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(For the period July 1, 1967 to December 31, 1967)

Contract No. AID/csd-834

For Research On Farm and Equipment Power Requirements for Production of Rice and Associated Food Crops in the Far East and South Asia

by

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INTRODUCTION

This is the fifth substantive report on Contract AID/csd-834. The last report was erroneously entitled "Annual Report" rather than "Semi-Annual Substantive Report No. 4."

The Contract AID/csd-834 is due to terminate on 28 June, 1968. A request for an extension of the Contract for one year has been submitted by Dr. Robert F. Chandler, Jr., Director, The International Rice Research Institute, to Mr. Frank Moncada, Contracting Officer, U. S. Agency for International Development, Washington, D. C.

A major change in personnel took place with the hiring of a design engineer, Dr. Amir U. Khan, on August 1, 1967. The International Rice Research Institute Agricultural Engineer, Mr. Loyd Johnson, departed for a year study leave on September 1, 1967. The agricultural economist, Dr. Stanley S. Johnson, remained on the project. Unless he is extended for a further period of time, he is due to depart in mid-September, 1968.

The report of research and the work plan are presented each in two sections: (1) agricultural machinery research, and (2) general engineering and economic research.

A. AGRICULTURAL MACHINERY RESEARCH
Research Report June - December 1967

Introduction

A total of five agricultural machinery research and design projects were undertaken during the later half of 1967. The first project was on the design of a tractor PTO driven threshing drum which was undertaken in June 1967. A prototype machine was built and tested in August.

The services of the Agricultural Engineer, Design, under the AID-IRRI Contract No. AID/csd-834, were acquired in August 1967. A review of past agricultural machinery research indicated that research under the AID-IRRI contract would have a significant impact on rice mechanization, if the research results could be commercially incorporated in new agricultural machines. In order to do so, it was essential to orient the contract research activities towards the manufacturers of agricultural machinery in the tropical rice producing as well as in the industrialized countries.

Research Direction

The design and development of agricultural machines in the advanced countries is primarily a function of the industry. General mechanization research is conducted at the public institutions of agricultural engineering research. Most manufacturers of agricultural machinery in the tropical rice growing countries do not have the resources or the know-how to develop suitable machines for local manufacture. A complete agricultural machine design and development service, patterned somewhat along the product development activities in industry, could provide suitable designs for local manufacture. On the other hand, the manufacturers in the industrialized countries have excellent resources to develop new and improved machines. Contract research activities on specific rice mechanization problems, could assist them in their rice machinery development programs.

It was subsequently decided that the contract research on agricultural machinery should concentrate along the following lines:

(a) Design, test and develop special rice machines for local manufacture within the rice growing countries. Such activities should envisage the complete development of a machine from the basic machine concept to the final design for production. It may include the field evaluation of initial trial production machines prior to regular commercial production. Provision for technical assistance to local manufacturers in their manufacturing plans may be considered as part of the machine development function. The commercial introduction of a new machine in a proper manner is an essential link in the mechanization process and needs appropriate emphasis in such a program.

(b) Conduct agricultural machinery research specifically aimed at assisting the design and development of sophisticated rice machinery in the industrially advanced countries. The emphasis is to be placed on specific problems of mechanization faced by manufacturers located abroad and not on the design and development of new machines.

Along these broad guidelines, two design and two research projects were initiated in September 1967. Prototype and experimental machines for these projects were constructed during the year. Further development work is underway and field

trials are planned for early 1968. The four projects are:

Project No. 2. Design and Development of a Drum Type Power Thresher
Project No. 3. Design and Development of a Table Type Power Thresher
Project No. 4. Tractor Tillage and Mobility Study Under Wetland Conditions
Project No. 5. Use of Mechanical Power for Rotary Weeding

Progress on the individual departmental projects during 1967 was as follows:

PROJECT NO. 1. Tractor PTO-Driven Threshing Drum Design

The efforts to develop a machine that could efficiently thresh high moisture freshly harvested rice was resumed in June 1967. A 10-foot long Japanese style threshing drum was mounted on a tractor trailer. The drive was taken from the 50-HP tractor PTO shaft which operated the threshing drum at 300 rpm. Preliminary threshing tests indicated a capacity of 300 kg of brown rice (14% M.C.) per hour when four men were used for simultaneous feeding of paddy bundles. The quality of threshing was satisfactory, however, the threshed material had to be separated and cleaned by manual methods which required considerable time. The power requirement was low and the machine was not able to make an effective use of the large tractor engine. The experience gained from this machine was utilized in the design and development of a drum type power thresher for small farm and custom threshing operators.

PROJECT NO. 2. Drum Type Power Thresher

The design and development of a low cost power operated paddy thresher was undertaken to meet the requirements of the small farmer and the custom operator in the tropical countries. The large McCormick type conventional threshers are too expensive and are no longer in production. The Japanese type threshers have not been well accepted in the tropical countries due to poor performance with wet crops, relatively complicated mechanisms and poor service facilities. Consequently, in areas of high humidity, threshing of paddy is done immediately after harvest by manual or animal threshing methods. Custom threshing by power equipment is not practised for small farmers because of lack of suitable equipment.

The use of Japanese style walking tractors has become increasingly popular for custom tillage in recent years. The custom operators can only make an effective use of their tractors for a relatively short period. A suitable low cost thresher, which could be towed and powered by a small tractor, would enable the custom operators to make an effective use of their equipment over a longer period. The machine needs to be designed for minimum set-up time since custom work may involve threshing at many different locations within a single day.

With the above objectives, the development of a drum type trailer-mounted paddy thresher was undertaken. Figure 1 shows the schematic drawing of the thresher which is under further development in the Department. The first prototype (Figure 2) was successfully tested during the later part of the year. A second prototype utilizing the same basic concept but incorporating many functional and manufacturing refinements has been built and is under further development. The design incorporates a maximum use of locally available components and has been kept as simple as possible

for ease of manufacture, operation and service. Extensive field trials of the second prototype are planned for the next harvest season. Development work will be continued till the design is ready for release to local manufacturers.

This thresher utilizes a Japanese style wire loop type threshing drum. This type of drum has been widely used and has proved itself as an effective threshing device with low power requirements. The design departs considerably from existing practices for conveying, separating, and cleaning of the threshed materials.

The 6-foot long hollow threshing drum is mounted within a sheet metal trough. Rubber flaps mounted spirally on the drum sweep the trough bottom to deliver the threshed materials to the rear end mounted rotary screen separator. An axially mounted fan blows an air stream through the hollow threshing drum and the rotary screen separator. The air blows the light straw leaves and chaff to the rear of the machine and the grains fall through the rotating screen. The tumbling action results in a more aggressive sieve separation under wet crop conditions. Four men can simultaneously feed bundles of paddy for non-stop threshing. The machine can be either powered by an independent 4-HP aircooled engine or the small tractor engines used for towing the thresher.

PROJECT NO. 3. Table Type Power Thresher

There is a need for simple portable power operated paddy thresher which could be manually carried into the fields. In many countries, paddy fields have no access roads and a trailer type thresher cannot be taken into the field for threshing. Moving of paddy to another location for threshing requires considerable manual labor. With these requirements in mind, a design project was initiated to develop a light thresher capable of being carried by four persons.

The wire loop method of threshing provides excellent threshing under wet crop condition. The arrangement of loops around the periphery of a conventional drum, however, restricts the effective threshing area to approximately a quarter of the total drum surface. To provide a maximum threshing area with minimum weight, a flat circular rotating table type surface with wire loops can be more effective. Such a thresher will also permit a compact, multiple operator feeding arrangement around the periphery of the circular threshing surface. Figure 3 shows a schematic drawing of this type of thresher which is currently under development.

A prototype machine (Figure 4) utilizing this concept has been built and tested. The machine uses a 4-foot diameter threshing surface with a wire loop mounted at 45° angle from vertical in a self-cleaning spiral arrangement. A wire fence around the periphery of the threshing table provides the initial mechanical separation of the straw and the grain. The underside of the threshing table has a large radial fan and air deflector to help blow the chaff from the grain . The grain collects at the bottom where it is swept and delivered at one end by rubber flaps. The chaff and straw are carried by the air to the top and delivered at one side of the machine. The machine utilizes partly mechanical and partly pneumatic means for straw-grain separation. The machine weighs 160 kg complete with a 4-HP aircooled engine and can be conveniently carried in the field by four persons. No major problem has been encountered with the threshing operation, however, more work is needed on the separating mechanism. Further development is in progress.

PROJECT NO. 4. Tractor Tillage and Mobility Under Soft Wetland Conditions.

Development of adequate traction, as achieved on dry land, is difficult under submerged wetland conditions, hence, mobility and bogging of large tractors is a serious problem. Non-traction dependant tillage devices such as rotary tillers have shown considerable promise under these difficult field conditions.

The Department has in the past worked on the development of light-weight wide rotary tillers for use with 40- to 50-RHP tractors. Figure 5(a) shows a schematic drawing of such a tiller. It has been found that a conventional rotary tiller provides a pushing reaction on the tractor of approximately 50 lb per foot of tiller width under wetland conditions. This work has indicated that conventional rotary tillers provide more than adequate degree of tillage under wetland conditions but inadequate pushing reaction to the tractor. Conventional rotary tiller blades are designed for tillage and do not significantly contribute in supporting the tractor-tiller weight during operation. Two major problems encountered in the use of conventional rotary tillers on wetland are:

(a) Inadequate tractor mobility
(b) Excessive ground contact pressures under the tractor rear wheels which result in deep wheel tracks, uneven field surface, and increased tractor bogging.

A project was initiated to find means of improving tractor mobility by increasing the forward tiller reaction and by supporting part of the tractor-tiller weight on the tiller.

Figure 6 shows the difference in soil reaction on a conventional tiller rotor and an experimental push-type tiller rotor. The horizontal component of the soil reaction is greater with a larger diameter tiller rotor for the same depth of tillage. Figure 5(b) shows the schematic drawing of an experimental push-type wetland rotary tiller with an alternate cutting and supporting blade arrangement for increased ground support and forward push. The experimental tiller is designed to be used with special tractor cage wheels which would have a similar blade arrangement for tillage and support.

Field tests with walking rotary tillers indicate reduced tractor bogging at lower tiller blade speeds. Little is known about the effect of blade speed on forward tiller reaction. It is believed that low blade velocities result in reduced energy transfer to the soil and an increased soil reaction on the blade. The blade velocity could perhaps be used to vary the forward tiller reaction and thus obtain a desired degree of tillage or mobility under soft wetland conditions. Maximum mobility may be achieved at low tiller blade velocities whereas maximum tillage at high tiller blade velocities.

An experimental PTO-driven 40-inch diameter push-type wetland rotary tiller (Figure 7) using alternate cutting and supporting blades was designed and built to study the performance under wetland conditions. Special tractor cage wheels for use with this tiller are under construction. The experimental tiller is driven through a mechanical step transmission which provides peripheral blade velocities of 500 to 900 feet per minute. Conventional rotary tiller blade peripheral velocities vary from 900 to 1500 feet per minute. A hydraulic stepless variable tiller drive arrangement is being investigated to permit stepless speed changes during field operations. The experimental machine will be tested in the near future.

PROJECT NO. 5. Use of Mechanical Power for Rotary Weeding.

