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EVALUATION OF DOUBLE-CROPPED RAINFED WETLAND RICE

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EVALUATION OF DOUBLE-CROPPED RAINFED WETLAND RICE[1]

ABSTRACT

The advent of short-duration photoperiod-insensitive rice cultivars has encouraged double-cropping of rice. However, the wet season in most of monsoonal Asia is not long enough to satisfy the water requirements of two rice crops in all years. Evaluating a particular rice-growing area for potential for rice double-cropping requires an estimate of the second rice crop's yield variability through the years and across a landscape. The usual approach -- extensive long-term field trials -- delays recommendation of a given cropping pattern. A possible solution to this predicament is crop modeling to predict second-crop yield response to planting date. When applied to nine sites in one province of central Philippines, modeling clearly defined rice areas and landscape positions suitable for double-cropping rice. Appropriate crop management practices were also identified.

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EVALUATION OF DOUBLE-CROPPED RAINFED WETLAND RICE

The potential for crop intensification in rainfed wetland rice-growing areas is determined by rainfall and the position of fields in the toposequence. Year-to-year variations in rainfall make it difficult to estimate the performance of alternative cropping patterns. Crop simulation techniques were, therefore, used to evaluate the performance of alternative cropping patterns and management techniques.

The model we present evaluates the performance of the second rainfed wetland rice crop in a two-rice pattern. The performance of the first rice crop is not in question because it is grown at the height of the wet season, but the second crop routinely suffers moisture stress because it is grown mostly in the wet-dry season transition. The method of establishing the first crop affects the second crop planting date because a dry-seeded first crop emerges earlier than a wet-seeded crop. The method of establishing the second crop is also important -- a transplanted crop may avoid drought in the reproductive stage (Morris and Zandstra 1978).

The objective of our study was to evaluate the performance of the two-crop rainfed rice pattern across years at nine sites in one province of the Philippines. The evaluation was only for the dominant land types on which the pattern may be grown. The model results were used to compare the expected performance of that cropping pattern with the major alternative land uses. This paper presents the application of simulation techniques to evaluate multiple cropping alternatives developed at one site for extrapolation to comparable sites.

THE CROPPING SYSTEM

Iloilo province, Philippines, has a normal rainfall of more than 200 mm for 5-6 consecutive months and 100-200 mm for 3-4 months. The 200 mm/month level is used as a rough guide to the rice-growing season (Oldeman and Suardi 1977). Figure 1 illustrates the cumulative rainfall probabilities for Iloilo. The destructive winds associated with tropical cyclones rarely cause crop damage there. The Iloilo rainfall pattern is representative of the pattern in larger areas of tropical Asia, including 70% of Bangladesh, 30% of Indonesia, and 40% of the Philippines (Manalo 1956, 1976; Oldeman 1979).

The Iloilo landscape was derived from erosion of old river terraces, which resulted in a toposequence of beach ridges (sandy), coastal plains (clayey), dissected low terraces (clay loam), colluvial high terraces (loamy), and foothills. The main rice-growing area is the fringe of coastal plain, which is mostly irrigated and adjoins rainfed miniplains between it and the foothills of the Western Cordillera mountain range. The rice soils are principally Pellic Vertisols (FAO-UNESCO 1974). Rice on the coastal plain and the miniplains is grown mostly on fertile Santa Rita clay loam. Paddy fields of the higher terraces are on less fertile series, such as the Alimodian and Barotac loams (Alicante et al 1947).

The traditional cropping pattern for the rainfed rice-growing areas of Iloilo is a single, long-duration, often photoperiod-sensitive rice crop,

