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DESIGN AND EVALUATION OF NEW TECHNOLOGIES FOR ADOPTION BY SMALL FARMERS: AN EXAMPLE FROM THE PHILIPPINES

James A. Chapman

The development of new technology appropriate for adoption by small-scale farmers is a major objective of farming systems research (FSR). This paper presents a set of criteria to aid in the design and evaulation of new technologies, and then uses them to examine a number of technologies potentially useful for small farmers in a rainfed area of the Philippines.

THE CRITERIA

The determination of criteria to be used in judging whether or not a new technology is potentially beneficial and acceptable to farmers should come during the initial stages of the farming systems research process. Such criteria guide the research, enabling technicians to specify aspects of new technologies which must be present in order to enhance productivity. They also aid in the determination of research priorities by helping to identify those new technologies with the highest potential payoffs or levels of acceptability.

Based on a review of FSR literature (particularly Collinson, 1978) and the personal experience of the author in participating in a cropping systems research effort in the Philippines, the following criteria were selected for assessing current and potential farm technologies.

Resource utilization

How does the technology in question make use of scarce resources (e.g. lard and capital) and plentiful resources (e.g. labor)? Technologies which maximize the use of abundant resources or minimize the use of scarce resources will be favored.

Contribution to household objectives

Will the new technology increase the quantity of preferred food for family subsistence or the amount of income derivable from productive activities? Is food produced at times when family food stocks are usually running low? Does the new technology enable production at

previous levels at a reduced resource cost? In order to be acceptable to farmers, any new technology should be production (income) increasing, cost reducing, or both.

Institutional requirements

What will be the effect of the new technology on the community resource system? Will new inputs, or greater quantities of current inputs have to be provided? Are marketing channels available for the increased output? Input delivery systems (including credit) are often poorly developed in rural areas. This fact tends to favor technologies that do not call for great changes in resource delivery systems over those that do.

Managerial requirements

Small farmers generally make changes in small steps which they view as consistent with their circumstances, abilities and risk preferences. They rarely adopt complete complex technological packages, which are sometimes quite dependent upon appropriate timing of crop activities (e.g. planting, fertilizing) and high levels of non-traditional capital inputs (e.g. fertilizer). Preferred technologies are those which are flexible: only a few, fairly simple managerial adjustments are required and the success of the technology is not overly contingent upon timing and level of input use.

Agroclimatic requirements

Is the new technology compatible with the natural circumstances prevalent in the area? New technologies must fit into the natural environment, especially when new crops or crop sequences are being proposed.

Acceptability to farmers

The criterion of the farmer acceptance summarizes the preceding criteria and allows for the inclusion of other criteria that may not have been detected previously. Farmer acceptance of existing technology can be objectively determined by examining adoption trends. Judging the acceptability of notional technologies is more difficult, as farmers cannot draw upon their own experience with the technology in order to reach a conclusion. Once the characteristics of the technology have been explained, however, most farmers are able to predict a likely response.

APPLICATION OF THE CRITERIA

The preceding criteria were used to evaluate new technologies being developed by the Cropping Systems Program at IRRI as well as those which arose as a product of the field research process, which examined the farming systems of a group of small farmers located in a rainfed lowland area in Iloilo Province, the Philippines (Figure 1).

The predominant activity of the Iloilo farmers is rice production, usually in combination with upland crops planted either before or after rice. Rice and upland crops are planted in distinct seasons, determined largely by the amount of water required for plant growth (Figure 2). The rice-growing (drought-free) season usually lasts for 5-6 months. Upland crops can be grown during two periods of the year; at the beginning of the wet season, and in the transition period from a flooded to a drought state. In other periods, upland crops would likely suffer due to either drought stress (February - April) or the presence of excessive moisture and flooding (June - October). The "competitive" period, when either rice or upland crops can be grown, normally has a duration of just over one month.

Although there is some year to year variation in the length of the growing seasons depicted, they can be considered safe in the sense that in most years, the probability of significant yield reductions due either to drought stress or excessive moisture is low. However, crops grown outside the designated safe periods are subjected to production risk, with the level of risk increasing with the length of growth time outside the period.

Rice forms the basis of the typical diet in Iloilo, usually supplemented by modest amounts of fish and vegetables. It is also the principal source of cash income, with production above consumption needs being readily sold either to the government or on local markets. Most of the food consumed by rural families is produced by the family on either owned, rented or sharecropped land. There is some division of labor allocated to crop production by age and sex, with adult males undertaking land preparation with draft animals and women and small children participating in weeding and harvesting activities. Hired labor use is concentrated during the harvest, with laborers receiving a one-sixth share of the production for their efforts.

Though Iloilo farmers have partially adopted improved rice varieties and modified planting techniques, the overall level of adoption of modern technology is low. This is manifested in the limited use of technology-embedded inputs such as machinery and agrochemicals. This is due in some cases to a low preceived benefit-cost relationship of such technologies, while in others it is due to the fact that cash or credit is unavailable for input purchase.

TECHNOLOGY EVALUATION

Given the importance of rice in Philippine rural society, and assertions of Iloilo farmers regarding the desirability of increasing rice production on their farms, the technologies chosen for analysis deal mainly with rice. Two types of new technologies are examined: existing and notional.

Existing new technologies are those which have been developed, are known to farmers, and are in some stage of the process of adoption (or rejection). Notional technologies, on the other hand, are undeveloped or poorly developed, but have a recognized potential for adoption by farmers in specific ecological and socioeconomic circumstances. According to Anderson and Hardaker (1979):

> Notional new technologies are, because of their hypothetical nature, cheap to invent and bounded only by the imagination of the inventor. Since more fully developed technologies have their genesis as notions, attention to generating notional technologies should not be disregarded. Evaluation of this category can range from intuition to analysis, but analytical appraisal is essentially confirmed to work on models rather than on real systems.

A total of seven existing and notional new technologies will now be evaluated according to the aforementioned criteria in the context of Iloilo socioeconomic and agroclimatic conditions. Before discussing and evaluating new rice technology, however, a description of traditional technology is necessary in order to facilitate comparison. Traditional technologies evolving over time tend to adapt to environmental requirements, bringing certain rigidities to agricultural production systems. An example of the phenomenon is the use by farmers of traditional rice varieties which mature only during certain times during a year when specific daylength requirements are met. In Iloilo, the most common traditional rice varieties mature in December when nearly all rains have subsided. It is quite beneficial to be able to harvest rice at the beginning of the dry season, when plenty of sunshine is available for solar drying. This minimizes losses due to grain rotting and germination and facilitates the maintenance of acceptable standards of grain quality. Moreover, traditional varieties mature at the same time, regardless of planting date, enabling farmers forced to plant late in years of late rainfall onset to catch up while sustaining relatively minor losses. As shown in Figure 3, a traditional rice variety can be planted in June and harvested in December. Two months would remain for possibly growing an upland crop after rice.

One disadvantage of the traditional varieties is the simultaneity with which labor is demanded for specific crop activities, especially transplanting and harvesting. It is possible to stagger land prepa-

ration, seeding and transplanting of traditional varieties without much penalty, though the tendency in rainfed areas is to plant nearly simultaneously with the onset of the rainy season. At harvest time, all rice in the area matures at once, creating a large demand for harvest labor. As Iloilo is not a particularly labor abundant area, the harvesting process for any one farm often lasts the whole month of December and absorbs large amounts of labor, thus creating a labor "bottleneck."

An actual labor profile for a rainfed farm planting only traditional rice varieties is presented in Figure 4. Land and seedbed preparation take place during the June to early August period. Seedlings are transplanted during mid-August through early September, and the mature plants harvested during December and January. The early onset of rainfall enables planting of an upland crop such as green corn before rice crop establishment on at least a portion of the farm. Alternatively, drought-resistant crops such as mungbean and cowpea can be successfully planted after rice on lower fields with heavy soils capable of retaining sufficient amounts of moisture.

EVALUATION OF EXISTING NEW TECHNOLOGIES

With the technology evaluation criteria in mind, three alternative existing technologies are evaluated to determine their suitability to current farming systems in Iloilo. One of the technologies, namely the utilization of early maturing varieties, is already in an advanced stage of adoption by Iloilo farmers. The remaining existing technologies have been tested by the CSP on farmers' fields, but their adoption is not yet widespread. All of the technologies discussed pertain to the growing of rainfed lowland rice.

Existing Technology 1 - Early maturing varieties (EMVs)

Resource utilization. The early maturation characteristic of new varieties causes them to use land for a shorter period during the wet season than do traditional varieties. This allows greater cropping intensity, assuming the time gained during the wet season can be used productively. Low photoperiod sensitivity allows better use of a usually abundant resource, labor. The EMVs generally require as much labor as do the traditional varieties, but some of the requirements during periods of high labor demand can be reduced. For example, labor requirements can be spread out over time by staggering land preparation and planting. Furthermore, since new varieties are of a relatively fixed field duration, harvesting labor requirements can also be spread out.

