FORECASTING CHANGES IN HUMAN ENERGY EXPENDITURE ASSOCIATED WITH AGRICULTURAL DEVELOPMENT:

A SAMPLING PROCEDURE FOR THE DRY ZONE OF CEYLON

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In much of the low-income world, unemployment is rapidly overtaking food production as the chief concern of politicians and planners. The well-documented farm-to-city migration continues to gain momentum at a time when industry is increasingly capital intensive. If political turmoil is to be averted, new sources of employment must be found. There are growing indications that careful investment in agriculture can help strengthen the demand for labor.

Governments committed to reducing unemployment must, of course, evaluate numerous investment possibilities. Precise data linking labor requirements to land at various levels of technical input (e.g., irrigation, multiple cropping) are not available for the tropics. This is due, in part, to problems with traditional means of measuring human energy expenditure. Were this data available, it would seem possible to work toward the creation of optimum

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labor-land ratios at alternate levels of technical input, and in this manner, develop elasticities of labor demand for specific types of investment in agriculture.

Up to now, efforts to measure human energy expenditure have been hampered by the bulkiness of the monitoring equipment and by the need to watch subjects throughout the day in order to chart accurate activity patterns. Both have generated unnatural reactions. However, these problems seem to have been largely overcome by recent improvements in technology. A small, light-weight instrument (SAMI) has been developed which can be inconspicuously carried about while it records the heart beat in pre-set ranges. Fortunately there exists a linear relationship between heart rate and oxygen intake for each individual, thus permitting daily caloric energy expenditure to be measured more quickly, more accurately and less expensively than ever before.

Since its development, the SAMI has been worn only by a few dozen students in a temperate zone environment. However, we are now in a position to test the feasibility of this new technique under tropical field conditions. One area in which the application of this technology would seem particularly useful is the Dry Zone of Ceylon. Major irrigation programs are rapidly transforming this region, and crucial decisions regarding the most efficient density of settlement must occasionally be made. The successful deployment of new energy-measuring technology could greatly enhance the accuracy of such decisions.

This paper is an attempt to begin dealing with these issues. Basically, it describes a sampling procedure designed to determine the impact of agricultural development on human energy expenditure in the

Dry Zone of Ceylon. The first few pages outline the nature and history of this region. Part II describes the structure of agriculture in the Dry Zone today. In part III, the new energy-measurement technology is introduced and explained. Part IV suggests an application of the new technology to the agricultural systems of the Dry Zone. It would, however, be foolish to launch such an ambitious study without first a rigorous testing of the new technology. Part V outlines a three-month field project with this objective.

I.

Two-thirds of Ceylon lies within what is known as the Dry Zone. Although annual rainfall exceeds 40 inches (Map 1), most of it falls from October to January. For the other eight months, high temperatures and hot winds prevail, making most crop production dependent on irrigation (1, p.9).

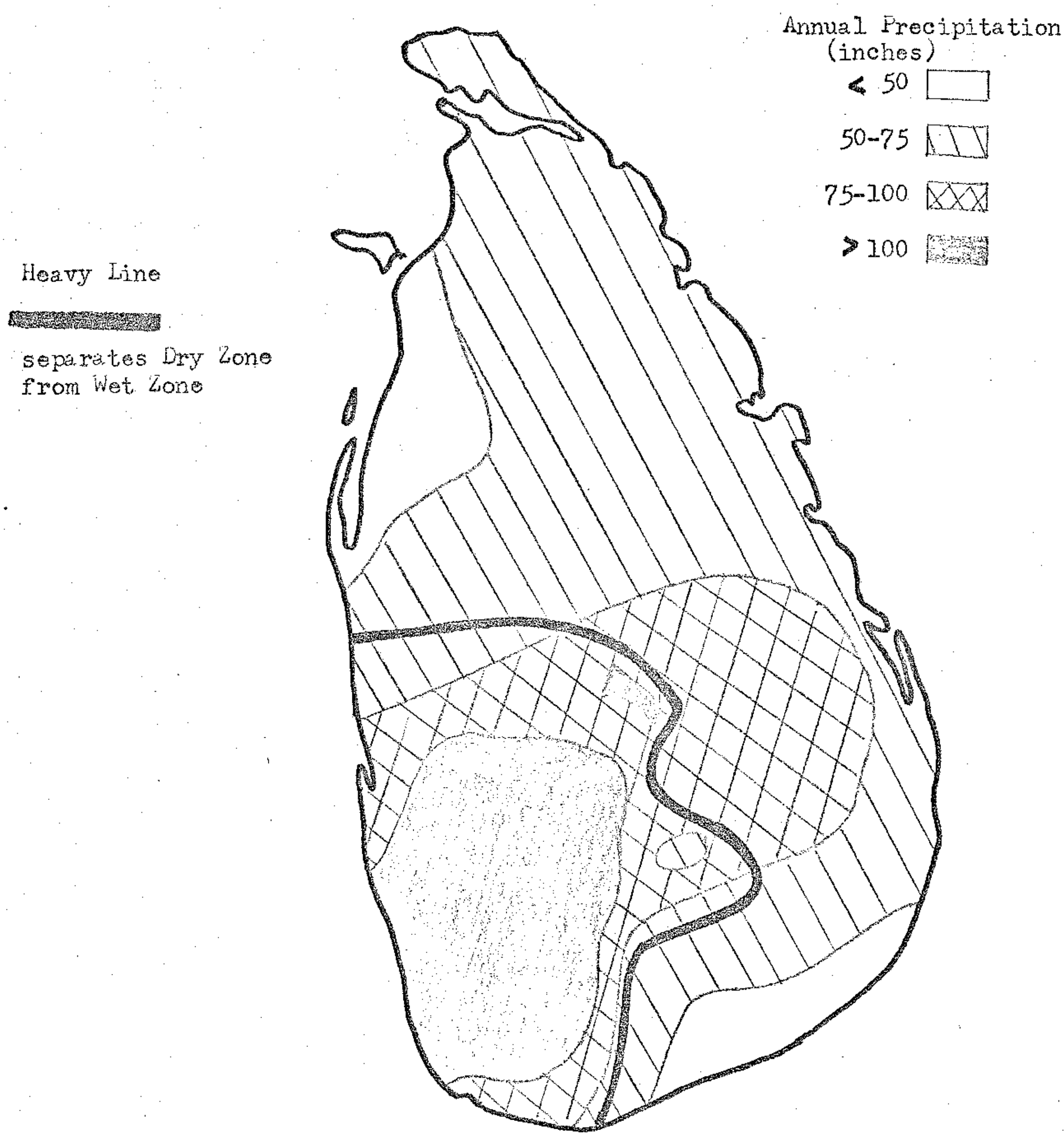
The long, seasonal drought has for many years made the Dry Zone the most neglected and unproductive region of Ceylon. This was not always the case. Legend and archeological evidence suggest the existence of several great kingdoms during the first millenium. All were dependent on complex and extensive irrigation systems (2, p.79). In the 13th century, however, the invasion of Indian Tamils began forcing most of the Sinhalese out of the dry regions into what is now the densely populated Wet Zone. Their ingenious irrigation systems were largely destroyed; the few human survivors faced drought and endemic malaria (3, pp. 15-18).

