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ENERGY REQUIREMENTS FOR ALTERNATIVE RICE PRODUCTION SYSTEMS IN THE TROPICS

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ENERGY REQUIREMENTS FOR ALTERNATIVE RICE PRODUCTION SYSTEMS IN THE TROPICS[1/]

ABSTRACT

The energy requirements of three alternative rice production systems used by most small Asian farmers are identified by task and energy source and the energy levels and components of each system compared. Human energy contributes a small portion of total energy input into most traditional Asian rice farming systems. As food production systems modernize, they become less energy efficient and more dependent on commercial energy.

1/By Donald O. Koether and Bart Duff, associate agricultural engineer and associate agricultural economist, International Rice Research Institute, Los Baños, Laguna, Philippines. A paper prepared for the Annual Meeting, Society of Automotive Engineers, September 1979. Revised and reprinted with permission of the Society of Automotive Engineers, Inc.

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ENERGY REQUIREMENTS FOR ALTERNATIVE RICE PRODUCTION SYSTEMS IN THE TROPICS

In the developing nations, the rising costs of energy and the resulting increase in prices of marketed commodities and factors of production have serious implications for achieving and sustaining economic growth. Because a greater portion of the population of many of these countries are in rural areas and derive a major share of their national income from agriculture, the adverse effects of higher energy costs are particularly relevant. During the past two decades, agriculture in many Asian countries has undergone dramatic change, much of it centered in the smallholder sector. Most of these farms are on the average less than 2 ha and in the past a substantial share of the energy to operate them has come from on-farm sources such as human labor and animal power. Recent developments in agriculture have been stimulated by the introduction of a biological chemical technology package consisting of improved crop varieties and chemical fertilizers, herbicides, and insecticides. In many areas, these developments were accompanied or brought about by the introduction of mechanical technologies such as power pumps, tractors, and mechanical threshers.

Traditional agricultural systems, in which little is bought or sold outside the home, have a low dependence on outside inputs and are largely insensitive to changing economic conditions. In contrast, improved production systems, which result in increased land and labor productivity, are highly dependent on purchased inputs, many of which embody substantial energy derived from fossil fuels. Because of this high level of dependence, those concerned with agricultural production in these nations are particularly interested in the level of energy inputs required to sustain modern systems and to evaluate their sensitivity to changing technologies and economic conditions.

This report focuses on two dimensions of the energy issue in small-farm rice production systems. The first section partitions the energy requirements of alternative systems by task and source. The second examines the relative costs of the alternative systems, and their sensitivity to changes in energy costs or to technology which changes the efficiency with which energy is used.

ALTERNATIVE RICE PRODUCTION SYSTEMS

The rice production systems analyzed here represent those used by the majority of Asian farmers: traditional, mechanical, and transitional systems as defined in Table 1. A small amount of Asian rice land is still tilled completely by human power. Conversely, there are a few large, highly mechanized rice farms that use the same machinery and cultural techniques used in the developed nations. Figure 1 illustrates typical machines used in the three production systems. Variations in the

Table 1. Components of alternative rice production systems.

Component	Traditional	Mechanical	Transitional
Land preparation			
Primary tillage	Water buffalo and plow	5- 7-hp tiller and plow	50-hp tractor and rototiller
Secondary tillage	Water buffalo and harrow	5- 7-hp tiller and harrow	Water buffalo and harrowing
Levee repair	Manual	Manual	Manual
Planting			
Seedbed	Wetbed system	Wetbed system	Wetbed system
Transplanting	Manual	Manual	Manual
Crop care	Manual	Manual	Manual
Harvesting	Hand sickle	Hand sickle	Hand sickle
Threshing and drying	Manual threshing Sun drying	IRRI-type power thresher Mechanical batch dryer	Manual threshing Sun drying

systems, such as mechanical threshing combined with animal tillage or mechanical threshing and solar drying, occur. The manpower and energy inputs of each system are presented in sufficient detail to permit the reader to calculate the manpower and energy requirements reflecting a combination of tasks or operations for a specific farming situation.

Table 2 and Figure 2 present the labor requirements for each system. The values were obtained by averaging the labor hours reported in indicated references. Most of the data result from research conducted in the Philippines but compare favorably with information on labor requirements from other parts of Asia (Chancellor 1977). The use of mechanical tillage and improved postharvest processing reduced labor hours per hectare from 735 to 545, or 26%. The introduction of the 4-wheel tractor in the transitional system had a less pronounced effect -- it reduced total labor hours by only 8% compared with the traditional system. Peak labor demands in most nonmechanized production systems occur during land preparation, transplanting, harvesting, and threshing. Crop care requires a large labor input but is generally allocated more uniformly over the entire growing season. Land preparation, planting, and harvesting-threshing, on the other hand, should ideally be completed in the shortest possible time for timely planting of the crop to maximize use of available moisture and sunlight and to harvest at optimum maturity to reduce losses.

