SIMULATION FOR OPTIMUM CROP PRODUCTION IN IRRIGATION SYSTEMS ADOPTING DIVERSIFIED CROPS DURING THE DRY SEASON 1/

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A B S T R A C T

This report presents some findings of the study conducted by the International Irrigation Management Institute (IIMI). The study was financed primarily by the Asian Development Bank (ADB) through a Technical Assistance grant (TA No. 859 PHI) to the Government of the Philippines.

IIMI's primary collaborators in this study were the National Irrigation Administration (NIA), the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and the Department of Agriculture (DA).

Simulation studies were used to determine optimal cropping patterns for 4 systems used in the Study3/. Increased diversification should produce substantial gains in cropping intensity, gross production value, water productivity and net incomes.

At BARIS and ARIP, corn is recommended to be planted along with rice. At UTRIS, the recommended dry season cropping pattern is the cultivation of rice in areas with heavy soils and onion in areas with medium-textured soils. At LVRIS, the crops recommended during the dry season are lowland white potato, garlic and tomato. Lowland white potato has the highest profitability even when prices are low compared to rice and the other non-rice crops. These cropping patterns could only be achieved with active farmers involvemnet in managing the system through irrigator's association groups and provision of appropriate irrigation structures.

1/ A paper for presentation during the Philippine Society of Agricultural Engineers 40th Annual Convention on April 25-28, 1990 at Punta Villa, Iloilo City.

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INTRODUCTION

The need to be self-sufficient in rice among developing countries in Southeast Asia, spurred the large investments in irrigation infrastructure and agricultural development in the 1970's. These efforts resulted in relatively consistent levels of increased rice production, except for years wherein natural calamities (e.g. floods and droughts) occurred. The foreseeable glut in rice production and the need for increased production of other crops, led to the consideration of crop diversification. The production of non-rice crops on lands currently allocated to irrigated rice during the dry season not only emerges as an alternative for optimizing land and water use for increased agricultural productivity but also as an important challenge in irrigation management on how best to manage water under different conditions relative to climate, soil and existing irrigation systems.

The Asian Development Bank (ADB)-supported study on *Food Demand and Supply for Developing Member Countries,* conducted by the International Food Policy Research Institute (IFPRI) and the International Rice Research Institute (IRRI), concluded that the Philippines has comparative advantage in the production of both irrigated rice and non-rice crops. The study's conclusions prompted the Bank to consider the potential of irrigated crop diversification. With the impending self-sufficiency in rice in the Philippines, excess capacity in existing irrigation systems was considered the most viable resource for increasing productivity. The potential for exporting rice is not at all lucrative considering the higher quality required in the world market. Furthermore, competition with Thailand and the United States makes rice exportation a dim prospect.

In existing Philippine irrigation systems, there are irrigated areas suitable for upland crop production. These areas are marginal for rice production due to their lighter soil texture. These areas are commonly found in the fringes of irrigation systems and in some cases even dominate the major portions of systems. The Philippines has approximately 207,000 ha of irrigated land suitable for non-rice crop production in existing irrigation systems (Table 1). These areas are found in regions where rainfall could not sustain rice production during the dry season. With suitable soils and limited water supply, the potential for crop diversification.

OBJECTIVE

The study aims to develop alternative cropping pattern through simulation which could be adopted by selected irrigation system in the Philippines for increased efficiency in land and water use and farmers and irrigation agency income.

STUDY SITES

The study was conducted in selected irrigation systems in the provinces of Nueva Ecija, Ilocos Norte and South Cotabato. Irrigation systems selected were the Upper Talavera River Irrigation System (UTRIS) in District 1 of the Upper Pampanga River Integrated Irrigation Systems (UPRIIS) in Nueva Ecija; and the Laoag-Vintar River Irrigation System (LVRIS) in Ilocos Norte. The Allah River Irrigation Project (ARIP), the Banga River Irrigation System (BARIS) and were the sites selected in South Cotabato in Mindanao (Table 2).

Table 1. Dual and diversified croplands in Philippine national irrigation systems (NIS), 1988.

REGION	Service Areas of NIS (ha)	Dual and Diversified Croplands 1/	Percent of Service Area
1	46,082	32,965	71.5
2	140,962	30,110	21.4
3	175,285	60,770	34.9
4	54,238	27,296	50.3
5	16,466	4,264	25.9
6	53,461	7,678	14.4
7	none	-	-
8	16,860	none	-
9	12,449	none	-
10	20,013	6,820	34.1
11	34,711	24,291	69.9
12	27,426	13,768	50.2
TOTAL	597,953	207,962	34.8

1/ Dual and diversified croplands are areas suitable for both rice and diversified crops.
Source: NIA, 1988.

THE ALLAH RIVER IRRIGATION PROJECT 1

The Allah River Irrigation System (ARIP) consists of two dams in the Allah River with a combined irrigable area of 18,800 ha. Dam #1 is located upstream and is served by a barrage dam at Colongulo, Surallah, South Cotabato. It has a service area of about 7,311 ha covering four municipalities of South Cotabato, namely, Banga, Surallah, Sto. Nino and Norala. The study was conducted at Dam #1. The system has eight main laterals and four sublaterals with a combined length of 83 km, all concrete-lined. Soil type of the area is generally sandy loam.

Construction of ARIP 1 started in the mid-1970's through a loan from ADB. The system was at its final stage of construction at the time of the study. ARIP started limited operation in 1986 and is expected to be in full service starting crop year 1989/90. Since the system could not serve all areas during the dry season, some were designed for irrigated diversified crops. These areas have relatively lighter soil. Laterals A-Extra, B-Extra and C-Extra were designed for diversified crops. Most of the service areas were planted to corn before the system was constructed.

Table 2. General characteristics of the study sites.

Site	Service Area (ha)	Topography	Cropping pattern3/	Cropping intensities (%) 1986/87	1987/88	1988/89	Dry season planted areas4/ (% of total area) 1986/87 R	NR	1987/88 R	NR	1988/89 R	NR
ARIP	7311	Generally flat	R - R R - C 1/	n.a.	102	116	99	1	99	1	99	1
BARIS	3160	Generally flat	R - R R - C	158	174	178	97	3	92	8	97	3
LVRIS	2377	Undulating	R - R R - G - M 2/	n.a.	161	162	60	40	60	40	63	37
UTRIS	3900	Generally flat	R - R R - O	n.a.	108	117	79	21	59	41	44	56

1/ For ARIP and BARIS, corn is planted as second crop in areas not programmed to be served during the dry season. However, these areas are assured of irrigation delivery in case of drought provided farmers are willing to pay the corresponding ISF and that water supply is adequate.
2/ At LVRIS, mungbean is planted as a third crop in garlic-planted areas and is not charged ISF although irrigated during abundant supply. At BP#2, garlic and mungbean are planted as second crops and are part of the program area.
3/ O,G,M,C - Onion, garlic, mungbean and corn, respectively
4/ R, NR - Rice and non-rice crops, respectively

ARIP started limited operation in mid-1986. At the start, cornlands were converted into ricelands. In crop year 1986/87 only about 3,000 ha was served. During the 1986/87 dry season, no area was served for diversified crops. Instead, the management decided to support irrigated lowland rice due to sufficient water supply.

To determine a scenario for crop diversification at ARIP, a simulation exercise was undertaken. Hybrid corn was selected over mungbean, peanuts and soybeans because of: availability of seed materials and market as well as farmers familiarity with the crop. Nonetheless, if ARIP was able to irrigate corn, then other non-rice crops can also be productively grown. Moreover, the extensive production of corn at ARIP during the dry season is a more likely scenario due to its acceptability among farmers. Factors that have to be mitigated, however, are increase and stability of market prices and reduction in cost of fertilizer.

Land suitability. The suitability map of ARIP for diversified crops during the dry season is shown in Figure 1. About 4,500 ha (62%) of the total service area is highly suitable for diversified crop production while 500 ha (7%) and 2,500 ha (31%) are moderately and marginally suitable, respectively (Table 3).

Available irrigation flow. To simulate the optimum cropping pattern for ARIP, the available water flow from the river was estimated using the dependable flow from the feasibility report for ARIP. To prevent silt from entering the canal, only 60% of the dependable river flow will be diverted for irrigation while 40% of the flow will be used to flush out silt and as a source of water for Dam #2. Peak river discharge occurs in either August or September (Figure 2). About 10,000 lps is available for irrigation from July to December.

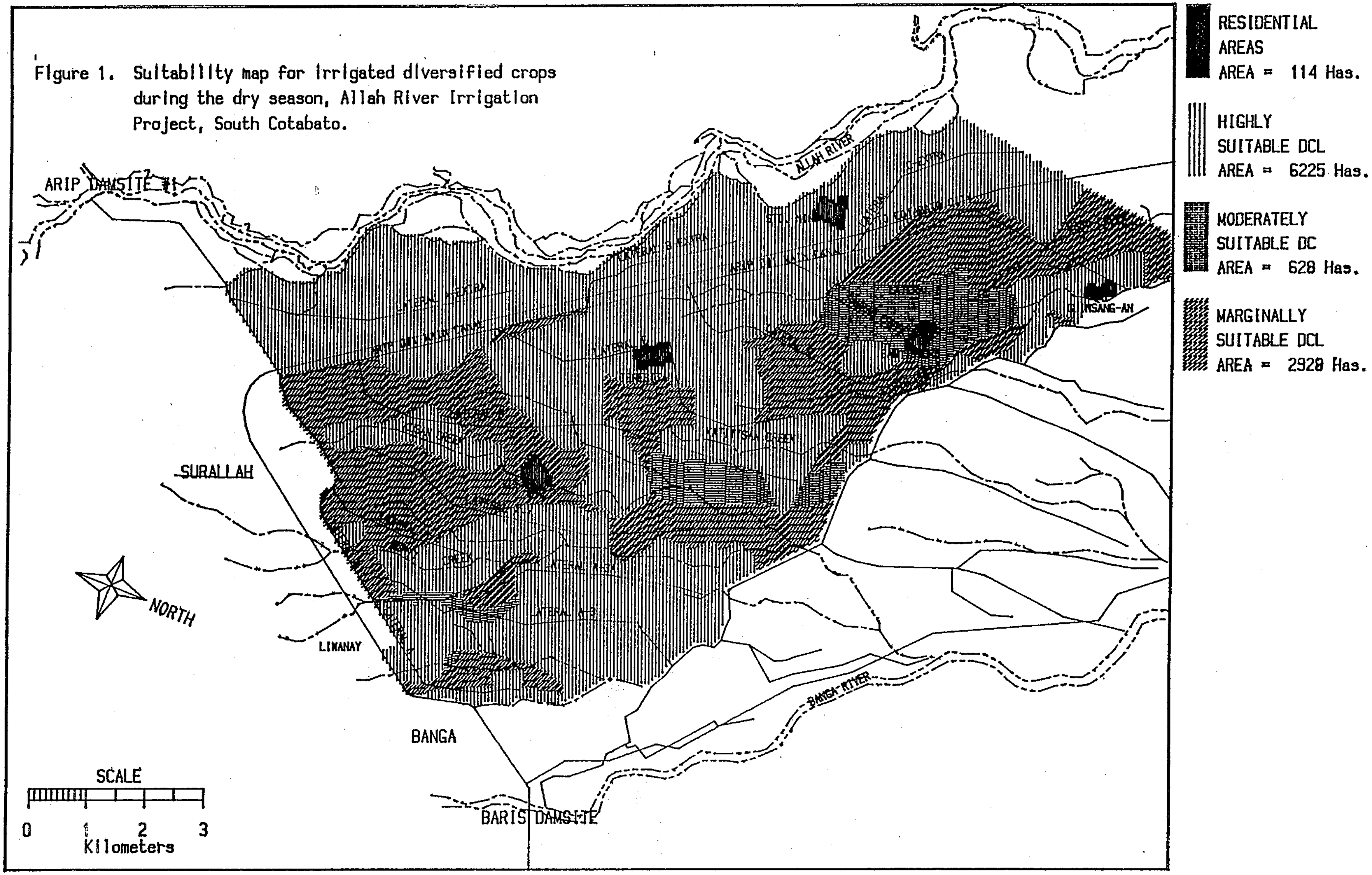
Table 3. Areas suitable for diversified crop production, ARIP 1.

Suitability	Location	Area, (ha)
Highly Suitable	Laterals A-extra, B-Extra & C-Extra, major parts of Laterals C, A3 & A3a, some parts of Laterals E, D, B, A-1, & A-2 & tail end of main canal & Lateral A.	4,500
Moderately Suitable	Major parts of Lateral E & some parts of Lateral A3	500
Marginally Suitable	Major parts of Laterals D, B, A-1, & A, A1 & A2 & tail portions of Main canal.	2,300
	Total	7,300

Water duty. The 50% dependable weekly rainfall is also shown in Figure 2. This was computed from the 20-year rainfall record available from the Norala Weather Station using the incomplete gamma distribution. Evapotranspiration was estimated at 4 - 6 mm/day with the lower limit used during the wet season and the higher limit during the dry season.

For areas which are moderately and marginally suitable for diversified crops, the percolation rate was estimated at 6 mm/day. Thus, the total water duty for normal crop growth is 10 - 12 mm/day depending on the season. For areas which are highly suitable for diversified crops, mean percolation rate is 12 mm/day. Since most of these areas have very light soil, 16 to 18 mm/day is the water duty for normal crop growth.

Figure 1. Suitability map for irrigated diversified crops during the dry season, Allah River Irrigation Project, South Cotabato.



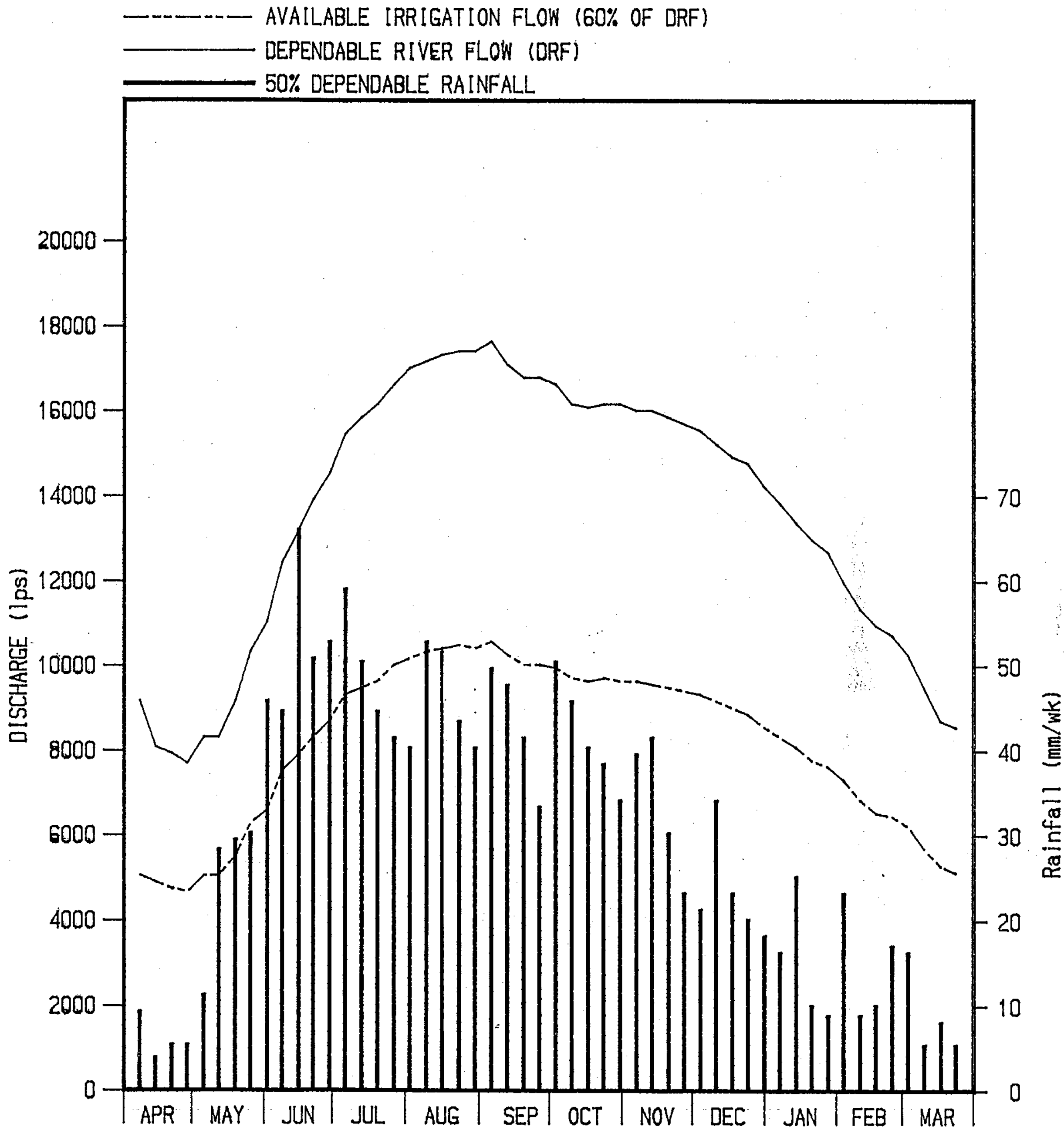


Figure 2. Dependable river flow, available irrigation flow, and 50% dependable rainfall, Allah River Irrigation Project, South Cotabato.

Residual soil moisture was estimated at 22.5% by volume during the start of the wet season. This value was adjusted weekly depending on the probable rainfall occurrence. The land soaking requirement is the amount of water needed to raise the soil moisture from the initial value to saturation. A 50-mm standing water necessary for land preparation is to be provided during the first week of operation. Thus, the total land soaking requirement for the first week of operation includes the soil moisture requirement, standing water requirement, percolation and evaporation requirement.

Computation of land soaking requirement. The following computations were based on values obtained from the adjacent service area of BARIS which has almost the same soil type as ARIP.

<u>Areas which are moderately and marginally suitable for diversified crops:</u>

Percolation rate (P)	=	6.0 mm/day
Residual Soil Moisture (M)	=	22.5% by volume
Soil Moisture at Saturation (Ms)	=	48.0% by volume
Evapotranspiration (Eo)	=	4.0 mm/day (wet season)
	=	6.0 mm/day (dry season)
Soil depth to be saturated (Ds)	=	150.0 mm (plow depth)
Standing water for soaking (SW)	=	50.0 mm
Saturation Requirement (SR)	=	[(Ms-M)(Ds)]/100
	=	[(48-22.5)(150)]/100
	=	86 mm
Land Soaking Requirement (LSR)	=	SR + SW + 7(Eo) + 7(P)
(1 week period)	=	86 + 50 + 7(4) +7(6)
	=	206 mm/wk

For areas which are highly suitable for diversified crops, the land soaking requirement was 248 mm/wk.

