IIMI-INDONESIA CROP DIVERSIFICATION RESEARCH

Sam H. Johnson III and Douglas L. Vermillion*

CROP DIVERSIFICATION IN INDONESIA

Indonesia, one of the largest rice consuming countries in the world, has a per capita consumption close to 150 kilograms (kg)/year, up from 99 kg/year in 1975. Indonesia has been self-sufficient in rice production since 1984, and now produces a small surplus. This transformation from the world's largest rice importer in the 1970s has been achieved through a combination of irrigation development and agricultural improvements.

Rice is the most important irrigated crop. Indonesia has about 5.1 million hectares (ha) of irrigated land; 4.1 million ha are under government systems and the remainder are under village systems. In the November-March wet season, almost all the cultivated land is planted to rice, while in the first dry season (March-July), depending on reliability of irrigation, rice is planted on 30-100 per cent of the irrigated land. But, in the second dry season (August-November), almost all this land is planted to non-rice crops.

According to the Department of Public Works, in 1984 about 88 per cent of the irrigated land served by government was planted to rice in the wet season. Of the remainder, 171,000 ha went to grow irrigated non-rice crops and 136,000 ha to irrigated sugarcane. In the two dry seasons, about 58 per cent of the area was planted to rice, but more than 1 million ha were planted to irrigated non-rice crops and 180,000 ha to irrigated sugarcane. Unfortunately, available statistics do not differentiate between the two dry seasons, so it is difficult to identify the mix of rice and non-rice crops. However, if the data from East Java (where the areas in non-rice crops are reported separately for each dry season) are used, it appears as if the areas in dry season rice and first dry season non-rice crops are almost equal, around 40 per cent of the available irrigated land. In the second dry season, again about 40 per cent of the irrigated land is in non-rice crops but, due to water shortages and pest control measures, the land in rice is very small.

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE CROP DIVERSIFICATION STUDY

Study Purpose

The purpose is to identify the physical, managerial, and institutional changes in irrigation management that must be made before non-rice crops can be more intensively cultivated in irrigation systems developed primarily for rice cultivation. The study also examines the technical and socioeconomic factors constraining more intensive palawija (non-rice) cropping during those crop seasons when water is insufficient to grow rice.

---

*Resident Scientist and Post-doctoral Fellow, International Irrigation Management Institute - Indonesia.

The crop diversification component of IIMI's Indonesia research has broader implications than irrigation management alone. Clearly, physical, biological, institutional, and economic factors also play an important role in determining the farmer's decision to grow palawija crops. However, as much as possible, IIMI's study is limited to the critical role of irrigation management in the diversification process.[1] To date, very little comparative irrigation research in Asia has concentrated on field irrigation practices for non-rice crops. This study collects data on the varying crops and labor requirements associated with the different irrigation practices used, with the assumption that these are key aspects of the diversification process.

Water Management Practices

When rice paddies are flooded, it is fairly simple to determine if they have sufficient moisture, but with non-rice crops moisture adequacy is much more difficult to determine but equally critical. One proven measure of system performance is to track field level soil moisture adequacy throughout the entire season. This variable is directly linked to irrigation management practices, in particular, irrigation rotation schedules. The study monitors available soil moisture in a set of "intensive" plots, where water balance is tracked, and in "extensive" plots, where both soil moisture and plant growth are tracked. The intensive and extensive plots are aggregated into research blocks. Irrigation management practices are also monitored in order to relate soil moisture status to particular management decisions.

Irrigation Practices for Palawija Crops

Farmers generally grow irrigated, lowland rice using flooded basins with continuous water flows, if possible. For irrigated palawija crops, they use a variety of bed arrangements and irrigation methods, the choice of which is influenced by physical considerations, including water and labor availability, soil type, depth to groundwater, drainage, pest prevalence, and climate. In addition, socio-economic considerations, such as local knowledge and acceptance, secure markets, transportation, price stability, off-farm employment alternatives, and timely availability of chemical inputs and seed are all important determinants of which palawija crop to plant.

In each research block, four to six irrigated palawija plots were selected. Every irrigation application into these plots is being measured, and weekly soil samples and farmer interviews are being made. In addition to the weekly field data, observers also collect daily rainfall and pan evaporation data for each block. Thus it is possible for a water input-output model to be developed for each intensive irrigated palawija plot. This data will help answer questions about farmers' actual field irrigation practices for palawija crops across much of Java. Table 1 presents a sample of the data from the intensive plots for the second dry season (July-November) 1986, and shows that there is not much over-irrigation, when the amount of irrigation water actually applied is compared to the evapotranspiration requirements. The data for Central Java from Table 2 show that the fields in Pemali Comal are, in general, continuously wet. This condition is not good for many palawija crops, particularly soybeans, and may well explain the extremely low yields for palawija crops in the research areas.

Table 1. Field irrigation rates (in millimeters) and yield (in kilograms per hectare) for selected non-rice crops, July-November 1986.

Location/code	Device	Crop	TI	Amount	ET	RF	Yield
Nganjuk - East Java							
EJWJ00099030	Tho	Soybean	3	85.1	382	0	828
00099008	Tho	Maize	3	211.1	453	0	2946
29208011	Tho	Soybean	1	81.1	404	0	380
00099060	Tho	Soybean	2	52.6	363	0	780
Gung - Central Java							
CJGUJT00578	Tho	Maize	1	31.7	281	66	3478
00290	Cip*	Maize	3	127.1	332	93	na
002139	Cip*	Maize	3	246.3	316	75	na
002021	Cip*	Soybean	1	14.2	344	0	625
005115A		Peanut	3	121.0	234	69	2446
CJPSCK007032	Cut	Maize	2	133.7	253	91	1100
Cirebon - West Java							
WJCWMT001033	Cut	Long bean	6	166.7	226	28	1869
001033	Tho	Mungbean	4	86.7	223	32	176
001026	Cut	Peanut	2	172.9	250	36	1297
001026	Tho	Long bean	5	151.5**	158	23	1463
002061	Cip*	Peanut	4	120.2	255	65	1216
001027	Cip	Maize	7	232.8	299	40	na

Measuring device: Tho = Thomson, Cip = Cipolletti, Cut = Cutthroat; TI = number of times irrigated; Amount = amount of water applied; ET = estimated evapotranspiration; RF = effective rainfall. *Some water readings were above the acceptable level for this type of measuring device; data for these fields are indicative only. **After rechecking the exact area for this field.

In many cases there was very little need to irrigate. In fact, in some of the intensive plots for the July-November 1986 dry season, the farmers were able to harvest a crop without applying any additional water. Further research will explore alternative irrigation practices and obtain better information on depth to groundwater during the two dry seasons.

