AN EMERGY EVALUATION OF THE SEVEN YEARS' DEVELOPMENT OF QINGYANZHOU ECOLOGICAL EXPERIMENTAL STATION

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Abstract

An emergy (spelled with an "M") evaluation of Qingyanzhou ecological station was performed in order to study its progress during 7 years' development, using changes of emergy inputs and outputs. Emergy indices of Qingyanzhou were evaluated and compared with those from other countries. The comparison showed that Qingyanzhou is developing optimum use of its natural resources.

Key words: Emergy; Qingyanzhou; Comparative analysis

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1. Background of Establishing Qingyanzhou Experimental Station

China is a country with a huge population of 1.2 billion, yet, it is still increasing with an annual growth rate of 1.5 million, and by 2040, the population of China will reach approximately 1.7 billion even under the most strict family planning. In China, the arable land only accounts for 11% of its total land and the water resources per capita is only 1/4 of the global average. At present, the economic development of the country is gaining momentum with an annual growth rate of about 10%, therefore, reasonable utilization of natural resources has become very urgent for stable economic development in China.

Meanwhile, China is confronted with severe environmental problems, such as expanding areas of acid precipitation. Desertification increased from 1560 km2/Yr in 1960s to 2100 km2/Yr in 1980s. Because of soil erosion, 5 billion T of soil will be lost each year resulting in an immense loss of soil fertility equivalent to the total annual input of fertilizers. The arable land, although very limited, is reducing at an annual rate of several million Mu (15 Mu = 1ha).

Facing those severe challenges, the Chinese government is taking countermeasures to increase the potential of natural resources. The ecological experiment on the exploitation of red earth hilly mountains is an example.

Red earth hills are widely distributed in southern China, with the total area about 4.6 billion ha. In southern mountain areas of Jianxi Province, the earth loss and soil erosion areas reached more than 1.1 million ha. That is more than 35% of its total area. About 53.4 million ton/Yr of silt and sands were washed away. According to a report of People's Daily (overseas edition, Feb. 8, 1996), in Jiangxi Province, there are about 0.22 billion T earth loss and soil erosion. The sailing distances in the river of Jiangxi Province decreased from 11,000 kilometers in the 1960s to 5,000 kilometers now. Meanwhile the capacity of the large fresh water lakes was reduced and couldn't absorb floods. As a result there were serious flood disasters in the surrounding areas.

Since it is very important to make rational use of the resources for Chinese sustainable economic development, the Chinese Academy of Science established an ecological station in Qingyanzhou village, Taihe County, Jiangxi Province of Southern China. Its main objectives are to find suitable ways to explore red earth hilly resources.

2. Introduction to Qingyanzhou Ecological Experimental Station

Qingyanzhou, located at north latitude N26^{o}44'48", and east longitude E115^{o}04'13", is a subtropical red earth hilly area. The average TM 18.6^{o}C,>=10^{o}C TM accumulation is 5921^{o}C annually. There are 290 frostless days in one year. The average rainfall is 1361 mm/Yr, the elevation is between 100m and 200m, the slopes of hilly mountains are 10^{o}-30^{o}. Because of long-term cutting and destroying of the original forest by peasants, the original vegetation disappeared. Grass, bushes and shrubs are the remaining vegetation.

The experimental area of Qingyanzhou Experimental Station is 204.16 ha. Before 1982 it had been an underdeveloped, landlocked poor village, with only 7 families and 31 persons. There was 6.3 ha farming land per capita, including 0.68 ha arable land, and 5.54 ha uncultivated land per capita. There was much more land per person compared with the average level of China. Therefore there are great potentialities to explore and develop. In 1982, the total GEP for this village was just $1040, with almost 80% from crop production.

Through 7 years' exploration and development, great changes occurred. The forest coverage increased from 0.43% in 1982 to 68.14% in 1989; the rate of land use increased from 10.9% to 91.5%; index of multi-cropping crops increased from 124% to 190%, the grain yield increased from 1718 kg/ha to 6120 kg/ha, and the earth soil loss decreased from 0.48 ton/ha to 0.103 ton/ha. Water areas increased from 4.13 ha to 8.93 ha, and the storage of water increased from 5.72 E+4 m^3 to 1.5 E+5 m^3. Fishery and animal husbandry had a great development too. The basic eco-agriculture production system was established in 1989, when there were 56 farmer families and 269 persons in Qingyanzhou. The total GNP reached $81,429 in 1989 (Figure 1).

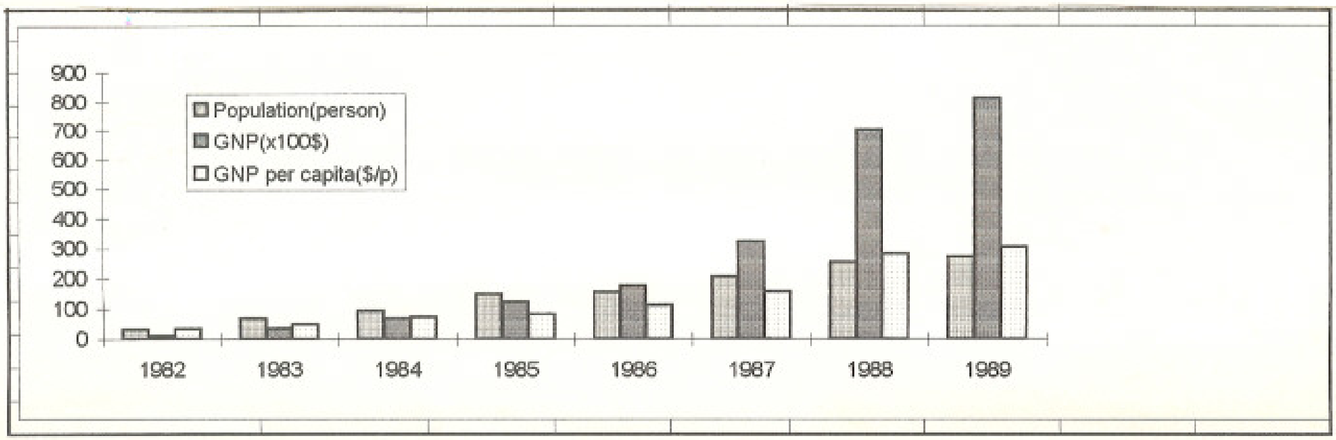


Figure 1. The main changes of Qingyanzhou eco-economic system.

In order to overview the 7 years' development of Qingyanzhou ecological experimental station, comparative analysis follows using systems diagrams and emergy evaluations.

3. Concepts and Methods

3.1 Basic Concepts and Principles

A new concept, emergy, spelled with an "m," is used is used in this paper as a common measures for comparing the worth of different inputs and products of systems. The emergy is defined as the energy of one type directly and indirectly used in the production of a resource, product, or service. Solar emergy is total solar energy required to generate (create) a product, whose units are solar emjoules (abbreviated sej), which is expressed in units of one form of energy. Because emergy measures what went into a product, it is also suggested that it measures the real wealth that product contributes to the economy if its use is to justify its production. The amount of real wealth that circulating money buys is indicated by the emergy/money ratios because more wealth goes directly from the environment to human consumers without money being paid to someone for the resource.

Transformity, another important concept, is the emergy per unit energy. Related measures are emergy per mass (sej/g) and emergy per money (sej/$). The solar transformity of an object or resource is the equivalent solar energy that would be required to generate (create) a unit of that object or resource efficiently. Its units are solar emjoules per joules. A list of solar transformities for many types of energy and commodities were derived from previous studies (Odum, 1987, 1988, 1991, 1993).

The emergy evaluation method and its use to improve public policy come from thermodynamics and systems ecology and are extended to ecological-economic systems. The emergy analysis of systems is based on both physical and economic considerations, which allow us to evaluate the environmental-economic ability and the national or regional economic systems. The emergy analysis of systems is based on physical and economic considerations which allow us to evaluate the environmental-economic activity. Decisions on the use of environmental resources and the economic development can't be made correctly using money because money is only paid for human services; but an emergy comparison can be prepared for choosing among environmental alternatives. The management with largest emergy contribution may be chosen to maximize the economy. Emergy evaluations and designs based on scientific principles should provide a direct way to achieve public wealth and sustainable economic patterns.