A6.72 *Normal Crop Growth Irrigation Requirement (NIR).*

NIR (Rice) = 7(Eo) + 7(P)

<u>For areas which are moderately and marginally suitable for irrigated diversified crops</u>:

Rice	Wet Season	=	70 mm/week
	Dry Season	=	84 mm/week

<u>For areas which are highly suitable for irrigated diversified crops</u>:

Rice	Wet Season	=	112 mm/week
	Dry Season	=	126 mm/week
Corn	Dry Season	=	Cc(Eo)

Crop coefficient (Cc) varies from 0.5 to 1.2. It is 0.5 at the start of crop growth and increases to 1.2 at the fifth week of crop growth and then decreases at the 12th week until it reaches 0.5 at harvest time. Estimated soil moisture at field capacity is 36% by volume and 12% at permanent wilting point. Irrigation should be applied if the available soil moisture falls below 35% or at about 20% soil moisture by volume. The irrigation requirement of corn was estimated using soil moisture balance. At the start of planting, soil moisture was assumed at field capacity.

For yields, the following assumptions were made:

Assumption 1: Optimum farmers yield

Rice (Wet Season)	=	5.0 t/ha
Rice (Dry Season)	=	6.0 t/ha
Corn (Dry Season)	=	7.0 t/ha

The targets for government-initiated crop production programs are as follows:

Assumption 2: *Masagana 100* and *Maisagana 99* target yields

Rice (Wet Season)	=	5.0 t/ha
Rice (Dry Season)	=	5.0 t/ha
Corn (Dry Season)	=	5.0 t/ha

These yield estimates were used in the computations of economic benefits.

Production Costs. Based on the results of the economic survey, the following adjusted costs were used:

Rice (Wet Season)	P7,000/ha
Rice (Dry Season)	7,500/ha
Corn (Dry Season)	P6,000/ha

These costs did not include family labor because it has been considered part of family income.

System irrigation efficiencies. For system IE, two assumptions were made:

<u>Assumption I</u>:

Wet season system efficiency	=	45%
Dry season system efficiency	=	55%

<u>Assumption II</u>:

Wet season system efficiency	=	60%
Dry season system efficiency	=	70%

The simulation assumed higher irrigation efficiencies (IEs) than what has been experienced by the system because the efficiencies estimated in evaluating the system did not include areas which were served by drainage reuse.

Results using system efficiency assumption I. The simulated cropping pattern, available water and corresponding irrigation diversion requirements based on Assumption 1 are shown in Figure 3. The entire service area of ARIP would be served for at least one season. It would take six months before the

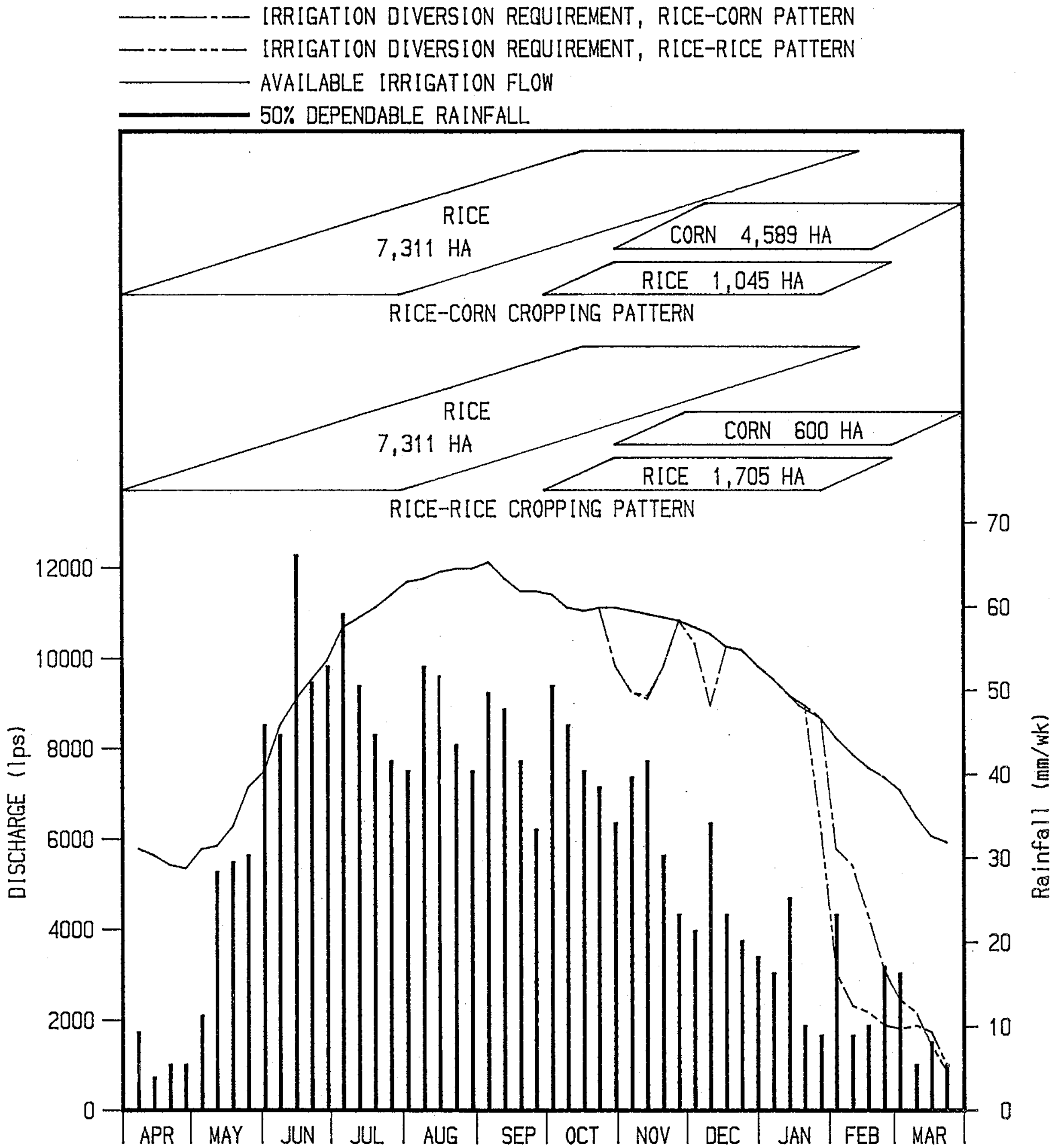


Figure 3. Available irrigation flow and simulated irrigation diversion requirement and cropping patterns, assuming 45% and 55% system efficiency during the wet and dry season respectively, Allah River Irrigation Project.

entire service area is planted to one crop of rice. At this time, 50% of the area would have already harvested and the area to be served for the dry season would have started planting.

Optimizing the area planted to corn during the dry season resulted to 35% more area served and 18% higher collectible ISF than when optimizing the rice planted area (Table 4). Cropping intensity is expected to increase by 46% and total gross production value and total family income by 28%.

Table 4. Simulated areas planted to rice and corn, collectible irrigation service fee (ISF), total gross production value and total family income, using 45% and 55% system efficiency during wet and dry seasons, respectively, ARIP 1.

Season	Irrigable Area ha		Total Collectible ISF* ('000 pesos)	Total Production value ('000 pesos)	Total farm family income ('000 pesos)
	Rice	Corn			
	Optimizing Rice Planted Area				
WET	7,311	0	3,838	127,943	76,766
DRY	1,705	600	1,084	38,538	22,150
TOTAL	9,016	600	4,922	166,480	98,916
	Cropping Intensity =		132 **		
	Optimizing Corn Planted Area				
WET	7,311	0	3,838	127,943	76,766
DRY	1,045	4,589	1,994	84,828	49,457
TOTAL	8,356	4,589	5,832	212,771	126,222
	Cropping Intensity =		177 **		

* ISF = Collectible irrigation service fee based on 100 kg rice /ha for wet season (rice) and 150 kg rice/ha for dry season rice crop and 60% of the rate for rice for corn areas, valued at current government support price of P3.50/kg for rice.
** Based on design service area of 7,311 ha.

Results using system efficiency Assumption II. The simulated cropping pattern based on Assumption II is shown in Figure 4. The time needed to plant the entire service area is only 3 months or 50% of that in assumption I. Considering the optimum area planted to rice, 70% of the entire service area could be served during the dry season. If all areas, which are highly suitable for diversified crops were planted to corn and the less suitable areas were planted to rice, ARIP could serve its entire service area during both seasons.

There is an expected increase of 31% in area planted to rice due to the increase in IE (Table 5). Collectible irrigation service fees will also increase by 35%, total gross production value by 33%, and total family income by 31%.

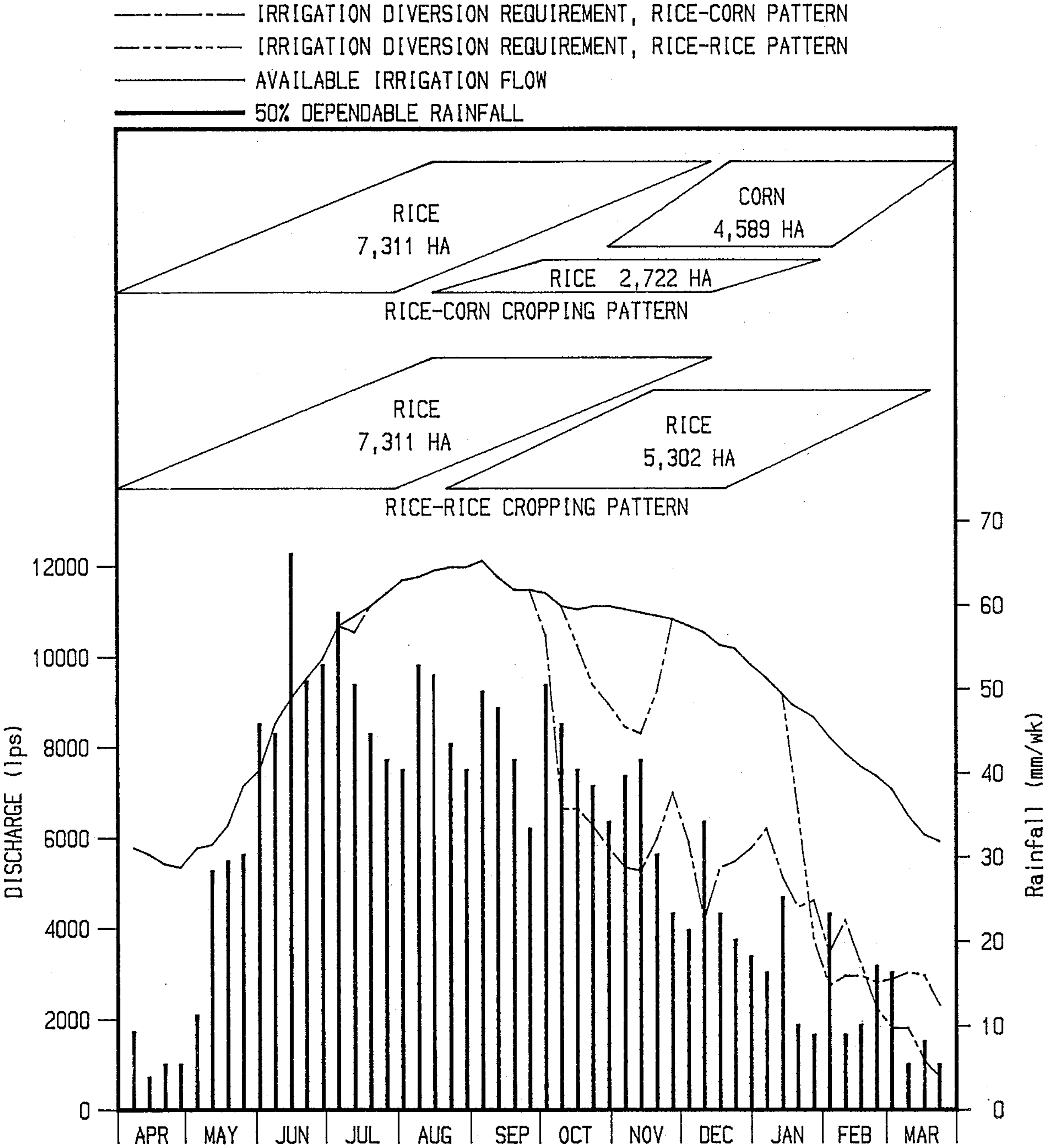


Figure 4. Cropping patterns, irrigation diversion requirements, available irrigation flow and dependable rainfall, Allah River Irrigation System.

Area planted to corn is expected to increase by 16%, total production value by 10% and total farm family income by 10%. However, collectible ISF will increase by only 1% (Table 5).

Table 5. Simulated areas planted to rice and corn, collectible irrigation service fee (ISF), total gross production value and total family income, using 60% and 70% system efficiency during wet and dry seasons, respectively, ARIP 1.

Season	Irrigable Area (ha)		Total Collectible ISF* ('000 pesos)	Total Production value ('000 pesos)	Total farm family income ('000 pesos)
	Rice	Corn			
	Optimizing Rice Planted Area				
WET	7,311	0	3,838	127,943	76,766
DRY	5,302	0	2,784	92,785	53,020
TOTAL	12,613	0	6,622	220,728	129,786
	Cropping Intensity = 172 **				
	Optimizing Corn Planted Area				
WET	7,311	0	3,838	127,943	76,766
DRY	2,722	4,589	2,875	114,176	66,227
TOTAL	10,033	4,589	6,713	242,118	142,992
	Cropping Intensity = 200 **				

* ISF = Collectible irrigation service fee based on 100 kg rice /ha for wet season (rice) and 150 kg rice/ha for dry season rice crop and 60% of the rate for rice for corn areas valued at current government support price of P3.50/kg for rice.

** Based on design service area of 7,311 ha.

Summary of simulation results. The simulation showed that irrigable area, collectible ISF and production can be increased by optimizing water use by planting diversified crops during the dry season and by increasing irrigation efficiency. Moreover, increase in IE can be achieved by identifying all areas which benefit from the system and by providing adequate farm level facilities to these areas.

THE BANGA RIVER IRRIGATION SYSTEM

The Banga River Irrigation System (BARIS) is a run-of-the-river type irrigation system served by a dam at the Banga River near the Marbel-Cotabato Highway, about 2 km from Banga, South Cotabato. It was constructed in 1971 with financing from the Asian Development Bank (ADB), at a total cost of P 12.6 million. It was completed and started operation in 1973. It has a service area of 3,360 ha covering the towns of Banga, Norala and Sto Nino, in South Cotabato.

BARIS has a main canal length of 15 km, 10.74 km of which are lined. It has nine laterals with a total length of 29.6 km, 2.3 km of which are lined. BARIS has 198 turnouts with an average service area per turnout of 11 ha.

The river flow contains 20-30% silt and fine sand. The river's watershed is heavily denuded and very erodible contributing to the high silt content of runoff water. In the initial operation, the area benefitted per season varied widely (Table 6). High silt accumulation in the canals resulted in the low seasonal benefitted area. Desilting increases the volume of diverted water and the irrigated area, but the continuous silt accumulation decreases the area served.

Table 6. Program area, irrigated area, cropping intensity (CI), irrigation service fee collectible and collection efficiency (CE), BARIS, 1975 to 1987.

Year	Program Area (ha)	Dry Season Area (ha)	Dry Season Yield (t/ha)	Wet Season Area (ha)	Wet Season Yield (t/ha)	CI (%)	Irrigation Service Fee Collectible ('000 Pesos)	Irrigation Service Fee CE (%)
1975	3,360	956	3.0	2,432	2.8	101	386,600	10
1976	3,071	1,334	2.6	1,011	3.0	76	332,110	11
1977	3,071	821	2.6	2,579	4.2	111	420,122	33
1978	3,094	1,549	4.0	2,421	4.9	128	535,395	39
1979	2,956	878	3.9	1,948	4.9	96	423,228	78
1980	2,965	1/	-	2,115	4.9	71	274,757	78
1981	2,970	1,673	3.9	2.034	4.3	125	653,447	40
1982	2,970	1,281	4.2	1,849	4.4	105	578,802	55
1983	2,445	1,328	3.9	1,851	4.9	130	561,280	62
1984	2,445	996	3.8	1,600	4.0	106	617,333	56
1985	2,450	1,305	4.2	1,751	4.7	125	1,107,450	63
1986	2,110	1,126	4.4	1,553	4.8	127	1,005,440	77
1987	2,110	1,326	3.93/	1,999	n.a.	158	1,186,466	
1988	2,110	1,750	3.34/	1,912**	n.a.	174		

CI = (IA, Wet season + IA, Dry season + Area O.C)/ Program Area*100
1/ No operation due to construction of settling basin.
2/ plus 160 ha of third crop of corn from March to April 1989
Collection Efficiency (CE) includes collected back accounts (unpaid previous accounts).
n.a. = not available

Source: NIA except 3/ and 4/ which were based on IIMI farm economic survey.

In 1980, a settling basin, costing about P188,000 was constructed to reduce the cost of frequent canal desiltation. Water diverted to BARIS first passes through the settling basin which is located at the intake of the main canal. The silt-free water is then diverted to the canals. However, there is rapid accumulation of silt at the settling basin. In 12 hours of operation, the water diverted into the system is reduced significantly. To stabilize water diversion, flushing out of silt is done every 12 hours using a bulldozer. The effective duration of water diversion is therefore only 22 hours per day. The desilting operation costs about P300,000 annually.

Due to limited water supply, the present service area of the system has been reduced to only 2,100 ha. About 2,000 ha can be irrigated during the wet season and 1,700 ha during the dry season.

To obtain a most likely scenario for crop diversification at BARIS, a simulation exercise was undertaken. The crop chosen was hybrid corn. There were other crops considered like mungbean, peanut and soybean. Two of these crops were even tested for adaptability at BARIS (Table 7). However, the unavailability of seeds and market, as well as lack of farmer's familiarity with the crops posed as constraints in the selection of other crops for simulation. However, if BARIS will be able to irrigate corn, then other non-rice crops can also be productively grown. The extensive production of corn at BARIS during the dry season is a more likely scenario due to the crop's acceptability among farmers. The only problems associated with corn production were prevailing market prices and costs of fertilizer. Thus, only corn was used as the alternative crop during the dry season for this simulation exercise.

