SUSTAINABILITY OF ECOTOURISM AND TRADITIONAL AGRICULTURAL PRACTICES IN CHIAPAS, MEXICO

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ABSTRACT

Issues of sustainability of ecotourism and household productive activities (shifting cultivation, cattle grazing and palm extraction) were evaluated using emergy and financial indicators in the Lacandon Forest area in Chiapas, Mexico. Indices and ratios such as emergy investment (purchased emergy to indigenous emergy), financial net-revenue/cost, total emergy/total revenue, and labor emergy/net-revenue were used.

The area's population was grouped as founders and sons households, and then regrouped as those involved and not involved in tourism. Land conversion data showed households involved in ecotourism activities did not conserve more land in forest than uninvolved households. Households averaged 59 hectares of land with sixty percent in forest with deforestation rates decreasing since 1975.

A total emergy flow/total revenue ratio indicated that traditional productive activities required 20E12 to 570E12 sej/US$ while ecotourism had a ratio of 0.84E12 sej/US$. The tourism resort had an emergy investment ratio (8.7/1), 300 times as intense as the local economy, questioning its long term viability.

Ecotourism activities (boat transportation and resort work) had the lowest labor emergy/net-revenue (0.33E12 and 1.15E12 sej/$, respectively) indicating the large fuel and

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purchased resources necessary. However, with few purchased inputs, traditional productive activities had larger ratios (8.9E12 to 177E12 sej/$). Net revenue per dollar cost indicated that the highest investment returns were obtained from traditional productive activities (2.32 to 5.75), with ecotourism activities returning 0.3/1 to 1.4/1.

Overall, the study results indicate that: 1) ecotourism activities were not among the most profitable activities studied, did not promote forest conservation, were highly subsidized and had a minimum of community involvement making households vulnerable to external pressures because of subsidies and material inputs; 2) cattle grazing activities were highly profitable but inefficient in human resource and land allocation; 3) corn cultivation with chemicals was 7.7 times as intense as shifting cultivation with an investment ratio of 5.68/1 and had lower net revenue per dollar cost, and 4) households involved in tourism activities doubled their investment ratio over those involved only in subsistence agriculture.

INTRODUCTION

Study area

The town of Corozal (17^{O} 23' N, 92^{O} W) located in the Lacandon Forest in Chiapas, Mexico is next to the river Usumacinta and close to the Yaxchilan ruins. These Mayan ruins, located in the Yaxchilan protected areas, are visited from Corozal by international and national tourists via boat or small airplane from Palenque. Corozal was founded in 1975 by the Mexican government settlement program to gather eight Mayan Chol Indian villages which were spread throughout the forest. The objective was to provide the required infrastructure for community development and more efficient government management of the protected areas. The Corozal community is surrounded by extensive protected areas of tropical rain forest. Conservation institutions (i.e., Conservation International) have discouraged conversion of forest to agriculture land that is not considered to be sustainable by promoting economic alternatives such as ecotourism, sustainable agroforestry systems, and handicraft production.

Importance of the Region for Conservation

The Lacandon forest is the most important remanent of tropical rain forest in North America with a richness in biodiversity, lakes, rivers, Mayan ruins, and cultural heritage. It has important protected natural areas including the Montes Azules and Lacantun Biosphere Reserves, Bonampak and Yaxchilan Natural Monuments, Chan Kin Wildlife Protection area and La Cojolita Communal Reserve. All these protected areas comprise around 500,000 hectares of tropical rain forest. The conservation of these ecosystems is threatened by high population pressure in the region (Guillén-Trujillo, 1995). The biggest threat to conservation in the area is the increasing agricultural and pasture land clearing due to the lack of other economic alternatives for rural poor. The Reserve Government Management Program limited the economic activities of the Chol, Lacandon, and Tzeltal Indian population who had lived in the reserve before its creation. To conserve the richness, it is a priority to find sustainable economic alternatives for the communities that inhabit the Lacandon Forest.

METHODS

Several different tools of analysis were used to address questions of sustainability of productive activities. Emergy analysis of the flows of energy, materials and labor were used to evaluate household productive activities and the economy of the community. Financial analysis was used to evaluate the economic benefits of productive activities. Questionnaires were used to gain data from households on land tenure and productive activities.

Emergy Analysis

The emergy analysis methodology is a top down systems approach and is designed to evaluate the flows of energy and materials of systems in common units that enable one to compare environmental and economic aspects of systems (Brown and Murphy, 1994; Guillén-Trujillo, 1998). The first step in each of the emergy analyses was to construct a system diagram to organize thinking and relationships between components and pathways of exchange and resource flow. The second step was to construct an emergy analysis table directly from the diagram, and the final step involved calculating several emergy indices that related emergy flows of the economy with those of the environment, and allowed for the prediction of economic viability and carrying capacity. Two ratios were calculated: emergy investment ratio (IR, economic/environment), and the environmental loading ratio (ELR). Several other indices (e.g., emergy money ratio, emergy per capita, and emergy exchange ratio) helped in gaining perspective about processes and are necessary precursors to the IR and ELR.

Financial Analysis

The economic appraisal suggested by Kiker and Lynne (1995) consist of the following steps: 1) to establish the socioeconomic boundaries associated with the alternative, 2) to identify the flows of important resources and outputs within and across the boundary, 3) to quantify the flows of resources and outputs within and across the boundary in multiple units, 4) to identify the benefits and costs associated with the alternative, 5) to quantify the monetary benefits and costs, and 6) to compare benefits and costs. The revenue/cost ratio is calculated in monetary terms.

RESULTS

Emergy Evaluation at the Community Level

Subsistence agriculture was practiced in the region, and forest regeneration was a key element for maintaining the cycle. However, the rapid increment in human population diminished the fallow period and caused a drop in the harvest. The most important renewable resource was rain (40.4E18 sej). Agricultural production and cattle grazing were the most significant contributions to the system (45.4E18 sej) from indigenous resources. The main crops were corn and beans. Forest extraction (0.68E18 sej) contributed very little to the system.

Tourism did not play an important role in the system. Tourist numbers are affected by the conservation of the natural (tropical rain forest) and cultural resources (Mayan ruins) and the flow of information. This information could have a negative impact in the visitation rate because of the present political instability in the region (indigenous uprising). Tourism generated income for five percent of the population who provided boat transportation and lodging facilities. The emergy contribution from tourist profits (boat transportation) was only 0.05E18 sej.

The emergy contribution of the indigenous sources (60.6E18 sej) was substantially greater than imports (1.39E18sej). The Corozal emergy/$ ratio (1.49E13 sej/$) was 2.4 and 7.9 times greater than the state and national emergy ratios, respectively. The total emergy used in the system was 6.2E19 sej, with more emergy being exported than imported. Import minus exports gave a negative value of 3.70E19 sej. The export to import ratio was 27.66, similar to the state (24.5) but bigger than the country (2.5). The investment ratio of the community was 0.023 compared to 0.052 and 0.366 for the state and the country, respectively. The environmental loading ratio was low (0.033) because 96% of the total emergy used came from renewable resources. The environmental loading ratio for the state and the country were 5.3 and 3.5, respectively.