Control of weeds is a problem in rice production and has a significant effect on rice yields. A joint UPCA-IRRI experiment had shown that weeds reduce rice yields by as much as 36%. IRRI's available data show that an average 120 hours are required to hand-weed one hectare. A push-type rotary hand weeder reduces this labor requirement to 70 hours per hectare. High costs and application problems limit the use of herbicide for weed control in many areas.

Planting of rice in rows has made it possible to use rotary hand weeder and reduce the labor requirement. However, the push-type manual rotary weeder has to be pushed two to three times to obtain satisfactory weeding performance. It is desirable to multiply the human effort by the use of mechanical power.

Small tractors are adequately replacing human and animal labor for plowing, harrowing, and puddling operations but are unable to function satisfactorily for weeding because of the extremely soft field conditions. The turning of weeds under the soil is generally done at a very shallow depth by manual rotary weeders. A mechanically powered machine, which is ground-supported for locomotion, tends to sink deeper than the desired weeding depth and also requires uncultivated headland area for turning at the end of the rows.

It was felt that the problem could be solved by using the operator to support the weight of the machine to provide the desired mobility and turning capability. Many Japanese manufacturers have developed small light-weight portable engine-driven saws mounted on the operator.

It was decided to study a similar possibility for the application of power to weeding. Improved mounting and better balance of machine would have to be achieved for a multi-row weeder as it would be heavier than the portable saws. The weeding head design should provide adequate flotation to avoid bogging in soft areas. It should have enough slicing and cutting action to scrape the top soil for a thorough mixing and burying of weeds in the mud. A multi-row weeding rotor should provide adequate clearance for the rice plants to pass under the axle without damage to the plants. Handling characteristics and operator comfort during weeding and turning at the end of the rows need to be studied.

A three-row prototype power weeder (Figure 8), using a light Japanese portable power saw engine, was designed to study this possibility. The machine weighs 24 kg. Many different shapes of blades have been tried to achieve proper weeding performance. Tests have shown satisfactory weeding performance, however, the load distribution and mounting arrangement on the operator needs to be improved. Work is underway on finding better ways to mount the mechanical weeder on the operator. Further experimental and test work is under way to evaluate and improve mechanical weeding.

B. GENERAL ECONOMIC AND ENGINEERING RESEARCH ON MECHANIZATION

1. Analysis of Rice Farm Operations

Reliable quantitative data are needed on rice farm operations in Southeast Asia in order to study the extent and potential for mechanization. Surveys are underway in the three major rice-producing areas of the Philippines: Central Luzon, Cagayan Valley in Northeast Luzon, and Cotabato Province in Southwest Mindanao (Figure 9). Data are collected by two methods: one, to observe weekly a number of randomly selected fields, and two, to interview the operators of the observed fields.

The survey in Central Luzon was started in the 1966-67 crop year, May through April, in that area. Some of the data are analyzed in the AID Report #4. The survey route was shortened for the 1967-68 season, and included in the new route a larger percentage of irrigated farms. A further analysis of Central Luzon data is presented below.

The surveys of the Cagayan Valley and in Mindanao were undertaken in late 1967 for the former, and in January 1968 for the latter. Some of the preliminary data from the Cagayan Valley are analyzed below.

The three areas under study constitute the three largest rice-growing areas in the Philippines. These three are studied for they vary widely in such factors as location, rainfall in total amount and in seasonality (Figure 10), infrastructure, labor availability, alternative crops, tenure, and percentage of paddy irrigated.

Weekly Survey of Central Luzon

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 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.

To sample the area initially for the 1966-67 year as reported in IRRI-AID Report #4, 145 rice fields were 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 11 (contained in Report #4). 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.

Yield Estimates: Yields of rice were obtained from as many of the sites as possible. Two yield estimates were obtained: one by harvesting a four-square meter plot in the particular paddy being observed; the second yield estimates were obtained through interviews.

A discrepancy arises between measured yields of specific fields and the reported yield for the total farm from the farmer interviews. A study is underway to quantify these differences in cooperation with the Statistics Department of The International Rice Research Institute.

The measured yield estimate is a single sample of four square meters taken from the center of the field. The criterion is to include as many rows as possible within the two-meter measure. The crop is harvested within this area, sacked, and taken to IRRI for threshing, drying, and weighing. Estimates of yield per hectare are linear expansions of the yield from the four square meters at the equivalence of 14 percent moisture.

The yield estimate from the farmer interview is that obtained for the farm as a whole since few farmers know the yield per field. Obvious discrepancies can arise because of lack of knowledge of the farmer of his total farm size, variations in quantity of land out of production, errors in yield measurement, and a crop consisting of more than one rice variety.

A trial was conducted at IRRI to estimate differences of randomly selected 4-square meter plots from the estimated total yield of the field. Table 1 below was prepared from several different trials. What is termed the "percentage bias" is the ratio of:

$$\frac{\text{mean sample yield} - \text{reported yield}}{\text{reported yield}}$$

The percentage difference of the yield estimates based on sampling was about 25 percent greater than the reported yields. While these are only preliminary data, they do indicate the direction and magnitude of yield differences mentioned in earlier studies. In future tests, we will try for better quantification of these differences.

Comparison of Varieties: The introduction of improved 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 the new varieties.

A regression of yield on a number of factors considered to affect rice yields was presented in Report #4.

Economic Survey of 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.

Carabao Use and Cost: 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 crop.

Work animals can be either owned or hired. 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 maintenance 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
Domestication & training of carabao	0.00	50
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/yr
Equipment: plow	45.00	45

continued

continued.

Cost category	Costs based on: Actual replies	Some cash cost assumptions
Equipment: harrow	₱ 45.00	₱ 45
harness & yoke	10.00	10
other tools	no data	no data
Miscellaneous costs: veterinary fee & medicines		10/yr
Supplemental feeding		10/yr

In examining the farmers' attitudes toward tractors, 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.

Weekly Survey of Isabela Province (Cagayan Valley of Northeastern Luzon)

A weekly survey of 142 rice fields was initiated in September 1967. This survey collects data similar to that obtained in the survey of Central Luzon. A preliminary summary of the sequence of farm operations for the period September 1967 to January 1968 is presented in Figures 12 and 13. Figure 12 shows the percentage of fields as observed in each stage of the farm operations. There is a symmetric pattern to the increase and decrease in numbers of fields in the vegetative and reproduction stages. Land preparation was being completed in September and October. A first crop was grown and harvested on many fields just prior to this land preparation. Figure 13 presents the same data as cumulative frequencies for the various operations. Note the rapid increase in mature fields in January, 1968.

Farmers interviews will commence in March and April to complete the background data for the area. These results will be contained in Report #6.

2. Studies of Hand Tractor Operations

Hand Tractor Survey in Laguna Province

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:

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

(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 then 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:

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

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

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 ₱8.00 per day for the man and carabao, the cost of operation per hectare is[2]:

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

[2] $1.00 = ₱3.90. The tractor crew consists of two men alternating in operating the machine because of the heavy work.

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 breakeven 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:

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.

Performance of Hand Tractors

Testing of the performance of hand tractors in Laguna Province has continued. A preliminary summary report is below. Details will be presented in the next Semi-Annual Report #6. The effective field capacity indicates work performance in square meters per hour, and is computed using the following equations:

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

where:

60 = Number of minutes in one hour
2 = Number of trips per round
N = Number of rounds
L = Length of trip, in meters
W = Width of implement, in meters
t = Time used during operation, in minutes

These capacities were computed on data for plowing, harrowing and rotovating. These data, in averages, are:

	No. Tested	Effective Field Capacity (efc) m^2/hr	$m^2/Rhp\text{-}hr$
Plowing: Tractive-type tractors	8	443	79
Harrowing: Tractive-type tractors	38	3659	645
Rotovating: Power tillers	25	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.

3. Trafficability Studies

Soil Depth Testing in Central Luzon and Laguna Province

The study of the relationship of weight of tractor and equipment and traction and flotation has continued. Earlier measurements on 145 rice fields of Central Luzon were made with a US Army Corps of Engineers WES cone penetrometer. Soil tests were taken weekly during the crop year 1966-1967, and the results were presented in summary form in Report #4.

On closer examination, a division of the data is necessary in those soils of Central Luzon, and those of the province to the south of Manila, Laguna. Problems of traction exist in Laguna Province that do not seem to be present in Central Luzon. The earlier analysis demonstrated that the irrigated two-crop fields, on the average, were softer than those growing only one crop.

Figures 14 and 15 present mean data on soil depth for each site, for two operations, plowing and harrowing, divided into fields in Laguna Province and the Central Luzon area, and for one-crop and two-crop farms. As previously analyzed, the soils of the one-crop sites were firmer than those of the two-crop sites. But furthermore, on the average, the soils of Laguna were softer than those of Central Luzon. Again, use is made of the criterion of a depth of 30 cm at a pressure of 70 psi as the point at which a standard tractor of 50-horsepower can expect difficulty in traction or in bogging down. For the Central Luzon area, 62 percent of the fields at plowing and at harrowing would be firmer than the 30-cm depth. Yet for Laguna Province, only 42 percent of the fields were as firm at plowing, and 30 percent at harrowing time.

Tests Using Soil Values Meter TN-4

Further measurements were taken in these areas at three stages of operation, just before land preparation, during final harrowing, and just after harvest. Preliminary results are presented below.

A Japanese made penetro-shear graph called Soil Values Meter TN-4 was used (Figure 16)[3]. The principal parts of this instrument consist of the handle bar,

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

rotating self-recording cylinder, coil spring, cylinder rotating mechanism, terminal for attaching the measuring rod, and vane for shear test. The cone and the vane used for measurement were so designed for easy replacement with the rod. The 30-degree cone penetrometer has a surface area of 3.2 cm^2 and the shear vane measures 10 mm in height and 46.5 mm in diameter with 4 vanes, 2 mm in thickness, crossed at an angle of 90 degrees.

Figure 17 shows the actual measurements recorded by the TN-4 meter on a very soft field at The International Rice Research Institute. Each line represents a reading at a particular spot in the field. Hence, at a pressure of 70 psi, there was a range of depth measurements of from about 42 to 52 cm. The dotted line represents a mean reading, and is presented alone in Figure 18. The "X" points represent mean computations. The mean reading at 70 psi of 47 cm indicates a very soft condition for supporting tractors.

Figure 19 presents the results of tests made just after harvest in Central Luzon and Laguna Provinces. For the non-irrigated sites (one-crop), soil depth at 35 psi for Laguna soils was about 12 cm, for Central Luzon, ≤ 1 cm; depth at 70 psi for Laguna was 25 cm, for Central Luzon 10 cm. One group of one-crop sites showed a distinct and separate pattern as shown by the dotted line in the figure. This group of soils had almost the same depths as the first group at the same bearing capacities but they do not seem to have any soft layer within the soil profile. For the irrigated (two-crop) sites, soil depth at 35 psi for Laguna and Central Luzon was approximately 15 cm; at 70 psi for Laguna was 27 cm, for Central Luzon, 24 cm. The hard pan for both areas starts at a depth of 5 cm and both have no soft layers up to a depth of 50 cm.

Further analysis of the measured sites and the analysis of the estimated soil shearing stress will follow in Report #6.

Cone Penetrometer Tests in Isabela Province.

Preliminary data have been collected in Northwestern Luzon in Isabela Province on firmness of soils there. These measurements are presented in cumulative frequencies taken during the various farm operation (Figure 20). In this stage, no distinction has been made between irrigated and non-irrigated fields, and between one- and two-crop fields. These data suggest that on the majority of fields, large equipment will have no bogging problem.