Because of the small sample from the intensive plots, three additional data sets are being collected. The first contains extensive data on a larger sample of plots, generally 20-25, in each block. This data set monitors soil moisture conditions and crop development but does not measure actual irrigation flows into the fields. A second set represents a 50 per cent sample of all the plots in each block. This sample provides additional data on planting dates, yield levels, and farmers' irrigation practices for palawija crops in every research block. Based on this data, irrigation practices for non-rice crops can be classified. Figure 1 shows the initial classification of

Table 2. Dates of irrigation and soil samples, and soil moisture status of research plots, Central Java, July-November 1986.

Plot code and crop	Irrigation date	Soil sample date	Average of three samples 10 cm	20 cm	30 cm
CJGUJT002139 - maize planted 01 Aug 86					
		30 Aug	M	M	M
		05 Sep	M	M	M
		12	M	M	M
	22 Aug	19	W	W	W
		26	M	M	M
		03 Oct	D	M	M
	09 Sep	10	W	W	W
		17	M	M	M
	21	24	W	W	W
		01 Nov	W	W	W
		08 Nov	***** harvest *****		
CJGUJT005115A - peanut planted 29 Jul 86					
		18 Aug	M	W	W
		26	M	M	W
		02 Sep	M	M	W
		08	M	M	W
	12 Sep	17	M	W	W
		24	M	W	W
		01 Oct	M	M	M
		08	D	M	M
		14	D	M	M
	15 Oct	21	M	M	M
		28	***** harvest *****		
CJPSCK007032 - maize planted 09 Sep 86					
	08 Sep*	18 Sep	W	W	W
		25	M	W	W
	31-9	02 Oct	W	W	W
		09	W	W	W
		16	M	M	M
		23	M	M	M
		30	M	M	M
		06 Nov	W	W	W
		13	***** harvest *****		

*Received 42mm of rain; W = wet, M = medium, D = dry.

some of these systems with both their local Indonesian names and the nearest English equivalent. Table 3 draws from the 50 per cent sample studies to relate type of crop grown to field irrigation land shapes.

Figure 1. Irrigated land shapes for various crops, Java, 1986.

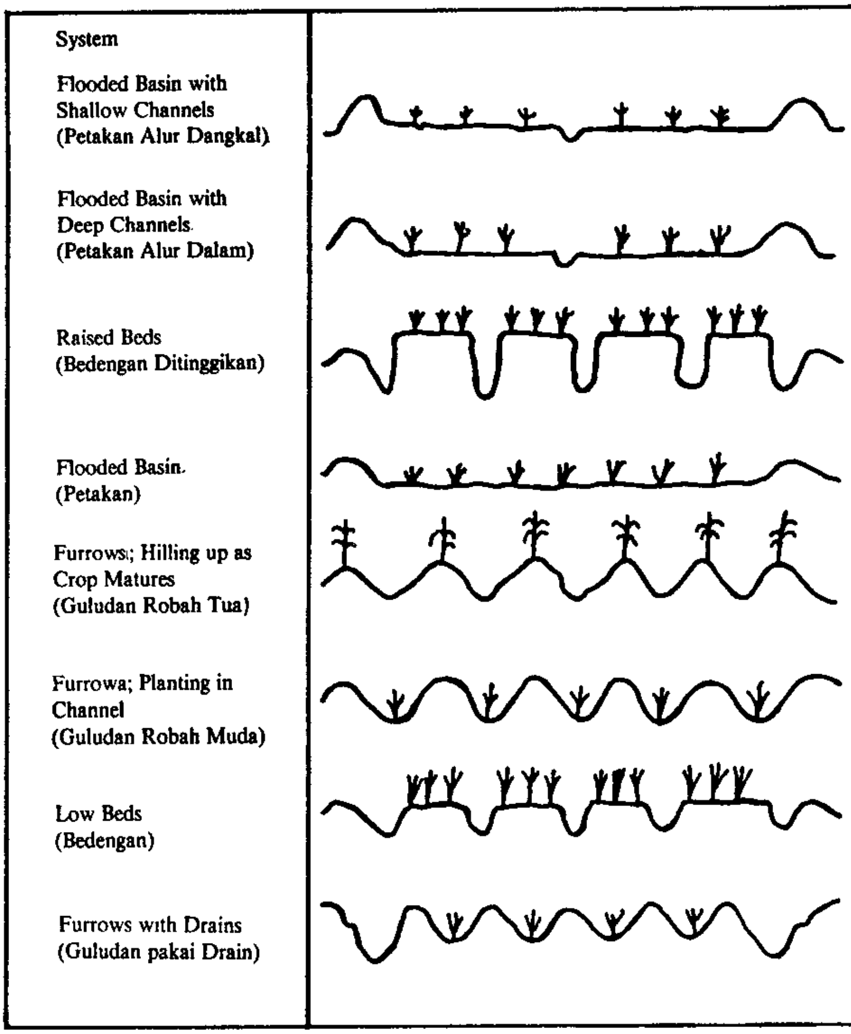


Table 3. Field irrigation land shapes for non-rice crops at IIMI research sites, dry season 1986.

Crop	Irrigation Practice
Corn	Furrows; hilling up as plant matures
Soybean	Flooded basins with shallow channels
Cassava	Furrows; hilling up as plant matures
Peanut	Flooded basins with shallow channels
Mungbean	Flooded basins with shallow channels
Rice	Flooded basins
Sugarcane	Furrows; hilling up and sugarcane beds
Long bean	Flooded basins with shallow channels
Cucumber	Low and raised beds
Shallot (red onion)	Raised beds

The third data set, which has just been completed, attempts to better understand how farmers decide to plant palawija crops. Additional data were collected to define the costs of converting land to the different irrigation land shapes. Preliminary estimates of these costs are presented in Table 4.

Table 4. Average labor inputs (in hours per hectare) for preparing different irrigated land shapes, Java, 1986.

Application method	Wet season	1st dry	2nd dry
West Java			
Flooded basin	392.1 (n=16)	360.2 (n=13)	
Flooded basin, shallow channel	333.5 (n=12)	385.3 (n=6)	
Flooded basin, deep channel			
Fixed furrows			
Hilling up from furrows (early)			
Hilling up from furrows (late)			
Low beds			345.1 (n=14)
Raised beds		528.1 (n=6)	757.9 (n=8)
Central Java			
Flooded basin	383.6 (n=34)	416.4 (n=25)	417.0 (n=9)
Flooded basin, shallow channel	511.0 (n=5)	188.8 (n=8)	308.5 (n=15)
Flooded basin, deep channel			
Fixed furrows	603.0 (n=10)	544.7 (n=10)	
Hilling up from furrows (early)			179.5 (n=8)
Hilling up from furrows (late)	917.6 (n=5)	917.6 (n=5)	
Low beds			
Raised beds			
East Java			
Flooded Basin	226.1 (n=65)	212.7 (n=54)	240.1 (n=12)
Flooded Basin, shallow channel		118.8 (n=5)	99.1 (n=15)
Flooded Basin, deep channel			
Fixed furrows			
Hilling up from furrows (early)			503.5 (n=5)
Hilling up from furrows (late)			234.2 (n=30)
Low beds			
Raised beds			

n = size of sample.