Table 7. Summary of costs and returns from alternative non-rice crops tested at BARIS, 1985/86 dry season.

Crop	Yield (kg/ha)	Gross 1/ Returns	Production 2/ Costs	Net Returns
Peanut	1120 (shelled)	8000	4933	3067
Mungbean	1320 (shelled)	6600	4979	1621

1/ Gross income in pesos
2/ Production costs excluding land rent
Source: Final Report, Study on Irrigation Management for Crop Diversification (TA No. 654 PHI), IIMI December 1986.

Land suitability. The entire service area of BARIS was classified as dual class land (Figure 5). This means that BARIS could be totally planted to irrigated diversified crops during the dry season. Figure 5 shows a larger service area of BARIS than what was used in the simulation. There are some pockets of highlands, small residential lots and barangay roads which cannot be delineated by the computer program used. These areas were not shown in the map but were included as service areas. In reality, there are also areas at low elevation which are randomly located in the system and are found mostly near creeks. These areas cannot be planted to diversified crops unless elaborate field drainage systems are installed. These areas are also too small individually to be recognized by the computer program used although they are significant if considered as a whole.

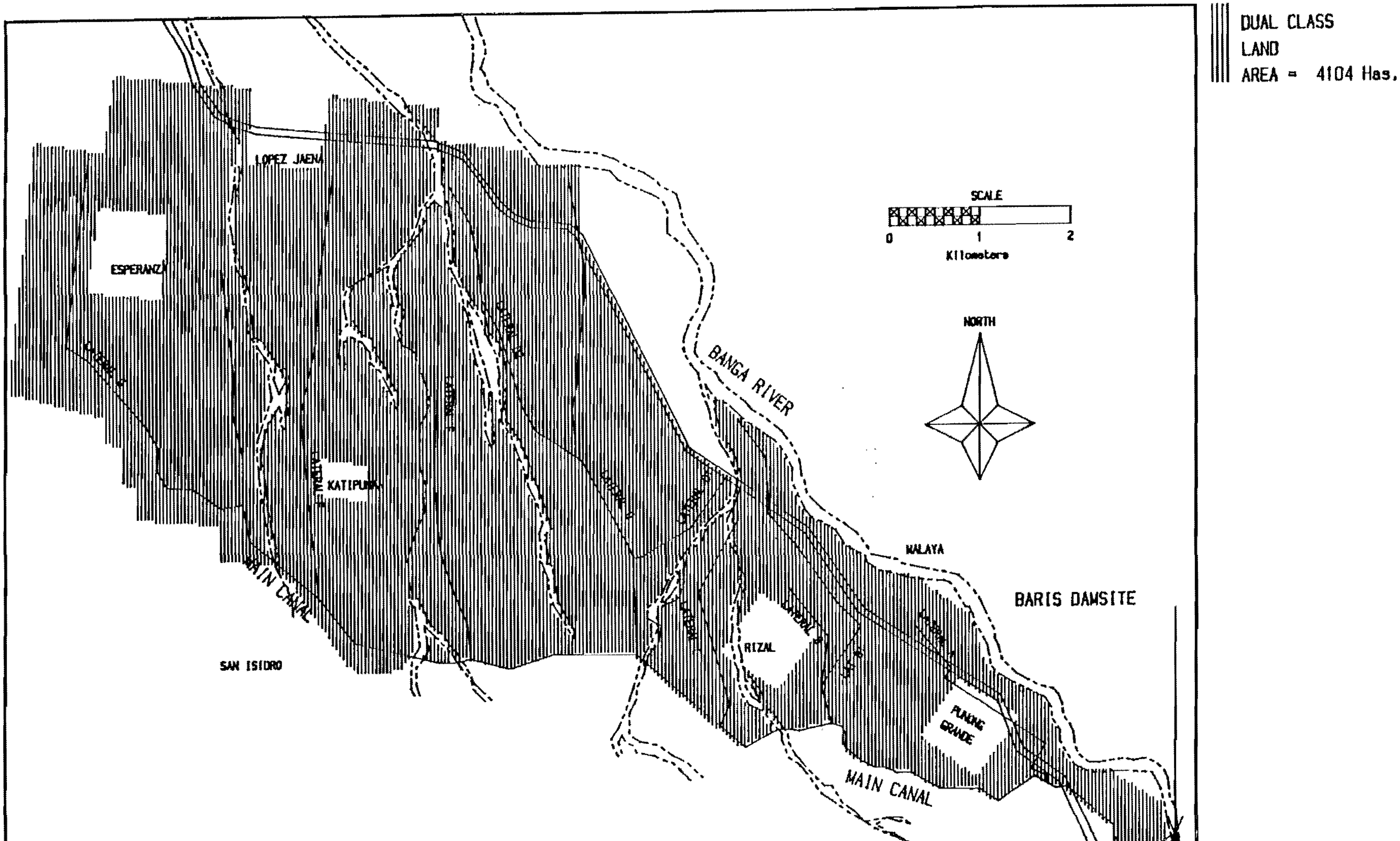


Figure 5. Suitability map for irrigated diversified crops during the dry season, Banga River Irrigation System, South Cotabato.

Available irrigation flow. To be able to simulate the optimum cropping pattern for BARIS, there is a need to estimate the available flow from the river. There are about three years of available data for river flow which is not enough for a hydrologic frequency analysis. However, there are 20 years of rainfall data. For the 3-year available data, regression analysis was done relating river discharge with 15, 30, 45 and 60-day cumulative rainfall. The highest regression coefficient (85%) was obtained using 45-day cumulative rainfall. Using the regression equation, the 20-year rainfall data were converted to discharge data and were analyzed using hydrologic frequency analysis. The hydrologic frequency distribution used was the log-normal distribution. The result is shown in Figure 6.

Peak discharge occurs in late June to late July, corresponding to the peak rainfall. At 84% dependability, the minimum river discharge was 3,200 lps with 5,000 lps or more from early June to early December. This 84% dependable flow was used in the simulation. Drainage reuse was considered an unreliable irrigation source, thus, it was excluded.

Water duty, rainfall and irrigation efficiency. Evapotranspiration was estimated at 4 and 6 mm/day during the wet and dry seasons, respectively. Percolation rate was estimated at 6 mm/day for a total water duty for normal crop growth at 10 to 12 mm/day depending on the season. For land soaking, the residual moisture was estimated to be 22.5% by volume at the start of the wet season. This value was adjusted weekly depending on the probable rainfall occurrence. The land soaking requirement was considered the moisture needed to raise the soil moisture from the initial value to saturation. A 50-mm standing water, necessary for land preparation, was assumed to be provided during the first week of operation. The total land soaking requirement for the first week of operation was the sum of the soil moisture requirement, standing water requirement, percolation and evaporation.

Computation of Land Soaking Requirement.

Percolation rate (P)	=	6.0 mm/day
Residual Soil Moisture (M)	=	22.5% by volume
Soil Moisture at Saturation (Ms)	=	48.0% by volume
Evapotranspiration (Eo)	=	4.0 mm/day (wet season)
	=	6.0 mm/day (dry season)
Soil depth to be saturated (Ds)	=	150.0 mm (plow depth)
Standing water for soaking (SW)	=	50.0 mm
Saturation Requirement (SR)	=	[(Ms-M)(Ds)]/100
	=	[(48-22.5)(150)]/100
	=	86 mm
Land Soaking Requirement (LSR)	=	SR + SW + 7(Eo)+7(P)
(1 week period)	=	206 mm/wk

Based on infiltration tests, the infiltrated amount plus evapotranspiration after a 6-hr period was 144 mm for a soil in BARIS with residual soil moisture of about 23%. At the end of the 6-hr period, the infiltration rate was already constant at about the percolation rate of 6 mm/day. The one week prorated infiltration and evapotranspiration rate was 204 mm, which is almost equal to the land soaking requirement. The

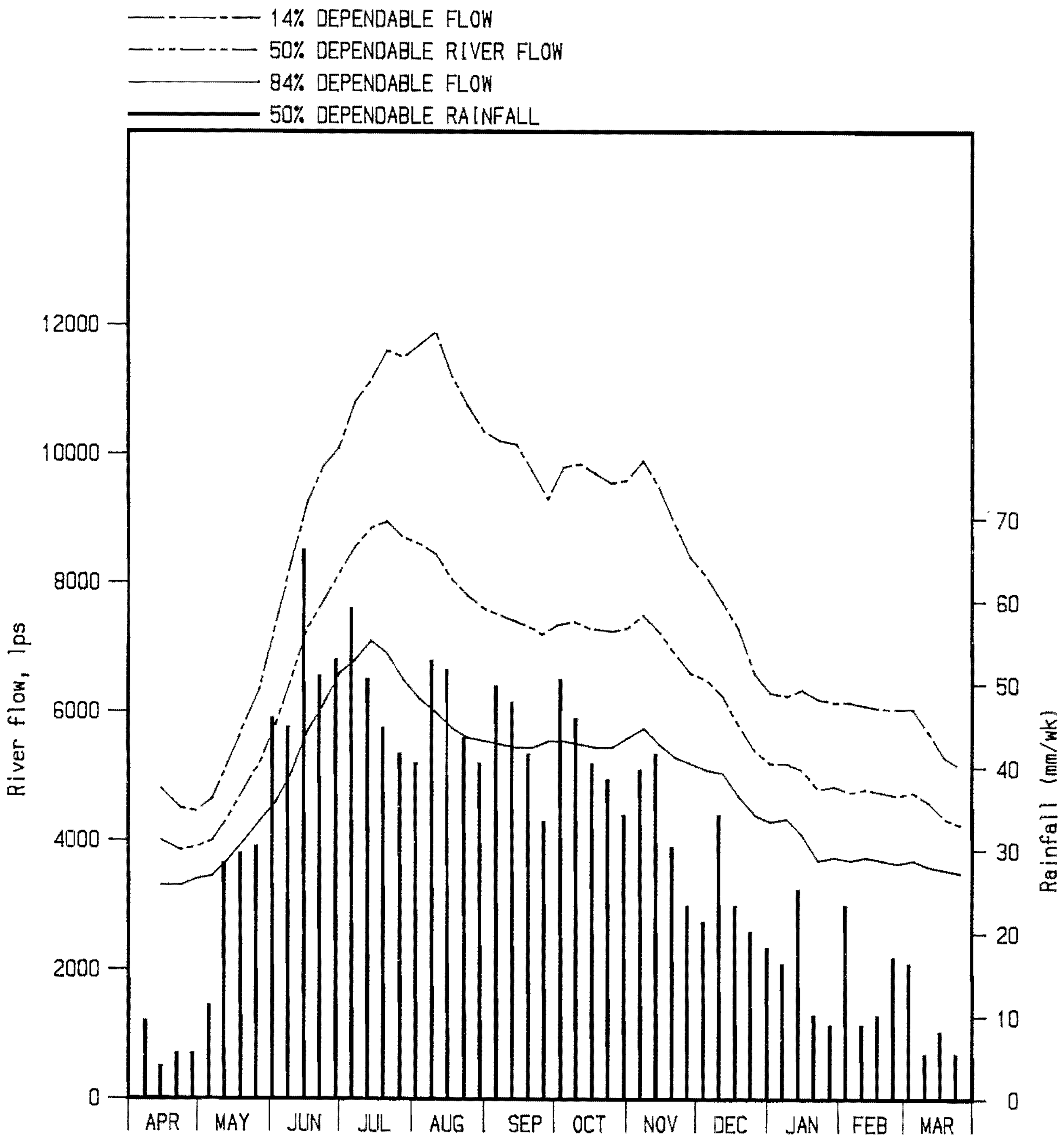


Figure 6. Dependable rainfall and river flow, Banga River Irrigation System, South Cotabato.

infiltration rate tests were done in an area planted to corn during the previous dry season. Infiltration rate test was also done in an almost saturated soil which was previously planted to rice. The cumulative infiltration after a 6-hour period was about 50 mm only. The difference between the rice and corn areas was attributed to the difference in residual moisture. One corn field which was almost saturated where the infiltration test was done, had the same cumulative infiltration rate as the rice field (about 50 mm in 6 hrs).

Normal Crop Growth Irrigation Requirement (NIR).

NIR (Rice)		=	7(Eo) + 7(P)
Rice	Wet Season	=	70 mm/day
	Dry Season	=	84 mm/day
Corn	Dry Season	=	Cc(Eo)

Cc is the crop coefficient which varies from 0.5 to 1.2. Cc is 0.5 at start of crop growth and increases to 1.2 at the 5th week of crop growth and start decreasing at 12th week of crop growth to 0.5 at harvest. Estimated soil moisture at field capacity was 36% by volume and permanent wilting point was 12% soil moisture by volume. The irrigation requirement of corn was estimated using soil moisture balance. At start of planting the soil moisture was assumed at field capacity. Irrigation should be applied if available soil moisture is less than 35% or about 20% soil moisture by volume.

From the 3-year system operation evaluation, the system's efficiency was estimated at 60% during the wet season and 70% during the dry season. The following yield assumptions were made:

Assumption 1: Optimum farmers yield:

Rice (Wet Season)	=	5.0 t/ha
Rice (Dry Season)	=	6.0 t/ha
Corn (Dry Season)	=	7.0 t/ha

The present mean rice yield for the system is about 5.0 t/ha for the wet season and 4.0 t/ha for the dry season. The present low yield is due to limited water supply during the dry season. The simulation model assumed lower irrigation efficiencies than what is currently experienced. The assumed yield for corn was 7.0 t/ha. The maximum yield of hybrid corn harvested by a farmer vying for the *Best Corn Farmer of the Year* award in Mindanao was more than 10.0 t/ha. The targets for government agricultural programs on crop yields are as follows:

Assumption 2: *Masagana 100* and *Malsagana 99* target yields:

Rice (Wet Season)	=	5.0 t/ha
Rice (Dry Season)	=	5.0 t/ha
Corn (Dry Season)	=	5.0 t/ha

These yield estimates were also used. Production cost less family labor was estimated at P7,000 and P7,500 per hectare for rice during the wet and dry seasons, respectively, and P6,000 per hectare for corn during the dry season.

Present rate of diversion. At present the diverted flow into the system is about 30% of the total river flow during the wet season and 50%

during the dry season. The weekly available flow was determined using the 84% dependable flow. From the available flow data, the optimum cropping pattern was determined. The first simulation optimized the area to be planted to rice in both seasons. The second simulation optimized the area to be planted to corn during the dry season. It was assumed that corn can be planted only in December to avoid waterlogging. The third simulation was the same as the second except that it assumed an earlier date of planting, i.e., land was prepared a month after harvest of the wet season rice crop. This is about a month earlier than the December planting.

Optimum cropping patterns are shown in Figure 7. The optimum area, if areas planted to rice is maximized, is less than what is being currently cropped. This shows that farmers and NIA have exhaustively used the water supply resulting in the low yields during the wet season because of water stress. To optimize the use of available water, an area should be planted to just one crop in a year. This area should be planted in September. This is currently being practiced by the system through staggered cropping.

Results of the simulation are shown in Tables 8 and 9. Shifting to irrigated corn during the dry season would increase the irrigable area, collectible irrigation service fee, total grain yield, total grossproduction value and total family income. The irrigable area produced by the simulation is less than the current area planted at BARIS. However, other areas which are being irrigated by drainage reuse were not considered in the simulation because of the unreliable source of water.

Simulation 3, which assumes early planting of corn is difficult to implement. It requires that 2,104 ha be planted to corn during the dry season but only 1,888 ha is planted to rice during the wet season. This means that certain areas will be planted to irrigated corn only. Simulation 2 which assumes an optimum corn planted area but to be planted in December is more realistic. Only fields planted to rice during the wet season will be scheduled for irrigated corn during the dry season.

Assuming that diverted flow can be increased to 60% during the wet season and 70% during the dry season, the optimum cropping patterns is shown in Figure 8. Optimum rice planted area results in 2,608 ha wet season cropped area and 1,760 dry season cropped area. Another 243 ha can be planted in September to utilize the excess water not used by areas under terminal drainage from the wet season planted area for a total of 2,003 ha dry season area. About 2,811 ha will be served for one season only and 1,760 ha will be served for two seasons.

For optimum corn planted area with corn planting in December, the rice area will be 3,360 ha and 2,500 ha of corn. The entire BARIS service area will be able to plant one crop of irrigated lowland rice in a year. Assuming that corn can be planted earlier, the entire service area of 3,360 ha could be served for dry season corn but some areas will not be served during the wet season.