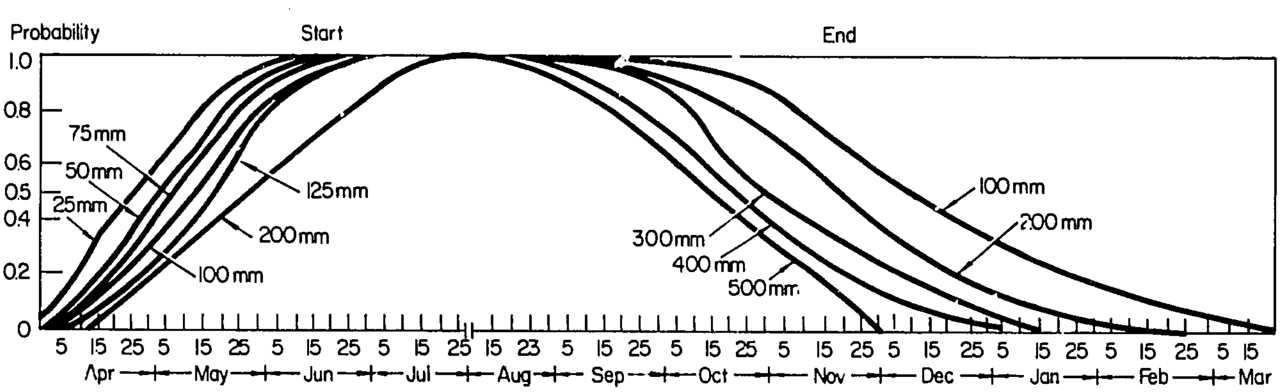

Fig. 1. The cumulative probabilities of having received a given amount of rain on a certain date (start) and of still receiving a certain amount of rain after a given date (end) for the Iloilo (Philippines) rainy season (Tigbauan rainfall records). Source: Morris and Zandstra (1978).

sometimes followed by a grain legume crop broadcast into the stubble (Palada et al 1976). The advent of irrigation and short-duration varieties has resulted in a shift to double-cropping of rice. However, the potential for crop intensification in the higher elevation rainfed areas is affected by rainfall and the position of fields in the toposequence.

The normal rainfall distribution in the province is marginal for double-cropping of rainfed rice; however, surface and subsurface moisture enrichment result in standing water being present longer in low-lying fields. Thus a range of cropping patterns can be practiced in the area. The principal cropping pattern choices resolve into double-cropping rice, a single rice crop (allowing it to ratoon if the soil is too wet for dryland crops), and a single rice followed or preceded by a dryland crop. For side slopes with good internal and surface drainage, a single rice crop may be grown in most years, either preceded by a dryland crop, usually maize, or followed by a dryland crop. Bottomlands and waterways, where standing water is present about 6 weeks longer, may be double-cropped to rice almost every year. Indeed, the high risk of inundation by late-season rainfall excludes dryland crops from these areas. The remaining rice-growing areas -- plateaus and plains -- represent about three-quarters of the rainfed rice area (Price 1980); it is here that cropping pattern decision rules are most complex. We identify these rules by the combined use of results from 4 years of cropping systems research and 2 simulation models.

METHODS

To evaluate cropping patterns for the plateaus and plains, we developed a model to simulate the response of both the wet-seeded (WSR) and transplanted rice (TPR) crops to planting date at both landscape positions. The model was constructed from 3 years of crop and water balance monitoring in field trials conducted for this purpose on 2 representative sites (Bolton and Zandstra 1980). The sole input to the model is the daily rainfall record. The model was validated against the yields of experimental cropping patterns for four seasons and farmers' yields for six seasons in a pilot project area. With these limited data, the 95% confidence interval for any given yield estimate on the regression line given in Figure 2 is less than the $\pm$ 0.7 t/ha interval for the actual yields.

The model assumes

- good farm-level management, including adequate levels of nutrition and insect pest protection for the rice crop;
- a 112-day rice crop of fixed duration, and other characteristics similar to IR36; and
- seedlings that are 20 to 25 days old at transplanting.

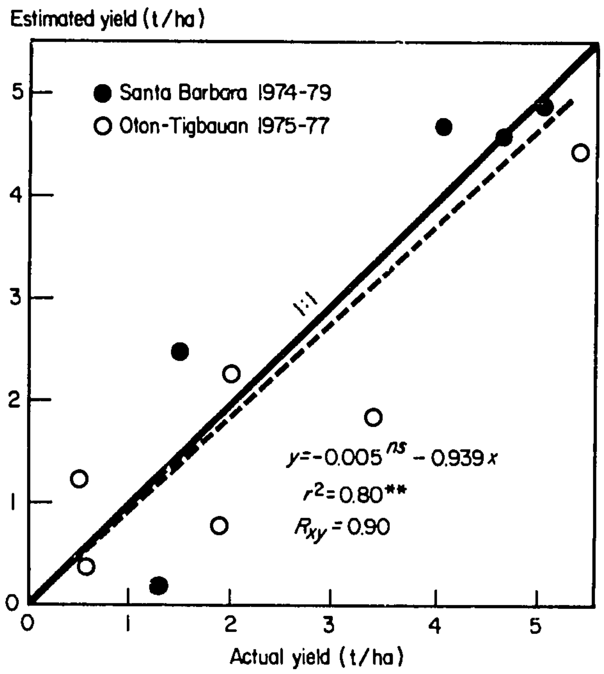

Fig. 2. Yields estimated by the PADIWATER model compared to actual yields from Santa Barbara, Oton, and Tigbauan in Iloilo, Philippines.

The model does not consider calamities and assumes no climatic changes are taking place. The influence of drought on length of the vegetative stage is ignored, but is known to add up to 3 weeks to that growth stage (Puckridge and O'Toole 1980).