The average total area per household in Corozal was 59 hectares with an average forest to cut ratio (F/C) and forest to total area ratio (F/T) of 2.31 and 0.60, respectively. More than fifty percent of the households interviewed had a F/C ratio greater than 1.5. In other words, for each hectare of forest that they had cut, 1.5 hectares were conserved in forest. More than fifty percent of the householders have 60 percent of their assigned land in forest.

Land Conversion by Households Involved in Ecotourism

Conservation organizations (e.g., Conservation International) and the State tourism agency were working with the households with boats in ecotourism activities such as boat transportation and, restaurant and bungalows services. The average deforestation rate per household varied among the households with boats and households without boats. Households with boats cut, in the year of this study, an average of 0.54 hectares of land in forest while households without boats cut an average of 0.98 hectares. Households with boats (ecotourism activities) and without boats had similar percentages of their total assigned land in forest. The households with boats and without boats both had approximately sixty percent of their total land in forest. Households with and without boats reported an average of 2.0 and 2.8 hectares per household, respectively, in agricultural production (p=0.067). Households with and without boats were involved in cattle activities. People without boats had a higher percentage (10.8) of their total land in pasture compared to 6.47% of other group. The average number of hectares per household in pasture were 3.71 and 6.86 for the households with and without boats, respectively.

Households with boats did not report Spring corn cultivation while the households without boats reported an average of 1.85 hectares of cultivation per household (p=0.072). Households with boats provided boat transportation to tourists to visit the Yaxchilan Natural Park and its archeological sites. January-February and July-August were the busiest months for tourism related activities. However, in the Fall corn cultivation, both groups were involved in shifting cultivation with an average of 2.15 and 2.64 hectares per household (p=0.319).

Households with boats were expected to have a higher forest/cut ratio than households without boats because their involvement in tourism activities. However, in 1996, the average F/C ratio was 1.89 and 2.49 for the households with and without boats, respectively (p=0.13). One possible explanation was that forty percent of the households with boats were founders' households who had been involved longer in agriculture. Fifty percent of the households with boats had a F/C ratio of 1.25 or greater while fifty percent of the households without boats had a F/C ratio of at least 1.75.

Households with and without boats had similar average forest to total land ratios. In 1996, the forest to total land (F/T) ratios were 0.61 and 0.59 for households with and without boats, respectively (p=0.38). At the household level, the cumulative frequency graph showed that half of the households with boats had at least fifty nine percent of their individual land in forest (Figure 3-31), and fifty percent of the households without boats had at least 65 percent of their land in forest (Figure 3-32).

Corn Cultivation Systems

Shifting cultivation (12.5 hectares)

The normal shifting cultivation pattern requires 12.5 hectares of land (2.5 hectares in cultivation and 10 hectares in various stages of succession over a 4 year rotation period). The usual intercropping system was corn, beans and jalapenos. Thirty six hectares were maintained in forest.

The highest renewable resource contribution was provided by transpiration of the mature and secondary growth forest (11.9E15 sej/yr). The eroded soil, considered in this study a nonrenewable source, contributed 0.87E15 sej/yr. Forest biomass that is cut and burned was the most important component of the system and its emergy contribution is included in the water transpired by plants (rain chemical contribution).

Purchased emergy in seeds, fertilizers, pesticides, tools and transportation (0.31 sej/yr) was relatively low compared to the environmental contributions (renewable and slow renewable resources). The next important component after environmental contributions was human labor (9.2E15 sej/yr). In primitive corn fields, labor is the most important component added to the system. The crop transformity for this system of 3.64E05 sej/j was obtained by dividing the total emergy yield (22.27E15 sej/yr) by the energy output (6.12E10 j/yr) of the crop yields. The purchased/free or investment ratio (.74) was lower than 1 because most contributions were coming from the environment. Less nonrenewable resources were used compared to renewable (nonrenewable/renewable ratio of 0.099). This ratio was lower than one because only soil erosion and purchased inputs were considered nonrenewable resources from the local environment. Forest biomass emergy included in the rain chemical was considered a free renewable resource. The ratio of developed to environmental components (0.87) shows that most of the emergy contribution to the system came from renewable resources such as the slash and burn of forest biomass.

One-hectare with chemical inputs

The characteristics of this system (one hectare of corn cultivation without shifting) were rain-fed, improved seeds, fertilizers, and mechanized agriculture. The land was arable all years. The most important contribution for the system came from fertilizers and tools purchased from outside (5.24E15 sej/yr). Rain chemical (0.95E15 sej/yr) accounted for 11 percent of the total emergy used (8.7E15 sej/yr). Topsoil erosion (0.35E15 sej/yr) was another component in the system with an annual erosion rate of 7 tons/hectare/yr. The environmental loading ratio (8.14) was greater than one because materials (fertilizers) and human labor inputs were higher than the free environmental service provided by rain chemical in one hectare. The investment ratio (5.68) was also high indicating that purchased emergy (materials and services) contributed more than the free renewable (rain chemical) and free nonrenewable (soil erosion) sources in one hectare of corn cultivation without shifting. The transformity for this system was 2.38E5 sej/J.

Low and High Intensity Cattle Grazing Systems

Corn fields were converted to pasture after they had been harvested. Cattle stock was acquired to begin the system and a rotation system of pasture land was established. Pasture land was added to the system gradually. Forest land was not usually converted directly to pasture. Two cattle grazing models, low and high intensity, were selected in the community as more representative of local cattle grazing systems in the region.

Each of the analyzed systems had forty hectares with different densities of cattle stock per unit area and rotation time. The highest renewable resource contribution was provided by rain chemical potential energy (38E15 sej/yr) in each system. Topsoil loss accounted for 7E15 sej/yr for each system equivalent to an annual soil erosion rate of 3.5 ton/ha. The low intensity cattle grazing system did not report any cattle acquisition while the high intensity system, that had the highest cattle density of the systems, acquired more emergy in cattle acquisition per year (47.3E15 sej). The next important component contributing emergy to the system was human labor. The high intensity system had a higher human emergy contribution of 52E15 sej/yr than the low intensity system (15.5E15 sej/yr). The emergy (sej) required to produce one unit of output energy (J) was higher in the higher intensity system. The transformities for the high and low intensity systems were 5.96E6 sej/J and 3.65E6 sej/J, respectively.

Purchased emergy, defined as materials and services brought to the system, was lower than free emergy (environmental contributions) in the lower intensity cattle grazing system as shown by the investment ratio (0.37). This ratio, purchased to free resources, was greater than 1 in the high intensity system (2.18) because of the cattle acquisition and more human labor required to maintain the systems. Environmental loading ratios (ELR) greater than one also reflect the system dependency on purchased emergy. The low intensity system had an ELR of 0.65 while the high intensity system had ELR of 2.88.

