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PERFORMANCE AND ECONOMICS OF USE OF SMALL EQUIPMENT IN TROPICAL MONSOON COUNTRIES: THE CASE OF THE PHILIPPINES

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PERFORMANCE AND ECONOMICS OF USE OF SMALL EQUIPMENT IN TROPICAL MONSOON COUNTRIES: THE CASE OF THE PHILIPPINES[1/]

Mechanization is being introduced in the countries of South East Asia with varying degrees of success and acceptance. This paper discusses the status of mechanization in one of those countries, the Philippines. I would like to discuss in this paper the background in which this mechanization is proceeding. Then I will discuss the types of equipment that are being introduced. And finally, I will present the performance of these machines as we have measured them and the economics of their use.

Background Data

The Philippines is diverse with respect to climate and soil. At IRRI, in order to characterize the differential features of rice growing in the Philippines, 3 major rice areas are being studied (Figure 1). They are the Central Luzon Valley extending north from Manila, the Cagayan Valley in northeastern Luzon, and Cotabato Province in the southernmost island of Mindanao. At this time, only the results of Central Luzon are available.

The Central Luzon "valley" historically has been largely planted to rice. In 1966, of the two million hectares of paddy rice land in the Philippines, 480,000 hectares or almost one-fourth of the paddy land hectarage are in the Central Luzon provinces. The greater part of the valley lies in the watershed of the Pampanga River, which flows south into Manila Bay; the remaining northern part is in the watershed area flowing into Lingayen Gulf. Laguna Province, lying south of Manila, is included in the survey, and is of

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[1/] Based on Research Projects of the International Rice Research Institute from funds of the U.S. Agency for International Development (Contract No. AID/csd-834).

interest because of the high percentage of irrigated farms. However, of the hectarage in Central Luzon, only 10 percent is irrigated for a second rice crop.

The area was sampled during the 1966-67 crop year, with 145 rice fields randomly selected for weekly survey. At each site, observations were made on cultural practices, plant type, water control, the need for and use of fertilizers, pesticides and herbicides, soil depth, and other soil and crop conditions, and a yield sample was taken.

The planting and harvesting sequence for the sampled one- and two-crop rice-fields during the period mid-1966 to mid-1967 is presented in Figure 2. The figure plots time on the x-axis and a cumulative frequency for 109 one-crop fields and for 31 two-crop fields on the y-axis. Superimposed on the figure are the rainfall data for the Manila area and the run-off data of the Pampanga River. For the one-crop or rainfall dependent farms, planting took place in July and August, considerably after the start of the monsoon rains. Land preparation on these farms was delayed until the ground was soft enough to prepare by animal power. The two-crop farms used supplemental irrigation to soak the fields in advance. These farms were planted six weeks before those dependent on rainfall. The maximum rate of planting or harvesting was about 15 percent per week. The steep slopes of the lines for the first planting indicate that a majority of farmers in the valley perform cultural operations simultaneously. The seasonality of rainfall thus creates conditions of high labor and power use for short time periods.

The two-crop farms were planted to shorter season varieties that required about 14 weeks from transplanting to maturity. The first crop from the two-crop sites, and a major portion of the one-crop sites, were harvested

during the rainy season. This timing was necessary in order to have adequate water for growing the single non-irrigated crop and also to best utilize the residual run-off water for irrigating the second crop.

Varieties grown. The largest number of varieties grown in the Philippines are of the tall, easily lodging Indica type. The introduction of improved short, stiff-straw varieties, especially IR-8, provides for a possible large yield increase over earlier varieties. In the survey of 145 rice fields only 14 of the fields were in Laguna Province. The rice varieties grown by operators of the sample fields have been compiled. Only in three fields was IR-8 grown during the 1966-67 crop year. Most numerous of the varieties are: Intan, Binato, Tjeremas, BE-3, and Raminad.

The 1967-68 survey has included more irrigated fields and in a smaller area. A comparison of the varieties grown on 39 fields included in both surveys during the wet season crop are listed below in Table 2. IR-8 and IR-5, the only improved varieties mentioned, were grown on 2 fields in 1966-67 and 7 fields in 1967-68. Laguna Province grew the most IR-8 and IR-5, having all but 2 of the improved varieties tested. Thus, there was a sizable increase of improved varieties grown in Laguna, while Central Luzon has been more reluctant to change to the new varieties.

Economic Survey of Central Luzon Farmers.

Along with the weekly field sampling, interviews were conducted with Central Luzon farmers. The Central Luzon farmers are largely share-tenants. The 1960 Census of Agriculture indicates that Pampanga and Nueva Ecija Provinces are 85 percent tenant-operated, and Laguna, 72 percent. The average farm size is about 3 hectares. Of 114 farmers interviewed in Central Luzon, 63 reported a farm size between 1.6 and 3.5 hectares.

Outside sources indicate that Central Luzon is about 9 percent irrigated for a second crop of rice. The percentage irrigation in Laguna Province contained in the sample was 8 farms out of 13 reporting, while for Central Luzon, the number was 22 out of 108.

The cultural practices are centered on the use of carabao and manual labor. A summary of farm equipment and animals owned is contained in Table 3. For farms below 1.5 hectares in size, the typical equipment was 1 plow, 1 harrow and 1 carabao. For farms between 1.6 and 3.5 hectares, the equipment in average terms was 1.4 plows, 1.5 harrows and 1.5 work animals. For farms above 3.6 hectares, the equipment was 2 plows, 2 harrows, and 2 carabaos. Of the 114 farms reporting, while several indicated tractor use, only one farm owned a tractor. Furthermore, use of tractors and carabao was confined to land preparation.

Several questions were asked as to the demand for and supply of farm labor, and concerning power use.

The first questions were with respect to labor use. The purpose of the inquiry was to determine the labor use throughout the crop year. Perhaps the extent of the farm operations requiring reliance on hired labor can indicate the immediate potential for changes in the operation which are more economical. Additionally, indications of labor shortage at peak period may indicate production bottlenecks.

Table 4 presents the man-days of labor for pre-harvest operations for hired labor and for the other labor categories. Hired labor plays the largest role in transplanting operations. However, this is misleading since the landlord pays for labor involved in transplanting, and the tenant is reported as hired labor. Thus, there is little indication of the participation of family

labor in that operation. Hired labor is used to some extent for other operations, but the primary labor source is the operator and family labor. Basically, the use of operator, family, exchange or hired labor varies according to family size, to skill required, or to payment source. Since land preparation requires some skill and is heavy work, this operation is performed by men. The other operations may need skill but can be done by men, women and children. The extent of work done by hired labor varied by type of operation. Hired labor was used almost exclusively for transplanting as already mentioned. Almost one-half of the weeding was by hired labor, and about one-sixth of the total for plowing and harrowing.

Table 5 contains estimates of average labor requirements of rice farms in the Central Luzon survey. There are three peak periods of labor use: land preparation, transplanting, and harvesting-threshing. Of total labor required, these operations use 20 to 30% for land preparation, 20% for transplanting and 25 to 30% for harvesting-threshing. Only 10% of the labor was used for weeding. Lack of weeding labor intensity is not surprising as 25 percent of the farmers interviewed indicated no weeding at all, as mentioned below.

On share-tenant farms, a common arrangement is for the landowner and tenant to share 50-50 in total receipts. The owner usually pays for all of the costs pertaining to the land and improvements, all the transplanting labor cost, half the materials and seed used, and half of the harvesting and threshing cost. The remaining costs are borne by the tenant.

Labor Shortage: Questions were asked about labor shortages during peak periods of labor need. The farmers stated that they had little difficulty in obtaining transplanting and harvesting labor, jobs for which women and

children are available. Farmers noted some difficulty in obtaining labor for plowing and harrowing. The shortage may be intensified because of the practice of local communities to perform particular farm operations simultaneously.

There is considerable variation in the intensity of land preparation between farms. The frequency of sequence of land preparation operations among the farms interviewed are as follows, given that each harrowing contains two "passes" of the field:

Operation	Frequency
one plow, three harrow	61
two plow, three harrow	10
one plow, two harrow	9
two plow, two harrow	8
one plow, five harrow	6
one plow, four harrow	5
one plow, six harrow	5
others	17
Total farmers interviewed	121

Farmers did not view weeding labor as a problem. Weeding practices among the 121 farmers were as follows:

No weeding	30
One hand or rotary weeding	66
Two or more weeding	22
No data	3
Total	121 farms

Hence, on one-fourth of the farms there was no weeding; on over three-fourths there was one weeding or less. However, the situation is likely to change towards a greater demand for weeding labor, for the improved varieties require more clean culture for better yields.

In brief, only in one farm operation, land preparation, was there any comment made as to labor shortage. This situation arises or is intensified by the practice of the entire community (barrio) performing the farm operation simultaneously. There will be little change in this practice for rainfall-dependent

operations. However, in the irrigated two-crop areas (15 percent of the total area or less) the practice of each barrio performing operations simultaneously is less strong. Thus, mechanizing land preparation will have the least undesirable effect on employment.

Use of Power and Equipment.

As can be seen from Tables 3 and 6, there is great reliance on the carabao (water buffalo) as the source of power. However, there is a beginning of mechanization in some of the farm operations. The two operations most amenable to mechanization have been land preparation and threshing. As was mentioned above, farmers have reported difficulty in obtaining labor for land preparation. But there is little information on availability of threshing labor in Central Luzon, for the threshing operation to a large extent relies on the large IH-McCormick threshing machine.

In looking at the status of mechanization, one can separate the Central Luzon area north of Manila from Laguna Province to the south of Manila. Threshers have been in use in Central Luzon for many years. In Laguna Province, on the other hand, there is little use of threshing machines, but land preparation is being mechanized by use of hand tractors.

The threshing methods vary in the country, but in comparing Central Luzon and Laguna Provinces, there are two extreme examples. In Laguna, the rainfall pattern, while monsoon seasonal, does spread throughout the year. Thus, the crop is harvested under rainy conditions. Their usual threshing method then is one in which grain and straw can be separated when wet. Use is made of primitive methods, such as beating bundles on a rock or on a threshing frame. In Central Luzon, the rain pattern is as indicated in Figure 10, and the harvesting time as noted in Figure 11. Notice the one-

crop harvest period. Harvesting is performed as the rainfall is disappearing. Thus the farmer has been able to thresh under relatively dry conditions, which are essential for use of the large threshing rigs. The rice is hand harvested, bundled, and put in small stacks to dry. When dry, these bundles are assembled in large stacks, and then fed into the threshing machine.