The sequence of decision rules determining the cropping patterns for a given site and year is compiled as follows. Average establishment and harvest dates of the first rice crop are predicted. Then, allowing time for land preparation, average dates and yields of second crop planting are predicted. The opportunity for a third crop -- a dryland crop -- is then determined.

Cropping patterns evolve along different lines because the current year's rainfall events determine the first crop planting date; therefore flexibility is built into the patterns. Decision rules that permit a choice of crops -- ratoon rice, dryland crop (e. g. mungbean) or second rice crop -- after harvest of the first rice crop are developed. The rules identify the expected date of the second rice crop planting and compare its expected economic returns with those from the two alternatives.

First rice crop planting dates were determined from the water balance simulation (Zandstra et al 1980). For dry-seeded rice (DSR) it was assumed that the land was thoroughly prepared before the onset of the wet season and that the crop would be sown as soon as 90 mm of soil moisture had accumulated in the top 30 cm with an additional 10 mm required for germination (Zandstra et al 1979). It was further assumed that crop emergence required 5 days and 100 days from thence to harvest.

By way of check, in 1978 about half of Santa Barbara farmers dry-seeded in the second half of May; however, some seeded as early as late April and as late as the end of June (Nicolas et al 1980). Based on our assumptions the predicted date for 1978 was 16 May.

For the wet-seeded first crop (pregerminated seed broadcast on puddled soil), it was assumed that wetland preparation before planting required 14 days with at least 30 mm standing water. A constant maturity period of 105 days and 15 days of turnaround period between rice crops were combined with the planting dates to give the predicted second crop planting dates for the present system of double-cropping rice. The predicted second crop planting date for 1978 was 17 September; with a maturity period of 105 days, harvest would be 31 December. About half the Santa Barbara farmers harvested their second crop between the last week of December and the first week of January (Nicolas et al 1980).

The assumption of a fixed crop duration creates an error of about 2 weeks for the predicted second crop planting dates in years that the dry-seeded first crop experiences drought in the vegetative phase. This difference may also occur between sites; for instance, the average maturity of dry-seeded IR36 is 115 days in Oton and Tigbauan but about 100 days in Santa Barbara (Nicolas et al 1980). The reason is rice is dry-seeded only on the more drought-prone higher fields of Oton and Tigbauan, and that results in some delay in flowering.

The prediction of opportunities for dryland crops after rice assumed that the crop would be either mungbean or cowpea, with minimum tillage or no cultivation at all. This type of dryland crop culture requires that soil be close to saturation at sowing time. Thus, simulation considered occasions on which the second rice crop harvesting date coincided with a predicted water balance at or above saturation. Simulation also assumed ease of draining standing water.

The preharvest costs used to determine economic returns of the second rice crop were obtained from the experimental cropping pattern trials of the Oton-Tigbauan outreach site (Genesila et al 1979). The management of those trials was virtually the same as for the planting-date trials that formed the basis of the yield model. The 1978 preharvest costs were recorded as ₱1,276 for WSR and ₱1,285 for TPR.[1/] The cost of harvesting was computed as one-sixth the value of production, the harvesters' share. The cost of fertilizer (₱338 and ₱375) was included only for predicted yields above 3.8 t/ha on the plain and 2.6 t/ha on the plateau. For lower predicted yields the cost of fertilizer was not included because such yields were similar to those obtained in field trials without nitrogen fertilizer and without drought stress (Bolton 1980).

[1/]US$1 = ₱ 7.5 as of July 1980.

The criterion used to determine the cutoff dates for the second rice crop was the last date on which net returns to the predicted second rice crop exceed the average net returns for the two major alternative land use patterns, namely ratoon rice and a mungbean crop. The average grain yield of ratoon rice over 4 years at the site was 0.87 t/ha, which was worth ₱957 at the 1978 price for rough rice. Deducting one-third of total returns as cost of harvesting gives average net returns of ₱638 for ratoon rice. The average net returns for a mungbean crop after rice was ₱1,003/ha for a 4-year average yield of 0.36 t/ha.

Two further conditions for determining the cutoff dates were:

- that the predicted crop failure rate should not exceed 1 year in 5; and
- that there should be a predicted opportunity for planting a second rice crop at least 4 years in 5.

It was assumed that outside those limits a second crop would be unacceptable to farmers. Most dates were predicted to be beyond the cutoff dates obtained by the economic returns above. The yield advantage of planting the second crop earlier was estimated from the predicted yields for each site, method of establishment, landscape position, and year. The difference between the yields at the estimated second crop planting date and the estimated yield 2 weeks earlier was expressed as a yield advantage due to time saved (kg/ha per day).