In order to realize their yield potential EMVs require increased amounts of fertilizer (especially nitrogen). This implies the increased use of relatively scarce small farm resources, namely cash or credit to obtain the needed inputs. Recommendations by researchers also call for increased use of other complementary inputs such as herbicide and

insecticide. These inputs, however, appear to affect yield less strongly than does fertilizer.

Contribution to household objectives. Early maturing varieties provide the potential for increased food production and farm income through increased yield per planted crop and through the possibility of increasing the number of crops planted on the same field during a crop season. Since the time between planting and harvest is reduced, food becomes available earlier in the season to replenish diminishing stocks, an important advantage to those farmers producing at or near subsistence levels. Although many of the new varieties approximate the eating quality of traditional varieties, some farmers continue to plant preferred traditional varieties to fill family food needs, while planting new varieties for income generation.

Institutional requirements. The EMVs require an increase in the application of productive inputs, especially fertilizer. However, farmers generally apply amounts of inputs less than those recommended by researchers. Increasing yields and cropping intensity have greatly increased the amount of grain which passes through the largely government-controlled marketing system. Therefore, storage capacity has become a major problem in the Iloilo area. The government offers to buy rice at a fixed price until its storage capacity is filled. At that point, the informal market begins to function. During periods when large amounts of rice are being harvested and the government is no longer able to purchase rice, produce is sold through local intermediaries, often at prices substantially lower than the government "guaranteed" price. Thus, while production may have increased, the possibility exists for a net reduction in farm income if the reduced output price received by farmers more than offsets the value of the increased production.

Managerial requirements. Modern varieties were developed on experiment stations under tightly controlled environmental conditions. Based on those experiments, recommendations were made as to crop management practices necessary to achieve maximum output. The recommendations were rather rigid, calling for large amounts of capital inputs and a high degree of water control. Furthermore, the recommendations contained strict guidelines as to the timing of operations such as transplanting and input application. In general, small farmers do not possess the quantity and quality of resources necessary to carry out these management recommendations, and therefore do not fully realize the production potential of the new varieties.

The early maturation characteristic has reduced the risk of yield loss due to drought stress, as EMVs are normally harvested within the bounds of the rice growing season. Traditional varieties, on the other hand, generally mature in December, and often face drought conditions before harvest.

Agroclimatic requirements. Early maturing rice varieties planted in June are ready for harvest in approximately 110 days from the date of initial planting, allowing for the possibility of planting a subsequent rice crop or an upland crop.[1] A second rice crop, however, would face a high probability of drought stress in the flowering and maturity periods (Fig. 5). Information gathered from CSP cropping pattern trials in Iloilo demonstrates that expected yields from second rice crops are on average one-half those of rice crops established at the beginning of the wet season. Moreover, while first crop yields tend to be somewhat stable, second rice crop yields exhibit large year to year variations.

Acceptability to farmers. During interviews of sample farmers, the question was raised as to why they had adopted, or were in the process of adopting, new rice varieties. The reasons expressed, in order of their importance were: a) increased potential for multiple cropping; b) increased yield levels per crop; c) early harvest replenishes rice stocks at an opportune time; d) lower incidence of pests and diseases; e) resistance to lodging.

Ten out of twelve farmers interviewed listed increased multiple cropping potential as the principal advantage of new varieties. All farmers mentioned increased per crop yields as important, though generally less significant than multiple cropping potential. Farmers with the smallest areas suitable for rice crop establishment mentioned early harvest as important for replenishing their family's dwindling or non-existant rice stocks. Pest, disease and lodging resistance were mentioned by less than one-half of the sample.

The reaction to EMVs is not entirely favorable, however. The harvest of a crop planted at the beginning of the wet season occurs during the part of the season when the frequency and intensity of rainfall are high. The rice must be harvested wet, causing the manual threshing process to be more difficult and time consuming. Significant grain losses may also be incurred due to grain rotting and germination if rice is allowed to remain wet over a long period. The most common method of drying rice is the use of solar energy, a scarce resource in the wet season.

On balance, the advantages of the new varieties seem to outweigh the disadvantages, as evidenced by both the adoption behavior of farmers (Figure 6) and their verbal responses.

Existing Technology 2 - Dry seeded rice crop establishment (DSR)

Dry seeded rice is not a new technology. The use of DSR in conjunction with new varieties, however, is new.

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[1]When transplanted, EMVs take slightly longer to mature (one to two weeks) due to time lost as each plant "recovers" from transplanting.

Resource utilization. The principal advantage of DSR is that i allows the early establishment of a rice crop at the beginning of th wet season. This increases the potential for growing a second rice cro under relatively favorable moisture supply conditions (Figure 7). I the second rice crop can be planted and harvested soon enough, th possibility also exists for a third planting under conditions favorabl for the growth of upland crops. Adoption of the DSR technique woul increase the requirement for land preparation labor during a period whe little or no farm work usually takes place. Capital requirements are similar to those required for planting early maturing varieties using other seeding methods with the possible exception of herbicide. Since dry land preparation does not effectively control weeds, the use of herbicide appears to be a necessary pre-condition for the adoption of DSR.

Contribution to household objectives. To the extent that DSR facilitates increased cropping intensity, the ability to meet household food requirements and increase farm incomes will be enhanced. Because planting takes place early in the season, rice stocks can be replenished at an early date.

Institutional requirements. The institutional requirements for DSR would be similar to those for establishing any new early maturing, high yielding rice variety.

Managerial requirements. Three significant problems have been encountered with DSR as a planting strategy: (a) poor and uneven germination; (b) death of germinated seedlings due to drought; and (c) excessive weed growth.

Problems (a) and (b) are influenced by the nature of the rainfall distribution before the onset of heavy sustained rains. Thus, they are beyond the farmer's control once the fields have been prepared and seeded. Problem (c), excessive weed growth, is controllable by farmers assuming that sufficient labor and cash resources are available.

Timing in DSR is critical, as fields must be prepared and planted at the very beginning of the wet season. After seeding, rainfall causes both weed and rice seeds to germinate. Since fields are never perfectly level, soil moisture conditions differ in different parts of the field, causing uneven germination. Due to their low photoperiod sensitivity, new varieties will mature in roughly a constant period of time after germination. Therefore, if germination occurs unevenly, maturation will also be uneven, thus delaying or complicating the harvesting process.

Agroclimatic requirements. Poor initial crop stands are likely if there is either too little or too much rainfall. If rainfall is heavy soon after dry seeding and sufficient water accumulates, seeds and young seedlings may drown. On the other hand, a two to three week dry spell after seeds have germinated can cause the death of a high proportion of young seedlings.

As rainfall tends to be unstable in both frequency and intensity at the beginning of the wet season, the probability of poor initial crop stands combined with strong competition from weeds is high. The type of damage likely to be suffered depends upon the position of the field within the topographic sequence and the type of soil. For example, paddy fields on side slopes or fields with light soils would be most likely to receive insufficient moisture to support a dry seeded crop in its early stages. Dry seeded fields in the lower landscape positions, or with heavy soils which easily impound water, would be most susceptible to flooding damage should initial rainfall be intense or very frequent.

Acceptability to farmers. Interviews and discussions were held with farmers trying DSR during the period of crop growth and subsequent to its harvest. Farmers who decided not to try DSR cited rainfall uncertainty and high expected weed growth as the main reason for their choice. Of the farmers that did try DSR, two said that they did not plan to repeat the technique the following year, due to poor yields caused by the previously mentioned conditions. A third farmer, who established DSR on a very low landscape position, achieved good results and is planning to continue the practice in the future on the same fields.

Examining the performance criteria stated at the beginning of this paper, one finds DSR deficient on two points. First, it appears that the levels of handweeding labor and cash for purchase of chemical inputs that farmers must have available in order to successfully utilize the technology are higher than farmers are willing or able to allocate. Second, DSR increases rather than reduces the effects of uncertainty on the farm system. In order to achieve the potential benefits desirable from DSR, the farmer must subject himself to a higher probability of yield loss due to flooding, drought stress and competition from weeds. Finally, with respect to farmer acceptability, the adoption of DSR as a crop establishment technique has been quite low.

Existing Technology 3 - Transplanting the second rice crop (TPR)

One means of increasing the potential yield of a second rice crop following the harvest of an EMV is to transplant the succeeding crop using mature (35-45 days-old) seedlings (IRRI, 1979). The second rice crop, also an EMV, must be sown in seedbeds before the harvest of the first crop and transplanted into the main field once the previous crop is harvested and the field has been prepared. The transplanted crop will mature in about 75 days after the date of transplanting (Figure 8). The probability of yield reduction due to drought stress is reduced as the amount of time necessary for the crop to be in the field after planting is shortened.