It was not until the mid-19th century, 600 years after the defeat of the Dry Zone kings, that the first efforts were made to restore the area. The British, who had occupied Ceylon since 1815, repaired a number of tanks and constructed several large irrigation facilities in the half century preceding World War I (3, pp. 105-106). In 1931, the government launched an ambitious program of planned peasant colonization designed to broaden the economy and relieve population pressure in the Wet Zone. But malaria made many potential colonists wary (3, pp. 141-150).

World War II brought major changes. Before the war, most of Ceylon's food requirements were cheaply imported from revenues earned

Map 1

RAINFALL DISTRIBUTION



*Adapted from map 3, Food & Agriculture Organization of the United Nations, Report of the Irrigation Program Review - Ceylon, (1968) by the great tea and rubber estates. Thus, while research programs and monetary incentives coaxed export production, domestic agriculture was stagnant. However, the post-war period saw the forced restriction of imports, deteriorating terms of trade for exports, and inflationary trends within the country combine to place a severe strain on local agriculture. At the same time, rapid population growth in the Wet Zone was creating an increasing demand for land (4, p. 191).

The solution to both problems seemed in sight following the war-time and post-war sprayings of D.D.T. As death rates dropped from 20.3 per thousand in 1946 to 12.9 per thousand in 1950, it became clear that the Dry Zone, after 600 years, was again safe for settlement (2, pp. 87-88).

II.

Although the Dry Zone[1/] has undergone steady development since 1945, Ceylon's agricultural output continues to be concentrated in the Wet Zone. A quick look at acreage data will explain why.

Table 1. Ceylon: Total acreage und acreage under crops for Wet and Dry Zones (July 1, 1962)*

	Total Acreage	Acreage under Crops (Excl. fallow chena)
Wet Zone	6,829,792	3,109,918
10 Dry Zone Districts	9,168,112	930,584
Total	15,997,904	4,013,502

*Based on data in Ceylon, Department of Census and Statistics, Census of Agriculture, Vol. II, pp. 18 & 186-241.

It is apparent that total acreage in the Wet Zone is only two-thirds that of the 10 Dry Zone districts. Yet acreage under crops is more than three times as great. The table does not reveal, however, the pace of development in the Dry Zone. Cultivated acreage has nearly tripled since World War II (5, p. 19), and some suggest that up to three million additional acres can be brought under the plow (6, p. 75).

Although nowhere in the Dry Zone is agriculture modern, three broad levels of development can be discerned. The most primitive

