EVALUATION OF ECOTOURISM AND RESOURCE USE IN CUBA

By
John McLachlan-Karr and Howard T. Odum
Center for Environmental Policy
Department of Environmental Engineering Sciences
University of Florida, Gainesville, Florida, U.S.A.

Edited by
William Messina

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Abstract

In order to evaluate the tourism potentials for the Pinar del Rio area of Cuba, information was assembled during a visit in April 1995. First a systems overview was made with a diagram and Emergy* evaluation (Emergy spelled with an "m") so that the potentials of nature tourism could be assessed from a national perspective. The overall analysis showed the large impact of interrupted fuels on Cuba's economy and the priority needed to channel foreign exchange into fuel imports. The study also showed that current national tourism is responsible for 3.2% direct contribution to the GNP in economic terms and 2.0% when environmental resources are included with Emergy evaluation. The effect of tourism on the system was studied by comparing the Emergy buying from abroad made possible by foreign money with the Emergy of the services supplied by Cuba (both economic and environmental) to the tourists. Because the Emergy/money ratio of Cuba is high (about 4.3 E12** solar emjoules (sej) per $U.S. compared to 2.6 E12 sej/$ for the U.S. and European countries), money spent by tourists contributes a fraction (0.17) of the Cuban resource carried away by tourists. Foreign exchange earned from tourism may be best concentrated in the buying of fuels, as there would be a better balance of real wealth. Measures such as taxes on tourist service and special currency arrangements for visitors may help equalize the exchange of real wealth. The average Emergy use per person (10.5 E15 sej/person/yr in 1989) is an index of real wealth per person. It has been declining since 1989 due to decrease in imported fuels and increases in population.

At a smaller scale, a systems diagram of a unit of ecotourism was made to relate the Cuban environmental resource and economic assets. On an Emergy basis, parks that attract nature tourists in other countries have a balanced ratio of economic inputs to undeveloped rural or natural areas (Emergy investment ratio of about 1.0 = economic/environmental ratio). As has been shown elsewhere, when this ratio increases, nature tourists go elsewhere. If the Emergy investment ratio for the Pinar del Rio area is similar to the average for Cuba at about 1.1 (economic/ environment ratio) and the tourism that can be added depends on the

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* For a description of the Emergy concept, see the "Evaluation Concepts" section of this paper (beginning on page 11).

** Scientific Notation used throught the paper for 4.3×10^{12}, in this instance 4,300,000,000,000 sej.

rural area that is attractive for urban visitors, then the carrying capacity for tourists (from the investment ratio) is about 3,650 per year with 20 km^2 support area.

Overview policy models given here as systems diagrams have defined equations for computer simulation, thus helping to show what the model would cause in time. Experience in most other tropical countries suggests that ecotourism may protect areas of natural vegetation if it remains profitable and numbers of tourists are limited to within the carrying capacity to prevent environmental degradation.

Key words: Emergy evaluation, ecotourism, resource use, economy of Cuba, natural systems, energy flows, economic beneficiaries, carrying capacity.

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EVALUATION OF ECOTOURISM AND RESOURCE USE IN CUBA

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INTRODUCTION

Cuba is the largest and western-most of the Caribbean Islands, with a population of about 11 million people. Cuba lies in the Caribbean Sea between Florida and the Yucatan Peninsula. The Cuban Archipelago consists of the Isle of Cuba and about 1600 smaller islands and cays. Most of the country's terrain is level or rolling, and climatic conditions are similar throughout the country.

Rich and generally well drained soils and moderate to high rainfall are ideal for growing varied crops, including tobacco, citrus, vegetables and sugar cane. Cuba also has extensive natural areas of great biological and ecological value.

Cuba's willingness to enter into expanded investment and development partnerships reflects its eagerness to join the world's economy. Ecotourism is one development option that has caught the attention of the Cuban tourism authorities as well as the scientific community because of its increasing economic importance and potential to provide incentives to protect ecologically sensitive areas. It is not well understood, however, how ecotourism interacts with natural systems through disruption of energy flows, waste and redirection of economic activity, and who are the real beneficiaries of ecotourism development.

The purpose of a study trip in April-May, 1995, funded by the Center for Latin American Studies, John Hopkins University, was to investigate the potential benefits of ecotourism in Pinar del Rio. During this trip, discussions were held with several Cuban institutions and researchers in order to establish collaboration and to facilitate data exchange. The initial weeks of the trip were spent visiting areas of ecotourism potential in Pinar del Rio. Locations visited included Sierra del Rosario, Peninsula de Guanahacabibes, Bahia de Corrientes and Viñales. The Valle de Viñales was selected as a study site because of its current infrastructure, the importance of its natural biological resources and the area's future development plans (Figure 1, study area).

The data collected was used to develop several models to forecast ecosystem response and economic changes for different intensities of

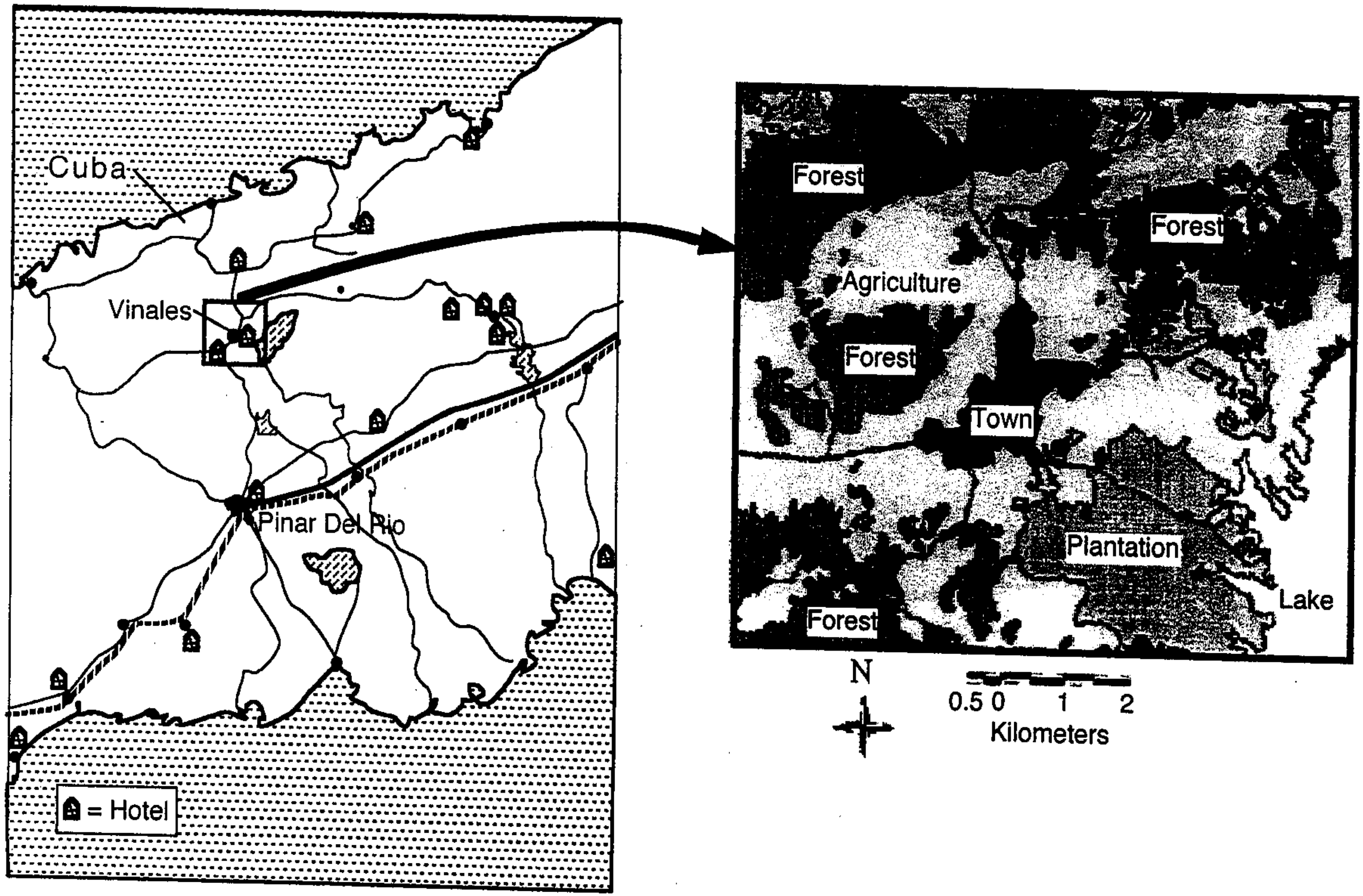


Figure 1. Map of Pinar del Rio, Cuba with inset of study area of Valle de Viñales.

development in Viñales. The following questions are addressed:

1. What are the beneficial and negative impacts of ecotourism?
2. What is the carrying capacity for outside economic investment within the region that is environmentally and culturally benign and economically beneficial?
3. How may ecotourism development be scaled to a region's economy and designed for sustainability?

Table 1 shows general economic statistics for Cuba.

For more than thirty years, the effects of the U.S. economic embargo on Cuba's economy had been offset by large economic subsidies from the former Soviet Union and by favorable trading relations with the members of the former Soviet bloc.[1] The collapse of these arrangements in 1989 led to greatly increased economic hardships in Cuba and rising international debt.[2] Figure 2 shows the Cuban economy and the price of sugar.

With sugar production declining after 1989-1990, the Cuban government began to encourage investment in tourism and the other sectors as a way to increase foreign exchange and to boost production in other sectors of the Cuban economy. After the decline in GDP noted in Table 1, in 1994 the Cuban GDP began to show some slight recovery. Most of this growth was in the tourism sector which grew by 14.4% in 1994. Growth of 8.5% in non-sugar related industrial production helped the Cuban economy grow by 0.7% in 1994.[3]

New trade regulations promulgated in 1995 were designed to encourage foreign entities to conclude joint ventures, cooperative production agreements, and autonomous enterprises with Cuban partners. European, Canadian, and East Asian countries are the main U.S. competitors taking advantage of the new opportunities in Cuba.

Ecotourism

Ecotourism may be simply defined as tourism where the primary objective of travel is nature related. The growing popularity of nature tourism reflects changing travel interests of many individuals; as people hear and learn more about the environment, they wish to experience the complexities and wonders of nature first-hand. Encouraged by increased marketing efforts by travel agencies and documented through the media, ecotourism is becoming an increasingly important tourist draw in

Table 1. General Economic Statisics for Cuba

Indice	1989	1994
GDP (billion Pesos)	19.6[a]	12.9[a]
Exports (billion US$)	5.4[b]	1.3[b]
Foreign Debt (billion US$) owed former USSR	1963-89 received 130 from USSR[b]	22[b]
Foreign Direct Investment (million US$)	3[b]	14[b]
Sugar Harvest (million metric tons)	8[b]	4[b]
Nickel Mine Production (thousand metric tons)	46[b]	25[b]
Foreign Tourists	340,000[c] (1990 est.)	600,000[c]

Source:

[a] The Economist Intelligence Unit Country Report, Cuba, Haiti, Dominican Republic, Puerto Rico, 1994-1945, published in UK.

[b] Statistical Abstract of Latin America, Vol. 37, 2001, U.C.L.A Latin American Center Publication, Univ. of California, Los Angeles.

[c] Garcia, A., Instituto de Investigacions Economicas. In Business Tips in Cuba, July, 1994. Published in Havana.