4. Power Weeder Tests

A test was run comparing the times of the experimental 3-row power weeder being developed at The International Rice Research Institute with the hand single-row rotary weeder and with hand weeding. Two sub-plots were chosen randomly out of six adjacent sub-plots for each type of treatment. The rice had been transplanted 22 days earlier, in square rows of 25-cm x 25-cm. The power and hand rotary weeders made two passes, once in each direction. The results of the test are as follows:

Variety: IR-5

	First Plot	Second Plot	Average	Endurance trial
	man-hours/ha			
Power weeder (2 men)	16.4 (32.8)	26.0 (52.0)	21.2 (42.4)	20.2 (40.4)
Rotary weeder	56.4	48.7	52.6	66.6
Hand weeding	107.7	153.5	130.6	137.6

Two men were used alternately on the power weeder, so the time per hectare was doubled so as to include the time of two men. The endurance trial was to compute the time for the various operations as they continued throughout the day. The data do not include rest time which was considerable for the rotary hand weeders as the day progressed. For an initial test, the performance of the power weeder was good.

C. WORK PLAN: January 1 to December 31, 1968

AGRICULTURAL MACHINERY RESEARCH

Continuing Projects:

1. Design and Development of a Drum Type Power Thresher

A second prototype thresher has been completed and will be field tested during early 1968. If the design proves satisfactory, five additional machines will be manufactured, preferably by manufacturers interested in its manufacture. These machines will be field tested in different areas of the Philippines during the next harvest season. Any weakness in design, which may come to light during this field evaluation, will be modified before the machine is released for regular production. Philippine patents will be applied for patentable features of the machine to ensure control on the proper commercial introduction of the thresher. The progressive manufacturers are generally reluctant in embarking on a new manufacturing venture unless patent protection is available on new machines.

2. Design and Development of a Table Type Power Thresher

Initial trials with the first prototype have indicated problems with the grain-straw separation. Further design and development work will be done during 1968 to achieve satisfactory separation. If the first prototype machine performs satisfactorily, a second prototype machine incorporating design and manufacturing refinements will be undertaken. The second prototype will be field evaluated and further developed until satisfactory performance is achieved. Additional machines will then be built by prospective manufacturers for field trials in different regions of the country. The final release of the design for production will depend on satisfactory field performance.

3. Tractor Tillage and Mobility Study Under Wetland Conditions

An experimental machine using a large diameter tiller has been built. The machine will be tested under different field conditions and additional components will be built to enable a study on the effect of different design factors such as tillage rotor diameter, blade speed, and blade shape on forward push. Two-channel dynamic strain gage recording equipment will be used to evaluate the effects of the different variables on the pushing reaction from the experimental wetland rotary tiller. The study will include the following:

(a) Effect of experimental tiller diameter on tiller forward reaction;
(b) Effect of experimental tiller blade velocity on tiller forward reaction;
(c) The relationship of pitch of cut and tiller forward reaction;
(d) Power required by the experimental tiller at different tiller speeds;
(e) Dynamic weight distribution under the tractor wheels and the experimental tiller; and
(f) Optimum blade design for effective tillage and support.

The results will be published in Agricultural Engineering magazines and journals and distributed to interested manufacturers of agricultural tractors and machinery.

4. Use of Mechanical Power for Rotary Weeding

A machine using an operator mounted engine has already been designed. Tests

on this machine have shown satisfactory weeding performance; however, improved mounting arrangement will reduce operator fatigue. Additional prototype machines will be built to try out different types of mounting arrangements. The project will go into the following study:

(a) Determine the optimum rotor diameter, rpm, and axle clearance;
(b) Determine the optimum blade design and arrangement for optimum flotation and mixing of weeds in the mud;
(c) Study of operator fatigue and weeding output;
(d) Optimum suspension and mounting system for the machine.

Future Projects:

5. Anhydrous Ammonia Applicator for Power Tillers

A knapsack type single row anhydrous ammonia applicator was designed by the IRRI Agricultural Engineering Department in 1965. This applicator has been used in experimental work by the Agronomy Department. Results indicate that anhydrous ammonia (82% N) is a promising fertilizer materiel for flooded rice fields. A single row manually operated machine is however not suitable for practical field application of anhydrous ammonia by the farmers.

Small power tillers are getting increasingly popular in many rice growing areas. A project to develop a power tiller mounted anhydrous ammonia applicator attachment will be initiated to permit economical field application by farmers. Field tests and development will be continued until satisfactory results are obtained and proper functional parameters are met. Economic study on the feasibility of such a machine will be subsequently conducted.

6. Physical Properties of the Rice Plant and Kernel

Little information is available on the physical properties of the rice plant and kernel. The proposed project will go into the study of the various mechanical properties of paddy and the rice plant. Study on seed germination as related to impact damage will be undertaken. Such information could be useful in the design of machines for rice mechanization.

7. Paddy Stripper Harvester

If time permits a project on the development of a stripper type paddy harvester will be initiated. The desirability of efficient handling of paddy from the field to the storage has always intrigued engineers. It is felt that current practice of harvesting and then threshing in two separate operations is inefficient. Use of combines for paddy harvest in tropical areas has not been very practical.

The development of a stripper to harvest paddy directly from standing rice plant, without cutting the plant, seems to be a promising approach. Attempts to design a stripper harvester for rice and other crops have been made in the past in many countries. However, serious shattering field loss has been a major problem. A new proposed concept in stripper design will be used in this project to overcome this field shattering problem. The proposed machine would be light enough to operate in soft paddy fields and would be driven by a 5- to 6-HP aircooled engine. This project may require considerable design and development effort and will depend on the completion of some of the existing projects already underway in the Department. It

is felt that with the present level of staff and facilities, it may be desirable to concentrate on a few major projects and add additional projects as and when a current project is completed.

GENERAL ENGINEERING AND ECONOMIC STUDIES

1. Survey of Rice Areas in the Philippines for Basic Agronomic, Engineering and Economic Data

These data are being collected to provide the basis for studies in mechanization of the techniques of rice production. Three major rice areas are being surveyed in the Philippines, each differing in rainfall pattern, actual and potential irrigation facilities, tenure, infrastructure, competitive crops, soil types and depths. The three primary survey areas are: (A) Survey of Central Luzon: 139 rice fields in Laguna, Bulacan, and Nueva Ecija Provinces for the 1967-68 wet and dry season; (B) Survey of Isabela Province (Cagayan Valley): 142 rice fields for the 1967-68 wet and dry season; (C) Survey of Cotabato Province (Mindanao): 125 rice fields, survey started on January 1, 1968; (D) Brief surveys and visits in other areas such as the large rice area in the western Visayan island of Iloilo, and the heavy rainfall area of Legaspi, Southern Luzon.

2. Economics of Power and Equipment Use

The objective is to examine the economic bases for the use of animals and other power units and associated equipment.

3. Testing and Evaluation of Power Units and Equipment

The objective is to perform engineering tests on power units and equipment presently in use or potentially available for use. This includes testing of experimental equipment developed at The International Rice Research Institute.

4. The Development and Use of Rice Threshers in Southeast Asia, and the Economics of Thresher Use.

The objective is to provide an inclusive study of present threshing methods and associated equipment. Tests will be made on the pertinent performance data and the associated economics of thresher use. In line with current development of experimental threshers at IRRI, this would provide a framework for assessing what is currently being done in threshing, and what is yet to be done.

5. Studies in Trafficability on Paddy Soils

These studies will continue in 1968 in an effort to quantify the relationship between soil depth and the traction and flotation of agricultural machinery.

6. Studies on Infrastructure in Paddy Rice Areas in the Philippines

If time permits, an investigation will be started into the extent of the infrastructure in the major rice areas. Secondary sources will be used when available. Much of the data can be estimated from aerial photographs which have been obtained for selected areas of Central Luzon and Laguna Provinces. Stress will be put on the existing roadways, irrigation systems, access to interior fields, and location of service facilities.

7. Experimental Machinery Project: Assessing Farmer Acceptance of New Machinery and Practices.

Based on techniques of farm machinery manufacturers, the market potential for particular farm machines will be assessed. Given the limitations involved of farmers not acquainted with machines, a trial will be made to assess farmer attitudes.

8. Development of Irrigation Facilities in Rice Paddy Areas: Isabela Province, Cagayan Valley, Philippines.

The objective of this study is to look into a particular valley where currently much effort is being made to increase the amount of irrigated hectarage. This should provide a good case study of how irrigated regions are being developed, what techniques are being used, the performance of the equipment, and the economics involved.

9. A General Evaluation of Mechanization of Rice Production and Economic Development.

If restrictions on travel and time permit, further studies would be initiated, listed below as 10 and 11.

10. A Summary of Agricultural Machinery Used in the Region of Tropical Monsoon Rice Culture in Southeast Asia.

This will include the areas of East India, East Pakistan, Burma, Thailand, Cambodia, South Vietnam, Malaysia, Indonesia, and the Philippines. The objective is to prepare a listing and description of current techniques of rice cultivation and to provide performance testing of equipment under fairly standardized environments, so that comparisons of output and performance of each item of equipment can be made. Based upon these data, an analysis of machinery selection and use in developing countries can be attempted.

11. A Study of the Demand for and Supply of Farm Tractors and Associated Equipment.

Along with this type of study, the limitations as well as the advantages of such a study will be emphasized, so as to provide a more workable tool than the usual demand-supply studies available.

Time Limitations of Accomplishing Work Outline

The agricultural economist on this project is due to finish a two-year contract on November 15, 1968. Under present leave regulation of the Agency for International Development, the economist will be departing two months prior to that date on terminal leave, or on or about September 16, 1968. Thus, much of the data will not be analyzed as closely a it should be by this person. However, there exists the possibility of a year extension, subject to negotiations with IRRI, AID, and with the organization (the U.S. Department of Agriculture), from which the agricultural economist is on leave.

D. PROJECT PERSONNEL

Personnel and the respective man-months engaged in the project for the past 6 months, July 1 to December 31, 1967, are presented below (in man-months).

Anticipated personnel needs for the coming year are presented in the last two columns (in man-months).

Name	Category	Actual July 1 to Dec. 31/67	Projected Jan. 1 to June 30/68	Projected July 1 to Dec. 31/68
		(man-months)		
Amir U. Khan	Agr. Engineer	5	6	6
Stanley S. Johnson	Agr. Economist	6	6	6
Emilio O. Casem	Asst. Agr. Engineer	6	6	2
Makoto Hoki	Visiting Asst. Design Engineer	-	5	6
Eliseo L. Ruiz	Jr. Technician	6	6	6
Ben Hur Aguila	Jr. Technician	6	6	6
F. C. Jalotjot	Draftsman	6	6	2
C. Ll. Jizmundo	Secretary	6	6	6
Videlia L. Go	Clerk-Stenographer	6	6	6
Nestor Navasero	Research Aide	2	6	6
Pedro Malabonga	Machinist	6	6	6
Benjamin Tamisin	Diesel Mechanic	6	6	2
Mario Lescano	Tractor Operator	6	6	6
Antonio Mangahis	Tinsmith	6	6	6
Rodolfo Tamisin	Welder	6	6	6
Juan P. Reyno	Laborer	6	6	2
Miguel Fabellar	Laborer	6	6	2
Marcelino Castro	Laborer	-	5.5	6
Dwayne Suter	Agr. Engineer (Consultant)	1	1	1
Josue Munar	Laborer	1	2	2
Francisco Babac	Laborer	0	1	1
Felix de la Cruz	Laborer	0	1	1

E. TRAVEL PLANS

A. Meetings

Effort in increasing manufacturer interest in rice mechanization will be continued in 1968. The design of machines developed under this Contract will be distributed to interested manufacturers. The Annual Project Committee Meeting is proposed to be held in the United States sometime during June, 1968. The current and future activities of this Contract will be explained by the Senior Staff Member to the representatives of industry and government at this meeting.