RESULTS AND DISCUSSION

The predicted second crop planting dates following a DSR and a WSR first crop are given in Table 1, with the corresponding predicted yields. The site differences in rainfall pattern during the wet-to-dry-season transition are reflected in the predicted yield responses to planting date in Figure 3 for four representative sites. The late season is wetter in the east of the province and thus the same yields were predicted to occur for planting dates about 6 weeks earlier in Miag-ao than in Barotac Viejo. The coefficients of variation indicate that yields for central Iloilo are considerably more stable than those for the coastal plain fringe areas that include Cabatuan and Miag-ao.

As a check on the estimated data, the reported second crop yields of farmers in Oton and Tigbauan over a 4-year period was 2.1 t/ha, compared to the predicted yield of 1.9 t/ha in Table 1 (Price 1980). The dominant double-cropping rice pattern in those municipalities is WSR followed by WSR. The farmers' second crop yields averaged over 6 years in Santa Barbara was 3.5 t/ha; the predicted yield (over 8 years) is 4.4 t/ha. The figure 3.5 t/ha includes 2 extremely dry years ($\underline{P} < 0.1$, Fig. 1), and the average of 4 years is $\overline{4}.6$ t/ha. The dominant cropping pattern in Santa Barbara is DSR followed by WSR.

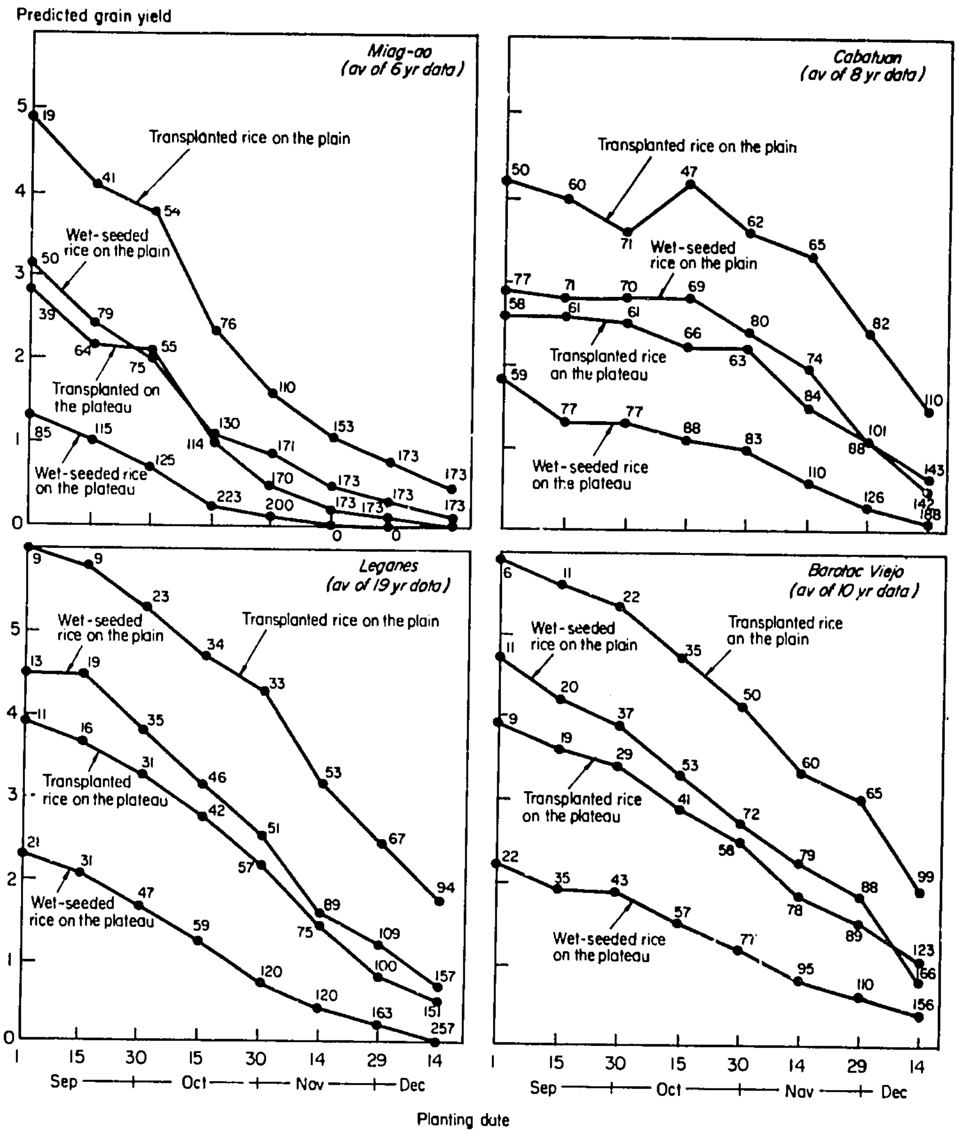

Fig. 3. The response to planting date at 4 sites in Iloilo, Philippines, as predicted by the PADIWATER model. Figures on the lines are the coefficients of variation for the predicted yield at a given date.