Palm Extraction and Cultivation Systems

Two different palm systems were evaluated: 1) a system of extraction where palm leaves were cut from plants found at their normal density within the forest, and 2) a system of cultivation where the understory of the forest was cleared and the palms were planted at a density of 40,000 plants/ha. The tropical rain forest was the driving force for these systems consisting of one hectare of mature forest. Understory palm (*Chamaedorea* spp.) was harvested from the forest and then sold in the market for the florist trade. Extraction took place in the surrounding protected areas close to the Corozal community.

For the two systems, it was assumed that the renewable resource contribution to the system was in the same proportion as the palm biomass was to the total forest biomass. Contribution of rain chemical potential emergy was smaller (0.22E12 sej/yr) in the system of palm extraction system compared to the system where palm was cultivated by humans (0.9E12 sej/yr).

In the palm extraction system, human labor was the most significant contribution to the system accounting for ninety four percent of the total emergy. In both systems, purchased emergy in the form of human labor, tools and transportation contributed most of the total emergy. In the intensively cultivated palm extraction system, the establishment and the operational inputs accounted for 6.5 and 93.5 percent of the total emergy used, respectively. The transformity of the palm extraction system (1.33E5 sej/J), obtained by dividing the total emergy yield (74.4E12 sej/yr) by the energy of the palm biomass extracted (5.57E8 J), was lower than the cultivated system (1.8E5 sej/J).

The extraction palm system had the lower investment ratio (purchased to emergy) of 0.078 because human labor was invested only in extraction activities. In the cultivation system, the investment ratio (5.22) was higher because maintenance investments were required besides extraction investment. The extraction system required less nonrenewable resources than the intensive cultivated systems as shown by the nonrenewable to renewable ratios. The environmental loading ratio of the cultivation system (5.22) was higher than the environmental loading ratio of the extraction system (0.078) because of the higher contribution emergy of establishment and operational inputs (tools, human labor and transportation) required in the intensive palm cultivated system.

Ecotourism Activities

The tourism system of Corozal drew on the resources of the local economy and imported resources from outside the local area. The ecotourism resort was being driven by two main sources of outside emergy: (1) free, renewable emergies, and (2) purchased emergies (fuel, electricity, tap water, equipment, furniture, goods and services). Renewable emergies combined and interacted to drive the productive processes in ecological systems. Purchased inputs from outside sources interacted with indigenous environmental resources to provide resources, emergies and products for tourists. Money derived from exported resources and from visiting tourists was used to purchase goods and fuels from other regions.

Resources were extracted or harvested from riparian and terrestrial systems and sold to the local economy or to the tourist facility. Money from tourists for imported goods, fuels, services, and locally derived resources entered the local economy before exiting the region in quantities equal to the inflows. Increased spending by tourists drove inflation up if inflows of local and imported resources and fuels were not increased.

The ecotourism resort in Corozal included 4 bungalows, a restaurant, water elevated tank, septic tank, and a camping area. Some of the bungalows were built by hand using local materials (wood and thatching) while the other structures were constructed with concrete. The main production function of the restaurant and bungalows was to provide goods and services for tourists by combining running water, food and liquor, fuels, electrical goods and materials, and labor. The assets and tourists were also part of the production function. Monetary income from tourists was used to pay for all of the above goods and services, shown as the dashed lines accompanying each purchased flow of energy.

The main free renewable emergy source was rain (3.8E15 sej/yr). Tap water was also considered in the analysis as a free renewable resource contributing 9.9E15 sej/yr. Most of the emergy in construction inputs came from purchased emergy subsidized by the government. Total construction inputs (15.3E15 sej/yr) accounted for 11.5 percent of the total emergy while annual operational inputs (104.1E15 sej/yr) accounted for 78.2 percent of the total emergy. Locally free renewable and nonrenewable resources contributed 10 percent of the total emergy. Labor accounted for 28.6 percent of the total emergy and provided employment for nine to sixteen local people based on tourist demand. Projections by the State Secretariat of Tourism indicated that the restaurant experienced 8,030 tourist-visits per year at 25 percent of its capacity, and that the bungalows experienced 6,912 tourists-nights per year 78 percent of the bungalows' full capacity.

Another important tourism activity was boat transportation provided by local people to tourists wanting to visit the Yaxchilan archaeological site.. Free renewable emergy contributed 99 percent of the total emergy. The river geopotential emergy accounted for 358.5E15 sej/yr. Construction inputs included the motor with a life span of 8 years and the materials (wood, palm and tin roofs) accounting for 0.35E15 sej/yr. Fuel and services for driving the boat were the main annual operational inputs that contributed with 3.62E15 sej/yr. Fuel (gasoline and oil) was the main operational emergy cost for boat transportation with 71.5 percent of the total purchased emergy. Tourist visitation emergy was calculated in proportion to the time spent by the tourists during the trip multiplied by their transformity.

The ratios for the ecotourism resort indicated that the system depended mainly on external resources (purchased emergy). The investment (purchased/free) ratio indicates that for each emergy unit that came from free locally renewable and nonrenewable resources, 8.73 were coming from purchased emergy such as fuels, electricity, goods and services brought from outside. The environmental loading ratio that indicated the amount of emergy coming into the system from nonrenewable, purchased goods and services to free renewable resources, was also 8.73.

Ratios for evaluating resources for the boat transportation system indicated that most of the emergy came from free renewable resources (river geopotential). The investment ratio indicated that only 0.01 units of purchase emergy are used per unit of locally free renewable emergy. Motor and fuel investment were the most important urban purchase emergy while local slow renewable materials (e.g., wood and palm for thatching) and local labor for driving the boat were the most important locally purchased emergy. The environmental loading ratio (0.011) was lower than one indicating that the system was driven mainly by free renewable emergy compared to purchased emergy.

Emergy Evaluation at the Householder Level

Households had homegarden plots of 50 by 50 meters in the town. In addition to these urban plots, they had agricultural plots located outside of the urban area usually within one hour biking distance. For longer distances, householders used local transportation. In their homegardens households grew vegetables, fruits, bananas, coffee and livestock. Forest products such as wildlife meat, extracted from protected areas, were consumed in the house. Palm extracted from the forest was sold to the market. Corn and bean from their agricultural plots were the main products partially consumed in the house. In addition to these products, squash seeds, jalapenos, and livestock (cattle) were sold in the market. With the cash generated from the agricultural and forest products, households bought goods and services. Households would also work in other economic activities besides their own agricultural plots, bringing additional cash to the family.

The typical household family was composed of two adults and four children. Average agricultural production and consumption were used in this example. Renewable (rain) and slow renewable resources (tap water) accounted for 56.2E15 sej/yr. Four different categories were considered in this analysis. Subsistence level households were those involved exclusively in shifting cultivation (corn and bean production mainly). The next household level included subsistence agriculture and palm extraction. The third level included subsistence agriculture plus cattle grazing activities. Finally, the fourth level was subsistence agriculture and boat transportation activities. Households could be involved in several activities at the same time.