Resource utilization. Transplanting the second rice crop with 35-40 day-old seedlings can enable farmers to harvest two rice crops in

a single season with a lower risk of severely reduced yields for either crop. There are, however, two significant factors which limit the adoption of this technology:

1. A portion of land must be set aside (not planted to a first rice crop) for seedbed preparation.

2. Labor must be available for transplanting when seedlings are mature and fields are prepared.

The first factor is relevant mainly to the smallest farms. Part of the income generated by a transplanted second crop must pay the cost of the foregone opportunity of a first crop of rice growing on the seedbed area. The second factor mentioned, that of transplanting labor availability, is probably most significant. During the time when transplanting of the second crop should take place, rice crops on other fields in the surrounding areas are being harvested.. The wage rate for harvest labor (including threshing) is based on a crop share, while the transplanting wage is usually a fixed amount. The transplanting wage was set when mainly traditional varieties were being used, and few alternative employment activities existed for transplanting labor. With the greatly increased adoption of non-photoperiod sensitive varieties, opportunities for harvest labor are available throughout most of the rice-growing season. The harvest wage varies with the yield of the crop, generally in the same direction. That is, the higher the yield per unit area, the higher the harvest wage per unit time. The analysis of farm records has shown that harvest wage rates vary from roughly equal to as much as four times the transplanting wage.[2] Since many of the harvesters are landless laborers, their share of the harvest may be worth something closer to the retail price of rice than the wholesale or farm gate price. If the rice earned is used for consumption, then a milling fee is the only additional cost, as they often transport the rice themselves and have no marketing expenses to pay. Therefore, the real harvest wage was as high as eight times the wage being offered for transplanting. This of course restricts the supply of labor for transplanting during harvest time.

Contribution to household objectives. Transplanting the second rice crop allows farmers to increase their cropping intensity, thereby increasing food production and farm income.

Institutional requirements. Transplanting is a common farm practice which requires no new capital inputs from outside the system. Other requirements would be similar to those which would necessarily accompany the adoption of any new variety.

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[2]These figures reflect valuation of the harvesters' crop share at the farm gate price of rice.

Managerial requirements. Managerial changes associated with the adoption of this technology would be minimal, as farmers are already familiar with transplanting techniques. The changes that would have to occur involve reducing the amount of land planted to the first rice crop in order to provide space for growing a seedbed, increasing the seedling transplanting age in order to reduce the amount of time the crop is in the field, and increasing the density of transplanted seedlings.

Agroclimatic requirements. As demonstrated in Figure 8, transplanting the second rice crop enables the two-crop sequence to fit mostly within the time period alotted for rice production. The major difference from previous recommendations for transplanted rice concerns the age of the seedlings upon transplanting. Experimental trials undertaken at IRRI in 1978 evaluated yield and growth duration effects of old seedlings. Average grain yields were significantly reduced when old seedlings were used when the transplanting intensity was three seedlings per hill. However, the use of an increased number of seedlings per hill was found to increase the yield of plots planted with 40-day-old seedlings to levels similar to those planted with 18-day-old seedlings (IRRI, 1978; Table 31).

Acceptability to farmers. Farmers in Iloilo have demonstrated a general reluctance to allocate land to seedbeds and to forego the more certain first rice crop for what they consider to be a less certain outcome for a second rice crop. Furthermore, farmers have been well versed on the necessity of transplanting EMV seedlings early (18-20 days after seeding). They therefore expect inferior yields using the older seedlings that form the basis of this new technology.

In Iloilo, there is not an overabundance of landless people offering their services as temporary agricultural laborers. In fact, many farmers with small holdings forego productive opportunities on their own farms in order to work as harvesters in neighboring larger farms. Moreover, it is unlikely that farmers in the area would be willing to increase transplanting wages sufficiently to attract labor that would ordinarily be used in harvesting.

In evaluating this technology according to the criteria for appropriateness presented at the beginning of this paper, we find that transplanting the second rice crop can improve the productivity of land (by increasing expected yield) and can reduce the effects of uncertainty on the farming system (by reducing the risk of yield loss due to drought stress). However, it is not compatible with the level of labor and capital farmers are willing and able to reallocate.

EVALUATION OF NOTIONAL TECHNOLOGIES

The previously evaluated technologies can be considered relatively developed in the sense that at least preliminary field testing and evaluation has occurred. As demonstrated previously, a large scale

adoption of Existing Technology 1 (EMVs) by farmers has already taken place. Existing Technologies 2 and 3 have been developed and tested, but adoption by farmers is not yet widespread. In this section, four notional new technologies will be briefly described and evaluated in the context of Iloilo rainfed farming systems. Each of the notional technologies is designed to enhance farm productivity, either by improving the utilization of currently available resources (especially land during the wet season) or by contributing to the alleviation of some of the problems plaguing unacceptable existing technologies.

Notional Technology 1 - Very early maturing varieties (VEVs)

As mentioned previously, early maturing varieties do not provide the opportunity for double rice cropping under rainfed conditions without entailing a substantial risk of yield reduction due to drought stress of the second rice crop (Figure 5). One potential means of allowing double rice cropping under less risky conditions would be to develop varieties with an even shorter maturation period (Figure 9).

Resource utilization. By enabling the planting and harvesting of two rice crops per season, VEVs would require increased amounts of labor and capital inputs than are currently employed under single crop production systems. Land would become roughly twice as productive as it currently is in areas where multiple rice crop potential is low using existing EMVs.

Contribution to household objectives. VEVs would contribute an increased supply of rice earlier in the season than late maturing varieties. Initial adopters of such varieties would likely obtain higher prices for their output due to the early harvest, thus generating greater farm incomes. Total rice production per unit of land would increase, resulting in an increased overall family food supply. Nutritional levels may decline, however, if double rice cropping implies a reduction in the production of other food crops.

Institutional requirements. No new inputs, other than seed (which farmers can produce themselves after the first year), would be required for VEVs. Levels of common capital inputs would need to be increased in a manner compatible with the growing of two crops of rice in a season instead of one. Marketing problems may arise, especially for the second crop, due to a lack of adequate capacity of governmental storage facilities.

Managerial requirements. The managerial requirements for VEVs would be similar to those for varieties currently used by Iloilo farmers. Timing of crop activities will become increasingly important if two rice crops are to be planted and harvested before the end of the wet season. This implies that labor must be available for timely land preparation, planting and harvesting of each crop.

Agroclimatic requirements. For rainfed areas such as Iloilo, with a 5-6 month rice growing season, rice varieties with field duration of about 90 days can be double cropped using wet seeded establishment techniques (Fig. 9). Both crops can be grown at least through the flowering stage during the period of the year that the probabilities of obtaining sufficient rainfall to support normal rice crop growth are high.

Scientists have already succeeded in breeding very early maturing varieties. In addition, rice varieties typically grown in temperate climates produce much more rapidly in the tropics, some in as little as 70 days. However, experimental results at IRRI appear to demonstrate a positive correlation between maturity and grain yield (Figure 10). The earliest maturing variety currently being recommended for use in the Philippines is IR26, which matures in 105 days. There is some question as to the physical feasibility of producing new varieties with significantly reduced field duration periods that still provide the high yield potential of some of the later maturing varieties currently in use. Significantly lower yield expectations could reduce the attractiveness of very early maturing varieties vis a vis other currently available production technologies.

Acceptability to farmers. When questioned as to the potential desirability of varieties with a very short field duration, all farmers responded affirmatively. In fact, some of the farmers were already experimenting with Japanese varieties that were said to mature in as little as 70 days in the Philippines. Most farmers who tried these varieties reported that yields were unacceptably low and that grain quality was inferior. The Japanese varieties would have to be improved upon in these two aspects before becoming acceptable to farmers.

Very early maturing varieties for the rainfed farming system appear promising providing problems of low yield and grain quality can be overcome. The major positive factor would be the reduction of uncertainty in the system with respect to rice yields, as both crops could be fully grown under favorable conditions for rice.

Notional Technology 2 - Late maturing varieties (LMVs)

If the positive relationship between rice yields and maturity period is confirmed, it may be possible to increase output over current levels by growing a long duration, non-photoperiod sensitive high yielding variety which can then be followed by an upland crop (Figure 9). The principal advantage of a non-photoperiod sensitive LMV over traditional varieties is that it could be harvested earlier in the season, leaving more time for establishing a subsequent upland crop under favorable conditions. On fields in the higher landscape positions, where yield loss probabilities tend to be highest for a wet seeded second rice crop planted late in the season, double rice cropping may not be viable in most years. In such areas, the planting of a late-maturing, high yielding single rice crop would be preferable over a single short-duration rice crop. Ample time would remain for planting a succeeding upland crop.

Resource utilization. The development of LMVs would not require large changes in current cropping practices. Land use intensity would increase somewhat as more upland second crops could be planted. Labor and capital use would remain virtually the same, with changes occurring only in timing.

Contribution to household objectives. Due to improved yield characteristics, a modest increase in rice production would be expected. Similarly, due to an early harvest, the potential for planting upland crops after rice would also increase (Figure 11). Assuming stable price levels, this would provide increased farm income as well as food for home consumption. The timeliness of food provision would not vary substantially from existing patterns.

Institutional requirements. Adoption of an LMV would require no new inputs or policies. Due to the similarity in timing to traditional varieties, no special market requirements are foreseen.

Managerial requirements. Management of LMVs would be similar to that required of traditional varieties. The level of risk for the second upland crop would, however, be reduced.