On the average, a second rice crop following a DSR first crop is predicted to have a 2 t/ha yield advantage over a second crop following a WSR first crop (Table 1) because a DSR crop can be established about 1 month earlier. This predicted yield difference may be overestimated because of the effect of drought on the first rice crop duration as mentioned earlier. DSR costs more to establish -- cost of herbicide and extra hand weeding average ₱338/ha more than that for WSR (Genesila et al 1979). However, that will be more than compensated for by the increase in yield of the second rice crop. A further advantage to dry-seeding the first crop is that the opportunity for double-cropping is greater. For Tigbauan it was predicted that a second rice crop after a WSR first crop would not be possible in 4 years out of 20. A second rice would not be possible in only 2 years out of 20 if the first crop were DSR. Therefore, where soil, weed, and hydrological conditions permit, the first crop should be DSR.

The predicted yield increases from transplanting instead of wet-seeding the second rice crop are given in Table 2. The increase is due to late season drought avoidance. Yields may be increased further by using seedlings 30 to 40 days old -- research in Oton and Tigbauan indicates both negligible yield loss from seedlings of that age and harvest dates earlier by a week (IRRI 1979). The predicted average yield increase across sites is 1.3 t/ha. In 1978, which was a typical year, a Tigbauan trial comparing TPR and WSR planted at the same time gave a yield difference of 1.1 t/ha (Bolton 1980). At the 1978 price for rice, the predicted increase was valued at ₱1,430, exceeding the cost of transplanting by a factor of 4.2 (Genesila et al 1979). A labor shortage occurs during the turnaround period in Iloilo, therefore, where rice is double-cropped wet seeding was the preferred method of establishment. At the indicated returns to cash, it may be economic to raise the wage rate for transplanting, or encourage the release of labor from threshing and land preparation by mechanizing those processes, or even partially mechanizing the transplanting itself (IRRI 1979).

The predicted frequencies of crop failure (Table 3) indicate that risk is considerably higher for WSR on the plateaus. The risk of failure is least in the center of the province (Leganes and Pototan).

The opportunity for a dryland crop after two rice crops is apparently not frequent, but dry-seeding the first crop and transplanting the second rice crop considerably increase the chance of being able to plant a (third) dryland crop (Table 4). Santa Barbara is a particularly favorable site.

The above predictions are appropriate for most years; however, actual patterns grown on a rainfed field will change in less typical years. Therefore it is necessary to establish cutoff dates for the second rice crop -- before those dates a second crop should be grown, but after them either a ratoon crop or a dryland crop should be grown. Table 5 gives the estimated cutoff dates for sites in Iloilo province. As a check on this date, the majority of Tigbauan farmers do not plant beyond the first week of November, which is roughly consistent with the predicted Tigbauan cutoff dates for WSR on the plain (Roxas et al 1978).

In using the proposed cutoff dates at any site, the differences between the idealized water balance in the model and the actual water balance in the late season for the site must be taken into account. The main factors that would affect the simulated water balance are major changes in evaporation, seepage and percolation rate, field-to-field overflow, soil texture, and the rates of groundwater recession and recharge; each is influenced by landform (Zandstra et al 1980). The cut-

Table 2. The predicted yield advantage of transplanting over wet-seeding the second rice crop in 9 municipalities of Iloilo, Philippines.

Municipality	Yield advantage[a] (t/ha)
Miag-ao	0.9
Tigbauan	1.7
Iloilo	1.3
Leganes	1.3
Santa Barbara	1.4
Cabatuan	1.1
Pototan	1.3
Dingle	1.3
Barotac Viejo	1.4

[a]Using the av of yield predictions for the plateau and plain, comparing wet seeded-transplanted with wet seeded-wet seeded rice pattern and including a 15-day turnaround period.

Table 1. Average predicted second crop planting dates after a dry-seeded and wet-seeded first rice crop, in 9 municipalities of Iloilo province, Philippines.

Municipality	Extent of rainfall record (yr)	Predicted second rice crop planting dates[a]	
		Dry-seeded rice first crop	Wet-seeded rice first crop
Miag-ao	6	20 Sep (2.1)	22 Oct (0.6)
Tigbauan	20	26 Sep (3.7)	26 Oct (1.9)
Iloilo	30	10 Oct (3.7)	12 Nov (1.4)
Leganes	19	30 Sep (3.8)	10 Nov (1.9)
Santa Barbara	8	23 Sep (4.4)	5 Nov (2.5)
Cabatuan	8	27 Sep (2.8)	20 Nov (1.5)
Pototan	11	26 Sep (4.3)	12 Nov (1.7)
Dingle	10	20 Nov (3.1)	27 Dec (1.0)
Barotac Viejo	10	18 Oct (3.6)	25 Dec (1.2)

[a]Assumes 105-day first crop, and 15 days turnaround time between crops. The figures in parentheses refer to the mean predicted yields (t/ha) corresponding to the predicted date of planting for a wet-seeded second rice crop on the plain.

off dates presented by site follow the same trends as for probabilities of crop failure. The central rice-growing areas of the province -- Leganes and Pototan -- have later cutoff dates.

