Crop Diversification: Problems and Prospects in Partially Irrigated Rice-based Farming Systems

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Abstract

A multidisciplinary on-farm research project was implemented in the service area of a deepwell pump system at Barangay Bantug, Guimba, Nueva Ecija in Central Luzon, Philippines. The project aimed to study techniques necessary to grow irrigated upland crops in rotation with wet season rice and to test the viability of these techniques with respect to agronomic, water management and socio-economic constraints. Agro-ecosystems of the research site were analyzed for infrastructural, socio-economical and technological constraints to crop diversification and intensification.

Baseline survey revealed that farmers practice double rice cropping in the lower strata (*lungog*) and single rice in the upper strata (*turod*) landforms. The rice-rice pattern leads to undue pressure on water resources during the dry season. With the present water use efficiency (WUE) of 50%, the irrigation system can adequately irrigate only one-third of the programmed area for dry season (DS) rice.

Research results for three consecutive crop years have shown that, if all farmers switch to upland crops such as corn and mungbean during the DS, it would be possible to cultivate 75 and 100% of the service area at 50 and 80% WUE, respectively. Evaluation and integration of component technology for upland crops improved the cropping sequence, i.e., rice-corn-mungbean and increased farmers income over existing cropping patterns.

introduction

Partially irrigated systems consist primarily of areas irrigated by deep tubewell (DTW) pumps. These areas usually have insufficient water supply for dry season rice (DS) cultivation. Consequently rice is cultivated over less than the full command area of many of these systems during the DS. Many governments saw groundwater development as an attractive alternative to high cost multi-purpose reservoir systems because of its potential to spread the benefits of irrigation to a wider area. As a result, deep and shallow tubewell systems have substantially increased in Asian countries during the past two decades. In most countries, the government subsidized both capital investment and annual operating cost to encourage the use of irrigation pumps.

At present, approximately 200,000 hectares (I 5.2%) of the irrigable areas in the Philippines rely on pumped water (NIA, 1984). The development of pump irrigation reached its peak during the early 1970's when the Central Luzon Groundwater Irrigation Project of the National Irrigation Administration (NIA) was established. This project constructed DTW pumps and necessary conveyance systems in five provinces in Central Luzon, namely, Pangasinan, Tarlac, Nueva Ecija, Pampanga and Bulacan. These DTW pumps were programmed to irrigate two rice crops in one year.

With low energy cost at the time, feasibility studies showed the potential viability of these systems. However, with increased operations and maintenance costs of DTW pumps for rice in the last few years, irrigation service fees rose to 91,400-₱2,000/ha (Moya, 1981). Due to high operations cost of DTW, double rice cropping is uneconomical. Therefore, there is a need to diversify cropping patterns to reduce water use and increase economic returns. Replacing dry season rice with

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upland crops will enable water distribution to wider area hence increasing cropping intensity on fallow land.

The shift in cropping patterns needs to address two issues: (1) the synthesis cropping systems, making them economically viable and acceptable to farmers in order to maximize farm resources and (2) the organizational arrangement necessary to distribute water to more fields on a given schedule. Considering these issues, the International Rice Research Institute (IRRI) Cropping Systems Program, in cooperation with the NIA and the Department of Agriculture (DA), initiated an on-farm research project with the following objectives:

1. to determine constraints to increased cropping on partially irrigated land,
2. to design alternative cropping patterns and develop component technologies related to these cropping sequences, and
3. to evaluate the alternative cropping patterns under existing farm resources and farmer management skills.

Materials and Methods

The Research Sire. The study was conducted in Barangay Bantug, 4 km southeast of Guimba, Nueva Ecija. It is within the service area of a DTW pump (P-27) under the management of an irrigators' association. Table I shows the socio-economic profile of the site.

Table *1.* Socio-economic characteristics of the Guimba Cropping System Site, Bantug, Guimba, Nueva Ecija, Philippines, 1984.

Mean farm size (ha)	1.7
Mean educational attainment of operators (years)	8
Mean age of operators (years)	39
Mean family sire	6
Family labor availability (man-days/month)	38
Multiple cropping index	1.4
Tenure (%):	
Own	41
Rent	39
Share crop	6
Amortizing	8

Guimba's climate is characterized by a 4-month wet period and a 6-month dry period. Transition between dry and wet season generally lasts for two months (May-June), and between wet and dry season also for two months (October-November). Solar radiation, air temperature and wind run characteristics at the site are shown in Figure 1.

Farmers at the research site classify land either as *turod*, slightly elevated fields with light textured and easily drained soil or as ***lungog,*** lower fields with heavy textured soil where water accumulates early during the wet season (WS) and remains longer during the DS. Major difference in surface soil properties of the two landforms are summarized in Table 2. In this site, water losses during DS rice cultivation are high specially on the *turod*. Thus, high seepage and percolation (S&P) losses result in marginal production for rice cultivation during the DS but highly favorable for upland crops.

On-Farm Research Methodology

The methods developed by Zandstra et al., (1981) for on-farm research were used in this study. The study was classified into four classes:

Socio-economic survey. Socio-economic data were obtained by first conducting a survey of all farmers in Barangay Bantug at the start of the project. Activities, input use, and outputs of sample farmer-cooperators were monitored.

Farmer-manoged cropping pattern (CP) trials. All operations and management decisions, from land preparation to harvesting, were performed by farmers in consultation with the site staff. The project provided all farm inputs for the trials except for irrigation fees which the farmer-cooperators paid. The cropping pattern field size was 1000 m^2. Crop cuts were taken from CP fields; farm produce were returned to the farmers after the necessary data were obtained.

Twelve farmer-cooperators were selected from each landform to test designed CPs. CP test fields were grouped together in sets of four to facilitate distribution and measurement of irrigation water. Regular field visits were scheduled to obtain reliable information on field operations.

Superimposed trials. The superimposed trials were designed to evaluate the response of crops to

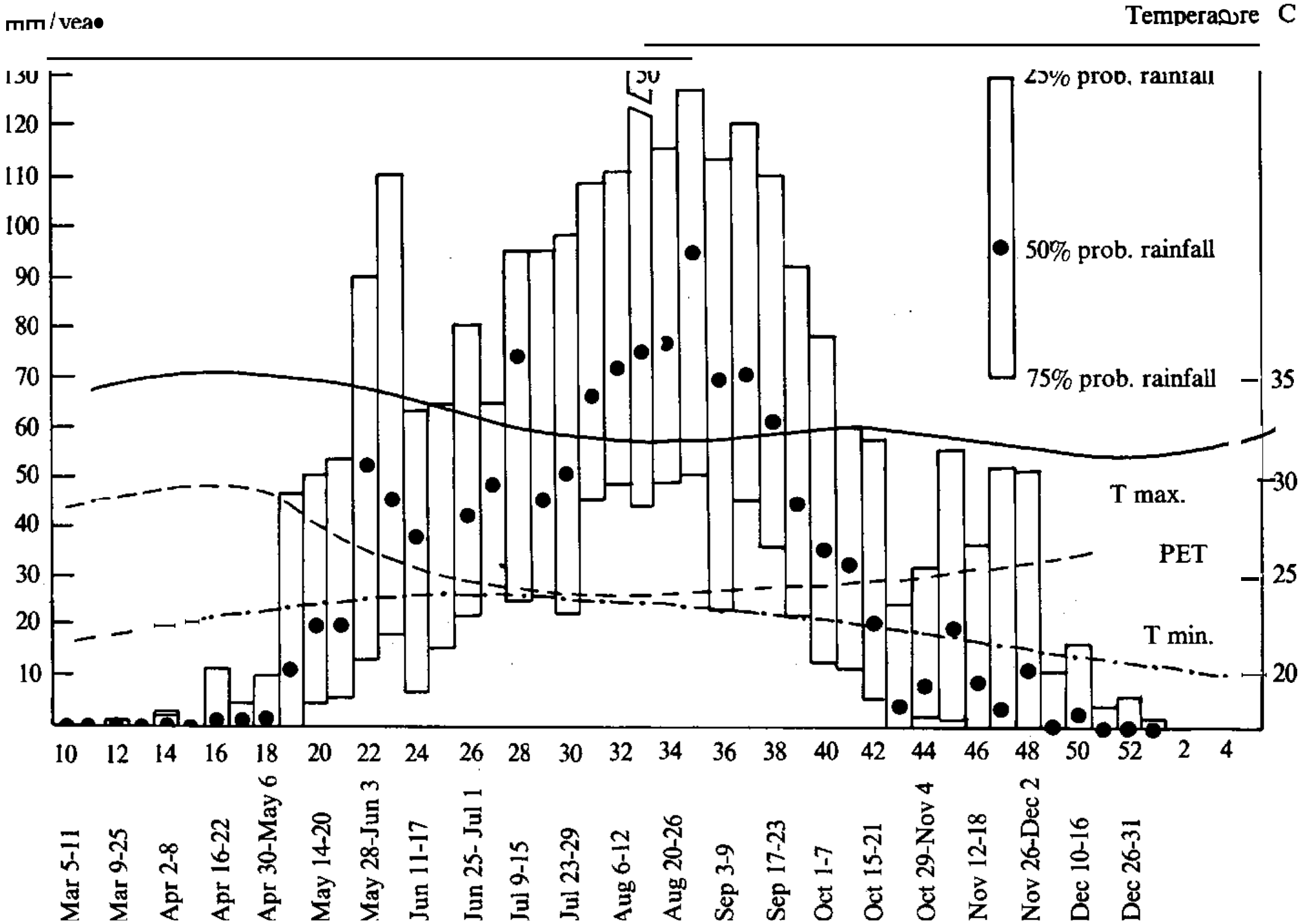

Figure 1. Upper quartile (75%), median (50%) and lower quartile (25%) rainfal probabilities, potential evapotranspiration (PET) and maximum and minimum temperatures (Tmax and Tmin) by weeks, for Cabanatuan, Nueva Ecija, Philippines.