Drs. Khan and Johnson, Mr. Casem, and Mr. Hoki plan to attend and present papers at the Annual Meeting of the Japan Society of Agricultural Machinery at Kyoto, Japan, on April 6 to 8, 1968. The purpose of attending the meeting is to acquaint the Japanese engineers with the work being conducted at The International Rice Research Institute; to discuss the problems that small tractors encounter in tropical conditions; to present an economic and engineering evaluation of hand tractors under tropical conditions; and to arouse the interest of Japanese farm machinery manufacturers in machinery development for Southeast Asian conditions.

B. Other Travel

Research travel within the Philippines will be taken when needed by the appropriate personnel involved. In accordance with A.I.D. directives on curtailing travel, travel will be taken only when necessary to fulfill the objectives of the Contract.

U.S.D.A. NATIONAL TILLAGE MACHINERY LABORATORY STUDY ON ROTARY TILLAGE AND TRACTION

Substantive Report No. 2 on the Cooperative Agreement #12-14-100-9058 (42) between IRRI and the U.S.D.A. National Tillage Machinery Laboratory was prepared by A.W. Cooper, L.W. Larson, J.H. Taylor, and Cheu-Shang Chang.

Rotary Tiller Studies

Progress during this report period has been limited to continuance of development work on test equipment, further study of prior work with rotary tillers, and preliminary investigation of methods for characterizing the physical condition and strength of saturated soil.

The first test unit, for handling a limited number of times, has been completed, and test work is scheduled to start the last half of February. A second test unit, for handling more and larger tines, has been designed and components ordered.

For characterizing soft soil conditions, the NTML hydraulically operated penetrometer is to be used. Larger heads for the rod end have been made up, and a new load cell ordered to replace the cell now in use. Other methods of characterization, using rotating devices, were found to give results unduly influenced by depth of operation.

Traction Studies

All construction of parts for the small wheel test device has been completed. The assembling of parts is essentially complete, but the final assembly must wait until the dynamometer car is available. Both the rotary tiller studies and the traction studies will utilize the same dynamometer car. When the first series of rotary tiller studies are completed we will begin the traction studies.

Present plans call for final assembly of the test device and calibration of the sensing elements in time for initial tests to begin this summer.

Characterization of soft soil conditions will be done as described above for the rotary tiller studies.

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					
	Total area		Laguna Province		Central Luzon	
	1966-67	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

3-13-68

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 - 109.5
	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.

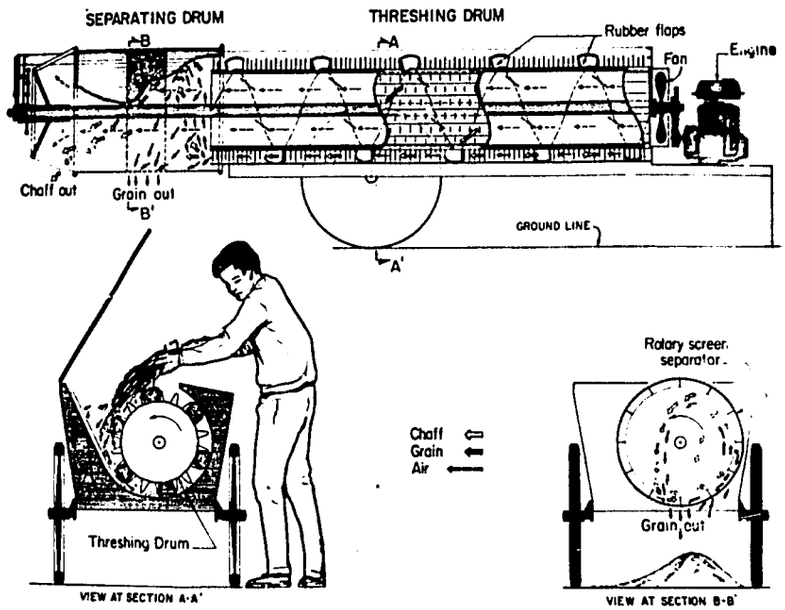


FIG. 1. Schematic drawing of drum type power thresher.

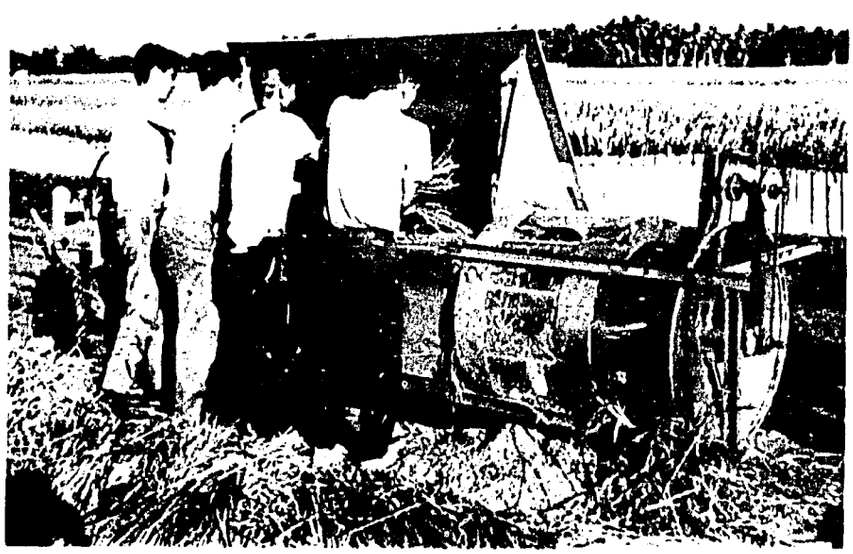


FIG. 2. First prototype drum type power thresher.

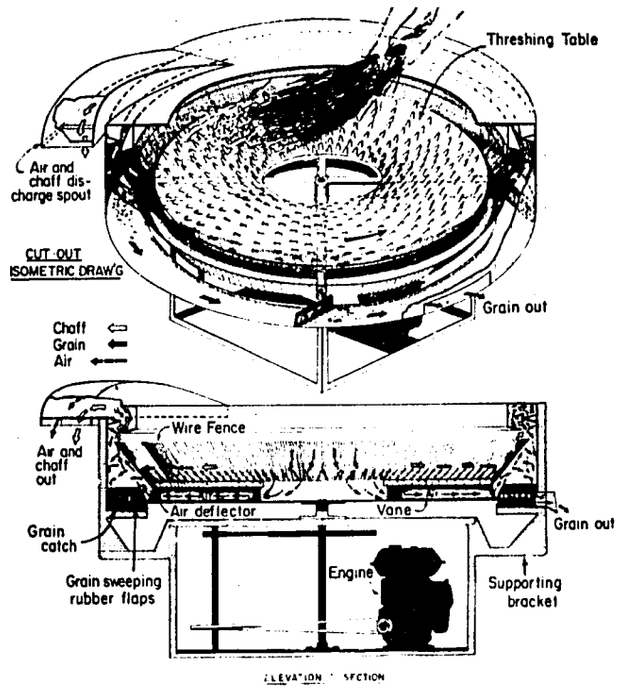


FIG. 3. Schematic drawing of table type thresher.

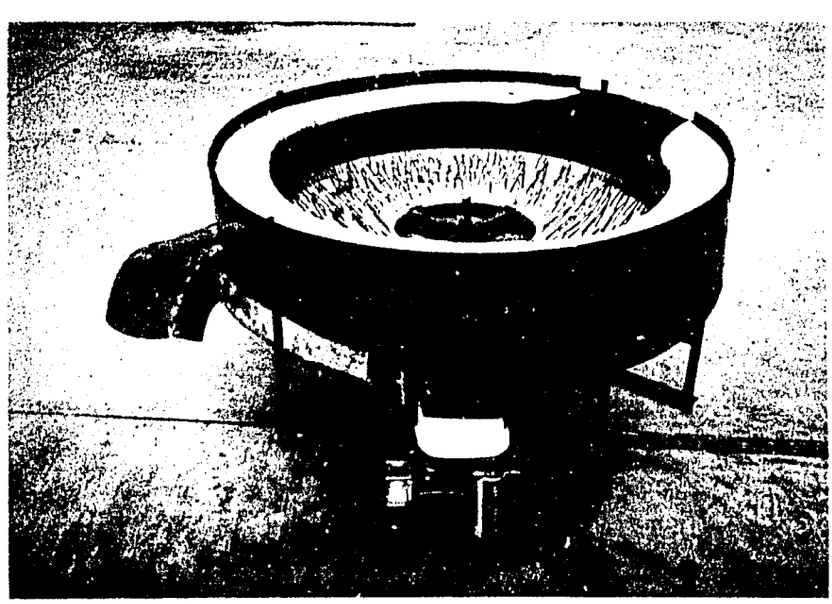


FIG. 4. Prototype table type thresher.

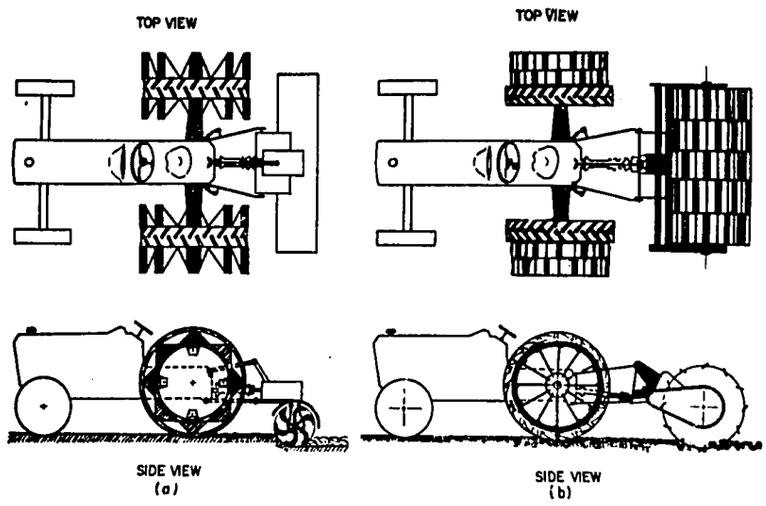


FIG. 5. Schematic drawing of a conventional (a) and an experimental (b) push type wetland rotary tiller.

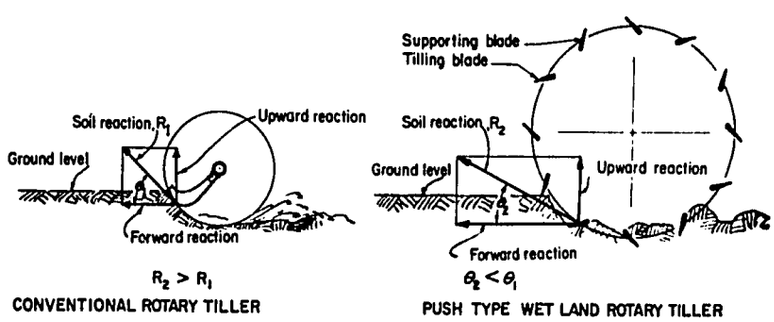


FIG. 6. Schematic drawing showing effect of tiller diameter and blade arrangement on forward reaction.