3.2 Methods

The first step is to construct systems diagrams to show the changes of diagrams of Qingyanzhou eco-economic systems in 1982 and 1989.

The second step is to evaluate the resources identified which contribute to the combined ecological-economic system under study.

The third step involves calculating several indices that relate resource flows and monetary exchange in order to identify the support base, economic vitality and carrying capacity.

Finally, a discussion considers the progress and related policy options recommended for sustainable development and resource use.

4. Results and Discussion

4.1 The Emergy Basis of Resources and Development of Qingyanzhou

Energy system diagrams of Qingyanzhou ecological station are given in Figures 2 and 3, which illustrate the status quo of 1982 and 1989, respectively.

The emergy evaluation of the major environmental and economic flows and storage are presented in Tables 1-3.

Figures 2 and 3 represent aggregated systems diagrams of main emergy flows and processes identified at Qingyanzhou station in 1982 and 1989.

The indigenous resources emergy basis for Qingyanzhou's economy includes main renewable environmental sources (sunlight, rain) as well as the non-renewable storage of soil (Table 1).

According to Table 1, the total macrovalue of renewable sources increase from $55,177/Yr in 1982 to $55,492/Yr in 1989, net increase is just $315, and the use of indigenous nonrenewable resources decrease from 1.77 E17 sej/Yr in 1982 to 3.59 E16 sej/yr, just 20.28% of that in 1982, but the products of indigenous renewable production have a great increase from 1.5 E17 sej/Yr to 1.39 E18 sej/Yr, about 9.3 times that in 1982. The macrovalue of these products increased from $17,582 to $160,442, more than 9 times that in 1982. Meanwhile, the exports have a great increase from 4.26 E16 sej/yr to 4.18 E17 sej/yr, 9.8 times those in 1982. Though the population increased from 31 persons to 269 persons, the GEP per capita still increased step by step from $34/person to $303/person, almost 9 times that in 1982 (Figure 1).

4.2 Emergy Flows and Economy.

An aggregated overview of the flows that drove Qingyanzhou's development are presented in Table 4 and Figures 4 and 5, which further summarize the nature and scale of these flows and processes in 1982 and 1989, separately.

The emergy/money ratios for Qingyanzhou were 3.39 E14 sej/$ in 1982 and 8.86 E12 sej/$ in 1989, both higher than the average emergy/$ ratio of China (8.67 E12 sej/$). These ratios show that Qingyanzhou is still