Table 2. Soil characteristics in two landforms, means of four composite samples from three fields in Guimba.

	Landform	
	Turod	Lungog
Textural class[a]	Loam	Clay loam
pH (1:1 water)	6.7	7.1
Organic matter (%)	2.3	5.5
Available P (Olsen, ppm)	11	16
Available K (Cold H_2SO_4 ppm)	57	35

[a]Soil analyzed at NIA Laboratory, Central Luzon Stale University, Nueva Ecija, Philippines.

fertilizer application in a range of field conditions on farmer's cropping pattern fields.

Water data management. Irrigation rates supplied to each experimental farm were measured by using either a cutthroat or a Parshall flume installed at a strategic point before each sub-stratum. Duration of irrigation application was computed from the records of the gatekeeper. Based on the flow rates and duration, the total amount of irrigation water applied was computed. Daily rainfall was monitored using a plastic rain-gauge placed near the pump site. The sum of the amount of rainfall and irrigation water applied represents the available water supply.

A sloping gauge, installed at a representative location on each farm, measured the daily rate of S&P. Evapotranspiration (ET) wasestimated using a class A open pan. The amount of water the irrigation system must deliver on time to avoid water stress was obtained by summing S&P and ET.

Technical Basis for Design of Cropping Pattern

Before alternative CPs were designed, data pertaining to the physical environment and demographic characteristics were collected from secondary sources. For market information, individuals involved in agribusiness were interviewed. Information on farm resources, current production practices and production levels were obtained by interviewing farmers.

Designed Cropping Sequence and Crop Culture

Existing and alternative cropping patterns are shown in Figure 2. Management practices for component crops designed for ***turod*** are presented in Table 3.

Agro-economic Evaluation

Data from CP fields were used to evaluate agronomic and economic performance. The economic analysis combined seasonal wage rates. The marginal henefit-cost ratio was used to test the profitability of designed cropping patterns.

RESULTS AND DISCUSSION

A crop year was divided into three seasons, i.e., WS (June to October), transition season (November to December) and late DS (January to May).

Agronomic Performance

Grain yield data for all component crops in CP trials for three consecutive crop years (1984 to 1987) are presented in Table 4.

Component Crop I - WS rice on turod and lungog. Grain yields in 1985 and 1986 averaged 4.5 and 5.0 t/ha, respectively, higher by 0.5 and 1.0 t/ha than in 1984. In 1985 and 1986, rice varieties IR56, IR58 and IR64, were grown in both landforms. These varieties were not affected by rice tungro virus (RTV). In 1984, RTV reduced grain yields of IR36 and IR42. Attack of stem borer and other insect pests were also lesser in 1985 and 1986 compared to 1984.

Component technology research in WS rice. Studies on fertilizer application in both landforms showed no evidence of phosphorus (P) and potassium (K) deficiency. Application of zinc did not

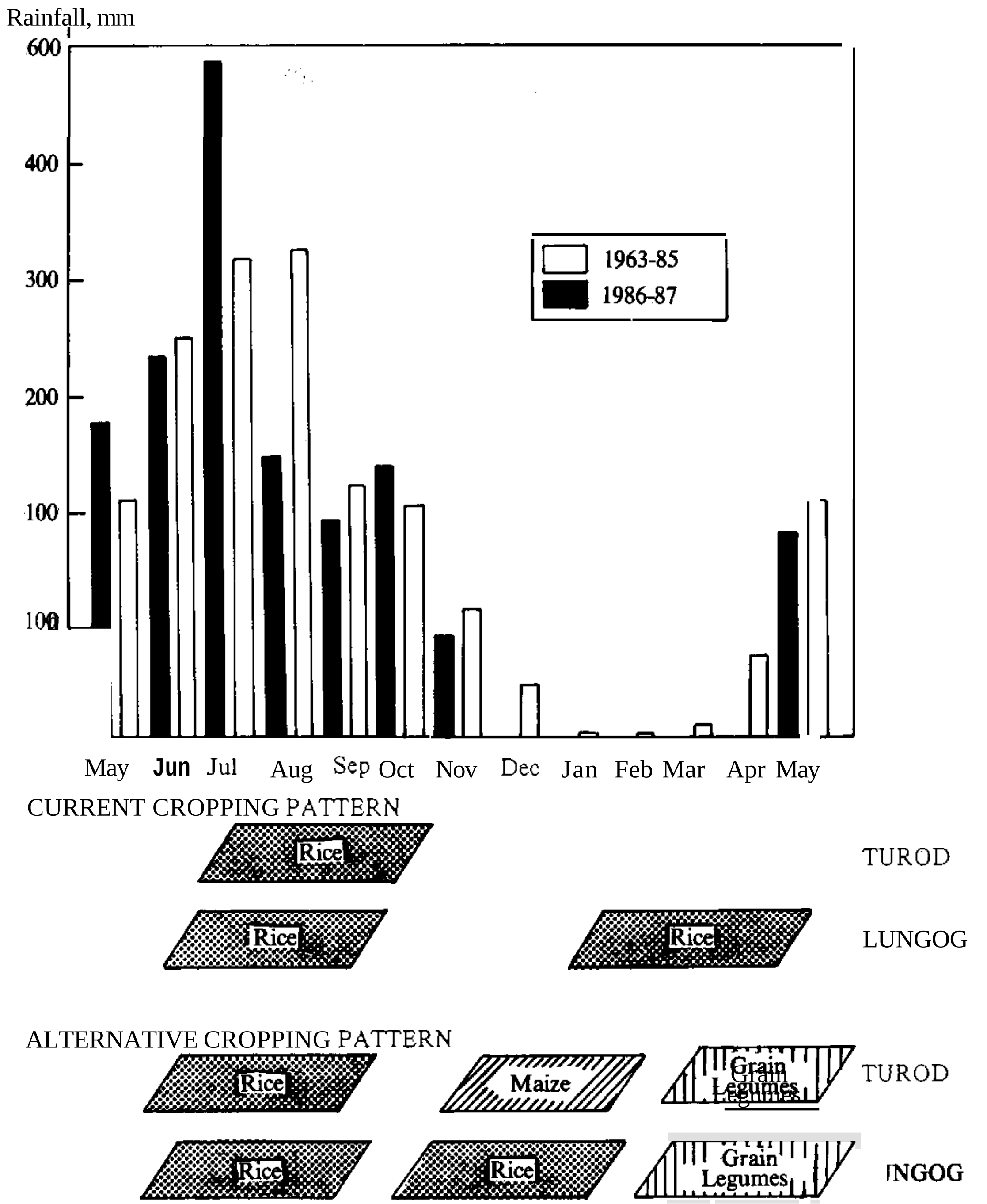

Figure 2. Mean monthly rainfall, current and alternative cropping patterns for partially irrigated land in Nueva Ecija Cropping Systems Research Site. Lungog land is lower lying than Turod and therefore easier to irrigate for rice in the early DS.

Table 3. Cultural nractices for crops included in the cropping pattern being tested **on** the *turod* landform.

Cultural Practices	First Crop Transplanted Rice	Maize	Munghean
Variety	IR42 (115 d FD)	Hybrid SMC-305	Pagasa (**85** d FD)
Establishment period	10-30 June	1-20 Nov	15 Feb - **5** Mar
Hill/row spacing	20 X 20 cm	75 cm bet. rows	46 cm bet. rows
Seedling/hill or plant density	2-3 plants/hill	50-60, '000 pph	225-250, '000 pph
Fertilizer ($N-P_2O_5-K_2O$) (kg/ha)	70-30-0 + Zn	None	None
Tillage	Plow and puddle	Plow and harrow	Zero tillage (RIP)
Weed control	Thorough land preparation fb butachlor 0.6/8 ai/ha; 3-4 DAT		None
Insect control	Economic threshold	lnterrow cultivation. Detassel and Furadan	4 sprays
Disease control	None	None	None
Irrigation strategy	Monitor rainfall suspend pumping when not needed	**4** times	2 times

Table *4.* Crop yields (kg/ha) in rice-corn-mungbean and rice-rice-mungbean cropping patterns for three crop years under partially irrigated environment, Guimba Cropping System Outreach.