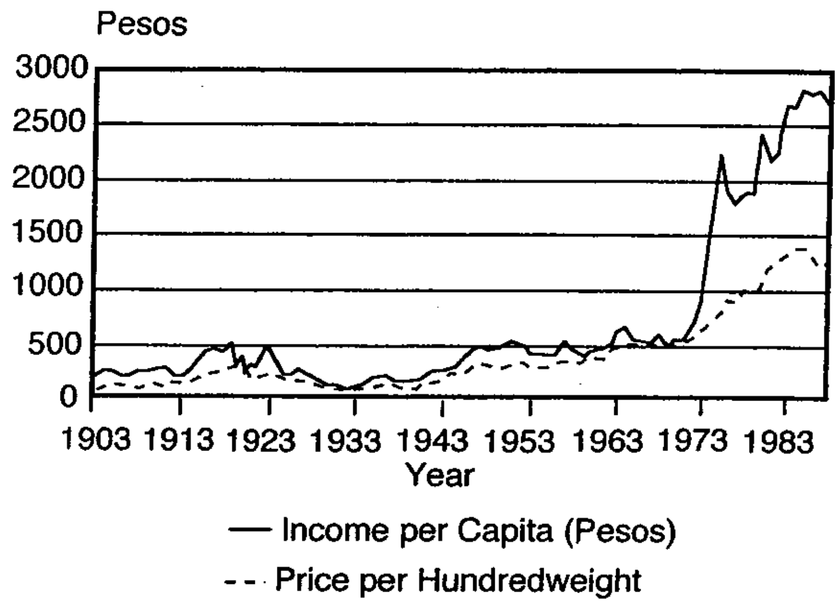


Figure 2. The Cuban economy and the price of sugar. Source: ACC CEDISAC, Banco de Datos, 1991.

developed countries. During the 1990s, tourism to natural areas of some tropical developing countries grew faster than any other form of economic development. In Central America and some parts of the Caribbean, ecotourism has become a major industry.[4] It was estimated that 15.7 million tourists arrived in the Caribbean in 1995, with about 600,000 visiting Cuba.[5] Table 2 shows the importance of protected areas for international visitors when choosing the country as a destination.

Primary goals and potential benefits of ecotourism are: to make significant contributions to local economies, to generate employment over a wide range of skill levels, and to attract investment for infrastructure development. If this is achieved, ecotourism may also provide economic justification for the protection of ecologically sensitive areas. Costa Rica, Belize and Ecuador have developed positive images as ecotourism destinations and have generated large and stable numbers of tourists. This has not been without degradation to their natural areas, however, as initial success in small ecotourism ventures can develop into mass tourism in about fifteen years. These examples illustrate the importance of having proper infrastructure in place to provide for an appropriate visitor carrying capacity so that a relatively large volume of tourists may continue to visit a protected area without its degradation.[7]

The most important component of a successful ecotourism model is image. Image is maintained by the combined interaction of environment, urban structure, culture and the development itself. If the environment becomes degraded as a result of tourism, destinations may lose visitors through competition from more appealing locations. A successful nature tourism industry depends largely on tourists' wilderness experience; crowded destinations can see a downturn in business.[8] To adequately compete in a crowded tourism market, care must be taken to avoid destruction of wildlife habitat, contamination of water supplies, and to provide for waste disposal. In the physical planning of an ecotourism center there is a need for a specialized approach in architectural design and construction technology to enhance this image.

For sustainable ecotourism to be successful it must be a profitable business. This requires capital and investment in advertising, accounting, planning and management and insurance to accommodate the minimum numbers of tourists for the venture to be economically feasible.[9] Large expenditures for imports may be necessary as well, especially for luxury goods, materials and fuels.

Table 2. Importance of Protected Areas for International Visitors When Choosing the Country as a Destination

Country	Primary	Important	Somewhat	Not	N.R.
Belize	0.08	0.36	0.29	0.23	0.04
Costa Rica	0.14	0.27	0.17	0.36	0.06
Dominica	0.13	0.12	0.25	0.35	0.15
Ecuador	0.52	0.13	0.14	0.17	0.04
Mexico	0.24	0.18	0.18	0.38	0.02

Source: WWF Airport Surveys.[6]

The Ecotourist

An important factor in ecotourism development is an understanding of the diverse desires and expectations of the ecotourist. More and more countries are competing for the ecotourism market. Most countries apply a standard tourism model and hope that ecotourism can be facilitated in this development. This model usually includes economic competitiveness, adequate infrastructure, sufficient accessibility and aggressive marketing. However, even with all four of these elements present, real success in developing a nature tourism industry requires providing an interesting and exciting experience.

The ecotourism development should cater to the requirements of ecotourists. Ecotourists may want all or a combination of the following: a meaningful, quality nature experience; encounters with wildlife of a region; interaction with local people; adventure in an exotic setting; skilled and experienced guides; a basic standard of comfort and safety; a feeling of contributing to conservation; the opportunity to indulge in a personal interest or pursuit; to have fun and relax; to fulfill a desire to see exotic animals or ecosystems; and to share these experiences in the form of photos, videos and memories.[10] Ecotourists often select their vacation expecting an experience of substance and intimacy. Those individuals seeking a specialized ecotourism experience and arriving to find a more conventional form of tourism may become bored and restless and leave disappointed.

Pure ecotourism and scientific tourism will typically allow fewer than 15 travelers in often primitive conditions to see a variety of habitats, wildlife and cultures. Accommodations can be fairly primitive and foods basic and local, as scientific tourists generally value the experience more than comforts and luxuries.

Adventure tourism is another rapidly growing form of nature tourism. Generally these travelers seek pristine locations for adventurous and exciting activities such as climbing and trekking. Pinar del Rio has the requisite beautiful scenery, mountains and exotic ecology to attract adventurous nature tourists. Levels of logistical support may vary and guides must be highly skilled in the particular industry and knowledgeable about the natural history of the region. The mountain areas near Viñales and the coastal areas to the north (Puerto Esperanza about 20 km away), and Cayo Ines de Soto may be tied in with the nature tourism image of Viñales. These areas may offer low impact nature-based activities such as sport fishing, sailing, diving and trekking.

Of major importance to the development of an ecotourism enterprise in Cuba is successful advertising. The first step is to determine exactly which type of tourist to address and why. The answer to this question will help decide which agencies and information will give the most return for dollars when advertising the tourism venture internationally. Costs associated with program development and advertising, and the effort required to conduct successful operations may be relatively high. Because of the lower market potential and lower volume permitted in ecotourism ventures, these programs may require several years before profits are realized, and require dedicated staff to develop and maintain them.

Evaluation Concepts[11]

Questions of development policy and resource use increasingly weigh the environmental impacts against economic gains. However, they are usually quantified in different units so there is not a common means of evaluating them using traditional economic analyses. Only monetary values are recognized by the market, but economies rely upon very large inputs from the environment. A regional economy is vital when there are abundant environmental resources and when they are used to purchase goods and services that reinforce productivity. Developments that export resources without importing goods and services that reinforce the productive systems will eventually be displaced by those that do.

In this study, various concepts and terms are used with which the reader may not be familiar. The most fundamental of these is Emergy. Emergy drives every system in the biosphere as well as the increase in complexity and biodiversity. The same holds for human economics, the development of which is driven by free inputs from nature and monetary inputs from the main economy. All of these flows have Emergy. This methodology is based on the thermodynamic principal common to all systems; that each component of a self organized system is coupled to higher and lower levels, and that each component contributes to system performance commensurate to its position. Emergy (Solar Emjoules (sej)) is the unit value used in the systems diagrams to express all inputs in the same unit. Because they are given a value commensurate with their actual contribution, they may be used accordingly. The model diagrams help connect verbal concepts with the complex systems that are being examined. Simulations can be made with the calibrated systems so the future prospects of the system can be investigated.

METHODOLOGY

In this study, an analysis of the Valle de Viñales ecotourism and forest systems was undertaken to better understand multiple functions and interaction of the systems and their contributions to Cuba's economy. A system diagram of the coupled/economic systems was used so that all known inputs to a productive process were identified and evaluated. As systems are interconnected with other natural systems and the human economy, the systems approach gives a regional view. The diagrams help organize information of components, pathways of exchange and resource flows that form the combined ecologic-economic system of Valle de Viñales (Figure 3, Valle de Viñales connected with the world economy).

An ecosystem contains a web of components that includes feedback loops. There is a convergence of successive energy transformations to form a hierarchy of quality, to provide for a storage of mass and information, and to recycle materials. The hierarchical order of the world makes it possible to simplify an overview enough for the human mind to visualize its patterns and still retain the features that are the most important in its operation. Aggregation is essential as there is always far greater complexity than can be feasibly assessed. The systems components with rapid turnover times will not affect the overall functioning of a system. The components of a system that have a similar function can be aggregated because their individual contributions do not affect the overall functioning of a system (Figure 4, Ecological/economic system in Viñales in greater detail).

The following steps were undertaken in the initial diagramming of the system to be evaluated:

1. The boundary of the system was defined (for example, in this study the area of Valle de Viñales on a topographical chart).
2. The principal components of the system were determined.
3. A list of processes (flows, relationships, interactions, production and consumption) were determined. Flows and transactions of money are included.
4. The diagram is drawn using the conventions of energy language diagramming.
5. A spreadsheet of the important sources of the system was made from data available.
6. The models are calibrated when the energy, matter and numbers are operating at their maximum potential.

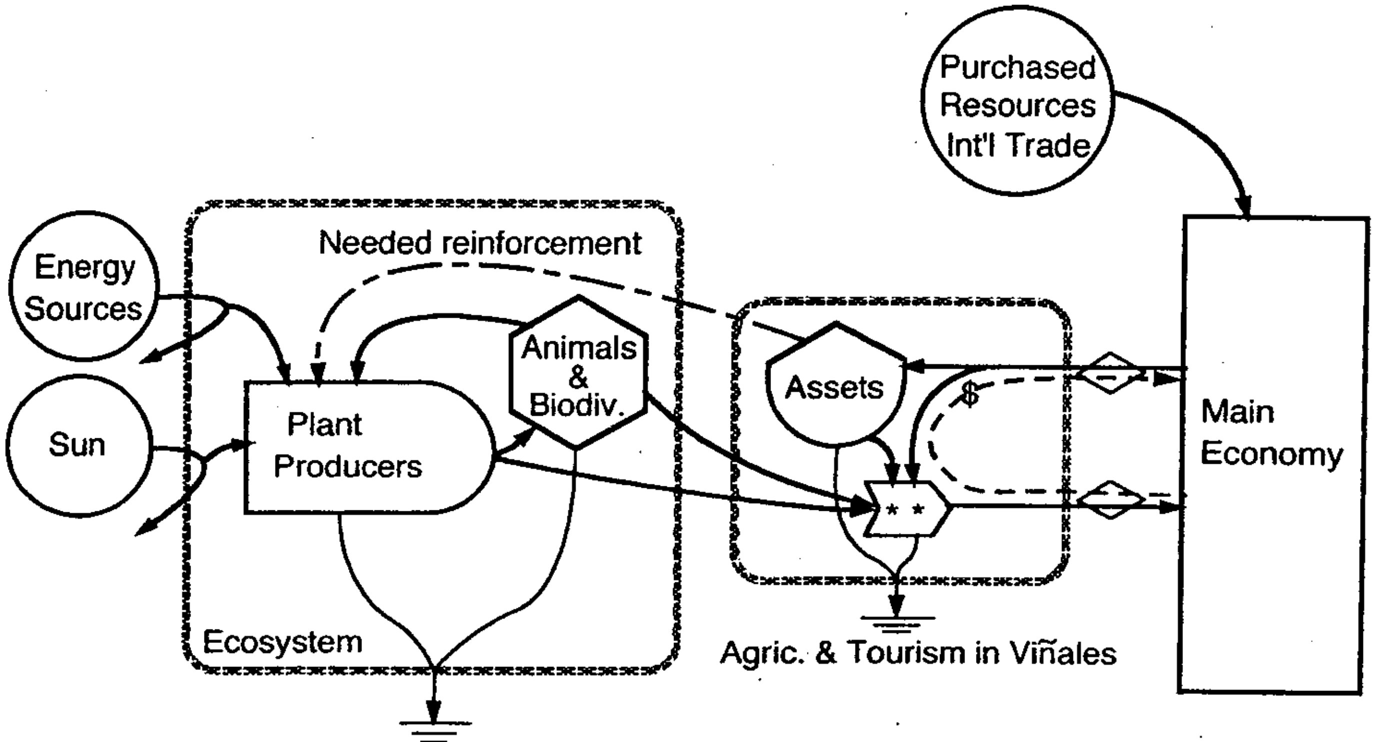


Figure 3. Systems diagram showing connection of Viñales to the regional and world economy.[11]