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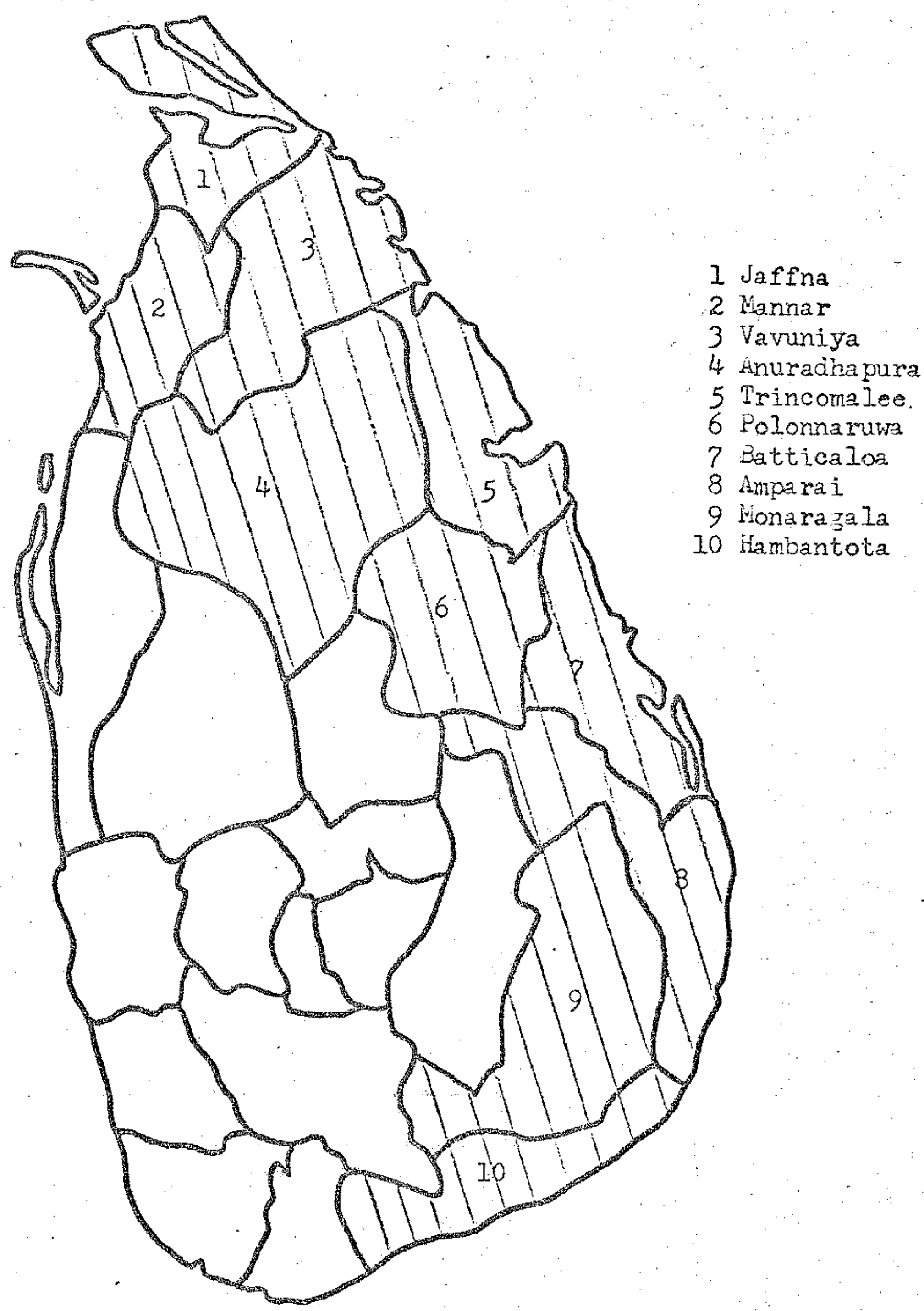
1/ The Dry Zone, as defined in this paper, includes only the 10 districts identified in Map 2. Four other districts lie partially within the Dry Zone, but because most data are presented by district, it is often not possible to break out the relevant material. In any event, the 10 districts constitute 85.9 percent of the total Dry Zone (7, p. 167; 5, p. 19 & 37).

Map 2

DISTRICTS ENTIRELY WITHIN
THE DRY ZONE



*Adapted from map 1, Food & Agriculture Organization of the United Nations, Report of the Irrigation Program Review - Ceylon, (1968) methods are associated with traditional-cum-chena cultivation. Somewhat better practices obtain in areas which have benefitted from the government's village expansion and/or minor irrigation projects. The most progressive cultivation seems to be carried on by those farmers living in the new colonies.

Traditional-cum-chena cultivation is characterized by a three-fold system of land use: irrigated paddy fields; village gardens; and chena--patches under shifting cultivation. The paddy tract is of greatest importance to the farmer, and is normally irrigated from a small village tank or seasonal stream. Techniques of production are inefficient: the peasant cultivates with a simple wooden implement; he has no system of manuring or rotations; and he generally broadcasts his poor-quality seed. Yields are low, even by Asian standards.

The second element in the traditional land-use pattern is the garden. Around each village compound can be found a partly-sown, partly-wild gathering of trees, vegetables, and other plants. The trees are usually sustained by their proximity to a tank. The vegetables either require little water or are grown only during Maha, the season of the north-east monsoon.

The third element in the land use pattern is the practice of chena cultivation. This is the slash-and-burn agriculture found in many parts of tropical Asia, Africa and Latin America. The jungle is felled and burned during the dry season, then seeded at the onset of the north-east monsoon. The land is cropped for several years before weeds and lowering fertility force its abandonment. Chena plots, like the village gardens, are characterized by mixed cultivation. Maize, finger millet, manioc, plantain, and vegetables such as pumpkins, tomatoes, and chillies are commonly found within a few feet of each other. Dry (or hill) paddy may be grown in waterlogged situations. Maha chenas sometimes fail through drought, although when cereals fail, vegetables may do well. The spreading of risk is, in fact, the central aim of the system (3, pp. 45-48).

It seems reasonable to expect that cultivation will be more intensive, and agricultural techniques somewhat less primitive in villages where there is increased availability of irrigation water. Thus, we can consider at the second level of development farmers reached by minor irrigation or who benefit from the village expansion program.