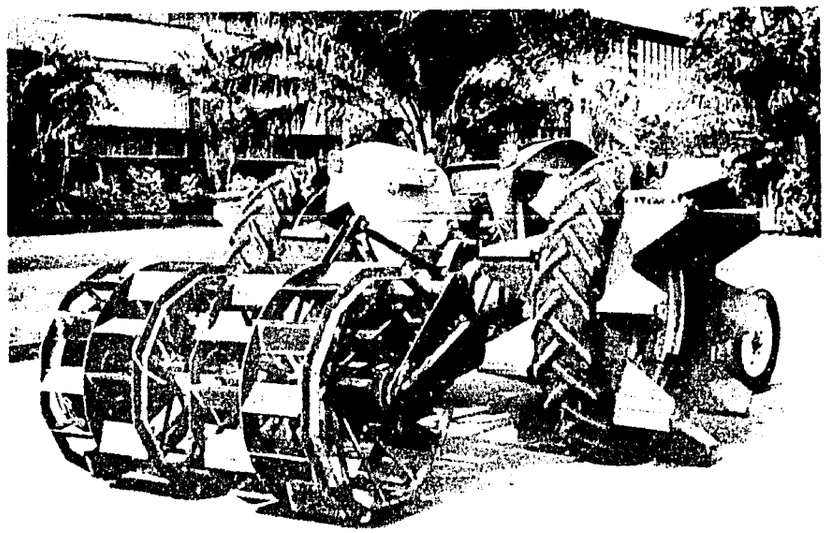


FIG. 7. Experimental push type wetland rotary tiller.

FIG. 8. Experimental power weeder.

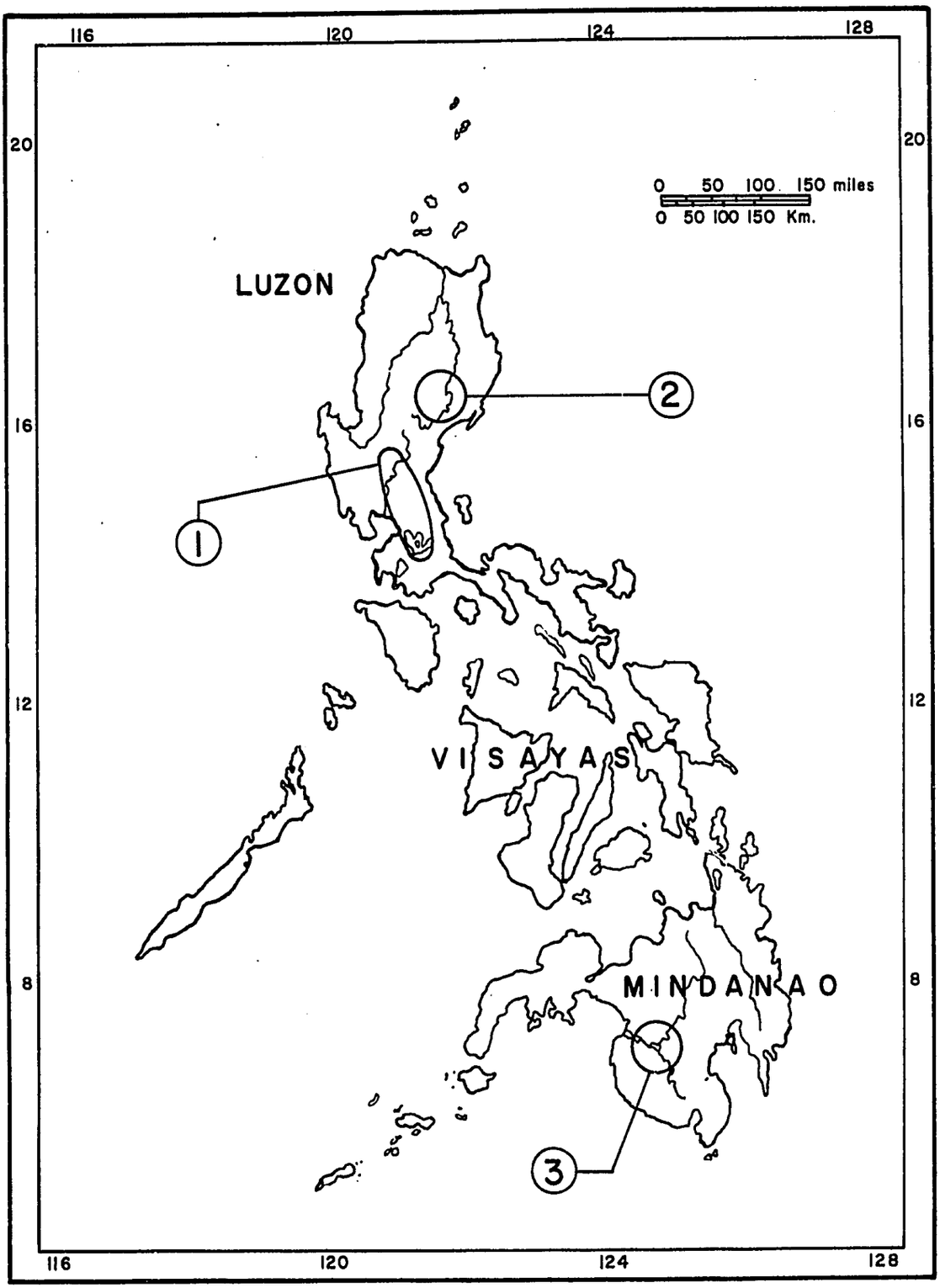
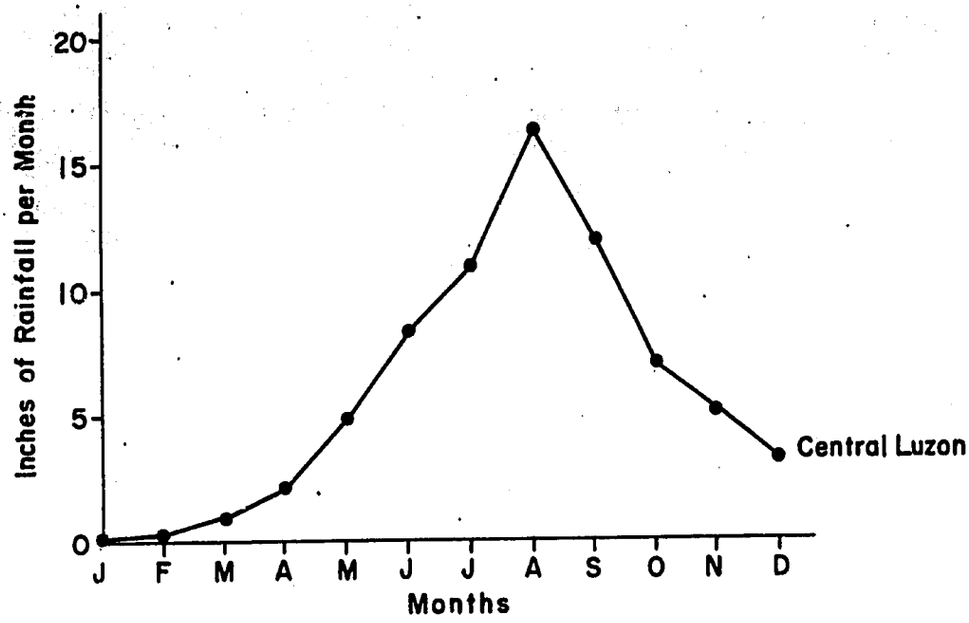


FIG. 9. Map of the Philippines. Three surveys undertaken in the Philippines: (1) Central Luzon; (2) Cagayan Valley (Isabela Province); and (3) Mindanao (Cotabato Province).



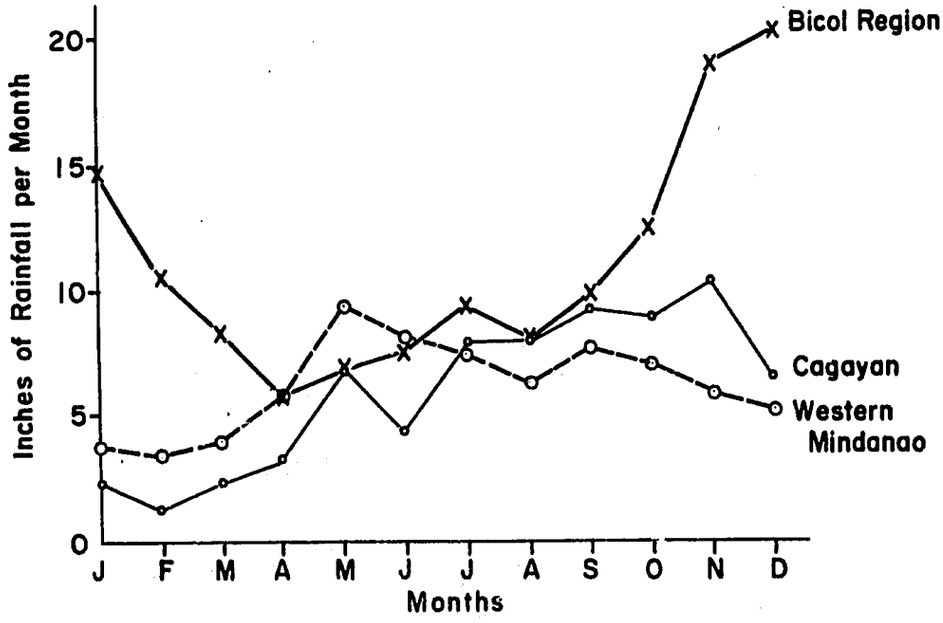


Fig. 10. Average annual rainfall for the Central Luzon area (Cabanatuan City, Nueva Ecija) [a], and for the following regions: Cagayan Valley (Echague, Isabela Province); Western Mindanao (Kabacan, Cotabato Province); and the Bicol Region (Legaspi, Albay Province) [b].