After the cutoff dates, the choice between ratoon rice and a mungbean crop depends on landscape position and date. The average latest dates of standing water were predicted using the water balance model of Zandstra et al 1980b (Table 6). Because of difficulty in draining water from paddy fields on the plain, those dates should be considered as the earliest for planting a mungbean crop. Plateau fields can be more readily drained and a mungbean crop may be planted up to a month earlier. If the first crop has been harvested before those dates, but after the second rice crop cutoff dates, then a ratoon should be allowed to grow until the earliest date for mungbean planting, at which time a decision is made to wait till

Table 3. Predicted second crop failure[a] rate, by site, in Iloilo, Philippines.[b]

Site	Extent of rainfall records (yr)	Plateau				Plain			
		Transplanted II		Wet-seeded II		Transplanted II		Wet-seeded II	
		DSR I	WSR I	DSR I	WSR I	DSR I	WSR I	DSR I	WSR I
Miag-ao	6	1	3 (1)	2	5 (2)	1	1 (1)	1	3 (1)
Tigbauan	20	0 (1)	4 (1)	2 (1)	13 (1)	0 (1)	0 (1)	0 (1)	2 (1)
Iloilo	30	2	8	5	18 (2)	0 (2)	3 (4)	3 (2)	9 (3)
Leganes	19	0	4 (1)	2	7 (1)	0	2 (1)	1	4 (1)
Santa Barbara	8	0	1	0	4	0	1	0	2
Cabatuan	8	1	2 (2)	1	4 (2)	1	1 (2)	1 (1)	2 (2)
Pototan	11	0	1	0	3	0	0	0	2
Dingle	10	1 (1)	>5 (1)[c]	5 (1)	>6 (1)[c]	1 (1)	>1 (2)[c]	1 (1)	>3 (2)[c]
Barotac Viejo	10	0	>5[c]	2 (1)	>7[c]	1 (1)	>6 (1)[c]	1 (1)	>6 (1)[c]

[a]Predicted yield less than 0.25 t/ha. Figures in parentheses indicate number of years in which the second crop could not be planted after first crop harvest. [b]I = first crop, II = second crop, DSR = dry-seeded rice, WSR = wet-seeded rice. [c]Predictions only available up to 14 December. Beyond that date rice is not planted on rainfed land.

Table 4. Predictions of opportunities[a] for dryland crops after a second rice crop for 9 sites in Iloilo, Philippines.[b]

Site	Extent of rainfall records (yr)	Plateau[c]				Plain[c]			
		Transplanted II		Wet-seeded II		Transplanted II		Wet-seeded II	
		DSR I	WSR I	DSR I	WSR I	DSR I	WSR I	DSR I	WSR I
Miag-ao	6	0	0	0	0	1	0	0	0
Tigbauan	20	3	0	2	0	5	3	4	0
Iloilo	30	4	0	0	0	6	0	1	0
Leganes	19	3	0	1	0	7	0	2	0
Santa Barbara	8	4	0	2	0	6	1	2	1
Cabatuan	8	4	0	0	0	3	0	0	0
Pototan	11	2	1	0	0	7	1	1	1
Dingle	10	0	0	0	0	0	0	0	0
Barotac Viejo	10	2	0	0	0	3	0	3	0

[a]Predicted water balance in second crop at least equal to saturation. [b]DSR = dry-seeded rice, WSR = wet-seeded rice. I = first crop, II = second crop. [c]The zero indicates no opportunities predicted.

Table 5. Estimated cutoff dates for the planting of a rainfed second rice crop in 9 municipalities of Iloilo, Philippines.