Minor irrigation schemes now command 163,231 acres throughout the Dry Zone (7, p. 169). Part of this acreage is the product of the village expansion program which began shortly after World War II. Within five years, 387 irrigation works had produced 10,559 acres of new land with irrigation, and provided 27,847 acres of existing land with irrigation. An additional 5500 acres were protected from flooding and salt water seepage (2, pp. 104-105).

Nearly 25,000 acres are now being developed annually under this program. It should be noted, however, that the opening of new lands around existing villages is not always accompanied by irrigation facilities. Some Dry Zone allotments can only be sown to catch crops and vegetables (8, pp. 132-133). An improved standard of cultivation under these conditions should not be expected.

The third and highest level of Dry Zone agriculture can be found in the colonies. Here irrigation water is most abundant, production requisites most available, and technical staff most accessible. Colonization, we have said, began in 1931. Basically it consists of settling farmers from other parts of the island on acreage once rainfed, but now commanded by major irrigation works.

There are now 67 peasant colonies with a total population of 43,804 and 221,903 acres under cultivation. The standard size of the individual allotment is five acres of lowland and three acres of highland in colonies established before 1955, and three acres of lowland and two acres of highland in those established after 1955. Recently, the size of allotments has been further reduced to two acres of lowland and one acre of highland (9, p. 148).

Agriculture practised in the colonies is of two types: lowland and highland. Irrigated paddy is dominant on the lowland, and is frequently double-cropped. However, much of the literature suggests that shortage of labor, among other things, limits the utilization of the highland. When the highland is cultivated, tree crops (coconut, jak, citrus, musunga, pomegranate, mango, cashewnut and kapok), plantain, vegetables (onions, chillies, yams and manioc), dry grains (finger millet, gingerly, maize, and sorghum) and rainfed paddy are most commonly found (9, p. 148).

III.

The preceding section has been but groundwork for the questions which must now be raised: What changes in human energy expenditure can be expected as farmers move toward intensive cultivation and advanced technology? Does irrigated farming, for example, including the use of inorganic fertilizers and better cultural methods, demand from the Dry Zone colonist more energy than is used by his countryman in the forest? How can answers to such questions be found? Why should they even be sought?

The last question has, to a degree, already been answered. Joblessness is an increasingly critical problem in most low-income countries, and Ceylon is no exception. Studies carried out by the International Labour Office have found that the unemployed constituted 10.5 to 12.8 percent of the labor force in 1960, depending on the definition used. Subsequent surveys have shown it growing beyond 15 percent (10, pp. 2-3).

One means of dealing with this problem has been to settle colonists from the over-populated Wet Zone in the command area of major new irrigation works. But although Ceylon's program of colonization is approaching its fortieth year, there is still no acceptable means for determining how large individual allotments should be. Farmer suggests that "...the original allotments were large enough to encourage larger families in order to best utilize the land" (11, p. 394). This condition, had it become widespread and general, could have defeated one of the main goals of colonization. Allotments were eventually made smaller, but there is no reason to believe that the ultimate solution has yet been found. Energy data could be of great value in helping to make these judgments.

A second reason for investigating energy costs is that it can help us quantify the world food situation. Despite persistent reports of global hunger, there is little reliable data on the food needs of people living in the tropics. For years, these countries have used the Food & Agriculture Organization's (FAO) scale of calorie requirements to estimate food shortages and plan future needs. Though these standards provide caloric adjustments for differences in weight, age, sex, and environment, they helplessly ignore the impact of alternate levels of physical activity--clearly the most crucial caloric variable.

Data on farmers, who make up the bulk of tropical populations, are particularly scarce. Poleman notes that "...only two expenditure/activity studies have been conducted among farming communities in the tropics. Both of these were done in West Africa some years ago..." (12, p. 12). McArthur's review of the tropical literature leads her to the conclusion that there is simply insufficient evidence on activity patterns in both the agricultural and non-agricultural sector to "...allow us to decide whether...(the FAO calorie scale) gives a per capita requirement figure which is too high, too low, or about right. Hence, we cannot assess accurately...the magnitude of any existing deficiency in order to make allowance for it in estimating future food needs" (13, p. 406).

Getting data on energy expenditure has bever been easy. For years it could only be guessed at through the use of detailed consumption surveys. But there were serious problems with this approach. Every morsel of food had to be weighed and analyzed. This was not only time consuming, but may have unknowingly distorted the normal diet. More important, unless the survey was taken over an extended time period, there was no way of knowing if food intake was being balanced with energy expenditure. For example, if the study was conducted on farmers immediately following the harvest, the subjects may have been in the process of gaining weight. On the other hand, in the months preceding the harvest they may have been eating less than the amount necessary to meet energy output, thus living partly off accumulated fat.

The development of indirect calorimetry was a major breakthrough in the technique of energy measurement. This approach rests on the relationship between energy and oxygen. It is well known that energy is provided by food and must be liberated before it can be used by the body for physical and chemical work. As energy can only be liberated from food through oxidation, the measurement of oxygen consumption by the body is, indirectly, a measurement of energy expenditure.

The application of this principle was first undertaken in industrial countries about 1930. A respirometer measured the energy costs of specific tasks, and these were then multiplied by appropriate time spans. But this method quickly revealed its drawbacks, particularly for tropical conditions. The respirometer is only worn for a few minutes, and is so bulky and uncomfortable that "...its presence is hardly conducive to normal behavior. Moreover, time-span recording must be meticulously accurate in order to be useful. And to obtain meticulously accurate time-span data under primitive conditions is probably asking too much of both subjects and enumerators" (12, p. 12).

