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THE MEASUREMENT OF ENERGY FLOW THROUGH INTENSIVE AGRICULTURAL SYSTEMS

by

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Since this workshop is a continuation of the one held in New York in January 1974, I would like to begin my presentation with a reference to the listing (Figure 1) of the applications of vital-rate monitoring which are of interest to the economist and which I introduced toward the end of my earlier paper. There I noted that of the two broad areas of application, food and employment, employment was the one most likely to command increasing concern in the less developed countries (LDCs). This is because of the very dramatic effects that may be expected from increased application of the scientific method to food production. "Most observers now perceive"--I wrote then--"that applied technology in agriculture has only scratched the surface, that, given reasonably honest and effective governmental administration, production almost everywhere can keep well ahead of (declining) rates of population growth; that whatever individual food problems which may persist will be best interpreted in terms of employment or income; and that it is to questions of employment and income that research should be focused" (1, p. 25).

A year later one might argue that this was a bit too sweeping. The last year has not been a good one for the world agriculturally. Most especially, the cost of fertilizers has risen to the point where some countries are considering abandoning the high-yielding varieties upon which the Green Revolution rests and returning to lower yielding, but

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FIGURE 1. APPLICATIONS OF VITAL RATE MONITORING*

Food Area

(Calorie taken as measure of energy; inferred from heart rate)

1. National or individual calorie needs.

   Original research aim, but now by-product of other objectives. Assumes activity not restricted by shortfall in food intake, a not unreasonable assumption. Perhaps most relevent to developed countries; here problem is of overfeeding and underactivity. But may still be useful in LDCs.

2. Economic cost of undernourishment.

   Application limited: for undernourishment to have cost to society full employment must be assumed; with full employment there is rarely a food problem. Usefulness probably confined to measuring impact on effort of food intervention programs.

Employment Area

(Calorie--or percent increase over resting rate--taken as common denominator of the factor of production labor, with time inferred according to local man-day customs; inferred from heart rate)

1. Quantification of existing patterns of human activity.

   Using SATR and diary:

   a. Determination of local man-day norms.
   b. Work/leisure trade-off.

2. Evaluation of effect on employment of alternative investment strategies.

   a. Effect on factor input of changed economic environment, presumed to enhance output.
   b. Determination of relative factor inputs associated with alternative means of accomplishing same task: to be employed in budgeting exercises aimed at enhancing factor input, output, and ameliorating bottlenecks.

3. Treating symptoms of unemployment.

   Psychological cost of alternative activity situations may be suggested by simultaneous monitoring of several physiological parameters. (Perhaps not science, but not necessarily fiction.)

* From T. T. Poleman, "Energy Flow Studies in South Pacific Populations" (Cornell Agric. Econ. Staff Paper No. 74-5, January 1974).

less fertilizer-demanding strains. Still, the point remains valid: the LDCs do have available to them the technical tools for producing far more food than their present or likely future populations can effectively demand. The real questions are whether they can get themselves sufficiently organized to exploit the technology and whether the general course of development can be carried out in such a way that jobs for all will be provided.

Jobs are crucial. In that they trigger rising incomes, reduced mortality, better education, and the other preconditions to effective family planning, they are basic to bringing the current "population explosion" under control. And without the more equitable distribution of income jobs imply, political stability in the LDCs will prove even more elusive than it is today.

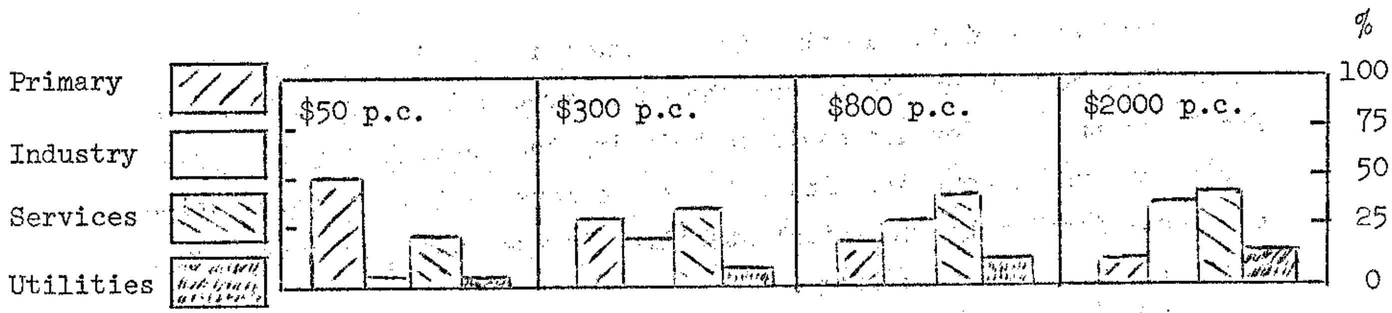
Figure 2 illustrates the sort of changes that have historically been associated with economies as they develop. In poor societies agriculture is the dominant source of wealth and employment. When our ancestors won their independence 200 years ago, 95 percent of them were farmers. Today,less than five percent of us are. First services, then industry replace farming with development and a nation's basis moves from its land to its cities.

The social upheaval this restructuring implies has never been easy. Witness the inequities and evils which attended the Industrial Revolution in England and which Dickens wrote of so eloquently. But the migrations from farm to town which the now industrial countries experienced during the last century were a relatively easy process compared to those which now confront the LDCs. Industry was growing and since industry then was comparatively labor intensive, virtually all who left the land eventually found a new job.