The energy inputs for each production system are given in Tables 3, 4, and 5. This information is presented as percentages of total energy by input and operation in Figures 3 and 4. Appendix A presents the energy constants and consumption rates used in the calculations. The energy available in fuel, oil, and seed is used as a direct input whereas the energy value of fertilizer, herbicides, insecticides, and farm machinery considers all energy used to produce the material, including the direct energy used in production and the energy to build and maintain the production facilities.

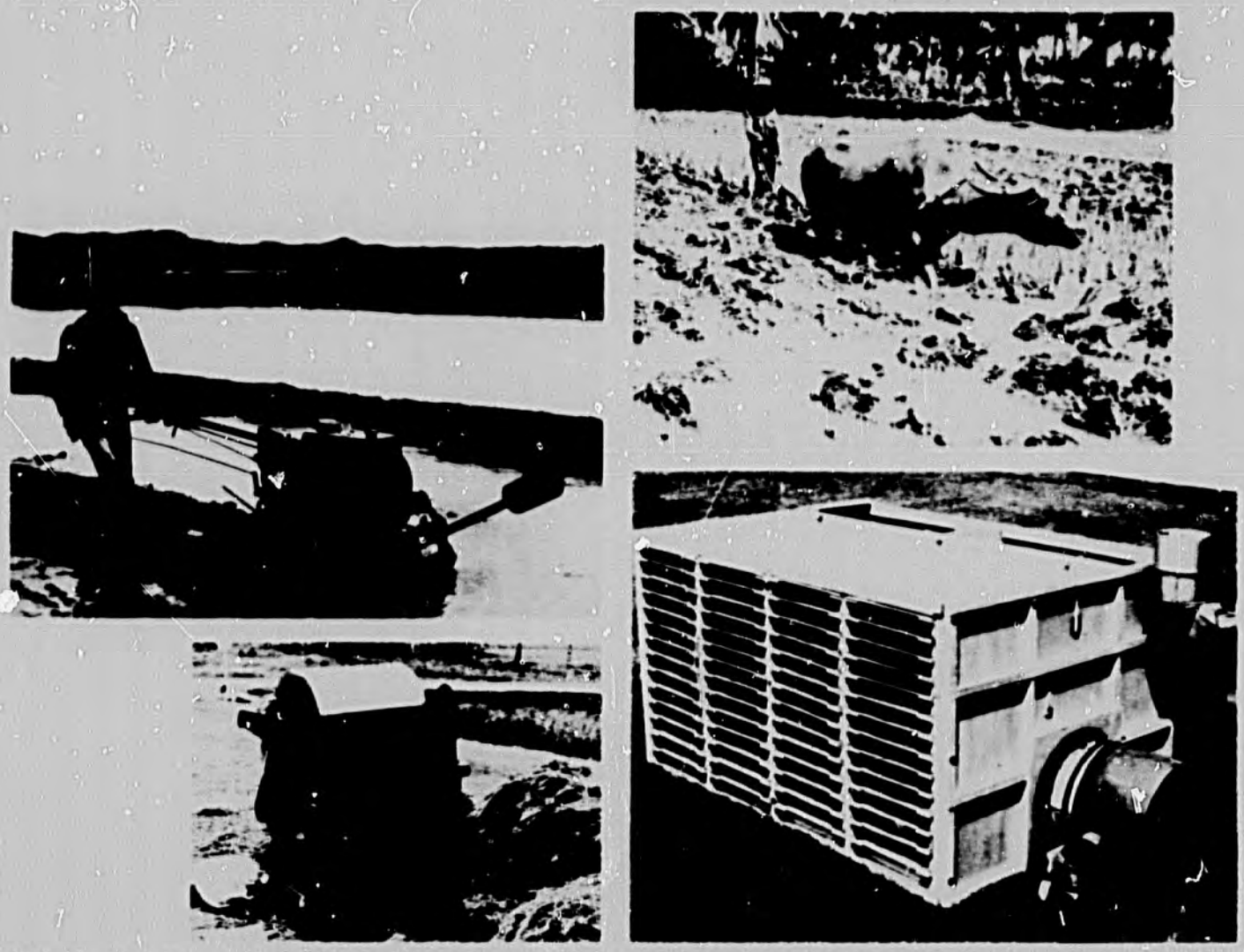

Fig. 1. Machines used in the traditional, mechanical, and transitional rice production systems.