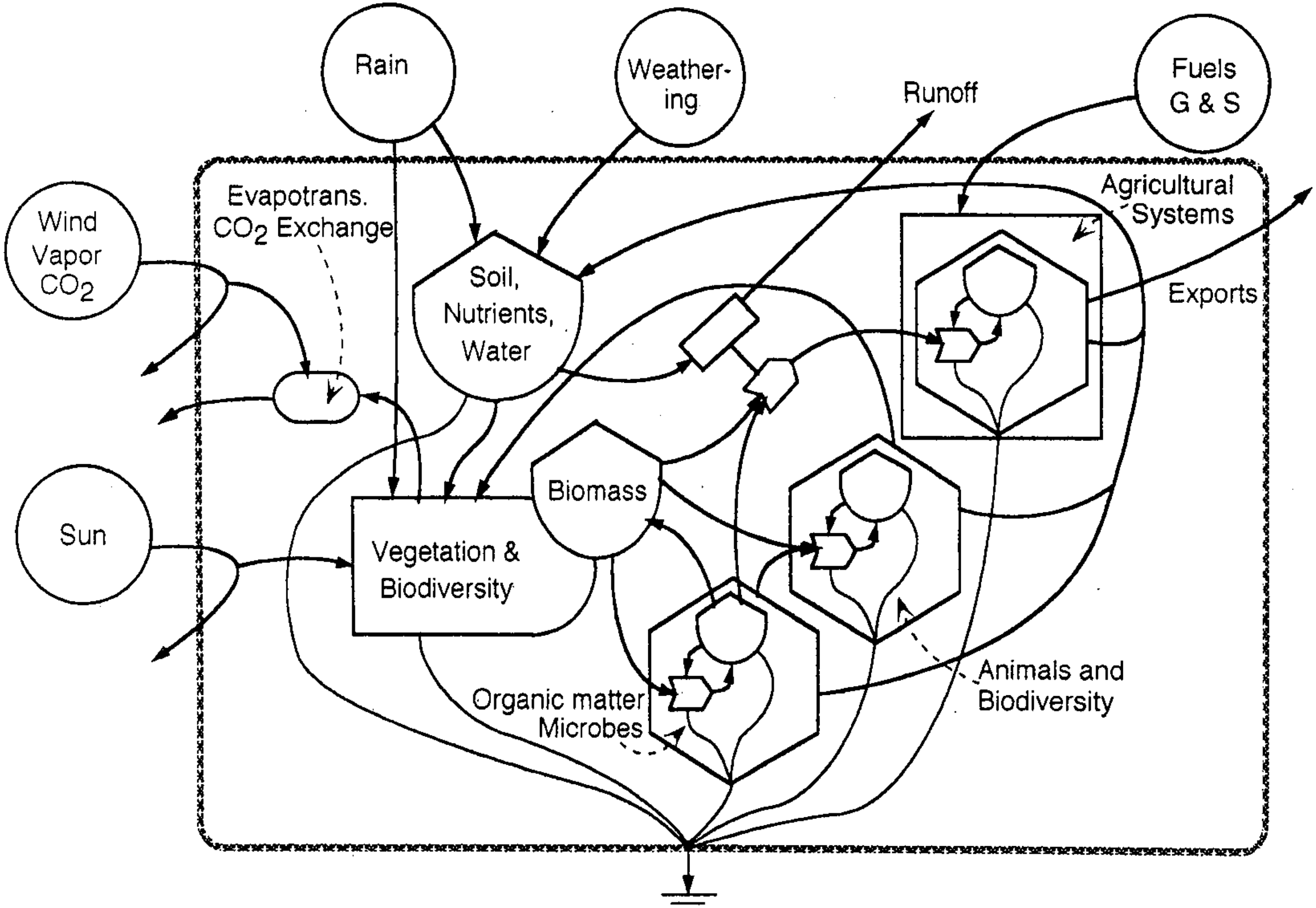


Figure 4. Energy systems diagram of the resource basis for nature and agriculture in Viñales, Cuba.[11]

In Table 3, the Solar Emergy evaluation spreadsheet, column 1 corresponds to the footnote number in a separate table (e.g., footnotes in Appendix A), which contains the raw data for the calculation. Column 2 corresponds to the name of the pathway in the aggregated systems diagram. Column 3 is the actual units of the flow, usually as flux per year. Column 4 is the transformity of the item, usually derived from previous studies. Column 5 is the solar Emergy of the resource input, measured in solar EMjoules per year per production output. It is the product of columns 3 and 4.

The following definitions for several key words in the methodology are given as follows:

Energy. The ability to do work. Energy is a property of all things which can be turned into heat and is measured in heat units (calories, joules, etc.).

Nonrenewable Energy. Energy and material storages like fossil fuels, mineral ores and soils. They are consumed at rates that far exceed the rates at which they are produced by geologic processes.

Renewable Energy. Energy flows of the biosphere that are more or less constant and recurring. They ultimately drive the biological and chemical processes of the earth and contribute to the geologic process.

Emergy. An expression of all the energy used in the work processes that generate a product or service in units of one type of energy. Emergy is defined as the energy of one type of required directly and indirectly to make a product. For example, some old, high quality wood may require 30,000 solar joules directly and indirectly through the climatic system of sun, rain, and nutrients to produce 1 joule of wood, whereas lower quality, fast growth plantation wood may have only 10% of this requirement.[12]

EMjoule. The unit of measure of Emergy. It is expressed in the units of energy previously used to generate the product. For example, the solar Emergy of wood is expressed as joules of solar energy that were required to produce the wood.

Solar Transformity. The ratio obtained by dividing the total Emergy that was used in a process by the energy yielded by the process. A transformity for a product is calculated by all independent contributing resources to a productive process, evaluated in solar Emergy, are summed

Table 3. Emergy Evaluation of Annual Inputs to Cuba in 1989

Col. 1 Notes	Col. 2 Item and Units	Col. 3 Inputs	Col. 4 Emergy/unit sej/unit	Col. 5 Solar Emergy E20 sej/yr
Renewable Sources				
1	Sunlight, J	3.84 E21	1.00 E0	38.4
2	Rain, Chemical, J	1.07 E17	1.54 E4	16.5
3	Rain Geopotential, J	5.46 E15	8.89 E3	0.49
4	Wind, Kinetic, J	1.33 E17	6.23 E2	0.83
5	Waves, J	5.25 E17	2.59 E4	136.0
6	Tide, J	1.70 E17	2.36 E4	40.1
7	River, Geopotential, J	7.50 E17	2.36 E4	177.0
8	Earth Cycle, J	4.40 E17	6.30 E3	27.7
Total				437.0
Indigenous Renewable Production				
9	Hydroelectricity, J	2.07 E16	2.00 E5	41.4
10	Agricultural Crops, J	3.32 E16	2.00 E5	66.4
11	Livestock, J	2.12 E15	2.00 E6	42.4
12	Fisheries, J	6.03 E14	2.00 E6	0.121
13	Fuelwood, Charcoal, J	8.23 E15	3.49 E4	2.87
14	Forest Extraction, J	1.48 E16	3.49 E4	5.17
Total				170.0
Nonrenewable Resources, Mined				
15	Natural Gas, J	5.74 E14	4.80 E4	0.276
16	Oil, J	2.60 E16	5.30 E4	13.8
17	Sand, g	4.83 E16	3.74 E4	18.1
18	Stone, g	8.84 E12	3.74 E4	0.0033
19	Nickel, g	3.76 E10	6.80 E10	25.6
20	Copper, g	4.50 E10	6.80 E10	30.6
21	Refractory Chrome, g	2.73 E10	6.80 E10	18.6
22	Top Soil, g	7.24 E16	6.30 E4	45.6
Total				152.0
Total Indigenous Sources and Products				759. 0
Imports and Outside Sources				
23	Oil Products, J	3.40 E17	5.30 E4	1.80.
24	Fertilizer & Chems., J	2.90 E14	1.69 E6	4.90
25	Coal, J	7.40 E15	3.98 E4	2.95

Table 3 (continued)

Notes	Item and Units	Inputs	Emergy/unit sej/unit	Solar Emergy E20 sej/yr
26	Steel, J	1.60 E9	1.97 E7	0.00032
27	Food, J	4.74 E16	8.50 E4	40.3
28	Wood, Paper, Text., J	6.70 E14	8.50 E4	0.57
29	Manufactured Goods, D	9.13 E8	3.80 E12	34.7
30	Mech. & Trans. Eqp., D	2.10 E9	3.80 E12	79.8
31	Foreign Aid, D	1.10 E9	3.80 E12	41.8
32	Net Migration, Ind.	-1.0 E4	3.18 E15	-0.31
Total				385.0
Total Imports and Indigenous Inputs				1140.0
Exports				
33	Agricultural Crops, J	3.30 E16	2.00 E5	66.0
34	Fishery Products, J	7.05 E13	2.00 E6	1.41
35	Tourist Services, D	2.75 E8	4.09 E12	11.2
36	Minerals, g	8.92 E10	6.80 E10	60.7
Total Export				139.0

Abbreviations: Cal = kcal = kilocalories

See Footnotes in Appendix A

together as the numerator and dividing by the observed or actual energy content in the denominator. Transformities are used to convert energies of different types to Emergy of the same type. If systems are operating at maximum power, solar transformity for a product or service is a measure of its potential value to the receiving system. A related theorem applied here is that systems will self organize over time to develop components and pathways that stimulate productive processes which generate at least as much as they require.

Emdollar. A measure of the money that circulates in an economy as the result of some process. In practice, to obtain the macroeconomic dollar value of an Emergy flow or storage, the Emergy is multiplied by the ratio of total Emergy to Gross National Product for the national economy.

Emergy to money ratio. The ratio of total Emergy flow in the economy of a region or nation to the GNP of the region or nation. The Emergy money ratio is a relative measure of purchasing power when the ratios of two or more regions or nations are compared.

Emergy per capita. The ratio of total Emergy in the economy of a region or nation to the total population. Emergy per capita can be used as a measure of average standard of living of the population.

Net Yield Ratio. The net solar Emergy yield ratio is the solar Emergy of an output divided by the solar Emergy of those inputs to the process that are purchased and fed back from the economy. The ratio indicates whether the process can compete in providing a primary energy source for an economy. Typical competitive fuel sources have been 4 or 6 to 1, though these favorable ratios are declining as fossil resources decline with increasing extraction and processing costs. Processes yielding less than those available may not be currently economical as primary sources. Ethanol from sugar cane only has a Net Yield Ratio of about 1.14 because of the resources used up in processing.

Exchange Ratio. The Emergy exchange ratio is the ratio of solar Emergy received to solar Emergy delivered in a trade or sales transaction. If the transaction is the sale of a commodity such as tourism services, in order to generate revenue to purchase necessary goods or services, the exchange ratio can be calculated as the solar Emergy of the product sold divided by the solar Emergy that could be purchased with the earned revenue. This is estimated using the solar Emergy/dollar index for the buyer nation or region.

A country or area receiving the more solar Emergy due to the market transaction has its economy stimulated more. Previous studies have indicated that raw products such as minerals, rural products from agriculture, fisheries and forestry generally have a high exchange ratio when sold at market prices.[13] This is a result of money being paid for human services and not for the extensive work of nature that went into these products. The solar Emergy exchange ratio is used in this study as a measure of the relative trade advantage of one trade partner over another.