The threshing machines cost about ₱20,000[1/], and are pulled by high-horsepower tractors or tracklayers. Thus, use of the thresher is a costly operation. Threshing machines are used on a contract basis at a cost of a percentage of the crop. These rates vary from 4 percent to 7 percent, depending on local conditions and distance traveled. Output of the machine is said to vary from 500 to 1,200 cavans[2/] of rough rice for up to a 14-hour day. The output would depend on the availability of work close at hand, and the time involved in shifting from one haystack to another.

The output of the hand method of threshing is difficult to measure. As a rough indication, the output on a continuous basis is probably one-to two cavans (44-88 kg) per hour. Since the work is hard, continuous operation is difficult to maintain.

Other threshing methods are: threshing by manipulation of the feet; threshing by carabao trampling, threshing by leaving the rice in the road and letting autos pass over it. There is little use of other power equipment for threshing, including the pedal thresher and powered drum thresher.

Performance tests are being conducted on the IRRI drum-type thresher

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[1/] ₱1.00 = ¥92.3; roughly use the ratio of 1:100. Thus, ₱20,000 = ¥2,000,000 = $5,000.

[2/] 1 cavan of rough rice = 44 kg. Thus 1,000 cavans = 44,000 kg or 44 metric tons.

and on the other thresher methods.

Selected tests indicate the following tentative data on output:

IRRI drum-type thresher:	6 cavans/hr	(264 kg/hr)
Iseki drum-type thresher:	8 cavans/hr	(352 kg/hr)
Hand method on threshing frame:	1-2 cavans/hr/man	(44-88 kg/hr)
IH-McCormick thresher (estimate)	85 cavans/hr	(3740 kg/hr)

These data are preliminary and can be used only as indicators of relative magnitudes of output.

Data will not be assembled on the economics of thresher use until adequate performance is available. We can, however, list the following costs:

Iseki thresher	₱2,500 + engine (₱600)
IH-McCormick thresher	20,000 + use of large standard tractor.
Hand threshing frame	very small amount
IRRI thresher (estimate)	1,500 + engine (₱400).

Land preparation in the Philippines, as shown in Table 3, is primarily performed by carabao (water buffalo), pulling a 12-cm moldboard plow and a 137-cm wide comb harrow. The data in Table 6 indicated the reliance of the farmers of the area on the carabao. Furthermore, these animals were typically owned by the farm operator. Table 5 lists the average number of eight-hour days of carabao use per hectare. For land preparation, farmers in Central Luzon worked their carabaos from 14 to 18 man-days per hectare per crop.

Work animals can be either owned or can be contracted. The data on hiring a man with carabao for custom work indicate that the prevailing cost is ₱7.50 to ₱10.00 per day. It is important to know the cost of ownership and use of a carabao, for comparisons need to be made between costs of use of the carabao and the tractor. Ownership costs can be estimated for the tractor, but the cost of main-

tenance of a carabao is not so easily quantifiable.

Some of the interview data on carabao are listed in Table 6. The carabao is asserted to have a working life of from age 3 to 25, or 22 years. These data indicate that farmers expected the animal to work up to age 20. If the farmer buys his replacements (60 percent said they did), he will pay ₱200 for a 2-year-old animal. Other data indicate that these farmers hire little help to look after the carabao during the time the animal is not working. No pasture or grazing land is set aside for the animal, and the practice of buying supplemental feed for the animal is not common. Only 20 percent of the farmers indicated use of a veterinarian or of medicines for the animals. However, farmers thought the carabao is getting scarce and harder to find. Evidently, the local carabao is an efficient converter of local grasses and is fed little supplemental feed.

A cost computation for carabao ownership is computed below based firstly on actual replies. Since opportunities for alternative work are lacking, the cost of labor for attending to the carabao is near zero. An alternative schedule of costs is also presented in which some allowance for cash costs is made. A comparison of tractor and carabao costs is made later.

Table 7. Cost involved in carabao ownership.

Cost Category	Cost based on: Actual replies	Some cash cost assumptions
Purchase: 2-yr-old carabao	₱200.00	₱200.00
Domestication & training of carabao	0.00	50.00
Man-hours of watching carabao, 20 hrs/wk	0.00 (20 hrs/wk or 1040 hrs/yr at ₱0.25 for 1/4 of the time)	65.00/yr
Equipment: plow	45.00	45.00
harrow	45.00	45.00
harness & yoke	10.00	10.00
other tools	no data	no data
Miscellaneous costs: veterinary fee and medicines		10.00/yr
Supplemental feeding		30.00/yr

In examining the farmers' attitudes toward tractor, over 50 percent indicated they would use the tractor for land preparation if they could conveniently hire one. They listed as reasons for tractor use: timeliness, ease of killing weeds, a less tedious operation, and a lack of carabaos.

For land preparation, standard-sized tractors are starting to be used in more remote areas of the country, especially areas where labor is short and the soil firm under wet conditions. The land is still prepared wet using a disc plow or rotovator. Further land preparation operations consist of harrowing and leveling with long planks with spikes.

The most numerous of the tractors are the 4- to 6- horsepower tractive-type hand tractors and the 8.5- to 12- horsepower tillers. For the hand tractor the sequence of land preparation is to plow once, and harrow twice. After one or two weeks, 3 further passes of the harrow. For the power tiller, the operation may consist of two passes of the tiller, then after one or two weeks, three passes of the comb harrow with a tractive type hand tractor.

For the other cultural operations of weeding and transplanting, little mechanization is occurring. In weeding, the hand rotary weeder has been selling well. And a power 3-row weeder operated from a back pack engine is being developed at IRRI. In time tests, the hand weeding time was around 130 man-hours per hectare under that particular set of weed and soil conditions. In comparison, the rotary weeders took 60 man-hours for two passes. And for the power weeder, 20 man-hours were used for two passes.

Trafficability Problems.

A further major problem in mechanization is that of trafficability: both in traction and floatation. Many soils are deep and will not provide traction for nor sustain the weight of heavy equipment. Tests have been run

in Thailand and in the Philippines to measure the depth of soil at various pressures in order to estimate whether certain types of equipment can operate in these fields. Figures 14 and 15 show in cumulative frequency a series of soil depth measurements taken on 145 fields in Central Luzon, Philippines. The instrument used is the U.S. Army Corps of Engineers WES cone penetrometer[1/]. An arbitrary "go" and "no go" criterion for a 50-horsepower tractor with cage wheels is a cone index pressure of 70 psi at a depth of 30 cm (12 inches). The figure lists the one- crop fields and two- crop fields separately. There is water on the two- crop fields for a much longer period, and these fields are likely to be softer, on the average, than for the one- crop fields. At the 30-cm-depth criterion, about 85 percent of the one-crop fields and 55 percent of the two-crop fields would be suitable for heavy machinery. Further testing is being conducted to provide more suitable answers on use of machinery in paddy soils. The Japanese-made penetro shear graph from the Soil Values Meter called TN-4 is being employed[2/] (Figure 17). Measurements are being taken in Central Luzon at three stages of farm operations: just before land preparation; during final harrowing; and just after harvest. And data are being collected by use of the WES cone penetrometer on soil depths in other major rice growing areas of the Philippines. Figure 20 presents measurements taken in Northeast Luzon (Isabela Province). These data suggest that large equipment will have no bogging problem here.

[1/] See Knight, S. Johnson and Freitag, D. R. 1962. Measurement of Soil Trafficability Characteristics. Transactions of the American Society of Agricultural Engineers. 5(2): 121-124 and 132.

[2/] Tanaka, T. Prediction of the Trafficability of the Tractor on the Soft Paddy Field. III Measuring Device of the Soil Penetrometers, TN-4. J. Soc. Agr. Machinery Japan 27(3): 150-154, 1965. (In Japanese).

Hand Tractor Studies.

During late 1966 and in 1967 hand tractor studies were conducted on the engineering and economic aspects of hand tractors for tillage operations on lowland rice farms in Laguna Province. While the purpose was not to obtain an accurate count of all tractors, of the tractor owners interviewed, 9 tractors were reported to have been purchased before 1960, and by 1967, 431 tractors were counted.

The hand tractors in Laguna Province are largely the tractive type tillers of 4 to 6 HP, designed to pull plows, comb harrows and small trailers. The larger horsepower (6 to 13 HP) rotary tiller types are also being sold and gaining in popularity. Few standard-sized 4-wheel tractors have been noted doing rice work in this area of soft soils.

Time studies were made on IRRI experimental fields where closer observations could be made. The fields had already produced one crop during the monsoon season and were still very soft as shown by the U.S. Army WES cone penetrometer readings of a depth of from 27 to 38 cm at a pressure of 70 psi. From 1 to 5 tons per hectare of weeds and stubble were incorporated and the land prepared ready for transplanting. Six of the fields were so soft that the comb harrow was used instead of the plow, and in several fields the tillers bogged often. The total fuel consumption averaged 39.9 liters/ha. Plowing averaged 15.3 liters/ha; harrowing averaged 5.11 liters/ha per pass, and 5.5 passes for a total of 27.5 liters/ha; and leveling averaged 2.21 liters/ha. The average fuel consumption was about 0.25 liters per rated horsepower-hour. The fuel requirement per pass for harrowing IRRI fields (5.11 liters/ha) was comparable with the results of the field survey in 1966 of 4.67 liters/ha while the fuel requirement for plowing IRRI fields of 15.3 liters/ha was much

less than the 33.7 liters/ha obtained in the 1966 field survey. The apparent explanation is that the farmers' fields were firmer in the first season and the farmers plowed a narrower furrow slice.

Comparison of Hand Tractors and Animals: During 1967 a series of trials were conducted on four adjacent quarter-hectare plots at the IRRI experimental farm to compare two power units. Four 4- to 6- HP tractive type hand tractors with two operators each, and eight carabaos with their individual owners were used in the trials. One hectare was subdivided into 16 plots. Individual plots measured approximately 25 meters by 26 meters. The whole area was flooded five days before the test. The depth of soil penetrated before reaching a bearing capacity of 20 psi, 35 psi, and 70 psi was determined through the use of the WES cone penetrometer; depths were found to be approximately 18 cm, 28 cm, and 35 cm, respectively. Hand tractors and carabaos started simultaneously in adjacent plots. Two plots were each plowed once and harrowed a few times by two hand tractors. The degree of puddling and incorporation of vegetation after every pass with the comb harrow was observed. Harrowing was stopped when the operators considered the plots comparable to outside farmers' fields ready for planting. Having completed one plowing, the two carabaos were then required to pass the comb harrow as many times as necessary to approximate the quality of work done by the hand tractors. The same procedure was followed in the other plots.