Table 2. Labor inputs (labor hours/ha) by system and task for alternative rice production systems.[a]

	Traditional	Mechanical	Transitional
Land preparation	138	68	76.3
Primary tillage	105[b]	35[c]	4.3[d]
Secondary tillage			39[e]
Levee repair	33[f]	33	33
Planting	142[g]	142	142
Seedbed preparation and care	142[h]	142	142
Seedling pulling			
Transplanting			
Crop care	163	163	163
Fertilizer application	8[i]	8	8
Insecticide application	10[j]	10	10
Herbicide application	8[k]	8	8
Weeding	137[l]	137	137
Harvesting	121[m]	121	121
Cutting and stacking	121	121	121
Threshing and drying	171	51	171
Threshing	144[n]	37[n]	144
Cleaning and bagging			
Hauling			
Drying	27[n]	14[n]	27
Total	735	545	673.3

[a]Labor inputs are averages of those reported in indicated sources. [b]Sources: Barker et al 1969, Barker and Cordova 1978, Duff 1978, Johnson 1969a, Kiamco and McMennamy 1978, Singh and Yadao 1979. [c]Sources: Duff 1978, Johnson 1969a, Kiamco and McMennamy 1978, Orcino and Duff 1974, Singh and Yadao 1979. [d]Source: Orcino and Duff 1973. [e]Sources: Barker and Cordova 1978; Johnson 1969a,b; Singh and Yadao 1979. [f]Sources: Duff 1978, Orcino and Duff 1974, Singh and Yadao 1979. [g]Sources: Barker et al 1969, Barker and Cordova 1978, Johnson 1969b, Ledesma 1978, Singh and Yadao 1979. [h]Sources: Johnson 1969a, Singh and Yadao 1979. [i]Source: Johnson 1969a. [j]Assume same as fertilizer application. [k]Sources: Barker and Cordova 1978, De Datta and Barker 1975. [l]Sources: IRRI 1978c, Johnson 1969a, Ledesma 1978, Singh and Yadao 1979, Toquero et al 1977. [m]Sources: Barker and Cordova 1978, IRRI 1978c, Johnson 1969a, Singh and Yadao 1979. [n]Sources: IRRI 1978c, Toquero et al 1977.

and provide for worker's food and transportation, packaging, and distribution. The human energy expenditures used in this paper for the rice growing tasks were obtained experimentally with portable cardiac monitoring instruments (Duff 1978). As expected, the energy consumption values varied by task but an average of expenditures for all tasks approximate those generally cited in the literature (Chancellor 1977). Human energy in those tasks not measured directly in the study were estimated using values from similar tasks.

Consumption rates for fuel and oil were obtained from test reports of similar machines being developed by the International Rice Research Institute Department of Agricultural Engineering, farmer surveys, and engine manufacturer's specifications. Energy equivalents for machinery use and depreciation were obtained by multiplying the estimated energy requirement to produce a kilogram of machine by 1.33 times the weight of the machine, prorated over machine life by hours used per hectare. The one-third weight increase is an adjustment for repairs based on the assumption that total repair cost approaches machine first cost over total life. Repairs cost 3 to 4 times the original part it replaces, so we assume that about one-third the weight of the machine in energy equivalents is replaced over its useful life.

Overall energy consumption increased 26% when mechanical land preparation and mechanical threshing and drying replaced human and animal power (Tables 3 and 4). Fuel, especially that used for drying,

Table 3. Energy inputs ($J \times 10^6$/ha) for the traditional rice production system.

Operation	Inputs[a]								
	Human	Animal	Machine	Fuel and oil	Seed	Fertilizer	Insecticide	Herbicide	Total
Land preparation									1567.0
Primary tillage	110.5	1099.0	331.3	-	-	-	-	-	
Secondary tillage									
Levee repair	26.2								
Planting									729.8
Seedbed preparation									
Seedling pulling	112.7	-	-	-	617.1	-	-	-	
Transplanting									
Crop care									3880.9
Fertilizer application	13.8	-	-	-	-	3243.3	-		
Insecticide application	17.2	-	-	-	-	-	304.1	-	
Herbicide application	13.8	-	-	-	-	-	-	74.8	
Weeding	213.9	-	-	-	-	-	-	-	
Harvesting									150.0
Cutting and stacking	150.0	-	-	-	-	-	-	-	
Threshing and drying									249.1
Threshing									
Cleaning and bagging	174.0	-	-	-	-	-	-	-	
Hauling				53.7					
Drying	21.4	-	-	-	-	-	-	-	
Total	853.5	1099.0	331.3	53.7	617.1	3243.3	304.1	74.8	6576.8
Energy equivalent (liters of diesel fuel)	22.3	28.7	8.6	1.4	16.1	84.5	7.9	1.9	171.4

[a]See Appendix A for constants and calculations.