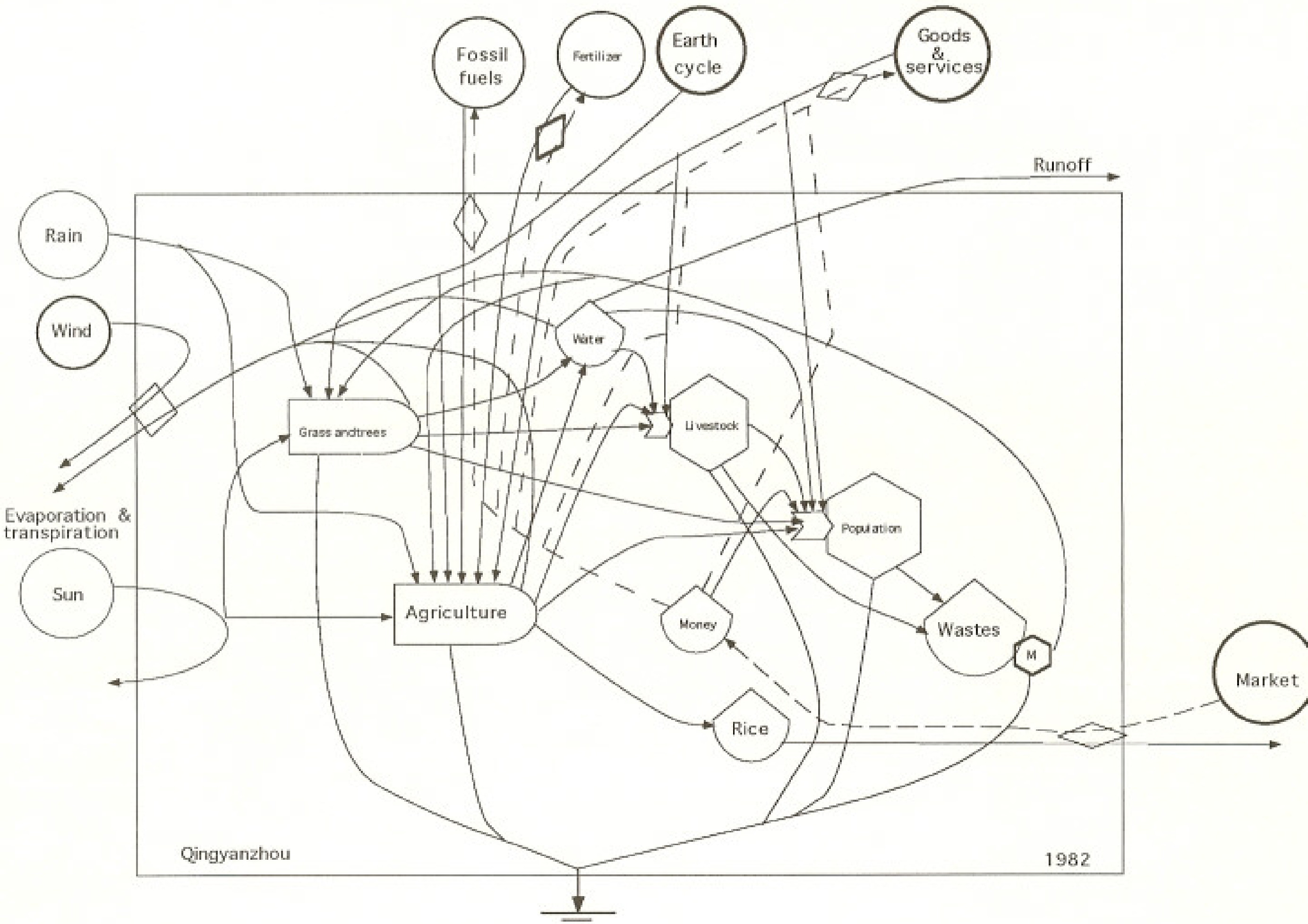


Fig.2 System diagram of Qingyanzhou ecological economic system in 1982

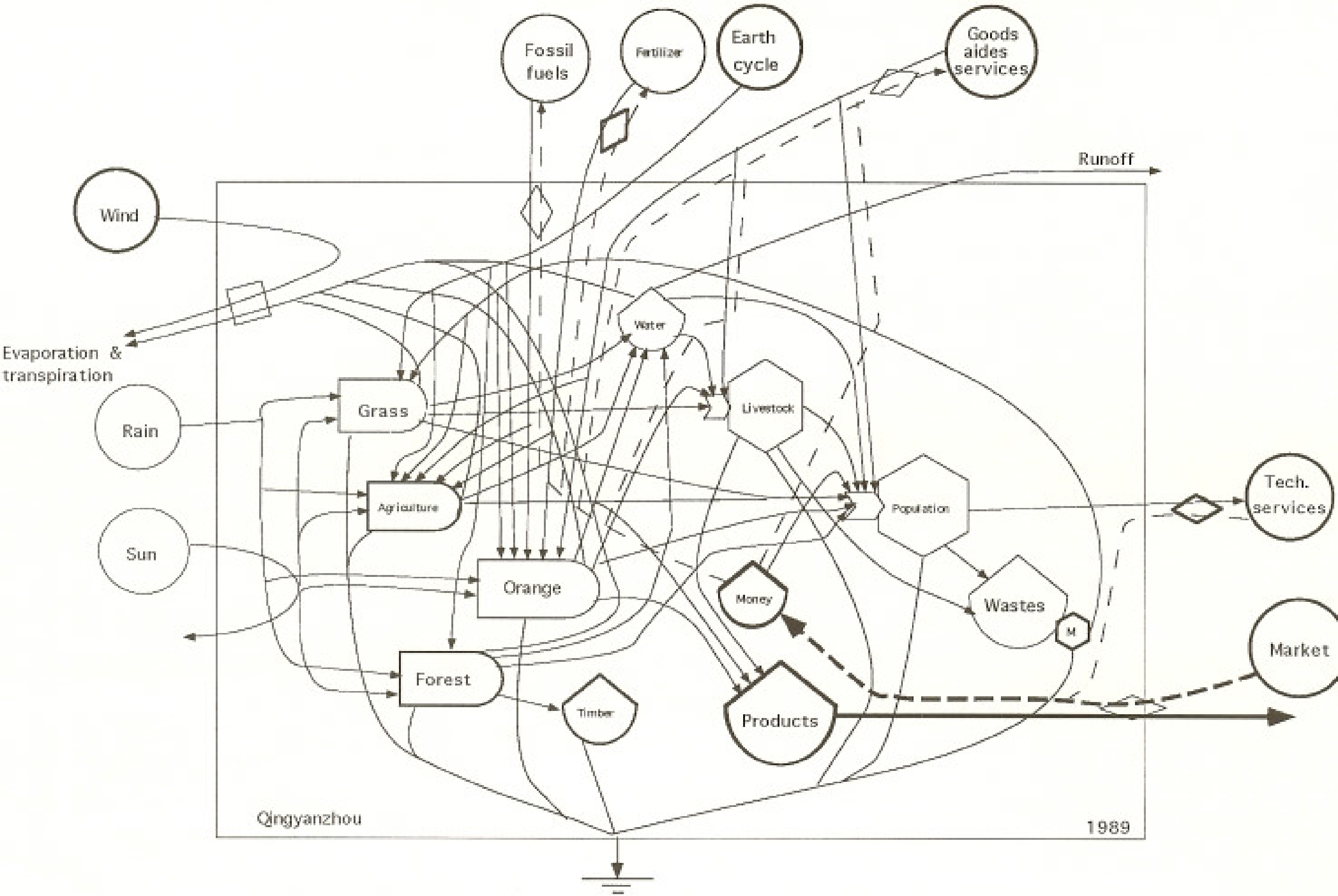


Fig.3 System diagram of Qingyanzhou ecological economic system in 1989

Table 1 Emergy evaluation of environmental resources basis of Qingyanzhou ecological station [a]

Note Item	Annual flows(raw unit/yr)		Emergy/unit	Solar emergy (sej/yr)		Macro value (Em$)[c]	
Year	1982	1989	sej/unit [b]	1982	1989	1982	1989
Renewable sources				4.78E+17	4.81E+17	55177	55492
1.solar insolation	7.33E+15J	7.33E+15J	1	7.33E+15	7.33E+15	846	846
2.wind, kinetic	3.54E+13J	3.54E+13J	1500	5.32E+16	5.32E+16	6131	6131
3.rain,chemical	1.37E+13J	1.37E+13J	18200	2.49E+17	2.49E+17	28759	28759
4.rain,geopotential	7.62E+11J	3.43E+11J	10500	8E+15	3.6E+15	923	415
5.Irrigation water	2.86E+11J	7.49E+11J	15400	4.4E+15	1.15E+16	508	1331
6.earth cycle	6.12E+12J	6.12E+12J	25514	1.56E+17	1.56E+17	18010	18010
Indigenous renewable production				1.52E+17	1.39E+18	17582	160442
7.agricultural production	8.44E+11J	2.20E+12J		5.11E+16	1.62E+17	5891	18705
1)rice	4.94E+11J	8.83E+11J	35900	1.78E+16	3.17E+16	2047	3656
2)soybean	5.92E+09J	4.00E+10J	690000	4.08E+15	2.76E+16	471	3183
3)vegetable oil	3.01E+10J	1.03E+11J	690000	2.08E+16	7.11E+16	2396	8197
4)vegetable & melon.	6.28E+10J	8.43E+11J	27000	1.7E+15	2.28E+16	196	2625
5)fresh feeding crops	2.51E+11J	3.35E+11J	27000	6.78E+15	9.04E+15	782	1043
8.fruits(orange etc)	0.00E+00J	1.13E+12J	382000	0	4.32E+17	0	49807
9.livestock	3.87E+09J	9.47E+10J	2000000	7.74E+15	1.89E+17	893	21845
10.fuelwood harvested etc	2.28E+12J	1.39E+13J	41000	9.35E+16	5.68E+17	10782	65543
11.fisheries	6.91E+07J	8.37E+09J	2000000	1.38E+14	1.67E+16	16	1931
12.topsoil formation	0.00E+00J	3.07E+11J	73750	0	2.26E+16	0	2611
Indigenous nonrenewable resources				1.77E+17	3.59E+16	20384	4142
13.earth soil loss	98T	21T	1.71E+15	1.68E+17	3.59E+16	19329	4142
14.net topsoil loss	1.24E+11J	0.00E+00J	73750	9.15E+15	0.00E+00	1055	0
Imports and outsides sources							
15.refined oil	0.00E+00J	1.51E+11J	66000	0	9.95E+15	0	1147
16.electricity	0.00E+00J	8.79E+11J	2.00E+05	0	1.76E+17	0	20278
17.fertilizer	2.06E+06g	5.05E+07g		8.82E+15	2.37E+17	1018	27328
1)Nitrogen	1.56E+06g	2.50E+07g	3.45E+09	5.38E+15	8.63E+16	621	9948
2)phosphate	5.00E+05g	1.50E+07g	6.88E+09	3.44E+15	1.03E+17	397	11903
3)potassium	0.00E+00g	5.00E+05g	2.96E+09	0	1.48E+15	0	171
4)mutifertilizer	0.00E+00g	1.00E+07g	4.60E+09	0	4.60E+16	0	5306
18.pesticides	2.00E+05g	1.00E+06g	1.48E+10	2.96E+15	1.48E+16	341	1707
19.miscellaneous goods	3.10E+01$	3.10E+03$	8.67E+12	2.69E+14	2.69E+16	31	3100
20.aids	0.00E+00$	3.00E+03$	8.67E+12	0	2.60E+16	0	3000
21.services in imports	1.50E+01$	1.50E+03$	8.67E+12	1.3E+14	1.30E+16	15	1500

Table 1 (continued)

Note	Item	Annual flows(raw unit/yr)		Emergy/unit	Solar emergy (sej/yr)		Macro value (Em$)	
Year		1982	1989	sej/unit	1982	1989	1982	1989
Exports								
22.agriculture products		3.55E+11J	1.04E+12J	7.53E+05	2.23E+16	5.06E+16	2570	5835
1)rice		3.40E+11J	0.00E+00J	35900	1.22E+16	0.00E+00	1408	0
2)vegetable oil		1.46E+10J	3.38E+10J	690000	1.01E+16	2.33E+16	1162	2690
3)vegetable & melon.		0.00E+00J	1.01E+12J	27000	0	2.73E+16	0	3145
23.fruits(orange etc)		0.00E+00J	3.96E+11J	3.82E+05	0	1.51E+17	0	17448
24.livestock		0.00E+00J	6.13E+10J	3.17E+06	0	1.94E+17	0	22413
25.service in exports[d]		60$	2500$		2.04E+16	2.22E+16	2349	2556

a) All flows are evaluated on a yearly basis(see footnotes, Annex 1)

b)References for transformities are given in Annex2.

c)Chinese Em$ is emergy divided by 8.67E+12sej/$(emergy/$ ratio, China, 1988, S. Lan, H.T Odum).

d)The emergy in exports in 1982 was 60$*3.39E+14 sej/$=2.04E+16 sej, in 1989 was 2500$*8.86E+12sej/$=2.22E+16sej.