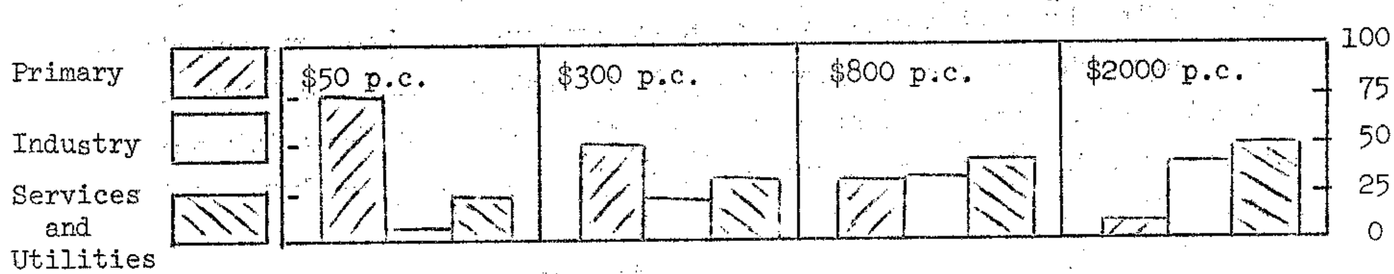
No longer is this so. For a variety of reasons, some simple, some complex, industrialization in the LDCs is proceeding along capital intensive lines and only a fortunate few of those flocking to town find employment. Joblessness is rife. In Ceylon, one of the few countries for which fairly accurate data are available, one million persons out of a total population of 13 million are unemployed, and among school-leavers under

FIGURE 2. NORMAL COMPOSITION OF OUTPUT AND OF LABOR FORCE AT DIFFERENT LEVELS OF GNP PER CAPITA*

Composition of Output:



Composition of Labor Force:



* From H. B. Chenery, "Growth and Structural Change," Finance and Development, No. 3, 1971.

25, no fewer than 83 percent are without work (2, p. 41). In India, Bangladesh, and Indonesia the situation is no better for our inability to attach precise numbers.

Though the unemployment problem in the LDCs is comparatively recent, it has within the past decade attracted a good deal of attention. Scholars decry it, politicians are surprised by it, Mao is praised for perhaps having avoided it. The literature though is impressively barren. Youths are exhorted to return to the land and capitalists to use less capital. But not much else. To these ears it all has a rather hollow ring.

The question however needs to be answered: can agricultural development be carried out in such a way that it will be labor demanding? Despite the fact that the bulk of the inputs of the Green Revolution are capital intensive, is it realistic--as the Ceylon government, for one, hopes--to look to rural revitalization to provide jobs for the bulk of the present and future unemployed?

On the face of it, it seems a futile hope: a flight into the face of history. Yet the truth is that our ignorance may conceal hope. We do not know what effect changes in the input mix will have on employment, whether, say, an irrigation scheme to permit double cropping would simply mean that the same work force was underemployed during fewer months of the year, or whether it would also allow additional hands to be employed. In jargon: we do not know what the labor-use elasticities are of alternative agricultural investment strategies.

One need not look far for the explanation. Research in the field of farm management has aimed not at maximizing the factors of production but the return to them. To have done otherwise would have been quite silly until very, very recently. Imagine the reaction in New York State to research designed to maximize the number of people milking cows.

In part for this reason our knowledge of the precise inputs of labor associated with various agricultural tasks is minimal. Our ignorance also stems in part from the difficulties associated with the traditional methods for quantifying labor. Because of problems of conceptualization as well as measurement--e.g., culture specific man-day norms--this has typically in the LDCs involved use of the time-motion technique. This technique is quite appropriate to industry, but not to agriculture. In effect the investigator has to spend virtually all his time with a handful of subjects throughout the agricultural cycle--a very expensive and time-consuming operation if a statistically meaningful sample is to be surveyed. The upshot is that our understanding of the inputs into even paddy production is deficient.

If in fact a socially acceptable method for measuring human energy expenditure has at last been perfected, it would seem an ideal vehicle for quantifying the labor inputs associated with various farming systems. The general approach I would recommend is the one we followed several years ago in our study of Philippine rice farmers and which is described in detail elsewhere (3).

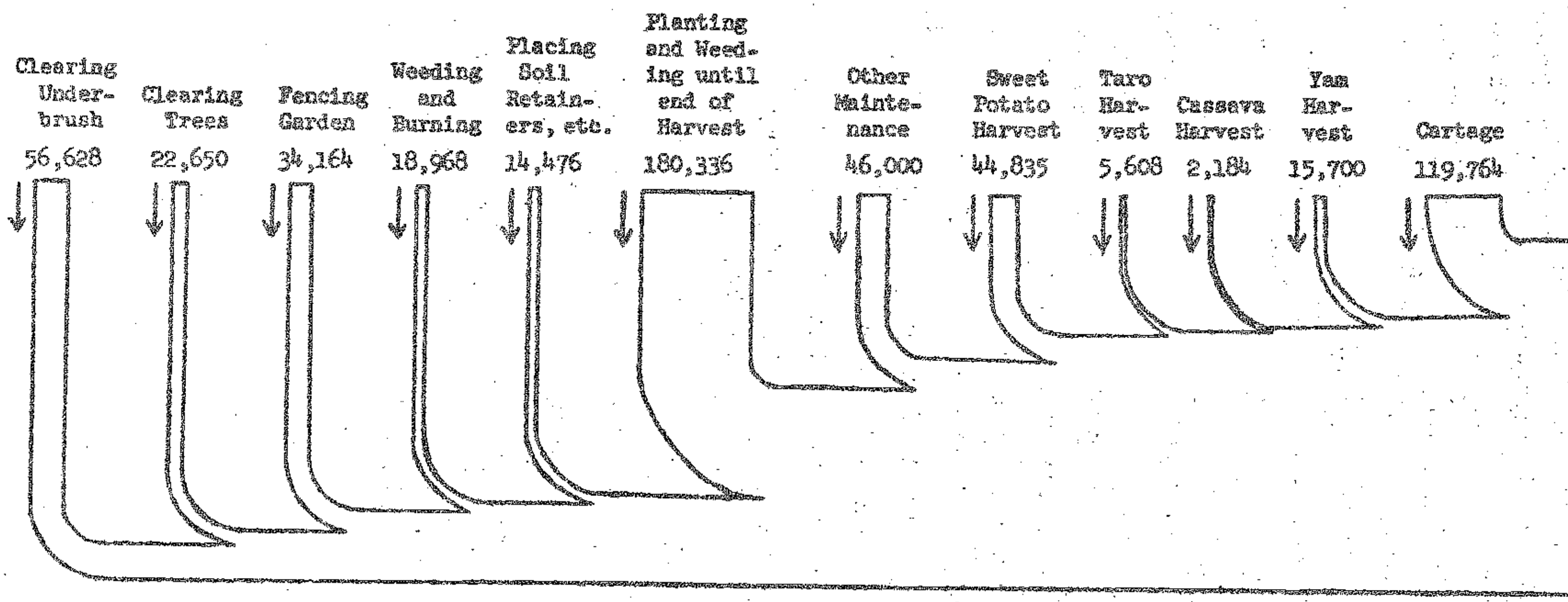
The first arm of this approach is to derive an appreciation of the labor inputs associated with existing land use possibilities by monitoring a number of farmers throughout the agricultural cycle. What should emerge would be pictures of the broad labor inputs similar to that illustrated in Figure 3, which Rappaport derived for New Guinea yam gardeners. Immediately identifiable would be any points at which labor constrained the size of operation--where introduction of a labor-saving device might increase employment--and an assessment of local work norms and some idea of the extent of unemployment and underemployment.