Investment Ratio. The solar Emergy investment ratio is the ratio of the solar Emergy derived from the economy (F) to the solar Emergy delivered free from environmental sources (both renewable (I) and nonrenewable (N)) (Figure 5).

$$\text{Investment Ratio} = F/(I + N)$$

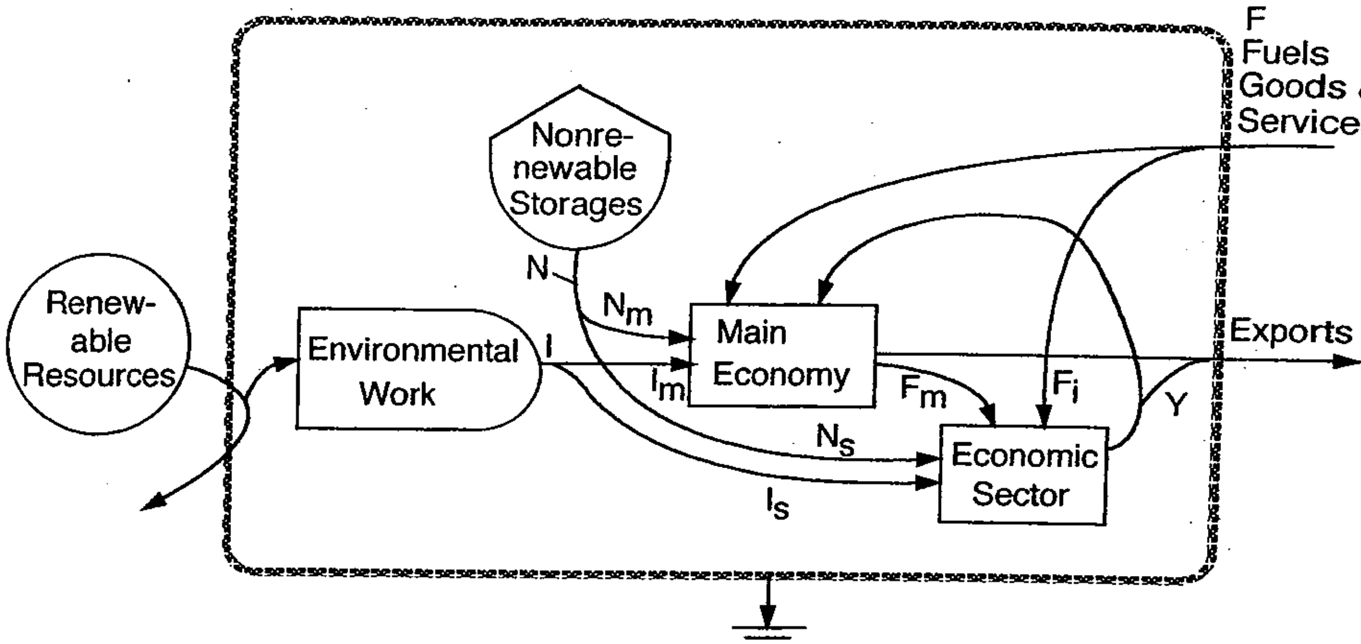
This ratio indicates if the process is economical as a utilizer of the economy's investment in comparison with alternatives. The larger the Investment Ratio, the greater the amount of purchased Emergy is required per unit of resident Emergy. To be economical, the process should have a similar ratio to its competitors. If it purchases less from the economy, the ratio is less, its price is less, and its products will tend to compete in the market place.

However, operation at a low investment ratio uses less of the attracted investment than is possible. The tendency is to increase the purchased inputs so as to process more output and generate more cash flow. The tendency is towards optimum resource use. This suggests that operations above or below the current investment ratio will tend to change toward the investment ratio common for that region.

Environmental Loading Ratio. Environmental loading ratio is a measure of potential impact or loading a particular development activity can have on its environment. It is the relationship of purchased Emergy (F) plus local nonrenewable Emergy (N) to local renewable Emergy (I) (Figure 5) as follows:

$$\text{Environmental Loading Ratio} = (N + F)/I$$

Nearly all productive processes of humanity involve the interaction of nonrenewable resources with renewable sources from the environment.



Investment Ratio for Economic Sector:
$= (F_i + F_m)/(I_s + N_s)$

Environmental Loading for Economic Sector:
$= (F_i + (F_m - kF_m) + N_s)/(I_s + kF_m)$

Net Yield Ratio for Economic Sector:
$= Y/(F_m + F_i)$

Figure 5. Systems diagram of a regional economy relating the flows of energy from external sources to those within the economy. (Doherty, S. and M. Brown, 1992).

Small environmental loading ratios indicate relatively small loading on the ecosystem support base, while high ratios reflect greater potential impact.

Biodiversity Assessment

A common method for indicating the species diversity of an area is the cumulative number of types found versus the numbers of individuals counted (Shannon-Weiner index).[14] The larger the area sampled, the more the number of cumulative species increases. Figure 6, is a species/area model which relates diversity to the available resource.[15] An indication of biodiversity in Viñales can be estimated by counting the numbers of species found among 1000 individual trees along a fixed transect up the slope of Sierra la Gausasa.

The areas of the Valley used in agriculture and in natural vegetation were calculated from a geographic information system image analyzed by ARC/INFO. Data were obtained from a 1/25000 topographic map (1985) obtained from the Instituto Cubano de Geodesia y Cartographia in Viñales.

RESULTS

Based on the data presented previously in Table 3 and other modelling efforts, Tables 4 and 5 summarize the Emergy evaluation of Cuba, and Table 6 compares Emergy indices for Cuba with other countries. In 1989 the total Emergy use in Cuba was 1155 E20 sej/yr. This is the contribution of all sources to Cuba's wealth: natural systems, production systems, imports and domestic use. The main resources for the Cuban economy are diagrammed in Figure 7. Thirty eight percent of this wealth comes free from the environment as sun, wind, rain, soils, etc. These resources are the necessary basis that supports the productive systems based on imported fuels, fertilizers, goods and services.

From Table 5, the Emergy/money ratio of Cuba is about 3.5 E12 sej/$ in 1989 U.S. dollars. This is the amount of real wealth that circulating money buys in 1989. Cuba's ratio is similar to the Soviet Union (3.4 E12 sej/$. Rural countries have higher Emergy/$ ratios because more of the wealth goes directly from the environment to the consumer without money changing hands. As the ratio increases, international transactions are less favorable for Cuba as invested money buys more Emergy (wealth) per $ and more wealth is exported. This is because economies with high Emergy/$ ratio are usually exporting natural resources for finishing abroad and money is only paid for the extraction

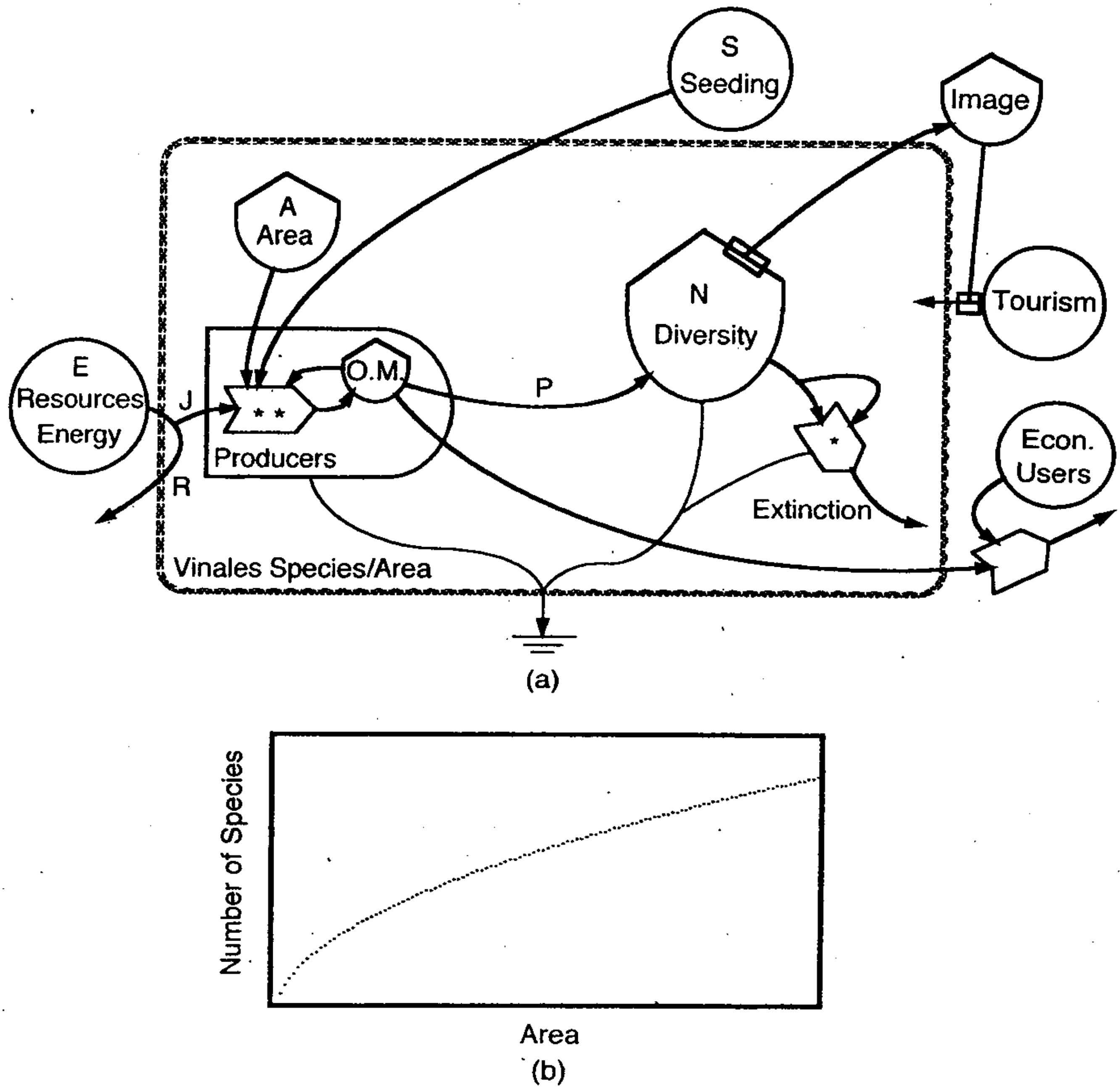


Figure 6. Systems model of species diversity.[24] Abbreviations: O.M. = organic matter; Econ. = economics. (a) Systems diagram; (b) typical simulation of the effect of increased support area.

Table 4. Summary of Annual Emergy Flows in Cuba in 1989 (Figure 7)

Item	E9 $/yr	E20 sej/yr
Renewable Source Flow (R)		4.37 E2
Renewable Rural Production (NO)		1.70 E2
Renewable Energy (N1)		4.14 E1
Total Indigenous Nonrenewable (N)		2.12 E2
Exported Without Use (N2)		6.07 E1
Imported Fuels and Minerals (F)		1.88 E2
Imported Goods (G)	1.97 E2	1.55 E2
Dollars Paid for Imports (I)	4.30 E9	
Exports Transformed in Cuba (B)		2.46 E2
Services in Imports (p2I)		1.63 E2
Exports (E)	5.40 E9	
Goods and Services Exports (p1E)	1.91 E2	
Gross Social Product	3.27 E10	
World Emergy/money Ratio in Imports (p2)		3.80 E12
Cuba Emergy/money ratio (E12 sej/$)(p1)		3.53 E12

Table 5. Emergy Indices for Cuba, Based on Table 4

Flow of Imported Emergy	F+G+p2I		sej/yr
Total Emergy Inflows	R+N+F+G+p2I	1.16 E23	sej/yr
Total Emergy Used (U)	NO+N1+R+F+G+p2I	1.16 E23	
Fraction from Home Sources	(NO+N1+R)/U	56.1	%
Fraction of Use Purchased	(F+G+p2I)/U	43.9	%
Empower Density		10.5	E12 m^2/yr
Emergy per Capita		11.0 E15	sej/person/yr
Land Area		1.10 E10	m^2
Population		10.5 E6	people
Fraction Renewable	R/U	37.8	%
		56.1	E1
Emergy/money ratio, 1994*		4.30 E12	sej/$

*Emergy/money Ratio for 1994 assumes 70% reduction in imports from 1989 and GNP of 18.6 E9 $/yr

Table 6. Comparison of Cuban Indices with Other Countries

Row	Index	Cuba (1989)	PNG (1987)[16]	Mexico (1987)[17]	USA (1983)[18]
1	Total Emergy use (E20 sej/yr)	1155.0	1213.0	6955.0	87570.0
2	Renewable Emergy (E20 sej/yr)	437.0	1050.0	1386.0	12355.0
3	Nonrenewable Emergy use (E20 sej/yr)	152.0	163.0	5569.0	75215.0
2	GNP (E9 US $/yr)	32.7	2.5	185.0	3305.0
3	Area (E10 m^2)	11.0	46.2	196.0	940.0
4	Population (E6 people)	10.6	3.5	81.1	234.0
5	Emergy/money ratio (E12 sej/$)	3.5	48.0	3.8	2.6
6	Empower density (E11 sej/m^2/yr)	10.5	2.6	3.5	9.3
7	Emergy per capita (E15 sej/person/yr)	11.0	34.7	8.5	37.4
8	World Emergy exchange ratio#	0.9	0.08	1.0	1.5
9	Environmental loading ratio	1.1	0.2	4.0	6.1

Source: Data for Cuba from Tables 3-5 based on Anulario Estadistico de Cuba 1989

Emergy trade advantage of country based on ratio of world Emergy/money ratio (3.8 E12 sej/$) to that of the nation.