The result of the simulation is shown Tables 10 and 11. Shifting to irrigated corn during the dry season would result in being able to

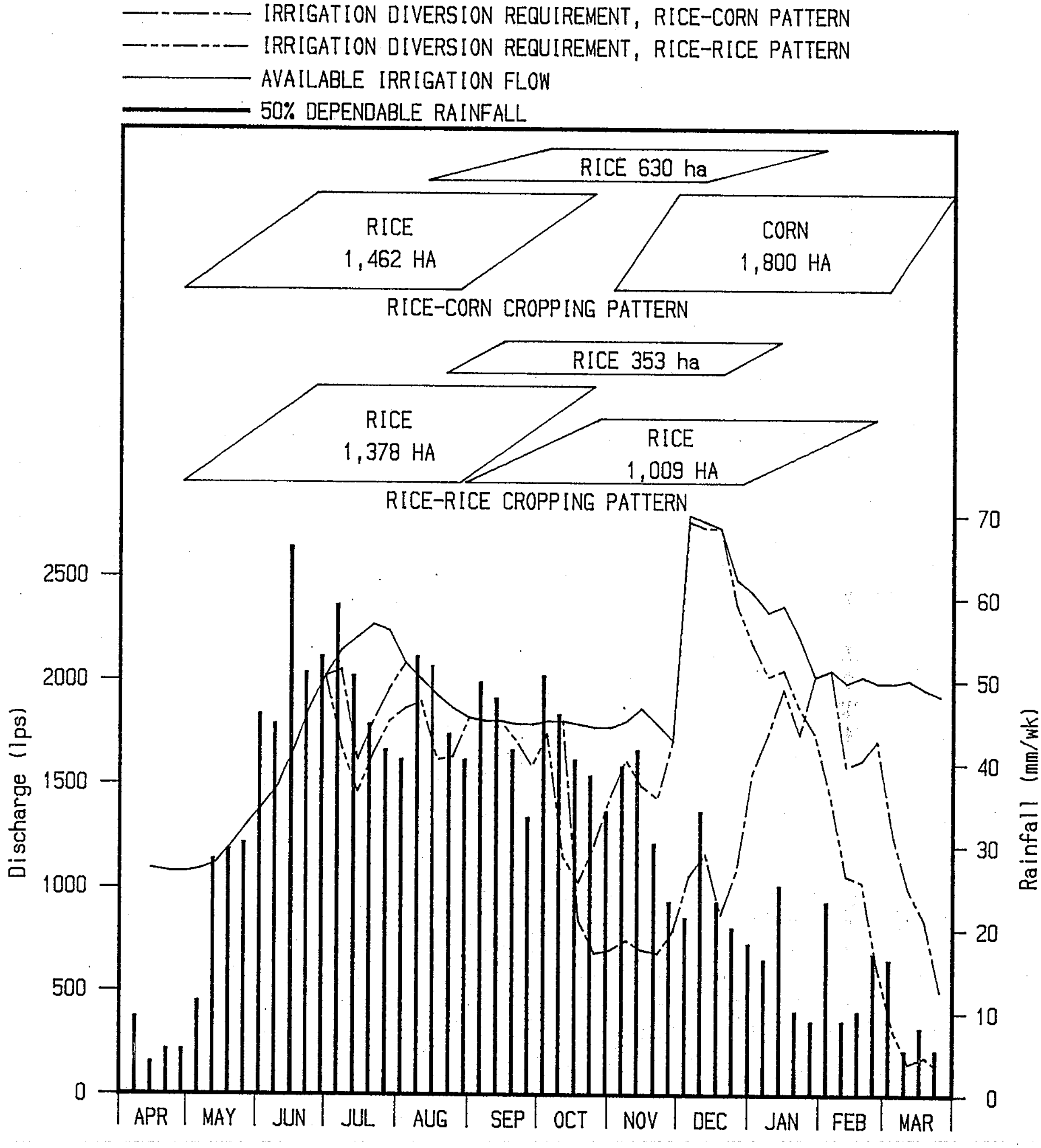


Figure 7. Optimum cropping pattern, available irrigation flow and irrigation diversion requirements, assuming that 30% and 50% of the dependable flow during the wet and dry season respectively can be diverted, Banga River Irrigation System.

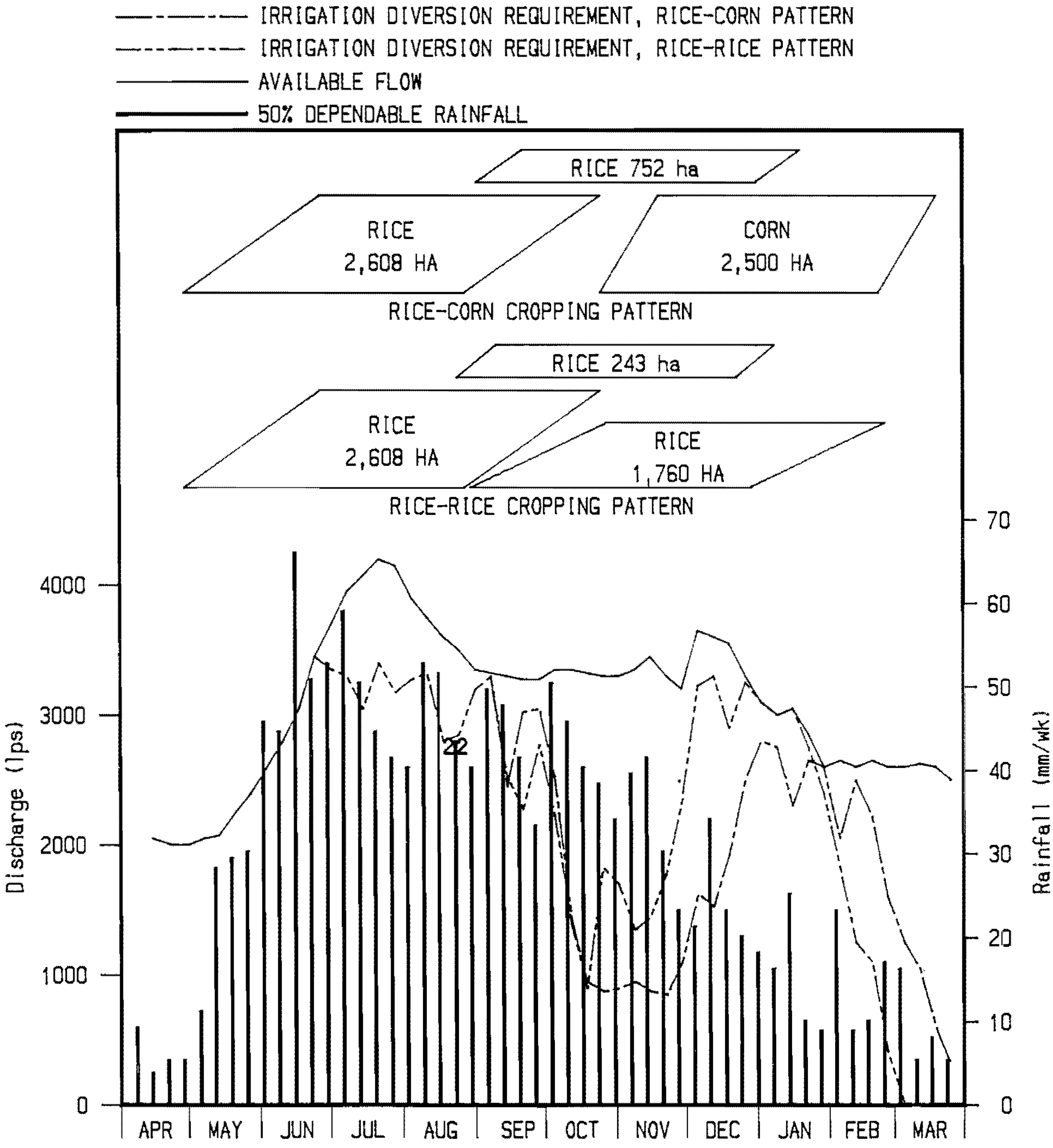


Figure 8. Optimum cropping pattern, available irrigation flow and irrigation diversion requirements, assuming that 60% and 70% of the dependable flow during the wet and dry season respectively can be diverted, Banga River Irrigation System.

irrigate the entire designed service area of BARIS (3,360 ha) for at least one season in a year. If corn is planted in December, the entire designed service area could be served for a wet season rice crop. If corn is planted earlier, the entire designed service area could be served for dry season corn.

Table 8. Areas planted to rice and corn and irrigation service fee collectible (ISF) based on simulation using 30% of river flow during the wet season and 50% of river flow during the dry season as dependable flow, assuming 60 and 70% system efficiency during the wet and dry season respectively, BARIS.

Season	Irrigable Area		Total	
	Rice (ha)	Corn (ha)	Area (ha)	ISF1/ ('000 pesos)
	Optimizing Rice Planted Area			
Wet	1,378	0	1,378	482
Dry	1,362	400	1,762	841
Total	2,740	400	3,140	1,323
Cropping Intensity, %			93.42/	
	Optimizing Corn Planted Area (December planting only)			
Wet	1,462	0	1,462	512
Dry	630	1,800	2,430	898
Total	2,092	1,800	3,892	1,410
Cropping Intensity, %			115.82/	
	Optimizing Corn Planted Area (early planting possible)			
Wet	1,462	0	1,462	512
Dry	426	2,104	2,530	898
Total	1,888	2,104	3,992	1,398
Cropping Intensity, %			118.82/	

1/ Irrigation service fee for rice is 100 kg rice/ha during the wet season and 150 kg rice/ha during dry season, for corn is 90 kg rice/ha during dry season or 60% of the value for rice. Peso conversion is at P3.50/kg rice.
2/ Designed irrigable area of BARIS is 3,360 ha.

Corn irrigation. Since corn has a different water requirement compared with rice, simulation of irrigation water delivery to corn areas using soil moisture balance was done. At 70% system efficiency, BARIS would only operate for 3 to 4 days per week to irrigate 2,500 ha of corn at 10 hour-day operation. It was assumed that farmers would use furrow irrigation which requires their presence while water was being delivered. This method also limits the daily operating hours. Thus, if assumed system efficiency could not be attained, the system has leeway to be able to irrigate these areas. The system must therefore increase its number of hours of operation per day or the number of days it operates weekly to accommodate areas planted to corn.

Table 9. Gross yield, total value of production, and total family income for Simulated Cropping Pattern assuming that 30% of the dependable river flow could be diverted during the wet season and 50% during the dry season, BARIS.

Simulation 1/	Yield (tons)		Total Production Value 2/ ('000 pesos)	Total Family Income 3/ ('000 pesos)
	Rice	Corn		
	Yield Assumption 1			
1	11,180	2,800	47,250	29,842
2	11,090	12,600	73,355	49,596
3	9,866	14,728	77,242	51,189
	Yield Assumption 2			
1	10,465	2,000	42,428	25,019
2	10,460	9,000	62,710	36,951
3	9,440	10,520	63,548	37,495

1/ Simulation 1 is optimum rice planted area. Simulation 2 is optimum corn planted area (December planting only). Simulation 3 is optimum corn planted area (Early planting possible).
2/ Assumed price for rice is P3.50/kg; for corn is P2.90/kg.
3/ Net family income is gross production value less total production cost plus value of family labor.

Summary of simulation results. In terms of collectible ISF and considering the current water diversion rate of 30% and 50% during wet and dry seasons, the optimum cropping pattern is rice-corn, with corn planted in December (Figure 7). The same is true at higher diversion rates of 60% during the wet season and 70% during the dry season. In terms of area irrigated, total production value and total farm family income, there is only a slight difference obtained when corn is planted early or when corn is planted in December. The December planting of corn enables a mid-wet season crop of rice, using the water not being used by the regular wet season areas. These areas, could only be cropped once a year. Such areas could be rotated yearly to any sector of the system, just like what is currently practiced in service area programming.

If the results of the simulation will be implemented, farmers' involvement in pre-seasonal planning and in operating the system should be continued and further enhanced to help in the efficient implementation of the program.

Table 10. Areas planted to rice and corn and irrigation service fee collectible (ISF) based on simulation using 60% of river flow and 70% of river flow during the wet and dry seasons as dependable flow, assuming 60 and 70% system efficiency during the wet and dry season respectively, BARIS.

Season	Irrigable Area		Total	
	Rice (ha)	Corn (ha)	Area (ha)	ISF1/ ('000 pesos)
	Optimizing Rice Planted Area			
Wet	2,608	0	2,608	913
Dry	2,003	0	2,003	1,051
Total	4,611	0	4,611	1,964
Cropping Intensity, %			137.22/	
	Optimizing Corn Planted Area (December planting only)			
Wet	2,608	0	2,608	913
Dry	760	2,500	3,360	1,239
Total	3,368	2,500	5,968	2,152
Cropping Intensity, %			177.62/	
	Optimizing Corn Planted Area (early planting possible)			
Wet	2,608	0	2,608	913
Dry	0	3,360	3,360	1,058
Total	2,608	3,360	5,968	1,701
Cropping Intensity, %			177.62/	

1/ Irrigation service fee for rice is 100 kg rice/ha during the wet season and 150 kg rice/ha during the dry season, for corn is 90 kg rice/ha during the dry season or 60% of the value for rice. Peso conversion is at P3.50/kg rice.

2/ Designed irrigable area of BARIS is 3,360 ha.

Table 11. Gross yield, total value of production, and total family income for Simulated Cropping Pattern assuming that 60% of the dependable river flow could be diverted during the wet season and 70% during the dry season, BARIS.

Simulation 1/	Yield (tons) Rice	Corn	Total Production Value 2/ ('000 pesos)	Total Family Income 3/ ('000 pesos)
		Yield Assumption 1		
1	25,058	0	87,703	54,425
2	18,200	16,900	112,350	73,494
3	13,040	23,520	113,848	5,432
		Yield Assumption 2		
1	23,055	0	80,693	47,414
2	16,800	12,500	95,050	56,154
3	13,040	16,800	94,360	55,944

1/ Simulation 1 is optimum rice planted area. Simulation 2 is optimum corn planted area (December planting only). Simulation 3 is optimum corn planted area (Early planting possible).
2/ Assumed rice yield is 5.0 t/ha during wet season and 6.0 t/ha during dry season. Assumed corn yield is 7.0 t/ha.
3/ Assumed price for rice is P3.50/kg; for corn is P2.90/kg.
4/ Net family income is gross production value less total production cost plus value of family labor.

THE UPPER TALAVERA RIVER IRRIGATION SYSTEM

The Upper Talavera River Irrigation System (UTRIS) is a run-of-the-river type irrigation system served by a dam at the Talavera River in Tayabo, San Jose City. Two main canals are located on both banks. The left bank main canal (facing downstream) is called the San Agustin Extension (SAE). SAE serves 750 ha and 150 ha during the wet and dry seasons, respectively. It has one main lateral and three sub-laterals with a total canal length of 10 km (Figure 9). The dominant soil type in the SAE service area is clay loam. However, soil in the diversified crop areas is sandy loam.

The right bank main canal (UTRIS main) serves 3,900 ha during the wet season and 500-750 ha during the dry season. Area planted to diversified crops during the dry season ranges from 200-300 ha. Onion is the major non-rice crop planted during the dry season. UTRIS main has six main laterals and seven sub-laterals with a total canal length of 40 km (Figure 9). Areas with light soil are found upstream while areas with heavy soil are found downstream.

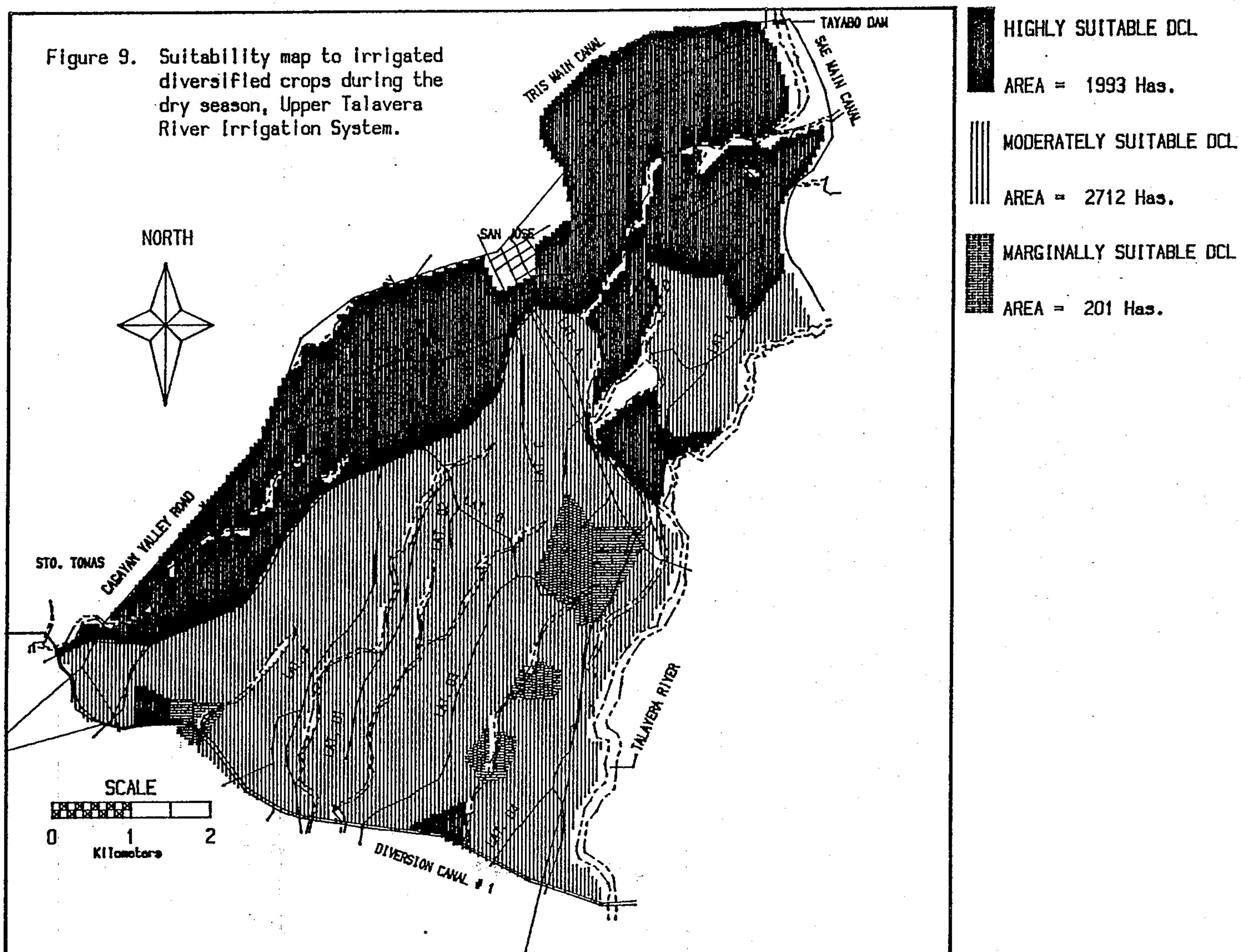


Figure 9. Suitability map to irrigated diversified crops during the dry season, Upper Talavera River Irrigation System.

UTRIS is administratively part of the Upper Pampanga River Integrated Irrigation System (UPRIIS). Other systems of UPRIIS are served by the Pantabangan Reservoir. Although part of UPRIIS, UTRIS is not served by the Reservoir. During some months, the system experiences low water supply. Thus, rotational schedule by sections of the main canal and lateral is enforced by NIA.

A simulation exercise was undertaken to determine a most likely scenario for crop diversification at UTRIS. The crops selected for this exercise were rice, onion, garlic, mungbean, soybeans and corn. The wet season crop was rice. For the dry season, different crops were considered.

Land suitability. The suitability map of UTRIS for irrigated diversified crops during the dry season is shown in Figure 9. About 41% of the total service area of UTRIS, including SAE, is highly suitable for irrigated diversified crops during the dry season while 55% is moderately suitable and 4% is marginally suitable (Table 12).