Table 2 Sumary of major solar flows and market economic monetary flows in 1982

Variable Item	Solar emergy(sej)	market value($)	Notes
R Renwable sources[a]	1.64E+17		Item 4 and 6 in Tab.1
N Nonrenewable sources wihin Qingyingzhou	1.77E+17		
N0 dispersed rural sources[b]	1.77E+17		Item 12+13+14 in Tab.1
N1 concentrated use	0		
N2 export of unprocessed raw material	0		
F.Imported fuels electricity and fertilizer and pesticides	1.18E+16	357	item 16+17+18+15 in Tab1
F1. fuel and electricity	0	0	
G Imported goods(exc. fuel, electr. and fertilizer)	2.69E+14	31	
I Dollars paid for service in imports		15	
P2I solar emergy value of service in imports	1.30E+14		
P2I3 Imported aids	0.00E+00		
Total Import: IMP[c]	1.22E+16		F+G+P2I+P2I3
E Dollars received for exports($)		388	
EXP Total emergy value of exports	4.26E+16		
X GEP in Qingyingzhou station($)		1040	
P2 China's emergy/$ ratio used for imports	8.67E+12		
P1 Emergy/$ ratio for its exports	3.39E+14		(N0+N1+R+IMP)/GEP

Table 3 Sumary of major solar flows and market economic monetary flows in 1989

Variable Item	Solar emergy(sej)	market value($)	Notes
R Renwable sources	1.60E+17		Item 4 and 6 in Tab.1
N Nonrenewable sources wihin Qingyingzhou	5.86E+16		
N0 dispersed rural sources	5.86E+16		Item 12+13+14 in Tab1
N1 concentrated use	0		
N2 export of unprocessed raw material	0		
F.Imported fuels electricity and fertilizer and pesticides	4.37E+17	2600	Item 15+16+17+18i Tab 1
F1.fuel and electricity	1.86E+17	1300	
G Imported goods(exc. fuel & electricity)	2.69E+16	3100	
I Dollars paid for service in imports		1500	
P_2I solar emergy value of service in imports	1.30E+16		
P_2I_3 Imported aids	2.60E+16	3000	
Total import: IMP	5.03E+17		F+G+P2I+P2I3
E Dollars received for exports($)		62500	
EXP Total emergy value of exports	4.18E+17		
X GEP in Qingyingzhou station($)		81429	
P_2 China's emergy/$ ratio used for imports	8.67E+12		
P_1 Emergy/$ ratio for its exports	8.86E+12		(N0+N1+R+IMP)/GEP

Footnote to Table 2-3.

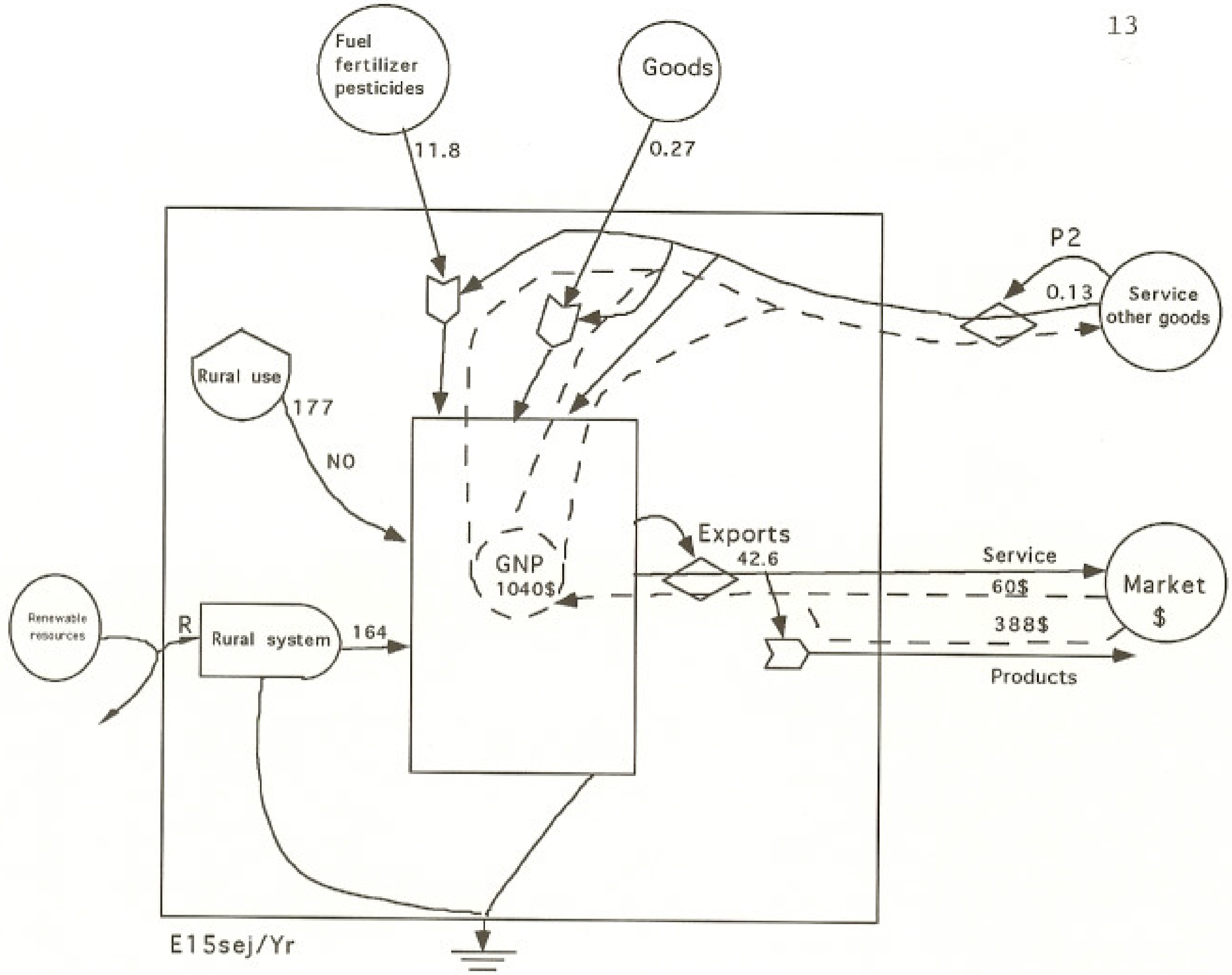
a)Solar emergy contribution from rainfall and earth cycle. Other renewable sources are accounted in this summation-since they are coupled, global flows, their solar transformaties share global solar emergy flux.

b)No. Dispersed rural sources(Tab 1): earth loss+net topsoil loss+soil formation.

c)Import from outside but from within China

Table 4 Emergy indices for overview of Qingyingzhou ecological station based on Table 2 and Table 3

Item	Name of index	Expression	Quantity or ratio 1982	1989	unit
1	renewable emergy flow	R	1.64E+17	1.60E+17	sej/yr
2	nonrenewable sources from Qingyingzhou	N	1.77E+17	5.86E+16	sej/yr
3	flow of imported emergy	IMP	1.22E+16	5.03E+17	sej/yr
4	total emergy inflows	R+N+IMP	3.53E+17	7.22E+17	sej/yr
5	total emergy used, U	N0+N1+R+IMP	3.53E+17	7.22E+17	sej/yr
6	total exported emergy	EXP	4.26E+16	4.18E+17	sej/yr
7	fraction of emergy used derived from home sources	(N0+N1+R)/U	97%	30%	
8	imports minus exports	IMP-EXP	-3.05E+16	8.50E+16	sej/yr
9	ratio of imports to exports	IMP/EXP	29%	120%	
10	fraction used, local ly renewable	R/U	46%	22%	
11	fraction of use purchased	IMP/U	3%	70%	
12	fraction of use that is free	(R+N0)/U	97%	30%	
13	concentrated/renewable ratio	N1/R	0	0	
14	emergy investment ratio (emergy import/environment)	IMP/(R+N)	0.04	2.31	
15	emergy use per unit area	U/area	1.73E+11	3.53E+11	sej/m2
16	emergy use per person	U/population	1.14E+16	2.68E+15	sej/peson
17	carrying capacity at same living standard using renewable resources	(R/U)*population	14	60	person
18	developed carrying capacity at same living standard	8*(R/U)*population)	115	476	person
19	ratio of electricity to use	electricity/U	0%	24%	
20	fuel, electricity,fertilizer, and pesticide use per person	F/ population	1.41E+16	1.63E+15	sej/person
21	Ratio of emergy use to GEP	P1=U/GEP	3.39E+14	8.86E+12	sej/$