Cropping Pattern	Crop Year 1984/85	1985/86	1986/87
	Turod		
I Rice	3.97"	4.70'	**5.02**[d]
2 Maize	2.59[f]	4.45'	4.489
3 Mungbean[h]	0.91	1.10	1.07
	Lungog		
I Rice	4.03'	4.26'	4.90[d]
2 Rice	1.91[e]		
3 Mungbean			

"Average yield **of IR42, IR54,** IR56
[b]Average yield of IR36, IR54, IR56
'Average yield of IR56, IR58
[d]**Average** yield **of** IR64
'Average yield of IR36
'Corn hybrid used – SMC 305

'Average yield of SMC 305 and IPB varieties
[h]**Mungbean** variety -- Pagasa I
Note: In the *lungog,* establishment of the second rice crop was suspended in crop year 1985/86 in CP fields. Mungbean was not planted due to waterlogging.

consistently show yield advantage. Response to nitrogen (N), however, was significant in both landforms. Partial budgeting was used to determine the most profitable level of fertilizer application in RM **1985 WS** rice experiment in ***lungog.*** Maximum yield was at **64-13-24** kg NPK/ha, but net benefit/ha was highest at the rate of 60-0-0. A comparison of ammonium sulfate and urea N in *lungog* showed that efficiency was not significantly different.

Component crop 2 - ***corn*** *on turod.* Mean yield of corn in **1984** was only **2.59** t/ha, much lower than the potential yield of the corn hybrid used. Crop establishment was a major bottleneck. In many fields, large clods that formed during primary tillage were not reduced in size even after secondary tillage resulting in poor soil-seed contact and low emergence. Other obstacles included drought in fields far from the pump and waterlogging in fields close to ditches or adjacent to flooded rice fields.

In **1985** and 1986, fields were sufficiently dried and was irrigated by flushing before primary tillage was performed. This method resulted in a relatively good soil tilth and improved crop stand. Yields increased by almost **50%** in **1985** and **1986** Nitrogen fertilizer efficiency averaged **28** kg grain/kg N.

To increase corn yield with improved cultural practices in 1986, a field study was conducted to evaluate the effect of frequency of irrigation and N rate on performance of hybrid corn (Table **5).**

Increasing water application from three to five times significantly improved grain yield. The increase in grain yield was brought by improvement in yield components. Application of 120 kg N/ha resulted in higher yield compared to **80** kg N/ha. The interaction of irrigation and N rate was significant. NPK uptake increased with higher irrigation frequency and was positively correlated with increase grain yield (Figure **3).**

Component Crop* 2 - *transition rice *on* ***lungog.*** Low solar radiation, lower night temperatures and strong winds from the northeast deterred the growth of rice during the transition season (TS). Mean yield of rice planted in late October **1984** was **1.91** t/ha. To improve rice yield, a field experiment was conducted with **six** transplanting dates at 3-week intervals from **30** October **1985** to 12 February **1986.** The **30** October planting yielded the lowest while the **22** January planting yielded the highest (Table **6).** Panicle exertion was reduced in the early planting dates (30 October to 11 December), with a mean panicle exertion of **74%** compared to a mean of **97%** in later planting dates.

Cool night temperature was associated with lower panicle initiation. The decrease in yield in the 12 February planting was a result of water stress

Table 5. Grain yield and yield components **as** influenced by the different rates of **N** and frequency **of** irrigation.

Number of Irrigation	Grain yields (kg/ha)	100-Grain weight (g)	Available Ear length (cm)	Available Diameter (cm)	Stem length (cm)
			N80-P30-K30 kg/ha		
3	3648	20.6	10.1	4.2	155.6
4	4666	22.1	11.1	4.3	158.2
5	5004	23.5	11.5	4.3	161.3
			N120-P30-K30 kg/ha		
3	5891	24.5	12.6	4.5	159.4
4	5983	23.9	13.2	4.5	153.9
5	6888	25.2	14.0	4.5	159.2
CV	7.8	5.7	5.0	2.3	3.4
LSD (.05)	6.31		0.9	0.15	ns

Although the mean yield in **1986** was **4.48** t/ha, highest yields obtained in one CP field was 7 t/ha.

Component technology research in corn. Fertilizer studies in corn showed positive response to N fertilizer, although response varied across fields. The highest mean yield in **1985** was **3.5** t/ha.

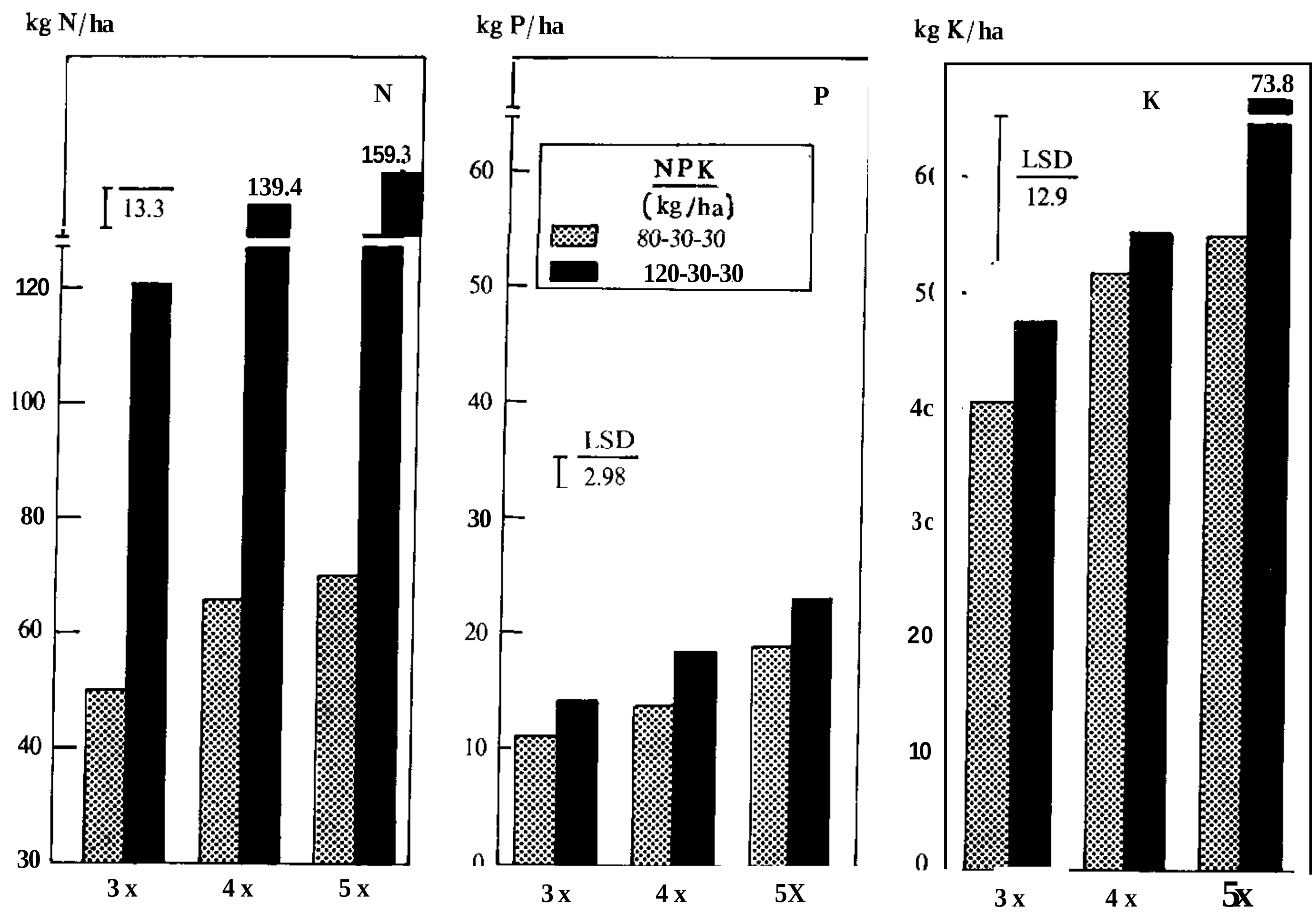

Figure 3. Total N, P, nd K. Uptake of corn as influenced by N rate and irrigation frequency.

Table 6. Yield and yield components of IR58 as affected by dates of transplanting, Guimba, Nueva Ecija, crop year 1985/86.