Table 12. Suitability for irrigated diversified crops of the service of UTRIS during the dry season.

Suitability	Location	Area (ha)
	UTRIS main	
Highly suitable	All areas upstream of Lateral A & left side of Main Canal facing upstream	1,584
Moderately suitable	Downstream of Lateral A & right side of Main Canal facing upstream	2,125
Marginally suitable	End of Lateral A & pockets in downstream Lateral D & Main Canal	191
Total		3,900
	SAE	
Highly suitable	Areas near Talavera River	305
Moderately suitable	Areas downstream (main canal) & middle lateral A2	445
Total		750
	TOTAL	
Highly suitable		1,889
Moderately suitable		2,570
Marginally suitable		191
Total		4,650

Available irrigation flow. To simulate the optimum cropping pattern for UTRIS, there was a need to estimate the available water flow from the river. Based on river discharge records, the probable weekly discharge was computed using hydrologic frequency analysis assuming log-normal distribution. The 84% probable river discharge was used. This probability is equivalent to the mean less the standard deviation. If the probable river discharge is less than the UTRIS main canal capacity, the available flow was assumed equal to the river discharge. If the UTRIS main canal capacity is less than the river discharge, the available flow was equated to the canal capacity.

The 50% dependable weekly rainfall was also computed from previous rainfall data using the incomplete gamma distribution analysis for weekly rainfall and was used in the simulation. Graph of the 84% weekly dependable river flow and 50% dependable weekly rainfall are shown in Figure 10.

Water duty. Percolation rate was assumed at 6 mm/day for the entire system. Potential evapotranspiration for rice was estimated to be equal to the mean pan evaporation at 4 and 6 mm/day for wet and dry seasons, respectively. For diversified crops, data on crop coefficients (Cc) were obtained from the Central Luzon State University (CLSU). To obtain the actual evapotranspiration of a crop, the pan evaporation data was multiplied by Cc. Cc ranged from 0 to 1.2 for all crops used in the simulation.

For rice, the land soaking requirement was considered as the amount of water needed to bring the soil moisture from an initial value at the start of the season to saturation. A 50-mm standing water for land soaking, the percolation rate and pan evaporation rate were also added to obtain the total land soaking requirement. A system efficiency of 60% was used for both seasons.

Yield, production costs and prices. Assumptions on yield, production costs and prices are shown in Table 13. For different diversified crops, three price levels were used, i.e., high, low and median prices. Yields assumed for rice and corn were the targets of the *Masagana 100* and *Maisagana 99* programs; for other crops, observed yields were used.

Table 13. Yield, production costs and prices of different crops used in the simulation, UTRIS.

Crop	Yield (t/ha)	Production cost, (P/ha)	Prices (P/kg)		
			High	Median	low
Rice	5.0	7,705		3.50	
Corn	5.0	7,000		2.90	
Onion	15.0	30,244	6.45	4.82	2.92
Garlic	2.0	25,000	70.00	40.00	12.00
Peanut	1.5	10,000	20.00	15.00	10.00
Mungbean	1.5	6,000	10.25	9.13	6.90
Soybeans	1.5	10,000	14.00	9.00	7.00

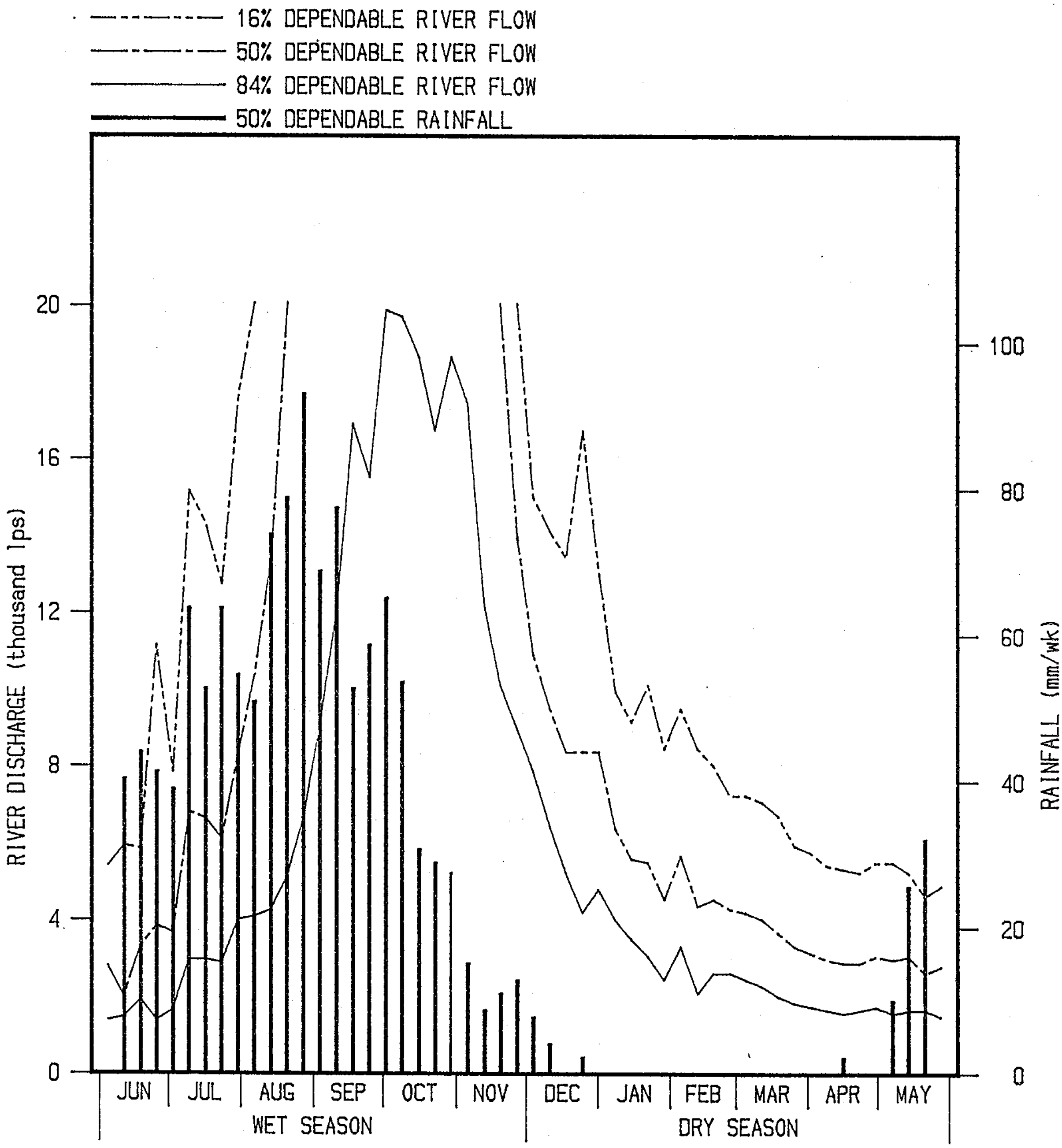


Figure 10. Dependable river flow with different levels of probabilities, Upper Talavera River Irrigation System, wet and dry season.

Simulation results. The entire service area could be planted to rice during the wet season. There is, however, limited water supply to serve the entire service area during the dry season. To compute for the optimum area that could be served with the available water, it was assumed that a diversified crop would be planted in the service area. However, excess water would be available to serve a limited rice area planted earlier in the dry season (Table 14). This available water is due to the less water requirement of diversified crops during the early stages of crop growth. The resulting irrigation diversion requirements and cropping patterns are shown in Figures 11 to 17.

Table 14. Simulated optimum area served per crop, production cost and collectible irrigation service fee (ISF), dry season, UTRIS.

Crop	Area served (ha)			Production cost* ('000 pesos)	ISF
	D.C.**	Rice	Total		
Rice		897		6,911	329,648
Corn	1,352	300	1,652	11,776	680,610
Onion	1,600	300	1,900	50,702	771,750
Garlic	1,600	300	1,900	42,312	771,750
Peanut	1,500	224	1,724	16,726	688,450
Mungbean	2,000	240	2,240	13,849	882,000
Soybeans	1,580	368	1,948	18,635	806,050

Shifting to diversified crops would mean an increase in collectible ISF because of the expected increase in the service area (Table 15). However, there is a need for higher farm credit due to high production cost, especially in onion and garlic (Table 14).

At high prices, the most profitable crop is garlic followed by onion, peanut, soybeans, corn, mungbean and rice (Table 15). At median prices, garlic is still the most profitable crop, followed by onion, corn, peanut, soybeans, mungbean and rice (Table 15). At low prices, onion is the most profitable followed by corn, peanut, rice, mungbean, soybeans and garlic (Table 15).

Summary of simulation results. Considering price fluctuations, onion is the most profitable crop, followed by garlic. At high prices these crops give high income to farmers. This is the reason why the two crops are popular in the area. Alternative crops, to be successfully introduced in the area, should be able to provide high income when prices are high to cover losses during years when prices are low. Unless high yielding leguminous crop varieties are developed and prices of such crops raised, onion and garlic will remain the main dry season crop in UTRIS.

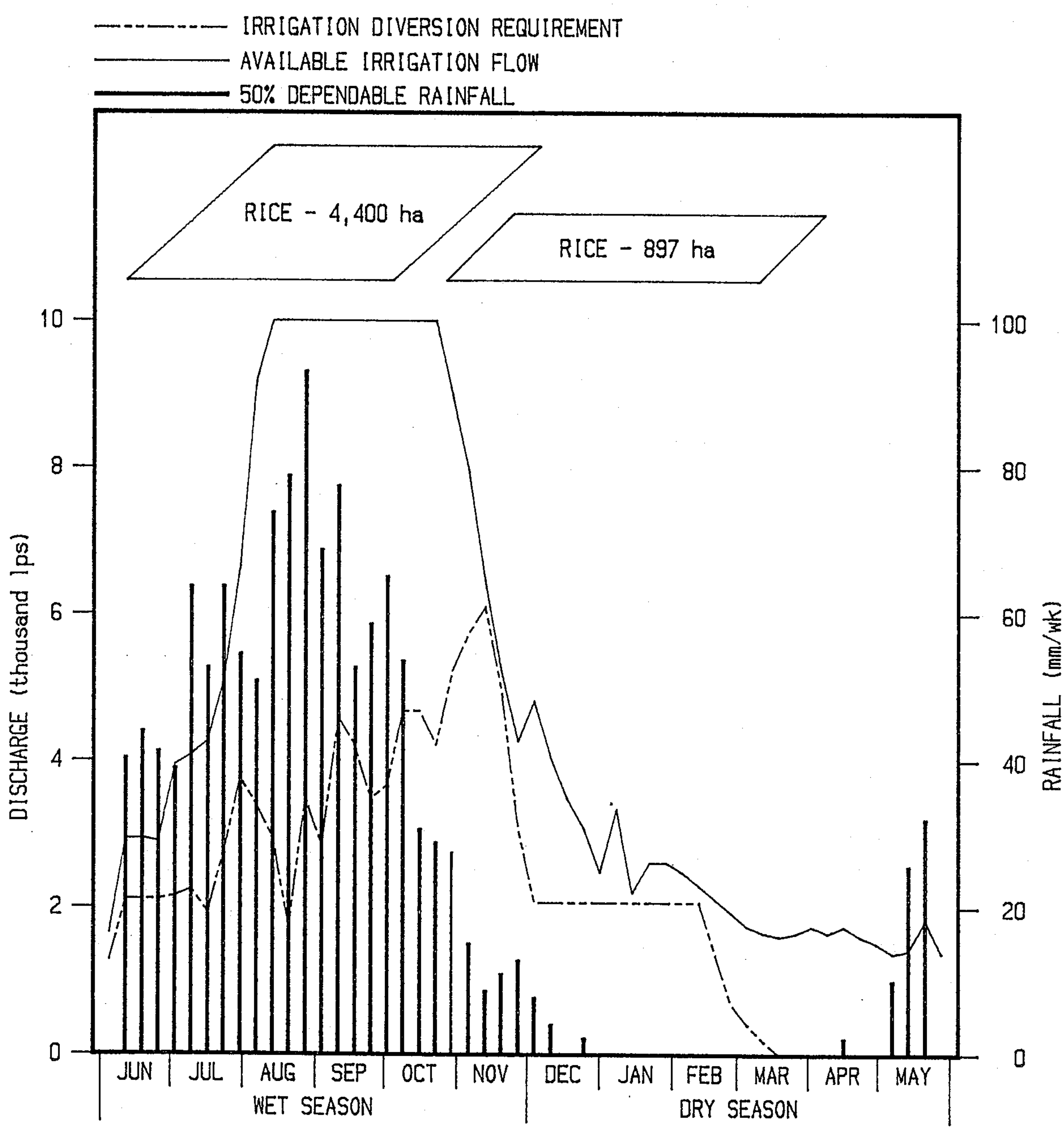


Figure 11. Available irrigation flow, irrigation diversion requirement, and dependable rainfall for RICE-RICE cropping pattern, Upper Talavera River Irrigation System.

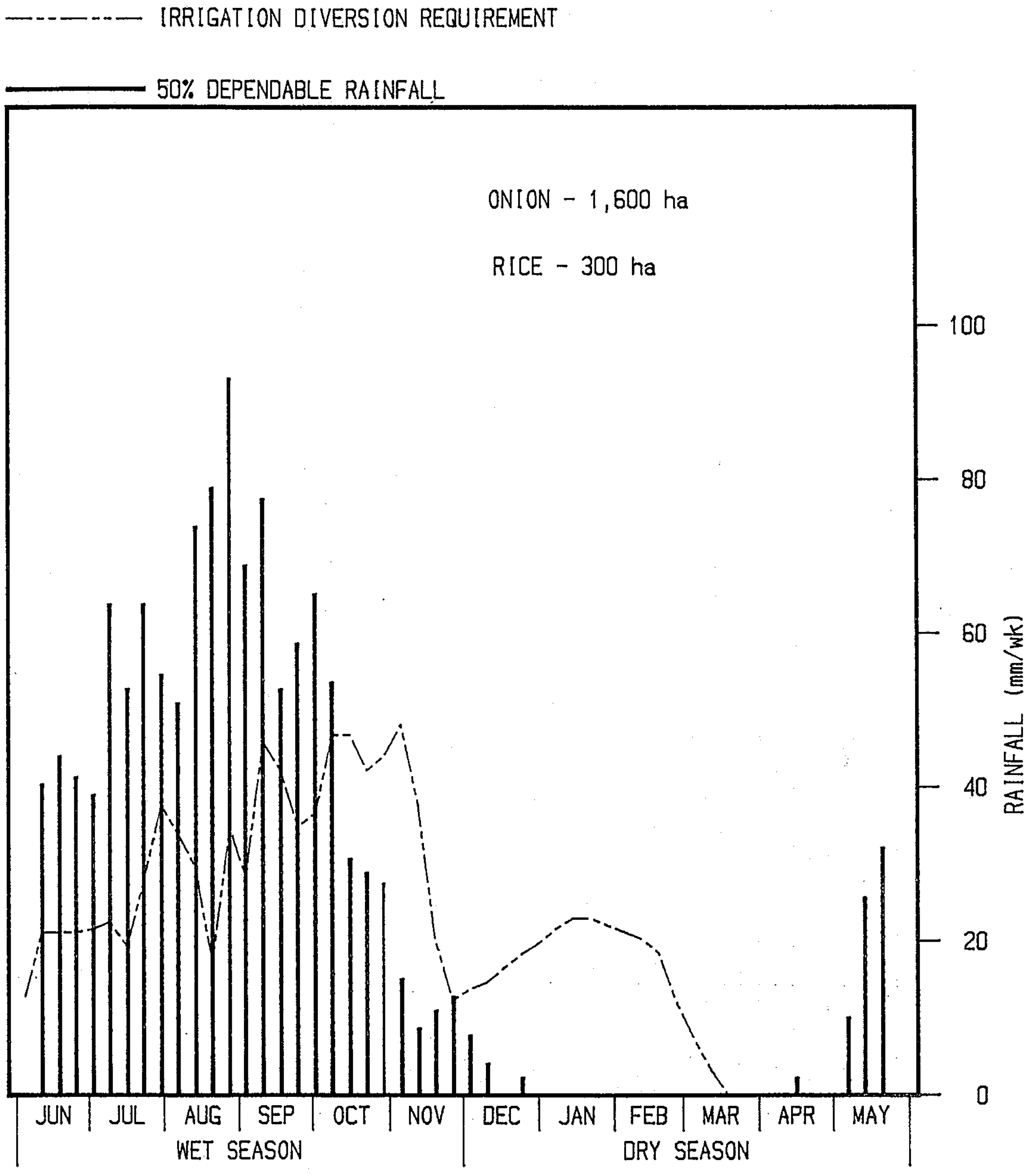


Figure 12. Available irrigation flow, irrigation diversion requirement and dependable rainfall for RICE-ONION cropping pattern, Upper Talavera River Irrigation System.