Inputs for the household were classified as rural and urban inputs. Rural inputs included products from their agricultural plots (corn, beans, jalapeno, squash, etc.), wildlife consumption, fuelwood and meat for food (cow and chickens). The most important contribution of the rural inputs were the crops and meat consumption (including hunting) providing 9.95E15 sej/yr and 4.4E15 sej/yr, respectively, which accounted for most of the rural inputs.

Urban inputs were defined as purchased emergy inputs from urban environments. The inputs considered in this category were: electricity, government agricultural subsidies, and the goods and services brought with the profits obtained from agricultural and forest products. For this analysis, it was assumed that all profits were reinvested in the purchase of goods and services. Boat transportation profits contributed the highest emergy (2.1E15 sej/yr) for acquiring goods and services, followed by agricultural profits (1.8E15 sej/yr) and cattle profits (1.7E15 sej/yr).

Transformities increased as households were more involved in economic activities. Two transformity values were calculated for this analysis. A transformity value per household was obtained by adding the emergy inputs and dividing by the energy required for the whole family. The second transformity value was calculated by dividing the total emergy coming to the household by the energy requirement for the householder. Transformities per household ranged from 1.91E7 sej/J to 1.97E7 sej/J, and for householder from 4.77E6 sej/J to 4.91E06/J which was one/fifth of the average transformity of an American householder (24.6E6 sej/J, Odum, 1996).

Investment and environmental loading ratios increased as households were more involved in other economic activities beside subsistence agriculture. The lower investment (0.03) and environmental loading (0.30) ratios corresponded to the household level with subsistence agriculture. The investment and environmental loading ratios obtained in subsistence agriculture plus tourism activities (boat transportation) were 0.06 and 0.34, respectively. More purchased emergy was required to maintain boats and buy supplies.

The contribution of renewable resources such as rain for agricultural and forest land provided 77 percent of the total emergy flow at the subsistence level. Tap water and rural inputs such as agricultural products, meat (bought in the local market and wildlife hunted), and fuelwood consumed per household accounted for 19.4 percent of the total emergy flow at the subsistence level. The most important urban inputs in goods and services brought to the household were those obtained from the revenues of boat transportation profits (2.12E15 sej/yr), followed by agricultural (1.76E15 sej/yr) and cattle grazing (1.67E15 sej/yr) profits. Electricity and agricultural government subsidies accounted for 0.9 percent of the total emergy at the subsistence level and 26.6 percent of the total urban inputs at the subsistence level.

The rural to urban ratio decreases as the households were more involved in other economic activities besides subsistence agriculture. The ratio varied from 5.99 to 3.17. The tourism to agriculture, palm extraction and cattle grazing ratios were 1.21, 2.09 and 1.27, respectively. These ratios indicate that, for a typical household, boat transportation provides more purchased emergy than the other economic activities evaluated.

DISCUSSION

Conservation and Land Tenure at the Community Level

At present, Corozal has abundant land for cultivation to feed its increasing population compared to other communities in the region. The communal system and the assignation of land by the government has made this possible so far. Corozal has an average of 59 hectares per household while most of the indigenous communities in the highlands are usually limited to less than 20 hectares per household (Guillén-Trujillo, 1998). When there was not enough land for shifting cultivation and there were no economic alternatives, the children would migrate to the government protected areas located in the lowlands where they converted forest to agriculture land. This scenario could be repeated in Corozal if the population continues to increase and there are no development alternatives other than shifting cultivation.

Conservation policies should target individual households to find sustainable ways to maintain their newly acquired forests. The average forest to cut ratio indicated that households have 2 hectares in forest per each one hectare that they have cut. The average forest to total area ratio indicated that sixty percent of households' land was still in forest.

Land conversion analyses by groups suggested that present forest land conservation was not only a consequence of outside conservation projects, but also a consequence of recent communal land assignation policies, and household's labor and economic limitations in land conversion. The community assembly established a maximum of seventy hectares per household. Children will share this land in the future with their parents. The present deforestation rate indicates less forest converted to agricultural land. However, when children start getting involved in agricultural activities, the deforestation rate is expected to increase, unless other economic alternatives are provided. The regional land conversion analyses provided useful information for conservation policies.

Ecotourism, Land Tenure and Conversion by Groups

Deforestation rates in founders' households and sons' households had been decreasing since they started agricultural activities. The variations in the deforestation rates observed in these groups were explained by the cultivation period and the frequency and availability of fallow land to be incorporated in crop production.

In summary, the following trends were found between founders' households and sons' households: 1) deforestation rates in both groups have been decreasing, and 2) sons' households were not involved in cattle activities.The difference found between these groups were 1) founders' households have more land in agriculture than sons' households, 2) sons' households have more land in forest than founders' households, 3) forest to total area (F/T) ratio was higher in the sons' households showing that the sons' households had more forest land than founders' households, and 4) sons' households converted on average more forest land into agriculture than founders' households.

To answer the question if ecotourism was less destructive of the environment than other household productive activities, and to find indications of whether involvement in boat transportation (ecotourism) promoted conservation, another comparison was done with households with boats and households without boats. Deforestation rates have been decreasing in both groups. However, households without boats had on average a higher deforestation rate.

Households that participated in ecotourism did not discontinue other productive activities that were considered more destructive to the environment such as shifting cultivation and cattle grazing. However, data suggested that people involved in boat transportation were less involved in agricultural activities. Although households with boats and households without boats had a similar percentage of their land in forest, households with boats converted less forest land than those without boats. Households without boats also had on average more land in agriculture. Some people with boats in the Corozal community reported that they had hired labor for their corn fields while they were busy with tourism transportation.

During this time, households with boats and households without boats were both involved in cattle activities. Households with boats had converted an average of 0.14 hectares from agriculture to pasture land while households without boats had converted nearly three times that area. Furthermore, households without boats had a higher percentage of their total land in pasture. It is also important to note that households with boats who were involved in cattle activities were only founders' households. Data indicated that households with boats were less involved in cattle grazing.

Will the people involved in tourism activities (i.e., boat transportation) cut less forest than those who are not? Households with boats did not report any Spring corn cultivation. January, February, July and August were the months with high demand for boat transportation. However, households with boats were involved in Fall corn cultivation, which was the most important cultivation season. Long term studies are needed to continue monitoring these groups and observe their land conversion trends.

In summary, both, households with boats and without boats had been decreasing their deforestation rates, had similar percentage of their total land in forest, had Fall corn cultivation, and were involved in cattle activities. However, some important considerations found were: 1) households without boats had more land in agriculture, 2) although both groups were involved in cattle activities, households without boats had a higher percentage of their total land in pasture, 3) households with boats did not report Spring corn cultivation, and 4) households with boats converted less forest land to agriculture.

Comparison Among Shifting Cultivation Systems

Slash and burn corn shifting cultivation systems depended mainly on nutrients released by burning forest biomass. These systems were practiced in Corozal where enough land was available to shift. In contrast, the emergy supplied by forest biomass was substituted by fertilizers and machinery. State agricultural research institutions were promoting these industrialized systems as a substitute for the slash and burn system. Environmental impacts of both systems have to be evaluated to determine the sustainability of each system.

