Energy Flows in Rural Communities

TECHNICAL PROGRESS REPORT 1983

CATIE

EEC

EUROPEAN ECONOMIC COMMUNITY

TROPICAL AGRICULTURAL RESEARCH AND TRAINING CENTER

CATIE is a civil, non-profit, autonomous association scientific and educational in nature. It carries out, promotes and stimulates research, training and technical cooperation in agricultural, animal and forestry production in order to offer alternatives to the needs of the American tropics, particularly in the countries of the Central American Isthmus and the Antilles. The Center was created in 1973 by the Government of Costa Rica and IICA. Accompanying Costa Rica as a founding member, Panamá joined in 1975, Nicaragua in 1978; and Honduras y Guatemala in 1979.

INTRODUCTION

One of the most important objectives of the Project "Energy Flows in Rural Communities" is to detect the processes in which the use of this resource could be bettered. This means to collect information and develop models to increase the energetic efficiency in a way compatible with an increase in productivity.

In order to achieve these objectives, it was considered convenient to focus the study on representative ecological areas of Central America. In some of these areas, detailed studies of production systems had previously taken place through dynamic surveys so that information on the inputs and outputs of the material and energy of each agroecosystem of the farm was available.

The project leader was hired in January 1983. The first months were dedicated to establishing contacts with other institutions which were also studying energetic sources in rural areas. Literature concerning this subject was gathered, including scientific articles as well as book purchases.

Once this phase was completed, and with some semi-elaborated information gathered from selected areas, an agronomist was hired (May 1983) to organize the information and make it compatible for the energetic analysis.

The agronomist will also gather field data whenever there are information gaps. In a second phase, the agronomist will manage the field trials.

Methodology

The selected areas were studied by the total energetic analysis of each group. Through this type of analysis all inputs and outputs were transformed into energy values (usually kilocalories).

The energy of the harvestable products of many crops was obtained from the literature. Such values were available for the basic grains and many tropical roots. Also obtained from the literature was information on the energetic value of fertilizers, herbicides and pesticides in general, in their different formulations.

A problem encountered was in the characterization of the farmer hand labor and the hired hand labor from the energetic point of view. In order to characterize the physical labor of a farmer, data was taken from a study done on rice workers in the Phillippines. In this study it was determined that a farmer spends an average of 350 Kcal/hour of physical labor in one crop.

In order to characterize in an energetic way the money spent in hired hand labor, many authors use the relation: national energy consumption/ gross national product. In the case of Costa Rica, changing the salary to dollars, the relation (for 1981) would be: 5795 Kcal/US$. However, this energetic evaluation was not considered satisfactory since it was taken from a general average of the country. The evaluation is even less satisfactory if we consider that most of the GNP is produced in rural areas, and most of the energy is consumed in urban areas.

As an alternative to this method is was considered that small farmers (for whom CATIE develops technology) spend most of their money on food. For this reason, the average diet, its monetary value and its calorific was studied in order to change the money into energetic equivalents. The relation between diet, price in 1981 colones, and Kcal/¢ can be seen in Appendix 1.

The same methodological problem was encountered with crops that do not produce energy in the way of food, for example tobacco and, to some extent coffee. However, we can consider these crops as money generators, with which energy can be bought. Therefore, a transformation was done of the money obtained from the harvested crop sold, to energy, in a similar way to the determination of the energetic value of the money spent on hand labor.

Formulation of a Detailed Model

Represented in Appendix 2 is the detailed model of a maize crop with some of the energy flows quantified. The symbols used correspond to the "energetic circuit language" developed by H.T. Odum (explained in Appendix 3).

The next step is the formulation of the mathematical relations between variables, in order to achieve the simulation of different alternatives in the energy flows. Later on, a model incorporating all the agroecosystems of a farm will be completed in order to study the interaction between them.

In addition, optimization models will be developed in order to consider the way to optimize the energetic efficiency, the net energy and the hand labor efficiency.

Characterization of the Studied Areas and Preliminary Results

1. Costa Rica

1.1. Guácimo, Jiménez and Cariari

The study region is located in the west-central area of the Atlantic zone, province of Limón, Costa Rica (see Figure 1). This region is characterized by two vegetation types or life zones (as described by Holdridge):

Guácimo and Jiménez: Humid tropical forest with an annual rainfall estimated between 2500 and 3500 mm.