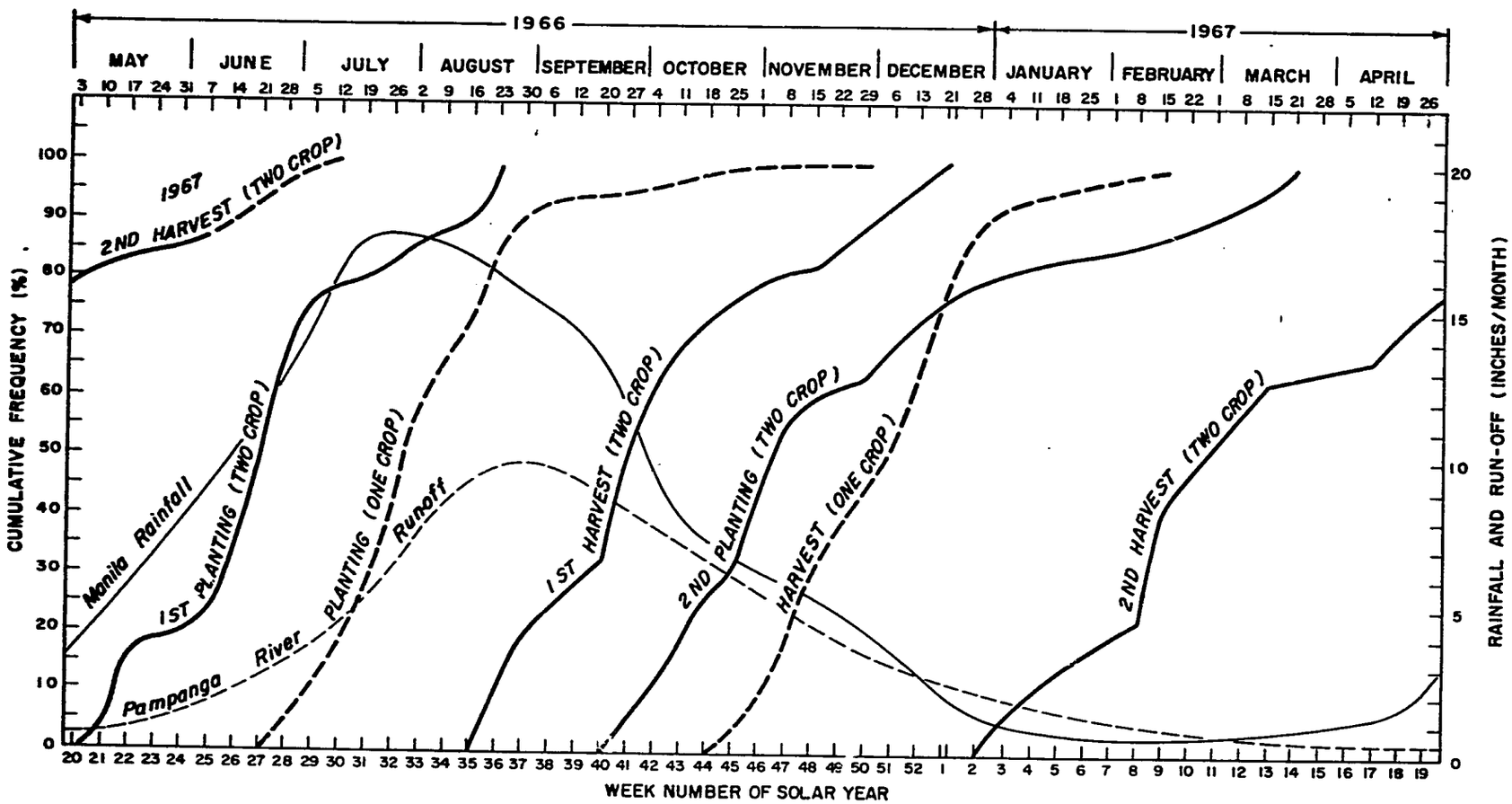


FIG. 11. Planting and harvest cycles for one- and two-crop rice sites in Central Luzon, Philippines, May, 1966 to July, 1967. (31 one-crop and 109 two-crop sites). Compared with average rainfall of Manila, Philippines and average run-off from the Pampanga River Basin.

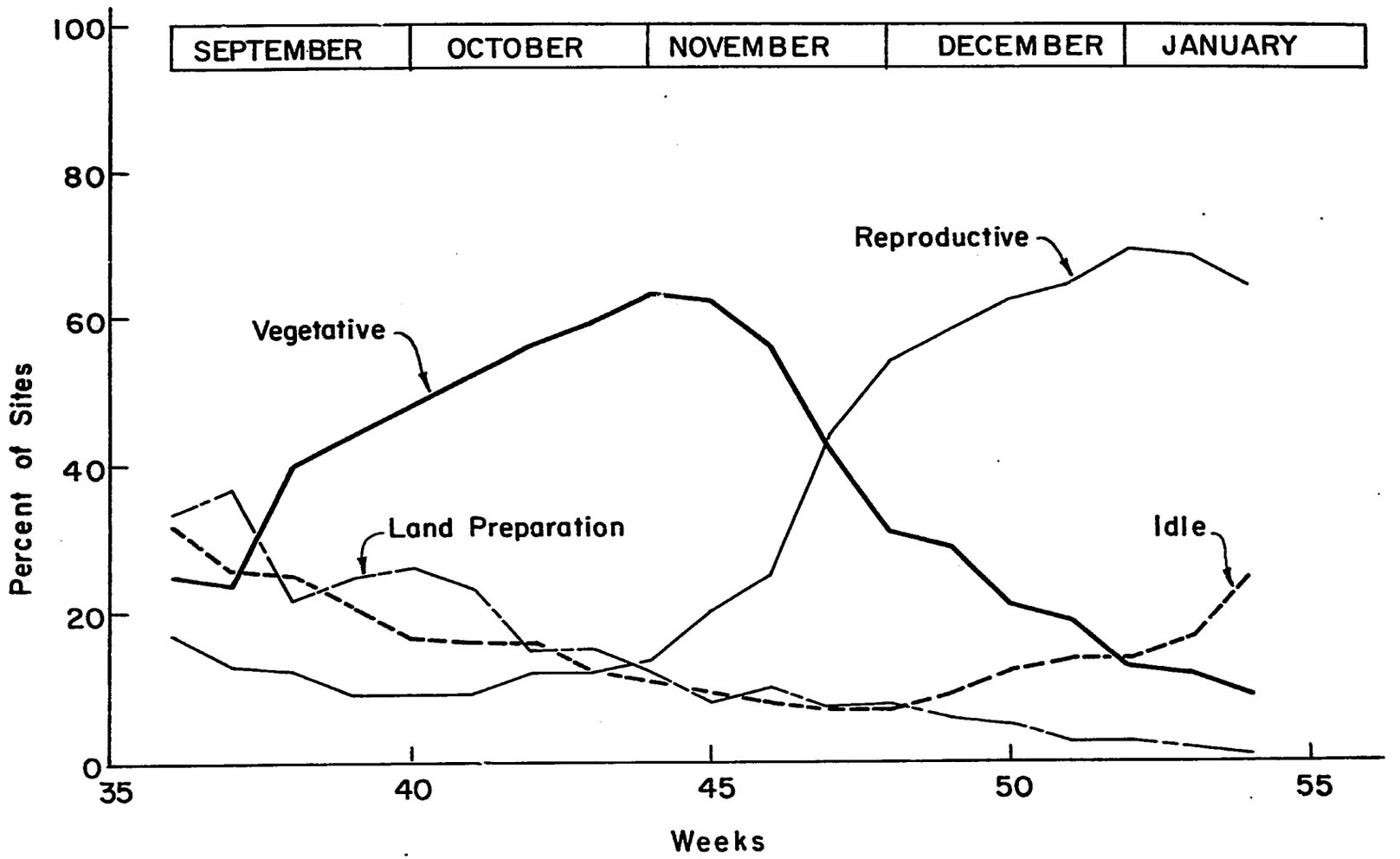


FIG. 12. Sequence of farm operations: Isabela, Philippines (September 1967 - January 1968).

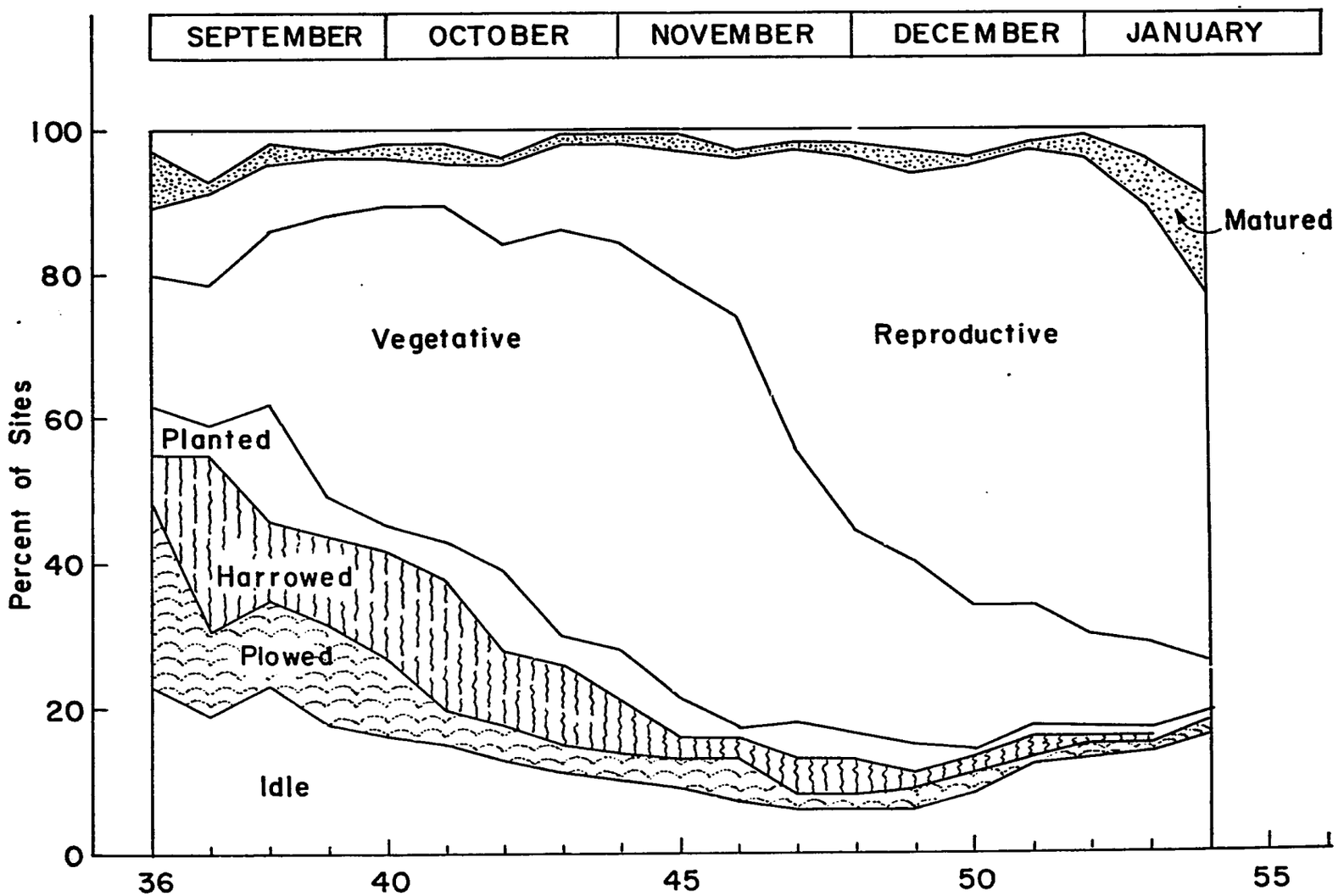


FIG. 13. Cumulative totals of the stages of the sequence of farm operations: Isabela, Philippines September 1967 - January 1968).