Date of transplanting	Yield	Plant height	TDMY	Productive tillers	Panicle exertion
30 Oct 1985	2.38 e	52.8 c	3.36 c	16 c	73 c
20 Nov 1985	3.34 cd	51.3 c	5.71 b	17 c	73 c
11 Dec 1985	3.04 d	55.2 bc	4.62 c	22 ab	75 c
I Jan 1986	3.82 h	55.0 bc	6.04 a	24a	91 b
22 Jan 1986	4.31 a	64.0 a	5.49 b	20 b	99 ab
12 Feb 1986	3.50 bc	59.3 b	5.59 b	22 ab	100 a
Diff. bet. treatment means	hs	hs	hs	s	hs
CV (%)	5.97	3.59	11.43	7.93	3.32

Means having a common letter are not significantly different at the 5% level of significance.

due to lack of timely irrigation. The relationships between planting date, weather data and field duration of IR58 at different dates are given in Figure 4. The highest yield was obtained when crop duration fell between January and April. During this period, the crop was exposed to favorable solar radiation and temperature with a low wind speed. A wind barrier study was conducted in 1987 to evaluate the performance of IR64. The study compared the performance of fully and partially protected and totally unprotected crops. A wind barrier made of plastic was constructed at three sides of the fully protected crops perpendicular to the wind flow. Results indicated that fully protected crops obtained significantly higher grain yield, taller plants and more filled grains than either the partially or totally unprotected plants.

Component Crop 3 - Late DS mungbean on both landforms. Mungbean on turod adapted well to the post-corn DS period. Mungbean yields were 0.91 t/ha in 1984 and at least 1.0 t/ha in 1985 and 1986. There were no production constraints encountered in mungbean. Grain quality of late planted mungbean was affected by the early rains in May. Delayed transplanting of rice on lungog left Little time to establish mungbean before the WS rain started. Therefore, mungbean was not planted on lungog.

Management of Water in the Service *Area*

Increase in electrical power costs had jeopardized the economic viability of deep tubewell irrigation systems. High energy cost resulted to the current irrigation service fees of 450 kg of paddy/ ha during the WS and 800 kg/ha during the DS. Because of high irrigation fees, many farmers within the P-27 service area decided not to avail of the pump's services.

Wet season water management. During the 1984 WS, all farmers in the P-27 service area planted rice. Rainfall provided most of the crop water requirements. The pump was used only when rainfall was inadequate (Figure 5). Data from six sample farms, three in *lungog* and three in turod areas, indicate high variability in S&P rates within the service area (Table 7). The average water requirement during the WS was 518 mm for land preparation and 694 mm for crop growth. Average water actually supplied was 446 mm for land preparation, of which 344 mm was rainfall and 102 mm was water supplied from the pump for three weeks in July, when rainfall averaged less than 60 mm/week. The water deficit of 72 mm during WS land preparation can be attributed to farmers' reluctance to use the pump, thereby reducing the energy bill. Many farmers opted to wait for more rain as was the case in many *lungog* fields. This was a major factor in delaying the bulk of transplanting

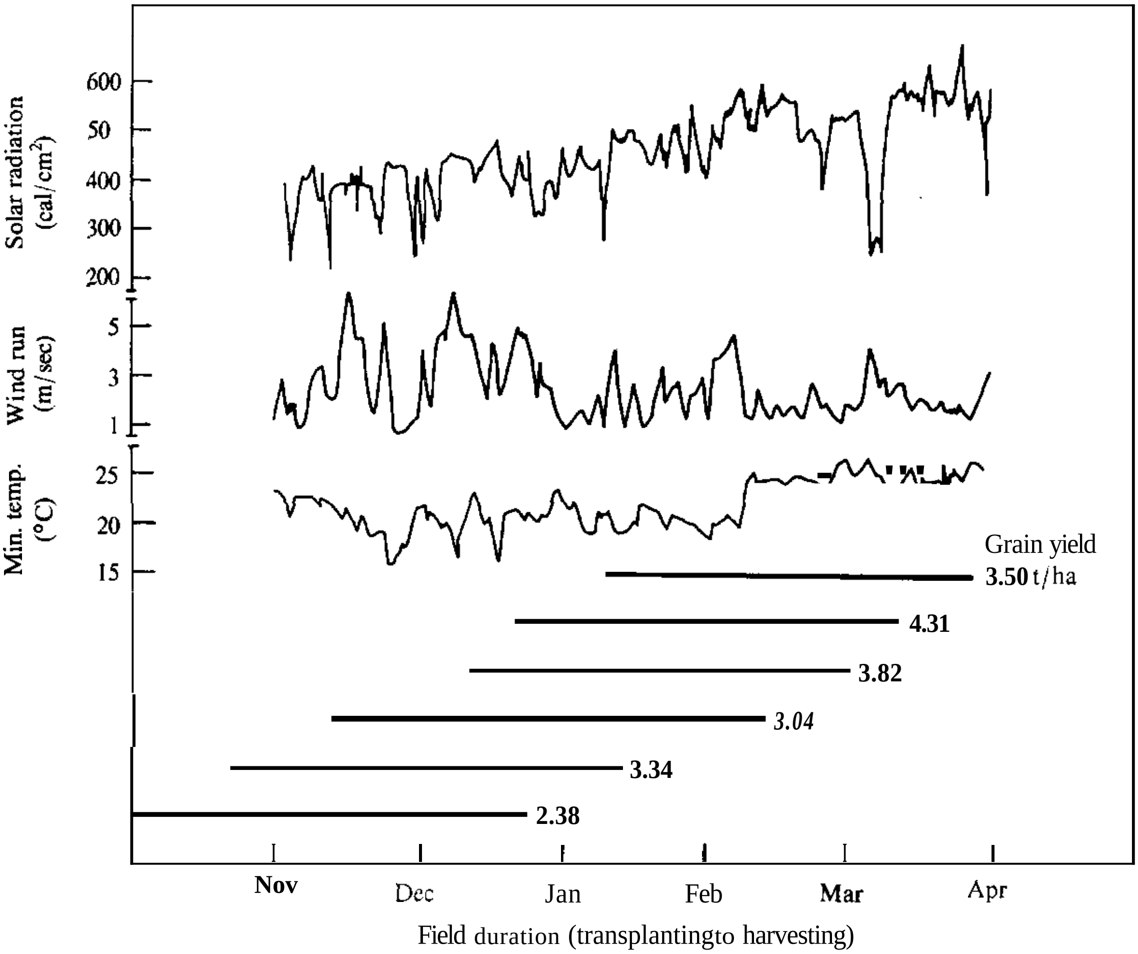

Figure 4. Field durations of IR58 as affected by temperature, wind velocity and solar radiation Guimba Diversified Cropping Systems Project. **CY** 1985-1986.

until August. The reluctance to use pumped water resulted in 110 days between initial plowing and final transplanting, about twice that of comparable systems in Tarlac and Bulacan.

Water use for the WS crop growth period averaged 896 mm, most of which was rainfall. Irrigations were applied only twice during the growth period to supplement rainfall, once in carly August and the other in late September. In both irrigations, however, the amount of water applied exceeded the deficit, leading to lower-than-desired water use efficiencies.

During the WS as a whole, water use efficiency when the pump was operated was low. Since each farmer **is** able to request water on an individual basis, channels must be filled up before water can flow onto his field. When irrigation stops, much water remains in the channel as dead storage losses. In addition to **losses** in the main channel system, measured at 28% **loss** over a **325** meter section of the lined main channel, average farm level water use efficiency was only 45% during the WS. indicating that farmers generally used more than twice as much water as needed to satisfy crop water requirements. The average water productivity, **0.22** kg of rice/m^3 of water during the WS (Table 8), was comparable to gravity systems where irrigation fees are only 100 kg paddy/ha.