Agroclimatic requirements. There is no reason to suspect that an LMV would not be biologically feasible, though most non-photoperiod sensitive varieties are early maturing. In regards to suitabilitly to rainfed climatic conditions, there should be no problem.

Acceptability to farmers. Due to the fact that LMV adoption would not stimulate great changes from current practices, farmers interviewed indicated that the technology would be acceptable. They were also able to recognize the advantage in regards to an earlier establishment of the upland crop.

Notional Technology 3 - Photo-sensitive, early maturing varieties (PSVs)

The development of early maturing, photoperiod sensitive rice varieties could be used as a major component in a technology based upon dry seeded rice. Previously, an analysis of DSR-based cropping patterns revealed major problems with respect to maturity and weed growth that would be alleviated or partially alleviated with the advent of such a variety.

High photoperiod sensitivity is a desirable characteristic for a dry seeded rice variety, since maturity is principally determined by day length even though the planting date may vary. One of the major problems with DSR is that of uneven maturity due to uneven germination and subsequent replanting of poor initial stands. Areas which require additional planting can be reseeded once rainfall has stabilized, and the new plants will mature at the same time as the older plants.

Resource utilization. As part of a multiple cropping scheme, the chief desirability of DSR is that it permits the establishment of an initial rice crop as soon as the soil has accumulated sufficient moisture to permit land preparation. The early establishment of the first rice crop greatly improves the chances of planting and harvesting a good second rice crop (Figure 7). Capital and labor use intensity would be affected in a fashion similar to any technique which would facilitate the double cropping of rice.

Contribution to household objectives. The utilization of a PSV would allow early rice crop establishment using dry seeding techniques, which in turn enhances the possibility for double rice cropping. The potential would then exist for increased rice production and farm income. Furthermore, two rice harvests would allow greater flexibility in the management of rice stocks for family consumption.

Institutional requirements. No new inputs or policies would necessarily accompany the adoption of this technology. Market effects would be to alter the pattern of supply, enabling rainfed farmers to market their rice crops earlier in the season, thus possibly gaining a price advantage.

Managerial requirements. Crop establishment practices would be altered with the use of DSR techniques. Furthermore, in order to derive full benefit from the PSVs, field preparation must be accompanied at the onset of the wet season. Production risks would be reduced as sparsely populated parts of a field could be replanted and the entire field would still mature simultaneously.

Agroclimatic requirements. The biological feasibility of varieties which flower and mature under day length conditions prevalent during the middle of the rainy season would need to be explored by the plant breeders. The climatic fit of such a variety as the first crop in a two rice crop pattern would be similar to that presented in Figure 7.

Acceptability to farmers. The idea of PSVs as notional technology was conceived after completion of field work, and hence was not presented to farmers for judgment. However, the probable benefit of this technology is that it would alleviate the uneven maturation constraint associated with DSR, which would therefore make the seeding method more acceptable to farmers.

Notional Technology 4 - Ratoon rice varieties (RAVs)

Ratooning of rice is the use of the plant's regenerative ability to produce a subsequent crop (or crops) from field stubble after the harvest of the first crop. The expected yields of a ratoon crop are almost always lower than those of the main crop. The principal advantage, then, is the potential saving of both time and labor. The time-saving feature of ratoon cropping is what makes it most attractive as a potential new technology for rainfed areas with agroclimatic conditions similar to those prevalent in Iloilo.

The principal characteristics of a cropping pattern featuring ratoon are shown in Figure 12. Since the period from initial ratoon growth to grain maturity is short, the first rice crop can be established late enough so that the risk of early drought stress is low. In most cases, this implies the use of wet seeding as the initial rice crop establishment technique. Ratoon growth begins immediately after (or sometimes before) the harvest of the plant crop. New shoots are produced at the base of the plant or grow from the nodes of previously cut tillers. Since ratoon matures much sooner than the main crop,[3] the total duration of the main-ratoon crop is approximately 170 days.

Resource utilization. The growing of a ratoon rice variety would make use of land in the latter part of the wet season which, in cases where growing a second crop is infeasible, has no alternative use. A ratoon crop would require few if any additional capital inputs, as the residual nitrogen not utilized by the main crop would be available for the ratoon. Since no effort would be spent preparing and planting land after the first rice crop, additional labor would be required only for the harvest.

Contribution to household objectives. By providing an added rice harvest from areas where double rice cropping is not feasible, ratoon cropping would increase the family food supply and modestly increase farm income.

Institutional requirements. Ratoon technology would not depend upon new or greatly increased levels of inputs from outside. Since expected ratoon crop yields are lower than expected main crop yields, minimal additional stress would be placed on the product market.

Managerial requirements. Ratoon rice cropping requires no new or unfamiliar techniques. The importance of timing of crop activities is not greatly increased, though main crop establishment early in the wet season would be preferable to ensure that both crops would grow under optimal moisture conditions. As the ratoon crop is ready for harvest just at the end of the rice growing season, the probability of substantial yield reduction or crop failure due to drought stress is low. Furthermore, the possibility still exists for planting and growing an upland crop under suitable soil moisture conditions.

Another feature that makes ratoon cropping attractive in a rice-based cropping pattern is the reduced labor requirements. Since no land preparation or planting labor is required for ratoon, farmers may utilize otherwise idle land and still avail themselves of alternative employment opportunities such as harvesting on neighboring fields.

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[3]In the case of IR-36, the ratoon matures in approximately 50-60 days after harvest of the main crop.

Ratoon cropping then becomes a complementary rather than a competitive activity, as output can be generated with low levels of inputs and management.

Agroclimatic requirements. All rice plants have a regenerative ability. However, experience with early maturing varieties indicates that ratoon yields can be expected to be much lower than those of the main crop. This is partly because "ratoonability" has not been a criterion for varietal selection in IRRI breeding programs. Results from cropping pattern trials indicate that the average yields of IR-36 ratoon approximate one-sixth of the main crop yield (Component Technology Research Staff, 1979).[4] While ratoon cropping is biologically feasible and fits the prevalent climatic pattern in Iloilo well, breeding work will have to be done to obtain varieties which would increase the benefits of ratoon technology.

Acceptability to farmers. The farmers participating in this study were questioned as to their preference between rice varieties currently available and a proposed new variety which would produce about one-third the yield of the new varieties they were using. All of the farmers had previous experience with ratoon, though few had done it intentionally. Their word for ratoon translated roughly as "volunteer rice". During years in which there was substantial rainfall late in the rice-growing season, some newly harvested rice plants would regenerate. In most years, farmers did not consider the ratoon rice to be worth harvesting, as the yields were extremely low. In years when it was harvested, the largest share went to the hired harvest labor.

When presented with the idea of ratooning the new varieties with the expectation of a better yield, farmers responded positively. Of the twelve farmers interviewed, ten stated that they would favor the adoption of a ratoon variety rather than risking the planting of two crops of the currently available new varieties. One of the farmers stated that he would try to plant two rice crops if the onset of the wet season was very early, and plant a ratoon variety otherwise. The other farmer indicated that he could not predict his response to a ratoon variety until he had had first-hand experience with it.

During the three previous cropping seasons in the Iloilo area (1976-79), an average of over 70 percent of the rainfed lowland was planted to either rice-upland crop or rice-fallow patterns. Ratoon cropping could conceivably increase the productivity of nearly all of this land, provided that ratoon yields are sufficiently high to warrant the expenditure of labor for harvest.

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[4]No cash inputs (such as fertilizer or pesticides) were added to the ratoon crop, which would in part explain low yield figures.

Each of the four notional technologies described is designed to alleviate at least one system constraint without aggravating other constraints or creating new ones. The utilization of very early maturing varieties (VEVs) would allow the double cropping of rice with a reduced degree of yield uncertainty due to adverse climatic conditions. For land with low double cropping potential, the planting of a higher yielding, medium to late maturing variety (LMV) can increase land productivity if new late maturing varieties can be found which achieve significantly higher and more stable yield levels than the EMVs. The third notional technology suggested was the utilization of an early maturing photoperiod sensitive variety (PSV) as a complement to dry seeded crop establishment. Such a variety would contribute to the alleviation of some of the problems plaguing farmers who have tried DSR. Lastly, the utilization of rice regenerative ability through the development of a vigorous ratooning variety (RAV) was suggested as a means of increasing rice production with a small investment in areas where double rice cropping is infeasible due to high drought probabilities or other constraints.

A TECHNOLOGY CHECKLIST

As a conclusion to this paper, a checklist of the possible effects on the farm system of a new technology is presented (Table 1). Each existing and notional technology is rated in terms of what changes in the farm system are necessary in order to facilitate the adoption of the technology and what likely effects the successful implementation of each technology would have on the farm system in question.

Notional and existing technologies possess different advantages and disadvantages in terms of their adaptability to rainfed farming systems. Before technology development should take place, a ranking of technologies would be desirable so that researchers could focus on inventing the better ones. Therefore, each technology was assigned a numerical rating according to whether it possessed favorable, neutral or unfavorable effects when compared to traditional technology for each of the evaluation criteria. The summation of positive, negative and zero ratings provided an overall desirability index for each technology (Table 2).