PNG = Papua New Guinea

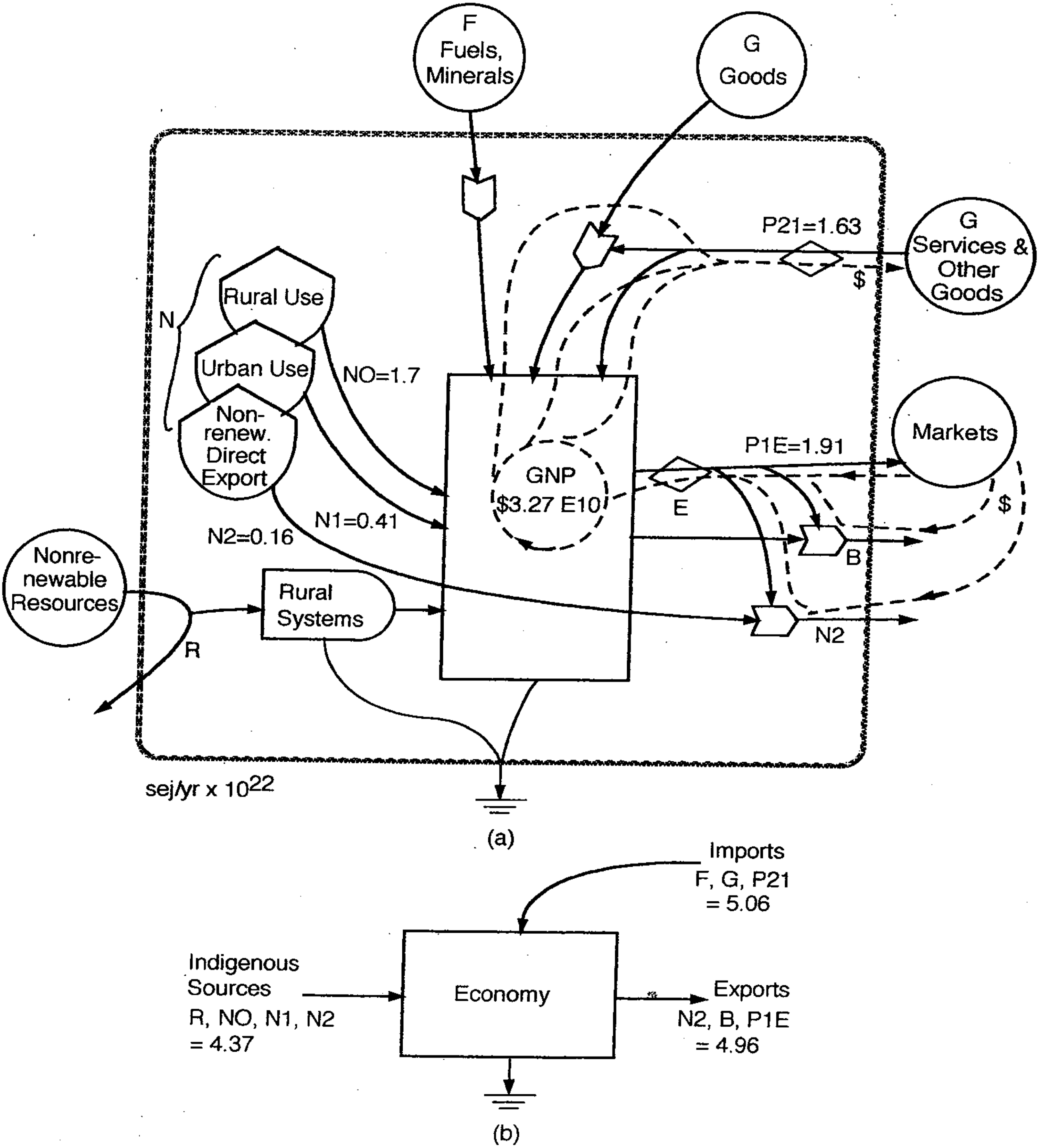


Figure 7. Overview of the Cuban economy in 1989. (a) Emergy and money; (b) summary.

of the resource, not the environmental energy that went into making it. Finished products bought abroad with the revenue generated have higher prices so that the Emergy of the money paid is more comparable with the Emergy of the products sold. Emergy balance of trade (ecotourism) is given in Figure 8a. Figure 8b gives the exchange ratio for Cuban sugar for Soviet oil (through barter arrangements).

Table 7 compares national activities and Emergy/$ for a number of countries with Cuba for 1989. The environmental loading ratio for Cuba in 1989 is calculated at 1.1. This is more than the world average of 0.96 and is similar to New Zealand and Brazil.[19] In 1989, Cuba had an EMpower (Emergy/unit area) density comparable to the United States. and higher than Mexico and Papua New Guinea. Cuba's Emergy use per capita was higher than Mexico but considerably less than Papua New Guinea and the United States. Although an underdeveloped nation, Papua New Guinea's Emergy per capita ratio is high because the population is low; it is resource rich, and much of its Emergy remains in the country and is not exported. Cuba imported approximately 60% of its real wealth in 1989, much of it as oil, which is coupled to indigenous resource flows to support an agriculture-based economy.

Review of Cuban Environmental Regulation Relevant to Ecotourism

Cuban Law 147 (April 21, 1994) grants authority for the Ministry of Sciences, Technology and Environment to direct and control the development of policies to protect the environment and provide for the rational use of those resources for the sustainable development of the country.

Cuban Ministry of Sciences, Technology and Environment Resolution on the Direction of Environmental Policy (Project 1 draft, March, 1995) authorizes ecotourism to be carried out in areas designated as such providing that certain administrative requirements are met. This is subject to administrative, management plans and the provision of personnel for the said purposes.[20] The Resolution also requires the establishment of a provincial environmental council in the planning and running of ecotourism ventures. The Ministry of the Interior and Ministry of the Armed Forces must also approve the project. The Resolution requires the establishment of a Responsible Authority for the coordination of development activities with the Ministry of Tourism. This coordination requires that a certain part of the economic benefits of the

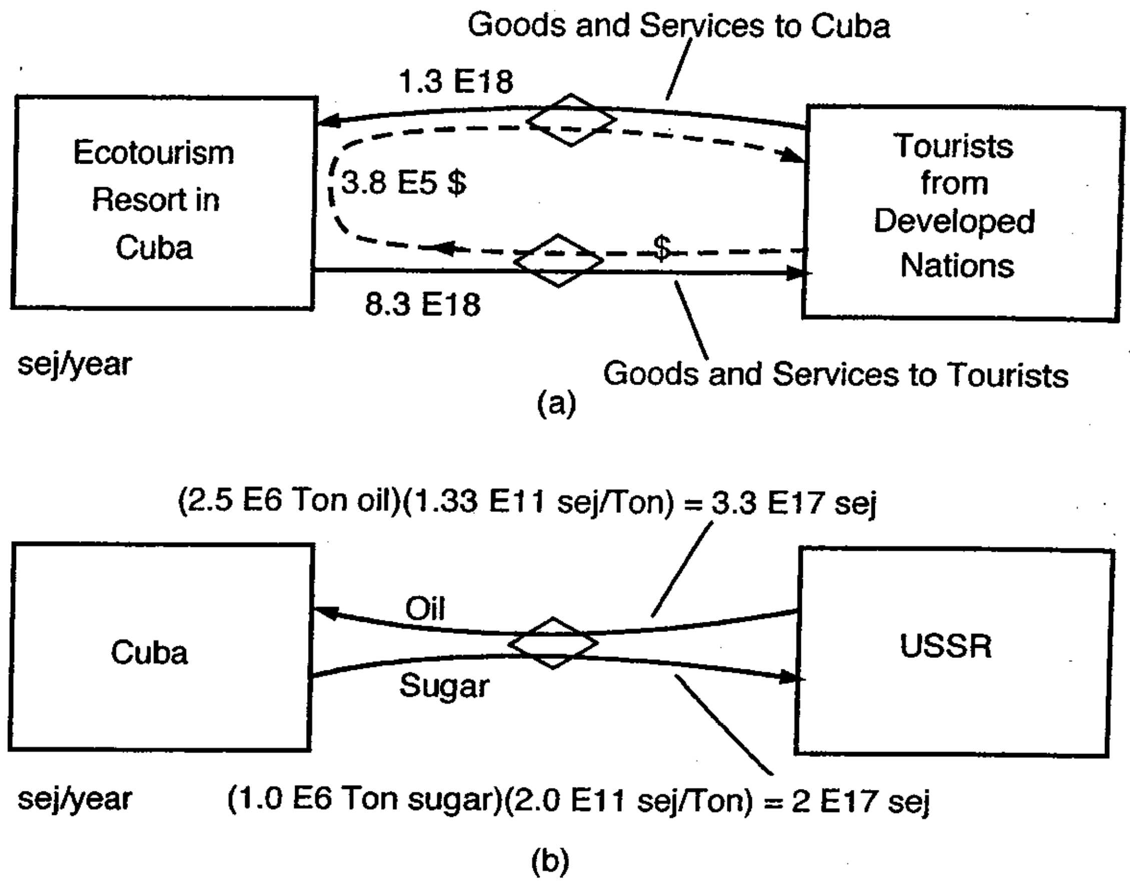


Figure 8. (a) Overview diagram illustrating possible USA trade advantage when tourists spend money in Cuba. The trade advantage is calculated using 1989 data and assuming that all tourist dollars are used to purchase goods and services from the USA; (b) Emergy trade advantage USSR oil for sugar. Emergy trade balance USSR 3.3/2. Source: Cuban trade conference, University of Florida, April, 1995. J. McLachlan-Karr, 1995.

Table 7. National Activity and Emergy/Money Ratio

Nation	Emergy use E20 sej/yr	Gross National Product E9 $/yr	Emergy/$ E12 sej/J
Liberia	465	1.34	34.5
Dominica	7	0.075	14.9
Ecuador	964	11.1	8.7
China	71,900	376	8.7
Brazil	17,820	214	8.4
India	6,750	106	6.4
Australia	8.850	139	6.4
Poland	3,305	54.9	6.0
World	202,400	5,000	4.0
Cuba,1989	1150	32.5	3.5
Soviet Union	43,150	1,300	3.4
New Zealand	791	26	3.0
U.S.A.	66,400	2,600	2.6
West Germany	17,500	715	2.5
Spain	2,090	139	1.6
Japan	15,300	715	1.5
Switzerland	733	102	0.7

Source: Odum, H.T., Environmental Accounting, 1994.

operation be returned for area maintenance and scientific study as well as support for local communities.

Although Cuban regulations concerning ecotourism developments in ecologically sensitive areas are still being developed, the ecotourism analysis approach is compatible with the draft regulations for ecotourism development.

Identification of Beneficial Environmental Impacts from Ecotourism in Valle de Viñales

The Valle de Viñales is unquestionably one of the most important areas in Cuba for international tourism.[21] The Valley is about a 30 minute drive from Pinar del Rio (20 km), which is about 250 km from the Jose Marti International Airport near Havana. The airport at Pinar del Rio has charter flights to Havana, Vadadero and Cayo Coco. There are several conventional hotel developments in the south of the Valley overlooking the town of Viñales. The largest hotel, Los Jazmines, dates from the 1930s. another major tourist center is the Model la Ermita. The main town and the settlement of Manuel Rodrigues in the north has some tourist accommodations.

Most of the current tourism activity in Viñales is conventional. Although the ecotourist and conventional tourist may travel to the same areas, their attitudes, interests, and activities may differ radically. Among the activities of interest to ecotourism in Viñales are wildlife observation (particularly bird watching), nature photography, geological exploration, climbing, spelunking, botanical studies, nature hiking and cultural activities, and research.