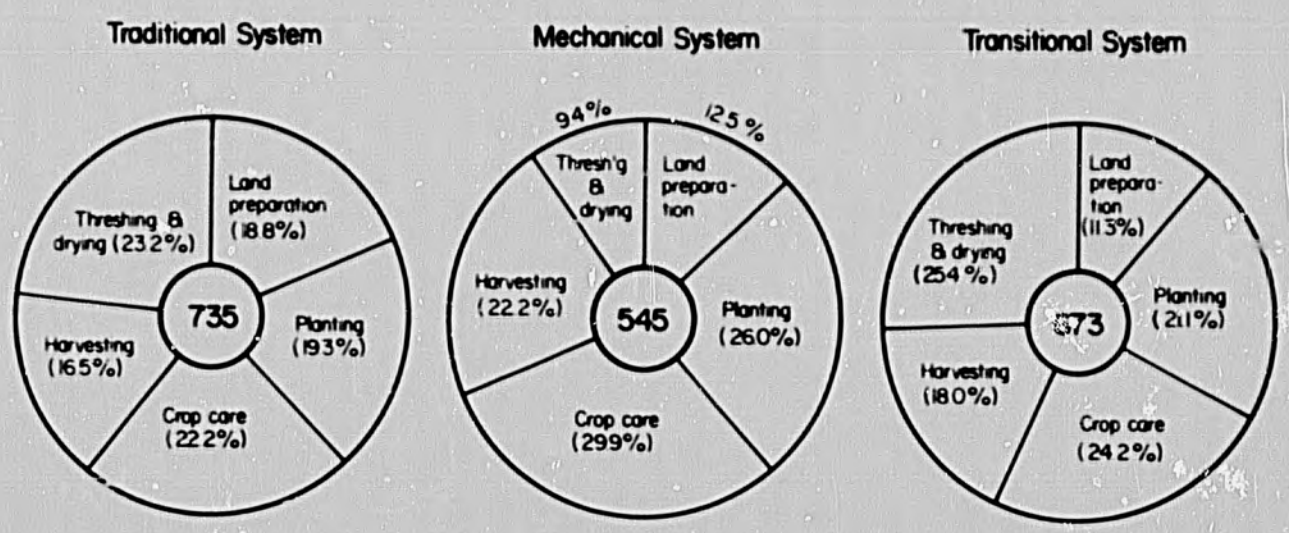

Fig. 2. Labor (labor hours) distribution by major task.

Table 4. Energy inputs (J x 10 /ha) for the mechanical rice production system.

Operation	Inputs[a]								
	Human	Animal	Machine	Fuel and oil	Seed	Fertil-izer	Insecti-cide	Herbi-cide	Total
Land preparation									1470.7
Primary tillage Secondary tillage	42.2	-	420.5	981.8	-	-	-	-	
Levee repair	26.2	-	-	-	-	-	-	-	
Planting									729.8
Seedbed preparation Seedling pulling Transplanting	112.7	-	-	-	617.1	-	-	-	
Crop care									3880.9
Fertilizer application	13.8	-	-	-	-	3243.3	-	-	
Insecticide application	17.2	-	-	-	-	-	304.1	-	
Herbicide application	13.8	-	-	-	-	-	-	74.8	
Weeding	215.9	-	-	-	-	-	-	-	
Harvesting									150.0
Cutting and stacking	150.0	-	-	-	-	-	-	-	
Threshing and drying									2484.4
Threshing Cleaning and bagging Hauling	41.1	-	157.1	300.6 53.7	-	-	-	-	
Drying	14.2	-	195.3	1722.4	-	-	-	-	
Total	645.1	0	772.9	3058.5	617.1	3243.3	304.1	74.8	8715.8
Energy equivalent (liters of diesel fuel)	16.8	0	20.2	79.7	16.1	84.5	7.9	1.9	227.1

[a]See Appendix A for constants and calculations.