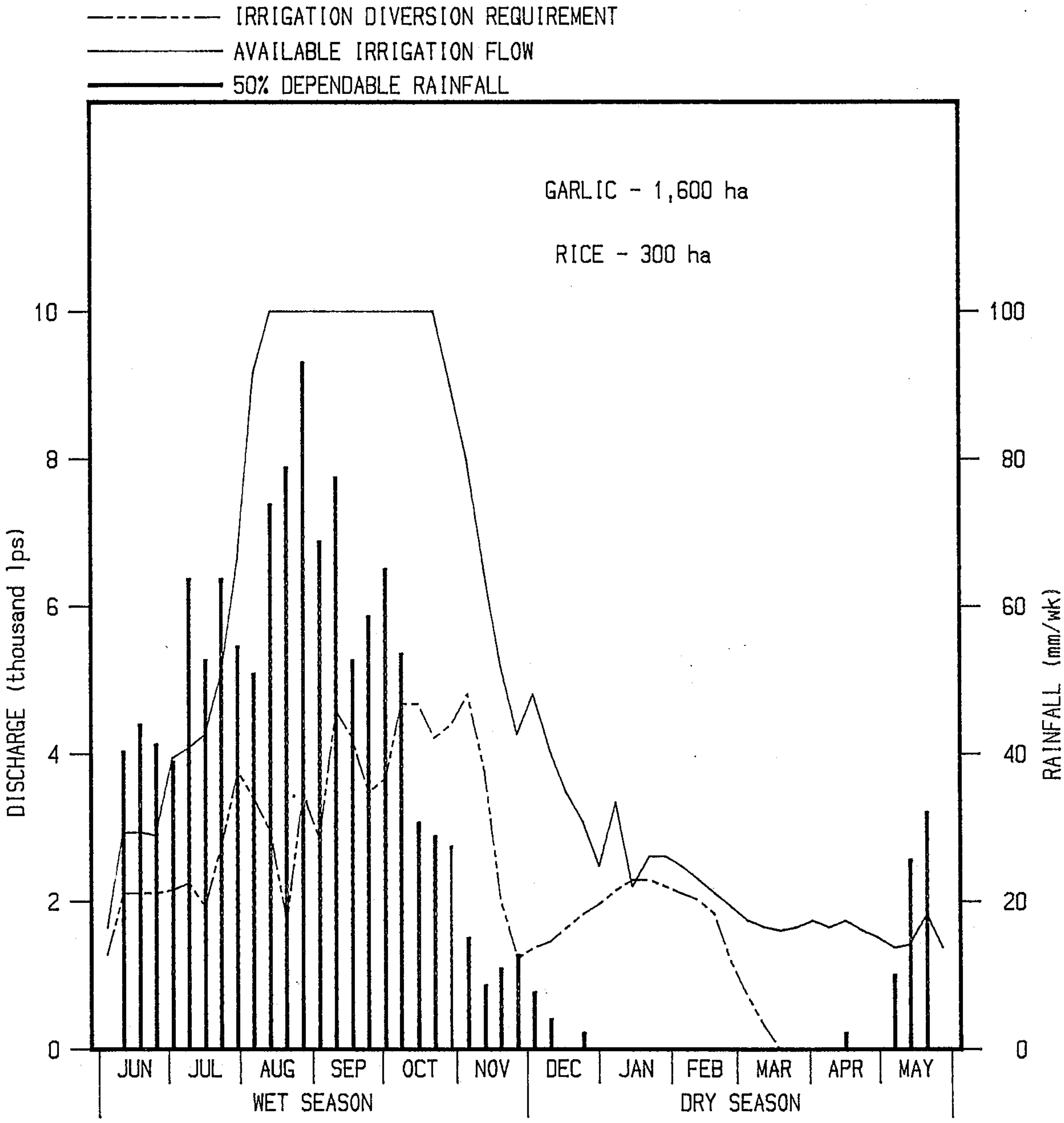


Figure 13. Available irrigation flow, irrigation diversion requirement and dependable rainfall for RICE-GARLIC cropping pattern, Upper Talavera River Irrigation System.

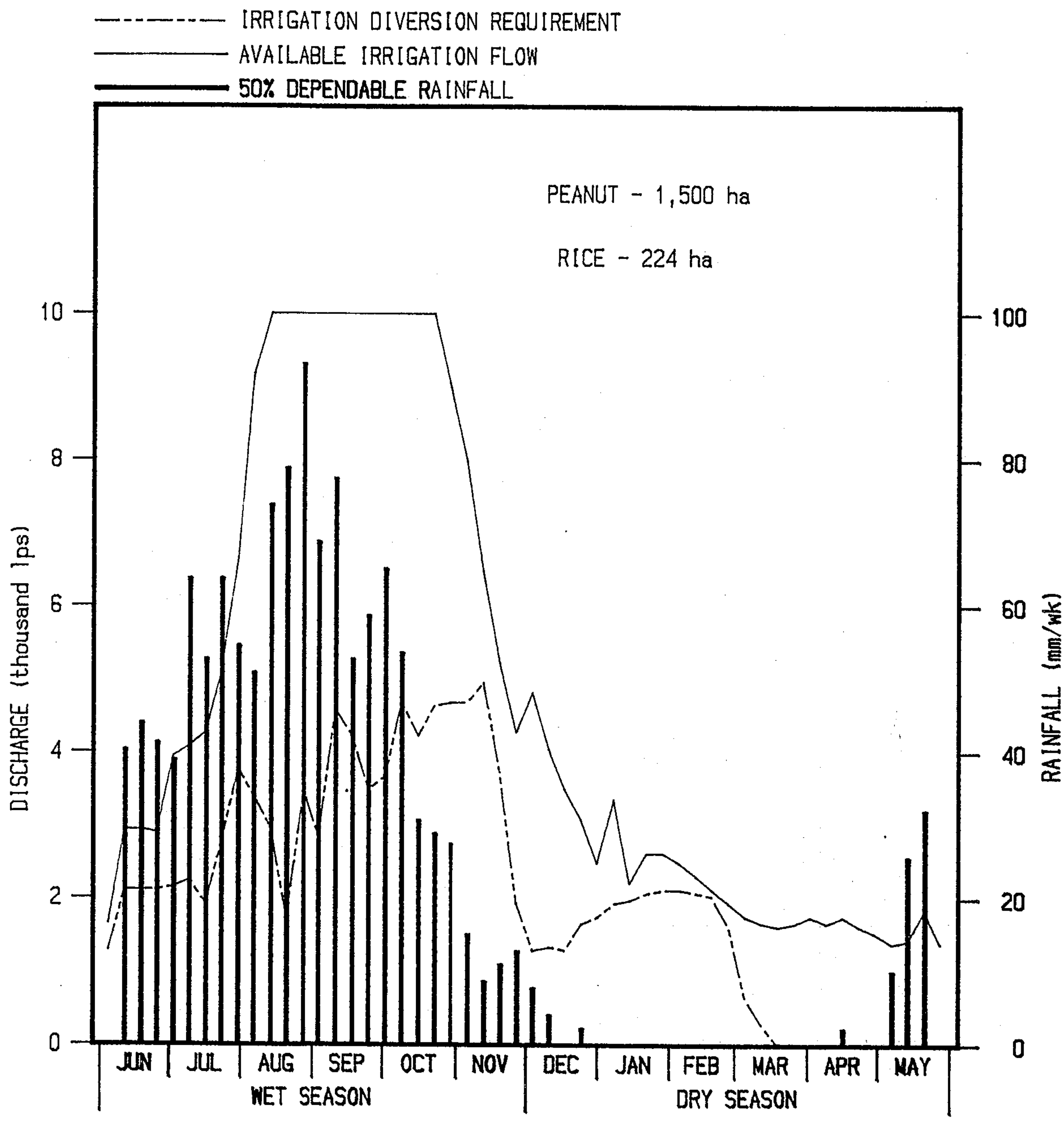


Figure 14. Available irrigation flow, irrigation diversion requirement and dependable rainfall for RICE-PEANUT cropping pattern, Upper Talavera River Irrigation System.

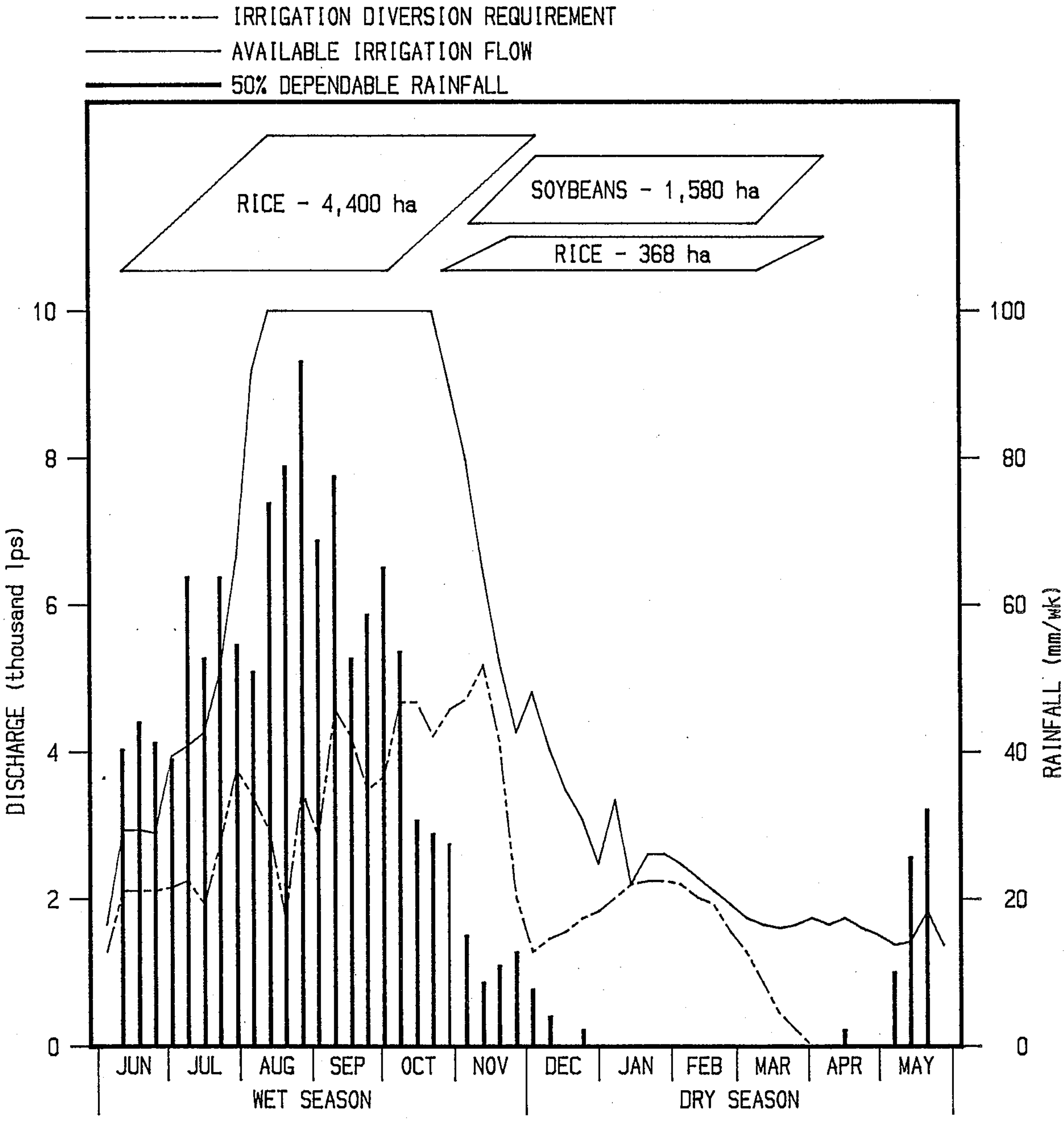


Figure 15. Available irrigation flow, irrigation diversion requirement and dependable rainfall for RICE-SOYBEANS cropping pattern, Upper Talavera River Irrigation System.

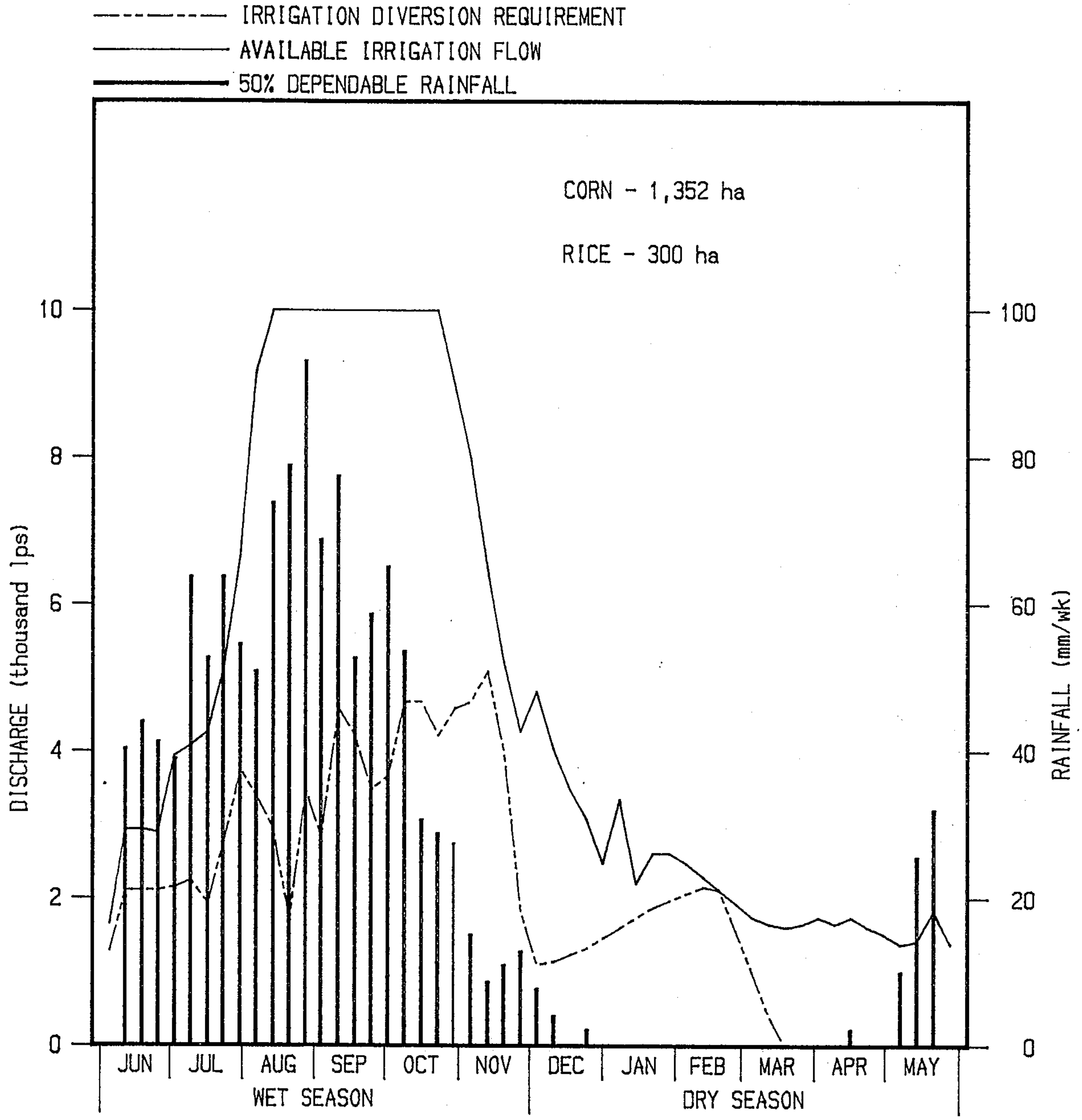


Figure 16. Available irrigation flow, irrigation diversion requirement and dependable rainfall for RICE-CORN cropping pattern, Upper Talavera River Irrigation System.

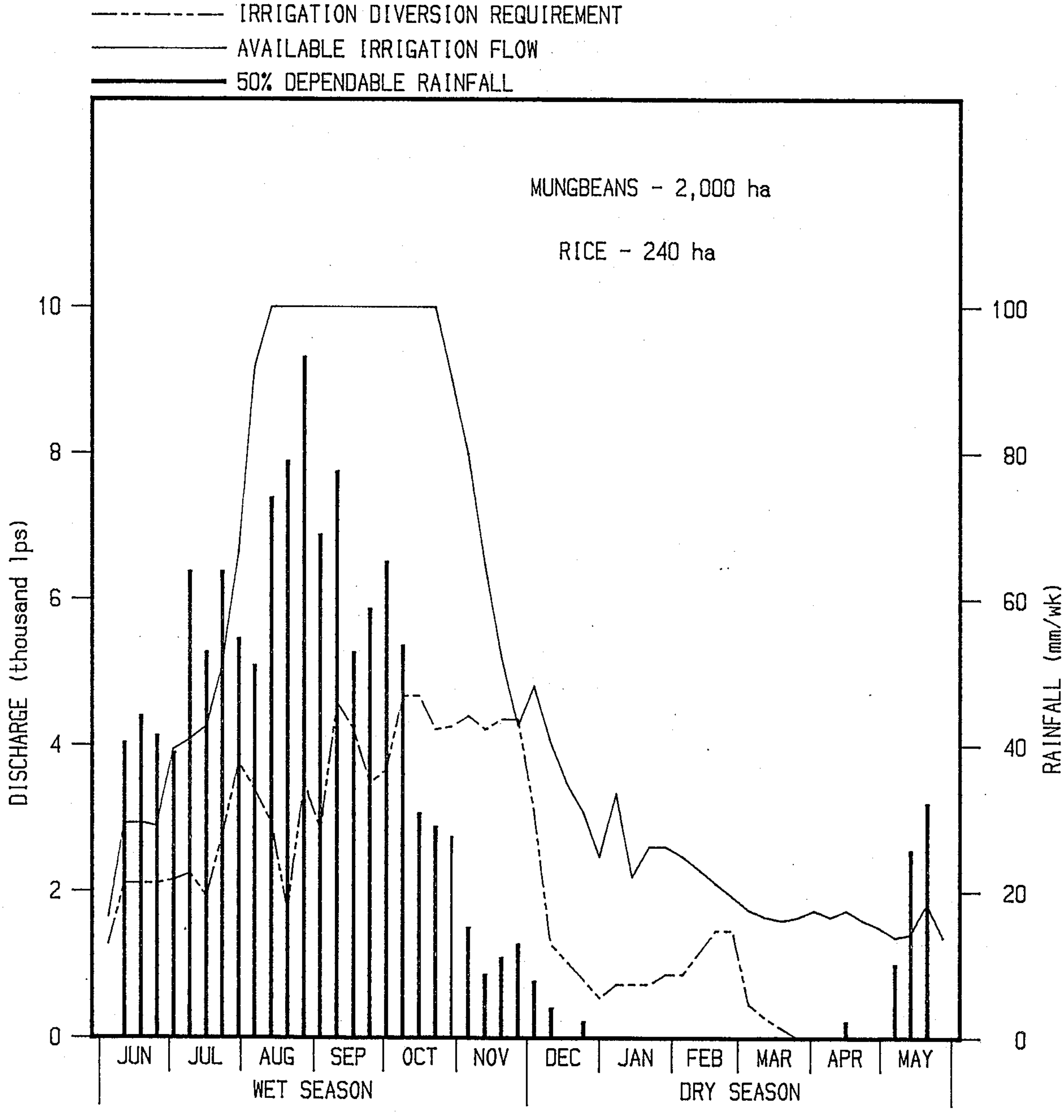


Figure 17. Available irrigation flow, irrigation diversion requirement and dependable rainfall for RICE-MUNGBEAN cropping pattern, Upper Talavera River Irrigation System.