Municipality	Cutoff dates for planting second rainfed rice crop[a]							
	Plain				Plateau			
	Transplanted		Wet seeded		Transplanted		Wet seeded	
	Month	Week	Month	Week	Month	Week	Month	Week
Miag-ao	Oct	4	Sep	4	Oct	1	-[b]	-
Tigbauan	Nov	2	Oct	4	Oct	4	Sep	3
Iloilo	Nov	2	Oct	4	Oct	4	Oct	2
Leganes	Dec	1	Nov	2	Nov	2	Sep	4
Santa Barbara	Nov	2	Oct	4	Nov	2	Oct	2
Cabatuan	Nov	3	Oct	4	Oct	4	-[b]	-
Pototan	Nov	4	Nov	2	Nov	2	Oct	2
Dingle	Dec	2	Nov	4	Nov	4	Oct	3
Barotac Viejo	Oct	3	Oct	3	Oct	4	Sep	4

[a]Determined as the date on which net returns to the second rice crop last exceeded the average net returns to ratoon rice or a mungbean crop; this also will be a planting date for which crop failure (yields 0.25 t/ha) is predicted less than 1 year in 5. [b]Predicted failures exceeded 1 year in 5 for 1 September planting.

harvest of the ratoon if it has a full canopy, or plant mungbean into the stubble when the soil is at or near saturation.

In determining appropriate cropping patterns, the opportunity to further intensify the cropping patterns by minimizing land preparation time during the growing season should not be ignored. This includes about 2 weeks of cultivation before both the first crop and the second rice crop. The yield advantage of planting the second crop earlier than at present varies according to landscape position and to the method of planting used for establishing the first crop. After a WSR first crop on the plain the predicted yield increase, averaged across sites and years, was 58 kg/ha for each day that a second crop was planted earlier. The range across sites was 36-83 kg/ha per day. For the plateau the average predicted yield increase was only 25 kg/ha per day (range of 23-36 kg/ha per day) for a WSR second crop, but 38 kg/ha per day (range of 32-64 kg/ha per day) for a TPR transplanted second crop. After a DSR first crop, the corresponding figures were 34 kg/ha per day (range of 4-50 kg/ha per day) for the plain, but only 18 kg/ha per day (11-46 kg/ha per day) for the plateau. The advantage for earlier second crop planting following DSR is smaller because the predicted yield response to planting date begins to be asymptotic for plantings in September (Fig. 3). In years with an extremely sharp cessation of rains, the simulated yield loss due to delayed planting can be as high as 250 kg/ha per day. This compares to the highest observed yield loss of 230 kg/ha per day (Bolton 1980).

Table 6. Average latest date when there is standing water in a field on the plain, predicted for 9 municipalities in Iloilo, Philippines, according to the PADIWATER model (Zandstra 1980).

Municipality	Latest date when there is standing water in field
Miag-ao	21 Nov
Tigbauan	28 Nov
Iloilo	10 Dec
Leganes	10 Dec
Santa Barbara	15 Dec
Cabatuan	24 Nov
Pototan	20 Dec
Dingle	30 Dec
Barotac Viejo	27 Dec

One time-saving technique is minimum tillage during the turnaround period. In sites with no preplant herbicides the technique has not significantly reduced yield (Bolton 1980). Current turnaround time in Iloilo is about 15 days (Juarez 1979); therefore the second rice crop could be planted about 7 to 11 days earlier by using minimum tillage. Further means of saving time are mechanized tillage for the first crop land preparation and machine threshing. A time-budget analysis by McMennamy and Zandstra (1978) estimated that combined use of power tillers and machine threshers could save 5 days of land preparation for the first crop and a week of turnaround between crops; thus, the second crop could be harvested about 12 days earlier.

In summary, the most stable area for double-cropping rainfed rice seems to be the main coastal plain of Iloilo province. This area was represented in the study by the municipalities of Iloilo, Leganes, Santa Barbara, and Pototan. It was predicted that in the western part of the province, represented by Cabatuan and Tigbauan, second crop production will be less stable because of erratic late season rains. Double-cropping may be ruled out as the dominant cropping pattern for Cabatuan because of its unacceptably variable estimated yields and the high risk of complete failure of the second crop. For Miag-ao in the far west, opportunities for a second crop would be few. In most years this area is best planted to a single rice crop followed by a ratoon or dryland crop. For the eastern part of the province, represented by Dingle and Barotac Viejo, a WSR first crop may not be ready for harvest early enough to establish a second crop because of the slow onset of the wet season; however, the pattern of a second rice crop following a DSR first crop was predicted to be stable for the area.

CONCLUSIONS

A crop model applied to nine comparable sites in one province of central Philippines successfully delineated which of the sites and which landscapes within sites could be regularly double-cropped to rainfed rice. The model indicated that dry-seeding the first crop and transplanting the second would be the preferred methods of establishment, for they lead to a considerable increase in yield and yield stability of the second rice crop. Time-saving practices, such as mechanized threshing and harvesting, and minimum cultivation, would be further aids to increased production.

The principal advantage of crop modeling was that without lengthy field evaluation, it identified the cropping pattern that is most likely to be adapted to a given site. A further advantage was that it identified critical research areas earlier. In the example, time and method of establishment, land preparation, crop duration, and fertilizer application rate were identified as key factors in determining both yields and economic returns from the double-cropped rice pattern.