Table 4 shows that costs vary by location as well as by season. Assuming that labor works 7-hour/day and that the average wage rate is US$1.81/day (US$1.00 = Indonesian rupiahs 1,514), land preparation costs for conversion from rice to palawija crops would range from US$25-238. Averaging is difficult because of the wide variation in practices by location, but for all the provinces a good first estimate is US$77-91/ha for land conversion from rice to a palawija crop and back to a rice crop.

Irrigated Palawija Crops

The results of IIMI's literature and research review is that only limited information exists on irrigated non-rice crops. Most research on secondary crops is focused on non-irrigated land at higher topography, consequently the results are only partially relevant to the present study. In order to address this problem, a two-round agro-economic field survey was implemented. However, the research schedule, which is dependent on cropping schedules, did not fit well with the times fixed for project reporting, and additional data on crop location and crop production calendars were collected from the research blocks. From this data it is possible to establish yield levels and up-to-date crop budgets and, thereby, examine the relative profitability of the various palawija crops. The returns in turn can be compared to returns from rice production during the same season to identify one set of possible "incentives/constraints" to crop diversification. Appendix I contains a set of "representative" crop budgets[2] from the three provinces. These budgets are representative in that they represent the usual situation in the provinces but, due to the small sample sizes, do not purport to be average.

What is not apparent from the crop budgets is the variation in yields and rates of return that exist for the various crops, particularly the palawija crops. Table 5 shows that non-rice crops generally have lower mean returns and higher standard deviations than rice. This implies that palawija crops are currently more variable in terms of production returns and, therefore, more risky. This risk, if proven to be representative of irrigated non-rice crops in Indonesia, is a major constraint to expanding diversified crops. Given that the data comes from some of the best irrigated areas in Indonesia, uncertainty must be even greater for more marginal areas.

Table 5. Comparison of average yields (in tons per hectare) and standard deviations (SD) for irrigated non-rice crops in Central Java research blocks, wet season, 1985-86.

Crop		Jarot 5	Jarot 2	Ck 7 kn	Ck 3
Maize	Avg	5.04	3.14		
	SD	2.57	0.39		
Soybean	Avg	0.83	1.33		
	SD	0.57	0.26		
Peanut	Avg	1.65	2.52		
	SD	0.99	0.22		
Mungbean	Avg	5.53			
	SD	3.14			
Sweet potato	Avg	3.17		5.87	9.13
	SD	2.13		3.26	5.17
Rice	Avg	3.14	4.32	4.04	2.32
	SD	2.15	1.04	1.20	1.55

From Table 5, it seems that growing irrigated palawija crops is an unstable enterprise in the wet season. Except for soybean, yields for palawija crops were about the same in the wet season as in the dry. But this is not unexpected as rice is clearly the dominant crop during the wet season at the research sites in East and West Java. However, the relatively high variation in yields of wet season rice in Central Java is surprising, particularly given the skills of the Javanese farmers and the availability of irrigation. Table 6 shows that the high variability in rice production appears to be the norm at almost all sites. Given that the production technologies, including rice varieties and level of inputs, are generally the same across sites, the significantly lower rice yields in West Java suggest further study is needed.

Table 6. Comparison of average yields (in tons per hectare) and standard deviations for irrigated in the research blocks, wet season, 1986.

East Java	Central Java	West Java
3.829 (0.765) Blocks - 206/207/208	3.135 (2.150) Block - Jarot 5	2.587 (0.936) Block - Jasem 2
6.088 (0.645) Block - a99	4.322 (1.04) Block - Jarot 2	3.151 (1.016) Block - Jasem 7
5.700 (1.93) Blocks - 74/a73/58	2.32 (1.55) Block - Ck 3	2.755 (1.267) Block - Wln I
	4.039 (1.199) Block - Ck 7 km	2.850 (0.968) Block - Mirat I ki

Constraints to Palawija Cropping

In order to understand the potential for irrigation in the process of expanding and intensifying palawija crop production, it is necessary to identify the full range of constraints and incentives, both those directly related to irrigation (such as system design or water rotation procedures), and those which are not (such as pests or prices). It is also necessary to identify the constraints or incentives which can be directly influenced by management or policy changes. However, the limits of this research preclude such an intensive analysis. Instead, short-term methods are employed for at least identifying constraints and incentives in the research sites, in addition to examining comparative factors such as prices, land tenure, marketing, soils, and decision making criteria from the farmer perspective.

Hierarchical decision models[3] can be used to identify and test the criteria actually used by farmers in deciding whether to plant rice, palawija crops, or fallow their fields. Through group and individual interviews, decision making criteria have been identified, and simple models constructed. These models have been partially tested and will soon be validated by interviewing larger numbers of farmers about actual decisions made.

Such decision models may enable researchers to identify the range of factors effecting planting decisions within a locality and understand the relative importance of the factors, both those related to irrigation and those which are not (by tracking how many farmers follow particular decision paths and choose particular outcomes in a model). The researcher can then compare across localities to see how local decision criteria vary in order to develop a broader perspective on constraints and incentives at the main irrigation system, or at national or regional levels. Only after identifying the relative importance of irrigation and non-irrigation related factors is it possible to estimate the likely effect of irrigation management or policy changes on the expansion or intensification of palawija crop production.

In the decision models, questions are posed to reflect the same level of abstraction expressed by farmers and then listed in order of frequency of relevance, determinacy, or logical relatedness. Questions evoke "yes" or "no" responses and determine which decision paths will be followed. In the model shown in Appendix II, the number of responses which were "explained" correctly (C) by the model and those which were in error (E) are noted below the respective decision outcomes.

Because the model has not yet been fully tested, only a few tentative inferences should be made at this time. In general, the timely availability and drainage of water figure prominently in the farmers' decisions to plant rice or palawija crops. Not surprisingly, in all three provinces there is a marked tendency to plant rice during the November-March rainy season (Musim Rendeng) and palawija crops during the August-November dry season (Musim Gadu II), except in a few cases specified in the model.

The March-July dry season (Musim Gadu I) is more problematic. Farmers often identify the availability of water at the desired time for land preparation as a key factor in deciding to plant rice. If experience tells farmers that there is usually enough irrigation and/or rain water for rice during Gadu I, they use the availability of water at the desired time as a seasonal decision criteria and begin land preparation (with a range of two weeks generally being the maximum waiting period to see if there will be sufficient water). During Gadu II, inadequately drained soils are sometimes a primary constraint to planting palawija.