Fortunately, another relationship has recently been discovered which extends the scope of indirect calorimetry. It has now been established that there is a linear relationship between heart rate and oxygen intake for each individual[2/]. Thus, energy expenditure can now be measured by recording heart beats in the small, light-weight instruments (SAMI) we have previously mentioned.

Before moving on to take up the application of the new technology in the field, an implicit assumption should be stated. There has long been the notion that hunger breeds hunger, i.e., that men who are without an adequate diet are unable to muster the energy needed to produce a good crop, and thus they remain hungry. The methodology used in part IV disregards this possibility. Ceylon's food policy is that each citizen of the country, including the cultivator, is entitled to two measures of rice per week at /25 cts. a measure. This means he is getting four pounds of rice at half the production cost. It is thus assumed that every farmer has access to a diet sufficient to meet his energy needs (6, p. 82).

2/ This relationship does not hold for very strenuous activities or when the level of activity is extremely low.

IV.

With the new technology in hand, we are now prepared to derive a model which will hopefully permit us to predict changes in human energy requirements as we move from one level of development to another. One approach would be to simply select a farmer using primitive methods, attach a SAMI, and document his energy output over time as he progressed through several stages of development. Although this method might yield reasonably accurate results, it has some obvious drawbacks. First, the farmer's "development" would undoubtedly take a number of years. Second, it would be difficult to find one man who could typify agricultural development for the entire Dry Zone. Thus we must seek another approach.

The careful use of sampling techniques appears to be the best alternative. This, of course, requires a certain amount of stratification. We must first define the stages of agricultural development. We will then divide the Dry Zone into homogeneous sections based on land use.

Basically, our stages of development correspond to those discussed in Part II. Development in the Dry Zone seems almost a function of the availability of irrigation water. Thus we select a few farmers from traditional-cum-chena areas, a few from areas under minor irrigation, and a few from the colonies. We would also hope to sample workers on the government's model farms, for this would represent the highest level of Dry Zone development. Table 2 on the following page summarizes what we might expect at these four levels of development. It should be noted that these are only very general characteristics, as the Dry Zone is not a homogeneous area. It is to this issue that we turn next.

Table 2. Ceylon: General stages of agricultural development

Traditional cum Chena	Village Expansion	Colonies	Modern
mostly rain-fed	minor irrigation	major irrigation	major irrigation for lowlands; lift irrigation for highlands
marginally-irrigated paddy; great dependence on wild gardens and chena	one well irrigated crop of paddy	double-cropped paddy in many areas	year-round diversified cropping
primitive agricultural	fair-quality animal-drawn	some mechanization	many operations mechanized
no chemical fertilizer	slight use of fertilizer	moderate use of fertilizer	heavy use of fertilizer
no plant protection measures	some use of plant protection measures	moderate use of plant protection techniques	sophisticated plant protection

We are now ready to refine our model by grouping Dry Zone districts on the basis of land use. The major zones are outlined on Map 3.

Jaffna district in the northern peninsula is Zone 1. In several ways it is distinct from the rest of the Dry Zone. It is densely populated by Tamils whose dietary habits have sharply influenced the nature of their agriculture. Gardens, given over to chillies, onions, and numerous vegetables, are more important than elsewhere in the Dry Zone. Little chena cultivation can be found. Jaffna farmers owe much to fortuitous geography. Most of the district is situated on sandstone which they have pierced with numerous wells to facilitate lift irrigation (3, pp. 50-52). Unlike the areas to the south, only 40 percent of the agricultural acreage is given over to paddy (5, pp. 186-241).

It is the emphasis upon paddy production which distinguishes what we have defined as Zone 2. The percentage of cropland under paddy in these seven districts ranges from 57 to 76 percent (5, pp. 186-241). This is the vast heart of the Dry Zone, making up nearly 60 percent of the total area.

Moving further south, we come to the two districts we can consider Zone 3. Here, as in Zone 1, paddy plays a lesser role, accounting for only 19 percent of the acreage in Moneragala and 28 percent of the acreage in Hambantota. But it is plantation crops and other cash items[3/]--not vegetables--which are important in these districts (5, pp. 186-241).

We have now stratified the Dry Zone along two lines: first, by defining four basic levels of agricultural development; and second, by separating the 10 districts into three homogeneous zones based on land use. It is now time to look at the cropping cycle in order to get some idea of how and when sampling should be done.

The cropping calendars on the next three pages (Figs. 1,2,3) are largely self-explanatory. Each calendar takes a specific level of development and shows a typical crop rotation in each of the three zones. Rotations for model farms have not been developed, as technology is constantly changing, and cropping patterns are too numerous and diverse. It should be stressed that the three calendars are very general schemes, based partly on the literature and