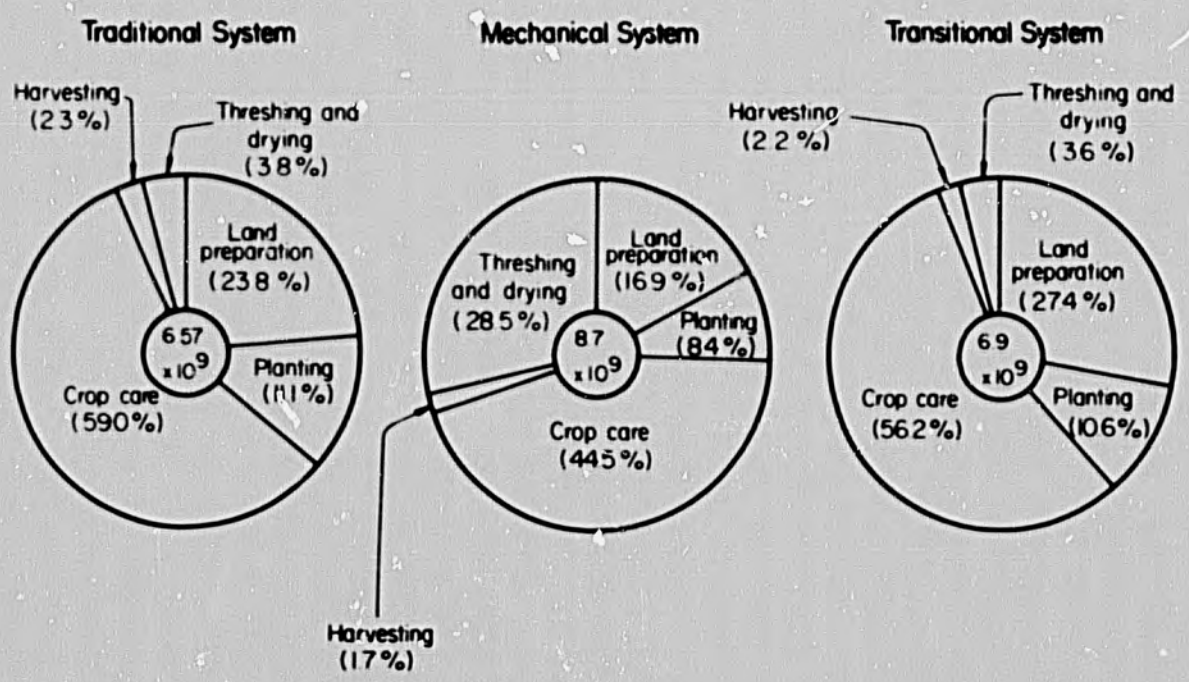

Fig. 3. Energy inputs (Joules) by major task.

Table 5. Energy inputs (J x 10^6/ha) for the transitional rice production system.

Operation	Inputs[a]								
	Human	Animal	Machine	Fuel and oil	Seed	Fertilizer	Insecticide	Herbicide	Total
Land preparation									1887.2
Primary tillage	3.4	-	151.9	1148.7					
Secondary tillage	38.4	408.2	110.4	-	-	-	-	-	
Levee repair	26.2	-	-	-	-	-	-	-	
Planting									729.8
Seedbed preparation, Seedling pulling, Transplanting	112.7	-	-	-	617.1	-	-	-	
Crop care									3880.9
Fertilizer application	13.8	-	-	-	-	3243.3	-	-	
Insecticide application	17.2	-	-	-	-	-	304.1	-	
Herbicide application	13.8	-	-	-	-	-	-	74.8	
Weeding	213.9	-	-	-	-	-	-	-	
Harvesting									150.0
Cutting and stacking	150.0	-	-	-	-	-	-	-	
Threshing and drying									249.1
Threshing, Cleaning and bagging	174.0	-	-	-	-	-	-	-	
Hauling				53.7					
Drying	21.4	-	-	-	-	-	-	-	
Total	784.8	408.2	262.3	1203.4	617.1	3243.3	304.1	74.8	6897.0
Energy equivalent (liters of diesel fuel)	20.5	10.6	6.8	31.3	16.1	84.5	7.9	1.9	179.6

[a] See Appendix A for constants and calculations.

contributed significantly to the increase, although decreases in human and animal energy offset some of the increase. Use of a 4-wheel tractor for primary tillage in the transitional system increased total energy requirements by only 5% and tillage energy by 20%, yet shortened the time required for land tillage from 105 to 43 hours. Many farmers pay for the added energy input to obtain the benefits of timely land preparation and reduce labor requirements.

Crop care and the related inputs make up more than 44% of the total energy inputs in all systems, primarily because fertilizer and agricultural chemicals require high amounts of energy in their production (Fig. 3, 4). Application rates used to calculate these energy costs approximate those used by Filipino farmers although they are less recommended by extension services for maximum yield. The high cost of these inputs, a reflection of high energy inputs in their production, is a primary reason for low application rates. This points to the need for more efficient application methods to increase the effectiveness of the chemicals and increase refinement of alternative fertilizer sources such as nitrogen-producing Azolla and composting. Root-zone placement of fertilizer can increase efficiency by up to 50% compared to traditional broadcast methods (IRRI 1978a), but a machine to apply the chemical efficiently and economically in the environment of the small Asian farmer has yet to be developed.

Reduced tillage or adoption of minimum-tillage practices could also contribute to energy reduction but weed control problems increase, so improved herbicides and more efficient application methods are required before net energy savings can be realized.

Human effort contributes a relatively small portion of the total energy consumed in each production system (Fig. 4, 5), never exceeding 13% of the total although 735 labor hours/ha is required to produce that share of the energy. This emphasizes the very low power production potential of humans and indicates that their abilities are most valuable in tasks that require decision-making capabilities as opposed to those requiring only routine energy inputs. Weeding, although still a laborious task, requires human decision capabilities (selecting the weeds from the rice plants)

and uses human energy more efficiently than such tasks as tilling with a hoe.

The input-output energy ratio or efficiency of each system is based on a 3.5 t/ha yield which is the average for the inputs used in this analysis. The input-output ratio is 6.57 for the traditional system, 4.95 for the mechanical system, and 6.26 for the transitional system. These efficiency ratios are in part an artifact of the assumption we have made relating to yield for the three systems included in the analysis. A higher yield without an increase in the energy inputs for any of the systems would clearly modify the rankings presented here. Alternatively, a decrease in the input of energy without a commensurate decrease in yield would also alter the ratios. Judged purely on the energy obtained in rice (output) to the energy required to produce the rice, the traditional system is superior. Empirical evidence substantiates the finding that efficiency in energy use declines as the total energy used in the system increases (Heichel 1973). Frequently this relationship comes about because systems with low energy inputs tend to involve high levels of land per unit energy input and high levels of human decision making per unit of energy input, with the result that output is more a product of these or other non-energy inputs. With the prevailing energy prices in the recent past and using available technology, lower efficiency ratios were acceptable in achieving higher absolute levels of yield and production. The evidence bearing on this issue clearly demonstrates that increased output and productivity have been the result of larger inputs of energy per unit of output.