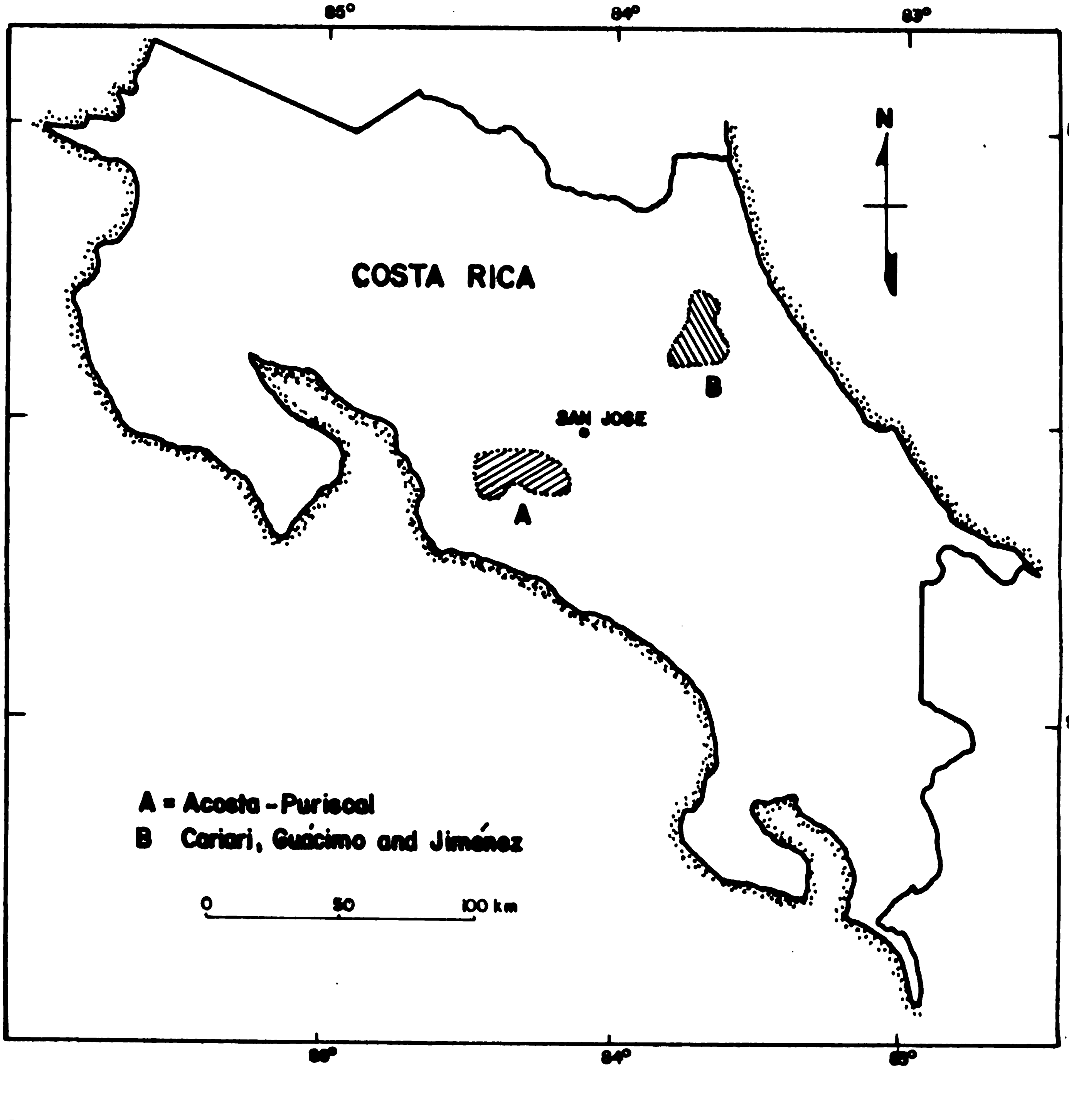


Fig. 1 Localization of selected study areas in Costa Rica.

Cariari: Humid premontane forest, with an annual rainfall ranging from 3500 to 4500 mm.

A two week dry period often occurs in August, while in July and December strong rains can cause floods. The area is flat and the soils have been classified as: ultisols, oxisols and histosols.

In 1981, a dynamic survey of farm activities was carried out on a group of farms. One of the objectives was to validate two alternative technologies for maize products and compare them with the farmers own practices.

The two alternative technologies tried out on the farm were:

a. Alternative weed control technology.

b. A more complete package which included weed control, fertilization and insecticide application.

Summary of Results

A. Net and Gross Energy

A.1. Cariari

Figure 2 shows the net gross energy as a function of the energy input. The quantities of the energy inputs ranked in the order:

Farmers' own technology < weed control technology < complete technological package.

In the case of the weed control technology, an increase of approximately 50% in the invested energy produced an increase of almost 130% in the energy of the harvested maize. The net energy result is similar. Fertilizer application produced a small decrease of the gross energy, and a greater decrease in the net energy.

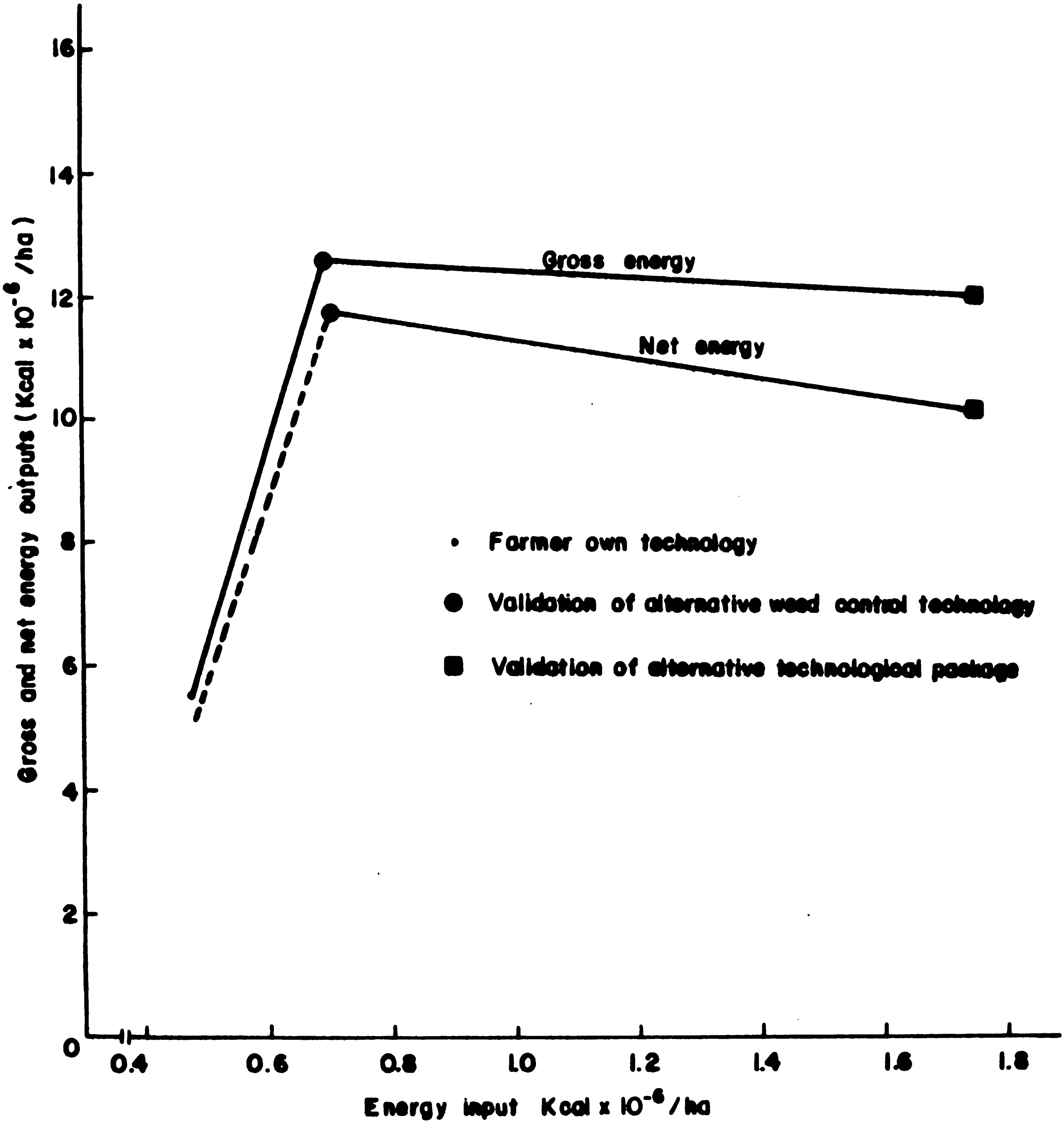


Figure 2 Relation between the gross and net energy output and the energy input for different maize cropping technologies in Cariari

It is probable that the difference between the weed control package and the complete package is not statistically significant as far as gross energy is concerned. As other factors are limiting the production, energy inputs in the form of fertilizers are ineffective, or negative, if net energy is considered.