The major restriction on using models of this type is that field data from at least one typical site are needed in building the model. Moreover, the researcher needs to have first-hand experience at other sites to be able to intelligently interpret the model results. Differences in land type from site to site may require changes in such parameters as seepage and percolation rate, field-to-field flow, groundwater contribution, and assumptions about crop nutrient status. Differences between yields predicted by the model and actual cropping pattern yields for any site provide valuable information on how fully the model reflects the real system.

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REFERENCES CITED

Alicante, M. M., D. Z. Rosell, A. Barbera, and I. Aristorenas. 1947. Soil survey of Iloilo Province. Soils Rep. 9, Dept. of Agric., Manila, Philippines.

Bolton, F. R. 1980. Double-cropping rainfed rice in Iloilo Province, Central Philippines. Unpublished Ph D thesis, University of Reading, England.

Bolton, F. R., and H. G. Zandstra. 1980. Double-cropping rainfed rice in Iloilo Province. Paper presented at a Saturday seminar, 26 July, International Rice Research Institute, Los Baños, Laguna, Philippines.

FAO-UNESCO (Food and Agriculture Organization of the United Nations-United Nations Educational, Scientific, and Cultural Organization). 1974. FAO-UNESCO soil map of the world 1:500,000, Vol. I, Paris.

Genesila, M. P., R. S. Servano, and E. C. Price. 1979. Socio-economic studies in Iloilo 1976-78. Paper presented at the Annual Cropping Systems Seminar-Workshop, 5-9 March, International Rice Research Institute, Los Baños, Laguna, Philippines.

IRRI (International Rice Research Institute). 1979. Annual report for 1978. Los Baños, Philippines. 478 p.

Juarez, R. 1979. The economic and institutional input of mechanical threshing in Iloilo and Laguna. Paper presented at the workshop on consequences of small rice farm mechanization, 1-4 October 1979, International Rice Research Institute, Los Baños, Laguna, Philippines.

Manalo, E. B. 1956. Distribution of rainfall in the Philippines. Philipp. Geogr. J. 6.

Manalo, E. B. 1976. Agroclimatic survey of Bangladesh. International Rice Research Institute, Los Baños, Philippines.

McMennamy, J. A., and H. G. Zandstra. 1978. Farm machinery for improved rice-based cropping systems. Paper submitted to IXth International Congress of Agricultural Engineering, 8-13 July, East Lansing, Michigan.

Morris, R. A., and H. G. Zandstra. 1978. Land and climate in relation to cropping patterns. Pages 255-274 in International Rice Research Institute. Rainfed lowland Rice: selected papers from the 1978 International Rice Research Conference. Los Baños, Philippines.

Nicholas, J. S., R. T. Dilag, Jr., and L. D. Haws. 1980. An evaluation of the Iloilo Province KABSAKA Program for 1978-79. Report of the Office of Rice Production, Training, and Research, International Rice Research Institute, Los Baños, Laguna, Philippines.

Oldeman, L. R. 1979. Climate of Java. Central Research Institute and Agriculture, Bogor Indonesia.

Oldeman, L. R., and S. Suardi. 1977. Climatic determinants in relation to cropping patterns. Central Research Institute for Agriculture, Jalan, Merdeka 99 Bogor, Indonesia.

Palada, M. C., R. L. Tinsley, and R. R. Harwood. 1976. Cropping systems agronomy program for rainfed lowland rice areas in Iloilo. Paper presented at a Saturday seminar, 24 April, International Rice Research Institute, Los Baños, Laguna, Philippines.

Price, E. C. 1981. Adoptions and impact of new cropping systems in Iloilo and Pangasinan, Philippines. Paper presented at the Cropping Systems Conference, 3-7 March 1980, International Rice Research Institute, Los Baños, Laguna, Philippines.

Puckridge, D. W., and J. C. O'Toole. 1980. Dry matter and grain production of rice using a line source sprinkler in drought studies. Field Crops Res. (in press)

Roxas, M., F. R. Bolton, R. D. Magbanua, and E. C. Price. 1978. Cropping strategies in rainfed lowland areas of Iloilo. Paper presented at the 9th Annual Meeting of the Crop Science Society of the Philippines, 11-13 May, Iloilo City.

Zandstra, H. G., J. F. Angus, and M. M. Tamisin. 1980. Climatic factors in rice-based cropping systems research. Pages 127-139 in World Meteorological Organization and the International Rice Research Institute. Proceedings of a Symposium on the agrometeorology of the rice crop. International Rice Research Institute, Los Baños, Laguna, Philippines.

Zandstra, H. G., D. E. Samarita, and A. N. Pontipedra. 1981. Growing season analyses for rainfed wetland fields. IRRI Res. Pap. Ser. (in press)

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