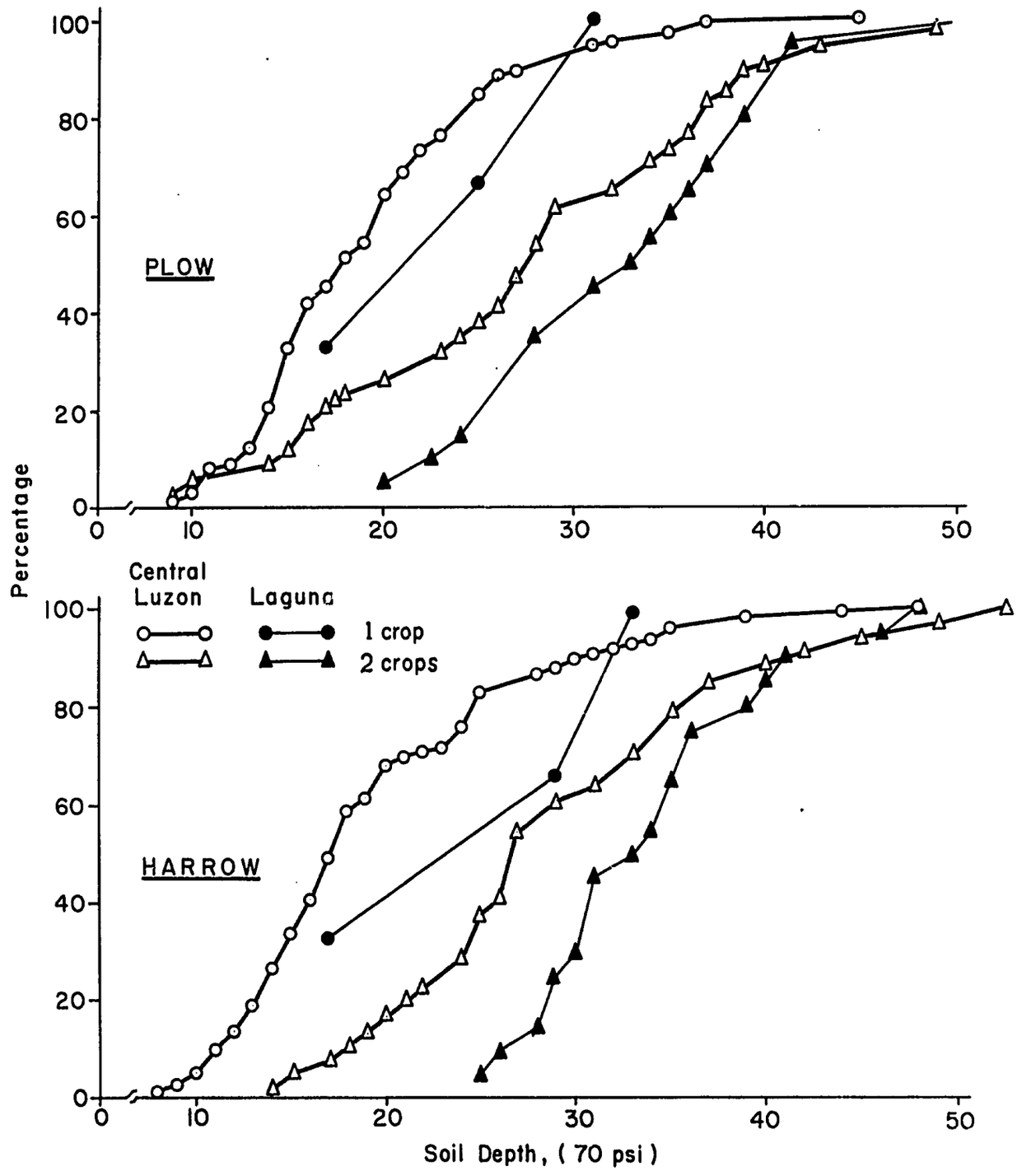


FIG. 14-15. Cumulative frequency of various mean soil depths (cm) during plowing or harrowing at which a U. S. Army Corps of Engineers WES cone penetrometer had a resistance of 70 psi: Central Luzon and Laguna Province, Philippines (1966-67).

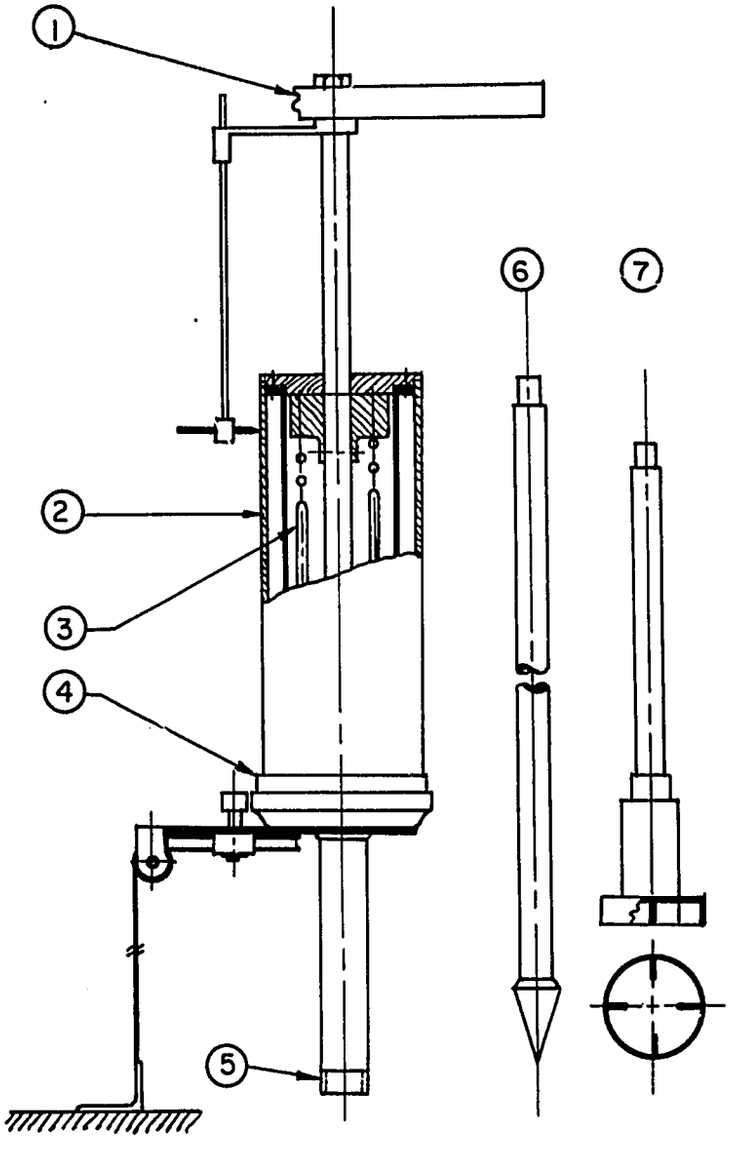


FIG. 16. Schematic Drawing of a Soil Values Meter TN-4.

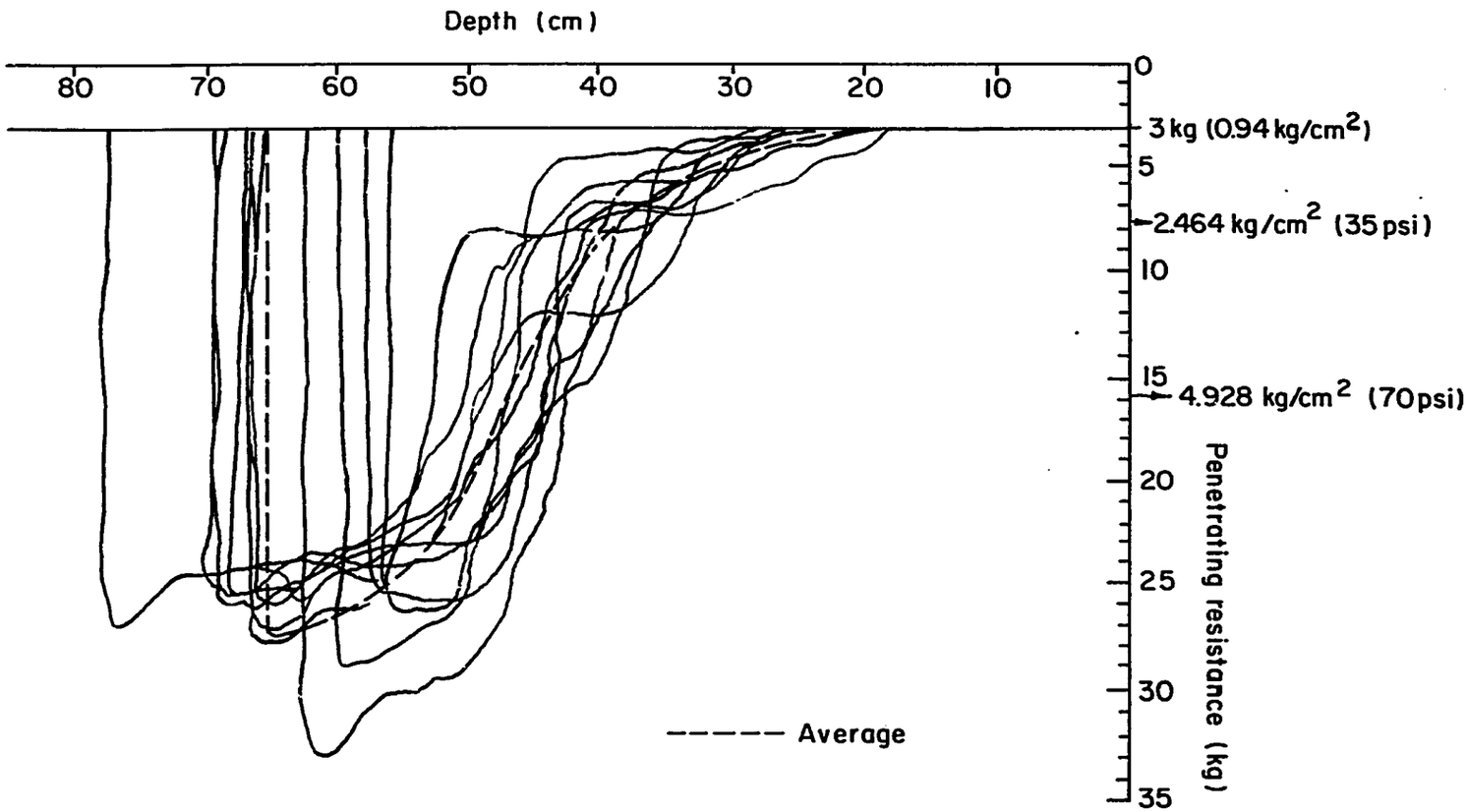


FIG. 17. Actual measurements recorded by the Soil Values Meter TN-4 on one of IRRI's Maximum Production Plots (3 crops per year), Laguna, Philippines (1967).