Different emergy trends could be observed as the shifting cultivation was industrialized. As the systems became more industrialized, the total emergy used increased because of the inputs from urbanized environmental sources such as fertilizers, pesticides and machinery. Both the investment and the environmental loading ratio increased indicating the dependency of the system on external sources (e.g., fertilizers and machinery). The environmental loading ratio of 0.87 (Table 1) calculated for the 12.5 hectare shifting cultivation system indicated the importance of land availability for shifting to allow for natural regeneration. Population pressure is a risk for the long term sustainability of this system causing the reduction of the fallow periods.

The revenue/cost ratio had a positive value indicating profitability in all the systems. One of the most profitable systems was the shifting cultivation system of Corozal (2.95) practiced without fertilizers, rain fed and rudimentary agriculture.

Comparison Among Cattle Grazing Systems

Cattle grazing systems with different cattle stock densities per unit area were compared to determine what system was more appropriate for development in the long (emergy analyses) and short (financial analyses) run. In the local cattle grazing systems, the high intensity system that had a cattle density of 1.64 heads/ha had the highest emergy flow (148E15 sej/yr). These local systems had the same extension of land but support different cattle densities. Emergy analysis tables showed that human labor for establishment and operation increased as cattle stock density increased.

When comparing similar systems, a lower transformity (sej/J) would reflect less emergy (sej) required per unit output of energy (J). The low intensity system with a lower investment ratio (0.37) had the lowest transformity (3.65E6 sej/J). This transformity may indicate that the low intensity system was the more appropriate cattle grazing system in the area.

Higher environmental loading ratios indicated that the system purchased more emergy from nonrenewable and external sources than free renewable emergy. The environmental loading ratio of the high intensity system was 4.4 times greater than the environmental loading ratio of the low intensity system (Table 1). The "loading" to the system came from more investment in human labor, purchased goods, and investment in cattle stock capital.

Financially, the low intensity system was more profitable as indicated by the higher revenue/cost ratio (Table 2). Revenues in these systems were defined as gain in value which was the net revenue (total sell minus establishment and operational costs) plus the increment in the cattle stock capital. This capital was increasing because of: 1) profits invested in more cattle acquisitions, and 2) number of calves born. The low intensity system was largely maintained with local resources with no additional cattle acquisitions except those produced in the same system. Several analyses are required for different years for this system to evaluate its profitability and sustainability in the long run. The low intensity system appeared to be the most appropriate in emergy (long run) and financial (short run) terms.

The main financial constraint for local people to convert land from corn field to pasture was the establishment cost and initial cattle acquisition. The establishment cost per hectare was 1/30th of the total cost.

Comparison Between Palm Extraction and Cultivation Systems

Palm production had been declining in the protected areas adjacent to the community because of overexploitation by local people, and the unsustainable practices involved in the cutting process. Although there was no consistent data about palm extraction, local people indicated that palm population density was declining. As alternative to palm forest extraction, a local palm extraction cooperative was planning to cultivate palm in managed forests. Purchased emergy increased as the system became more intensive. Cultivated systems required more emergy to maintain the system. This emergy was reflected in higher yields. The investment ratio in the cultivated system was sixty five times higher than the extraction system. Extractions plots close to the collection centers would decrease the emergy costs for palm extraction because would not required transportation. Environmental loading ratios had the same trend as investment ratios. Cultivated systems would be "loaded" compared to extraction systems.

Lower transformities indicated that more energy output was obtained per unit of renewable and nonrenewable emergy required to maintain the system. The palm extraction system had the lower transformity (1.34E5 sej/J) compared to the palm cultivated system (1.8 sej/J). More purchased emergy was required to maintain the cultivated system.

Revenue/cost monetary ratios (Table 2) indicated that both the extraction and cultivated systems were profitable for local people. The revenue/cost ratio of 3.48 in the extraction system explained why local people quickly extracted these resources when they were abundant. However, lack of individual land titles would favor the overexploitation of the palm because the access to protected areas was open to the community and the people would deplete the resources to maximize profits in the short term. As a consequence of its depletion, local people would have to walk longer distances and take higher risks to harvest the palm in more distant forests lowering the revenue/cost ratio.

The financial analysis also reflected that government subsidies in the first year of the cultivated system were important for covering part of the establishment costs. For the cultivated system the total establishment cost was N$3,000, equivalent to five monthly minimum wages in the region. Both emergy and financial systems gave insight in the sensitive variables for comparing extraction versus cultivated palm systems. These variables also have to be compared to other development alternatives in the region in order to have a better understanding of decisions taken at the household level.

Comparison Among Ecotourism Activities

Activities that involved tourism required additional purchase emergy for equipment, goods and services to satisfy tourist demand. The area's ecotourism resort had a total construction input of 301E15 sej and required government subsidies. Higher construction inputs increased the investment and environmental loading ratios. The boat transportation activity also required high initial investment and households usually had to get loans or government subsidies. However, the investment and environmental loading ratios for boat transportation (0.01, Table 1) were lower because the locally free renewable resources had a larger emergy contribution. In boat activities, free renewable resources contributed 99 percent of the total emergy while in the ecotourism resort, free emergy accounted for only 10 percent. Outdoor recreation activities, such as boat transportation, would use more of the locally free emergy.

Most of the total emergy required for running the ecotourism resort was for operational inputs. The ecotourism resort required 78 percent of the total annual emergy flow to be invested in operational inputs. In the boat transportation, fuel and services (driver's salary) accounted for 90 percent of the total purchased input emergy. Cash availability was required to run tourism activities. Salaries in the ecotourism resort accounted for 28.5 percent of the total emergy and provided employment for nine to sixteen local people according to the tourist demand, while in the boat transportation, 20 percent of the purchased emergy went for salaries, mainly of the boat owners.

The ecotourism resort was highly subsidized by outside institutions. Seventy five percent of the investment for construction, goods, furniture and equipment for restaurant and bungalows was provided through government loans. Future studies are needed to evaluate the profitability of the ecotourism resort in Corozal.

Credit availability and the restriction of members in the cooperative were the main constraints for households wanting to get involved in boat transportation. Boat owners received a government loan to acquire new motors. Government loans had the advantage that no interest rate was charged and opportunities for payments were given to the local people.

Boat transportation also required cash availability to cover operational costs. As indicated in the emergy analysis, gasoline was the most significant cost accounting for 33% of the total costs. In order to increase the revenue to cost ratio, householders had to drive their own boats. If the driver salary was earned by the owner, then the revenue to cost ratio was 1.42 compared to 0.68 when someone else was hired.

The consequences of international tourism on the balance of trade is often seen as only beneficial to undeveloped economies since it seems to be a nonextractive source of much needed foreign currency. What is often overlooked is the environmental support required and resources consumed to provide the goods and services for an expanded population of visitors. In essence, the resources that are consumed in support of a tourist population are "extracted" and exported with each tourist and therefore not available for consumption by the local population.