To feed an increasing world population a higher production per unit of land is required. Hence, the use of greater cropping intensity, through substitution of mechanical for human and animal power, higher chemical application rates, and increased irrigation is necessary to supplement high-yielding varieties and improved management. These inputs are high energy consumers and will probably reduce the energy efficiency of the rice production system.

The rice production systems analyzed here are defined as rainfed. These are flooded wetland systems that receive all moisture from accumulated rainfall. More than 50% of South and Southeast Asia's rice land is classified as rainfed. Another 25-35% is irrigated for at least one crop with the remainder categorized as dryland in which water is not impounded (IRRI 1978b). Irrigation can increase crop yields even during the dry season when drought often occurs. Controlled water supplies can also mean the difference between a good crop and no crop during the dry season. The majority of the irrigation systems in Asia draw water, by gravity, from reservoirs or diversion structures. An increasing number of farmers are, however, turning to powered pump sets to draw water from shallow wells or low-lying water sources. Table 6 presents the energy requirements for a small, low-lift pump irrigation system. To maintain the energy efficiency of the traditional system, the yield would have to increase by 1.6 t/ha. Studies indicate that supplemental irrigation during the wet season, which requires less energy than the above example, can increase yields by as much as 0.35 t/ha (Herdt 1980). Irrigation during the dry season can double the annual yield compared to the rainfed water regime which permits only one crop per year. Therefore, irrigation can provide large increases in annual production with relatively small decreases in energy output-input efficiency.

Table 6. Energy requirements for low-lift irrigation system (dry season).

Input	J x 10^6 /ha
Fuel	2013.0
Labor hours	17.5
Machine use	941.0
Total	2971.5
Energy equivalent (liters of diesel fuel)	77.5

Assumptions:

10,000 m^3 water/ha	
3-m lift	
.75 hp-h/100 m^3 at 1-m lift[a]	
30% diesel engine efficiency	
Pump capacity - .75 m^3/min	
Pump set weight + repair equivalent	144 kg
Useful life	3000 h
Human energy	0.79 x 10^6 J/h
Labor hours	10% of pumping time

[a]Source: Johnson 1965.

COMPARATIVE ECONOMICS OF ALTERNATIVE SYSTEMS

Much of the energy in traditional agricultural systems is derived from on-farm sources. Labor and animal power are notable examples. As agriculture is modernized more resources are purchased outside of the traditional sector. For the three systems, it is evident that the incremental energy added is acquired largely from nonfarm sources. Figure 6 illustrates this increasing reliance on commercial forms of energy as one moves from the traditional to the more highly mechanized systems. In the present examples, the traditional system embodies about 60%, the transitional 73%, and the mechanical system 85% of the total energy needs in commercial forms. Removing chemical fertilizer from the traditional system would reduce commercial energy needs to about 20% of the total requirements, a condition common in areas where the introduction and the use of modern rice technology are not widespread. This diagram emphasizes the greater sensitivity of modern production systems to changes in energy costs compared to traditional technologies.

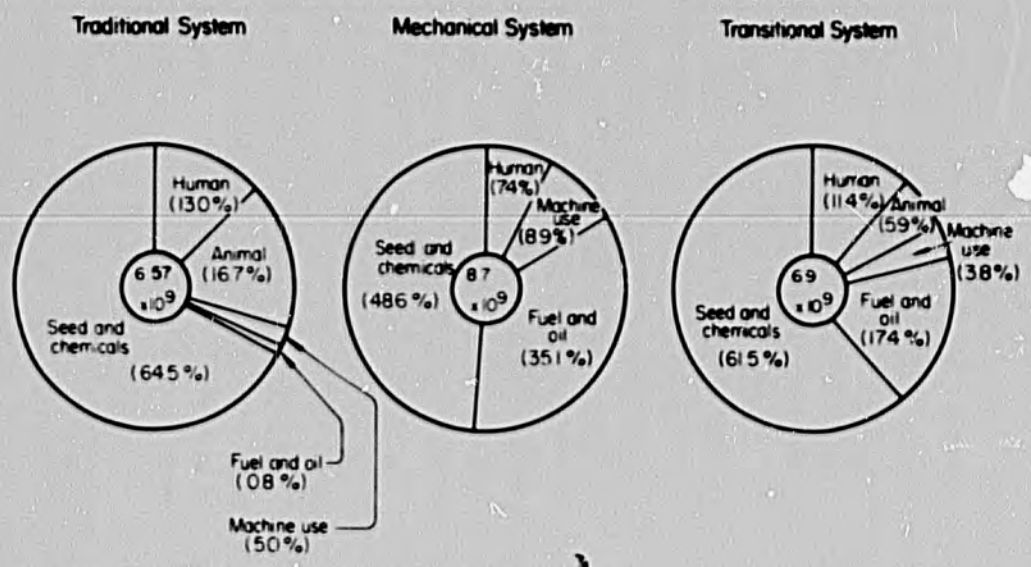

Fig. 4. Energy inputs (Joules) by source.