The base of the Valley (elevation 100-160 m) is used for agriculture, which is the largest land use within the boundaries of the 84 square km Viñales tourism study area (inset in Figure 1). The principal crops are vegetables, tobacco and sugar. In the western zone there are some citrus groves, tropical fruit and tobacco. To the north are, maize, beans, tobacco and rice. Land ownership is by state and private landholders. Except for a few isolated examples, the riparian areas have been cleared of trees. The mogotes (haystack hills) themselves make up about 30% of the study area. Planted pine plantations are found to the southeast. Table 8 shows the land use of the study area in Valle de Viñales.

Cuban population has decreased the land area per individual from approximately 6 hectares in 1903 to about 1 hectare in 1989 (Figure 9).

Table 8. Land Use of Study Area in Valle de Viñales

Note	Land Use	Area km^2	Perimeter
1	Agriculture	42.6	235.9
2	Forest	28.0	180.6
3	Lake	0.12	4.0
4	Plantation	9.9	51.9
5	Urban	3.2	19.9
Total		83.8	

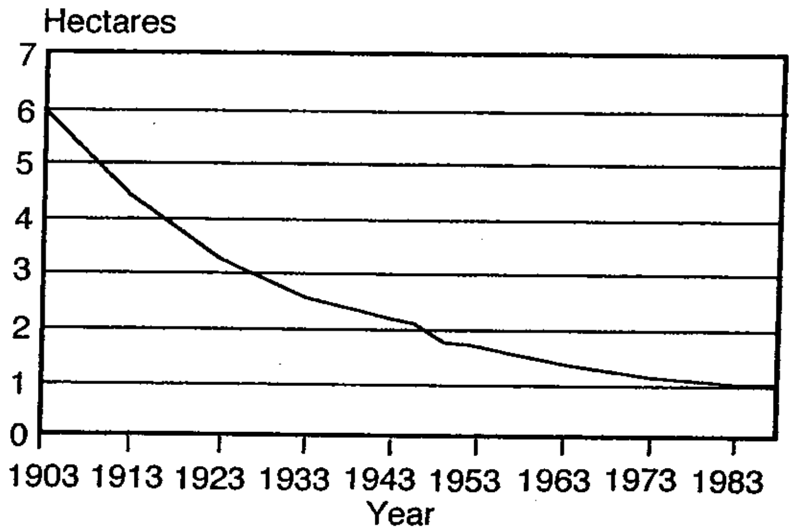


Figure 9. Land area per inhabitant 1903-1988. Source: ACC CEDISAC, Banco de Datos, 1991.

If the price of agricultural products (p1) exceeds that of ecotourism per unit area (p2), the money flows will convert more land to agricultural production. A decrease in price (p1) or the area becoming very degraded causes a decline in short term extraction and increase in areas of forest regrowth. This is typical of shifting agriculture in underdeveloped countries that lack fuels and imported fertilizers to maintain productivity.

Biodiversity

Viñales has the highest level of endemism in western Cuba with more than 200 species. Included among these is *Microcycas colocoma*, declared a natural national monument of Cuba. In the high areas of the Pizarras are found pine forests (both *Pinus caribaea* and *P. tropicalis*) together with *Quercus aleoides* (var. *virginiana*) and other species.[22]

The word biodiversity has been used in study of systems to refer to various aspects of the numbers and kinds of units and their properties examined with various functions and ways of studying distributions. Since diversity requires flows of energy and is a stored manifestation of previous energy flow (evolution), indices of diversity can be used as an indicator of the state of a system in the balance between energy flows that develop diversity and those negative actions that may decrease diversity.[23] Often high diversity, such as that found in the Valley, is the result of large flows of energy relative to negative actions. Time is required to develop diversity starting from low diversity states.

Figure 6 is a model of diversity as a function of support energy.[24] Because the requirement to support biodiversity may increase with square of the number of kinds, there is a characteristic curve of biodiversity with area (Figure 6b). Figure 6b is the simulation of the species/area model. For ecosystems in steady state, the addition of external populations and genetic material may stabilize the pattern of natural extinction as shown in the right of the model. For this to function, suitable seed sources are required. Agricultural development and infrastructure reduce the area needed to maintain and store genetic material and reduce access to areas of dispersal exchange to which species were evolved.

The high endemism and panoramic views of the Valley associated with mogotes are the most important tourism draws. Therefore, protection of the unique mogote vegetation should be the primary concern for an ecotourism initiative. One approach for protecting sufficient habitat for long term conservation purposes may be the establishment of buffer areas around the mogotes and associated with ecotourism activities. In this area, it may be necessary to limit human activities which impact the natural areas, and to allow migration of species between protected and unprotected areas.

Determination of Potential Negative Impacts of Ecotourism on the Valley

The local resources that may be impacted by tourism development include potable water, waste water and solid waste systems, electric systems and road and transportation systems. Environmental impacts from operation of the resort complex could occur as the result of overuse of the environment and water pollution from wastes and fuels.

With any development, the local environment may see declines in productivity, increase in pollutant loads, and conversion of wilderness areas. The local population may find themselves excluded from traditional hunting, grazing and recreational areas. Alternative development and management strategies and mitigation measures are discussed that, if implemented, may help ensure that negative impacts are minimized and greater economic benefits are realized.

For site selection of any new construction, careful consideration should be given to current infrastructure, access to areas attractive for ecotourism, local water supplies, views, and areas of ecological sensitivity. The siting of the main building and service area is of major importance. To balance the environmental loading of ecotourism it may be best to locate it near the urban area.

The architectural program of the center must include controlled access points and cabins, roads, self-guided nature trails, transportation options, interpretive centers, signs, and observation points. Living quarters and facilities for area personnel and researchers should be included. The design of the structure should reflect the purpose and philosophy of the ecotourism development. The center should include an interpretation or research center, dining and staff areas and accommodations for nature tourists and researchers.

Accommodation for nature tourists must be modest but comfortable and clean. A low density type of development may function both to decrease environmental impact from waste, noise and also to provide greater privacy and wilderness experience for the guests. Greater draw will be obtained from the use of "eco-technologies" and design than greater comfort of traditional tourism. Savings in construction and operating costs may be realized by the use of local material and labor and energy-efficient technologies. Compared to current tourism operations in Viñales, a low energy ecotourism development should compete very favorably by reducing the high energy costs associated with conventional tourism, and add to the experience that an ecotourist seeks, the opportunity to commune with nature and participate in a learning experience.

To reduce the amount of physical damage and disturbance to animals in areas used for ecotourism and to maintain the wilderness experience for the visitors, it is necessary to determine a carrying capacity number. It may be necessary to restrict access by tourists to fragile areas and provide infrastructure for the viewing of ecologically sensitive areas such as nesting sites.

Identification and Mitigation of Adverse Environmental Impacts on Public Infrastructure and Economy

The relationship between natural systems and the outside economy was pointed out in Figure 3. As tourism connects the natural systems in Viñales with the world economy, more wealth flows out of the region to repay loans, as profit, and to pay for goods and services. The main production function of the hotel provides services for visitors. To provide resources for the ecotourism facility, resources are extracted from other systems in the Valley and elsewhere and sold to the tourist facility (Figure 8a). The dashed lines shown in the diagram are the money flows from tourists used to pay for goods and services. Money that is spent on goods and services (G&S) outside the region flows out.

If the development is scaled to that of the regional economy, more wealth accrues in the local population and incentives to support nature conservation increase. If the intensity of a proposed development is much greater than that of the surrounding area, the development has greater capacity for disruption of the surrounding ecology, economy and social structure. As has occurred in other ecotourism destinations, if anticipated benefits to the local population do not result, support for the initiative is lost. Larger-scale development can be integrated into the local economy and environment if there is sufficient regional area to balance its effect. If more laborers, material and visitors are planned, then the area of natural undeveloped environment for its support must also increase.

In this analysis, Emergy is used as a measure of the intensity of the development by comparing the ratio of purchased Emergy to local renewable Emergy. The primary assumption is that this ratio is, in itself, a measure of the intensity of the local economy based on how the environmental and cultural systems are adapted to the level of economic activity present. This is complicated when the local economy is in a state of flux to which neither the ecological nor cultural systems have fully adapted, as may be the situation in Viñales.

The simplified diagram in Figure 5 shows the main driving energies and internal processes of an ecotourist resort facility in Viñales. The resort is shown as being driven by two main sources of outside Emergy: 1. Free Renewable Emergy, and 2. Purchased Emergy. Inflowing renewable Emergies combine and interact to drive the productive processes in ecological systems. Tourism is shown drawing on resources from the local economy and importing resources from outside. Purchased inputs from outside develop systems of extraction and consumption internally, which interact with indigenous environmental resources to provide an appropriate image for international ecotourism. Evaluation of the Emergy trade advantage calculated for the U.S.A. with Cuba in an ecotourism development of this size is about 6 to 1 in 1989 figures (see Figure 8a for trade advantage in exchange of Emergy).

An environmental loading ratio for the ecotourism development was calculated using data from Table 9 (calculations for Cuba are in Appendix B).

Table 10 shows comparative Emergy indices for a tourist resort and Cuba for calculation of support area.

The environmental loading ratio for the resort is much higher than for Cuba in general because of the concentration on imports (fuel, electricity and services) in a small area. The support area calculated for an average sized ecotourism resort with 15 rooms is about 20 km^2. There are numerous ways that the resort and support area might be organized spatially and yet maintain a balanced environmental loading (Figure 11, support area diagram). Although the resort area and support area may not be the same, restrictions should be applied to the support area to prevent further development. The best approach may be to use the support area as a buffer zone between isolated mogotes.

The development should be close to the urban center of Viñales. In this way, the eco-resort is integrated into the regional economy and can

Table 9. Emergy Evaluation of Annual Inputs for a Viñales Ecotourism Center

Notes	Item and Units	Inputs	Emergy/unit sej/unit	Solar Emergy E14 sej/yr
On Site Environmental Sources				
1	Sunlight, J	1.0 E13	1.00	0.1
2	Rain, chemical, J	1.2 E11	1.54 E4	18.4
3	Rain geopotential, J	3.9 E10	8.89 E3	3.5
4	Wind, kinetic, J	7.4 E10	6.23 E2	0.5
5	Potable water, J	4.94 E9	2.36 E4	1.2
On site environmental inputs		--	--	23.7
Purchased & Cultural Inputs				
6	Wood, J	2.77 E9	1.0 E4	0.3
7	Concrete, g	3.0 E7	2.4 E9	720.0
8	Steel, g	8.33 E4	1.4 E9	1.2
9	Furnishings, J	4.46 E9	4.0 E6	178.4
10	Construct Services, $	1.04 E4	1.6 E12	166.4
11	Fuel, J	2.87 E12	5.0 E5	14,350.0
12	Electricity, J	3.6 E13	1.7 E5	61,200.0
13	Food, J	6.88 E10	1.0 E6	688.0
14	Liquor, J	1.54 E10	6.0 E4	9.2
15	Services, Cuba, $	2 E4	3.4 E12	680.0
16	Services, World, $	2 E4	3.8 E12	760.0
Purchased inputs		--	--	79,450.0
Tourist Interactions				
17	Tourists input, J*	7.6 E10	1.0 E8	76,000.0
18	Tourist input, $	$2.2 E6	1.6 E12	35,200.0
Tourist input		--	--	111,200.0
19	Landscape Attraction, m2	7.85 E7	4.6 E11	361,100.0

Based on a dispersed 12 Bungalow development on 20,000 m^2 land area with potential of 5,840 person days/year

* Personal participation based on 7300 person-days/yr

See footnotes in Appendix B

Table 10. Comparison of Emergy Indices of Eco-Resort and Cuba

Index	Cuba	Eco-Resort
Total Emergy use (E18 sej/yr)	115500	21.5
Percent Renewable	38%	2%
Empower density (E11 sej/m^2/yr)	10.5	433
EMergy per capita (E15 sej/person/yr)	11	865
Investment Ratio		535
Environmental Loading Ratio	1.1	551
Support Area Required	---	~20 km^2

make better use of available services. This causes less disruption to the environment and economy--people are provided employment where they live instead of being displaced by a high intensity center in which they cannot participate except as displaced cheap labor.