Comparison Among Household Productive Activities

Emergy and financial analyses were performed for household productive activities to compare indices that indicate the short (financial) and long (emergy) sustainability of the systems. Householders would usually get involved in different alternatives for maintaining their households and increasing their standards of living.

In general, the ecotourism resort brought more money to the households with the minimum amount of emergy invested (free and purchased) (Table 3 and Figure 1) followed by palm cultivation and extraction activities. Tourist river transportation had a high emergy/$ because the free renewable resources included the river geopotential. Cattle grazing systems required more emergy invested to obtain financial benefits. Using the national emergy money ratio (1.88E12 sej/US$), the ecotourism resort, with estimates from the State Tourism Agency, had the best trade advantage when buying goods and services in outside markets.

The total emergy /total revenue ratio did not describe the systems' dependency on external sources as it did the investment ratio. Household productive activities were listed in ascending investment ratio order in Table 1 to illustrate the dependency of these activities from purchased resources (materials and services) compared to free local resources (renewable, slow renewable and nonrenewable). Tourist river transportation had the lowest investment ratio because in its calculation river geopotential increased the free renewable resources considerably. Palm extraction and low intensity cattle grazing were the next systems with less purchased emergy from outside sources. The 12.5 hectare shifting cultivation system had an investment ratio lower than one indicating that the nutrients to maintain yields came from natural regeneration instead of purchased emergy as chemical fertilizers. However, with increasing population, fallow periods had been reduced not allowing natural regeneration enough time to provide the nutrients required for the crops to grow; therefore the yields decreased. Then shifting cultivators switched to systems with a more intensive use of labor and chemical inputs to maintain yields. This trend could be seen in the one hectare corn cultivation system that had an investment ratio of 5.68. The ecotourism resort had an investment ratio similar to that found in industrialized economies such as United States (7).

The emergy in the labor to net-revenue ratio and the net-revenue/ cost ratio indicated human effort invested to obtain profits in the systems. Ecotourism activities (ecotourism resort and tourist river transportation) were the systems with the least labor emergy required to obtain one dollar in net-revenue (Table 1). However, the ecotourism activities were not among the activities with the highest financial net-revenue/cost ratios (Table 2). The ecotourism resort (b) with a labor emergy investment of 0.33 to one US$ net-revenue was calculated from the Tourism State Agency's estimates. Using more realistic data from the Misolha resort that operates in a similar region to the Corozal resort, the ratio would be 3.27. Tourist river transportation had a low emergy required from human labor to obtain 1 US$ in profits. If local people had to pay the government loan (subsidy), the net-revenue/cost would be 0.26 instead of 2.67 (Table 2).

The least sustainable activities measured either by the amount of total emergy required to bring one US$ (in total revenue) to the household or the amount of labor emergy to obtain one dollar in net-revenue (profits) were the cattle grazing activities. However, low intensity cattle grazing was one of the most profitable activity measured by the financial revenue/cost ratio.

Government loans and subsidies that affect the financial revenue to cost ratio, influenced the householder's decision of which productive activities they wanted to be involved. The most profitable activity measured by this ratio (5.75) was the low intensity cattle grazing (Table 4-2) followed by palm extraction in forest. Corn shifting cultivation system had a higher net-revenue/cost ratio than that found in the corn cultivation with chemicals.

Although ecotourism activities had the most efficient total emergy/total revenue ratios for households, they created dependency on outside markets. A limitation of the tourism activities was that tourism visitation rates and government subsidies could fluctuate because of political and economical factors making households more vulnerable to external markets instabilities. Shifting cultivation systems would be less affected because households could obtain from their plots the agricultural products for their subsistence regardless of external markets.

Environmental impacts or externalities have to be evaluated when substituting one alternative for other. For example, shifting cultivation systems would demand that forest land be converted in agriculture. When more land is not available, the system would intensify its requirements for labor and chemical inputs such as fertilizers to maintain yields. As a consequence, lakes and rivers would be polluted unless sustainable practices are promoted. Ecotourism activities such as boat transportation and the resort would be more efficient (lower emergy inputs per total revenue) but they would make households vulnerable to external sources. Presently, political instability in Chiapas is already lowering tourist visitation rates. Furthermore, tourist demand competes for local resources which generates local inflation.

If every household was involved in all the productive activities, then supply and demand would affect prices. As a consequence, the revenue to cost ratios would be different. For example, all households were involved in shifting cultivation but only twenty and five percent were in palm collection and tourism activities, respectively. At the household level, emergy investment ratios increased as households got involved in more economic activities (Table 1).

More money flowing into the household brought the opportunity for more goods and services (purchased resources).

Emergy and financial analyses provided insight into the systems. Ratios such as emergy investment, emergy transformities, financial revenue cost, total emergy to financial benefits, and labor emergy to revenue, indicated the sustainability of the system in the short and long term. Conservation programs in the region should consider the political and socioeconomic interests of the households to compromise development alternatives and conservation programs.

SUMMARY AND CONCLUSIONS

In this summary, background information and brief conclusions are first given as summary components, then they are elaborated upon in the sections that follow. Recommendations are then derived from the conclusions, and finally limitations and suggestions for further study are provided.

1. Corozal was chosen due to its proximity to the Lacandon Forest.

2. Emergy and financial analyses were performed on Corozal to identify the most/least effective emergy use and financial returns of natural resources, labor and purchased materials.

Land Tenure

1. Forest conversion rates of households have been declining through the years since establishment of the Corozal community from an average of 2.89 ha/household in 1976 to 0.84 ha/household in 1996.

2. Each household, on average, has been increasing land in cultivation since Corozal was founded, from 3.03 ha/household in 1976 to 25.03 ha/household in 1996.

3. There were no differences in land tenure or rates of land conversion between households that engaged in tourism services (boat transportation) and those that did not.

4. In 1996, sons' households converted on average more forest land into agriculture than founders' households.

Productive Activities

1. Highest revenue to cost ratios (5.75/1 to 2.32/1) were found in traditional agricultural practices followed by ecotourism activities (1.42/1 to 0.26/1).

2. Cattle grazing required the highest human input per dollar of revenue (177E12 sej/US$), yet had the highest revenue to cost ratio (5.75).

3. The ecotourism resort and boat transportation activities had the lowest human labor input per dollar of income generated (from 0.33E12 sej/US$ to 1.15E12 sej/US$).

Ecotourism

1. Emergy use per area (3.33E12 sej/m^2) and emergy investment ratio (8.73) of the ecotourism project in Corozal was 18.8 and over 300 times the intensity of the local economy, respectively.

2. Ecotourism did not appear to lead to reductions in shifting cultivation, cattle husbandry, or palm extraction by household engaged in the tourism activities.

3. If tourist visitations reach predicted levels and remain there, the ecotourism resort will have the lowest emergy expenditure per dollar of income generated of all productive activities (0.84E12 sej/US$).

4. The sustainability of tourism development will be greatly affected by whether or not the local community will prepay government loans.

5. The low percent of renewable emergy supporting tourism activities indicates that ecotourism increases householder vulnerability to economic fluctuations and availability of non-renewable resources.