Dry season wafer management. Water management activities during the 1985 DS were closely monitored because these are the most critical activities in terms of cost saving. Pump discharge records showed a much greater decline in discharge during the DS than was expected (Figure 6). Pump

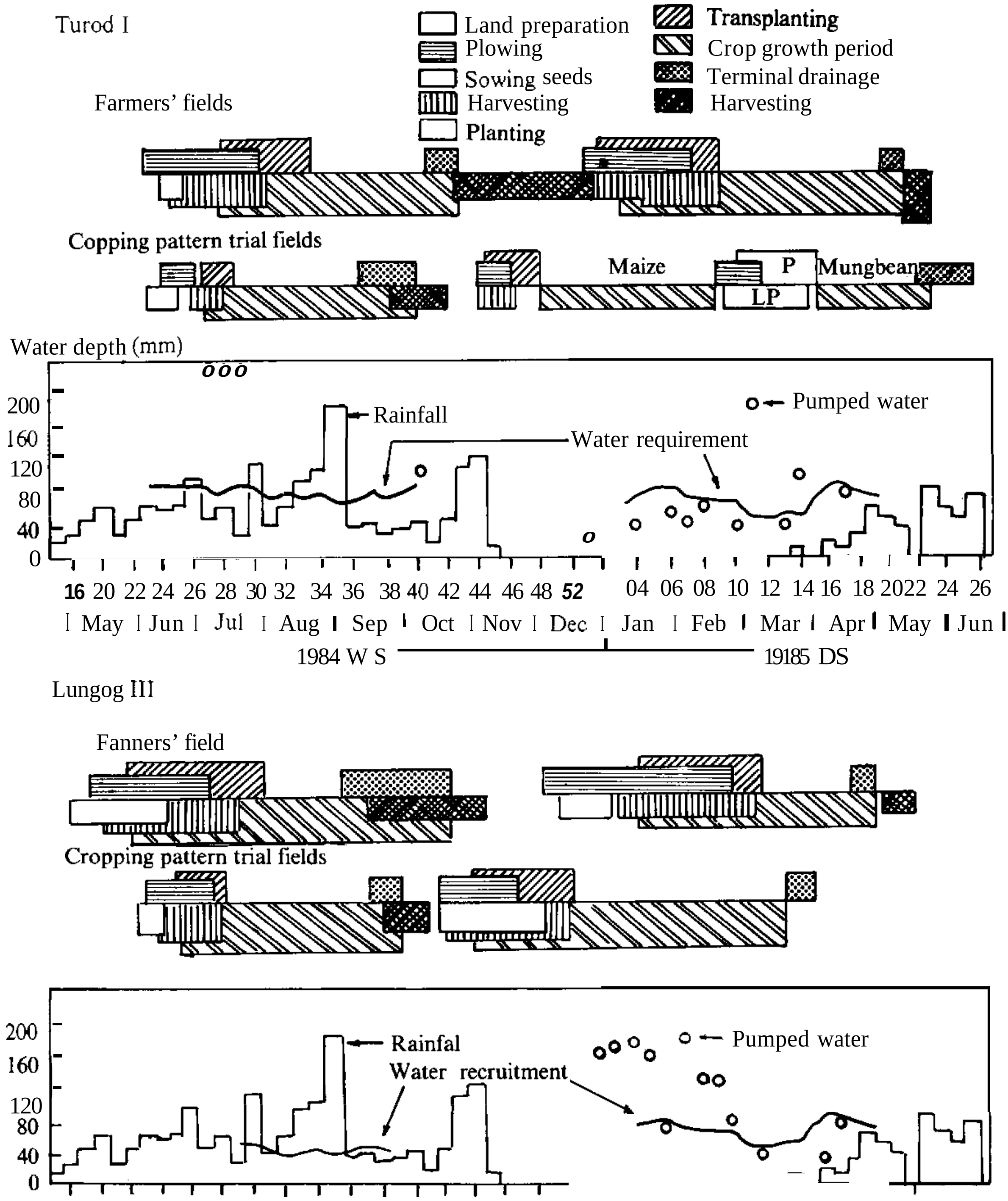

Figure 5. Cropping pattern and crop activity schedules in farmer's and experimental cropping patterns, weekly rainfall, pumped water, and crop water requirements. Guimba, Nueva Ecija, Philippines, 1984 WS and 1985 DS.

Table 7. Water requirements for rice and water supplied to Farmers' fields for land preparation and crop growth, **P-27,** Guimba, Nueva Ecija, **1984** WS and **1985** DS.

Land strata	1984 wet season		1985 dry season	
	Water Requirement (mm)	Water Supplied (mm)	Water Requirement (mm)	Water Supplied (mm)
		Land Preparation		
Lungog	492	331	408	320
Lungog I	324	370	369	316
Lungog II	363	479	352	394
Lungog III	739	143	527	250
Turod	557	561	368	402
Turod I	557	483	356	241
Turod II	31 I	532		
Turod IIi	816	669	380	564
P-27 Service Areo	518	446	397	353
		Crop Growth		
Lungog	628	853	761	1041
Lungog I	659	940	860	1223
Lungog II	733	865	607	500
Lungog III	494	755	817	580
Turod	759	939	1036	583
Turod I	956	879	1171	471
Turod II	737	1078		
Turod III	584	859	901	695
P-27 Service Area	694	896	871	694

"Farmers at Turod II did not plant rice

discharge remained static at 112 liters per second **(Ips)** throughout the WS. However, in mid-December, pump discharge steadily declined to *56* **Ips** until mid-March and remained at this level until the end of the DS. At thisdischarge level, water use efficiency must be high to irrigate sufficient land to make energy costs reasonable since water requirements are considerably higher during the DS.

Average water requirements were 397 mm for land preparation and 871 mm for crop growth (Table **7).** The low value for land preparation was attributed to residual moisture from the WS crop while increased value for crop growth **was** due to higher evapotranspiration during the latter part of the DS.

During the DS, virtually all crop water needs must be met by pumping. During land preparation, average water deliveries were almost adequate to meet requirements: deliveries of 353 mm were made compared to a requirement of 397 mm. However ***lungog*** areas received **116%** of the requirement while ***rurod*** areas received only **70%.**

During rice crop growth period, water supply became increasingly constrained. In the initial stages, relative water supply (RWS) was almost always greater than 1.0 indicating that supplies exceeded demand. ***Lungog*** areas were better off than *turod* areas, with RWS averaging **1.48** compared with 1.15 (Table **9). However, as** the **DS** progressed, evapotranspiration increased and pump discharge declined, resulting in adecrease in RWS in **all** areas. Drought stress was widespread. Lungogareas had RWS values of 0.91 while RWS fell to **0.73** in rurod areas. Breakdown of the pump in April intensified the stress that had developed.

Yields were higher during the DS than during the WS because of higher solar radia 'on.

Because rainfall was negligible, there **was** higher productive value of water during the DS. In *lungog* and *turod* areas, about **0.42**kg **of** rice/m^3 **of**

Table 8. Mean crop-cut yield and water productivity in farmers' fields, **P-27,** Guimba, Nueva Ecija, **1984** WS and **1985 DS.**

Land strata	1984 wet season		1985 dry season	
	Yield (kg/ha)	Water productivity (kg/m³)	Yield (kg/ha)	Water productivity (kg/m³)
Lungog	**3488**	**0.25**	**4150**	**0.40**
Lungog I	**3666**	0.26	**4265**	**0.30**
Lungog **II**	**3063**	**0.21**	**3961**	**0.44**
Lungog III	**3736**	**0.28**	**4225**	0.51
Turod	**2713**	**0.17**	**3809**	**0.39**
Turod **I**	**2874**	**0.21**	**3803**	**0.53**
Turod **II**	**2009**	0.12		
Turod **III**	**3251**	**0.22**	**3815**	**0.30**
P-27 Service Area	**3100**	**0.22**	**4014**	**0.42**

“Farmers at Turod II did not plant rice.

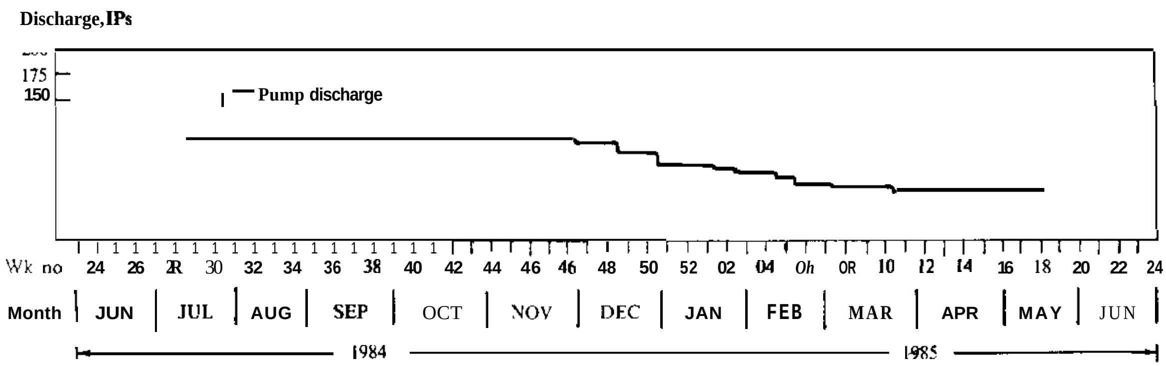

***Figure* 6**.:Pump discharge from P-27, Guimba, Nueva Ecija, 1984 WS and 1985 **DS.**

water was obtained, indicating that the system was more ‘efficient than gravity irrigation systems but still well below what could he achieved. In experiments conducted in one ***turod*** farm planted to corn, the productive value of water was 1.18 kg of corn/m³ of water. However, the price of rice exceeds that of corn by about **2.5** times, meaning that in monetary terms, the productive value of water was almost the same for the two crops.