A.2. Guácimo and Jiménez

In this area, the weed control technology produced an increase of more than 100% in the energetic production of maize, with only a 18% increase in the energy input (see Figure 3).

The additonal inputs of fertilizers and insecticides produced a slight increase in both gross and net energy outputs, but this was small compared to the increase due to weed control.

B. Energy Ratio

Another way of characterizing the energetic relations of a crop is through a consideration of energy production per unit energy input.

The relation harvested energy/energy input as a function of the energy input can be seen in Figure 4. The tendencies are similar to those in Figures 2 and 3.

The application of the weed control technology increased the energy input, but its effect on the efficiency of this input was considerable. The effect is more obvious in Guácimo than in Cariari, probably due to the different climatic conditions.

The application of the complete technological package reduced the energy ratio to lower values than the ones obtained in the farmer's traditional practices both in Guácimo and Cariari. This effect was greater in Cariari than in Guácimo.

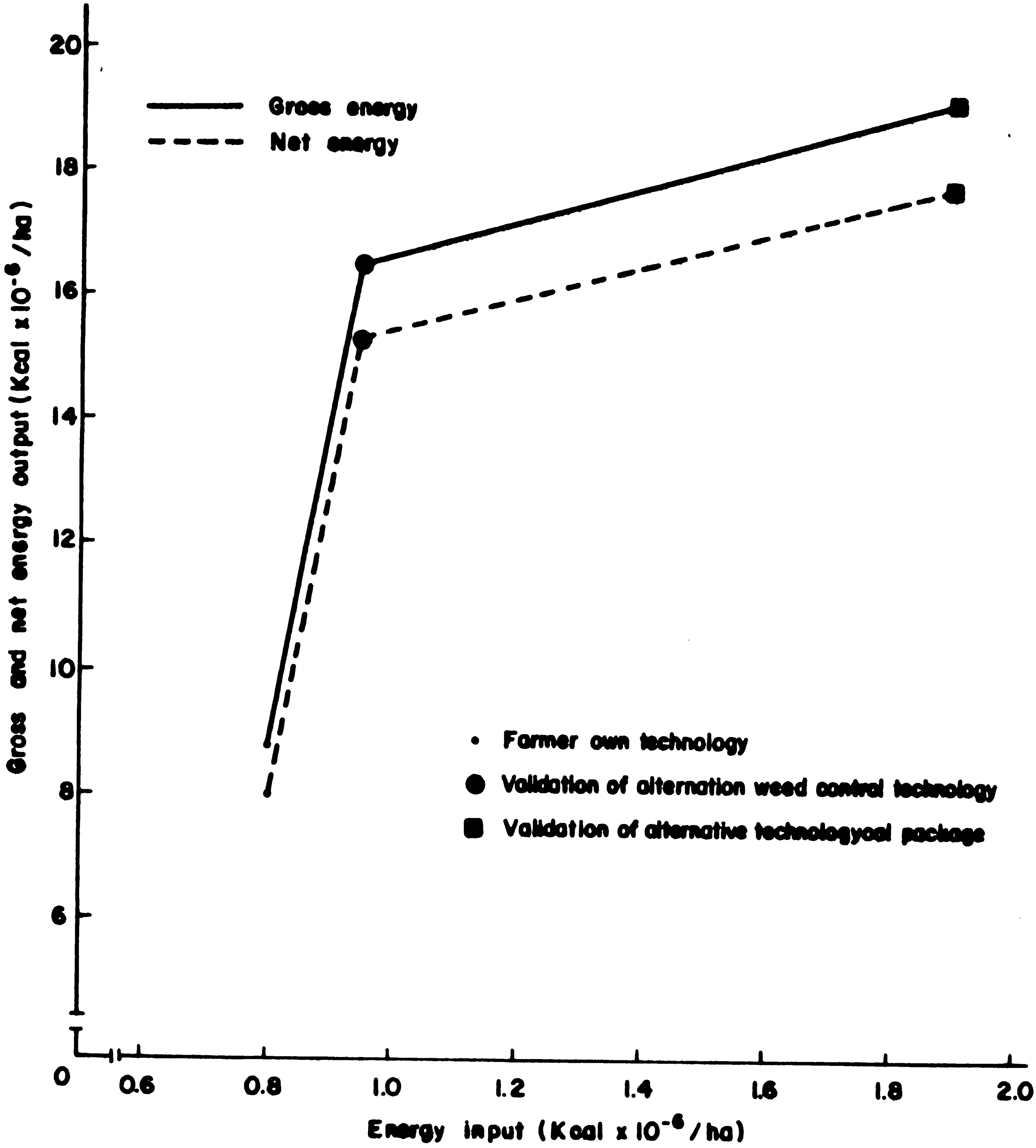


Figure 3 Relation between gross and net energy output and the energy input for different cropping technologies in Guacimo / Jimenez

