Trujillo 1998)

12 Feed
Annual consumption: 0 kg
Annual consumption: 0.00E+00 g
Emergy per unit input = 1.82E+09 sej/g (Castellini et al. 2006)

13 Vaccinations
Annual consumption, cm³: 964 cm³
Annual consumption, g: 9.64E+02 g
Emergy per unit input = 1.48E+10 sej/g (Castellini et al. 2006)

14 Nutritional Blocks
Annual consumption: 0 kg
Annual consumption: 0.00E+00 g
Emergy per unit input = 1.82E+09 sej/g (Castellini et al. 2006)

15a Government Assistance - monetary
Annual consumption: 2.27E+03 US$
Emergy per unit input = 1.88E+12 sej/US$

15b Government Assistance - calves
Calves = 0.00E+00 calves/year
6.85E+08 J/cow (Rotolo et al. 2006)
40 kg/calf
200 kg/cow
1.37E+08 J/calf
Annual consumption: 0.00E+00 J
Emergy per unit input = 1.73E+06 sej/J (Rotolo et al. 2006)

15c Government Assistance - machinery
Annual consumption: 2991 US$
Annual consumption: 2.99E+03 sej/US$
Emergy per unit input = 1.25E+10 sej/g (Comar et al. 2004)

16 Calves = 0.00E+00 calves/year
6.85E+08 J/cow (Rotolo et al. 2006)
40 kg/calf
200 kg/cow
1.37E+08 J/calf
Annual consumption: 0.00E+00 J
Emergy per unit input = 1.73E+06 sej/J (Rotolo et al. 2006)

17 Pesticides
Annual consumption: 4 L
Annual consumption: 4.00E+03 g
Emergy per unit input = 1.48E+10 sej/g (Brandt-Williams 2002)

18 Nitrogen Fertilizer
Annual consumption: 0 L
Annual consumption: 0.00E+00 g
Emergy per unit input = 2.41E+10 sej/g (Brandt-Williams 2002)