At the West and East Java sites, almost no palawija crops are planted in the rainy season. During Gadu I, farmers prefer to plant rice, even if their fields are dry enough for palawija crops. However, there are additional influential factors, such as lateness in planting and harvesting the prior rainy season crop (which may cause farmers to plant palawija crops to "catch up") and the threat of pest attack. In Central Java, a significant number of farmers will plant palawija crops during the rainy season, apparently because of soil characteristics, late planting, and palawija crop price speculation.

The research sites in West Java have an established pattern of planting rice twice a year, except in fields at high topography or at the bottom-end of secondary canals or tertiary blocks where they cannot obtain adequate water supplies. Historically, during Gadu II, in three of the four research tertiary blocks, rainfall and irrigation water are insecure even for palawija crops. The relative insecurity of water supplies, the prevalence of off-farm work, and the high risk of crop damage by rats (which has been frequent and severe in recent years) prompt many farmers to leave their fields fallow or to permit landless villagers to cultivate free of charge.

In the research sites in Central Java, there is considerable variation in cropping patterns and planting dates between individual fields within tertiary blocks. Generally speaking, farmers have long experience cultivating palawija crops, such as soybean, corn, groundnut, mungbean, long bean, red onion, cucumber, tomato, sweet potato, red pepper, and cassava. Planting decisions are more individual than group oriented. Generally, pest damage has not been high in recent years. Soils are lighter and more well-drained than those in West and East Java.

In two of the research tertiary blocks in East Java (a99 and a206-8, Desa Barong) there are usually abundant water supplies in both the wet and first dry seasons. Farmers generally plant only soybean, corn, or groundnut. In recent years, soybean has required weekly spraying with pesticides. The availability of land for rice seed beds permits relay cropping (2 rice crops in 7 months) so that renters, who typically rent for 12 months, can plant rice twice and palawija twice (3 months for soybean and 2 for corn). Farmers in this area are more oriented towards group-level planting decisions based on discussions among individual farmers. Soils in many areas are not well-drained between November and June.

In one research site in East Java (a73, Desa Mojokendil) farmers are experienced in planting and marketing a variety of palawija crops. There have been no serious pest attacks against palawija crops in recent years. There is a prevalence of sandy, permeable soils which require frequent applications of water for rice during the dry season. This leads farmers to prefer planting palawija, as reflected in the model for Desa Mojokendil.

Spatial Distribution of Palawija

Variation in palawija cropping patterns and planting dates can be seen between irrigation systems, between secondary canals of the same system, between tertiary blocks on the same canal, and within the same block. In many cases soil chemical properties and associated drainage are a major determinant. In others, variation is due to water availability (including irrigation and rainfall) and water holding capacity of the soils. The rotation, pests, prices, seed availability, and labor all play a role in determining selection and spatial variability of crops and planting dates.

Detailed maps, such as Figures 2 and 3, made of every land holding within a research block allows the research staff direct observation of crops to identify their exact location and area by season. Data from farmer interviews can then be cross-checked and areas needing further study can be identified. The maps can be linked with irrigation rotation schedules and maps to see the relationship between water allocation practices and crop diversification. In conjunction with the decision models, maps help the researchers identify critical variables and confirm the relationship of the variables to planting decisions made by the farmers.

Figure 2. Map showing first dry season crop in Jarot 2, Central Java, 1986.