Additional analysis was done to compute the yields and prices at which no additional family income would be derived when shifting from rice to diversified crop production. Computed valued were termed *cut-off* price at current yield and *cut-off* yield at different prices (Table 16)

Table 15. Simulated total gross production value (GPV) and family income (FI) at high, median and low prices, dry season, UTRIS.

Crop	High price		Median price		Low price	
	GPV ('000 P)	FI ('000 P)	GPV ('000 P)	FI ('000 P)	GPV ('000 P)	FI ('000 P)
Garlic	229,880	187,569	133,235	90,924	43,005	694
Onion	158,280	187,569	120,915	70,213	74,685	23,983
Peanut	49,390	32,664	37,659	20,933	25,938	9,212
Soybeans	40,393	21,757	27,752	9,116	22,239	3,603
Corn	36,570	25,795	29,774	17,998	27,792	16,016
Mungbean	25,204	11,355	22,448	8,559	17,484	3,635
Rice	17,581	10,670	15,653	8,741	13,769	6,858

Table 16. *Cut-off* 1/ prices and yields of different diversified crops used in simulation, dry season, UTRIS.

Crop	*Cut-off* price, P/kg at different rice prices			*Cut-off* yields (t/ha) at different crop prices		
	High	Medium	Low	High	Medium	Low
Onion	2.32	2.26	2.21	5.47	7.03	11.34
Corn	2.46	2.27	2.08	2.70	3.12	3.03
Soybeans	9.33	8.85	8.38	1.00	1.48	1.80
Mungbean	9.91	9.21	8.52	0.97	1.01	1.24
Peanut	10.23	9.59	8.96	0.77	0.96	1.35
Garlic	14.72	14.32	13.93	0.43	0.72	2.33

1/ The price and yield at which the total family income when all available water is used to irrigate rice is equal to the family income when all the available water is used to irrigate other crops.

Soybeans, mungbean, peanut and corn have high *cut-off* yields, even higher than yields observed in farmers' fields in other sites. The high *cut-off* yield of these crops make them unattractive substitutes for rice. At all price levels, onion has a *cut-off* lower than most observed yields in farmers' fields. Garlic has a high *cut-off* yield only at low price level. The analysis, therefore, proves the attractiveness of the crops which are currently grown in the area.

THE LAOAG-VINTAR RIVER IRRIGATION SYSTEM

The Laoag-Vintar River Irrigation System (LVRIS) is a run-of-the-river type irrigation system with a total service area of 2377 ha covering Laoag City, Vintar and some areas of Bacarra and Sarrat in the province of Ilocos Norte. The system was recently rehabilitated from 1975 to 1985 through the National Irrigation Systems Improvement Project (NISIP).

LVRIS is one of the eight national systems under the Ilocos Norte Irrigation Service (INIS). INIS is headed by an Irrigation Superintendent (IS). Each system is divided into watermasters divisions directly supervised by a watermaster.

LVRIS has a total canal length of 72.98 km composed of a 27.5-km main canal, seven laterals and five sublaterals. Only curved sections of the main canal which are susceptible to erosion are lined. Due to undulating terrain, the system has a series of closely spaced turnouts serving small areas.

Rice is the main wet season crop in LVRIS. During the dry season, rice is planted upstream and in areas with low elevation. Diversified crops are planted in well-drained light soils, mostly at tail sections. Rice is planted near the main canal and in low elevation areas. Diversified crops are planted at the tail sections and in light and well-drained soils. The total area planted during dry season is about 1500 ha, 800 ha of which is planted to rice. The major non-rice crop grown is garlic. Other crops are tomato, onion, corn, peanut, watermelon, mungbean and vegetables.

The system serves the entire service area of about 2,377 ha during the wet season. Delivery to every programmed area is assured as long as there is enough river flow.

There are other dams, most of which are brush dams on the Vintar River upstream of the LVRIS dam. Service areas of these brush dams range from 600-900 ha. During periods of low river flow, they compete with LVRIS. Low river flows usually occur from February until the end of the dry season. Diversion of water is continuous unless canals are being repaired.

A third crop of mungbean is usually planted in non-rice areas right after the harvest of the second crop during the dry season. Mungbean is exempt from paying irrigation service fee (ISF), thus it is a last priority crop for irrigation.

To determine a scenario for crop diversification at LVRIS, a simulation exercise was undertaken. The crops selected for this exercise were garlic, potato, wheat and tomato.

Land suitability. The suitability map of LVRIS for irrigated diversified crops during the dry season is shown in Figure 13. About 53% of LVRIS service area is highly suitable for diversified crops during the dry season. Most of these areas are located in Lateral F and at the tail-end of the main canal (Table 17).

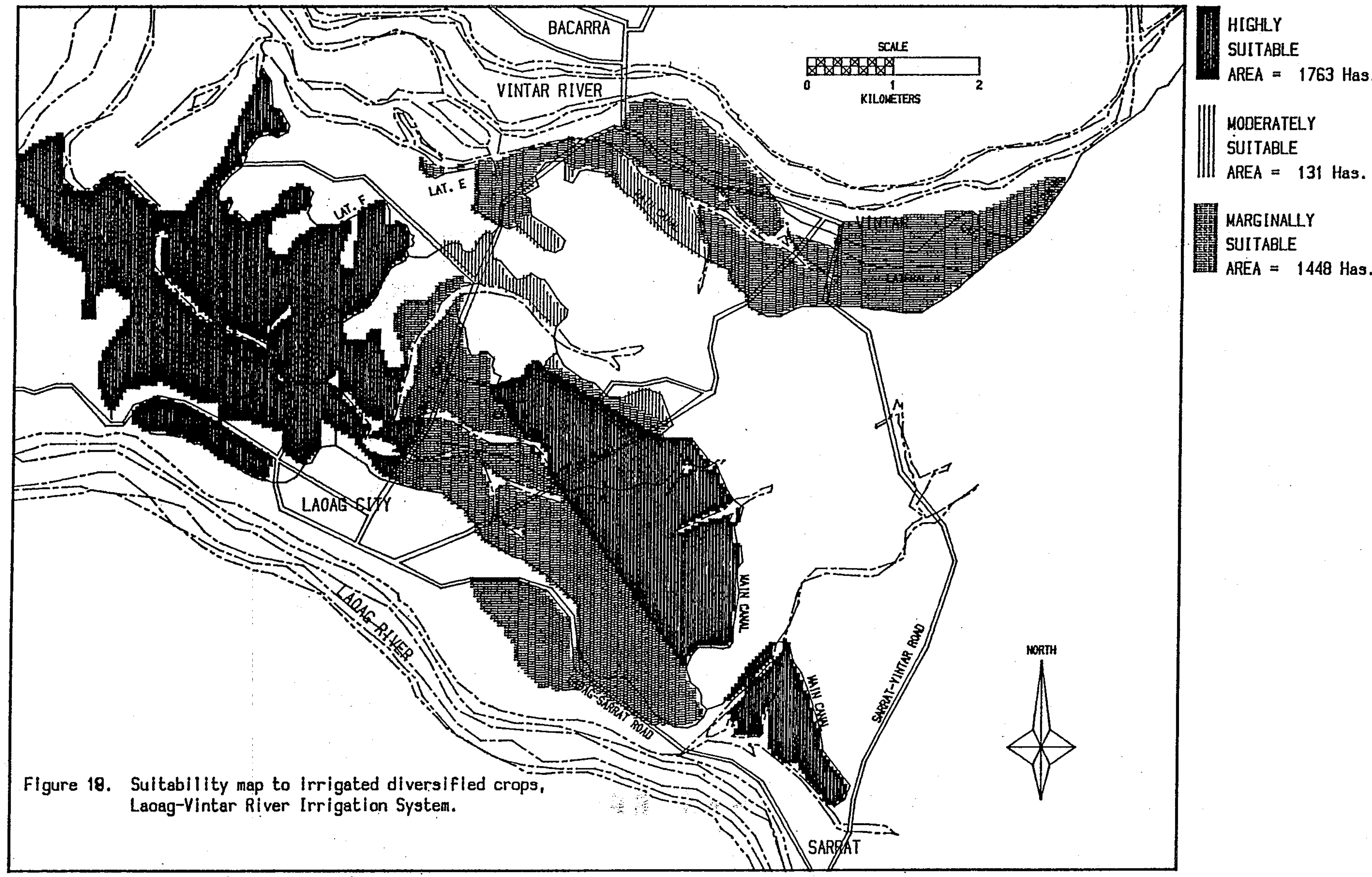


Figure 18. Suitability map to irrigated diversified crops, Laoag-Vintar River Irrigation System.

Table 17. Suitability for irrigated diversified crops during the dry season, LVRIS, Ilocos Norte, Philippines.

Suitability	Location	Area (ha)
Highly suitable	Lateral F, tailend Main Canal & Upstream Lateral G & G1	1,254
Moderately Suitable	Middle Main Canal	93
Marginally Suitable	Upstream Main Canal, tail-end Lateral G & G1 & Lateral H	1,030
	TOTAL	2,377

Available water supply. The probable amount of available water was computed from data on river discharge and rainfall. Data on river discharge at the LVRIS damsite from 1980 to 1987 were summarized on a monthly basis. The river flow is maximum in August at 25,000 lps and minimum in April at 1,779 lps (Table 18).

Table 18. Average monthly river discharge (lps) of the Vintar River at LVRIS Dam, 1980-1989.

Month	1980	1981	1982	1983	1984	1985	1986	1987	Mean
Jan		12670	9690	11452	3164	3240	3538	4770	6932
Feb		2879	7514	7500	1645	2440	2957	1843	3825
Mar		2810	3200	2610	1710	1622	2006	1570	2218
Apr	2270	2350	2550	1067	1675	1810	1460	1050	1779
May	2100	5540	5370	880	5113	1438	1520	820	2848
Jun	9130	15070	8830	1205	10800	46070	1520	5110	12217
Jul	19000	16600	33840	5645	10000	5350	5858	6000	11665
Aug	19000	16600	33840	26258	53290	18097	8153		25034
Sep	21330	16600	26900	17667	14400	8500	4500	54000	20487
Oct	21000	18880	23480	8067	11110	7806	5200		13649
Nov	21000	15430	25600	3980	6100	5000	5890		11857
Dec	17670	13000	12740	3990	3460	4265	12120		9606
Mean	14722	11536	15382	7527	10206	8803	4560	9395	6427

Data on rainfall from 1965 to 1987 were reduced into weekly total rainfall. The incomplete gamma distribution function was used to determine the 50% probable rainfall.

Water Duty. The irrigation water requirement was estimated based on crop and soil demands, irrigation efficiency and canal capacities of the system. For lowland rice, seepage and percolation has a mean value of 4 mm/day for the entire system. Evapotranspiration (ET) was estimated at 5 mm/day during the wet season and 6 mm/day during the dry season. Soil saturation requirement during the wet season was estimatd at 141 mm. This has to be supplied during the first week of irrigation. Land soaking requirement during the dry season was assumed to be zero because of residual soil moisture from the previous wet season crop.

ET for diversified crops was computed using the crop cofficients (Kc's). Kc is the ratio of the actual ET to pan evaporation. The diversified crops grown at LVRIS are garlic, tomato, watermelon, mungbean and vegetables. For these crops, the maximum ET is at about 40-90 days after planting. Details on the computation of water duty are shown in Annex 11.

Yield, production costs and prices. Yield of the crops used in the simulation were based on socio-economic interviews. The highest, lowest and current observed prices were also used. The price of rice did not vary because rice areas were not optimized. Rice yield was assumed as optimum target yield of the *Masagana 99* program (Table 19).

Table 19. Yields, production costs and prices of crops used in simulation, LVRIS.

Crop	Yield (t/ha)	Cost (pesos)	Prices (P/kg)		
			High	Present	Low
Rice	5.00	6,690		3.50	
Garlic	2.25	20,525	70.00	40.00	12.00
Tomato	48.00	5,979	0.35	0.30	0.20
Potato	27.00	25,239	20.00	12.00	7.00
Wheat	1.69	4,197	7.75	7.50	5.70

Simulation considering current area combination of rice and other crops. The system could irrigate the entire service area (2,377 ha) for lowland rice during the wet season and 843 ha for lowland rice and 834 ha for diversified crops during the dry season. Based on canal capacities and available flow, the system should start its wet season operation on the first week of June with one month allocated for land soaking. Assuming transplanted rice with 120-days maturity, transplanting could start on the first week of July. The entire area could be planted by the end of July. By mid-November, the wet season rice crop is expected to be harvested (Figure 14).

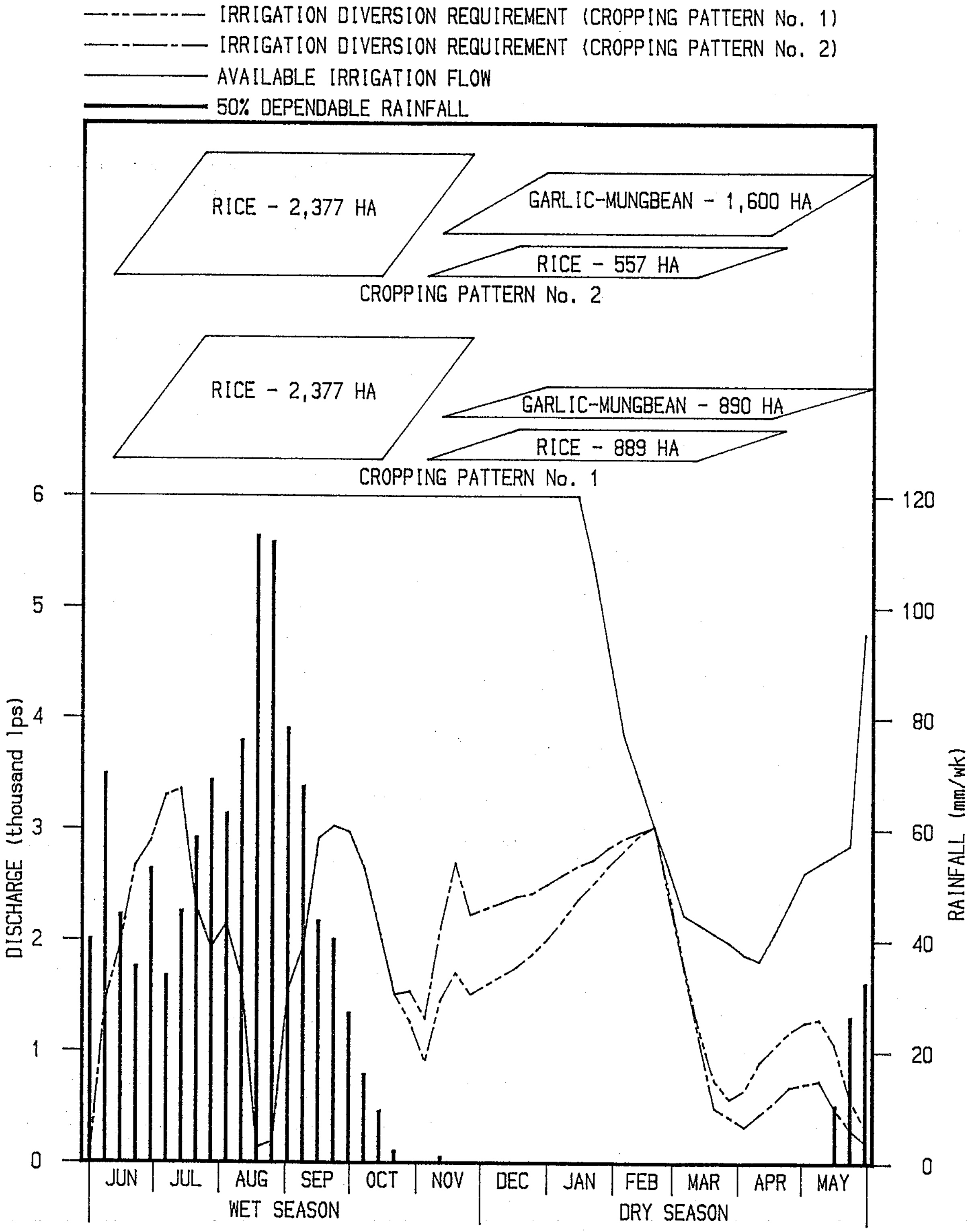


Figure 19. Available irrigation flow, rainfall and simulated irrigation diversion requirement for RICE-GARLIC-MUNGBEAN cropping pattern, Laoag-Vintar River Irrigation System.

For the dry season, heavy textured areas are planted to rice (Figure 15). These could be planted late in November and harvested in March.

Areas suitable for diversified crops could be planted to garlic, tomato, tropical wheat and white potato. The collectible irrigation service fee from this cropping pattern is P705,285. The economic analysis, assuming different prices, is shown in Table 20.

Table 20. Simulated total gross production value1/ and family income, assuming present rice and non-rice area combination (843 ha rice and 834 ha diversified crops), LVRIS.

Crop	Total gross production value ('000 pesos)			Total family income ('000 pesos)		
	high	current	low	high	current	low
Potato	465,113	284,969	172,379	438,424	258,280	145,690
Garlic	146,108	89,813	37,271	123,350	67,055	14,513
Tomato	28,764	26,762	22,759	18,138	16,136	12,133
Wheat	25,676	25,323	22,786	16,536	16,183	13,646

Simulation for optimum diversified crop planted area. In this simulation, all areas highly suitable for diversified crop production was assumed to be planted to diversified crops. This was done by reducing the area planted to rice and shifting the area to diversified crops until all areas highly suitable for diversified crops is planted to any non-rice crop or until the available water is used up. Results showed that 591 ha can be planted to rice and 1,254 ha to diversified crops. The economic analysis was computed using the different crops used in the first simulation. Collectible irrigation service fee was the same as in the first simulation.

In terms of production costs, white potato has the highest followed by garlic, tomato and wheat, in that order (Table 21). At current prices, potato give the highest increase in total gross production value and family income while tomato and wheat give insignificant increases.

Even at the lowest price, white potato gives a significant increase in both gross production value and family income. At the lowest price, gross production value from garlic increases but family income remains constant. At the lowest prices, tomato and tropical wheat decrease in both gross production value and family income.

Summary of simulation results. White potato seem to be the most advantageous crop that should be adopted at LVRIS. Garlic follows, but both of these crops require high production cost at more than P20,000.00 per hectare. Tomato and tropical wheat in comparison give lower production value and farm income. Yield or price increase may improve economic performance of these crops.