Table 7. Estimate energy equivalents for alternative production systems, in kg/ha of unmilled rice.[a]

Item	Traditional	Transitional	Mechanical
	Unmilled rice equivalent (kg/ha)		
Seed	50.0	50.0	50.0
Fertilizer	262.0	262.0	262.0
Insecticide	24.5	24.5	24.5
Herbicide	5.9	5.9	5.9
Fuel and oil	4.3	97.0	247.1
Machinery	26.7	21.1	62.6
Animal power	89.0	32.9	0
Human labor	69.2	63.6	52.1
Total	531.6	557.0	704.2

[a]Based on 2,952 Kcal per kg unmilled rice.

Table 7 contains a comparative energy budget in which all energy requirements have been converted to unmilled rice equivalents. To the farmer, the figures shown represent the amount of rice that must be produced to generate the energy needed by each system. Pricing the unmilled rice at US$0.16/kg gives the relative energy costs in monetary terms (Table 8).

In Table 9, inputs are valued at market prices. We can now compare the energy costs in Tables 7 and 8 with the monetary costs in Table 9. In energy terms, the use of chemicals and mechanical land preparation, threshing, and drying increase energy requirements significantly. In monetary terms, however, substitution of mechanical for animal and human energy decreases the average per-hectare costs. The use of machines substitutes low-cost fossil fuel energy for higher-cost man and animal energy. The use of market prices also allows us to examine the possible impact of changes in energy

Table 8. Relative costs (US$) of commercial and non-commercial energy in alternative rice production systems.[a]

Source	Traditional	Transitional	Mechanical
Commercial	51.75	65.68	96.34
On farm	33.38	23.52	16.32
Total	85.13	89.20	112.66

[a]Based on the data in Table 7 and all energy charged at the cost of energy in unmilled rice priced at $0.16/kg.

costs on choice of technique. An example is the price of fuel. Doubling the price of fuel reduces but does not change the comparative advantage of the mechanical system over others. Incorporating indirect effects of a fuel price change, such increases in the costs of machinery would, however, partially reduce the advantage of the transitional and mechanical systems.

Reviewing particular operations within each system, we find that crop care, particularly the use of fertilizer, uses the most commercial energy for all systems. In the mechanical system, fertilizer is closely followed by fuel and oil. These items are used at a much lower level in both the transitional and traditional systems. These findings reinforce our hypothesis that the development of technologies that use high-energy inputs such as fertilizer more efficiently is beneficial. Further exploration of alternative forms of energy such as biogas or use of crop residues for such operations as mechanical drying, which consumes almost 60% of the overall fuel requirements in the mechanical system, should also be highly beneficial.

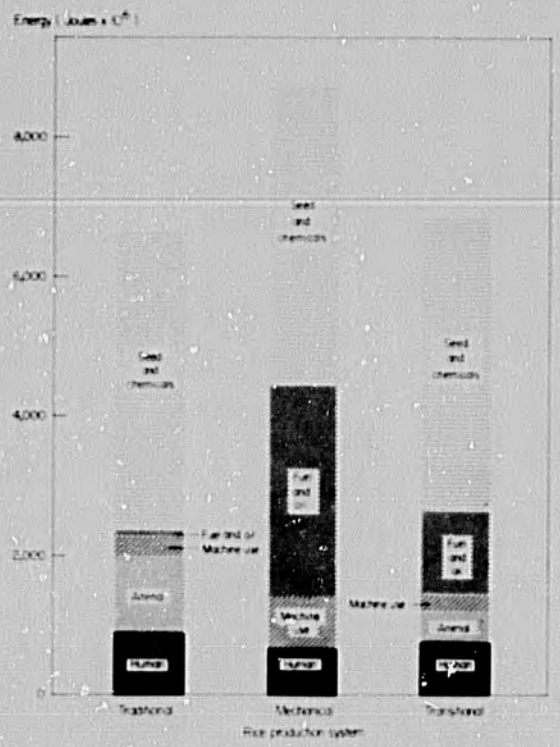

Fig. 5. Total energy inputs (Joules per hectare) by source.