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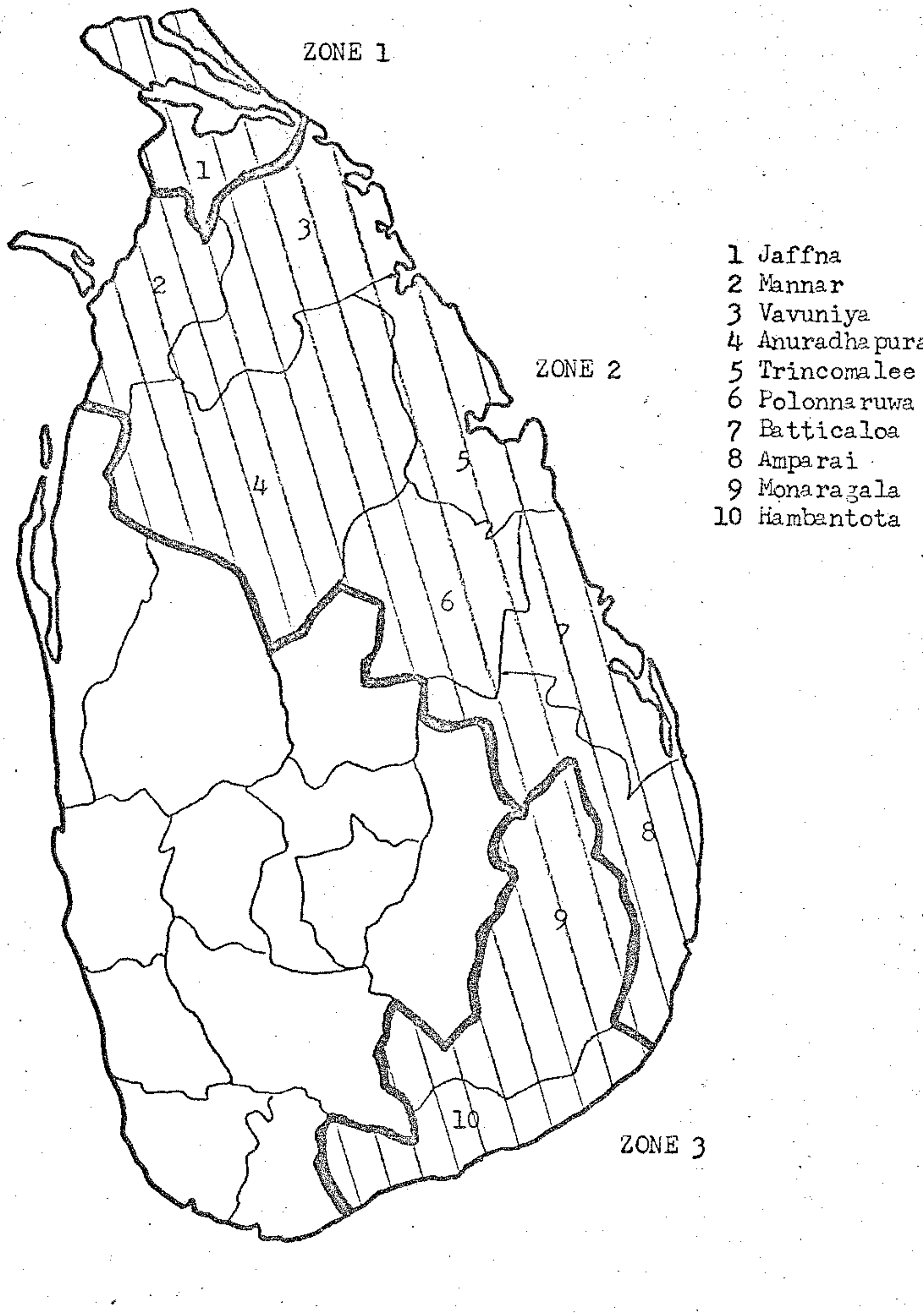
3/ fruit trees, spices, nuts, and oils

Map 3



DIVISION OF THE DRY ZONE INTO HOMOGENIOUS AREAS
BASED ON LAND USE

Figure 1. Crop Calendar for Traditional-cum-Chena Cultivation

	Maha						Yala					
	Oct	Nov	Dec	Jan	Feb	Mar	Apr.	May	Jun	Jul	Aug	Sep
Zone 1	Pr	P	some paddy		H							
					sporatic care of garden							
	P	P	chena		H	H	H		clearing of chena		firing	
Zone 2	Pr	P paddy on irrigable lowlands H										
					sporatic care of garden							
	P	P	chena		H	H	H		clearing		firing	
Zone 3	Pr	P	paddy		H		some double-crop paddy					
					sporatic care of garden							
			less china than in zones 1+2						clearing		firing	
					some coconut							