Because the energy approach to labor quantification tends to tide over individual variations, the number of persons sampled need not be excessive. A score or two per system might suffice. Care, however, would need to be taken in their selection and the choice of areas and farming alternatives to represent a given geographical region. Appendix A, drawn from a proposal for evaluating the alternatives for the Dry Zone of Ceylon, is suggestive of how the selection process can be progressively narrowed.

The second arm of the suggested research approach would seek to build up the kind of data needed to predict the effect on employment of specific new technologies: to calculate those labor-use elasticities I was talking about. Here our aim would be to derive the labor costs associated with

FIGURE 3. ENERGY INPUT INTO YAM GARDENING IN NEW GUINEA*

(Calories per acre)



* From R. A. Rappaport, "The Flow of Energy in an Agricultural Society," Scientific American, September 1971.

various means of performing the same task. Examples of the types of comparisons which were attempted for Philippine rice farmers are shown in Figure 4. Appendix B contains the protocol of a rather different comparison done in Ceylon in 1972. In both cases, because use of the calorie or physiological common denominators allowed us to smooth over individual variations, relatively small samples could yield statistically meaningful results.

All this now looks technically feasible for widespread implementation, and since it is the application of energy work with the greatest relevance to the "real world" it should be pushed with priority. Still I would reiterate the note of caution expressed earlier. History equates progress with a decline, not a rise in agricultural employment. Though the conditions seem singularly unfavorable in most LDCs for an expansion of urban employment, it would perhaps be more fruitful to seek to alter these conditions than to expect peoples with rising expectations to overcome their historical aversion to the drudgery of farm labor. Mao may be the genius of the age. But it is by no means clear that even he has done that.

CITATIONS

1. T. T. Poleman, "Energy Flow Studies in South Pacific Populations" (Cornell Agric. Econ. Staff Paper No. 74-5, January 1974).

2. T. T. Poleman, "Food, Population, and Employment: Ceylon's Crisis in Global Perspective," MARGA (Colombo, Sri Lanka), Vol. 1, No. 3, 1972.

3. Weyland Beeghly, "Nutrition, Employment, and Working Efficiency: Toward Measuring Human Activity in the Rural Tropics," in T. T. Poleman, et al., "The Economic Applications of Vital-Rate Monitoring" (Cornell Int'l. Agric. Dev. Mimeo. 38, November 1972).

FIGURE 4. ENERGY MEASUREMENT TARGETS FOR SPECIFIED TASKS IN RICE PRODUCTION

Task	Operation Alternatives	Data to be Measured
Plowing	1. Tractor 2. Carabao	Cal./hectare
Harrowing	1. Tractor 2. Carabao	Cal./ha.
Planting	1. Manual transplanting (dapog) 2. IRRI row seeder 3. Broadcast seeding	Cal./ha.
Weeding	1. Manual 2. Hand rotary 3. Power rotary 4. Herbicide	Cal./ha.
Harvesting	1. Sickle 2. Hand drop manual harvester	Cal./ha.
Threshing	1. Manual 2. Hampasan (frame) 3. Pedal thresher 4. IRRI table thresher	Cal./ton rice
Winnowing	1. Manual 2. Native winnower 3. IRRI hand winnower	Cal./ton cleaned grain

* From Weyland Beeghly, "Nutrition, Employment, and Working Efficiency: Toward Measuring Human Activity in the Rural Tropics," in T. T. Poleman, et al., "The Economic Applications of Vital-Rate Monitoring" (Cornell Int'l. Agric. Dev. Mimeo. 38, November 1972).

APPENDIX A

Excerpts from Weyland Beeghly and T. T. Poleman, "Forecasting Changes in Human Energy Expenditure Associated with Agricultural Development: A Sampling Procedure for the Dry Zone of Ceylon" (Cornell Agric. Econ. Staff Paper No. 27, January 1971).

I.