Land Tenure and Conversion

The regional land conversion analyses provided useful information for conservation policies and suggest that present forest land conservation was not only influenced by conservation projects sponsored by international agencies, but also was a consequence of recent communal land assignment policies, and a household's labor and economic limitations in land conversion. Corozal had an average of 59 hectares per household while most indigenous communities in the area were usually limited to less than 20 hectares per household. Average deforestation rates per household had been decreasing since Corozal was founded while the total land in cultivation had been increasing since that time. More fallow land was used for crop production, but with less forest converted to agricultural land.

Land distribution in older communities than Corozal were more representative of most indigenous communities in the highlands who were experiencing increasing population and less available land for shifting cultivation. This scenario of deforestation could be seen in the future in Corozal if the population continues to increase and there are no other development alternatives but shifting cultivation.

In Corozal, while it was recognized that both genders were involved in land and resource utilization, the local land tenure system only allowed males to inherit land. The following trends were found in founders' households and sons' households: 1) deforestation rates in both groups had been decreasing since 1976, 2) from 1983 to 1996, sons' households were not involved in cattle activities, 3) sons' households started agricultural activities in 1983. In 1996, the difference found between these groups were a) founders' households had more land in agriculture than sons' households, b) sons' households had more land in forest than founders' households, c) forest to total area (F/T) ratio was higher for the sons' households showing that a larger percentage of the sons' households had more forest land than founders' households, and d) sons' households converted on average more forest land into agriculture than founders' households.

Data suggested that people involved in ecotourism activities (boat transportation) did not conserve more land in forest than people not involved. Households with boats did not discontinue other productive activities such as shifting cultivation and cattle grazing that were considered more destructive to the environment. In summary, both households with boats and without boats had been decreasing their deforestation rates, had similar percentage of their total land in forest, had Fall corn cultivation, and were involved in cattle activities. However, in 1996, some important considerations found were: 1) households without boats had more land in agriculture, 2) households without boats had a higher percentage of their total land in pasture although both groups were involved in cattle activities, 3) households with boats had no Spring corn cultivation, and 4) households with boats converted less forest land to agriculture.

Household Productive Activities and Sustainability of Ecotourism

In general, the ecotourism resort (0.84E12 sej/US$) brought more money to the community with the minimum amount of emergy invested (free and purchased) followed by palm cultivation (6.22E12 sej/US$) and extraction (7.39E12sej/US$) activities. Low and high intensity cattle grazing systems (571E12 sej/US$ and 935E12 sej/US$, respectively) required more emergy invested to obtain financial benefits.

Depending on how the renewable emergy input to boat transportation was calculated, this activity (0.01) had the lowest investment ratio followed by palm extraction (0.08) and low intensity cattle grazing (0.37) systems. The ecotourism resort (8.7) had an investment ratio similar to those found in industrialized economies such as United States.

The labor emergy to net revenue ratio and the net revenue to cost ratio indicated human effort invested to obtain profits in the systems. Ecotourism activities (ecotourism resort and tourist river transportation) were the systems with the least labor emergy required to obtain one dollar in net revenue (0.33E12 sej/US$ and 1.15E12 sej/US$, respectively); however, they were not the activities with the highest financial revenue/cost ratios.

The least efficient activities measured either by the amount of total emergy required to bring one dollar (in total revenue) to the community or the amount of labor emergy it took to obtain one dollar (in net revenue) were the cattle grazing activities. However, the low intensity cattle grazing system (5.75/1) was one of the most profitable activities measured by the financial net revenue/cost ratio. Government loans and subsidies that affected the financial net revenue to cost ratio influenced the households' decisions of which productive activities they chose.

Emergy and financial analyses provided insight into the systems. Ratios such as emergy investment, emergy transformities, financial net revenue cost, total emergy to financial total revenue, and labor emergy to financial net revenue, indicated the sustainability of the system in the short and long term. Data showed that ecotourism activities such as boat transportation and the resort were: 1) not among the most profitable household productive activities studied (high revenue/cost ratio), 2) did not promote forest conservation, and 3) made households vulnerable to external pressures because of subsidies, materials and services purchased from outside.

However, the ecotourism resort required the lowest emergy input to obtain one dollar in total revenue.

Recommendations

Final recomendations are: 1) international conservation institutions should finance only householders involvement in ecotourism if householders guarantee forest conservation, 2) the promotion of cattle activities should not be based only on its profitability but it should take into consideration its inefficiency in human resource and land allocation, and 3) high subsidies or grants for ecotourism activities are an inefficient allocation of financial resources because of the low percent of the population involved, unless other activities, such as environmental education, are also included.

Limitations and Suggestions

There were several constraints found in the households' data collection: 1) the sample was not completely random because the households were reticent to talk to outside interviewers as a consequence of political instability in the study area, 2) the data collected for the household productive activities was only for the year of study and does not track the dynamics of the systems in the long run, and 3) due to the large scale and variety of the systems, some data had to be taken from other similar studies.

The sustainability of ecotourism in Corozal was questioned when tourism activities such as the resort were over 300 times as intense as the local community. Further studies in the area will be required to monitor households involved and not involved in tourism activities, to suggest better allocation of resources (subsidies and loans), and to determine sustainable productive activities appropriate for the area.

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APPENDIX

Table 1. Emergy Ratios for Evaluating Household Productive Activities in Corozal.

Alternatives/ratios	Purchased/ free	Nonren./ renew.	Service/ free	Service/ resource	Develop./ environ.	Emergy Use (sej) 1E+15	Transformity (sej/J) 1E+05
Productive activities:							
Tourist river transportation (550 hectares)	0.01	0.01	0.002	0.002	0.01	368.75	97.91
Palm extraction in forest (one hectare)	0.08	0.002	0.08	0.08	0.08	0.07	1.34
Cattle grazing low intensity (40 hectares)	0.37	0.21	0.37	0.36	0.65	63.07	36.50
Corn Shifting cultivation (12.5 hectares)	0.74	0.10	0.72	0.70	0.87	22.27	3.64
Cattle grazing high intensity (40 hectares)	2.18	1.48	1.15	0.57	2.88	148.10	59.61
Palm cultivation in forest (one hectare)	5.22	0.03	5.19	5.06	5.22	4.97	1.80
Corn cultivation with chemicals (1 hectare)	5.68	5.98	1.58	0.31	8.14	8.70	2.38
Ecotourism resort (4 ha.)	8.73	5.95	2.78	0.40	8.73	133.09	97.91
Household economic activities:							
Subsistence level (only agric. activities)	0.03	0.26	N/A	N/A	0.30	72.94	47.74
Subsist. level (plus forest palm extraction)	0.05	0.26	N/A	N/A	0.32	73.96	48.41
Subsist. level (plus cattle grazing activities)	0.06	0.26	N/A	N/A	0.33	74.61	48.83
Subsist. level (plus boat tranps. activities)	0.06	0.26	N/A	N/A	0.34	75.07	49.13

FOOTNOTES:

1) Transformity for ecotourism resort is for avg. tourists staying in the resort.
2) Transformity for tourist river transportation is for avg. tourists taking the trip.
3) Transformity for household economic activities is for householder.
4) Corn cultivation with chemicals is the TMF-MC (Palenque) system defined previously.
5) Corn Shifting cultivation (12.5 hectares) is the system analyzed for Corozal.