Despite the scarcity of water during the DS, it was not used efficiently. Farm level water use efficiencies averaged only 48%, indicating that farmers applied twice as much water as required. Main system efficiencies were also similar to WS levels, despite efforts to cement cracks in the lining. Following repairs to the channel, losses decreased from ***28*** to ***25%*** over the ***325*** meter section. Overall efficiency of the system was less than 35%, well below the acceptable level.

Improving water use. If pumping costs of P-*21* are to be reduced, attention must be given to coordination **of** field operation, on-farm water use efficiency and coordination in water deliveries.

1. ***Timing of operations.*** The current cropping calenaar leads to undue pressure on water resources during the DS. Because discharge from the pump is lowest in March, a late start of DS land preparation means that the period of highest crop water requirements coincides with lowest level of water availability This effectively limits the area that can be served. The irrigators' association (PAFIA) aims to irrigate ***35*** hectares during the DS. Using

Table 9. Mean weekly relative water supply[a] P-27, Guimba, Nueva Ecija, 1984 WS and 1985 DS

Land strata	1984 wet season		1985 dry season	
	Vegetative oeriod	Reproductive period	Vegetative period	Reproductive period
Lungog	1.61	1.44	I.48	0.91
Lungog I	1.42	1.50	I.67	1.46
Lungog II	1.37	1.63	1.66	0.74
Lungog III	2.04	1.20	1.10	0.52
Turod	1.46	1.12	1.15	0.73
Turod I	1.18	0.80	0.77	0.66
Turod II	I.42	1.28	b	
Turod III	1.77	1.27	1.53	0.80
P-27 Service Area	1.53	1.28	1.35	0.84

$$RWS = \frac{\text{Irrigation} + \text{Rainfall}}{\text{Water requirement}}$$

[b]Sample farmers at Turod II did not plant rice

measured values of field level water requirements and assuming zero rainfall, it is possible to determine what area can he irrigated at different levels of water use efficiency (WUE) if no crop stress is to occur, These calculations indicate that if the pump is operated for 12 hours/day (actual use during the 1985 DS was 12.8 hours/day) and if WUE is 100%, the latest planting date for a 35 hectare DS area is week 45 (Figure 7). If an 80% WUE is assumed, the latest planting date is at week 41 (early October). If WUE is lower than 65%, it is not possible to irrigate 35 hectares for rice during the DS. For an early DS planting, the WS crop must have been harvested, which in turn presumes that the WS crop is transplanted earlier than is currently the case.

The modal date of planting of farmers during the 1985 DS was week 7 (mid-February). If WUE is 80%, then it is possible to guarantee only 16 hectares of rice, given the declining pump discharge (Table 10). Current WUE of 35% can guarantee only 8 hectares of rice, indicating that crop stress is inevitable with larger areas cultivated. Operating the pump for periods longer than 12 hours/day would enable larger areas to he cultivated but does not reduce per hectare pumping costs. There is also a risk that longer pumping hours make crops more susceptible to widespread drought stress if the pump fails and cannot be repaired quickly.

An analysis of the pumping cost per hectare shows the same basic trend (Table 11). If rice is transplanted by mid-October, then with 12 hours/day of pumping and WUE of 80%, the cost to farmers would be ₱1,764/ha. Delaying planting to February increases the cost to ₱4200/ha provided other factors are kept constant. If planting is in February, then costs increases to ₱6,552/ha at 50% WUE and ₱9,513/ha at 35% WUE. The current DS irrigation fee is ₱2,898/ha, which can only be achieved by planting in October and operating the system at more than 50% WUE.

If farmers plant crops other than rice, then there is a potential for a large increase in the irrigated area and a consequent reduction in operating cost per hectare. If all farmers were to plant either corn or mungbean during the DS, then it is possible to cultivate the entire service area if planting is to be done early and WUE is 80% (Table 10). Pumping costs would range from P378 to ₱483/ha. At 50% WUE, it is possible to grow 52 hectares of corn or 63 hectares of mungbean, with pumping costs of only ₱819/ha and ₱630/ha, respectively. However, due to waterlogging in *lungog* areas, it is likely that rice will remain the preferred crop, at least during the TS and early DS. Thus, it is more advisable to grow upland crops in lighter *turod* soil and rice in *lungog* soil. This would permit 30 hectares for each crop to be cultivated if WUE is 80%, decreasing to 19 hectares each if WUE is 50%. However, it is essential to maintain an early start during the DS. Each day of delayed planting after mid-October requires an increase in WUE of approximately 1% or a reduction in area of 0.25 hectare to avoid crop stress.

2. *On-farm water use efficiency.* During the WS and DS, average water use efficiency at the

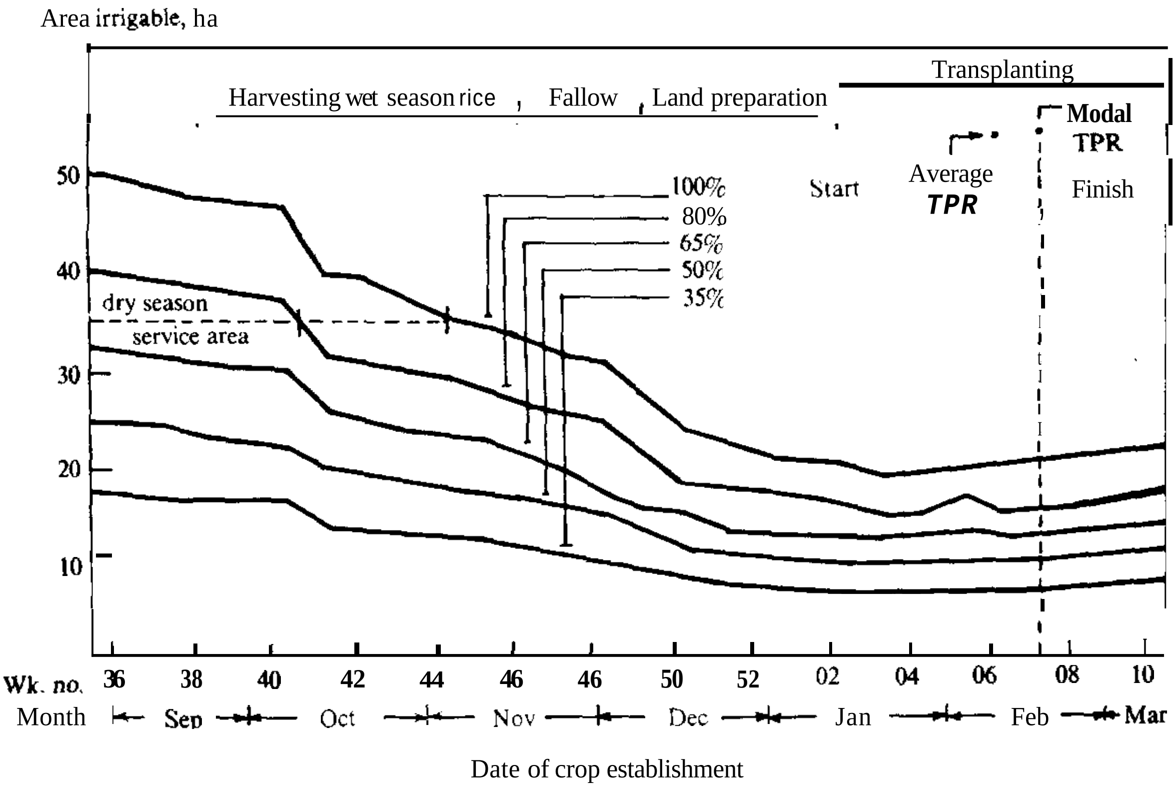

Figure 7. Irrigable areas for differrent crop establishment dates at 5 water use efficiency levels; assuming that P-27 operates 12 hours per day, Guimba, Nueva Ecija.

Table 10. Dry season irrigable areas (ha) under four WUE for three cropping patterns establishedat different periods, assuming that P-27 operates for 12 hours daily, Guimba. Nueva Ecija.

Cropping patterns	Establishment period	Water Use Efficiency			
		80%	65%	50%	35%
Pattern 1: ***Rice-Rice***					
• ***Rice*** (lungog and turod)	1-15 Oct	37.1	30.2	23.2	16.2
	12-25 Feb	15.6	12.8	10.0	6.9
• ***Rice*** (iungog only)	1-15 Oct	40.2	32.6	25.1	17.6
	12-25 Feb	16.7	13.6	10.4	7.3
• ***Rice*** (turod only)	1-15 Oct	34.5	28.0	21.6	15.1
	12-25 Feb	14.7	12.0	9.2	6.4
Pattern 2					
Rice-rice (lungog)					
Upland crops (turod)	1-15 Oct[a]	(41.3)[b]	(33.6)	(25.9)	(18.2)
Pattern 3:					
Rice-Upland crops	1-20 Nov				
• corn		89.4	67.4	51.8	39.1
• Mungbean		100.4	81.6	62.7	43.4

[a]Es nt period nly for ıd crops p e on 1 0 No emt
[b]Ef ic area weighed at farmgate of ₱1.05/kg of corn and ₱3.50/kg of rice.