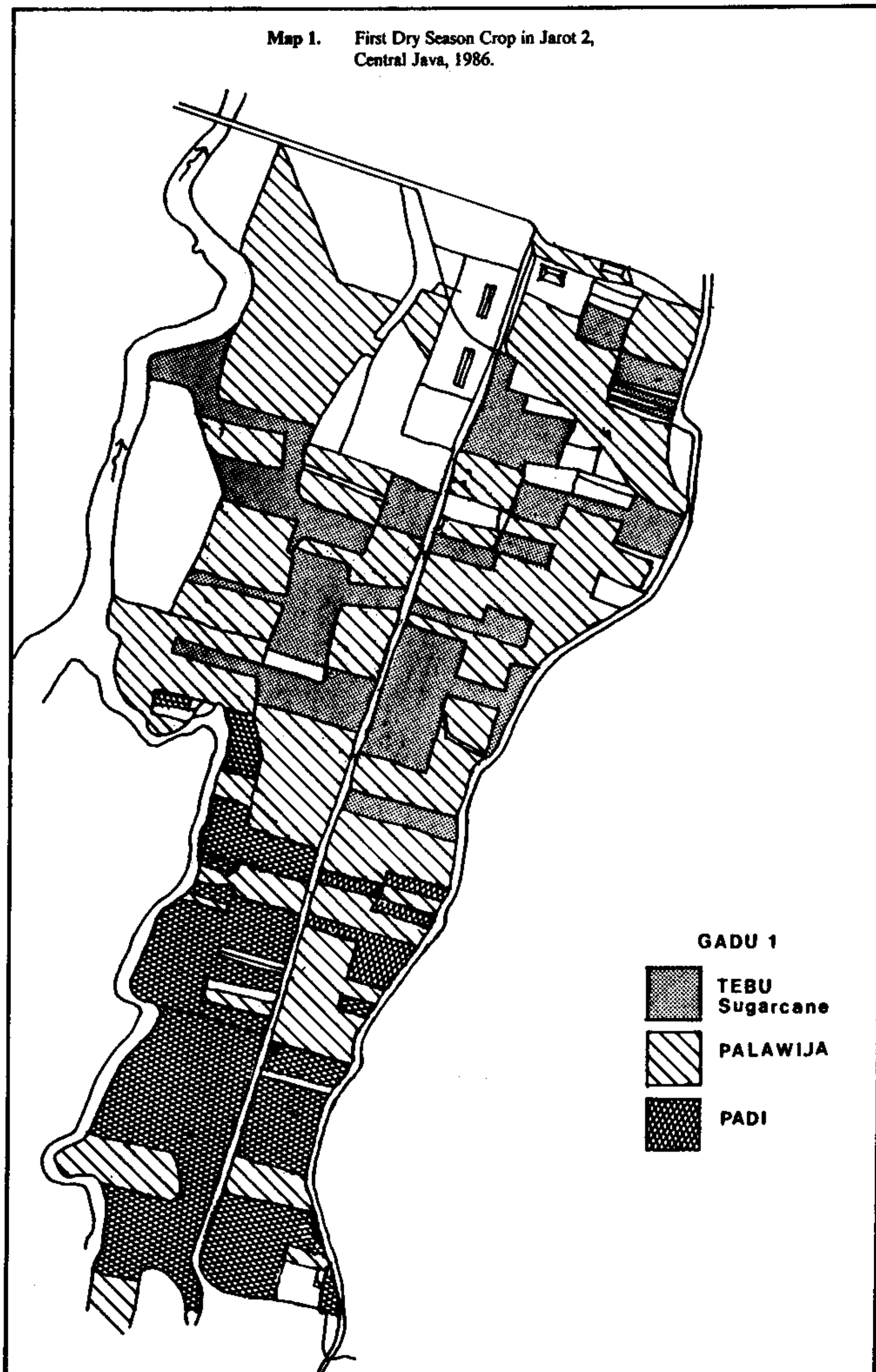
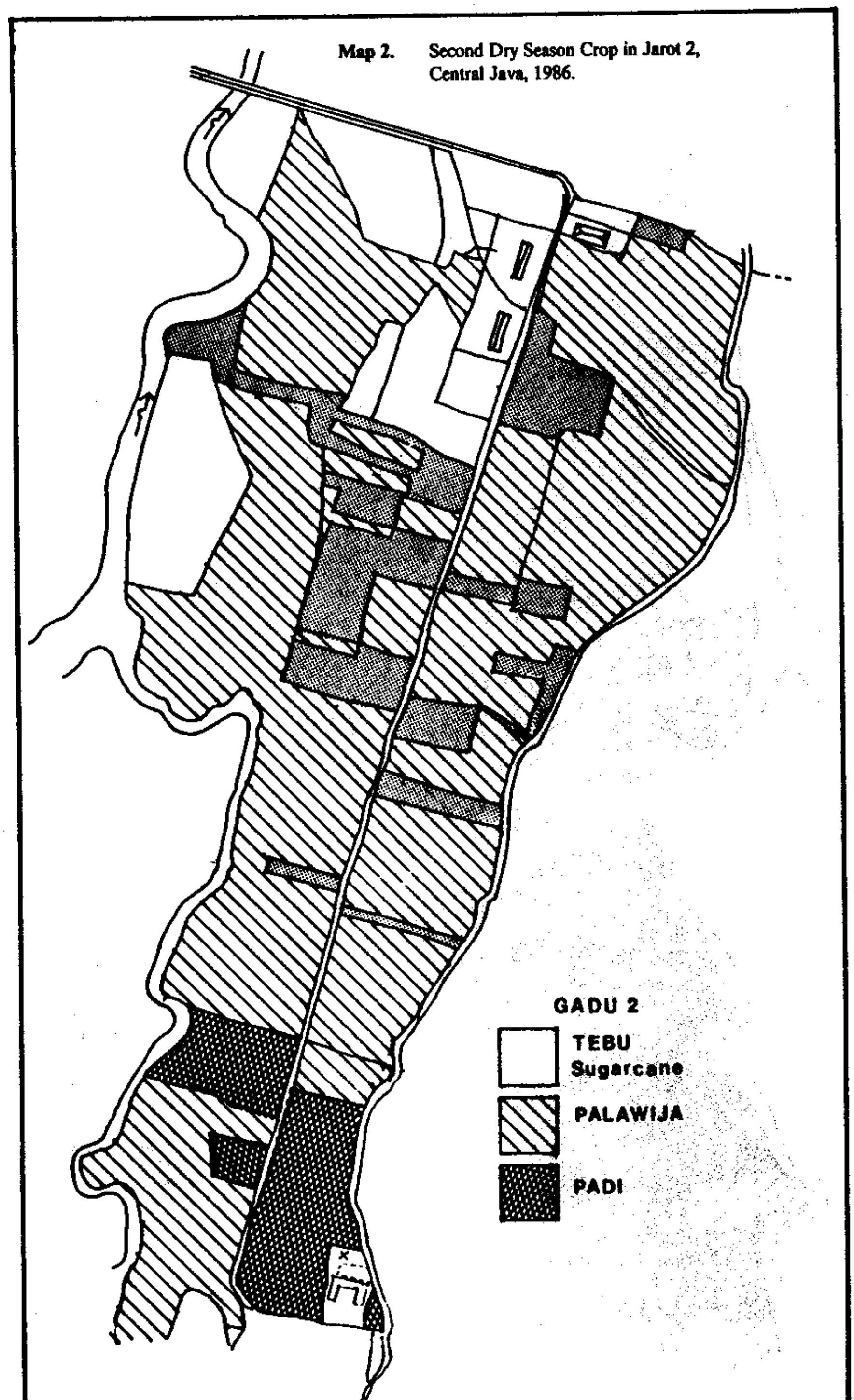


Figure 3. Map showing second dry season crop in Jarot 2, Central Java, 1986.



Due to the high levels of cropping intensity found in Indonesia, particularly in Java, unique irrigation management techniques have been developed. Three major methods are used for water distribution: 1) pasten, 2) Faktor-K, and 3) Factor Palawija Relative (FPR). These methods are differentiated by the way each uses relative versus actual water requirements, and the method used to account for distribution and tertiary losses.

The relative water requirement (RWR)[4] assumes that fields are provided with their full water needs which, for rice, means flooded throughout crop growth. RWR values have been developed from past experience for different stages of rice and sugarcane relative to values for secondary crops (Table 7). Accordingly, rice fields are assumed to require about 4 times as much water as those of secondary crops, while sugarcane requires about 1.5 times as much. In addition, there is often a distinction between palawija crops that use large amounts of water and those that only use limited amounts.

Table 7. The relative water requirement (RWR) for selected crops and their stages of production, East Java, 1985.

Crop	Production stage	RWR*
Rice:	Seed bed	20.0
	Land preparation	6.0
	Transplanting and vegetative growth	4.0
	Ripening	2.5
Sugarcane:	Young cane	1.5
	Mature cane	0.0
Secondary crops		1.0
Unauthorized rice**		1.0

*Water requirements in lps/ha relative to an index value of 1, which is the requirement for secondary crops such as maize, soybeans, and tobacco.
**Rice that was not included in the cropping system plan.

The Direktorat of Irigasi I has recently recommended using the Faktor-K method for water allocation. This method was developed to incorporate distribution system losses into the original pasten method and to reduce the need to use the RWR concept. Other than East Java where the FPR is used extensively, the Faktor-K method is now used widely in the country. Mathematically, the Faktor-K method may be expressed similarly to that of the pasten method; the main difference is that the former uses the actual water requirement values (Table 8) rather than the RWR values. This is felt to reflect crop water requirements more accurately, and to be easier to calculate because the values from agronomic research can be substituted directly.

The equation for Faktor-K is as follows:

$$K_k = \sum_{i=1} \frac{Q}{(A_i * q_i) * (1 + t_1) * (1 + s_1) * (1 + p_1)}$$

where: K_k = Faktor-K for irrigation system (k)
i = 1st to nth crop
Q = actual discharge of water in liters per second (lps) at intake taken from a discharge curve or from flow discharge data
A_i = crop area in hectares
q_i = crop water need by growth stage for crops (i) in lps/ha
t_1 = tertiary canal losses
s_1 = secondary canal losses
p_1 = primary canal losses

Table 8. Full water requirements (in liters per second/hectare) for selected crops and their production stages, Faktor K method, Central Java, 1985.