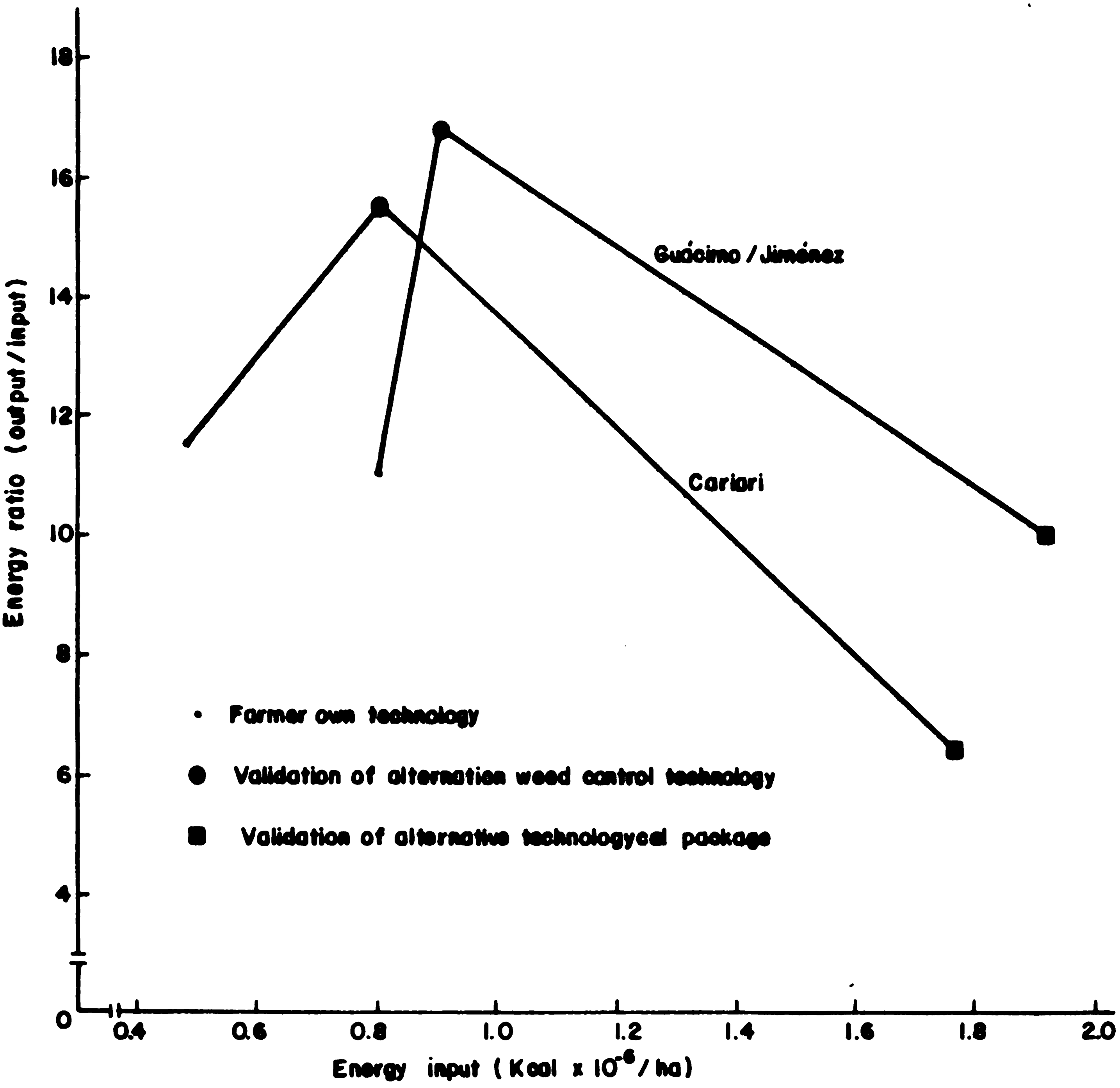


Figure 6 Relation between the energy ratio and the energy input for different maize cropping technologies in Guacimo / Jimenez

It is interesting to note, however, that the energy ratio is much higher in both technologies and localities than in maize agriculture in developed countries.

C. Hand Labor Efficiency

Another variable which characterizes the energetic behaviour of an agroecosystem is the amount of Kcal generated per hour of labor (work). Figure 5 shows the efficiency of hand labor (Kcal/hour of work), in relation to the energy used in maize production. First of all, it was observed that for any level of energy input, the efficiency in hand labor was greater in Guácimo than in Cariari. The difference is not due to the amounts of hand labor, since it is similar in both locations, but to the higher productivity obtained in Guácimo.

The application of the weed control technology produced a high increase of hand labor efficiency in both cases. This result is obtained due to an increase in maize production as well as a reduction of worked hour/ha in the manual weed control.

The application of the complete technological package has a similar effect to the one shown in Figures 2 and 3. The efficiency reduction in Cariari is due to the fact that the harvested energy did not increase, as well as to an increase in the hand labor used both in fertilization and insecticide application.

Conclusions and Future Plans

Table 1 shows the energetic costs of each production technology in both Guácimo and Cariari. Also en Table 1 are the percentages with which the hand labor and inputs contribute to the total.

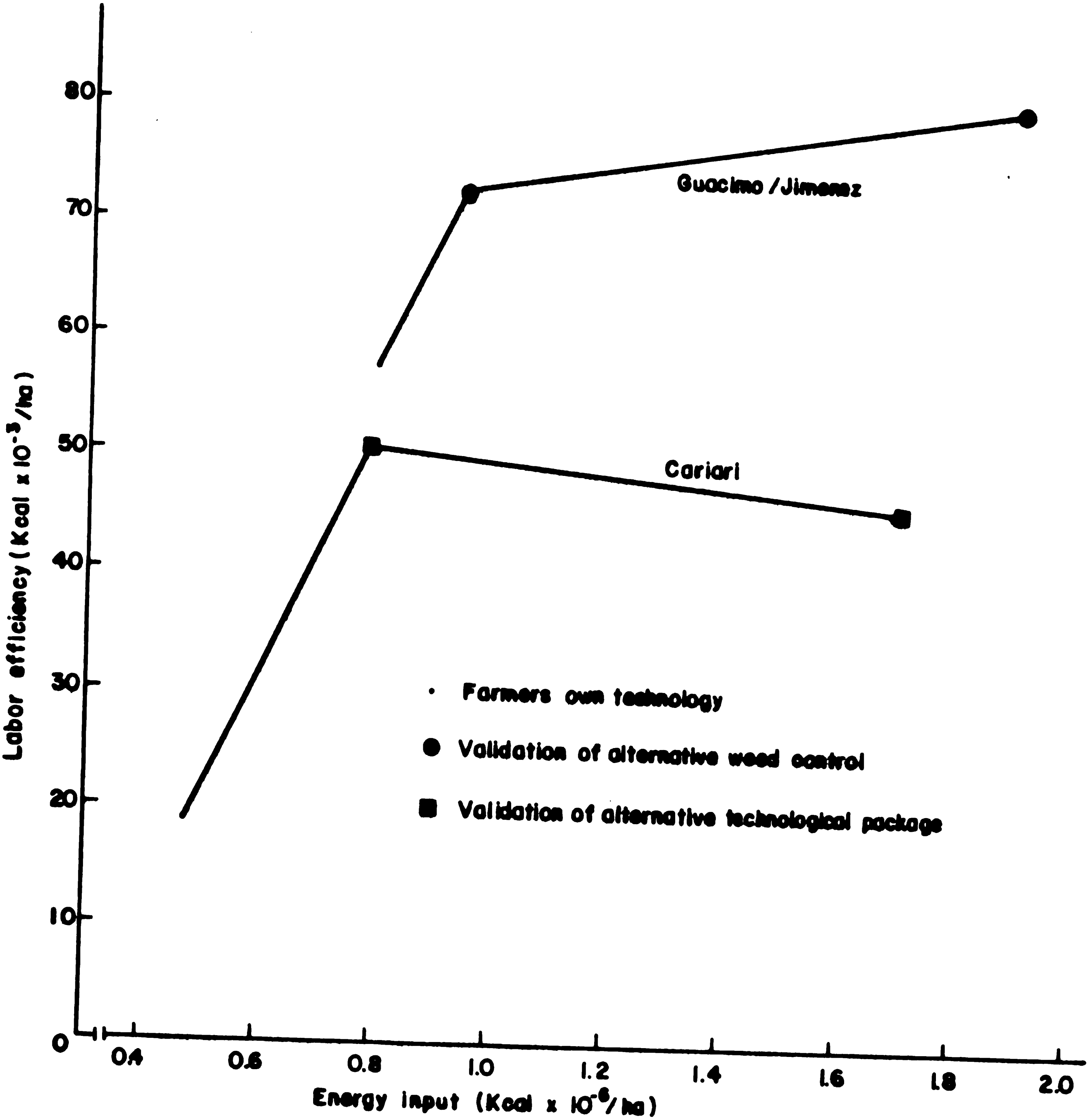


Figure 5 Relation between labor efficiency and energy input for different maize cropping technologies in Cariari and Guacimo / Jimenez