Each pass with the plow and the harrow was timed; the number of passes and of rounds per pass was noted.

The effective field capacity (efc) was computed by substituting values in the formula:

$$\text{efc (sq m/hr)} = \frac{60 \times 2:N:L:W}{t}$$

where:

60 = No. of minutes in one hour
2 = No. of trips per round
N = No. of rounds
L = Length of trip, in meters
W = Width of implement, in meters
t = Time used during operation, in minutes

The plowing or harrowing time is arrived at by substituting values in the formula:

$$\text{Plowing or harrowing time per single pass (hrs/ha)} = \frac{10000}{A} \times T \times P$$

where:

10000 = No. of square meters in a hectare
A = Area of plot in square meters
T = Time used during operation, in hours
P = No. of passes of the implement, usually 1 for plowing and several for harrowing

Hand tractors with 18 cm moldboard plows were computed to have a mean effective field capacity of 311 square meters per hour. This would require 32.2 hours of plowing time per hectare. However, actual mean time used was only 12.90 hrs/ha. This indicates that the plows were cutting furrows 18 cm wide and covering unplowed strips about 27 cm wide.

With the 137-cm comb harrow, the same hand tractors had to make 3 to 4 passes through the test plots to complete preparation of the land for transplanting. These 3 to 4 passes took 13.90 hours to finish a hectare. However, with their mean effective field capacity of 2381 sq m/hr, it would require 14.7 hours to harrow a hectare. This shows that about 6 percent of the area, at one time or another, was not harrowed. Adding up the time used for plowing and harrowing a hectare of land, we have 26.80 = 3.11 hours or roughly 4.5 days.

With the 12-cm moldboard plows, the carabaos have a mean effective field capacity of 138 sq m/hr. Although it would require a mean time of 72.5 hrs/ha, the actual time required was only 36.34 hours. The plows, therefore, were cutting furrows about 12 cm wide and covering unplowed strips about 12 cm

wide. The animal and machine plowing methods were about the same. The mean depth of plowing was 16 cm. As in the case of the hand tractor-drawn plows, the carabao-drawn plows were operating through soft soil

With the 137-cm comb harrow, the carabaos had to traverse the test plots 9 to 13 times to achieve a finish comparable to that in the plots prepared by means of the hand tractors. These 9 to 13 passes took 83.41 hours to finish a hectare. With a mean effective field capacity of 1554 sq m/hr, it would take 73.3 hours to harrow a hectare. This shows that there was overlapping of about 20 cm in the operation, or about 14 percent of the area was harrowed twice on each pass. Some 119.75 ± 29.54 hours (about 20 days) are needed to plow and harrow a hectare adequately for planting.

Some recent field data were computed for Laguna Province for plowing, harrowing and rotovating. These data, in averages, are:

	Effective field capacity	
	m^2/hr	m^2/Rhp-hr
Plowing: Tractive-type tractors	443	79
Harrowing: Tractive-type tractors	3659	645
Rotovating: Power tillers	1610	186

A typical sequence of land preparation in Laguna Province is: (1) for rototilling, two passes of the rototiller, followed one or two weeks later by three passes of the harrow; (2) for tractive-type tillers, one pass of the plow, followed by two or three passes of the harrow; after one or two weeks, another two or three passes of the harrow.

Survey of Hand Tractor Owners: In Laguna Province, on data tabulated for the tractive type hand tractor (Table 8), about one-third of the farmers owning tractors operated 2 to 3 hectares of irrigated paddy land. A further third operated 3 to 4 hectares, while most of the remaining third had from 5 to 8 hectares. In addition to land preparation on the machine owner's farm, contract work away from the owner's farm was common. The most frequently mentioned number of days worked were 15 to 30 days of contract hire. Thus,

for a typical owner, the machine would be used for land preparation on the 2 to 8 hectares of land for two crops, and an additional 15 to 30 days of contract hire.

Several types of small hand tractors, mostly Japanese, were sold in the Province. The tractive type tillers were of comparable size and horsepower and sold for roughly the same price. Payments made for these tractors ranged from ₱1,000 to ₱4,900, depending on size, equipment, and type of payment. A typical cash price for a 6-HP tractive-type tiller with cage wheels, plow and comb harrow was ₱3,700. Terms could usually be obtained for two-crop farmers by extending the payments over 7 crops, or 3-1/2 years. In addition to the ₱3,700 base price, a service charge of ₱1,200 was made, making each of the 7 payments ₱700. The two most quoted range of prices were between ₱2,500-2,900 and ₱4,500-4,900.

The daily contract rate for hand tractor work varied between ₱25.00 to ₱35.00. However, the lower rates required meals to be provided for the two operators of each tractor. The present rate around Los Baños which includes meals is ₱35.00 per day.

Hand Tractor Cost of Operation

The cost of a 6-HP tractor with equipment is ₱3,700 cash or ₱4,900 when spread out over 42 months.

The annual fixed cost of owning a tractor is presented below under three assumptions:

(1) Straight line depreciation for the cash price yields the following, considering a 7-year life:

$$\frac{₱3,700.00}{7} = ₱530.00 \text{ per year}^{1/}$$

1/ The present rate of exchange is US $1.00 = ₱3.90 or roughly, 1:4.

(2) For the tractor cash price plus interest, at a more pessimistic 5-year life:

$$\frac{₱4,900.00}{5} = ₱980.00 \text{ per year}$$

(3) For the farmer to meet his payment of ₱700 per crop, he needs to earn:

$$.2 \times ₱700.00 = ₱1,400.00 \text{ per year}$$

One can estimate the farmer's breakeven (B/E) work load to meet his payments or to compare with computed depreciation. The simplest form of the breakeven formula is to compute a ratio of the amount of money needed to be paid or earned to the variable profit per unit of measurement. The ratio is:

$$B/E = \frac{\text{Fixed cost (FC)}}{\text{Total revenue - variable cost}}$$

The variable costs of tractor operation are the hire of the tractor operators and the fuel and repair costs.

Two men combine to operate a tractor at a daily wage of ₱5.00 plus meals and merienda. The cost may be ₱15.00 daily in total. Fuel cost per day is roughly ₱4.00. Not enough years of data on repairs have been collected to adequately estimate repair costs. A repair cost is assumed of ₱100 per year, or for 100 days of operation, ₱1.00 per day.

Tractor contract costs vary from ₱25.00 to ₱35.00. The latter amount is typical of rates in which meals are included.

Using these operating costs, the breakeven point in terms of 8-hour work days is from the three assumptions:

1. (Cash cost, 7-year life):

$$B/E = \frac{₱530.00}{₱35.00 - ₱15.00 - ₱4.00 - ₱1.00}$$

$$\frac{₱530.00}{₱15.00}$$

$$= 35.3 \text{ days}$$

2. (Installment cost, 5-year life):

$$B/E = \frac{₱980.00}{₱15.00} = 65.3 \text{ days}$$

3. (To meet yearly payment of ₱1,400.00):

$$B/E = \frac{₱1,400.00}{₱15.00} = 93.3 \text{ days}$$

Under the most favorable assumptions of depreciation and length of life, the number of tractor operating days needed to cover the fixed cost is 35.3 days. For the shortest life assumption and depreciation based on computed cost plus interest, the number of days of work needed rises to 65.3 days. And, finally, the number of working days approaches 100 in order to meet the yearly payment. These requirements could be reduced by one-third if the owner is an operator of the machine.

From Table 9, the mean time to prepare one hectare of land by tractor is 27 hours or 3.4 days. Then the number of hectares of land prepared necessary to cover the annual fixed cost is, for the low estimate, 35.3 ÷ 3.4 = 10.4 hectares, and for the high estimate, 65.3 ÷ 3.4 = 19.4 hectares. Thus, if the contract rate is the appropriate measure, the farmer needs to prepare between 10 and 20 hectares of land per year in order to cover the tractor depreciation costs, and roughly 30 hectares to meet the twice-yearly tractor payment.

Another means of comparison is, by partial budgeting, to make the cost comparisons with the cost of land preparation before the tractor purchase. For instance, if the work is done by animal on a contractual basis, the cost of preparing one hectare (using mean data from Table 9) is ₱160. From these data, the tractor owner can calculate if his hectarage is sizable enough to warrant tractor purchase. One must also recognize the amount of time worked off the tractor owner's farm. If the owner works the tractor 30

days off his own farm, he contributes ₱15.00 per day to cover fixed cost, or ₱450.00.

Relative Cost of Operation of Hand Tractor and Carabao (Water Buffalo) Power

Comparisons of the tractive-type hand tractor and the carabao in the land preparation can be made by using the current contract hire rates of each (Table 9). At a contract rate of ₱35.00 per day for the hand tractor and ₱8 per day for the man and carabao, the cost of operation per hectare is[1]:

Plow:	Carabao	₱ 48.33
	Tractor	56.50
Harrow:	Carabao	110.94
	Tractor	60.88

Thus, the plowing cost is similar, while the big cost difference is in harrowing. One must remember, however, that most farmers own their carabaos. Since the opportunity cost of family labor may approach zero, the ownership cost of carabao is low.

Data on tractor ownership is presented above in discussing the break-even point. The data on carabao ownership is more difficult to compute. General information on carabao use and ownership was presented earlier. Below some conjectural data are presented. The first column is the minimum cost that a carabao owner could expect to achieve, using labor at a "zero" price. The second column contains projected costs including a cost of ₱0.25 per hour for one-fourth of the hours in watching the carabao, and some cost for medicine and feed supplement:

[1] $1.00 = ₱3.80. The tractor crew consists of two men alternating in operating the machine because of the heavy work.

Carabao Cost Category	Minimum Cost	Projected Cost
Yearly cost: watching	₱ 0.00	₱ 65.00
Depreciation of equipment (5 yr. life)	20.00	20.00
Medicine	0.00	10.00
Supplemental feeding	0.00	10.00
	₱20.00	₱105.00

Hourly Cost of Carabao Use Under:

Minimum Cost: ₱20.00 per year for 200 hours use:

$$\frac{₱20.00}{200} = ₱0.10 \text{ per hour of land preparation}$$

Projected Cost: ₱105.00 per year for 200 hours use:

$$\frac{₱105.00}{200} = ₱0.50 \text{ per hour of land preparation}$$

Admittedly, these costs are rough, but they may provide at least some basis of comparison where no estimates existed before.

TABLE 1. Yield estimates from a test conducted on IRRI fields. These tests were based on a comparison of the reported total yield and the yield estimated from harvesting a 4-square-meter sample.