Crop	Production stage	Water requirement
Rice:	Seed bed	1.20
	Land preparation	1.20
	Tillering	0.73
	Flowering	0.79
	Ripening	0.52
Sugarcane:	Land preparation	0.45
	Young cane	0.36
	Mature cane	0.00
Secondary crops:	Much water	0.30
	Less water	0.15
Unauthorized rice*		0.30

*Rice that was not included in the cropping system plan.

Faktor-K, like the pasten method, is used in operational decisions on water allocation. Twice each month (on the 9th and 24th), the ulu-ulu (village water masters) assess and report to their respective juru pengairan (irrigation inspectors) the area and growth stage for each crop expected during the next two weeks in the area for which they are responsible. The juru calculates the field water requirement (lps/ha) for each crop and growth stage, and the total in-field water requirement (liters per second) for the area covered by his tertiary block(s). This total is multiplied by a constant that varies from 1.2-1.3 to account for distribution system losses. The result is taken to represent the "normal" water requirement at the inlet.

The quantity of water to be diverted in a specific 10-14 day period is calculated when the juru pengairan submit their forms to their respective pengamat (water masters), who aggregate the data for all tertiary blocks served by each diversion point (bendung). The total water requirement is adjusted for losses in the intake (induk) and secondary channels, and for water reallocation (supplemental), if available. The adjusted total (call it "D") represents the total "normal" demand for irrigation water at the diversion headworks.

The penjaga pintu/bendung (gate keeper) responsible for each diversion point records the quantities which have entered the system(s) served by his diversion point, and the amounts which have passed over the diversion point each day during the prior two weeks. The average daily total (call it "S") represents the best estimate of water availability (supply) over the forthcoming two weeks. The quotient, S/D, represents the expected value of Faktor-K (call it K_e). The diversion point gate keeper then notifies the appropriate water masters of the value of K_e. The water masters, in turn, notify their respective irrigation inspectors who then notify their respective village water masters. At each level, gates are adjusted to reflect the new value of K_e. The new value is also posted on the sign-boards adjacent to each respective control structure.

At one, two, or three day intervals during the two-week period, the gate keeper recalculates Faktor-K -- taking into account that day's actual flow discharge. If the recalculated value of Faktor-K is equal to or greater than K_e, no further action is taken; if it is less than K_e, the chain of communication just described is set in motion. As long as the value of K remains above roughly 0.6-0.7, water is distributed continuously through all intended water control structures. However, if the value of K falls below a certain level, a rotational (giliran) system is usually introduced.

IIMI has developed a computer model that compares estimated water requirements (including distribution losses) with scheduled water deliveries. Figures 4a and b show that the method used now in Indonesia is fairly accurate in meeting field water requirements for the dry season, but for some critical periods it falls short. Further research will focus on this issue.

Figure 4a. Comparison of estimated water needs and scheduled deliveries.

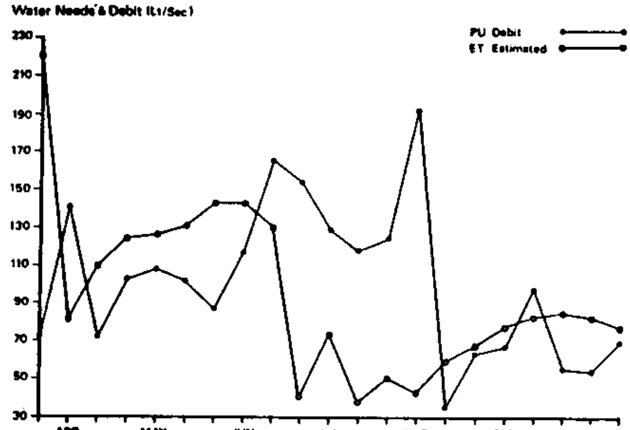
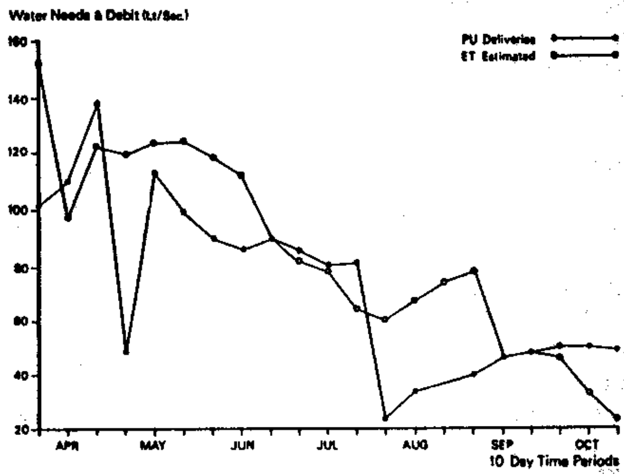


Figure 4b. Comparison of estimated water needs and scheduled deliveries.



CONCLUSION

IIMI's research program in Indonesia has the task of analyzing the implications of irrigation management for expanding and intensifying crop diversification. In this paper, two basic questions are addressed: what are the incentives and constraints to crop diversification in irrigated areas designed primarily for rice cultivation, and what are the appropriate irrigation management practices in areas where diversified cropping already exists?

Until recently more attention has been given to the first question. In the future more attention will be directed toward the second question, which will involve comparing the performance of different irrigation management practices for diversified cropping.

NOTES

1. Interested readers are encouraged to see the July 1986 document by the World Bank Projects Department, "Indonesia: Agricultural assessment," for a discussion of many of the non-irrigation aspects of crop diversification. Also, the recent studies by Stanford Food Research Institute on corn and cassava present a wealth of information on non-rice crop production and marketing in Indonesia.

2. The budgets provide information on economic returns to capital, management, and land when it is not rented.

3. See Christina Gladwin. 1980. A theory of real-life choice: Applications to agricultural decisions. In P. Barlett (ed.), Agricultural decision making: Anthropological contributions to rural development. New York: Academic Press. Also see Human organization (Fall 1984).

4. RWR is the estimated water requirement for all the crops, where an index value of 1.0 is taken as the requirement for secondary crops.