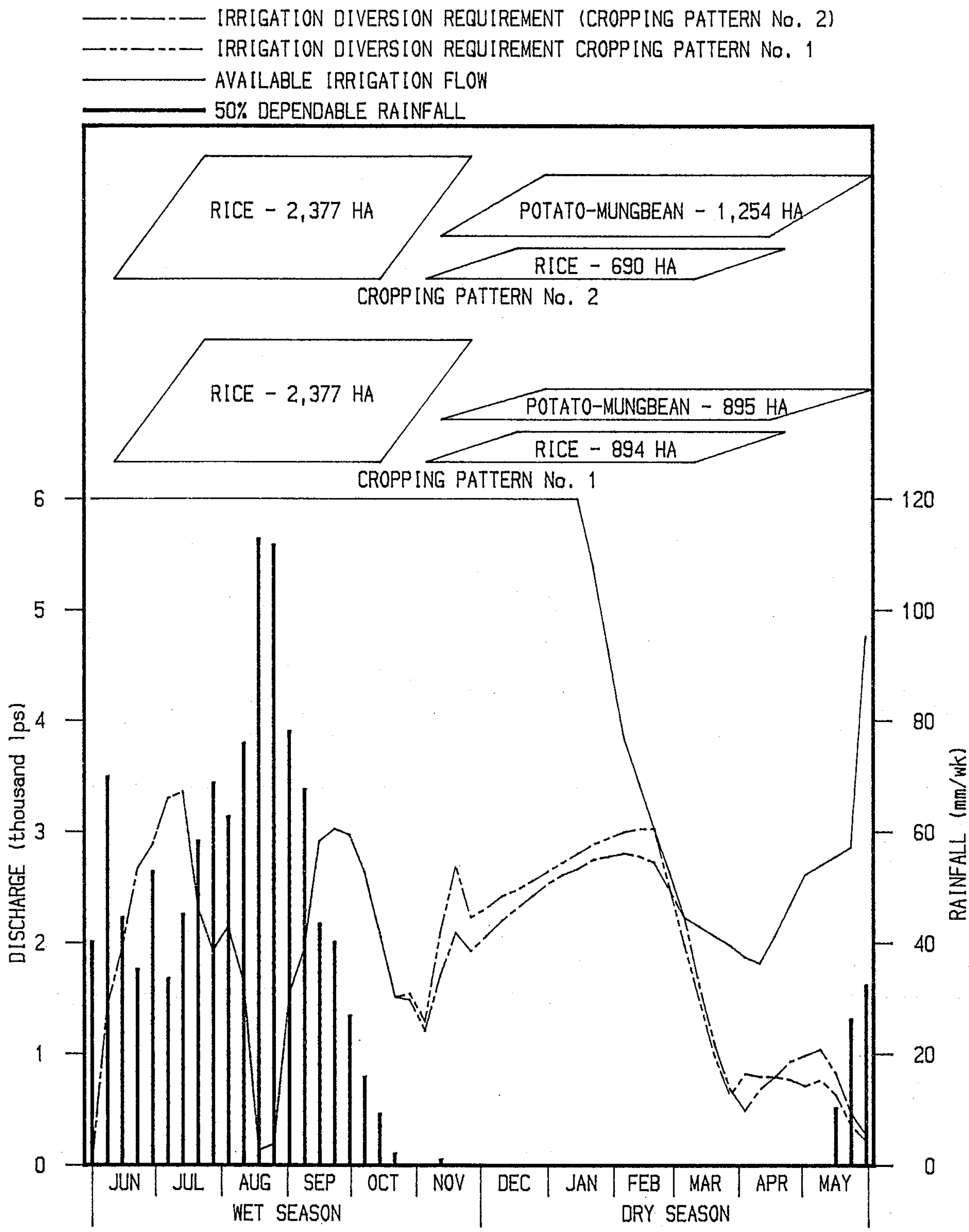


Figure 20. Available irrigation flow, rainfall and simulated irrigation diversion requirement for RICE-POTATO-MUNGBEAN cropping pattern, Laoag-Vintar River Irrigation System.

Table 21. Simulated total gross production value and family income, assuming optimum area planted to diversified crops (591 ha rice and 1254 ha diversified crops), LVRIS.

Crop	Total gross production value ('000 pesos)			Total family income ('000 pesos)		
	high	current	low	high	current	low
Potato	687,503	416,639	247,349	651,899	381,035	211,745
Garlic	207,848	123,203	44,201	178,155	93,510	14,508
Tomato	31,410	28,400	22,381	19,958	16,949	10,929
Wheat	26,767	26,237	22,422	17,550	17,020	13,205

Results of the simulation were subjected to sensitivity analysis (Table 22). Prices of the different crops were varied until the total family income from the current rice/non-rice area combination equals that of the reduced rice/increased non-rice area combination. This price was termed as *cut-off* price. Yield was varied for the different prices until the family income from the two simulations were equal. These yields were termed as *cut-off* yield.

Table 22. *Cut-off* yields and prices for different dry season crops, LVRIS.

Crop	High	current	low	*cut-off*
White potato:				
Prices (P/kg)	20.00	12.00	7.00	1.18
Cut-off yield (t/ha)	1.59	2.64	4.53	
Garlic:				
Prices (P/kg)	70.00	40.00	12.00	12.01
Cut-off yield (t/ha)	0.39	0.68	2.25	
Tomato:				
Prices (P/kg)	0.35	0.30	0.20	0.26
Cut-off yield (t/ha)	35.62	41.55	62.32	
Tropical wheat:				
Prices (P/kg)	7.75	7.50	5.70	6.32
Cut-off yield (t/ha)	1.38	1.42	1.87	

White potato shows an advantage such that *cut-off* yields are much lower than yields attained in farmers' fields. At current mean yield on farmers' fields, the *cut-off* price is also lower than the lowest observed price.

Garlic entails much risk because of high cost of production and the analysis shows that the *cut-off* price is slightly higher than the lowest observed price. At the lowest price the *cut-off* yield is also quite high.

Unless the price of tomato is increased, it is a less lucrative crop compared with garlic, although high yield could also be attained.

Yield from tropical wheat is even lower than the computed *cut-off* yield at the highest observed price. This then poses as a constraint in introducing wheat in LVRIS, unless both prices and yield are increased.

DISCUSSION OF RESULTS

The simulation of UTRIS tested the effects of several crop combinations during the dry season, and compared these with the rice-only option. It was accepted that soil-type constraints would render around 200 ha (5% of the system) unsuitable for crops other than rice. By optimizing the balance (during the dry season only) between rice and another, less water-demanding crop, it was found that all alternatives tested would give significant improvements, in all or nearly all of the performance indicators used, in comparison with the rice-only option (Tables 23 and 24).

To address price fluctuations, Tables 23 and 25 show parallel results which are derived under pessimistic price assumptions. With prices near or below the minimum of recent times, all six alternative crops would be better than rice in terms of crop intensity, gross production value, irrigation fees generated, and productivity of water applied. Three of the six would (at these low prices) generate less net farm income, but the other three, corn, onion and peanuts, pass this test by ample margins.

Simulations of LVRIS tell a very similar story, which is summarized (Table 25). An optimal cropping pattern with a reduced rice area could bring about significant gains in the performance indicators.

The simulations of UTRIS and LVRIS using the *break-even* or *cut-off* prices showed that the alternative crops are more profitable (Table 26). For each of the six alternative crops, the ratio of its price to the price of rice is higher than the *cut-off* prices or the prices at which net returns from non-rice crops are equal to net returns from rice. Past prices may show how other non-rice crops have exceeded these *break-even* levels.

As noted earlier, the prices of most of alternative crops are more volatile than rice, and most farmers (because of lack of credit and/or storage facilities) are usually obliged to sell their outputs when prices are lowest. Thus, in assuming these *break-even* prices, they should not be compared with annual average prices, but with annual minima.

Table 27 shows the ratio of annual minimum and annual average in recent years. This has been used to estimate (see Table 26, last column) the break-even ratios between annual average prices of diversified crops to the annual average prices of rice. Throughout the past 12 years, the various alternative crops generally had prices significantly above the break-even levels (Table 28). Corn and onion prices stayed consistently well above the break-even level; garlic and mungbean dipped below in only two of the twelve years. In these systems, the most likely alternative crop (considered in these favorable projections) is corn, which (see Table 29) does not experience the price fluctuations of some of the other crops, such as onion, garlic and mungbean. Indeed, corn price is even more stable than that of rice.

Table 23. Key results from simulations of alternative cropping patterns for UTRIS.

Crops	Optimal Propor- tions	Crop Intensity (%)	Gross Value Product	Net Returns	Irrigation Service Fees	Gross Water Utilized (mil cm)	Water Product- ivity (P/cm)
			(	million pesos	)		
			Assuming current median crop prices				
Rice	100	23.0	15.65	8.74	0.330	21.93	0.71
Rice/Mungbean	11:89	57.4	22.45	8.56	0.882	7.62	2.94
Rice/Corn	18:82	42.4	29.77	18.00	0.681	15.83	1.88
Rice/Soybean	19:81	49.9	27.75	9.12	0.806	18.65	1.49
Rice/Peanut	13:87	44.2	37.66	20.93	0.688	17.14	2.20
Rice/Onion	16:84	48.7	120.91	70.21	0.772	17.66	6.85
Rice/Garlic	16:84	48.7	133.24	90.92	0.772	17.66	7.54
			Assuming low crop prices				
Rice	100	23.0	13.77	6.86	0.330	21.93	0.63
Rice/Mungbean	11:89	57.4	17.48	3.64	0.882	7.62	2.29
Rice/Corn	18:82	42.4	27.79	16.02	0.681	15.83	1.76
Rice/Soybean	19:81	49.9	22.24	3.60	0.806	18.65	1.19
Rice/Peanut	13:87	44.2	25.94	9.21	0.688	17.14	1.51
Rice/Onion	16:84	48.7	74.69	23.98	0.772	17.66	4.23
Rice/Garlic	16:84	48.7	43.01	0.69	0.772	17.66	2.44

Table 24. Key results from simulations of alternative cropping patterns for UTRIS, ratio of performance parameters in diversified and undiversified options.

Dry Season Crops	Crop Intensity	Value Product	Gross Net Returns	Irrigation Service Fees	Water* Productivity
		Assuming current median crop prices			
Rice only	1.00	1.00	1.00	1.00	1.00
Rice-Mungbean	2.50	1.43	0.98	2.67	4.14
Rice-Corn	1.84	1.90	2.06	2.06	2.65
Rice-Soybean	2.17	1.77	1.04	2.44	2.09
Rice-Peanut	1.92	2.41	2.39	2.08	3.08
Rice-Onion	2.12	7.73	8.03	2.34	9.59
Rice-Garlic	2.12	8.51	10.40	2.34	10.57
		Assuming low crop prices			
Rice only	1.00	1.00	1.00	1.00	1.00
Rice-Mungbean	2.50	1.27	0.53	2.67	3.63
Rice-Corn	1.84	2.02	2.34	2.06	2.80
Rice-Soybean	2.17	1.62	0.52	2.44	1.90
Rice-Peanut	1.92	1.88	1.34	2.08	2.41
Rice-Onion	2.12	5.42	3.50	2.34	6.74
Rice-Garlic	2.12	3.12	0.10	2.34	3.88

Table 25. Key results from simulations of alternative cropping patterns for LVRIS.

Dry Season Crops	Propor- tions	Assumed Price Level	Crop Intensity (%)	Gross Value Product (M pesos)	Net Returns (M pesos)	Water Product- ivity (P/cu.m.)
Rice-Garlic	50:50	current	70.6	89.81	67.05	2.53
Rice-Garlic	50:50	low	70.6	37.27	14.51	1.05
Rice-Garlic	32:68	current	77.6	123.20	93.51	3.47
Rice-Garlic	32:68	low	77.6	44.20	14.51	1.24

Table 26. Break-even prices of alternative non-rice crops.

Crop	Break-even price (P/kg)	Ratio of break-even price to rice price	Required ratio of annual average price to rice price to ensure minimum is not below break-even
Mungbean	9.21	2.63	2.92
Corn	2.27	0.65	0.63
Soybean	8.85	2.53	
Peanut	9.29	2.74	
Onion	2.26	0.65	1.28
Garlic (UTRIS)	14.32	4.09	11.67
Garlic (LVRIS)	12.01	3.43	9.79

Table 27. Monthly average farmgate prices of rice and selected non-rice crops, 1988-89.

	Average Farmgate Price (P/kg)				
	Rice	Corn	Mungbean	Onion	Garlic
1988					
Jan	3.06	3.67	11.46	4.31	45.00
Feb	3.29	3.53	10.70	3.79	19.67
Mar	3.45	3.83	11.26	5.26	19.40
Apr	3.40	4.25	11.53	7.33	46.69
May	3.53	4.28	11.70	12.59	54.67
Jun	3.58	4.13	11.57	13.88	92.25
Jul	3.61	3.94	11.51	n.a.	115.50
Aug	3.74	3.92	14.13	n.a.	110.00
Sep	3.60	3.77	11.67	n.a.	75.00
Oct	3.30	3.72	13.47	13.83	n.a.
Nov	3.31	3.08	13.73	14.56	n.a.
Dec	3.45	3.97	15.30	10.44	n.a.
1989					
Jan	3.54	3.84	19.04	11.77	85.50
Feb	3.63	3.90	16.49	7.89	39.50
Mar	3.83	4.12	15.63	5.82	69.34
Apr	4.03	4.38	13.24	6.48	60.22
May	4.05	4.42	14.36	6.12	69.90
Jun	4.14	4.39	16.83	6.15	69.59
Jul	n.a.	n.a.	16.69	9.26	61.19
Aug	n.a.	n.a.	17.80	8.86	68.49
Coefficient of Variation (%)	8.1	6.6	18.1	40.5	41.5
Minimum/Mean	0.853	0.881	0.769	0.434	0.299

n.a. - data not available

Table 28. Ratio of annual average price of alternative non-rice crops to price of rice.

	Mungbean	Corn	Onion	Garlic
Required ratio for break-even	2.92	0.63	1.28	10.73
1978	4.89	1.24	3.07	10.58
1979	4.33	1.14	3.37	13.72
1980	5.32	1.23	3.06	19.83
1981	5.38	1.23	3.39	26.76
1982	4.78	1.16	2.79	17.02
1983	4.86	1.16	5.59	14.92
1984	2.28	1.18	2.68	21.37
1985	2.10	1.10	2.83	16.86
1986	5.00	1.23	3.06	11.56
1987	4.44	1.19	2.61	9.37
1988	4.37	1.15	4.62	32.71
1989	3.97	1.08	2.76	27.33

Table 29. Annual average wholesale prices of rice and selected non-rice crops, adjusted to constant 1987 terms.

	Rice	Corn	Mungbean	Onion	Garlic
1978	2.97	3.69	14.53	9.11	31.43
1979	2.95	3.37	12.78	9.95	40.46
1980	3.05	3.74	16.22	9.32	60.47
1981	3.05	3.75	16.40	10.33	81.62
1982	2.92	3.39	13.97	8.14	49.71
1983	2.96	3.44	14.38	16.55	44.16
1984	3.18	3.76	14.35	8.51	67.96
1985	3.39	3.73	14.50	9.58	57.14
1986	2.93	3.61	14.64	8.96	33.87
1987	3.07	3.65	13.63	8.02	28.78
1988	3.21	3.68	14.03	14.83	105.00
1989	3.29	3.55	13.07	9.07	89.90
Mean	3.08	3.61	12.59	10.20	57.54
Std. Dev.	0.154	0.143	4.55	2.68	24.49
C.V. (%)	5.0	4.0	36.2	26.3	42.6

SUMMARY AND RECOMMENDATIONS

The simulation studies determined the *break even* prices above which each of the alternative non-rice crop becomes more profitable than rice. These are illustrated in Tables 26 to 27. The prices of onion and corn have stayed consistently above the *break even* level for the last twelve years while the prices of garlic and mungbean have dipped twice below this *break even* level.

The volatility of the average annual and monthly prices for non-cereal grain crops suggests the need for post-harvest technology (handling and storage) for these crops (Tables 28 and 29). With better post-harvest technology for the non-cereal grain crops, fluctuation in prices will be reduced. This will subsequently reduce the risk of farmers in growing these crops.

Potential of irrigated diversified cropping. The simulation studies for ARIP, BARIS, LVRIS and UTRIS demonstrated that increased diversification should produce substantial gains in cropping intensity, gross production value, water productivity and net income. The assumptions made were realistic but will also require improvement in the equity and reliability of irrigation water delivery, among other things.

Simulation studies could assist in optimizing cropping patterns. The results of these simulations could serve as guides in making projections as to which non-rice crop will most likely produce substantial gains in cropping intensity, gross production value, water productivity and net income. At BARIS and ARIP, corn was identified to be most likely adopted by farmers if the price is high enough, irrigation and drainage facilities are provided, and farmers adhere to the schedules of water delivery. Leaving some areas for rice cultivation and planting of corn in December is the most promising dry season cropping pattern. Although no simulation study was done for TASMORIS, the survey data show that corn is the most promising dry season crop in this system. Its adoption in more areas during the dry season is recommended to increase the cropping intensity and net income of farmers.

At UTRIS, the dry season cropping pattern recommended is the cultivation of rice in areas with heavy soils planting of onion in December and in areas with medium-textured soils which are mostly on the right side of the main canal. Other non-rice crops with greater profitability than rice were peanut, garlic and corn. This cropping pattern will only be viable if more farmers will participate through the IAs, and irrigation and control facilities are provided with more active involvement of NIA field staff.

At LVRIS, the crops recommended for planting during the dry season are lowland white potato, garlic and tomato. Lowland white potato has the highest profitability even when prices are low compared to rice and other non-rice crops. However, its high production costs and difficulty in procuring seed materials might not make this crop attractive to farmers. Nonetheless, these three crops are the most profitable crops for this system. Improvement in the equity and reliability of irrigation water delivery will increase water productivity, cropping intensity and net income at LVRIS.

This entails more participation of farmers as supported by the NIA field staff in the planning and implementation of irrigation water delivery schedules.

Corn as a dry season alternative crop to rice is recommended in the Mindanao sites and in TASMORIS. However, unless the high cost of transporting corn from Mindanao to the feed mills in Cebu and Manila is not mitigated, the production of irrigated corn will not prosper. For non-cereal grain crops, like garlic, onion, peanut, soybean and lowland white potato, credit, post-harvest technology, marketing and infrastructure support will have to be provided if stability of prices is to be attained and risks reduced.

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