All of the evaluation criteria were weighted equally. It is likely, however, that the relative weights of each criterion would vary from farm to farm depending upon such individual characteristics as land, labor and capital availabilit, and risk preferences. Though different weights would change the individual scores for each technology, there is sufficient difference in the scores obtained by most of them that the ordinal rankings would still be likely to hold.

According to the criteria used in technology evaluation, all of the notional technologies would be superior to any of the existing new technologies. However, not all of the notional technologies would be

equally desirable or beneficial in the Iloilo context. Based upon the rankings presented, it would appear that the development of an early maturing, non-photoperiod sensitive variety with a vigorous ratooning capability would best serve the needs and conditions of Iloilo farmers. From the farmers' viewpoint however, no one technology can be considered appropriate for all situations. Under current agroclimatic and socio-economic conditions, it appears that double rice cropping is feasible mainly in the lower landscape positions with heavy clay soils which easily retain moisture. Labor and power constraints also limit the amount of land per farm that can be multiple cropped. In order to further increase the productivity of small farms, it is desirable to present farmers with a set of alternative technologies which are appropriate for different socioeconomic and agroclimatic situations. Priority should be given to the development of the most flexible technologies, i.e. those which are appropriate under the greatest number of circumstances.

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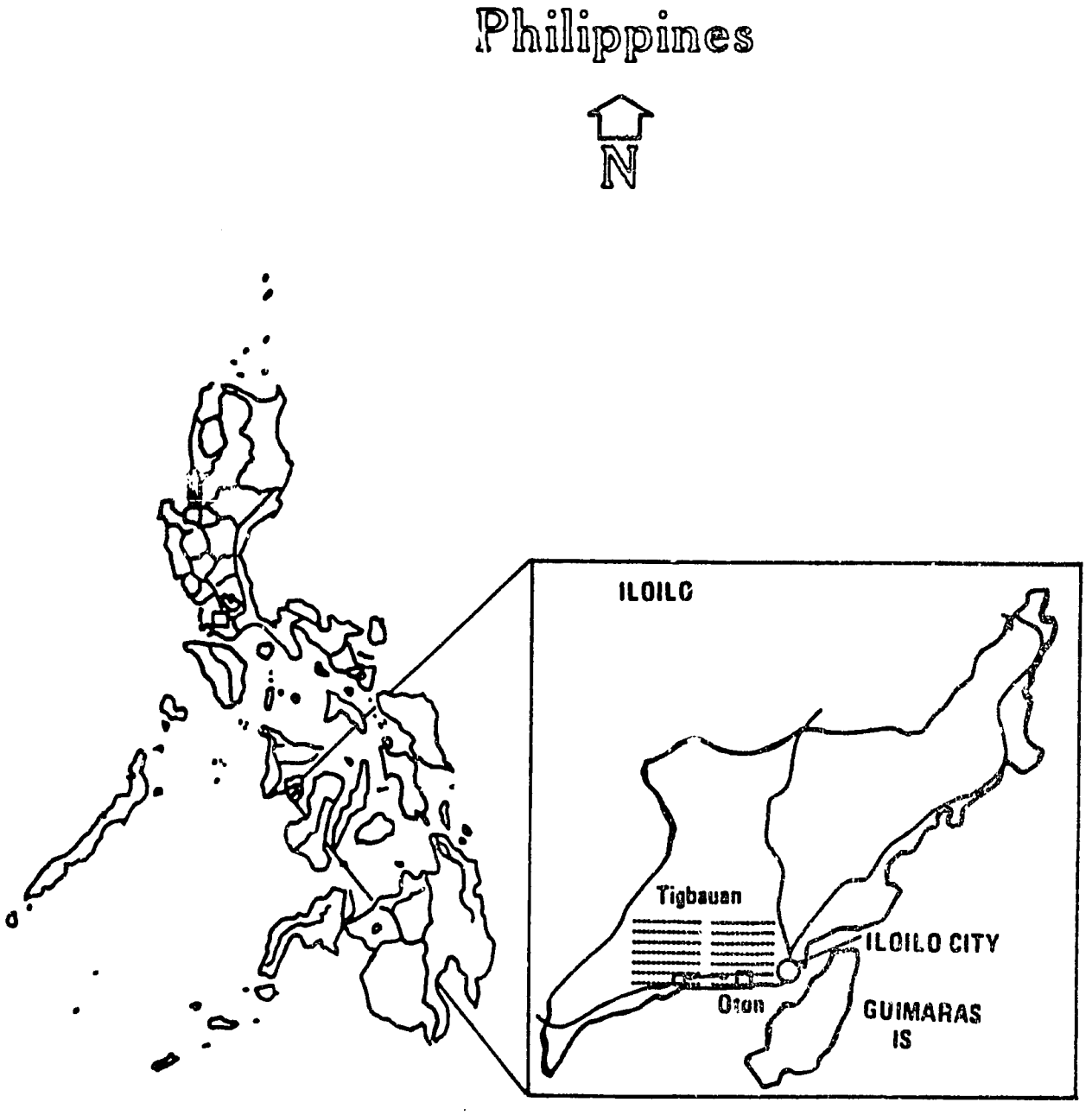

Figure 1. Location of the Iloilo research site.

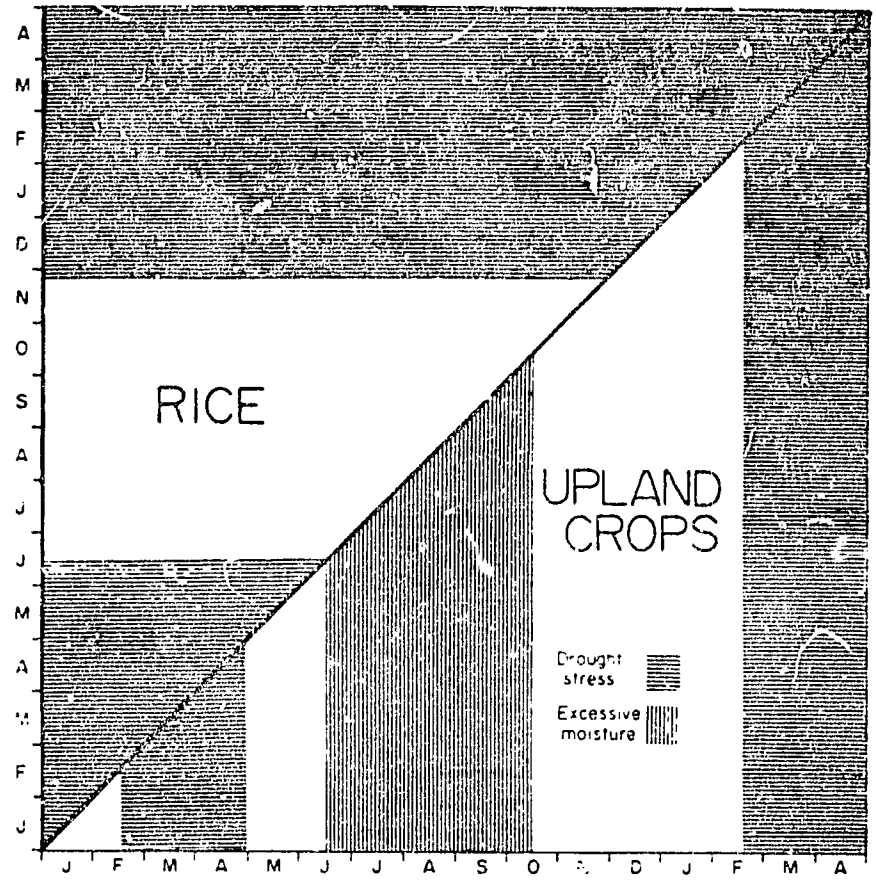

Figure 3. An agroclimatic map of cropping potential in the Iloilo rainfed area.

Note: The environmental conditions for rice are specified above the diagonal; those for upland crops below the diagonal. These conditions correspond to areas with 5-6 wet (> 200 mm) and 2-4 dry (< 100 mm) months per year.