Variety	Reported yield	Sample mean yield	Sample median yield	Mean % bias	Median % bias
		kg/ha			
IR60-27-1-3-1	3894	5135	5378	32	38
IR76-154-1-2	2516	4128	4145	64	65
IR160-44-1-2	4556	5983	5865	31	29
IR11-452-1-1	4115	5720	5240	39	27
IR11-288-3-1-2	5848	7438	7628	28	30
IR11-288-3-1-2	6184	7870	7805	27	26
IR11-288-3-1-2	6840	7137	7458	4	9

Note: Bias is used here to indicate the difference between the sample mean or median yield and the reported yield over the reported yield (times 100), or

$$\frac{\text{Mean} - \text{Reported}}{\text{Reported}} \times 100$$

If the sampled yield is greater than reported, the bias is positive; if less than reported, negative bias.

TABLE 2. Preliminary comparison of rice varieties planted in Laguna, Bulacan, and Nueva Ecija Provinces, 1966-67 and 1967-68.[1]

Variety	Number of fields planted to the variety					
	tal area		Laguna Province		Central Luzon	
	7	1967-68	1966-67	1967-68	1966-67	1967-68
IR-8	2	6	2	4	0	2
IR-5	0	1	0	1	0	0
Intan	9	6	2	0	7	6
Malagkit	2	1	1	1	1	0
Wagwag	2	1	2	1	0	0
Tjeremas	8	10	0	0	8	10
Milagrosa	1	0	0	0	1	0
Binato	9	7	1	1	8	6
BE-3	2	2	0	0	2	2
Macan	1	0	0	0	1	0
Ramadia	2	4	0	0	2	4
Peta	1	0	0	0	1	0
Dara	0	1	0	0	0	1
TOTAL	39	39	8	8	31	31

[1]SOURCE: Agricultural Engineering Survey, The International Rice Research Institute.

TABLE 3. Farm equipment and animals owned, by area of farm, (in percent), 1966-67 Central Luzon survey.

Hectarage	No. of farms reporting	Tractor	Plow	Harrow[1]	Weeder	Sprayer	Carabao	Cattle
		percent						
Below 1.5	17[2]	(11)[3]	111	123	17	11	94	5
1.6 - 2.5	30	(16)	140	140	10	3	143	0
2.6 - 3.5	33	3(36)	142	163	18	12	163	15
3.6 - 5.5	16	(6)	212	218	12	18	231	0
5.6 - above	18	(11)	250	238	22	38	244	0
All farms	114	(16)[a]	164	171	15	14	170	5

1/ Includes upland harrows used in lowland paddies, specifically in Pangasinan.
2/ Two farmers reported no equipment owned.
3/ Tractor hired.
a/ Less than 1%.

Farm equipment and animals owned, by area of farm, (actual numbers), 1966-67 Central Luzon survey.

Hectarage	No. of farms reporting	Tractor	Plow	Harrow[1]	Weeder	Sprayer	Carabao	Cattle
Below 1.5	17	(2)	19	21	3	2	16	1
1.6 - 2.5	30	(5)	42	42	3	1	43	0
2.6 - 3.5	33	1(12)	47	54	6	4	54	5
3.6 - 5.5	16	(1)	34	35	2	3	37	0
5.6 - above	18	(2)	45	43	4	7	44	0
All farms	114	1(22)	187	195	18	17	194	6

1/ Includes upland harrow used in lowland paddies, specifically in Pangasinan.
2/ Two farmers reported no equipment owned.
3/ Numbers enclosed are hired tractors.

TABLE 4. Average number of man-days (8-hour day) per hectare used to perform pre-harvest operations.[1]

Operations	Operator labor	Family labor	Hired labor	Exchange labor	Total labor
Total number of farms			100		
Total area (ha)			232.9		
			per hectare		
Seedbed preparation	1.1	0.3	0.2	a/	1.6
Care of seedbed	0.8	a/	a/	a/	0.8
Plowing	2.5	1.9	1.5	1.6	7.5
Harrowing	2.2	1.7	1.5	3.5	8.9
Repair of dikes	1.1	0.6	0.7	0.1	2.5
Cleaning of dikes	0.7	0.4	0.6	a/	1.7
Pulling of seedlings	a/	a/	1.3	0.1	1.4
Transplanting		0.1	14.3	0.1	14.5
Weeding	1.4	1.1	2.3	0.5	5.3
Fertilizing	0.3	0.1	a/		0.4
Spraying	0.1	0.2	0.1		0.4
					45.0

[1] Source: Interviews with 100 farmers, Central Luzon, 1966-67.
a/ Less than 0.1 man-day.

TABLE 5. Average labor requirements of rice farms using carabaos, in man-days, Laguna Province and Central Luzon survey, 1966-67.

	Irrigated		Non-irrigated
	2-crop	1-crop	1-crop
No. of farms	27	39	41
	Man-days (8 hours per day) per hectare		
Seedbed preparation and care	2.51	2.68	3.12
Plowing	5.94	7.91	8.32
Harrowing	8.06	9.30	10.42
Repair and cleaning of dikes	2.43	3.87	4.52
Pulling and rolling seedlings	2.53	2.44	2.83
Transplanting	10.85	13.47	14.11
Weeding	4.58	6.55	4.79
Fertilizing	0.28	0.72	0.48
Spraying	1.08	0.44	0.62
Harvesting-threshing	18.33	16.12	15.30
Total	56.59	63.50	64.51

TABLE 6. Carabao data.

Province	No. of farms surveyed	No. of farms reporting no carabao	Average no. of carabaos owned	Carabaos worked	Age - years	Age limit to work	Hours/day work	Hours/week to look after carabao	Cost of 2-year-old carabao
Laguna	11	6	2	1.6	9	21	5	19	₱ 240
Bulacan	24	1	1.7	1.4	11	20.6	8.1	22.4	218
Nueva Ecija	53	5	2.2	1.8	9.1	19.7	7.5	24.9	206
Pangasinan	17	1	2.3	2.3	9.8	22.8	6.8	21.9	206
Tarlac	5	0	2.6	2.2	8.0	22.4	8.2	26.6	192
Pampanga	6	0	3.3	2.0	8.8	20.0	5.6	22.6	217

TABLE 8. Hand tractor survey data: Laguna, 1967.

Age of all machines:

Total No. of Machines	Months			Years												No Data
	1	2-5	6-12	1	2	3	4	5	6	7	8	10	12	13	14	
227	6	23	15	38	47	30	22	23	10	4	3	1	1	1	2	1

Hiring fee for all machines (pesos/day):

Total No. of Machines	₱ 25	₱ 30	₱ 35	₱ 60	₱ 65	₱ 70	₱ 80	Machine Not Hired	No Idea
227	45	97	4	2	1	1	2	29	46

Area worked on own farm by Landmaster tractor (hectares/tractor):

Total No. of Machines	0.5 ha.	1.0 ha.	1.5 ha.	2.0 ha.	2.5 ha.	3.0 ha.	3.5 ha.	4.0 ha.	5.0 ha.	6.0 ha.	7.0 ha.	8.0 ha.	9.0 ha.	10.0 ha.	11.0 ha.	19.5 ha.	24.0 ha.
142	0	2	4	21	12	18	8	38	16	6	4	6	1	2	2	1	1

Number of days the Landmaster tractor was hired out per year:

1-5 da.	6-10 da.	11-15 da.	16-20 da.	21-25 da.	26-30 da.	31-35 da.	36-40 da.	41-45 da.	46-50 da.	51-55 da.	56-60 da.	61-89 da.	90-119 da.	120 da.	160 da.
2	9	19	14	2	15	3	9	4	6	1	7	3	6	1	1

TABLE 9. Plowing and harrowing: Carabao and the Hand Tractor (6 HP)[1/]

	Mean Time	Range
	hr/ha	
Plow: Carabao	36.3	28.8 - 41.2
Tractor	12.9	11.2 - 14.6
Harrow: Carabao	83.4	55.5 - 09.5
Tractor	13.9	11.3 - 16.6

Contract rates: Tractor, ₱ 35.00 per 8-hour day, or ₱ 4.38/hr.

Carabao ₱ 8.00 per 6-hour day, or ₱ 1.33/hr.

Cost Comparisons:

	Average Cost	Range	
		Low	High
Plow: Carabao	₱ 48.33	₱ 38.25	₱ 54.85
(at ₱10/day)	(60.69)	(48.03)	(68.87)
Tractor	56.50	49.14	63.95
Harrow: Carabao	110.94	73.75	145.57
(at ₱10/day)	(139.29)	(92.60)	(182.78)
Tractor	60.88	49.54	72.80

[1/] Tests conducted on IRRI soils. Plowing = one pass. Harrowing judged to be "adequate" at 9-13 passes of the carabao and 3-4 passes of the tractor.