Table 11. Energy costs (₱/ha) for three cropping Patterns established at different periods, and WUE assuming that P-27 operates **for** 12 hours daily, Guimba, Nueva Ecija.

Cropping patterns	Establishment period	Water Use Efficiency			
		80%	65%	50%	35%
Pattern 1: ***Rice-Rice***					
• Rice (lungog and turod)	***1-15*** Oct	1764	2163	283.5	4053
	12-25 Feb	4200	5124	6552	9513
• Rice (lungog only)	1-15 Oct	1638	2016	2604	3738
	12-25 Feb	3927	4830	6300	8988
• Rice (turod only)	1-15 Oct	1911	2352	3045	4347
	12-25 Feb	4452	5460	7140	10248
Pattern 2: ***Rice-rice (lungog) Upland crops (turod)***	1-15 Oct[a]	1596	1953	2541	3612
Pattern *3:* ***Rice- Upland crops***	**1-20** Nov				
• Corn		483	630	819	1092
• Munghean		378	483	630	924

Note: Energy cost per hectare computed based on farmgate price of **₱12.60/kg** for corn, **₱3.57/kg** for rice and ₱11.55/kg for mungbean and electricity cost of **$1.89/kWhr.**
[a]Establishment period **only** for rice, upland crops planted on 1-20 November.

farm level ranged from 45 to 50%. Having decided to irrigate, farmers used water extravagantly.

3. ***Main system efficiency.*** Lesser improvement in the conveyance efficiency following repair of cracks in portions of the main system indicated that most losses were operational rather than structural in nature. It took a long time to **fill** the main channel before water can **flow** into the fields. Thus, serving isolated farms was found to be inefficient. Moreover, many farmers deliberately made access to the main channel, ***so*** that they benefited whenever farmers further down the channel receives water. At present, it is incumbent on the farmer requesting water to close upstream turnouts, most of which no longer have gates.

The Former-Irrigators' Association

Although many technical factors affect the efficiency of water use, there is still potential to increase **DS** crop production in the P-27 service area. Realization of the potential centers around farmers' ability to use a limiting resource (water in an aquifer) more efficientlv. To increase efficiency, the management of the P-27 system must improve. P-27 is managed by an irrigators' association.

The organization, power structure and functions of the P-27 irrigators' association were examined. Collection of the seasonal irrigation fee is an important function of the association. Costs and farmers' perceptions on the benefit from paying the fee affect farmers' decision to pay.

Assessing Economic Viability of Improved CPs

Economic returns from the experimental CPs were compared with the farmers' CPs and cultivation practices. Enterprise budgeting was used to compare the results of the experimental (E) and farmer (F) CPs (Tables 12 and 13).

In the ***turod,*** the experimental pattern rice-corn-mungbean, consistently generated higher rates of return to labor and power, material inputs and total variable costs than farmers' CPs. The mean marginal benefitsost ratio was **2.90** for the rice-corn-mungbean pattern for three crop years (i.e., for every **₱1.00** increaseinvariablecost above the farmers' rice-fallow pattern, an increase of ₱2.90 was returned). Tables 12 and 13 show the benefit-cost ratio of shifting farmers' dominant CPs for three crop years.

Technical Feasibility

Credit, labor, marketing and irrigation were major constraints to the adoption of the rice-corn-

Table 12. Cost and returns of cropping patterns in the experimental (E) and farmer's (F) fields by year, *turod* land form. Bantug. [illegible]

Cropping pattern[b]	Cost (₱/ha) Labor and [illegible]	Mate-rials	Irri-gation	Total Vari-able	Yield (t/ha) 1	2	3	Gross returns (₱/ha)	Returns: Above variable cost (₱/ha)[c]	To labor and power (₱/₱)[d]	To material cost (₱/₱)[e]	To irrigation cost (₱/₱)[f]	Ratio of gross returns to total variable[g]	Marginal benefit-cost ratio[h] R-F (F)
								1984/85[a]						
R-C-M(E)[i]	6543	8990[j]	4434	19967	3.87	2.45	0.92	32254	12287	2.88	2.37	3.77	1.62	1.87
R-C-P(E)[i]	8137	9017	4434	21588	3.71	2.99	0.74	29951	8363	2.03	1.93	2.87	1.39	1.53
R-R (E)[k]	5036	4583	3628	13247	3.35	2.40	-	17327	4080	1.81	1.89	2.12	1.31	1.54
R-F (F)[k]	2307	2318	1565	6290	2.07	-	-	6448	258	1.11	1.11	1.16	1.04	-
								1985/86[a]						
R-C-M(E)[l,n]	8201	6191	2402	16794	4.89	4.41	1.13	51408	34614	5.22	6.59	15.41	3.06	3.64
R-C-P(E)[l,n]	4119	4826	1491	10436	4.88	0.00	-	15600	5164	2.25	2.07	4.46	1.49	0.73
R-R (F)[k]	6859	5549	2951	15359	3.89	4.08	-	24032	8673	2.26	2.56	3.94	1.56	1.25
R-F (F)[k]	2640	2150	1280	6070	3.74	-	-	12412	6342	3.40	3.95	5.95	2.04	-
								1986/87[a]						
R-C-M(E)[l]	10626	5939	1902	18467	5.25	4.53	1.03	49988	31521	3.97	6.31	17.57	2.71	3.17
R-C-P(F)[k]	8023	2887	1851	12761	4.73	4.80	-	30096	17335	3.16	7.06	10.36	2.36	2.87
R-R (F)[k]	7757	2846	3133	13736	4.24	4.13	-	24455	10719	2.38	4.77	4.42	1.78	1.70
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			12263	5711	2.64	3.97	6.01	1.87	-

[a]Cost of labor, power, materials and irrigation were deflated using the consumer price index (Central Luzon) from 19[illegible]

[b]R = rice, C = corn, M = mungbean, P = peanut, F = fallow

[c]Gross return - Total variable cost

[d][Gross return - (Material + irrigation cost)/(Labor and power cost)]

[e][Gross return - (Labor and power + Irrigation cost)/(Material cost)]

[f][Gross return - (Labor and power + Material cost)/(Irrigation cost)]

[g]Gross return / Total variable cost

[h]Marginal benefit-cost ratio = $\frac{\text{(Gross return of potential) - (Gross return of prevalent pattern)}}{\text{(Total variable cost of potential pattern) - (Total variable cost of prevalent pattern)}}$

[i]With IR42 as first crop

[j]An interest rate of 40% for material cost was included

[k]Average of all varieties

[l]With SMC 305 corn variety as second crop

[m]With IR36 as first crop

[n]With IR64 as first crop

***Table* 13.** Cost and returns of cropping patterns in the experimental (E) and fanner's (F) fields by year, *lungog* landform, **Bantug, Guimba**, Nueva Eciia,

Cropping pattern[b]	Cost (₱/ha) Labor and power	Cost (₱/ha) Materials	Cost (₱/ha) Irrigation	Cost (₱/ha) Total Variable	Yield (t/ha) 1	Yield (t/ha) 2	Yield (t/ha) 3	Gross returns (₱/ha)	Returns: Above variable cost (₱/ha)[c]	Returns: To labor and power (₱/₱)[d]	Returns: To material cost (₱/₱)[e]	Returns: To irrigation cost (₱/₱)[f]	Ratio of gross returns to total variable[g]	Marginal benefit-cost ratio[h] R-F (F)
								1984/85[a]						
R-R (E)[n]	7568	9239	3628	20615	3.74	1.91	-	23073	2458	1.32	1.26	1.68	1.12	1.14
R-C (F)[k]	5190	4955	3628	13773	3.42	2.99	-	17828	4055	1.78	1.82	2.12	1.29	1.52
R-F (F)	2903	2368	1565	6836	2.38	-		7291	455	1.16	1.19	1.29	1.07	
								1985/86						
R-R (E)[n]	3436	1814	1280	6530	4.35	-	-	13922	7392	3.15	5.07	6.71	1.13	2.60
R-C (F)[k]	6963	5008	2995	14966	4.05	4.24	-	24733	9767	2.40	2.95	4.26	1.65	1.39
R-F (F)	2578	1943	1280	5801	3.77	-	-	12028	6227	3.42	4.20	5.86	2.07	
								1986/87						
R-R (E)"	3479	1309	1140	5224	-			14024	8100	3.33	7.18	8.07	2.37	l.M
R-C (F)[k]	7561	3126	2694	13981	4.22	3.97	-	23928	9947	2.31	3.67	4.69	1.71	0.59
R-F (F)	3541	1940	1144	6425	-		-	12200	5575	2.57	3.87	5.87	1.84	