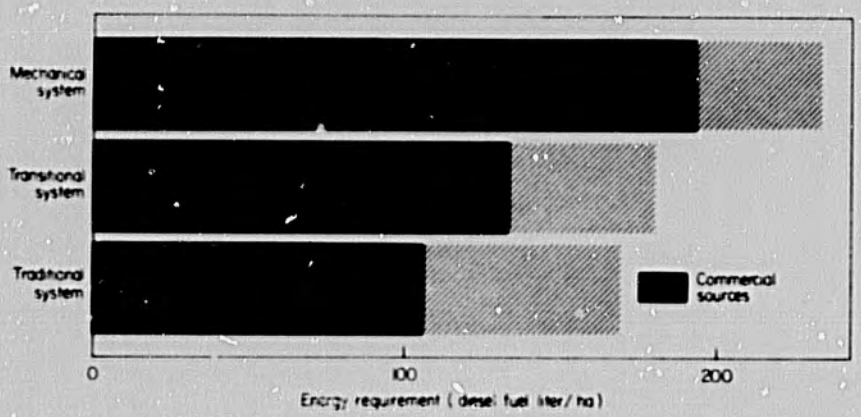

Fig. 6. Comparative level of commercial energy utilization for three alternative rice production systems.

Table 9. Costs of inputs (US$/ha) at market prices for alternative rice production systems.[a]

Item	Unit cost	Traditional	Transitional	Mechanical
Seed	0.16/kg	8.00	8.00	8.00
Fertilizer	0.58/kg N	23.20	23.20	23.20
Insecticide	36/kg a.i.	27.00	27.00	27.00
Herbicide	38/kg a.i.	26.60	26.60	26.60
Fuel[b]	0.193/liter	0.38	6.04	15.42
Machinery[c]	-	10.00	24.00	29.34
Animal power[d]	0.65/h	68.25	25.35	0
Human labor	0.17/h	125.00	114.46	92.68
Total		288.43	254.65	222.24

[a]Input prices are averages prevailing in rural areas of the Philippines. US$ = ₱7.35. [b]Fuel costs are valued in terms of diesel fuel equivalents (Tables 3, 4, and 5). [c]Includes only fixed cost component. [d]Based on daily rental rate without operator.

CONCLUSIONS

1. In most traditional small-farm food production systems human energy represents a relatively small portion of the total input energy.

2. As food production systems modernize, energy consumption increases, and the system becomes less energy efficient and increasingly more dependent on commercial forms of energy.

3. Modernizing the food production system is more sensitive to changing costs of purchased inputs because of reliance on commercial energy.

4. Development of methods and machines to more efficiently use high-energy inputs offers the most potential for reducing the total input energy of the food production systems, thereby making them less sensitive to input price fluctuations.

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Appendix A. Constants and calculations.

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1. Energy values (J x 10^6)	
Gasoline: .74 kg/liter at 48.16 - 43.45/kg = 33.89/liter	Baumeister 1958
Diesel fuel: .87 kg/liter at 45.08 - 42.36/kg = 38.36/liter	Baumeister 1958
Kerosene: .83 kg/liter at 45.84 - 42.97/kg = 36.68/liter	Baumeister 1958
Lub oil: .93 kg/liter at 44.15 - 41.62/kg = 40.10/liter	Baumeister 1958
Nitrogen: 80 - 82.2/kg = 81.1/kg N	Faidley 1977, Green 1978
2,4-D, 2,4,5-T: 85 - 135/kg a.i. = 110.0/kg a.i.	Faidley 1977, Green 1978
Carbofuran: 357 - 454 kg a.i. = 405.5/kg a.i.	Green 1978, Rutger and Grant 19__
Seed = 12.36/kg	Faidley 1977, Leach /1976/
Machinery: 86.7-90/kg = 88.4/kg	Duff 1978

2. Human energy expenditures (J x 10^6/h) by task	
Tillage with animal (plowing and harrowing)	1.05
Tillage with tiller (plowing and harrowing)	1.21
Tillage with 4-wheel tractor (estimate)	0.79
Harrow with animal	0.98
Levee repair (assumed same as transplanting)	0.79
Transplanting	0.79
Fertilizer application (used herbicide application value)	1.72
Insecticide application (used herbicide application value)	1.72
Herbicide application	1.72
Weeding (average of hand and manual rotary)	1.56
Harvesting (average of cutting and stacking)	1.24
Threshing (manual)	1.21
Threshing (mechanical) (prorated stacking and table thresher)	1.67
Drying (sun) (author estimate)	0.79
Drying (mechanical) (author estimate)	1.02

3. Animal energy expenditure (J x 10^6/h)		
Tillage with water buffalo	10.47	Kiamco and McMennamy 1978

4. Input usage rates

Operation	Input	Rate
Power tiller tillage	Diesel fuel	.7 liter/h
	Oil	3.0 liters/100 h
4-wheel tractor tillage	Diesel fuel	6.86 liters/h
	Oil	10 liters/100 h
Threshing	Gasoline	1.22 liters/h
	Oil	1 liter/25 h
Drying	Kerosene	2.7 liters/h
	Gasoline	1.5 liters/h
	Oil	1.0 liters/25 h
	Seed	50 kg/ha[a]
	Fertilizer	40 kg N/ha[a]
	Insecticide (carbofuran)	.75 kg a.i./ha[a]
	Herbicide (2,4-D, 2,4,5-T)	.7 kg a.i./ha[a]

[a]Average rates used by Philippine farmers (IRRI 1978 a,b,c).

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