APPENDIX I: REPRESENTATIVE CROP BUDGETS, JAVA, INDONESIA, 1986

Summary of Production Costs for Soybean, Dry Season I, Gung Section, Central Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			
	Cash			
Inputs:	Seed	42	900	37800
	Urea	60	125	7500
	Organic fertilizer	100	125	12500
	Pesticide	6 6 24 24	2800 3200 450 450	57600
	Herbicide			
	Tractor			
	Well water			
	Other: KCl	60	125	7500
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	35	1500	52500
	Planting			
	Family			
	Hired	20F 7M 2M	600 750 1500	19500
	Cultivation			
	Family			
	Hired			
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	14M 8F	1500 600	25800
	Processing			
	Family			
	Hired			
Taxes				4000
Marketing				10000
Credit				
Water fees				5000
Total costs				285300
Gross returns (yield and price)				888000
Net returns				602700

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Rice, Wet Season, Nganjuk Section, East Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			44000
	Cash			
Inputs:	Seed	55	300	16500
	Urea	600	110	29370
	TSP	204	110	22400
	Organic fertilizer			
	Pesticide			
	Herbicide			
	Tractor			
	Well water			
	Other: animal power	14	2500	35000
Labor use:	Seed bed			
	Family			
	Hired	10	1200	12000
	Land preparation			
	Family			
	Hired	26	1000	26000
	Planting			
	Family			
	Hired	50	800	40000
	Cultivation			
	Family			
	Hired	58	800	46400
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired		1.8 share	86072
	Processing			
	Family			
	Hired	28	1000	28000
Taxes				8800
Marketing				
Credit				
Water fees				10838
Total costs				404700
Gross returns (yield and price)		5.43	126810	688578
Net returns				283878

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Chilli, Wet Season, Cerebon Section, West Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			
	Cash			
Inputs:	Seed	3	4000	12000
	Urea	90	125	11250
	TSP			
	Organic fertilizer			35000
	Pesticide	7 35	1500 500	28000
	Herbicide			
	Tractor			
	Well water			
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	77	1500	115500
	Planting			
	Family			
	Hired	20F 37M	1000 1500	75500
	Cultivation			
	Family			
	Hired	17 56	1000 1500	101000
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	64	1000	64000
	Processing			
	Family			
	Hired			
Taxes				
Marketing				
Credit				
Water fees				
Total costs				442250
Gross returns (yield and price)		4800	400	1920000
Net returns				147750

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Maize, Dry Season I, Nganjuk Section, East Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share		1 season	44000
	Cash			
Inputs:	Seed	34	550	18700
	Urea	622	100	62200
	TSP			
	Organic fertilizer			
	Pesticide			
	Herbicide	6.5	1000	6500
	Tractor			
	Well water			12650
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	12	2500	30000
	Planting			
	Family			
	Hired	40	1000	40000
	Cultivation			
	Family			
	Hired	34	1000	34000
	Irrigation			
	Family			
	Hired	21	1250	26250
	Harvesting			
	Family			
	Hired	24	1000	24000
	Processing			
	Family			
	Hired	50	1000	50000
Taxes				4500
Marketing				
Credit				
Water fees				
Total costs				352800
Gross returns (yield and price)		3.842	139370	535647
Net returns				182847

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Peanut, Dry Season I, Nganjuk Section, East Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share		1 season	44000
	Cash			
Inputs:	Seed	112.97	1033.07	16670
	Urea			
	TSP	58.72	102.21	6022
	Organic fertilizer			
	Pesticide	18.72	928.63	17226
	Herbicide			
	Tractor			
	Well water			
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	31	1500	46500
	Planting			
	Family			
	Hired	57F	600	34200
	Cultivation			
	Family			
	Hired	80	1000	80000
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	30	1000	30000
	Processing			
	Family			
	Hired	40	1000	40000
Taxes				2400
Marketing				
Credit				
Water fees				6500
Total costs				318498
Gross returns (yield and price)		1.328	46265	614400
Net returns				295902

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Shallot, Wet Season, Gung Section, Central Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share		1 season	25000
	Cash			
Inputs:	Seed	1100	200	220000
	Urea	200	120	24000
	TSP	380	120	45600
	Organic fertilizer			
	Pesticide	1.5 0.1 0.5	300 1100 4900	7060
	Herbicide			
	Well water			
	Other: NPK	80	400	32000
	ZA	280	120	24000
	KCl	80	120	9600
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	155M	1500	232500
	Planting			
	Family			
	Hired	40F	800	32000
	Cultivation			
	Family			
	Hired	70M	1500	105000
	Irrigation			
	Family			
	Hired	155	1000	155000
	Harvesting			
	Family			
	Hired	120F	800	96000
	Processing			
	Family			
	Hired			
Taxes				2000
Marketing				
Credit				
Water fees				4000
Total costs				1013760
Gross returns (yield and price)		55	45000	2475000
Net returns				1461240

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Cucumber, Dry Season I, Cirebon Section, West Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			100000
	Cash			
Inputs:	Seed	3	10500	31500
	Urea	280	120	33600
	TSP	280	120	33600
	Organic fertilizer			
	Pesticide	10 7.5	1500 1500	26250
	Herbicide			
	Tractor			
	Well water			
	Other: bamboo			50000
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	86	1500	129000
	Planting			
	Family			
	Hired	21	750	15750
	Cultivation			
	Family			
	Hired	24 10 21 42 100	1500 x 3 750 x 2	189000
	Irrigation			
	Family			
	Hired	84	1500	126000
	Harvesting			
	Family			
	Hired	96	1500	144000
	Processing			
	Family			
	Hired			
Taxes				
Marketing				
Credit				
Water fees				
Total costs				878700
Gross returns (yield and price)		199	10000	1990000
Net returns				1111300