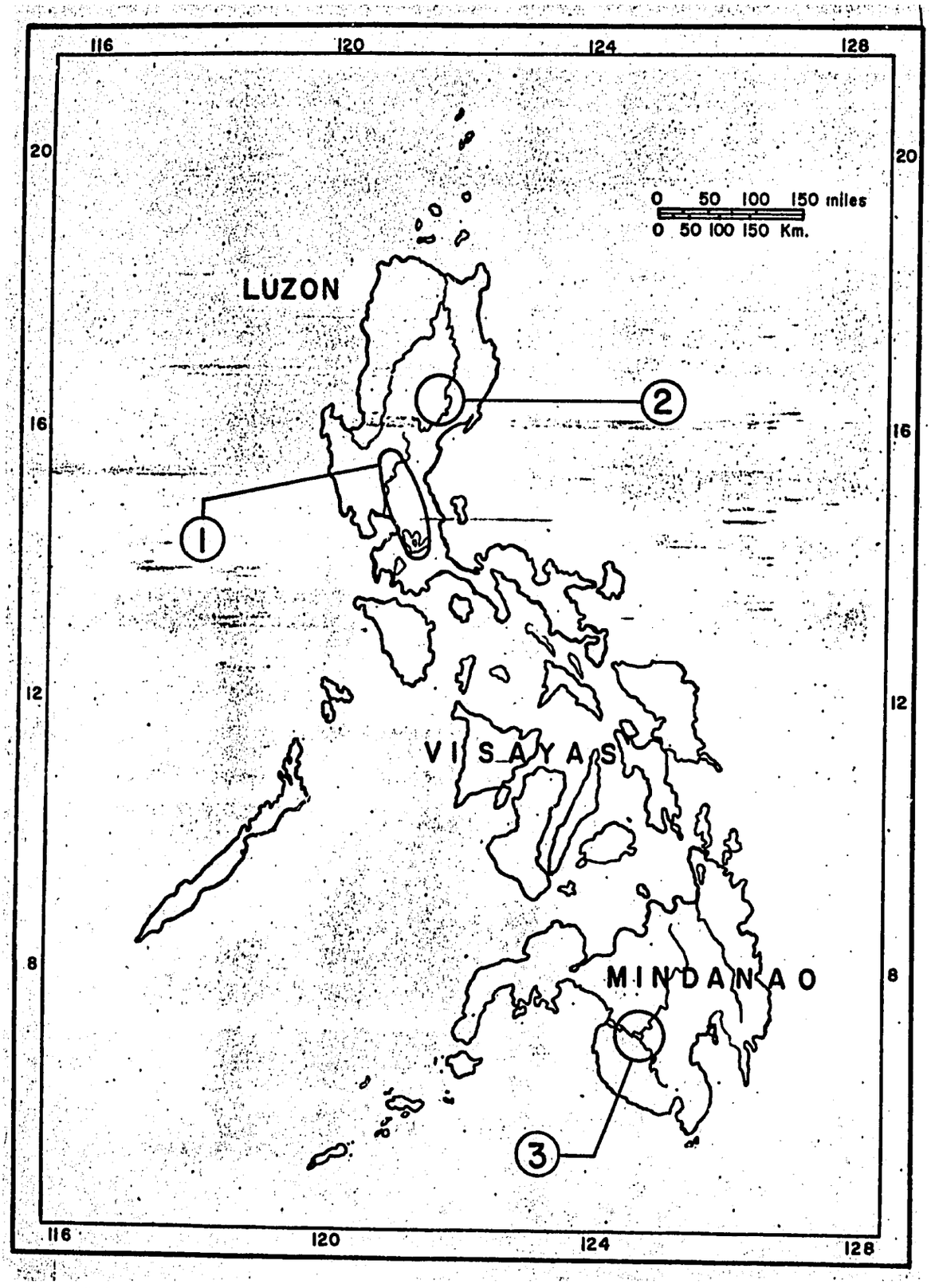
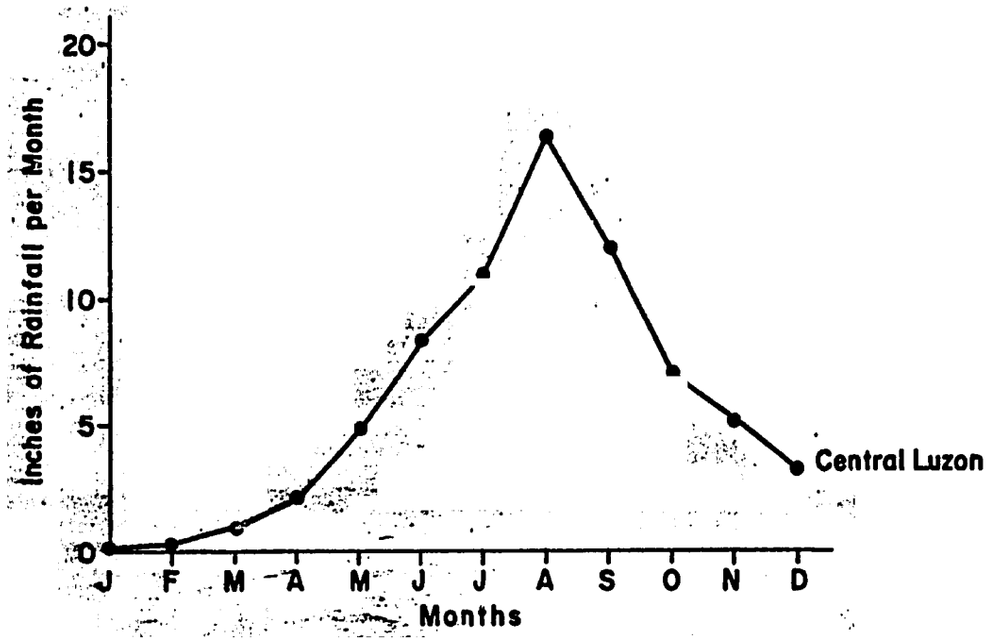


FIG. 9. Map of the Philippines. Three surveys undertaken in the Philippines: (1) Central Luzon; (2) Cagayan Valley (Isabela Province); and (3) Mindanao (Cotabato Province).



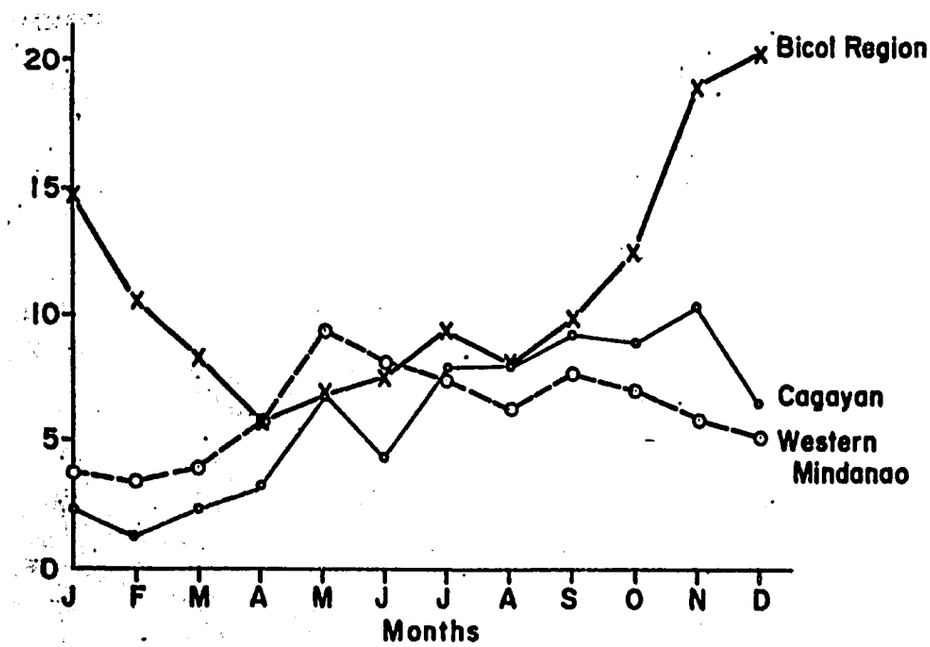


Fig. 10. Average annual rainfall for the Central Luzon area (Cabanatuan City, Nueva Ecija) [a], and for the following regions: Cagayan Valley (Echague, Isabela Province); Western Mindanao (Kabacan, Cotabato Province); and the Bicol Region (Legaspi, Albay Province) [b].

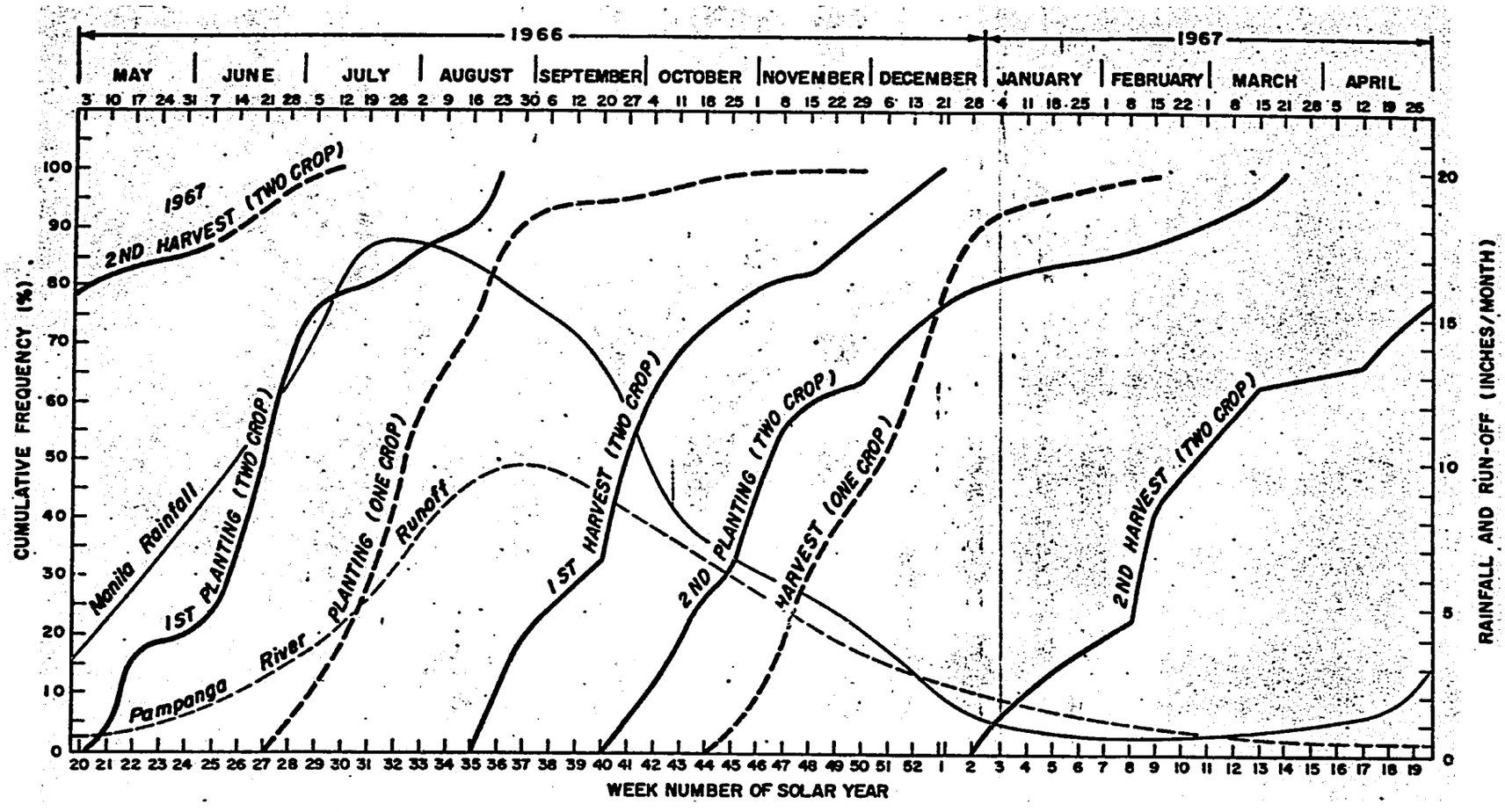


FIG. 11. Planting and harvest cycles for one- and two-crop rice sites in Central Luzon, Philippines, May, 1966 to July, 1967. (31 one-crop and 109 two-crop sites). Compared with average rainfall of Manila, Philippines and average run-off from the Pampanga River Basin.