Surface area of cone = 3.2 cm^2

1 psi = 0.0704 kg/cm^2

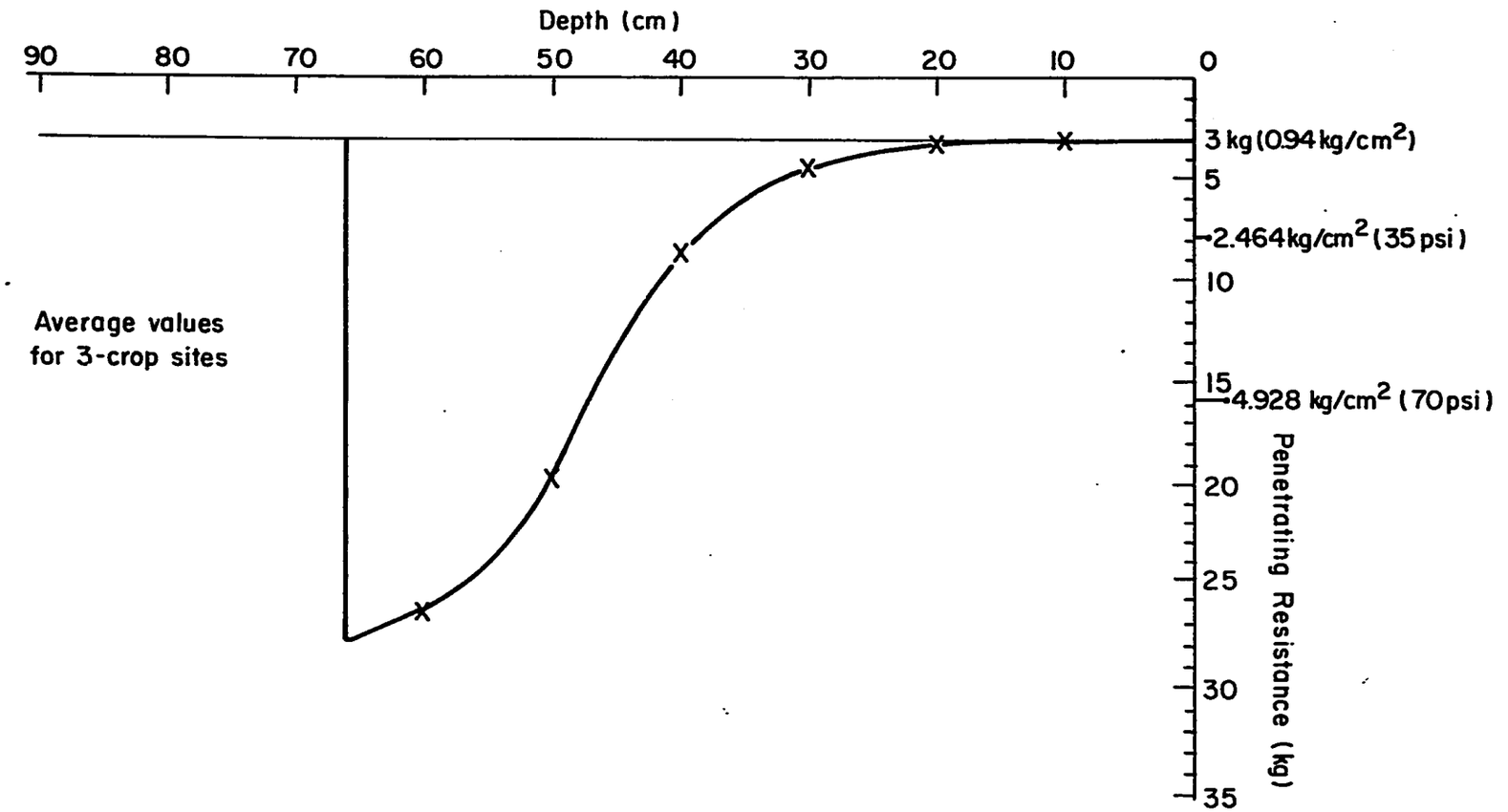


FIG. 18. Soil resistances at different depths (cone index) measured just after harvest and just before land preparation with the Soil Values Meter TN-4. IRRI Maximum Production Plots (3 crops per year) Laguna, Philippines (1967).

Surface Area of Cone = 3.2 cm^2

1 psi = 0.0704 kg/cm^2

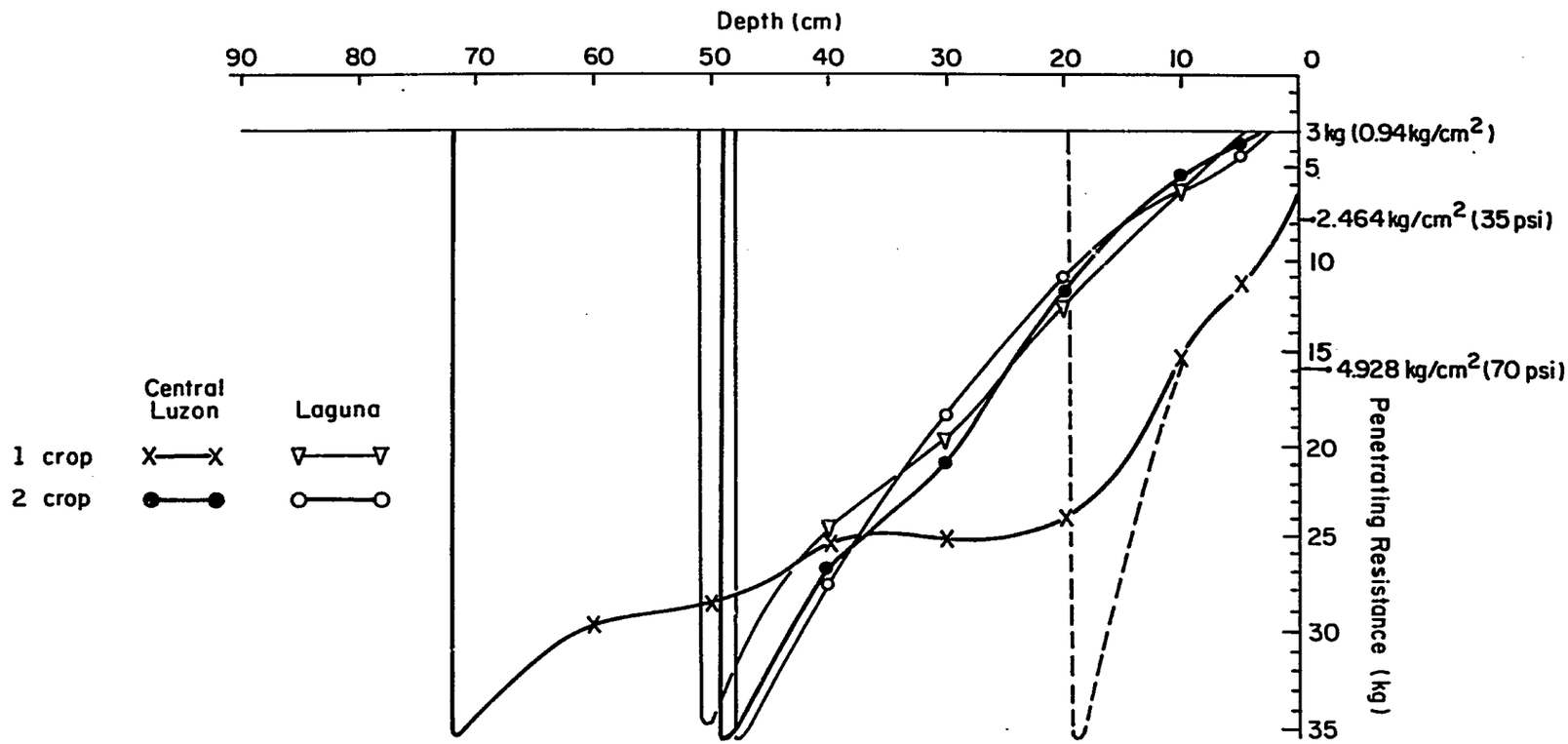


FIG. 19. Soil resistances at different depths (cone index) measured just after harvest with the Soil Values Meter TN-4. Central Luzon and Laguna Provinces, (1967).

Surface Area of Cone = 3.2 cm^2

1 psi = 0.0704 kg/cm^2

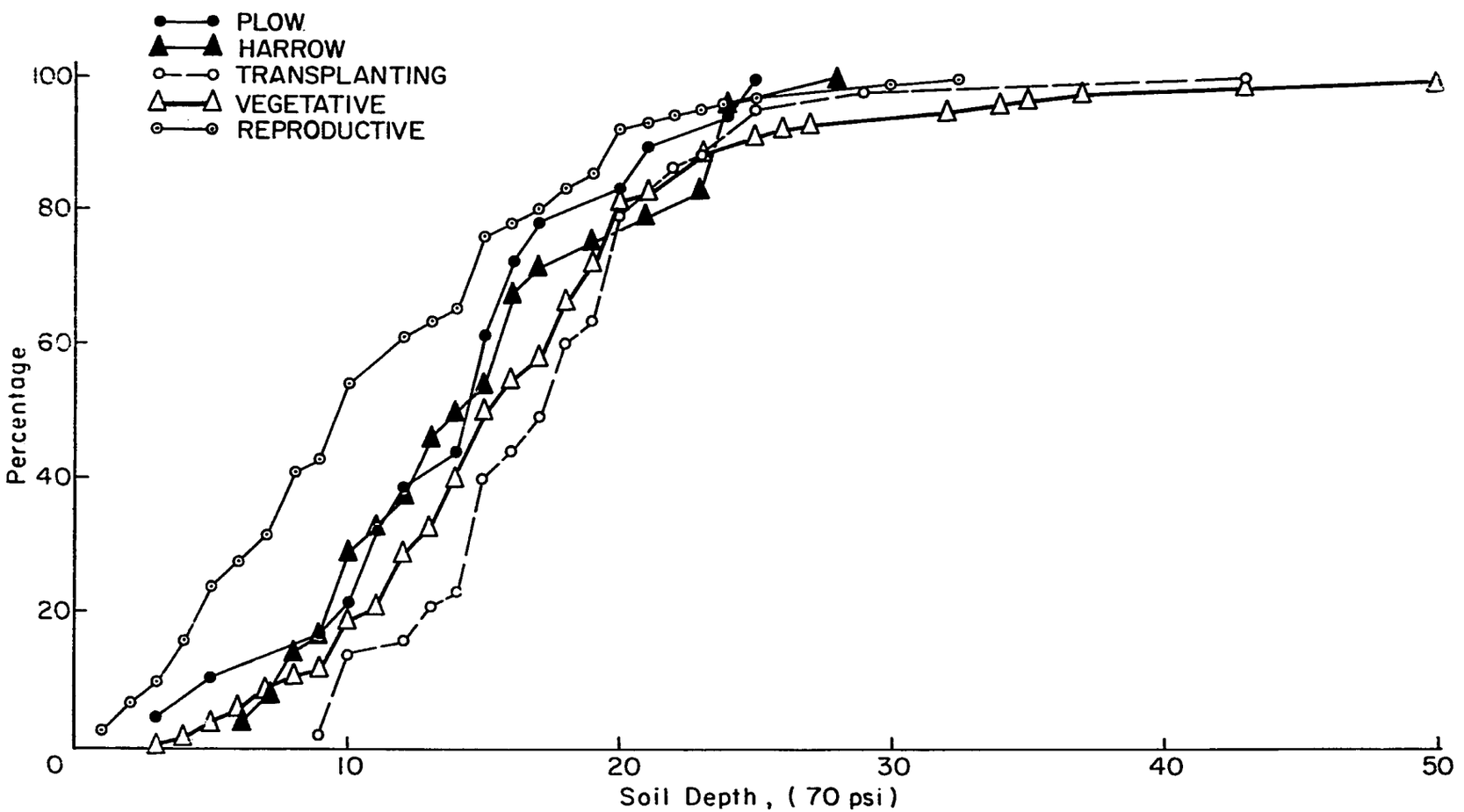


FIG. 20. Cumulative frequency of various mean soil depths (cm) during the plowing, harrowing, transplanting, vegetative, or reproductive stages at which a U. S. Army Corps of Engineers WES cone penetrometer had a resistance of 70 psi: Isabela, Philippines (October 23, 1967 - January 13, 1968).