Table 1: Total Energy Input for Maize by Technological Patterns and Selected Production Factors in Cariari and Guácimo/Jiménez Regions. 1981.

CARIARI

TECHNOLOGY	Total Energy Input (Kcal/ha)	% Fertilizers	% Herbicides + Pesticides	% Labor
Farmers' own technology	479304	58.9	16.11	24.71
Validation of alternative weed control technology	803602	72.64	16.20	10.8
Validation of alternative technological package	1763943	86.66	7.85	5.48

GUACIMO/JIMENEZ

TECHNOLOGY	Total Energy Input (Kcal/ha)	% Fertilizers	% Herbicides + Pesticides	% Labor
Farmers' own technology	800000	69.2	17.9	12.8
Validation of alternative weed control technology	947000	64.61	26.8	8.6
Validation of alternative technological package	1914324	82.41	11.27	6.3

The greatest percentages of the energy input in any of the production systems are due to the fertilizers. The most important of these are the compound (N-P-K) and ammonium nitrate.

As can be seen in Figures 2-5, an increase in the energy input can cause a strong increase in the energetic indicators, as long as the correct technology is used. These findings refute the general assertion that imported energy inputs increase yields but lower the energy efficiency.

Various sources of information state that the soils in Guácimo and Cariari are low in some elements, especially zinc. If this is true, experiments should be designed in a way such that the lacking (limiting) elements should also be applied, in addition to normal fertilizers.

Due to the high rainfall in both localities, but especially in Cariari, it can be expected that losses of fertilizer through leaching are severe. This indicates the need to establish different forms of applying chemical fertilizer and the use of organic fertilizer, in order to diminish the losses caused by leaching. These experiments can be included in a second phase of the Energy Flows Project.

Information has also been gathered in this region for crops such as cassava, cacao and livestock activities. This information will be analyzed, in order to obtain a complete diagnosis of the energy flows in these communities.

1.2. Acosta-Puriscal

The study region is located in the central highlands on the southeast slope of the mountains forming the southern limit of Costa Rica's central valleys (Figure 1). This area includes life zones ranging from moist tropical forest to premontane rain forest with altitudes from 800 m to 1200 m.

Annual rainfall in Acosta ranges from 1300 mm to 3400 mm, with an average of 2300 mm. In Puriscal annual rainfall varies from 1600 to 3500 mm with an average of 2100 mm. The rainy season begins in May and extends until November in Acosta and until December in Puriscal.

The average monthly temperatures vary from 19.6°C to 22.4°C. The topography of the area is very rough with "moderate" slopes from 30% to very steep inclines of more than 80%, with very few flat locations.

Soil types found are ultisols, oxisols and in few places, inceptisols. During 1981 various surveys were done of the farms in this area. The information gathered from these surveys is basically the same as the type obtained in Guácimo and Cariari and includes annual crops like maize, bean (growth both in monoculture and as a maize-bean intercrop) and tobacco, and perennial crops including coffee, bananas, and citrus.

The monoculture beans are cultivated in two different ways. One is the planted bean, which involves cleaning, preparing the soil, weed control and fertilization, the other way is called "covered bean", which consists in broadcasting the seeds and then, cutting the existing vegetation to form a mulch. This latter type of production requires very little hand labor and inputs.

Summary of Results

Table 2 shows an energetic analysis of an average tobacco plantation in Puriscal. This production system requires heavy inputs of hired labor, especially at harvest time. The nitrogen fertilizers and compound formula show the highest percentage of total energy consumed (77%).

Table 3 shows a similar analysis for a coffee plantation in Puriscal. Again we can see that the fertilizer contributes 85% of the total energetic

Table 2: Energy analysis of tobacco production in Puriscal (Costa Rica)

Labor input	Hr/Ha	Energy (Kcal/Ha)
Land preparation	24	8400
Ploughing	240	84000
Planting	96	33600
Weeding	168	58800
Fertilizing	96	33600
Application of herbicides	15	5250
Application of other pesticides	20	7000
Harvest	448	156800
Hired labor	208 (= 1248 ¢)	243553
	Sub-total	631003
Agrochemical inputs	**Kg/Ha**	
N-P-K	1000	3130900
NO_3NH_4	25	155350
Herbicides	1.2	131756
Other pesticides	8	222160
	Sub-total	3640166
Total energy input		4271169
Yield (kg/ha) 1144 kg/ha (35882 ¢)		9095669
Energy ratio (output/input)		2.14
Net energy output		5677663
Labor efficiency (Kcal/Hr)		7461

Table 3: Energy analysis of coffee production in Puriscal.

Labor input	(Hr/Ha)	Energy (Kcal/Ha)
Land preparation	3.2	1120
Planting	24	25200
Weeding	168	58800
Fertilizing	88	30800
Application of other agrochemicals	16	5600
Pruning (coffee trees)	104	36400
Pruning (shade trees)	5	1750
Harvest	664	232400
Hired labor	160 (= 960 ₡)	187349
	Sub-total	579819
Agrochemical inputs	**(Kg/Ha)**	
N-P-K	313	979972
NO_3NH_4	449	2790086
Herbicides	.6	65878
	Sub-total	3835936
Total energy input		4415745
Yield 1014.3 kg coffee (Gold) (35280 ₡)		8973070
Fuelwood (1081 kg)		5137315
TOTAL OUTPUT		14080385
ENERGY RATIO (OUTPUT/INPUT)		3.19
NET ENERGY		9664640
LABOR EFFICIENCY (Kcal/Hr)		11137

cost. Coffee has a higher energetic yield with respect to tobacco, if we consider the wood left over after pruning. This wood is usually used as fuel for cooking and is of a high caloric value (4750 Kcal/kg).