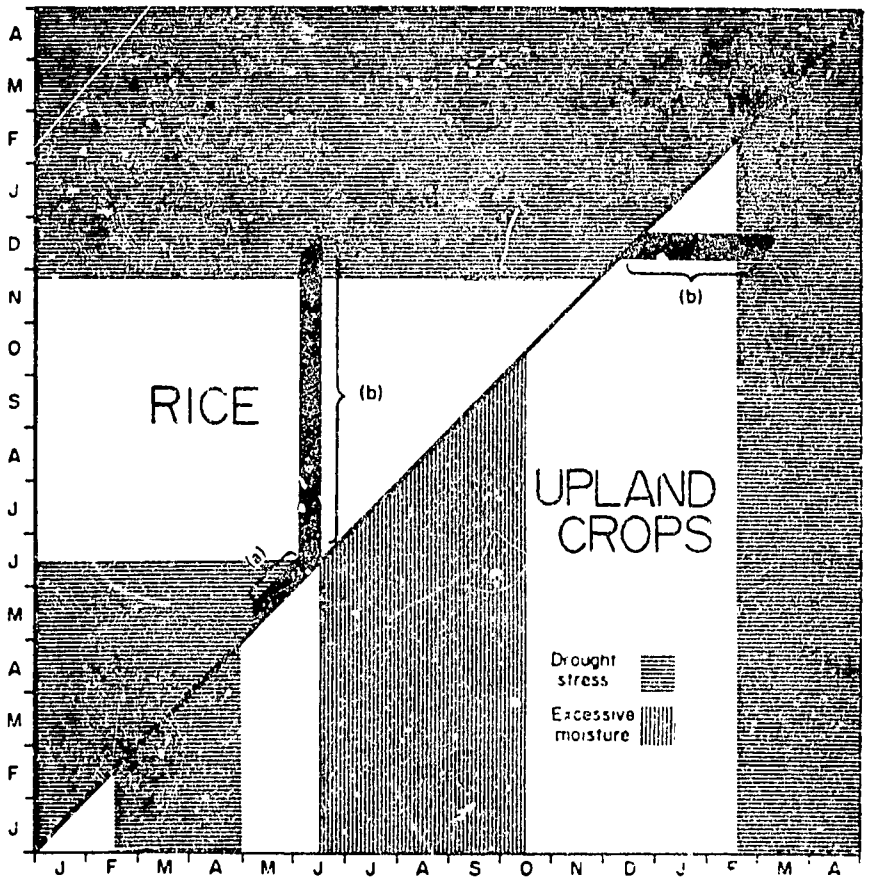

Figure 3. The suitability of traditional cropping practices to Iloilo agroclimatic conditions.

Note: Time for land preparation activities is measured along the diagonal (a), while time for planting through harvesting is represented as bars emerging from the diagonal (b).

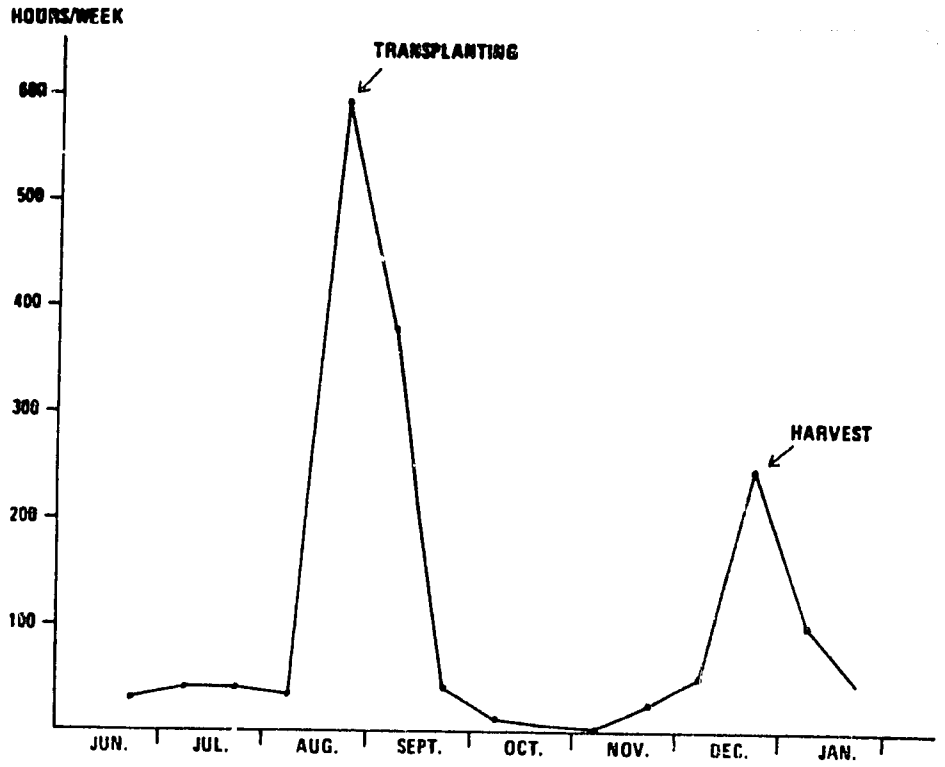

Figure 4. A labor profile for a rainfed rice farm planting traditional rice varieties.

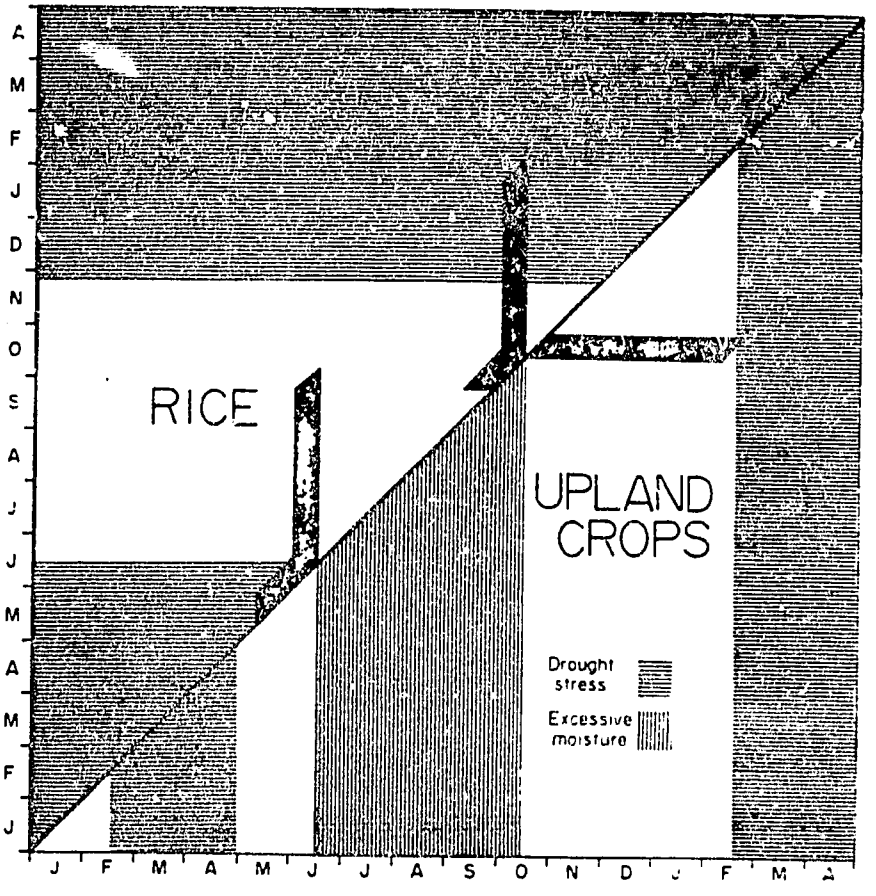

Figure 5. Agroclimatic suitability of early maturing rice varieties to Iloilo conditions.

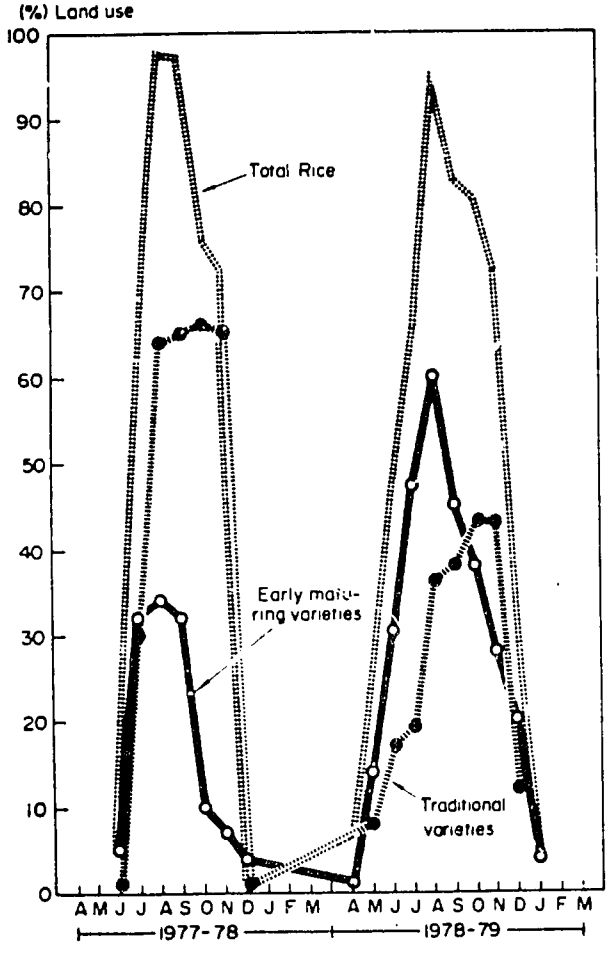

Figure 6. Trends in adoption of early maturing rice varieties in Iloilo, rainfed areas, 1977-1979.