Figure 2. Crop Calendar for Areas Receiving Minor Irrigation

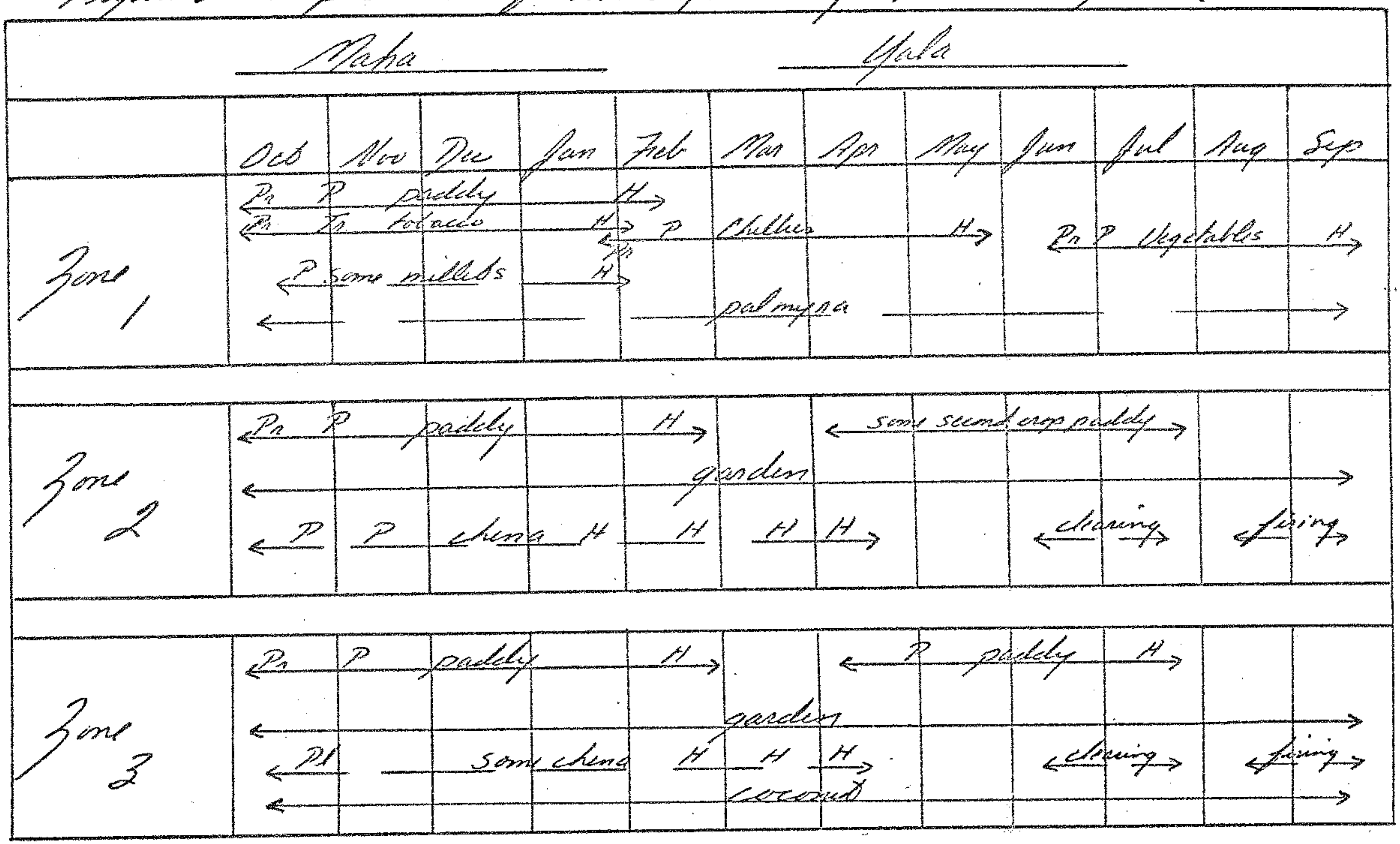
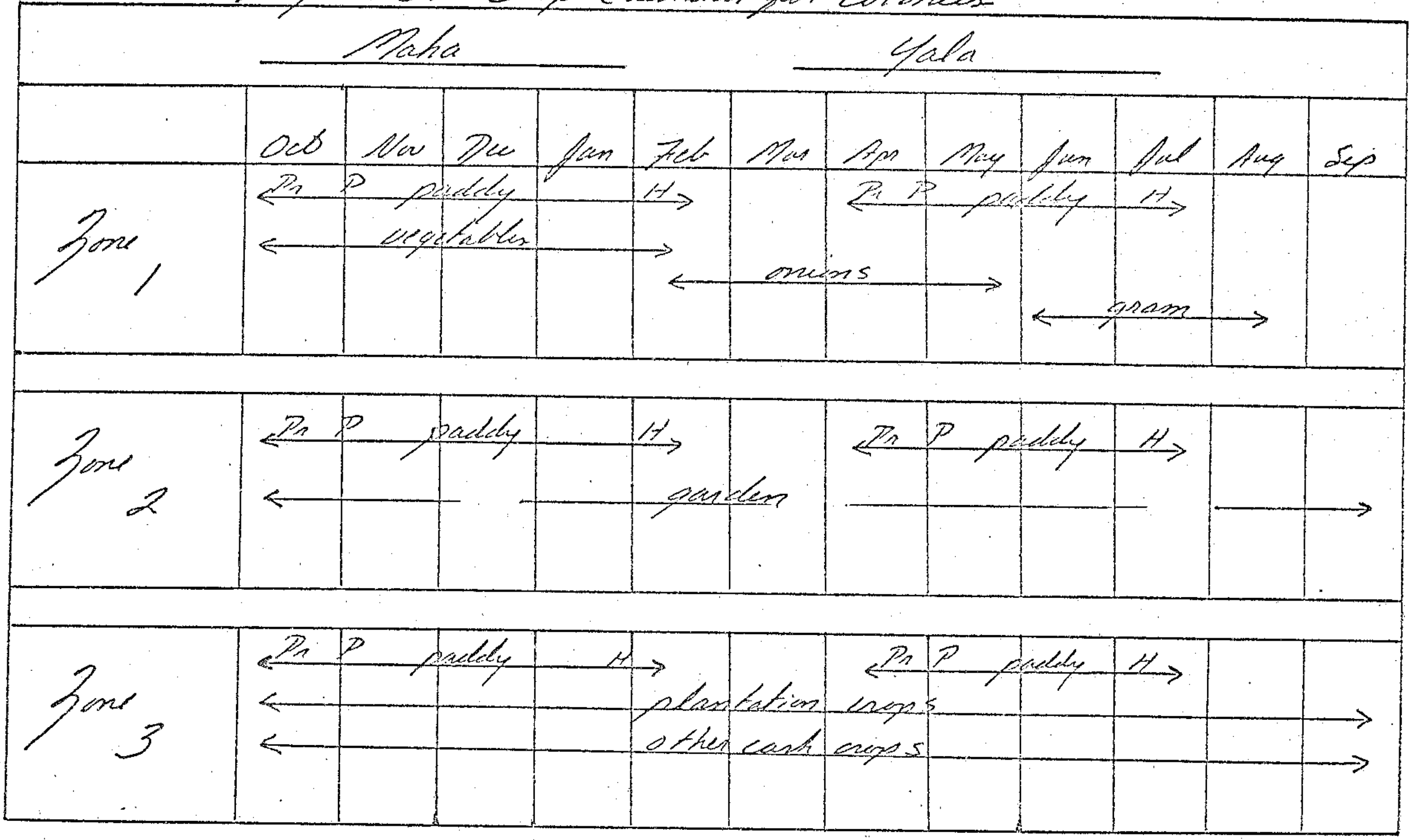