Another source of energy obtained from coffee is the pulp of the fruit. The pulp, which constitutes about 41% of the total fruit weight, can be dried and used as fuel with a caloric value of 3100 Kcal/kg. The energetic cost of the pulp processing is not included in the energetic analysis of Table 3, since it was not analysed.

Table 4 shows the energetic analysis of for annual crops. As can be seen, the covered bean shows the highest energy ratio, and the lowest net energy. The latter is due to the low yield of this crop. If we consider the net energy and the energetic efficiency of hand labor, the most efficient crops would be maize and bean grown in association (intercrop) and maize monoculture.

Conclusions and Future Activities

In the case of coffee and tobacco, the highest energetic consumption factors are the fertilizers, mainly nitrogen. In the case of coffee, tobacco, and planted bean there is a linear relation between fertilizer and yield. This is not so in the maize and maize-bean system. From this, it can be supposed that there is another limiting factor, or that strong rains in the area cause fertilizer losses through leaching.

Another problem encountered in this area, which probably contributes in the high use of fertilizer, is erosion, caused by a combination of steep slopes and heavy rainfall. For this reason, an experiment to protect the soild and fertilize it with mulch from Gliricidia sepium (madero negro) is being conducted in Puriscal. Soil variables and maize yields from fertilized

Table 4: Energy Analysis of Annual Crops in Puriscal (Costa Rica)

Energy Inputs	%	Maize/Beans (Kcal/ha)	%	Covered Beans (Kcal/ha)	%	Planted Beans (Kcal/ha)	%	Maize (Kcal/ha)
ertilizers	71.36	1012332			46.54	325613	64.88	1004469
ther agrochemicals	52	73748			10.23	71620	11.8	182725
abor input	14	198800	35.97	86800	21.21	148400	11.88	184000
ired labor	1.38	19600	7.76	18735	4.0	28000	6.65	103142
eed	8.04	114132	56.27	135720	18.0	125976	4.77	73920
otal energy input	100.00	1418612	100.00	241255	100.00	699609	100.00	1548156
NERGY OUTPUT (Kcal/ha)		6437040		1611240		3480000		7258240
NERGY RATIO (output/input)		4.53		6.67		4.68		4.97
ET ENERGY (Kcal/ha)		5018428		1369985		5710084		2780391
ABOR EFFICIENCY (Kcal/ha)		10315		6103		6904		11782

and non-fertilized crops will be compared in the future. Comparison of the energy balances of crops receiving mulch from leguminous tree species and non-leguminous species will also be carried out. A graduate student is undertaking his thesis on this subject, under the direction of the research leader of the Energy Flows Project.

Another study proposed is the use of coffee pulp as fertilizer which has a nitrogen content of 2%. At present, this material is not being used as fertilizer, fuel or animal feed, and is disposed of in the rivers, thereby causing pollution. CATIE is installing a processing plant for coffee, which could be used to make the coffee pulp useful as fertilizer. Another alternative is to process the pulp on-farm, as is done in some areas of Colombia.

Future plans include the completion of analysis for Puriscal, and for Acosta, in order to establish a diagnosis of energy flows both at farm level and a community level.

2. Nicaragua

2.1. Jinotega

This region is located around Lake Apanás on the side of the Cordillera Isabelia (see Figure 6). The region includes areas characterized as tropical dry forest, sub-tropical humid forests and mountain rain forest life zones.

The region was stratified into three areas which differ, apart from altitude, principally in rainfall conditions. Detailed information was gathered in this area in 1981, mainly through surveying farmers. In the near future, this information will be organized in order to analyze the energy flows.

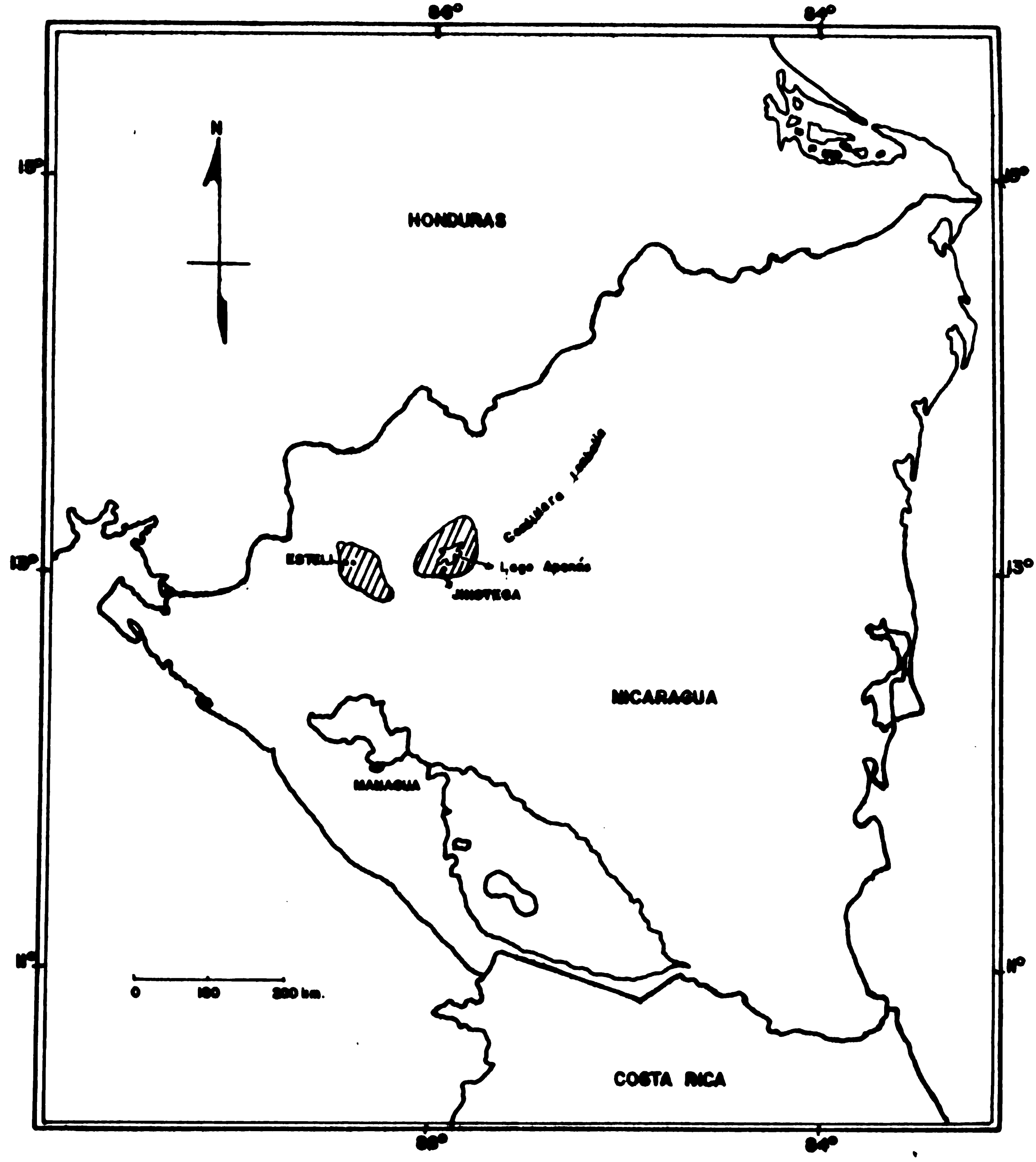


Fig. 6 Localization of selected study areas in Nicaragua.