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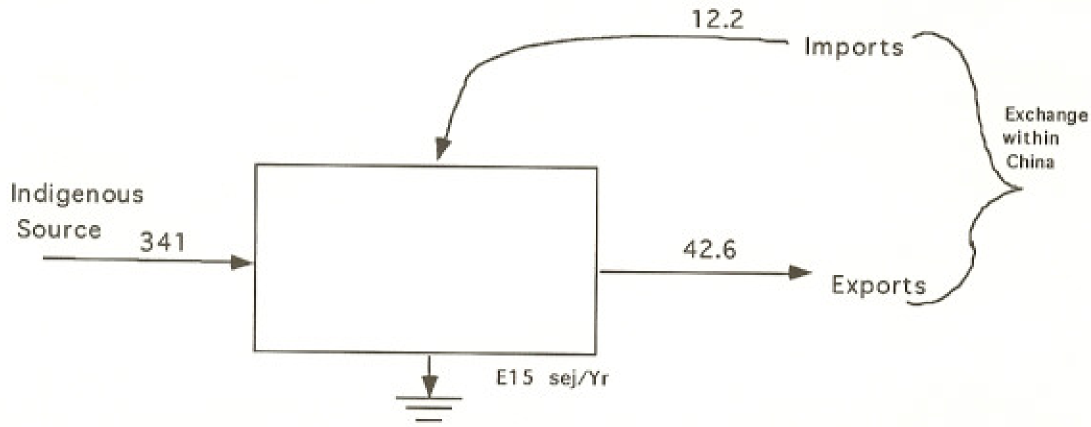
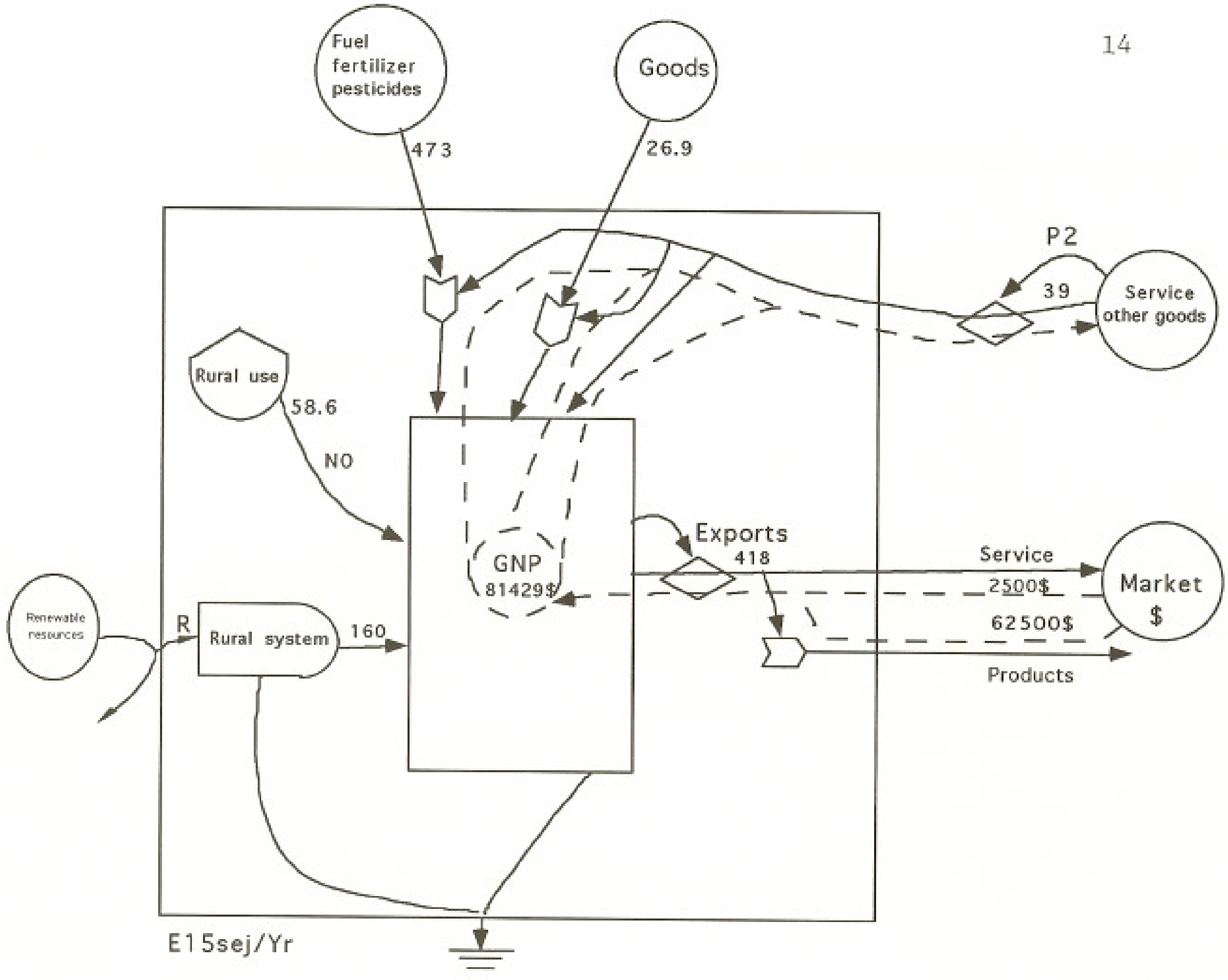


(b)

Fig 4 Sumary of Emergy Flows of Qingyanzhou in 1982



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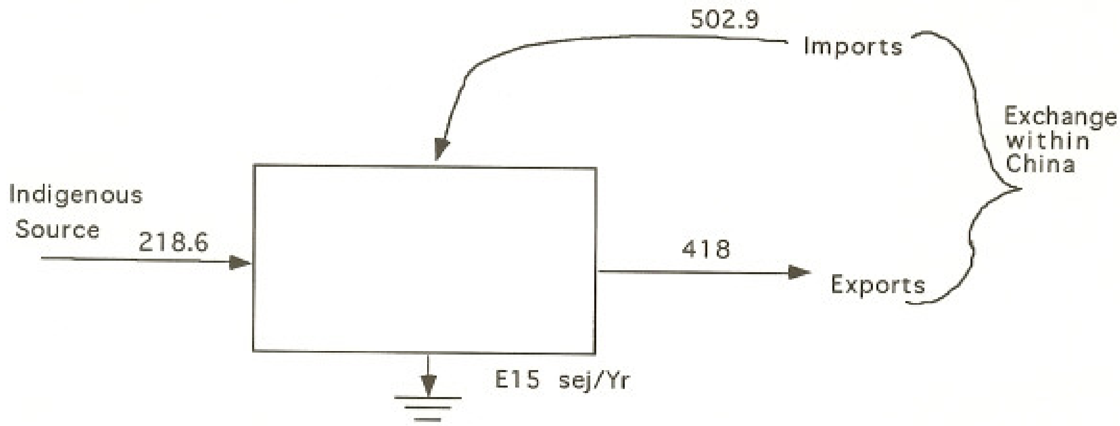


(b)

Fig 5 Sumary of Emergy Flows of Qingyanzhou in 1989 a developing area. As a countryside area, more of the economy involves direct environmental resources inputs which are not paid for. Due to Qingyanzhou's many free environmental products, money could buy more real wealth in 1982 than in 1989.

Emergy flows also include exchanges with surrounding economy. The emergy value of exports in 1982 was 42.6 E15 sej/Yr, and emergy inflow was only 12.9 E15 sej/yr. Much more value was sent to outside than was received in return. There was a great change after 7 years' development. In 1989, the emergy value of exports was 418 E15 sej/Yr, and the emergy inflows from imports was 502.9 E15 sej/Yr. The practice of Qingyanzhou proved that the input increase stimulated the development of red hill areas, so there was also a great possibility of increasing the output in red earth hill areas.

4.3 Comparison with China and Other Countries

Table 4 lists the various indices. These can be useful for comparison with China and other nations.

The total emergy of fuels and electricity per person per year increased from 0 to 0.69 E15 sej/person/yr, but it is still less than China and many countries (China 1.75 E15 sej, USA 22.8 E15 sej, Australia 12.7 E15 sej; New Zealand 8.6 E15 sej).

Annual emergy use per person in Qingyanzhou decreased from 11.4 E15 sej/person/yr to 2.68 E15 sej/person/yr. It is much less than many countries (Australia 58 E15; USA 29 E15; Netherlands 26 E15; Japan 13 E15; Taiwan 7.5 E15; China 6.5 E15; Thailand 3.2 E15; India 1.0 E15).