Figure 3: Crop Calendar for Colonies



partly on reasonable guesses. The tentativeness of the calendars should be particularly apparent to those who understand the vagaries of the monsoon. Moreover, as most crops can be sown within two or three months of recommended planting dates, the calendars can only hope to provide some indication of the best times to sample.

At last we are ready to take the SAMI's to the field and begin sampling. We will, of course, want to sample at all four levels of development in each of the three zones. This means a total of 12 samples must be taken. If crop cycles were less similar, we could perhaps stagger our sampling, thus minimizing manpower and equipment costs. But this is not the case. Ceylon is small, and the monsoon strikes all areas at about the same time, causing a feverish burst of activity. Thus, sampling will have to be carried out in all zones simultaneously.

To accomplish our objective at least cost, the following procedure seems reasonable:

1) <u>One man, equipped with four SAMI's, should be sent to each of the three zones.</u> In urban situations it has been found that one man can handle up to 10 SAMI's. It is expected that the four levels of agricultural development in each section of the Dry Zone can be found close enough to each other to allow one man to monitor the four instruments.

2) <u>A sample of 10 men should be randomly selected from each level of agriculture in each zone.</u> A sample of this size would seem to minimize the impact of any variables unrelated to energy output. If possible, three or four women should be added to the sample, as they participate in the transplanting process--a characteristic of progressive paddy cultivation.

3) <u>Sampling should occur at three times during the year: 20 days in October-November immediately following the onset of the northeast monsoon; 20 days in March-April following the harvest of the monsoon paddy; and 20 days in July-August.</u> The first period will catch some field preparation, the sowing of paddy, and the first

application of fertilizer (if any). The second period will catch a bit of the paddy harvest, the harvest of chena (if any), and the sowing of the second crop (if any). The third period will catch the harvest of the second crop (if any), and the clearing and firing for chena (if any). All three sampling periods will pick up any garden activity or work with cash crops.

4) Each of the 10 men in each of the 12 sample areas will wear the SAMI twice during each 20 day period. The days each man will wear it will be randomly selected. This means that each man chosen for the study will wear a SAMI six times during the year.

Using this system, it would seem possible to develop reliable energy data shich could be used by planners to help Ceylon deal with her major problems.

V.

Before undertaking the type of study just described, it is clearly appropriate to test the new methodology on a modest scale. A pilot project will therefore be carried out at the Maha Illuppalama Dry Zone Research Institute in June, July and August 1971. This station includes the first-year teaching facilities of the Faculty of Agriculture of the University of Ceylon and is located near both established colonies and traditional farmers.

Three SAMI's will be used to measure the energy expenditure of 21 farmers over a ten-week period during the Yala (dry) season. Seven farmers will be selected from irrigated, intensively-cropped acreages; another seven will farm rainfed, traditionally-cropped lands. A third group will be engaged in implementing alternative cropping patterns under phase I of the Mahawali Ganga irrigation scheme. While a random selection of subjects would be preferred, it is--at this stage--perhaps more important to identify farmers who will conscientiously cooperate with the study. Each participant will be asked to wear a SAMI once each week on a randomly selected day.

A fourth SAMI will be available to: 1) measure energy output on the more highly developed government farms; 2) cross-check the typicalness of our sample populations; and 3) make some preliminary investigations on women laborers. It will also, of course, replace one of the other SAMI's should a breakdown occur.

The major objectives of the three-month study can be summarized as follows:

A. To discover and attempt to resolve any problems encountered in the use of SAMI's under tropical field conditions, thus preparing the way for more extensive surveys;

B. To develop preliminary data regarding differences in energy expenditure at various levels of agricultural development;

C. To begin to explore the efficiency of production in the colonies in terms of seasonality of work.

Though an implicit assumption of the study is that all farmers have access to an adequate diet, an effort will be made to determine dietary patterns so that possible nutritional constraints bearing on the energy output of each subject can be identified.

All field work will be carried out with the cooperation and guidance of the Faculties of Agriculture and Medicine at the University of Ceylon, in particular, Professor T. Jogaratnam (Department of Agricultural Economics) and Dr. E.S.G. Hettiaratchi (Department of Physiology).

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