2.2. Estelí

The Estelí region is located between 12° 30' and 14° 30' north and 85° and 86° 45' west (see Figure 6).

Mean annual temperature varies from 22.5°C to 25°C. Mean annual precipitation varies across the region from 700 mm to 1600 mm with a rainy season from May to September and a marked dry season from November to April.

The soils of the region mainly are mollisols, which accupy the greatest part of the region. Also alfisols, inceptisols, entisols and vertisols are found in small extensions in the interior valleys north and west of the region.

At present surveys are being done to obtain information concerning the labor requirements, materials and monetary inputs and production outputs.

In May 1983, the research leader traveled to Estelí in order to supervise the present activities and to help with the future information gathering. Processing this information is planned for the end of 1983.

3. Honduras

3.1 Comayagua

The study region is located at 87° 50° west and 14° 30' north (see Figure 7). It includes the Comayagua Valley and the area around El Rosario. The rainy season extends from May to Octover and the dry season from November to April. There tends to be a dry spell of 2-4 weeks during July and August, known as the "canicula". The average annual rainfall is around 900 mm. The man temperature in the valley varies from 23°C to 26°C. This region is characterized by alluvial soils.

During 1983, work was initiated to collect information from the farmers of the area. As irrigation is very common in this area, information about

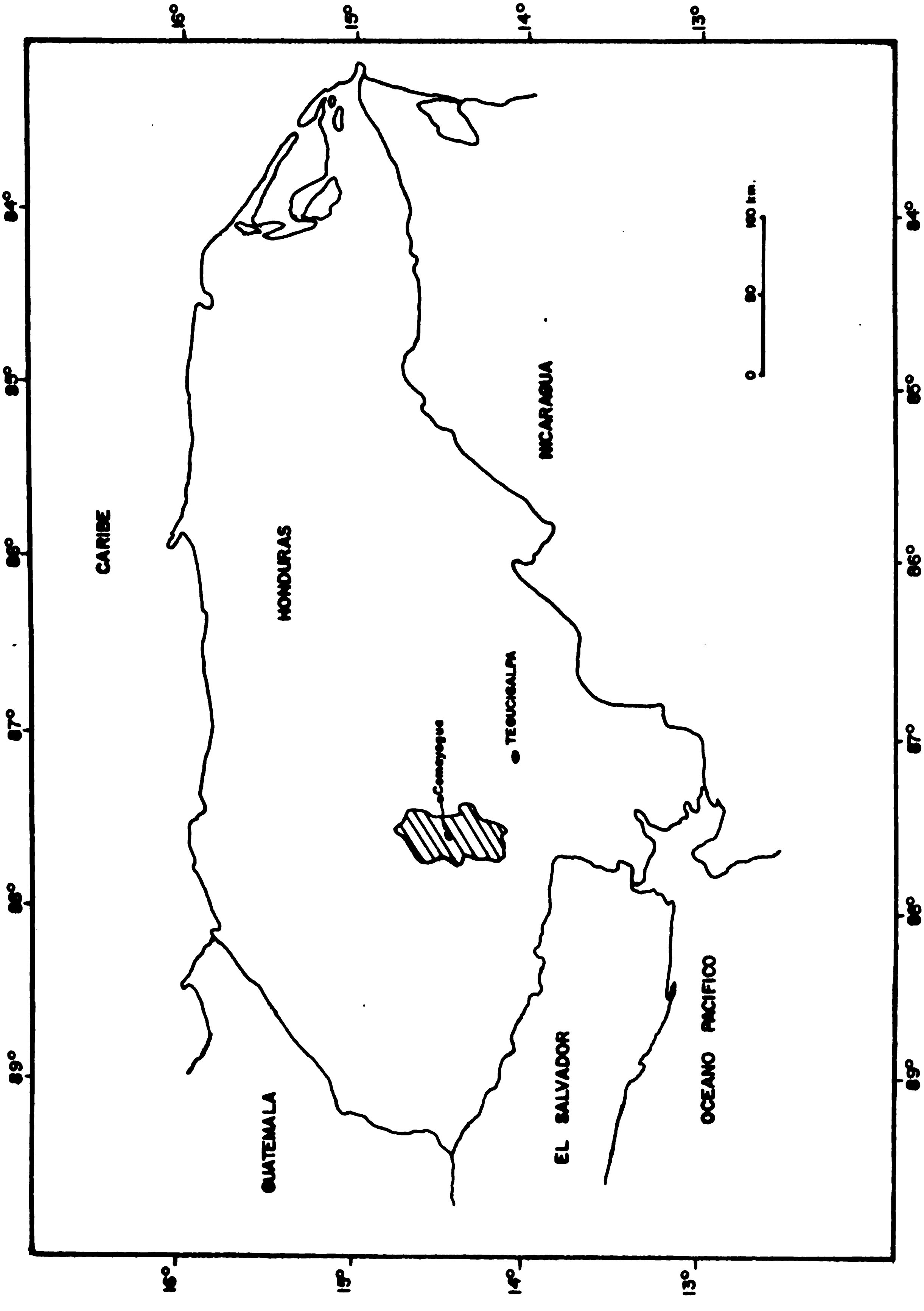


Fig. 7 Localization of selected study area in Honduras.

the materials used in this activity is also being gathered.

In April 1983, the research leader of the Energy Flows Project traveled to Honduras to see the different cropping systems and possible problems regarding irrigation systems. As a result of this trip, a survey concerning irrigation activities was developed. In addition, another questionnaire to estimate wood consumption has been developed. Two types of surveys were carried out; one on individual farms, and one on production cooperatives, in order to compare their different energy strategies.

Other Activities

Teaching: From the middle of June until September, the project leader was in charge of teaching the "Agroecosystems", a course for post-graduate students. During the last week of August he participated in the course "Research and Development of Technology", organized by the Plant Production Department. This course, which will last 3 months, is being given to Central and South American students.