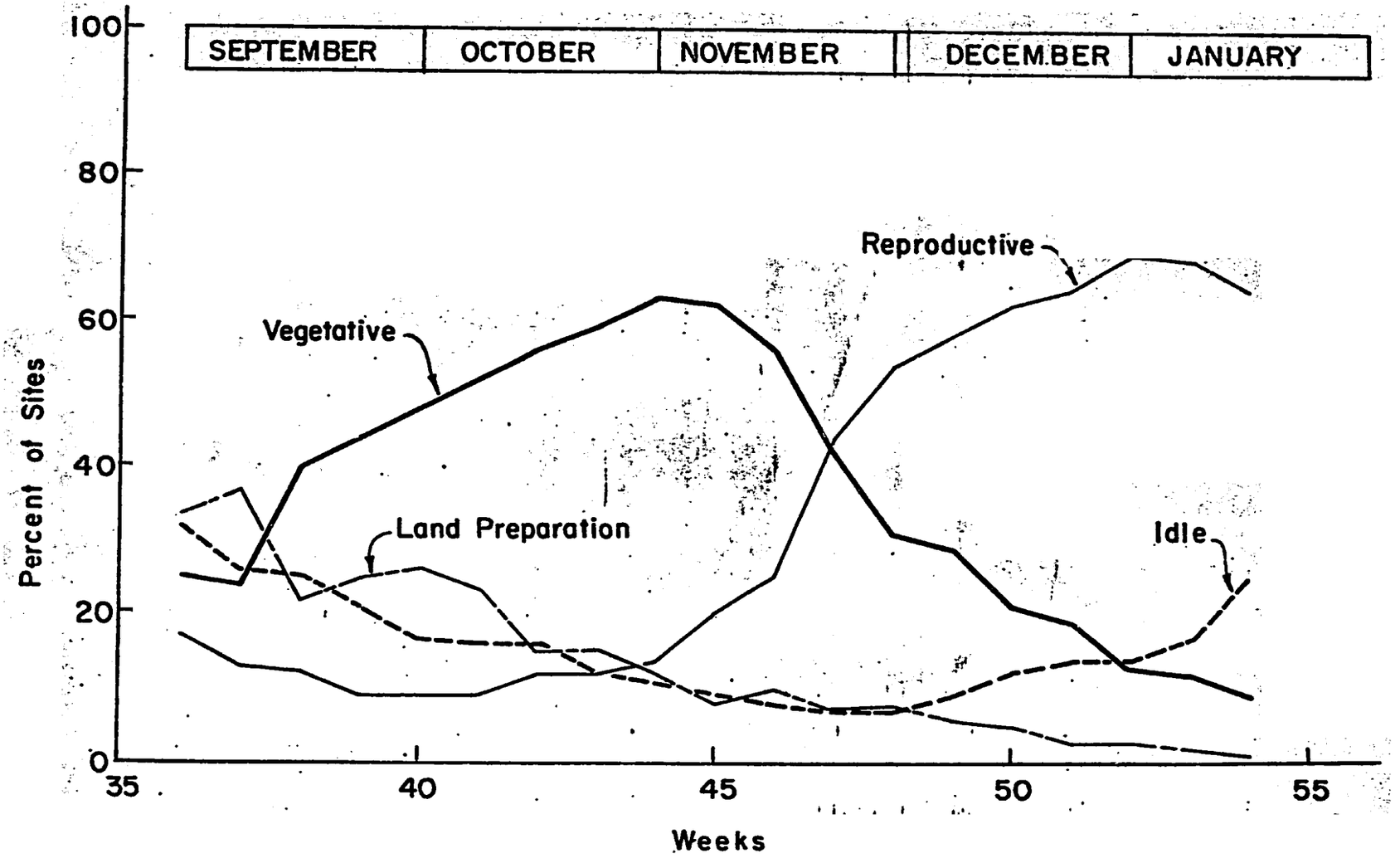


FIG. 12. Sequence of farm operations: Isabela, Philippines (September 1967 - January 1968).

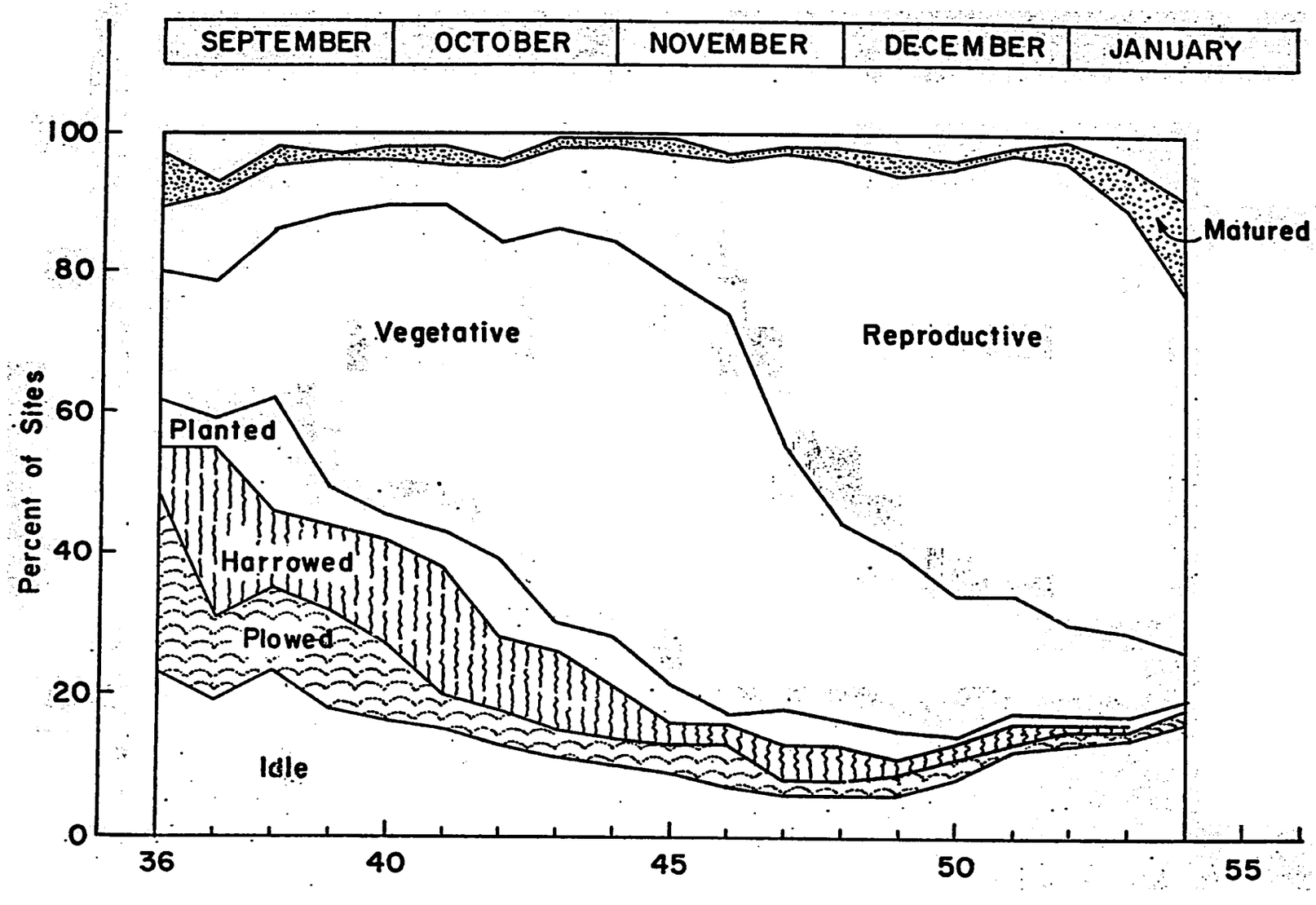


FIG. 13. Cumulative totals of the stages of the sequence of farm operations: Isabela, Philippines September 1967 - January 1968).