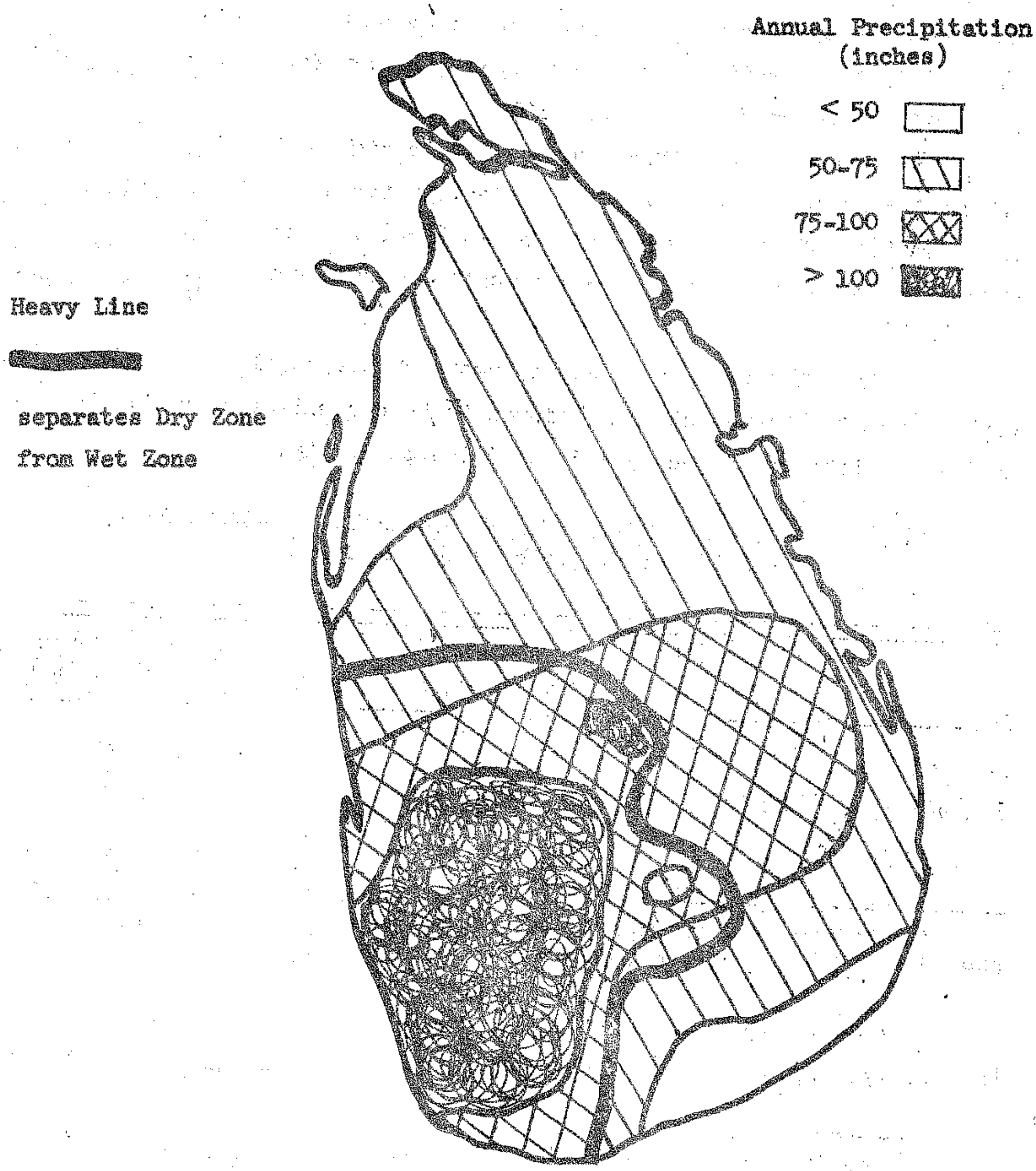
Two-thirds of Ceylon lies within what is known as the Dry Zone, Although annual rainfall exceeds 40 inches (Map 1), most of it falls from October to January. For the other eight months, high temperatures and hot winds prevail, making most crop production dependent on irrigation (1, p. 9).

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 by the great tea and rubber estates. Thus, while research programs and monetary

MAP 1. RAINFALL DISTRIBUTION *



* Adapted from Map 3, Food and Agriculture Organization of the United Nations, Report of the Irrigation Program Review - Ceylon, (1968).

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 Zone1/ 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 AND ACREAGE UNDER CROPS FOR WET AND DRY ZONES (JULY 1, 1962)*

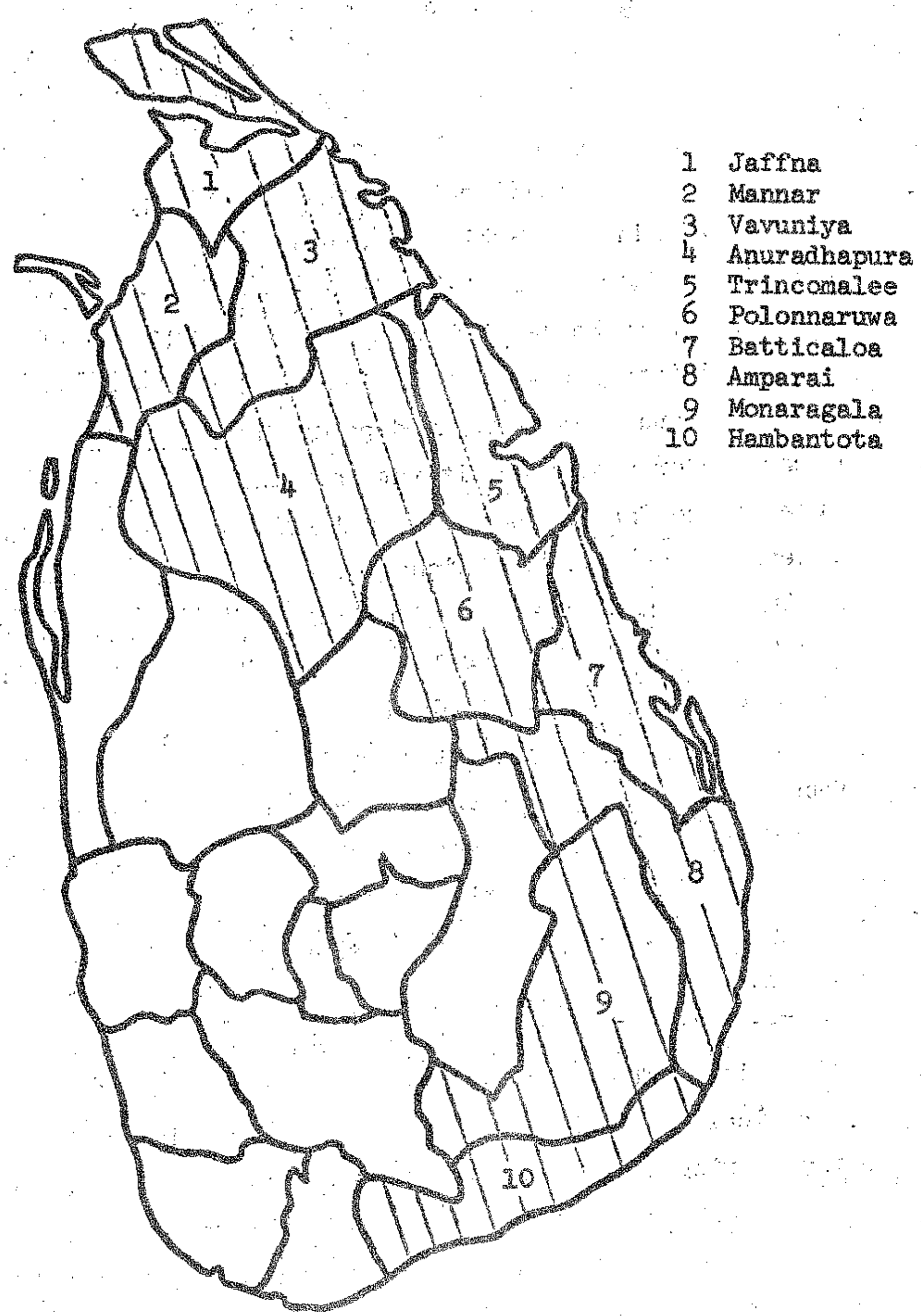
	Total Acreage	Acreage Under Crops (Excl. fallow chena)
Wet Zone	6,829,792	3,109,918
Ten Dry Zone Districts	9,168,112	930,584
TOTAL	15,997,904	4,013,502