Ecological engineering approaches can be used in the construction and planning of facilities to reduce dependence on local and imported fuels. Such potential designs include solar energy for water heating, constructed wetlands for waste water disposal, use of rainwater, recycling of garbage, natural cross-ventilation instead of air-conditioning, self-sufficiency in food generation, the application to locally available building materials and native technologies and the blending of architectural design with natural or planted vegetation. Buildings should not overpower or compete with the natural landscapes and vegetation, but should blend with them to create an "away from it all" experience.

The use of wetlands for waste water treatment and recycle is increasing worldwide as a low cost way to dispose of waste water. This ecological engineering approach may be particularly suited to use in Cuba for the following reasons[25]: 1. Low cost of construction and operation. 2. Low energy consumption of fossil fuels. 3. Operation of the unit does not require highly trained personnel and parts need not be imported. 4. The systems are flexible and easily scaled to a variety of treatment requirements and loading rates. A constructed wetland system would also enhance wildlife values, help to remove sediments and colloidal materials, and at the same time contribute organic matter to the newly established landscaping designed to shade the center, enhance the wilderness appeal and to attract wildlife.

Development of an ecotourism center using local construction methods will result in benefits in both the construction and operational phases of the resort to the local economy, especially if the local population is given preferential access to employment. to avoid displacement of workers, retraining of construction workers should begin as the resort nears completion so that they may make the transition to the work force needed for hotel operation and maintenance. Once the resort is in operation, local labor can be employed in repairs or expansion of the facilities should it be required.

Several steps can be taken to incorporate the local economy in the development of an ecotourism development: 1. Train and hire local people before going outside the area for workers. 2. Work with the local community leaders to present the benefits of the development to the local community. 3. Use local Cuban technologies and expertise to develop a center that may be used as a model for other areas in Cuba.

DISCUSSION

Cuban authorities have indicated that sustainability is a key factor when analyzing potential impacts of proposed natural resource development projects. However, sustainability is an elusive concept. It may be argued that a sustainable development is one that can be supported by the flows of renewable energy from a region. But if this region does not use imported goods and services from outside to amplify a region's environmental basis it does not give good economic return and thus does not attract investment. Economic developments that do not provide for feedbacks eventually drain the environmental assets that sustain them.

The modeling approach and diagrams used in this study illustrate the importance of scale in the development of ecotourism in Cuba. By scaling the development to that of the regional economy, the resort is able to be supported by the region. If the development exceeds the carrying capacity of the local economy the resort will be dependent on the purchases of goods and services from outside the economy. The resulting development exports national wealth through debt and purchases of goods and services. Because of the inequalities in Emergy/unit of currency (more Emergy in developing countries than developed) the developing economy exports raw materials and imports finished goods of lower Emergy value per currency unit. Emergy analysis as a measure of value offers a realistic perspective to international tourism and may help explain why many tourism developments in many developing nations have not provided the local economy or host country with the benefits anticipated.

What is often overlooked in tourism development is the environmental support required and resources consumed to provide the goods and services for an expanding population of visitors. With tourism, many of these resources are luxury items and high energy services used by tourists who consume more than the local population. These resources are then not available for the local population to use. Ecotourism development using ecological engineering techniques that use local renewable energy may be less dependent on imported goods and services.

Some economic data for Cuba may be subject to double counting because of Cuba's accounting methods.[26] Not included in the calculations are expenditures for overseas military operations up to 1989. Because decreased imports of fuels and fertilizer brings about a disproportionate reduction in productivity when compared to their monetary value because of a high Emergy/dollar ratio, current Emergy indices for Cuba will be lower than those for 1989.

Ecotourism

For any tourist resort, there is an image maintained by the combined interaction of the environment, urban structure, culture and the development itself. Image is the information that draws visitors to the region. Every care should be taken when planning an ecotourism development to preserve the region's environmental basis, as it is the most important component of a successful venture. The initial success of ecotourism in Viñales may attract further economic development that may exceed the carrying capacity of the area as has occurred in many other developing countries. When the carrying capacity is exceeded the area may become degraded, resulting in a loss of business.

The support area calculated for a tourism development in Viñales reflects the area necessary to reduce the environmental loading to that which is characteristic of the Cuban economy. In essence, the support area provides the carrying capacity of the environment to absorb the resort itself and possibly more developments of a like kind. There are numerous ways that resorts and support areas might be organized spatially and yet maintain a balanced environmental loading ratio. Since in Viñales a major basis for ecotourism is the protection of natural vegetation, the resort should be placed within or adjacent to the mogote vegetation.

If the size and/or intensity of the development changes, the support region should also change, since its determination is based on these factors. In this way, the determination of carrying capacity using the environmental loading ratio achieves a dynamic balance that is affected not only by the environment's ability to absorb the development, but by the size and intensity of the development itself. Carrying capacity on the same area may be increased by increased feedback to provide infrastructure and management for the resort area.

Biodiversity

Biodiversity is lost through forest fragmentation and disruption of previous energy flows. A smaller system may lose species due to gene loss from system instability and emigration. Numerous species usually require smaller areas than rarer species. Further development and population increase may cause further loss of biodiversity in Valle de Viñales.

In any forest system, however, there are large and long-interval phenomena that disturb ecosystems with infrequent destructive pulses. Gaps of various sizes are normal events and reflect the many levels of hierarchical organization of a complex forest system.[27] The normal pattern of gap generation is large numbers of small gaps caused by small perturbations such as tree falls, fewer intermediate sized gaps due to storms, landslides and biological outbreaks, and a small number of infrequent large gaps due to hurricanes, fires, or clearing.

When conditions change, ecosystems reorganize through succession. When ecosystems come under stress because of detrimental factors such as clearing and burning or landslides, components and functions are lost, and the ecosystem changes and new patterns emerge. Stress may be defined as some factor for which species are not adapted. Stress, therefore, is only temporary because self organization can usually provide a new system that derives some utility from the former stress.

Among the reasons why more energy is required for maintaining variety than for maintaining units of one type, is the energy or organization required to prevent competitive exclusion. Without organization, units of different type tend to exclude each other and become simple (competition). When examined on an energy basis, however, the organization that characterizes the various functions of the system originating from its energy budget renders many different phenomena complementary. Whereas diversity is sometimes generated by stability that allows energy to be used for organization, there are other situations where diversity has been related to fluctuating conditions. Diversity is then due to no one condition remaining long enough for a small number of species to prevail in competition. These two concepts for developing diversity may not be conflicting and may both be operating in Viñales, resulting in the high levels of endemism found there. For example, if the area of stress is limited, for example a rock slide on a mogote, the larger realm which includes this area may have its diversity increased, as appropriate seeding from the larger system will provide individuals appropriate for that stage of succession. The same concept can be viewed as a hierarchical means by which each system can maximize power by contributing to the next-larger system, where the larger area permits some special kinds of high quality service to be developed to feed back. Both of the mentioned mechanisms provide diversity adapted to appropriate energy flows, and in the process, maximize the ability to process energy available to the system (maximum power principle).[28]

In the longer term (perhaps 100 years), the areas of complex forest and biodiversity contained within it are required to supply diverse genetic material to maximize forest succession and restore the supply of forest products, soil, and clean water. If too much area is cleared and the distance between disturbance and seed storages is great, arrested succession may result and greatly delay the supply of valuable forest services to the economy. As shown in this model, the rate of reseeding depends on the close proximity of a complex forest with the high diversity of plants and their animal means of seeding and transport. Ecotourism through natural area preservation may assist in retaining this capability. Without the nearby availability of seeding, regrowth may only be through wind blown seeds, and arrested succession may occur with a long delay in restoring economic potentials. This overview shows why retaining diversity areas, with gene pools of complex forest, is essential to maximize long term economic yields.

SUMMARY

Ecotourism has increased over the past decade, driven by the desire of tourists to visit unspoiled environments to observe nature and experience different cultures. Cuba has potential to be a major destination for ecotourism as it is the last major unspoiled island in the Western Hemisphere. Valle de Viñales has the potential to develop a sustainable scientific and nature based tourism industry if the appropriate infrastructure is provided.

In this research, a systems analysis of Valle de Vinales' environmental and economic system is undertaken using a common measure (Emergy). A simulated model of this system demonstrates how ecotourism development should be scaled to the regional economy and resource base so as not to overload the area's capacity to provide food, materials and assimilate waste. By using renewable energy, it is less dependent on outside capital and material flows to maintain it. For nature tourism this is vitally important; too high a level of economic

development will eventually impact the environmental base upon which nature tourism depends.

Although tourism developments in other parts of the Caribbean and Central America have not always provided the anticipated benefits to the host country, large projects are still often favored because of the greater capital inflow, in spite of their potential to disorder the environment and disrupt the local economic system. A systems analysis indicates that smaller projects scaled to the local economy and social organization may be better integrated into the economy and may be more beneficial to the host country. If local capital, materials, and renewable resources are used, more money will remain in the local economy and the development can compete very favorably with traditional tourism developments.

Ecotourism can assist Cuba in generating foreign capital that would in turn be used to purchase oil and fuel products. As these imports have the highest Emergy/dollar ratio, they contribute most to balancing the Emergy import/export ratio. This is essential if Cuba is to lower its Emergy/dollar ratio and increase its economic vitality.

Ecotourism development that is planned on a scale appropriate for the region will be more profitable, so it will provide greater economic incentives to protect natural areas. The greatest long term contribution ecotourism may have in Viñales and Cuba is the protection of unique and priceless biodiversity.

Acknowledgments

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Appendix A
Footnotes for Table 3
Emergy Evaluation of Annual Inputs to Cuba in 1989

Data from Anuario Estadistico de Cuba, 1989
Abbreviations: MT = Thousand tons, J = joules, kcal = kilocalories

1 Solar energy
Continental shelf area = 1.11 E11 m^2 (estimate)
Land area = 1.11 E11 m^2
Insolation = 1.62 kcal/cm^2/d (calculated from ICGC, 1978)
Albedo = 0.30
Energy J = (area land + shelf)(ave. inslation)(1-albedo)
= (2.22 E11 m^2)(cal/cm^2/yr)(E4 cm^2/m^2)(1-0.10)(4186 J/kcal)
= 3.84 E21 J

2 Rain, chemical potential energy
Continental shelf area = 2.37 E10 m2 (estimate)
Land area = 2.37 E11 m^2
Rain (land) = 1.16 m/yr (AEC, 1989)
Rain (shelf) = 1.16 m/yr (estimate)
Evapotranspiration rate = 0.91 m/yr (assumed 8% evapotranspiration)
Energy (land)(J) = area (evapotranspiration)(rainfall)(Gibbs no.)
= 2.37 E10 m^2)(0.91 m)(1000 kg/m^2)(4.94 E3 J/kg)
= 1.07 E17 J
Energy (shelf)(J) = (area of shelf)(rainfall)(Gibbs no.)
= 2.37 E10 m^2)(1.16 m/yr)(4.94 E3 J/kg) = 1.3 E14
Total Energy = 1.07 E17 J

3 Rain, geopotential energy
Area = 2.4 E10 m^2
Rainfall = 1.16 m
Average elevation = 100 m (Rudolf, 1987)
Runoff rate = 0.20 m (1-evapotranspiration)
Energy (J) = (area)(% runoff)(rainfall)(ave. elevation)(gravity)
= 2.4 E10 m^2)(0.2 m)(1.16 m)(1000 kg/m^3)(100 m)(9.8 m/s^2)
= 5.46 E15 J

4 Wind energy
= 3.68 E10 kwh/yr (World energy data sheet, 1978)
= (100)(3.686 E6 J/kwh/yr)
= 1.33 E17 J

5 Wave energy
Energy (J) = 1.46 E11 kwh/yr (World energy data sheet, 1978)
= (1.46 E11 kwh/yr)(3.606 E6 J/kwh) = 5.26 E17 J/yr

6 Tidal energy
Continental shelf area = 1.11 E11 m^2 (estimate)
Ave. tide range = 0.65 (Tide Tables: Port of Spain, 1988)
Density = 1.03 E3 kg/m^3 (Odum, 1983))
Tides/yr = 7.20 E2 (Tide Tables, Port of Spain, 1988)
Energy (J) = (shelf)(0.5)(tides/yr)(mean tidal range)(density of seawater)(gravity)
= 1.11 E11 m2)(0.5)(7.2 E2/yr)(0.65 m2)(1.03 E3 kg/m3)(9.8 m/s^2)
= 1.70 E17 J

7 River geopotential
= 1.70 E4 m^3/sec (Brown, 1990)
Elevation change = 3.0 E2 m (Rudolph, 1987)
Energy (J) = (flow)(elevation change)(gravity)(sec/yr)(0.5 energy available to Cuba)
= (1.70 E4)(3.0 E2)(9.8 m^2)(1000 kg/m^2)(3.1 E7 s/yr)(0.5)
= 7.5 E17 (units?)