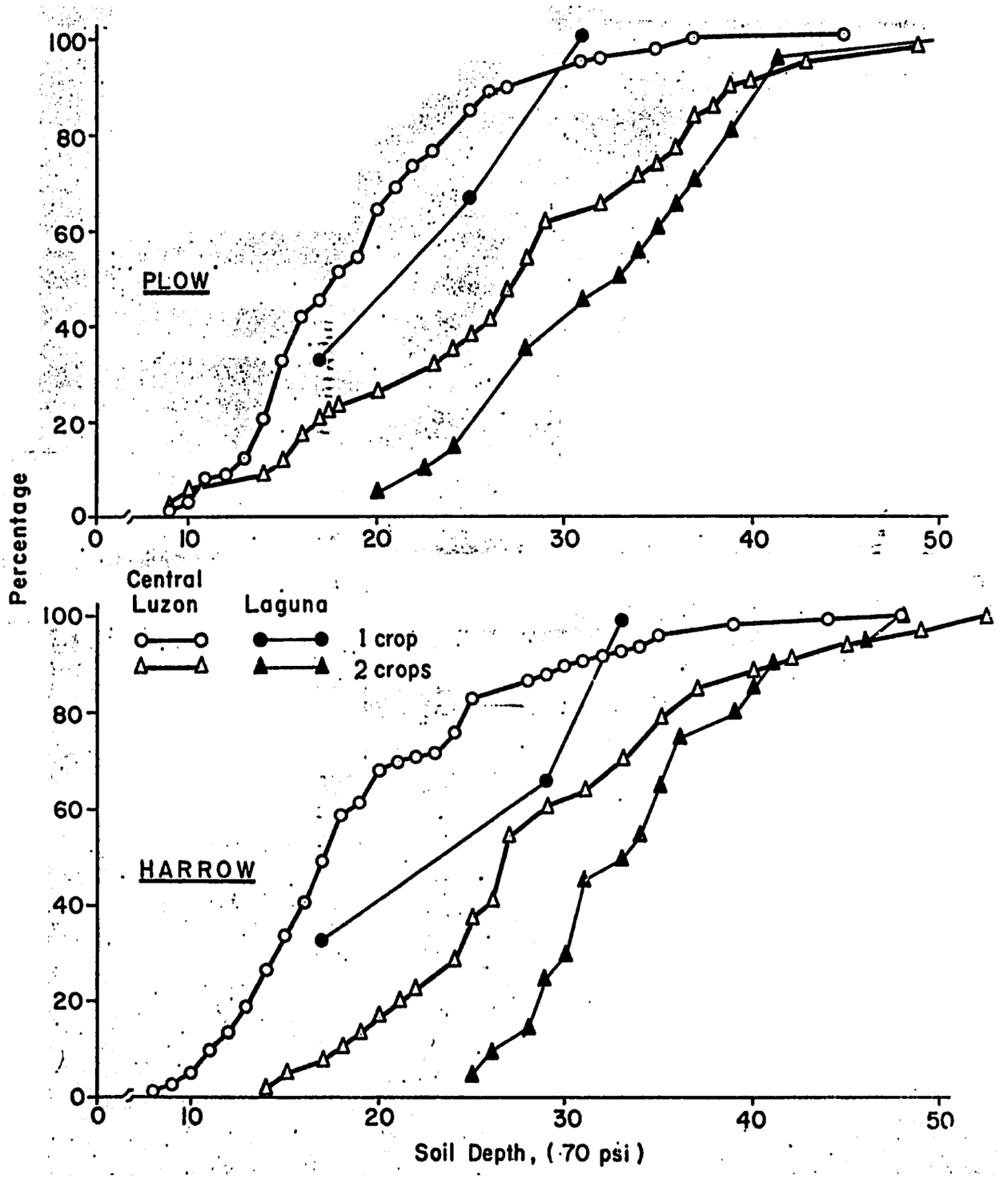


FIG. 14-15. Cumulative frequency of various mean soil depths (cm) during plowing or harrowing at which a U. S. Army Corps of Engineers WES cone penetrometer had a resistance of 70 psi: Central Luzon and Laguna Province, Philippines (1966-67).

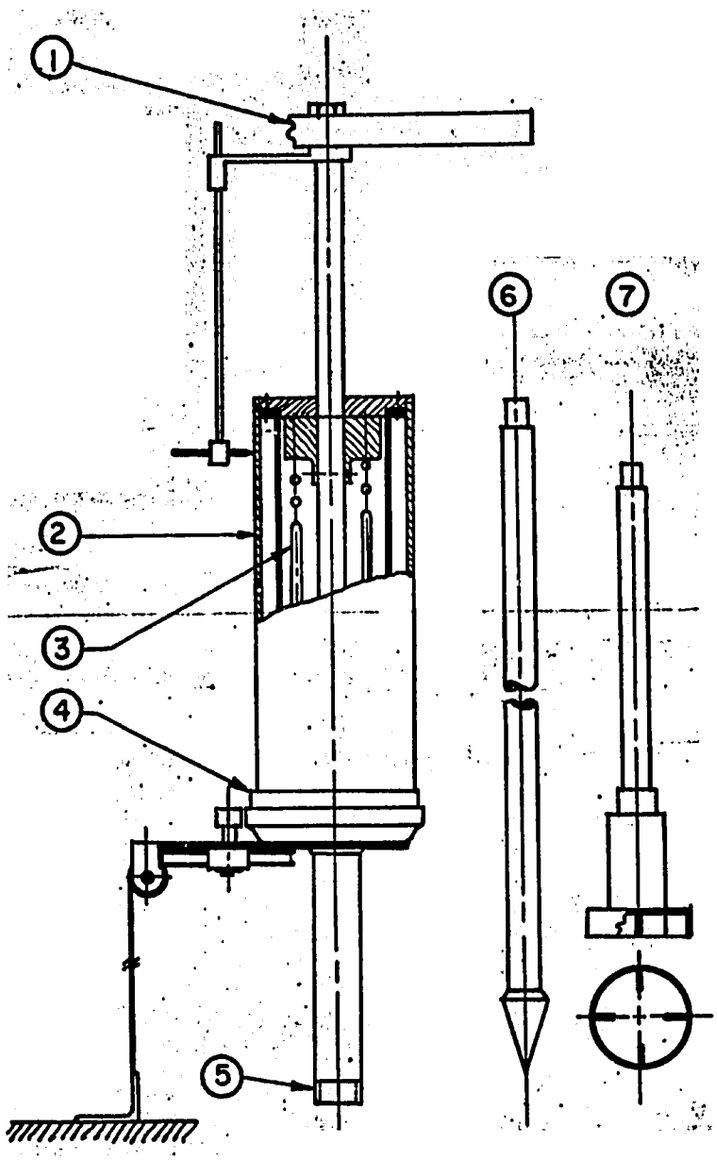


FIG. 16. Schematic Drawing of a Soil Values Meter TN-4.

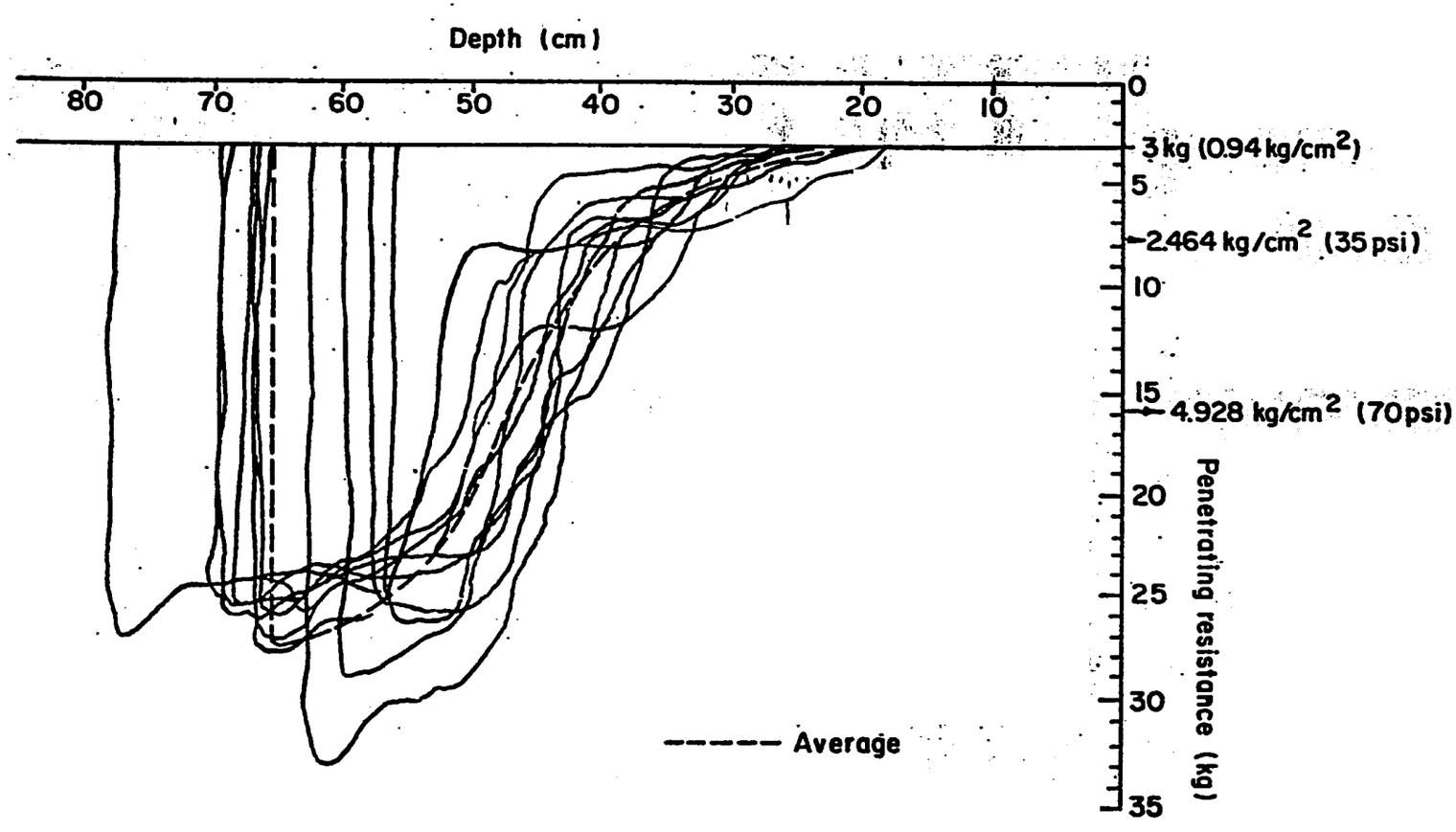


FIG. 17. Actual measurements recorded by the Soil Values Meter TN-4 on one of IRRI's Maximum Production Plots (3 crops per year), Laguna, Philippines (1967).