Table 2. Financial Ratios for Evaluating Household Productive Activities in Corozal.

Alternatives/ratios	Net revenue/ cost	Total revenue N$	Total costs N$	Net Revenue N$	Governm. subsidy N$	Assets N$
Productive activities:						
Cattle grazing low intensity (40 hectares) (a)	5.75	884	131	753	0	2,828
Palm extraction in forest (one hectare)	3.48	81	18	63	0	0
Corn Shifting cultivation with subsidy (12.5 hectares) (b)	2.95	7,506	1,900	5,606	1,200	0
Ecotourism resort without loan payment (subsidy) (4 ha.) (c)	2.67	1,270,612	346,496	924,116	1,316,800	1,215,541
Corn Shifting cultivation without subsidy (12.5 hectares) (b)	2.32	6,306	1,900	4,406	1,200	0
Tourist river transportation (550 hectares) (d)	1.42	22,400	9,248	13,152	23,000	28,000
Cattle grazing high intensity (40 hectares) (a)	1.39	1,268	530	737	0	4,241
Corn cultivation with chemicals (1 hectare) (e)	1.05	4,255	2,079	2,176	480	0
Palm cultivation in forest (one hectare)	0.62	5,194	3,208	1,986	1,200	0
Ecotourism resort with loan payment (4 ha.) (c)	0.26	1,270,612	1,006,549	264,063	1,316,800	1,215,541

FOOTNOTES:
-See individual financial analyses for details.
a) Total revenue includes increment to capital (calves born + weight gain in stock) plus total sell
b) The system is only for corn production. System analyzed for Corozal.
c) Total costs are the operational inputs from restaurant and bungallows.
c) Goverment subsidy was given as a credit to the cooperative members through a social development program.
d) Boat's owner drives the boat. Government subsidy is per household with boat and
given as credit through social development programs.
e) Corn cultivation with chemicals is the TMF-MC (Palenque) system defined previously.

ASSETS:
-Land opportunity cost and family labor are not included in any system.
-For different cattle systems, it is the total weight of stock per hectare in a monetary value for 1995.
-For ecotourism resort, it includes civil infrastructure of restaurant and bungalows, equiptment and furniture.
-For boat transportation, it includes the cost of boat and motor (1995).

Table 3. Emergy Requirements for Bringing One US$ from Productive Activities to the
Household Economy (1995).

	Total Emergy to one US$	Total Emergy (sej)	Total Revenue (tot. rev.)	Labor Emergy (sej)	Net Revenue (net rev.)	Labor Emergy to one US$

	(tot. rev.)					(net rev.)
	1E+12	1E+15	US$	1E+15	US$	1E+12
Development alternatives:						
Ecotourism resort without loan payment (subsidy) (4 ha.)	0.84	133.09	158826.50	38.02	115514.50	0.33
Ecotourism resort with loan payment (4 ha.)	0.84	133.09	158826.50	38.02	33007.88	1.15
Palm cultivation in forest (one hectare)	6.22	4.97	799.26	4.22	248.26	16.98
Palm extraction in forest (one hectare)	7.39	0.07	10.07	0.07	7.82	8.94
Corn cultivation with chemicals (1 hectare)	14.70	8.70	591.88	2.06	272.00	7.56
Corn Shifting cultivation with subsidy (12.5 hectares)	23.73	22.27	938.19	9.18	700.69	13.10
Corn Shifting cultivation without subsidy (12.5 hectares)	28.25	22.27	788.19	9.18	550.69	16.67
Tourist river transportation (550 hectares)	131.70	368.75	2800.00	0.79	1644.00	0.48
Cattle grazing low intensity (40 hectares)	570.77	63.07	110.50	16.68	94.13	177.19
Cattle grazing high intensity (40 hectares)	934.77	148.10	158.44	53.43	92.18	579.68

FOOTNOTES:

1) US$ = 8 N$

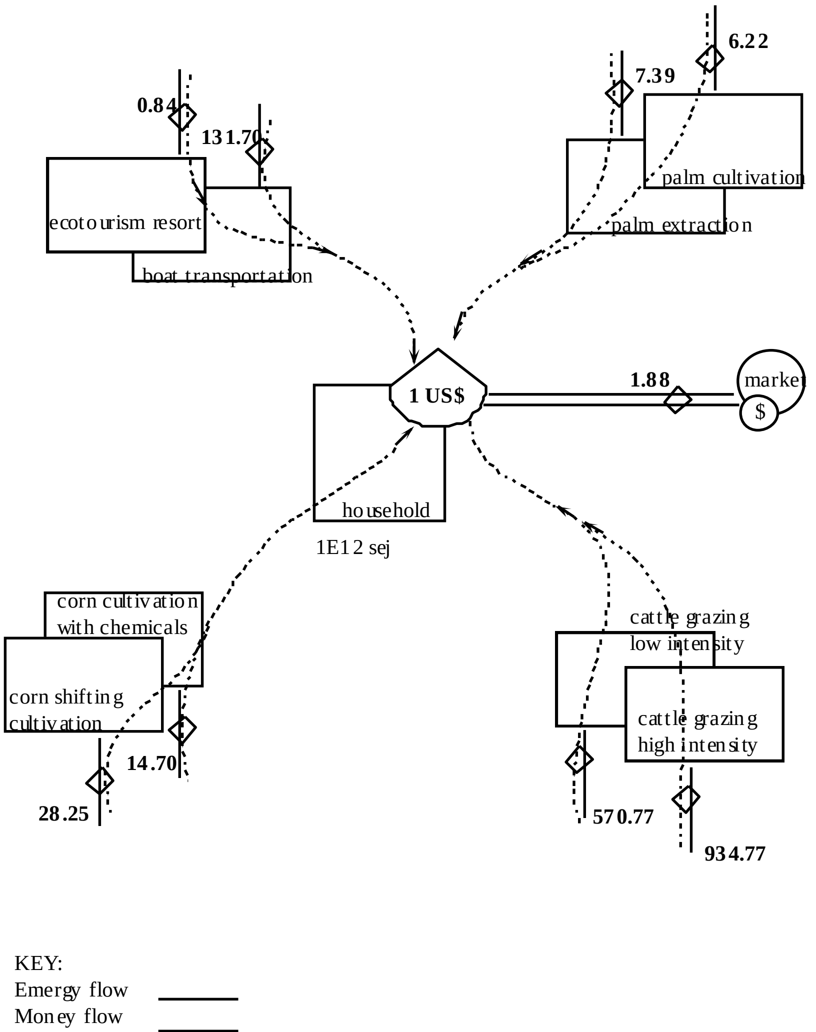

Figure 1. Emergy Requirements for Bringing One US$ from Household Productive Activities to the Local Economy (1995)