8 Earth cycle = (1.1 E11 m^2)(estimate heat flow/area 4 E6 J/m^2/yr (Odum et al., 1983)
= 4.4 E17 J/yr

Indigenous Renewable Energy

9 Hydroelectricity
Hydro. Prod. = 8.20 kwh/yr (AEC, 1989)
Efficiency = 8.0 E-01
Energy = (8.2 E3 MW)(eff.)(8760 hr/yr)(1000 kwh/MW)(860 Cal/kwh)(4187 J/Cal)
= 2.07 E16 J

10 Ag. Prod. (veg. oils, wheat, rice, tobacco, fruits) = 1.15 E6 T
Energy (J) = (1.15 E6 T)(1.0 E6 g/T)(3.5 Cal/g)(4186 J/Cal)(0.25 dry weight)
= 3.84 E16 + Sugar production (refined raw units 1989 = 7.9 E6 T)
Energy (J) = 7.9 E6 T)(1.0 E6 g/MT)(3.5 Cal/g)(4186 J/Cal)(0.25)
= 3.32 E16 (units?)

11 Livestock Production (bovine production, pigs, poultry)
Total production 3.16 E5 T
Energy (J) = (3.16 E5 T)(E6 g/T)(4 Cal/g)(4187 J/Cal)(40% dry weight)
= 2.12 E15 (units?)

12 Fisheries Production
Fish Catch = 1.80 E5 MT
Energy (J) = (E5 MT)(1 E6 g/MT)(4 Cal/g)(4186 J/Cal)(0.20 dry weight)
= 6.3 E14 (units?)

13 Fuelwood/Charcoal
Consumption = 5.74 E3 boed (source CIA, 1984)
(5.74 E3 boed)(42 gal/b)(3.81/g)(9800 kcal/l))(4186 J/kcal)
(365 d/yr)(0.6 dry weight)
= 8.23 E15 (units?)

14 Forest Extraction (source CIA, 1984)
Harvest = 3.26 E6 m^3/yr
Energy (J) = (3.36 E6 m^3)(0.5 E6 g/m^3)(3.6 Cal/g)(4186 J)(0.6)
= 1.48 E16 J/yr

<u>Nonrenewable Resource Use from Within Cuba</u>

15 Natural Gas (CIA, 1984)
Consumption = 9.13 E4 bbl/yr
Energy (J) = (9.13 E4 bbl/yr)(6.28 E9 J/bbl)
= 5.73 E14 (units?)

16 Oil (1989 extraction of crude 7.18 E5 T)(1988 imports crude 8.5 E6 T). Most of the imported oil is refined and exported.
Consumption = 1.09 E4 bbl/d
Energy (J) = 1.09 E4 boed)(42 gal/bo)(3.6 l/gal)(9800 Cal/l)
= 2.60 E16 (units?)

17 Sand
Consumption = 4.61 E6 MT
Energy (J) = 4.61 E6 MT)(1 E3 kg/MT)(2500 Cal/kg)(4186 J/Cal)
= 4.83 E16 (units?)

18 Stone
Consumption 4.61 E6 = (3.84 E6 MT)(1 E6 g/MT)
= 8.84 E12 g

19 Nickel
Production = 3.76 E4 MT = (3.76 E4 MT)(1 E6 g/MT)
= 3.76 E10 g

20 Copper
Consumption = 2.60 E3 MT = (2.60 E3 MT)(1 E6 g/MT)
= 2.60 E9 g

21 Refractory Chrome
Consumption = 2.73 E3 = (2.73 E3 MT)(1 E6 g/MT)
= 2.73 E10 g

22 Topsoil
Soil Loss
Energy (J) = 6.86 MT/yr)(1 E6 g/MT)(0.07 g OM/g sed.)(3.6 Cal/g)
(4186 J/Cal)
= 7.24 E16 (units?)

Imports of Outside Energy Sources

23 Oil Products
Imports Energy (J) = 8.3 E6 tons)(1000 l/t)(9800 Cal/l)(4186 J/Cal)
= 3.4 E17 (units?)

24 Coal and Coke (1989)
Imports = 2.607 E5 t
Energy (J) = 2.607 E5 t)(1.0 E6 g/t)(9.80 Cal/g)(4186 J/Cal)
= 7.4 E15 J

25 Steel
Imports 1.6 E6 T
Energy (J) = 1.6 E6 T)(1 E3 g/T)
= 1.6 E9 (units?)

26 Fertilizers and Chemicals
Imports 1.37 E6 MT (nitrogen (3.5 E5)% N by atomic wt.
= 8.2 E-1 % NH_3 in Fert. = 1 E1
Potassium imports = 3.19 E5
Energy (J) = 3.5 E5 MT)(0.82)(0.1)(1 E6 g/MT)(2.17 E3 J/g) + (9.99 E5)
(1 E6 g/MT)(2.17 E3 J/g)
= 2.21 E14 (units?)
(+ Potassium (3.19 E5 MT)(1 E-1)(1 E6 g/MT)(2.17 E3 J/g)) = 2.9 E14

27 Foods
Imports = 3.14 E6 MT
Energy (J) = (3.14 E6 MT)(1 E6 g/MT)(15.1 E3 J/g
= 4.748 E16 (units?)

28 Wood, Paper, Textiles, Rubber, etc.
Imports = 6.93 E5 MT (AEC, 1989)
Energy (J) = (6.93 E5 MT)(1 E6 g/MT)(15 E3 J/g)
= 6.75 E14 (units?)

29 Manufactured Goods
Imports = 9.1 E8 $ (CIA, 1984)

30 Machinery, Transportation and Equipment
Imports = 2.1 E9 $ (CIA, 1984)

31 Foreign Aid
Dollar Value = 9.75 E9 $ (CIA, 1984)

32 Net Migration = 1.0 E4 (units? -- People?)

Exports of Energy, Materials and Services

33 Cash Crops (mainly tobacco, sugar and coffee)
9 E6 MT
Energy (J) = (9 E6 T)(1.0 E6 g/MT)(3.5 Cal/g)(4186 J/Cal)(0.25)
= 2.75 E16 (3948.5 MMP) equivalent
= 3.3 E16 (units?)

34 Fishery Production Exports
2.104 E4 MT (128.8 MMP)
Energy (J) = (2.104 E4 MT)(1 E6 g/MT)(4 Cal/g)(4187 J/Cal)(0.2 dry weight)
= 7.047 E13 (units?)

35 Mineral Exports
8.92 E4 MT = (8.92 E7 T)(1.0 E6 g/MT)
= 8.92 E13 g (497 MMP)

36 Tourism Services
Number of tourists 275,618. Ave. expenses on trip $1,000 (Business Tips on Cuba)
Amount = 2.75 E8 $

Appendix B
Footnotes for Table 9

Data for a Viñales Ecotourism Center Based on a Dispersed 12 Bungalow Development on 20,000 m^2 Land Area with Potential of 5,840 Person-days/year

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1 Solar energy (J)
Land area = 2.0 E4 m^2 (Ave. area for ecotourism development including park area)
Insolation = 1.62 E6 kcal/m^2/d (calculated from ICGC, 1978)
Albedo = 0.30
Energy J = (area)(insolation)(1-albedo)
= (2.0 E4 m^2)(1.62 E6 kcal/m^2/y)(1 - 0.30)(4186 J/kcal)
= 1.0 E13 J/yr

2 Rain, chemical potential energy (J)
Land area = 2.0 E4 m^2
Rain (land) = 1.67 m/yr (AEC, ave. La Palma weather station nearest Viñales, 1977-1989
Evapotranspiration rate = 1.33 m/yr (assumed 80% evapotranspiration)
Energy (laned)(J) = (area)(evapotranspiration)(rainfall)(Gibbs no.)
= (2.0 E4 m^2)(1.33 m/yr)(1000 kg/m^3)(4.94 E3 J/kg) = 1.2 E11 J/yr

3 Rain, geopotential energy (J)
Area = 2.0 E4 m^2
Rainfall = 1.67 m/yr
Ave. elevation = 600 m (AEC, 1989)
Runoff rate = 0.20 m (1-evapotranspiration)
Energy (J) = (area)(% runoff)(rainfall)(ave. elevation)(gravity)
= (2.0 E4 m^2)(0.2 m)(1.67 m)(1000 kg/m^3)(600 m)(9.8 m/s^2)
= 3.9 E10 J/yr

4 Wind energy (J)
= 3.68 + 10 kwh/y (World Energy data sheet, 1978)
= (2.0 E4)(3.686 E6 J/kwh/y)
= 7.4 E10 J/yr

5 Potable water (J) 1.0 E3 m^3/yr
(1.0 E3 m^3/yr)(1000 g/m^3)(4.94 E3 J/g)
= 4.94 E9 J/yr

Purchased inputs

6 Wood 1000 m^3 (estimated from other ecotourism resort data)
1000 m^3)(5.5 kg/m^2)(15.1 E6 J/kg)
= 8.31 E10 J/30 yr
= 2.77 E9 J/yr

7 Concrete 500 m^3 (estimated from other tourism data)
(500 m3)(1.81 E6 g/m^3) = 9.05 E7 g/30 yrs = 3.02 E7 g/yr

8 Steel 2.5 E3 kg (based on average steel/unit concrete
(2.5 E3)(1000 g/kg) = 2.5 E6 g/30 yrs
= 8.33 E4 g/yr

9 Furnishings
= (3.38 E6 g)(90% dry wt)(3500 cal/g)(4.186 J/cal)/10 years
= 4.46 E9 (J)

10 Services total cost of construction + furnishings = US 300,000 (1988)(estimate)
3 E5 $/30 = 1.0 E4 US $/yr

11 Fuel 70,000 liter/yr of gasoline
(7 E4 liter)(4.1 E7 J/liter)
= 2.87 E12 J/yr

12 Electricity 10,000,000 kwh per year
(10 E6 kwh)(3.6 E6 J/kwh)
= 3.6 E13

13 Food (2 kg/person (est.))(7.3 E3 people)
(25% dry weight)(4500 cal/g)(4.186 J/cal)
= 6.88 E10 J/yr

14 Liquor 7.3 E4 (1 liter/person est.)
(7.3 E3)(2.11 E7 J/liter)(10% alc.)
= 1.54 E10 J/yr

15 Services (Cuba)
$20,000 purchased from Cuba at 3.4 E12 sej/$ (1989)

16 Services (World) 20,000 purchases from world at 3.8 E12 sej/$

17 Tourists input with 7,300 person days per year,
(7300 person-days)(2500 Kcal/person-day)(4186 J/kcal = 7.6 E10 J/yr

18 Tourist monetary input:
(7300 person-dayss)($300 U.S./day) = 2.2 E6 $/yr. Outside money evaluated at 1.6 E12 sej/1989 U.S.$..

19 Attractions for Tourists estimated as the area of interaction including the panorama, mountains, field trip areas, vegetation, and climate.
Assume area with radius of 5 km = 7.85 E7 m2.
Annual emergy for the landscape = sum of rain used and Geol. Support
Geologic support estimated from the erosion rate 0.15 E3 g/m2/yr and a unit emergy, 1.3 E9 sej/g (Odum, 2000 Folio #2);
Geologic support: (0.15 E3 g/m2/yr)(1.3 E9 sej/g) = 1.95 E11 sej/m2/yr
Climate support as in note #3
= (1.33 m rain/yr)(1 E6 g/m^3)(2 E5 sej/g)= 2.66 E11 sej/m2/yr
Total emergy of landscape support: (1.95 + 2.66 = 4.61) E11 sej/m2/yr