Surface area of cone = 3.2 cm^2

1 psi = 0.0704 kg/cm^2

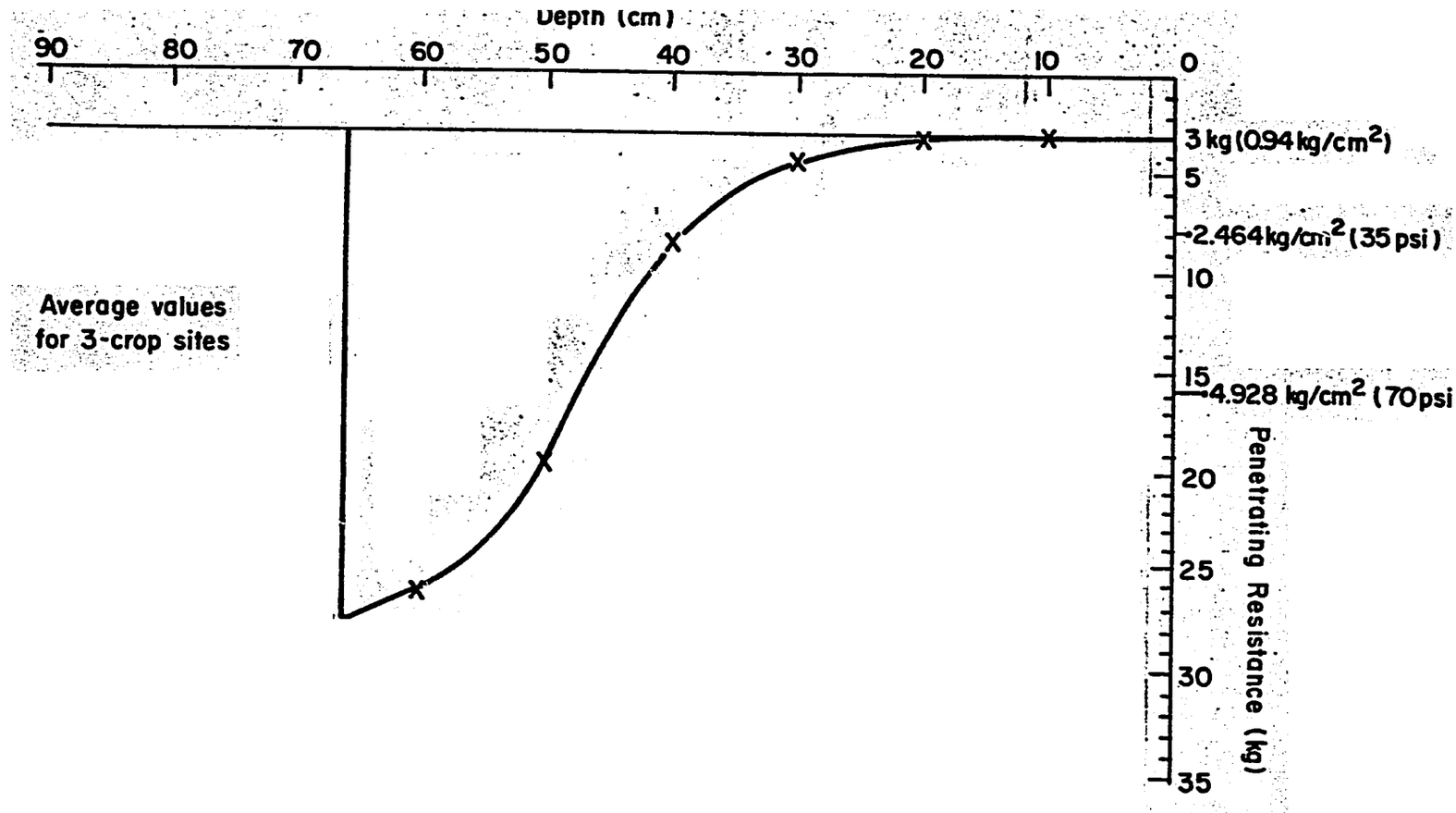


FIG. 18. Soil resistances at different depths (cone index) measured just after harvest and just before land preparation with the Soil Values Meter TN-4. IRRI Maximum Production Plots (3 crops per year) Laguna, Philippines (1967).

Surface Area of Cone = 3.2 cm^2

1 psi = 0.0704 kg/cm^2

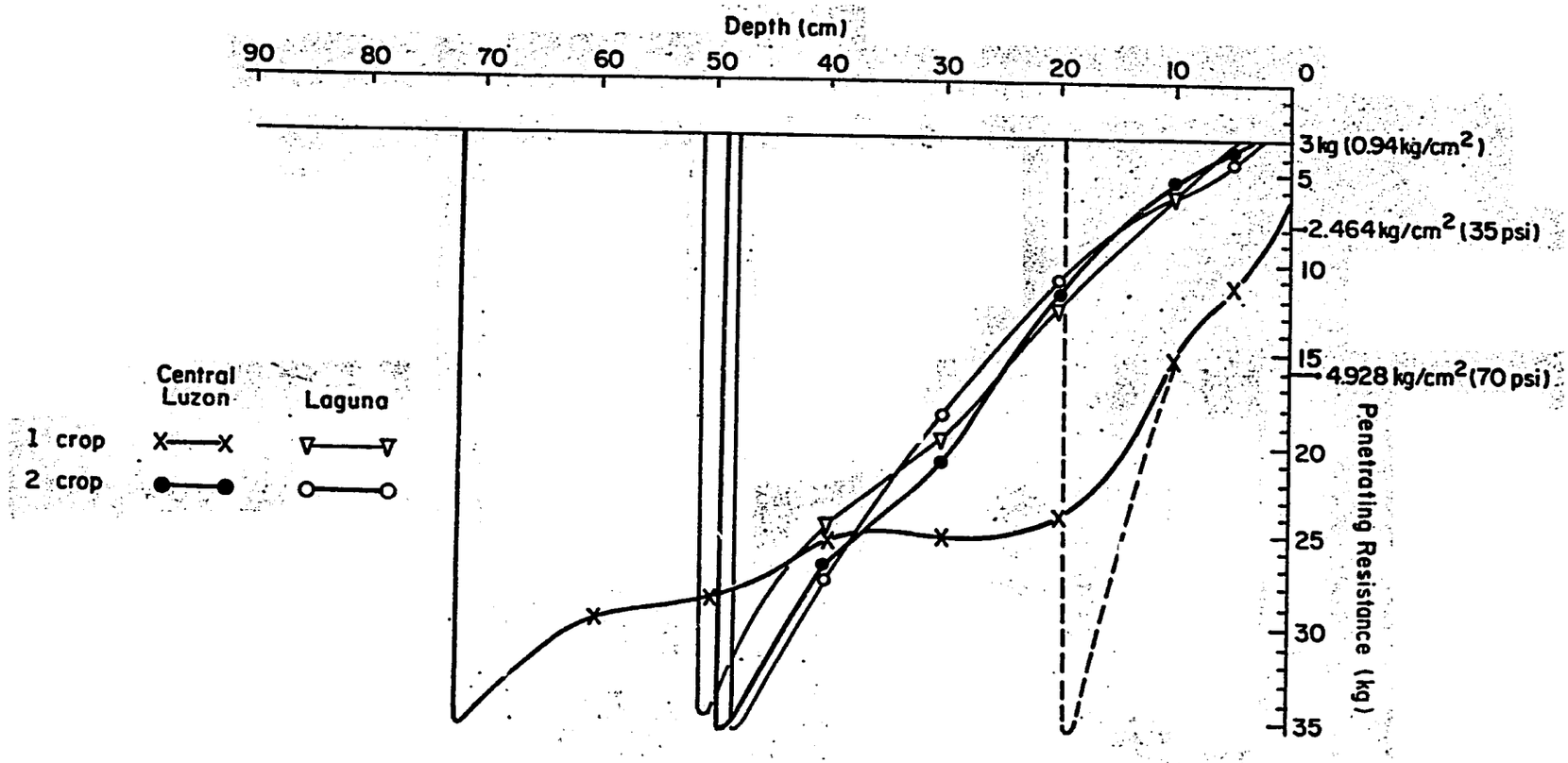


FIG. 19. Soil resistances at different depths (cone index) measured just after harvest with the Soil Values Meter TN-4. Central Luzon and Laguna Provinces, (1967).

Surface Area of Cone = 3.2 cm^2

1 psi = 0.0704 kg/cm^2

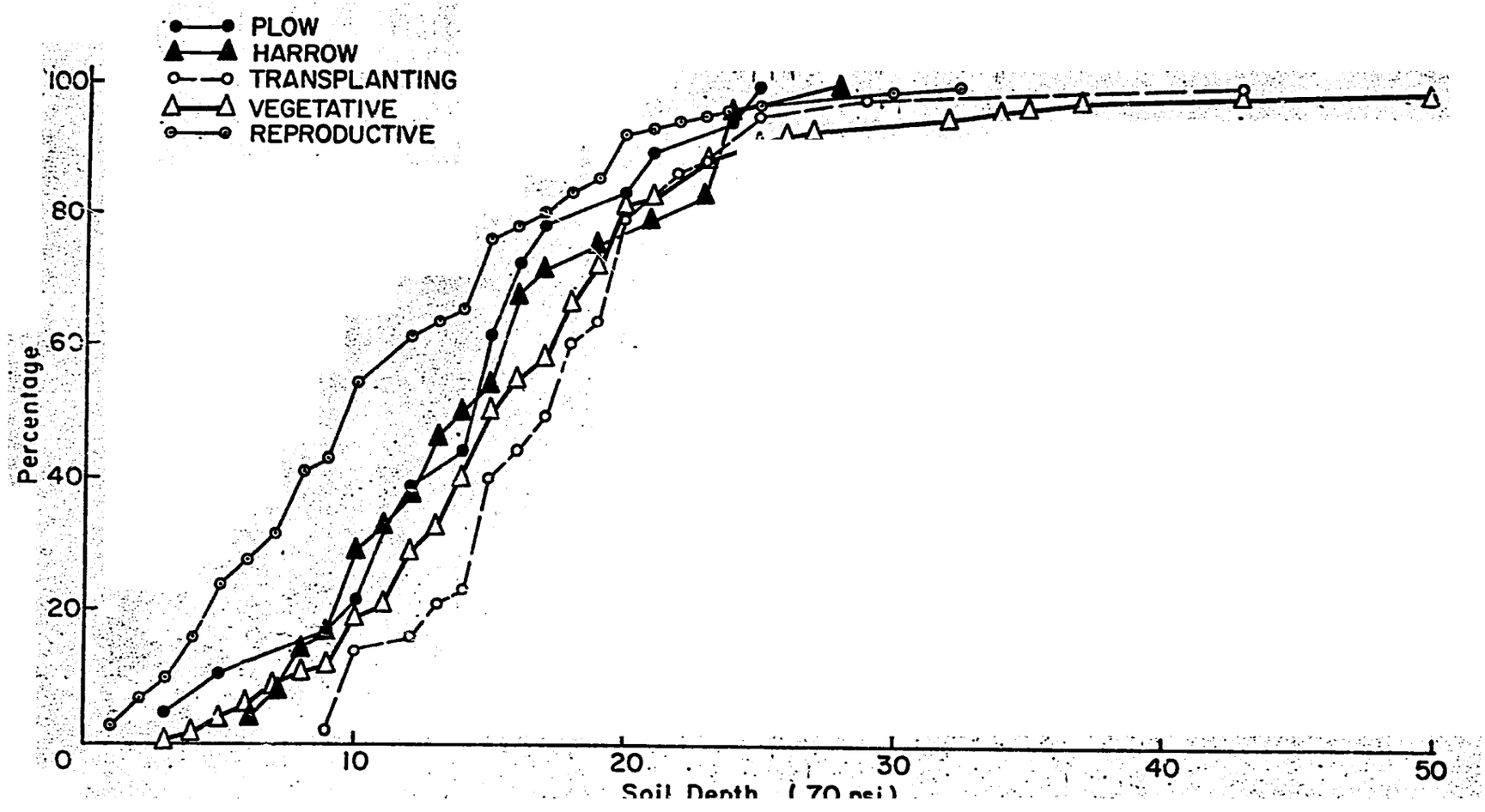


FIG. 20. Cumulative frequency of various mean soil depths (cm) during the plowing, harrowing, transplanting, vegetative, or reproductive stages at which a U. S. Army Corps of Engineers WES cone penetrometer had a resistance of 70 psi: Isabela, Philippines (October 23, 1967 - January 13, 1968).