The emergy/money ratio of Qingyanzhou in 1982 was 3.39 E14 sej/$ and in 1989 was 8.86 E12 sej/$. That is higher than that of China (8.67 E12 sej/$), and is comparable to developing areas and countries (Liberia 34.5 E12; Dominica 15.9 E12; Brazil 8.5 E12; India 6.4 E12), while the developed countries show lower ratios (Netherlands 2.2 E12; USA 1.7 E12; Japan and Spain 1.6 E12; Italy 1.44 E12).

The ratio of import emergy to export emergy for Qingyanzhou had increased from 0.29 in 1982 to 1.20 in 1989, but is much less than most countries (Netherlands 4.3; Japan 4.2; Italy 2.48; USA 2.2; Taiwan 1.0; Thailand 0.5; Australia 0.4; China 0.28).

Empower density, the rate of solar emergy use per unit area of Qingyanzhou, had a great increase from 1.73 E11 sej/m2/Yr in 1982 to 3.53 E11 sej/m2/yr in 1989. It reflected the spatial intensity of economic development of the areas or country under study (Netherlands 100 E11; Italy 41.1 E11; Switzerland 17.7 E11; Dominica 8.8 E11; China 7.5 E11 sej; USA 7.0 E11; Brazil and India 2.1 E11; Australia 1.42 E11).

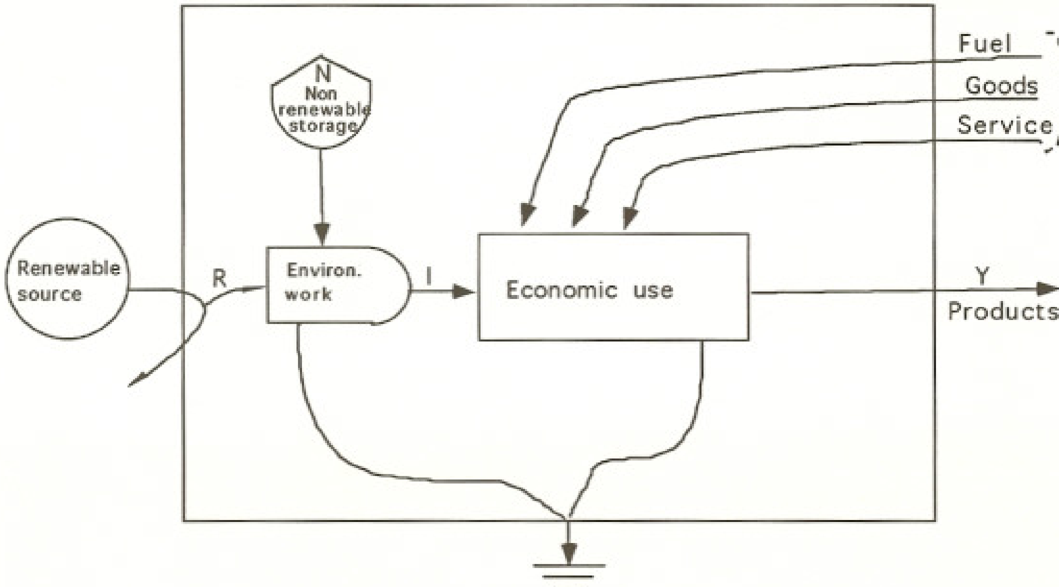
The ratio of purchased (outside) emergy to free environmental emergy from within Qingyanzhou had great change too, increasing from 0.04 in 1982 to 2.31 in 1989. This ratio is a measure of intensity of development. The ratio in Qingyanzhou in 1989 was much less than the values in the developed countries and higher than the values in some developing countries (Holland 15.9; Switzerland 7.4; USA 7.1; Spain 7.2; Sweden 7.0; Dominica 2.7; Australia 1.1; India 1.0; New Zealand 0.8; Liberia 0.09, China 0.016).

4.4 Population and Resources

Qingyanzhou has a much lower emergy use per person, a measure of standard of living. The developed carrying capacity at the same living standard in 1982 was 115 persons, and in 1989 was 476 persons. It shows that with the development of Qingyanzhou, the developed carrying capacity at the same living standard in 1989 is almost 3 times than that in 1982. This also means that the present population is less than the developed carrying capacity of developed countries.

4.5 The Comparison of Ratios of Net Emergy Yield, Emergy Investment and Environment Loading in 1982 and 1989

The net emergy yield ratio is the emergy of an output divided by the emergy of those inputs to the process that are fed back from the economy (Figure 6). This ratio indicates whether the process can compete in supplying a primary emergy source for an economy. Recently the ratio for typical competitive sources of fuels on world markets has been about 6 to 1 (Odum, 1988), varying from 3 to 12 in some years. Processes yielding less than this cannot be considered primary emergy sources. If the ratio is lower than unity, the process is not a positive source of net emergy; if the ratio is lower than alternatives, less return will be obtained per unit of emergy invested in comparison with alternatives. Less competitive emergy sources (i.e. having a lower net emergy yield ratio) may have a lower cost, due to local conditions: costs are affected by international markets and value of currencies.



I=N+R

Y=I+F

Net Eemrgy Yield Ratio=Y/F

Emergy Investment Ratio=F/I

Environment Loading Ratio=(F+N)/R

Fig.6 Emergy Diagram Illustating Computation of Emergy Yields and Use Ratio

The emergy investment ratio is the emergy fed back from the economy to the indigenous emergy inputs (F in Figure 6). This ratio indicates if the process is economical as utilizer of the economy's investments in comparison to alternatives. The physical meaning of this ratio is to evaluate the emergy input from the economy needed to exploit a unit of indigenous local resources. To be economical, the process should have a similar ratio to its competitors. If it receives less from the economy, the ratio is less and its price is less, so that it will tend to compete in the market. Its price is less when it is receiving a higher percentage of its useful work free from the environment than its competitors.

However, operation at a low investment ratio uses less of indigenous resources exploited. The tendency will be to increase the purchased inputs so as to process more output and more money. The tendency is towards optimum resources use. Thus, operations above or below the regional investment ratio will tend to change towards the investment ratio. Of course, this index is affected by the region boundaries. They can be determined by political reasons (boundaries of a nation) or socio-economical reasons (a special area within in a nation, like Singzhen Special Area of China) and usually show homogeneous conditions and trends of development over the whole area. This requires a special economic policy for investment and trade so that evaluation of indices on such a regional scale may be useful for comparison.

The environmental loading ratio (Figure 6) is the ratio of purchased and non-renewable indigenous emergy to free environmental emergy. It is like the "load" on an electric circuit. A large ratio suggests a high technological level in emergy use as well as high level of environmental stress. Even when the emergy investment ratio is low (the process upon indigenous minerals or fuels sources), the environmental loading ratio can be very high. The ratio of economic components (emergy use other than free renewable) to environmental components is 0.55 to 1 in 1982 and 2.57 to 1 in 1989 for Qingyanzhou station. Many developed countries have a higher environmental loading ratio (Table 5).

The ratios of net emergy yield, emergy investment and environment loading in Qingyanzhou are listed in Table 6.