In March, the project leader attended a week-long intensive workshop with ICRAF personnel (International Council for Research in Agroforestry). The main objective was to develop agroforestry alternatives for the Acosta-Puriscal region. In this workshop, several agroforestry techniques were discussed.

ICRAF personnel will write a document, in the form of research projects, using the data and ideas discussed in the workshop.

Appendix 1: Daily diet of nutriments/person in the rural dispersed area of Costa Rica.

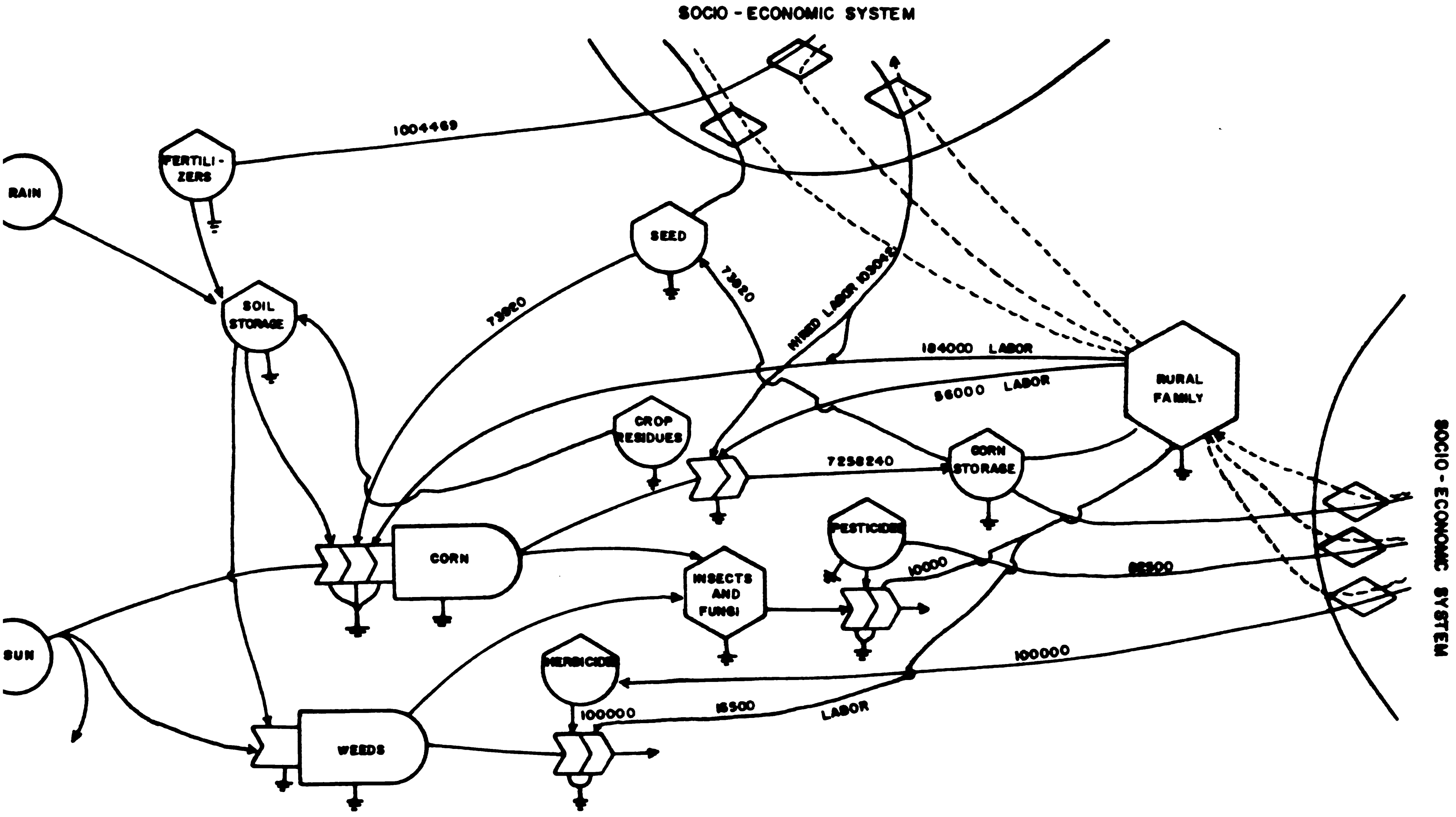
Calories	(Kcal)	2184
Proteins	(g)	57.00
Fats	(g)	55.50
Carbohydrates	(g)	373.00
Calcium	(mg)	740.00
Phosphorus	(mg)	1075.00
Iron	(mg)	14.10
Retinal (vitamin A)	(mg)	478.00
Thiamine	(mg)	0.92
Riboflavin	(mg)	1.09
Niacin	(mg)	9.90
Vitamin C	(mg)	40.00

Diet cost for 1981 : ¢8.60

Transformation of colones (¢) to Kcal :

$$\frac{\text{Income in Colones} \times 2184 \text{ Kcal}}{¢8.60} = \text{Caloric value of money}$$

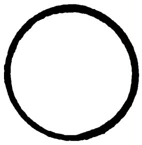
<u>NOTE</u>: In the case of hired labor the energetic value of physical labor was subtracted from the caloric value of money.



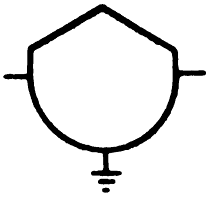
Appendix 2 Energy flow diagram for a crop maize production system in Puriscal, Costa Rica (Numbers in Kcal / ha)

IICA - CIDIA

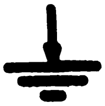
Economic transaction. Energy (solid line) and money (dotted line) flow in an opposite direction.



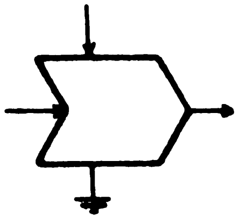
Outside source of energy - forcing function.



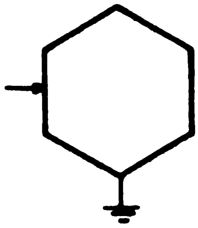
Tank. A compartment of energy storage within the system.



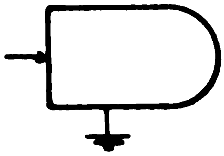
Heat sink. Dispersion of potential energy into heat that accompanies all energy transformation and storage.



Work interaction. Intersection of two or more flows.



Consumers. Unit that transforms energy quality, stores it and feeds it back to improve inflow.



Producers. Unit that collects and transforms low quality energy under control of high quality flows.

Appendix 3: Symbols of the Energy Circuit Language Used in the Energy Flow Model of Appendix 2