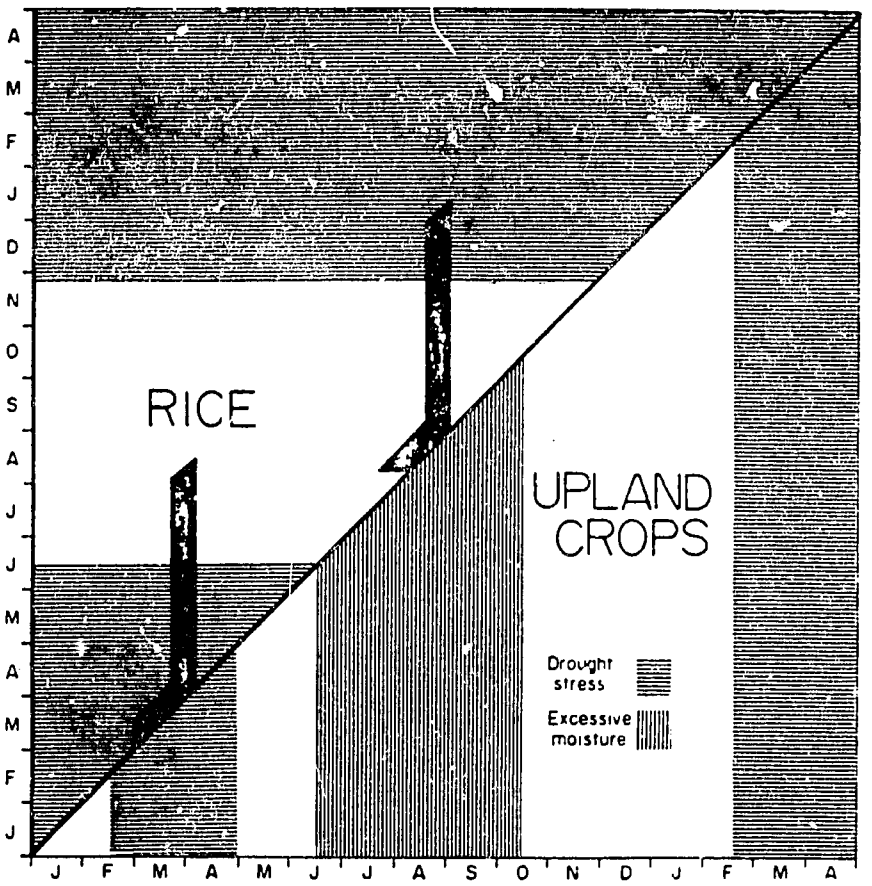

Figure 7. Suitability of DSR under typical Iloilo agroclimatic conditions.

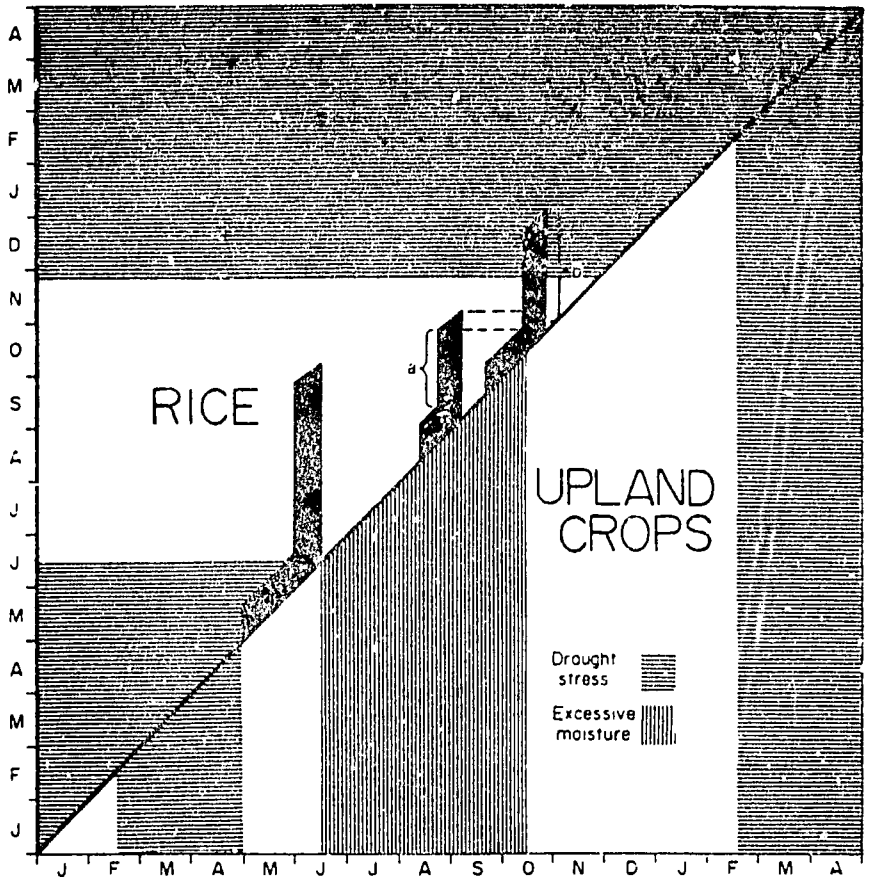

Figure 3. Transplanting a second rice crop with older seedlings under Iloilo agroclimatic conditions.

Note: a. Seedling growth
b. Main crop growth

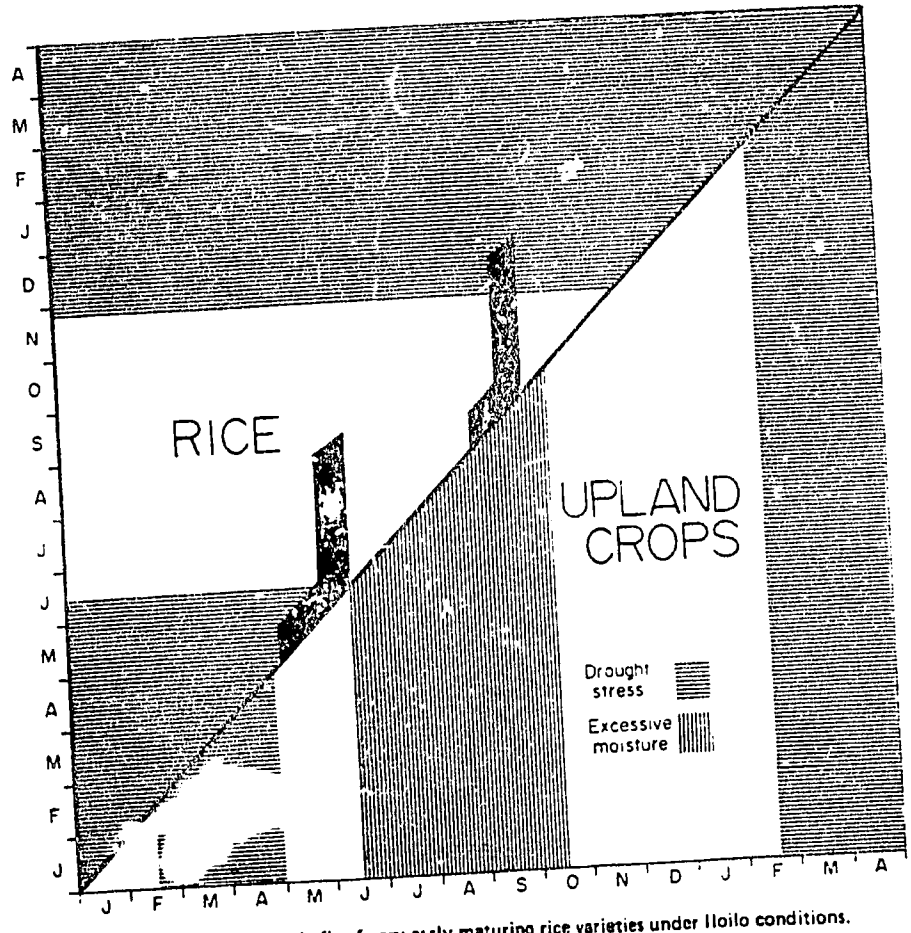

Figure 3. Agroclimatic fit of very early maturing rice varieties under Iloilo conditions.