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

It is apparent that total acreage in the Wet Zone is only two-thirds that of the ten Dry Zone districts. Yet acreage under crops is more than

1/ The Dry Zone, as defined in this paper, includes only the ten 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 ten districts constitute 85.9 percent of the total Dry Zone (7, p. 167; 5, pp. 19 and 37).

MAP 2. DISTRICTS ENTIRELY WITHIN THE DRY ZONE*



* Adapted from Map 1, Food and Agriculture Organization of the United Nations, Report of the Irrigation Program Review - Ceylon, (1968).

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 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 5,500 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 practiced 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 jdugments.

IV.

...We are now / in a position / 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.

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.

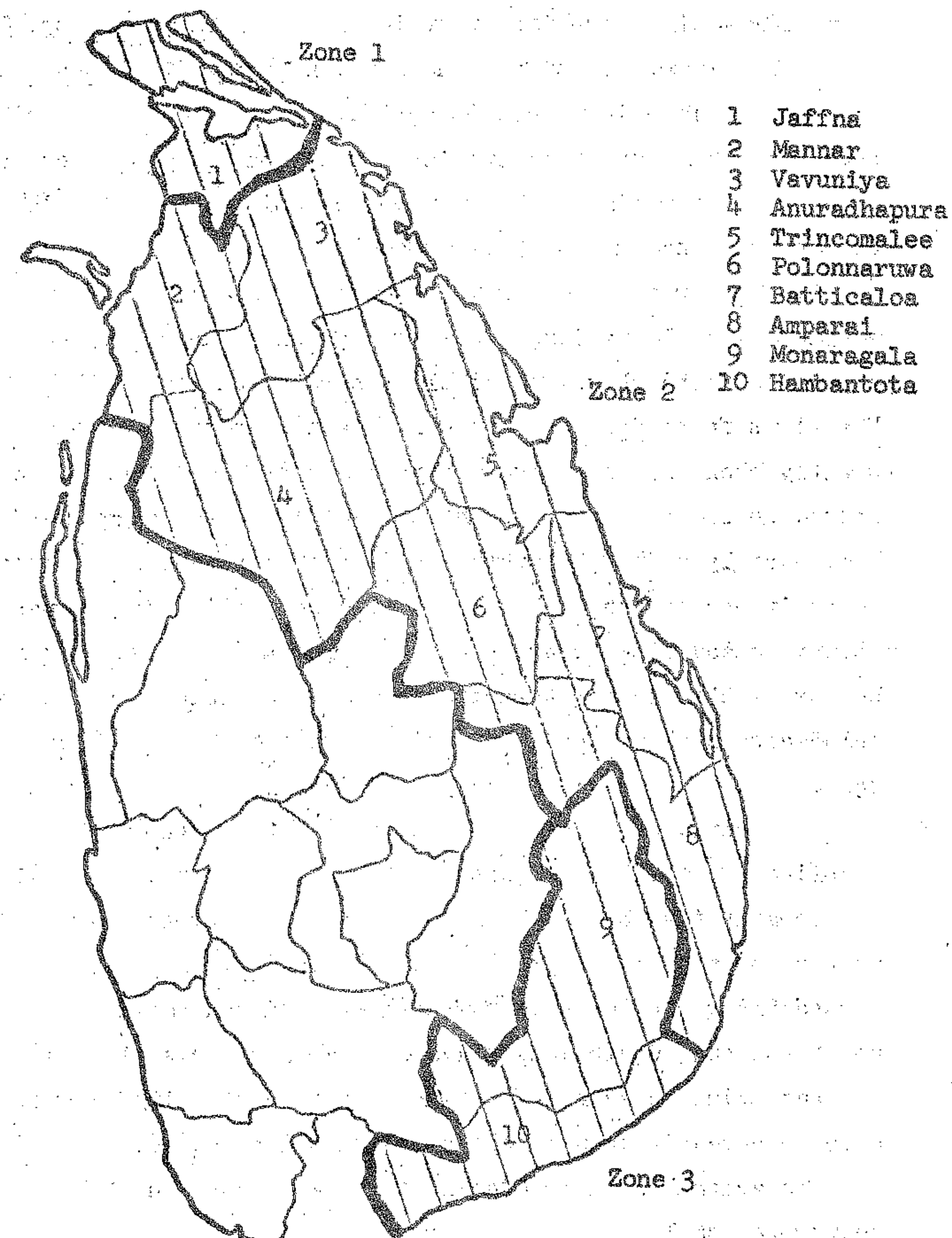
TABLE 2. CEYLON: GENERAL STAGES OF AGRICULTURAL DEVELOPMENT

Traditional cum Chena	Village Expansion	Colonies	Modern
mostly rainfed	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

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.