Table 5 Environmental loading ratio for selected countries in 1990

Nations	Environmental component(E20sej/yr)	Economic component (E20sej/yr)	Environment loading ratio
Poland	159.00	3145.6	19.78
Netherland	219.00	3483.00	15.00
Italy	1207.62	11442.13	9.47
Taiwan	213.00	1924.00	9.03
Switzland	86.80	646.00	7.44
Spain	255.00	1835.00	7.20
USA	8240.00	58160.00	7.06
Dominica	1.80	4.8	2.67
World	94000.00	108000.00	1.15
Thailand	779.00	811.00	1.04
India	3340.00	3410.00	1.02
Australia	4590.00	3960.00	0.86
New Zealand	438.00	353.00	0.81
Brazil	10100.00	7600.00	0.75
Ecuador	891.00	483.00	0.54
Papua New Guinea	1052.00	163.00	0.15
Liberia	427.00	38.00	0.09

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Table 6 The comparison of ratios of net emergy yield, emergy investment and environment Loading ratios in 1982 and 1989

Item	1982	1989	Units
R Renewable resource	1.64E+17	1.60E+17	sej/Yr
N Nonrenewable resource	1.77E+17	5.86E+16	sej/Yr
F Fuels, goods and services	1.22E+16	5.03E+17	sej/Yr
I R+N	3.41E+17	2.18E+17	sej/Yr
Y R+N+F	3.53E+17	7.22E+17	
Net emergy yield ratio(Y/F)	28.98	1.43	
Emergy investment ratio(F/I)	0.04	2.31	
Environmental loading ratio(F+N)/I	0.55	2.57	

4.6 Concluding Remarks

China is a large developing country with huge population and a complex natural and economic condition in the world. According to results of emergy analysis to China and the emergy analysis to Qingyanzhou station, on the one hand, the developed carrying capacity at the same living standard is 1.16 billion people, and presently the total population of China is over 1.2 billion who need more resources to feed themselves and meanwhile more opportunities to work; but on the other hand, many resources and environment haven't been exploited wisely and intelligently. This situation leads to existing multi-wastes of natural resources and human resources. The 7 years' developments of Qingyanzhou show:

4.6.1 Some resources of red earth hilly mountain areas such as Qingyanzhou station haven't been used in an optimum way before 1982, and there is a great potentiality to develop these areas. There was a great increase both in GNP and emergy yield in 1989 compared with 1982. The main reasons are: (1) Favorable balance of imports and exports of emergy and materials between Qingyanzhou and outside; (2) sustainable exploitation of indigenous storage of resources according to ideas of eco-agriculture engineering, to reorganize and restructure the systems which recycle wastes to production in Qingyanzhou, and improved efficiency; (3) attraction of outside emergy (scientific instruction from scientists, information inflows, trained immigrants from outside, etc.).

4.6.2 The way of Qingyanzhou is a successful approach to stimulate the development of widespread red earth hilly areas. The social effects of Qingyanzhou station are very great too. In order to develop and manage

366,700 ha red earth hilly areas in Jie'an Prefecture of Jiangxi Province, increase the vitality of the eco-economic system, find sustainable pathways for the red earth hilly mountain areas, and establish the dynamic balance between outputs and inputs, many local governments and farmers visited "The Example of Qingyanzhou's Eco-economic Systems," which is "an active classroom with an active book" suitable for farmer's copying and studying. There are about 30 new examples with high economic effect established in different counties of Jiangxi province since 1985. Figure 7 shows the operational mechanism for Qingyanzhou's extension to other areas.

According to the reports of People's Daily (Feb.8, 1996), the radiation of different models and examples in Jiangxi Province, the developments and explorations of mountain areas, river and lakes, made great progress in the past 15 years, widely attracting attention from domestic and overseas interests. About 0.6 billion dollars in investment loans from China, UNDP, Japan and Germany, etc., will be used to support agriculture integrated development in Jiangxi Province.

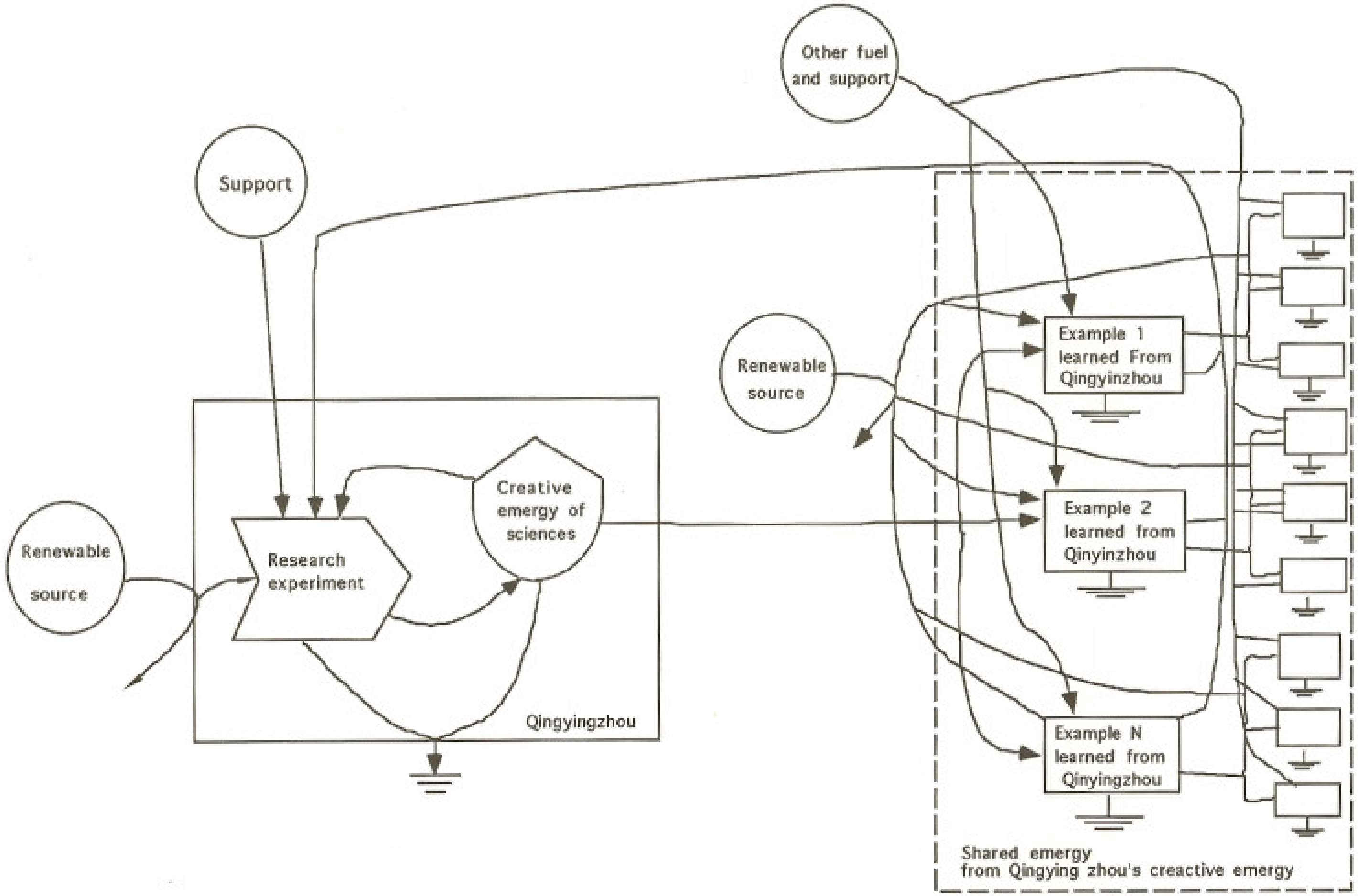

Fig.7 The operation machanism of spreading Qingyingzhou's creactive emergy of sciences to outsiside

Annex 1

Footnotes to Table 1; references for data are given in Annex 2

Renewable resources

1.Solar energy

Land area	2.0416E+06 m^2
Insolation	4.49E+05 J/cm^2
Albedo	0.2
Land energy=	(land area)(avg. insolation)(1-albedo)
	7.33E+15 J/Yr

2.wind,kinetic

Land area	2.0416E+06 m2
Wind energy in first half Yr=	(1E3m)(1.23kg/m^3)(22.3m^2/s)(365*24*3600*0.5s)(6.08E-3/s/m)^2(2.0416E+6m^2)
=	3.26E+13 J/0.5Yr
Wind energy in sec. half Yr=	(1E3m)(1.23kg/m^3)(22.3m^2/s)(365*24*3600*0.5s)(1.78E-3/s/m)^2(2.0416E+6m^2)
=	2.80E+12 J/0.5yr
Total energy=	3.54E+13 J

3.Rain chemical potential

=	2.0416E+06m^2*1.36m*4.94J/g*E+06cm^3/m^3*1g/cm^3
=	1.37E+13 J/Yr

4.Rain Geopotential energy

in 1982:	2.0416E6m^2*1.36m*E3kg/m^3*70m*0.4runoff rate*9.8m/sec^2
	7.62E+11 J/Yr
in 1989:	2.0416E6m2*1.36m*E3kg/m^3*70m*0.18runoff rate*9.8m/sec^2
	3.43E+11 J/Yr