"Cost of labor, power, materials and irrigation were deflated using the consumer price index (Central Luzon) from 1984-1987 as base year.
[b]R = rice, C = corn, M = mungbean, P = peanut, F = fallow
'Gross return − Total variable cost
[d][Gross return - (Material + irrigation cost)/(Labor and power cost)]
'[Gross return - (Labor and power + Irrigation cost)/(Material cost)]
'[Gross return -(Labor and power + Material cost)/(Irrigation cost)]
[g]Gross return / Total variable cost,

$$^{h}\text{Marginal benefit-cost ratio} = \frac{\text{(Gross return of potential)} - \text{(Gross return of prevalent pattern)}}{\text{(Total variable cost of potential pattern)} - \text{(Total variable cost of prevalent pattern)}}$$

'With IR42 as first crop
'An interest rate of 40% for material cost was included
'Average of all varieties
'With SMC 305 corn variety as second crop
'"With IR36 as first crop
"With IR64 as first crop

mungbean pattern on a substantial part of the DTW service area, although both DS upland crops in three crop sequences do not require more than 30 man-days/ha during the 180 days DS (Figure 8). If all turod areas were planted to rice-corn-mungbean, whole farm graphing showed that household labor was not enough to meet labor requirements for land preparation, seeding, transplanting and harvesting. However, hired labor was available to meet labor needs.

Infrastructure Support *Credit*

The local Land Bank Office at Guimba extended loans to farmers who would adopt the rice-corn-mungbean pattern during crop year 1987/88. Substantial portion of the *turod* was planted to corn during the 1987 TS (Figure 9). These areas in previous years were either planted to rice as second crop or fallowed. Yields of corn averaged 4.8 t/ha and 2.5 t/ha for rice. Consequently, irrigation fee payment of farmers who planted corn was almost 100% compared to less than 1% of farmers who planted rice as second crop.

Conclusion

Crop production could be increased significantly in the service area of a DTW by crop diversification, i.e., shifting to upland crops l i e corn and mungbean which require less water during the dry season. To improve water distribution, there is a need for close coordination of field operations, improvements of on-farm WUE and main system efficiency. There is also a need to reassess irrigation policies and how these are implemented. Alternate cropping pattern, rice-corn-mungbean, maximizes the effective utilization of farm resources and provides greater income to farmers than the current cropping patterns (rice-fallow or rice-rice).

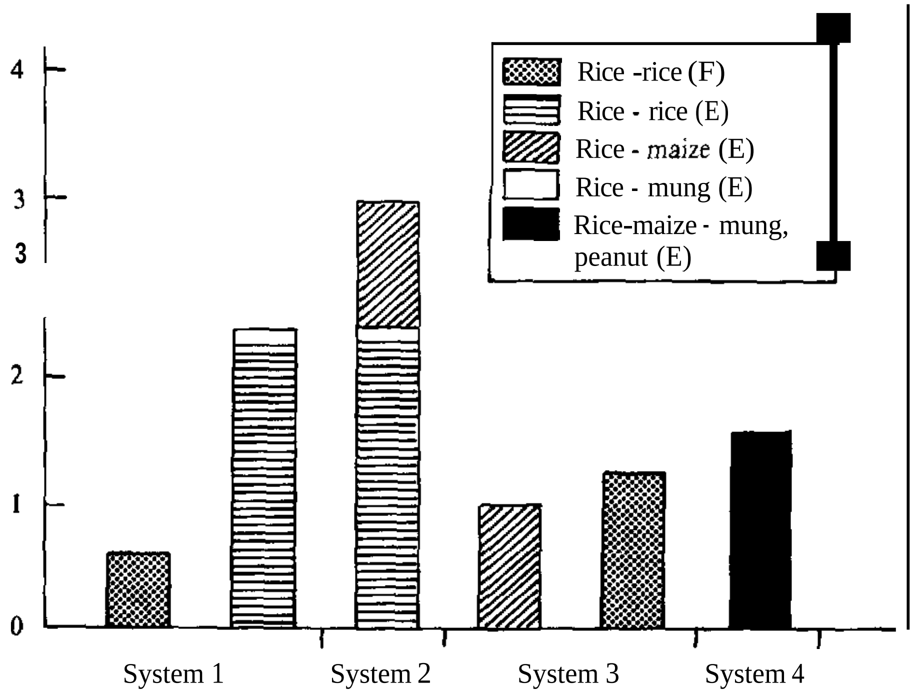

Figure 8. Potential total DS employment from growing alternative cropping systems in the P-27 service area, 50% water use efficiency, Guimba, Nueva Ecija, Philippines, 1984-85.

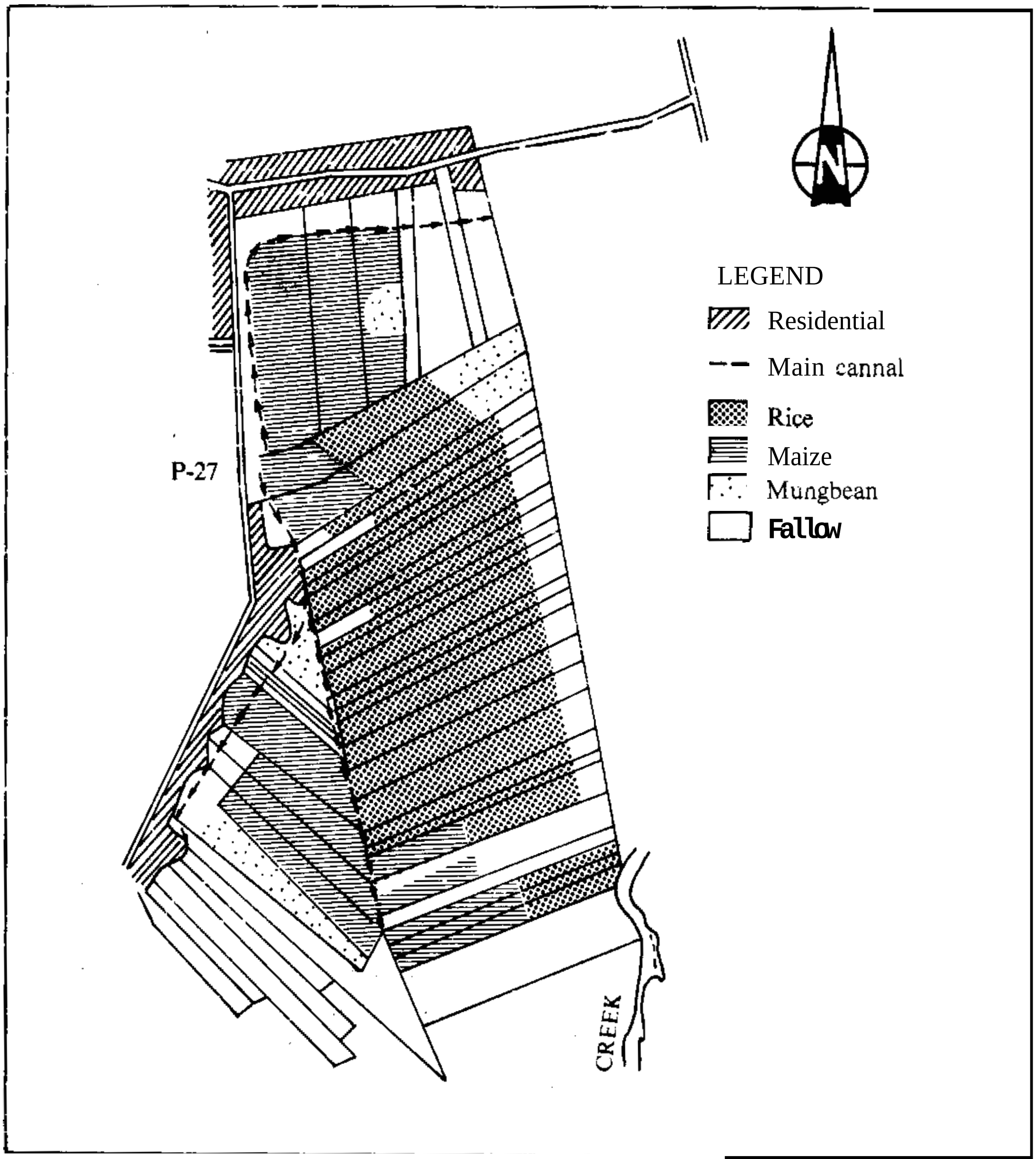

Figure 9. Map showing areas planted to upland crops and rice during the 1988 DS, P-27 service area. Guimba, Nueva Ecija, Philippines.

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