MAP 3. DIVISION OF THE DRY ZONE INTO HOMOGENEOUS AREAS BASED ON LAND USE



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 Monaragala and 28 percent of the acreage in Hambantota. But it is plantation crops and other cash items[2/]--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 ten 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 (Figures 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 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 SAMIs 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:

FIGURE 1. CROP CALENDAR FOR TRADITIONAL-CUM-CHENA CULTIVATION

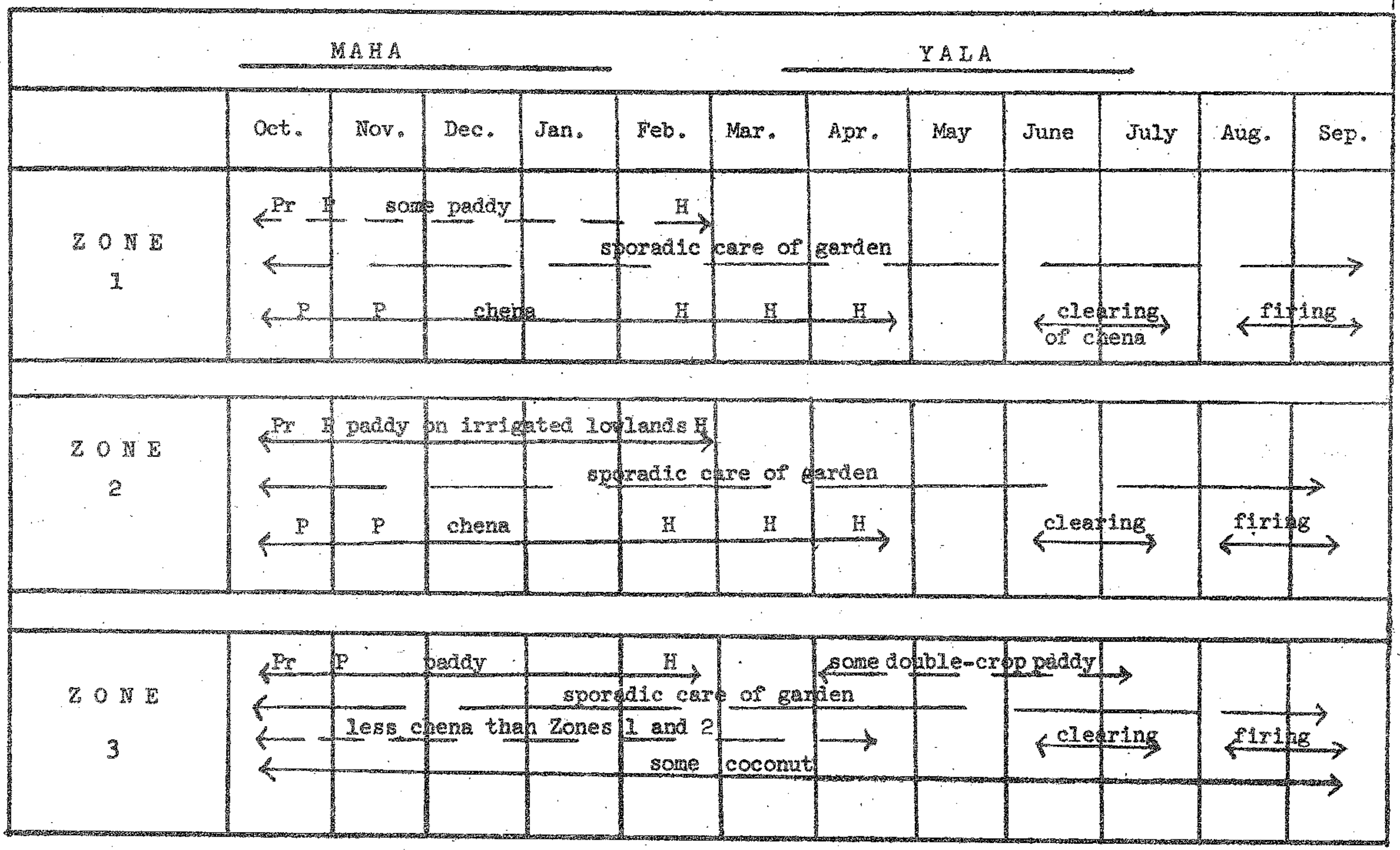


FIGURE 2. CROP CALENDAR FOR AREAS RECEIVING MINOR IRRIGATION

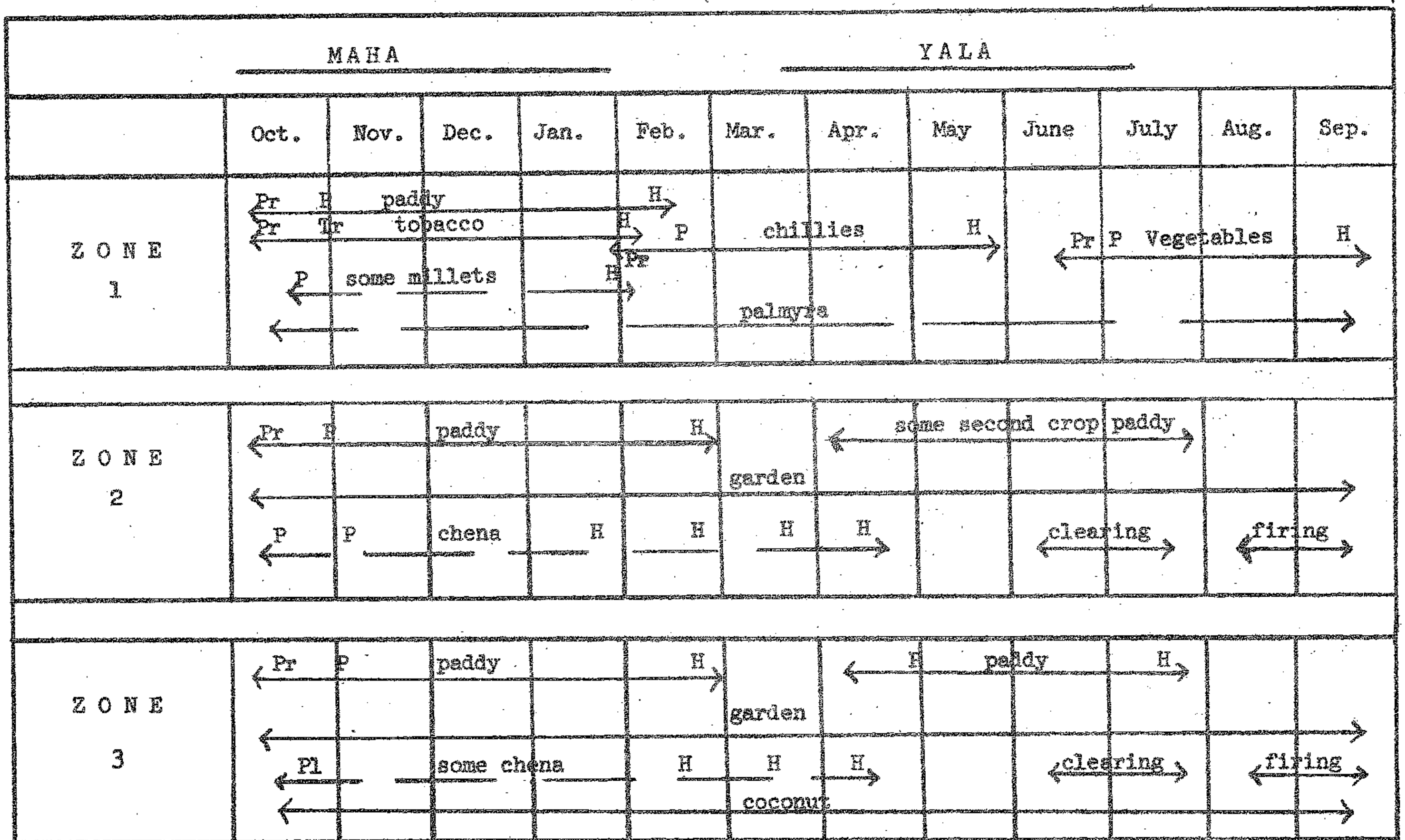
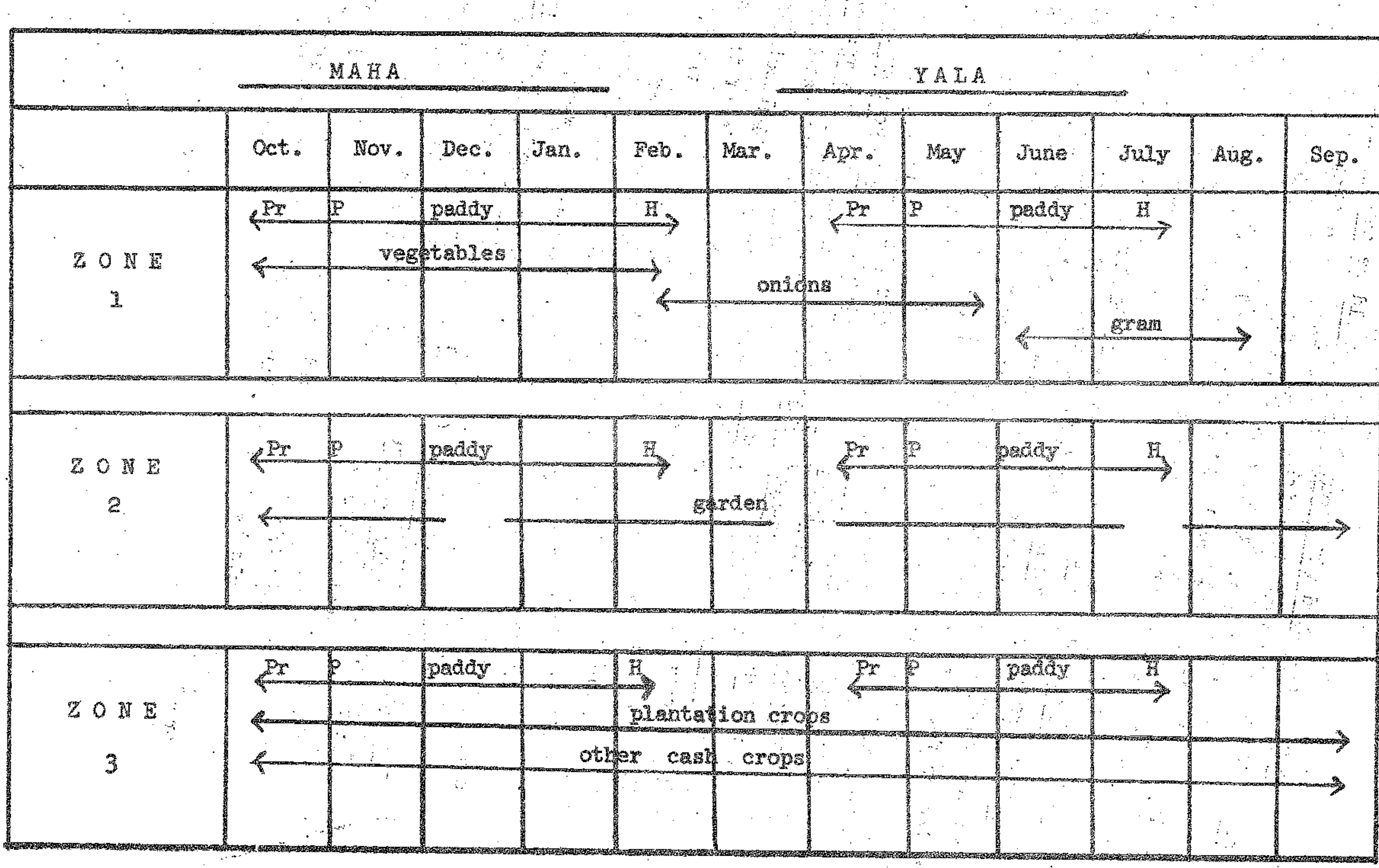