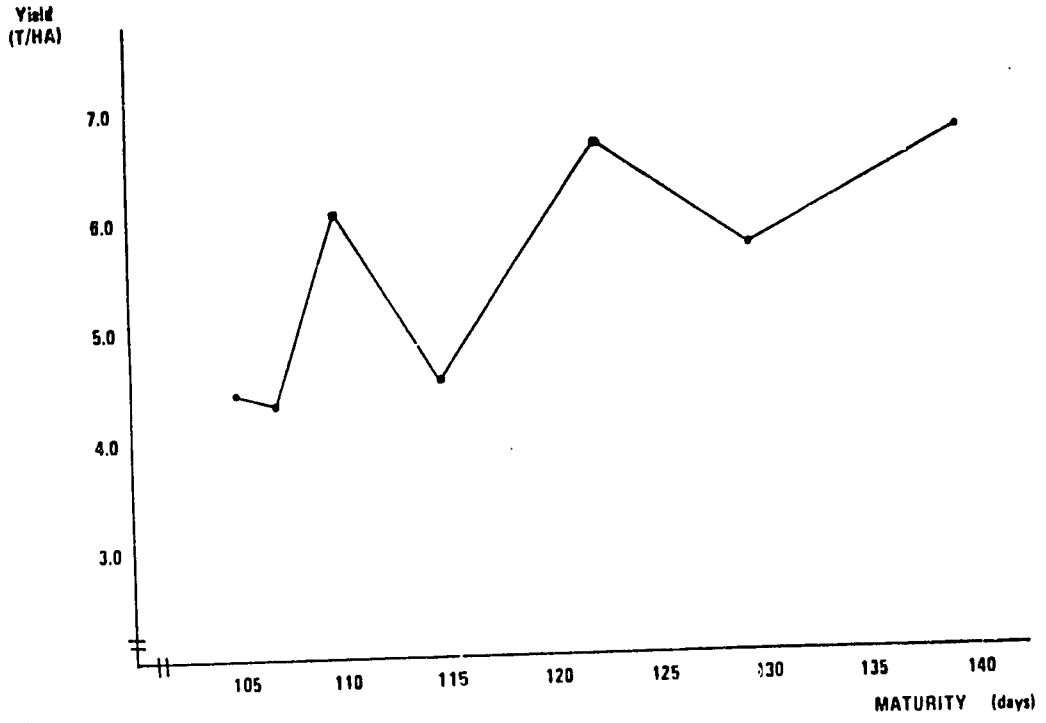

Figure 10. Relationship between average grain yield and maturity period of ten IRRI varieties recommended for the Philippines.

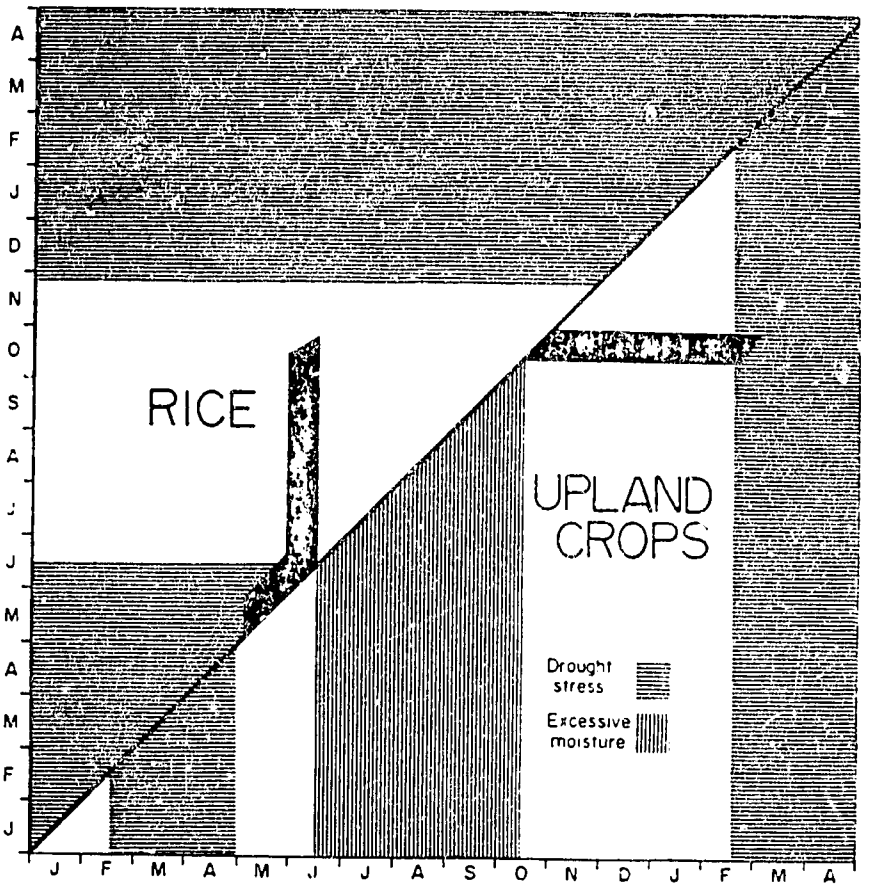

Figure 11. Suitability of a late maturing variety under Iloilo agroclimatic conditions.

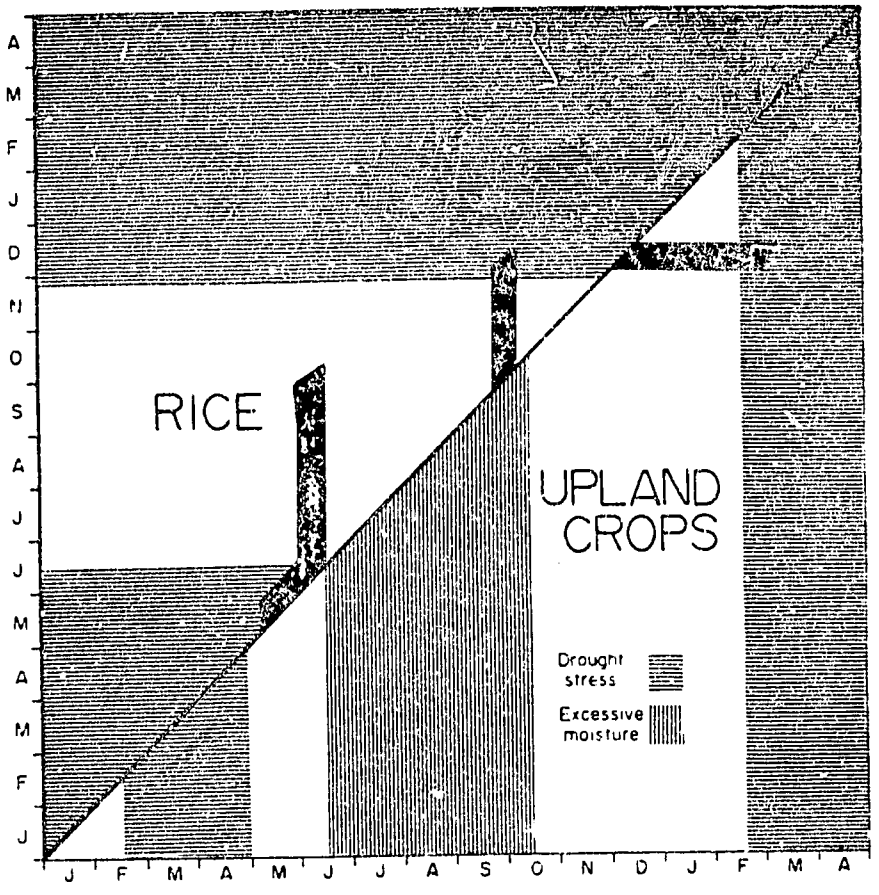

Figure 12. Ratoon rice cropping under Iloilo agroclimatic conditions.

Table 1. A Technology Checklist

Evaluation Criterion	Existing Technologies			Notional Technologies			
	Adopted	Unadopted					
	EMV	DSR	TPR	VEV	LMV	PSV	RAV
Resources							
Land Use Intensity	1	2	1	2	1	2	2
Labor Use	0	1	-2	1	0	1	1
Capital Use	-1	-2	-1	-1	0	0	0
Household Objectives							
Food Production	1	2	2	2	1	2	2
Farm Income	1	1	1	1	1	1	1
Timeliness	1	1	1	1	0	1	1
Institutions							
New Inputs or Policies	-1	-1	-1	-1	-1	-1	-1
Market Changes	-1	-1	-1	-1	1	-1	-1
Management							
New Techniques	1	-1	-1	1	1	-1	1
Critical Timing	0	-2	-1	1	0	1	1
Level of Risk	1	-2	1	1	1	1	2
Agroclimate							
Biological Feasibility	1	1	1	0	0	0	1
Climatic Fit	1	-2	1	1	1	1	2
Farmer Evaluation							
Acceptable	1	-2	-1	1	1	0	2
Foreseen Problems	-1	-1	-1	1	1	1	1

Headings: EMV - Early Maturing Variety, DSR - Dry Seed Rice, TPR - Transplanted Second Crop, VEV - Very Early Maturing Variety, LMV - Late Maturing Variety, PSV - Early Maturing Photosensitive Variety, RAV - Ratoon Variety.

Code:
- 2(-2) - Strong favorable (unfavorable) effect in comparison to traditional technology.
- 1(-1) - Favorable (unfavorable) effect in comparison to traditional technology.
- 0 - Neutral or unknown effect.

Table 2. Technology ranking according to evaluation criteria

Rank	Technology	Overall Score
1	Ratoon Variety (RAV)	15
2	Very Early Maturing Variety (VEV)	10
3	Late Maturing Variety (LMV)	8
4	Early Maturing Photosensitive Variety(PSV)	8
5	Early Maturing Variety (EMV)	5
6	Transplanted Second Crop (TPR)	-1
7	Dry Seeded Rice (DSR)	-6