5.Irrigation water

in 1982, the vol. of irr. water	5.72E+04 m^3
Energy contained in 1982=	2.86E+11 J/Yr
in 1989, the vol. of Irr. water	1.50E+05 m^3
Energy contained in 1989=	7.50E+11 J/Yr

6.Earth cycle

Heat flow per area	3.00E+06 j/m^2/Yr
Land area	2.04E+06 m^2
Energy=	Land area*Heat flow per area=
	6.12E+12 J/Yr

Indigenous renewable production

7.Agriculture production

Item	Annual flows data(kg) in 1982	in 1989	Energy content (J/kg)	Energy (J/Yr) In 1982	in 1989
1)rice	3.192E+04	5.700E+04	1.55E+07	4.94E+11	8.83E+11
2)soybean	3.200E+02	2.160E+03	1.85E+07	5.92E+09	4.00E+10
3)vegetable oil	1.20E+03	4.104E+03	2.51E+07	3.01E+10	1.03E+11
4)vegetable & melon	1.50E+04	2.013E+05	4.19E+06	6.28E+10	8.43E+11
5)fresh feeding crops	6.00E+04	8.000E+04	4.19E+06	2.51E+11	3.35E+11
Subtotal				8.45E+11	2.20E+12
8.fruits(orange etc)	0.00E+00	2.70E+05	4.19E+06	0.00E+00	1.13E+12

9.livestock

	in 1982(kg)	in 1989(kg)	(J/kg)	in 1982(J)	in 1989(J)
1)total products	8.40E+02	2.06E+04			
2)energy=(total prod.*o.22 organic*1000g/kg*5kcal/g*4186j/kcal)			4.60E+06	3.87E+09	9.47E+10
10.fuelwood etc harvested	1.52E+05	9.24E+05	1.50E+07	2.28E+12	1.39E+13
11.fisheries					
1)total products	1.50E+01	1.82E+03			
2)energy=(total prod.*o.22 organic*1000g/kg*5kcal/g*4186j/kcal)			4.60E+06	6.91E+07	8.37E+09

12.net topsoil formation

1)net topsoil formation in1982

a)soil formation assumed occurring on half of forest area =1/2*2041600m^2/ha*0.4% frt. cov.*1260g soil build up/m^2/Yr = 5144832 g/Yr.

b)soil loss on agriculture areas estimated as (22.14ha*10000m^2 agr. land)(850g soil loss/m^2/yr;est. Odum et al 1987)= 188190000 g/yr

(soil formation)-(soil eroded)= -1.83E+08 g/yr, this is net soil loss in 1982.

Energy in organic matter of soil estimated as (-183e+08g/yr)(3%OM content)(5.4kcal/g)(4186J/kcal)= -1.24E+11 J/yr

2)net topsoil formation in1989

a)soil formation assumed occurring on 50%of forest area =1/2*2041600m^2/ha*68.14% frt. cov.*1260g soil build up/m^2/Yr = 876422131.2 g/Yr.

b)soil loss on agriculture areas estimated as (49.77ha*10000m^2 agri. land;1989)(850g soil loss/m2/yr;est. Odum et al 1987)= 423045000 g/yr

(soil formation)-(soil eroded)= 4.53E+08 g/yr, this is net soil formation in 1989.

Energy in organic matter of soil estimated as (4.53E+08g/yr)(3%OM content)(5.4kcal/g)(4.186J/kcal)= 3.07E+11 J/yr

Indigenous nonrenewable resources

13. earth soil loss

The average loss of earth soil in 1982 was 0.48T/ha, so the total loss of earth soil =0.48T/ha*total area=98T.

The average loss of earth soil in 1989 was 0.103T/ha, so the total loss of earth soil =0.103T/ha*total area=21T

14.net topsoil loss

Energy in organic matter of net topsoil l in 1982 was 1.24 E+011J/yr(see footnote 12).

Imports and outsides sources

15 .Refined oil

The total imports in 1989 was 3.6Toil equivalent. The energy =3.6T*(1E+07kcal/t)*4186J/kcal= 1.50696E+11 J/Yr.

No oil imports in 1982.

16.electicity

The total use of electricity in 1989 was 15000 Kw.h. Energy =15000Kw.h*3.6E+6J/Kw.h= 5.40E+10 J/Yr

No electricity in 1982.

17.fertilizer

1)Nitrogen(g)

N content in 1982 was 1.56E+06 g/Yr; in 1989 was2.50E+07 g/Yr.

2)phosphate(g)

P_2O_5 content	in 1982 was 5.00E+05 J/Yr; in 1989 was 1.50 E+07 g/Yr.
3)Potassium(g)	
K_2O content	in 1982 was 0 ; in 1989 was 5.00E+05 g/Yr.
4)mutifertilizer(g)	in 1982 was 0; in 1989was 5.00+05g/Yr.
18.pesticides(g)	in 1982 was 2.00E+05g/Yr; in 1989 was 1.00E+06g/Yr.
19.miscellaneous goods($)	in 1982 was 31$; in 1989 was 3100$.
20.aides($)	in 1982 was 0$; in 1989 was 3000$.
21.services in imports($)	in 1982 was 15$; in 1989 was 1500$.

Exports

22. agriculture products

Item	Annual flows data(kg) in 1982	in 1989	Energy content (J/kg)	Energy (J/Yr) in 1982	in 1989
1)rice	2.192E+04	0.000E+00	1.55E+07	3.40E+11	0.00E+00
2)vegetable oil	580	1.345E+03	2.51E+07	1.46E+10	3.38E+10
3)vegetable & melon	0.00E+00	6.039E+04	4.19E+06	0.00E+00	2.53E+11
Subtotal				3.54E+11	2.87E+11
23.fruits(orange etc)	0.00E+00	2.15E+05	4.19E+06	0.00E+00	9.00E+11
24.livestock					
1)total products	0.00E+00	1.33E+04			
2)energy=(total prod.*o.22 organic*1000g/kg*5kcal/g*4186j/kcal)			4.60E+06	0.00E+00	6.13E+10

25.service in exports

In 1982, the total services in exports was just 60$; in 1989, some farmers who mastered useful agriculture technologies gave technical services to adjacent villages, and intook 2500$.

Annex2 Reference for transformities

Note Item	Transformity sej/unit	Reference
Renewable sources		
1.solar insolation	1 sej/J	A
2.wind, kinetic	1500 sej/J	B
3.rain,chemical	18200 sej/J	A
4.rain,geopotential	10500 sej/J	B
5.Irrigation water	15400 sej/J	F
6.earth cycle	25514 sej/J	A
Indigenous renewable production		
7.agricultural production		
1)rice	3.590E+04 sej/J	C
2)soybean	6.900E+05 sej/J	C
3)vegetable oil	6.900E+05 sej/J	C
4)vegetable & melon.	2.700E+04 sej/J	C
5)fresh feeding crops	2.700E+04 sej/J	C
8.fruits(orange etc)	3.820E+05 sej/J	D
9.livestock	2.000E+06 sej/J	D
10.fuelwood harvested etc	4.100E+04 sej/J	A
11.fisheries	2.000E+06 sej/J	D
12.topsoil formation	7.375E+04 sej/J	A
Indigenous nonrenewable resources		
13.earth soil loss	1.710E+15 sej/J	G
14.net topsoil loss	7.375E+04 sej/J	A
Imports and outsides sources .		
15.refined oil	6.600E+04 sej/J	E
16.electricity	2.000E+05 sej/J	B
17.fertilizer		
1)Nitrogen	3.450E+09 sej/g	A
2)phosphate	6.880E+09 sej/g	A
3)potassium	2.960E+09 sej/g	A
4)mutifertilizer	4.600E+09 sej/g	Average of N, P, K fert.
18.pesticides	1.480E+10 sej/g	A
19.miscellaneous goods	8.670E+12 sej/$	C
20.aids	8.670E+12 sej/$	C
21.services in imports	8.670E+12 sej/$	C

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B S. J Doherty, M. T Brown, H.T Odum et al, 1992 Emergy synthesis perspectives, sustainable development, and public policy options for Papua New Guinea, Center for Wetlands, Unversity of Florida, USA