FIGURE 3. CROP CALENDAR FOR COLONIES



1) One man, equipped with four SAMIs, should be sent to each of the three zones. In urban situations it has been found that one man can handle up to ten SAMIs. 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) A sample of ten men should be randomly selected from each level of agriculture in each zone. 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) Sampling should occur at three times during the year: 20 days in October-November immediately following the onset of the north-east monsoon; 20 days in March-April following the harvest of the monsoon paddy; and 20 days in July-August. 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 ten 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 which could be used by planners to help Ceylon deal with her major problems.

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APPENDIX B

Protocol prepared for a cooperative study of labor utilization in an animal protein production system: Zero-grazing dairying in the Mid-Country of Ceylon.

1. Objectives:

   a) To compare the relative production and employment potential of two systems of dairy farming in the Mid-Country, Wet Zone of Ceylon.

      System 1: Extensive Method - Pasture Grazing.
      System 2: Intensive Method - Zero Grazing.

      System 1 will not be studies in this case since the inputs, man-hours, carrying capacities, etc. are well known.

      System 2 will be studied in detail.

   b) To determine the dietary intakes of dairy workers and their families and relate these to energy demands; to experiment with alternative methods of collecting food consumption data for individuals.

   c) To estimate energy requirements of rural laborers by monitoring vital values; to experiment with new methods for establishing calorie requirements for Ceylon conditions.

   The study is to be carried out at Government Dairy, Undugoda, where all the animals are presently on a Zero-Grazing System. The herd consists of purebred Ayrshires. (The Farm Manager is Mr. Dayaratne).

2. Participants:

   1. University of Ceylon
   2. Department of Agriculture
   3. Ministry of Planning and Employment
   4. Medical Research Institute
   5. United Nations Development Programme.

3. Experimental Procedure:

a) Zero Grazing Production and Labor Trial (Pusa Giant Napier):

To be carried out by the Agriculture Department (Mr. L. Fonseka) and the University Agriculture Faculty (Prof. R. R. Appadurai). Twenty cows will be required for the study. The number of followers required for a twenty-cow unit will also be taken into account. The herd composition will therefore be as follows:

Cows in milk	-	20
Cows, dry	-	6
Heifers, 2-3 years	-	6
Heifers, 1-2 years	-	8
Heifers up to 1 year	-	8
Total		48

Labor:

Milkers	-	2
Calf keepers	-	2
Grass cutters	-	4
Total		8

All animals will be fed cut fodder (Pusa Giant Napier). The quantities of grass supplied and the quantities left over will be recorded daily. Cutting of grass should ideally be at 30-day intervals but in this experiment, the fodder fed is likely to be between 40-55 days old. To compensate for the decline in feeding value the rations given below will be fed. Samples will be taken of both grass and concentrates for proximate analysis.

Ten cows in the trial will be fed the normal farm ration--Grass plus five pounds concentrates for maintenance and a half pound per pint of milk. This will be the control. The other ten cows will be fed no concentrates for maintenance, but will be given one-quarter pound of concentrates for every pint of milk--i.e., half the present production ration. Grass will be fed ad lib. Milk recording will be carried out as usual on a daily basis. Butterfat tests should be carried out daily.

b) Nutrition Survey:

To be carried out by MRI Nutrition Department (Dr. B. V. de Mel and Dr. C. C. Mahendra) and Agricultural Extension Service (Miss F. R. A. Abeyawardene).

Diet Survey. On the Families of the workers under investigation, with particular reference to calories and protein:

1. Family Unit Survey
2. Distribution of food within the family by analysis of duplicate samples of cooked food.

Nutritional Assessment:

Of all members of family:

1. Anthropometry - heights, weights, skinfold thickness, etc. A regular check will be kept on the weights of the workers during the 15-day study period.
2. Clinical assessment for nutritional deficiency signs
3. Biochemical investigations.

The data obtained should give an indication of the calorie intakes and how they relate with calorie expenditure as determined by use of the SAMIs.

It is hoped to perfect a reliable method of assessing the distribution of food within the family on the basis of this investigation.

The study will also reveal the extent of malnutrition in the sample families--particularly protein-calorie deficiency, nutritional anemias, and goiter.

c) Energy Measurement and Calorie Input Enquiry:

To be carried out by University Medical Faculty (Dr. E. S. G. Hettiaratchi) and UNDP Consultant, Ministry of Planning and Employment (Dr. T. T. Poleman).

Experiment will build on indirect calorimetry, the oxygen/heart rate linkage, and SAMI heart-rate and/temperative monitoring devices. Ten workers to be calibrated. All will wear HR/3 instruments during working days. Three each day will also wear ambient and skin temperature SAMIs and tape recorders (24 hours) to ascertain effect of heat stress on the oxygen/heart rate relationship.

Data should yield insights into labor costs of various dairying operations and lay foundation for establishment of new food allowance recommendations for Ceylon conditions.

Period of Experiment: 6th July - 21 July 1972.