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

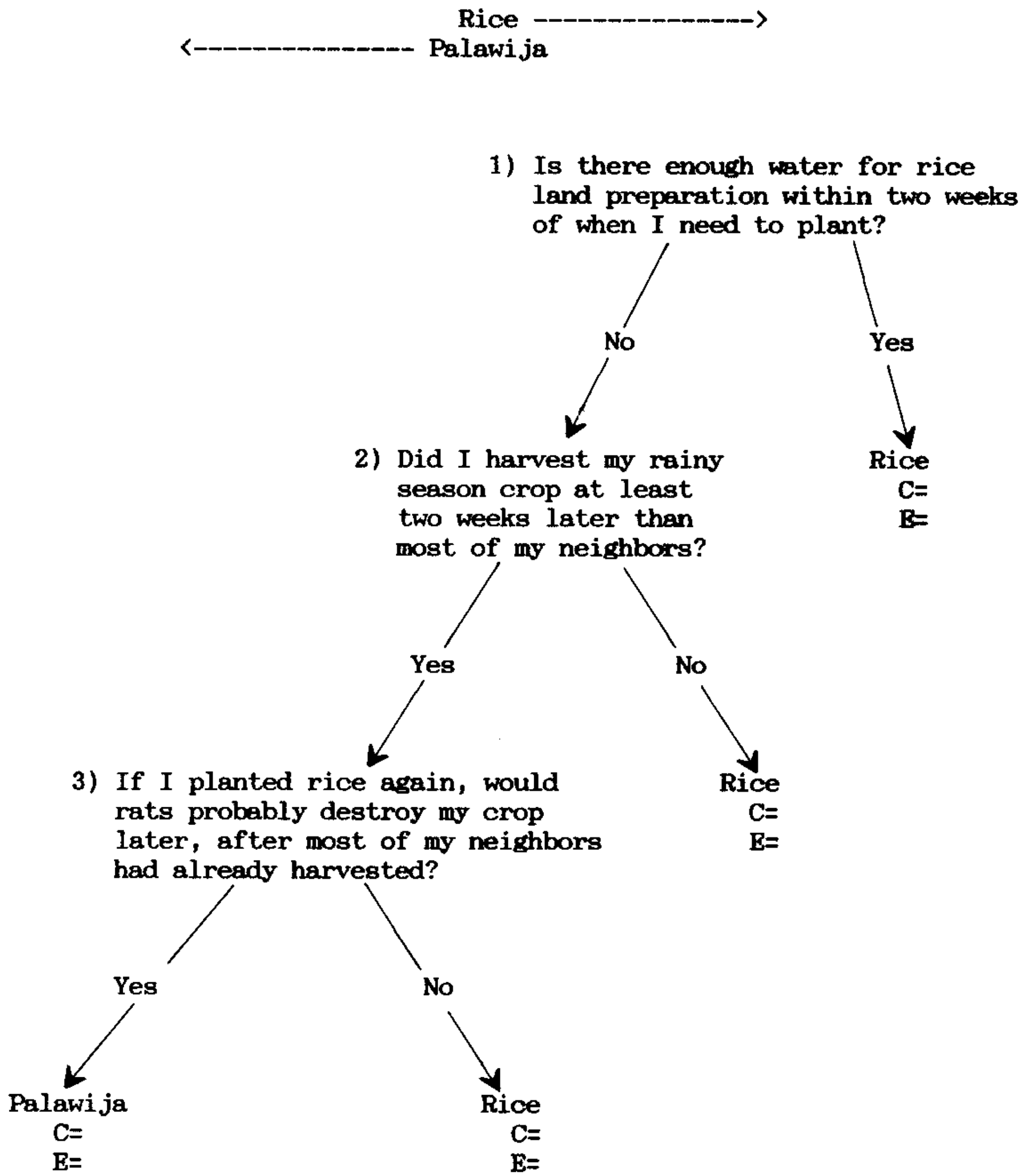
Summary of Production Costs for Mungbean, Wet Season, Gundon Section, Central Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land Rent:	Share	1 season		30000
	Cash			
Inputs:	Seed	15	850	12750
	Urea			
	TSP			
	Organic fertilizer			
	Pesticide	1.5 1.5 8.0	950 1400 100	4087
	Herbicide			
	Tractor			
	Well water			
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	22M	1500	33000
	Planting			
	Family			
	Hired	17MF	800	13600
	Cultivation			
	Family			
	Hired	20F	800	16000
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	14M	1500	21000
	Processing			
	Family			
	Hired			
Taxes				1000
Marketing				
Credit				
Water fees				1500
Total costs				132937
Gross returns (yield and price)		290	650	188500
Net Returns				55563

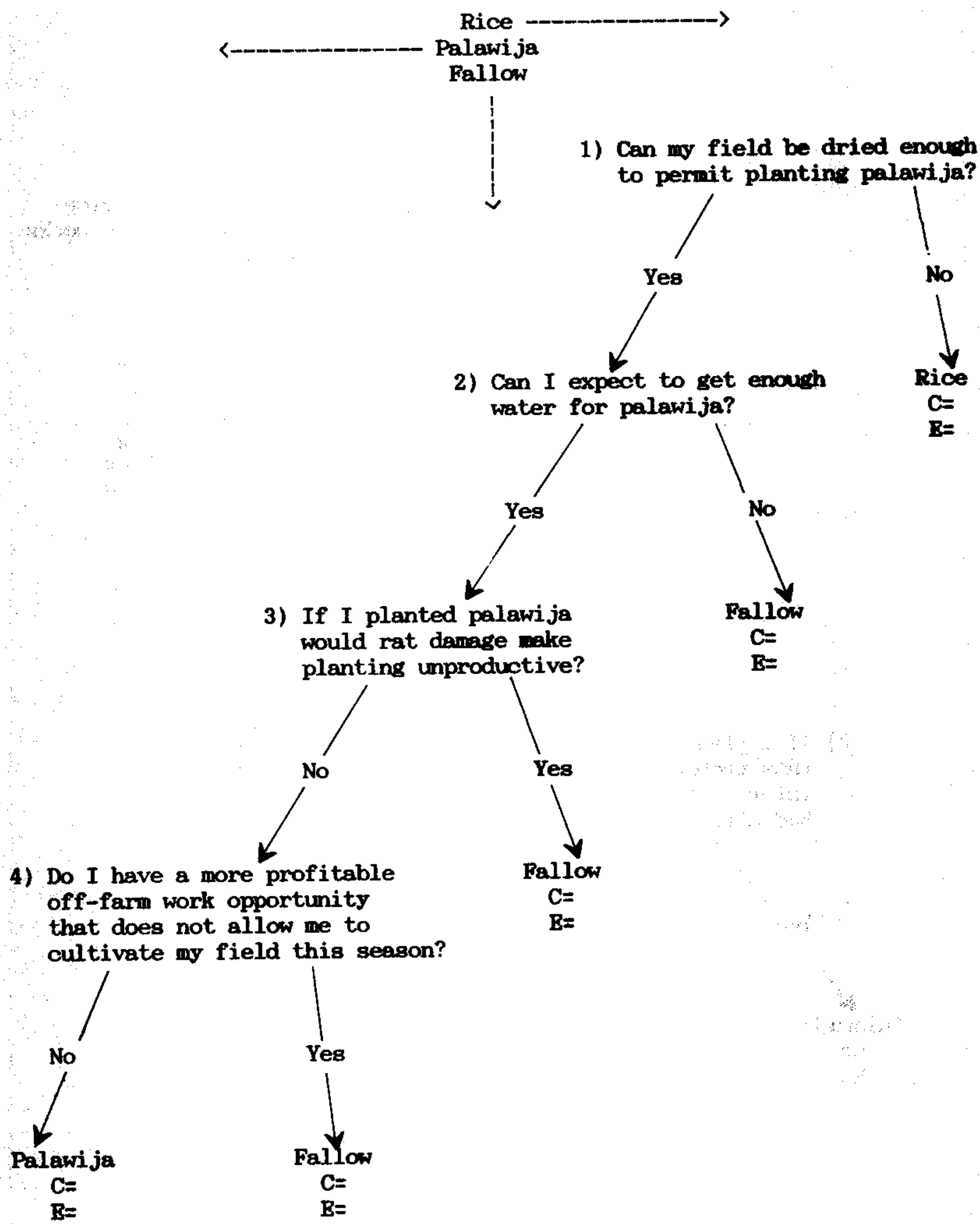
Notes: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

APPENDIX II: FARMER DECISION MODELS

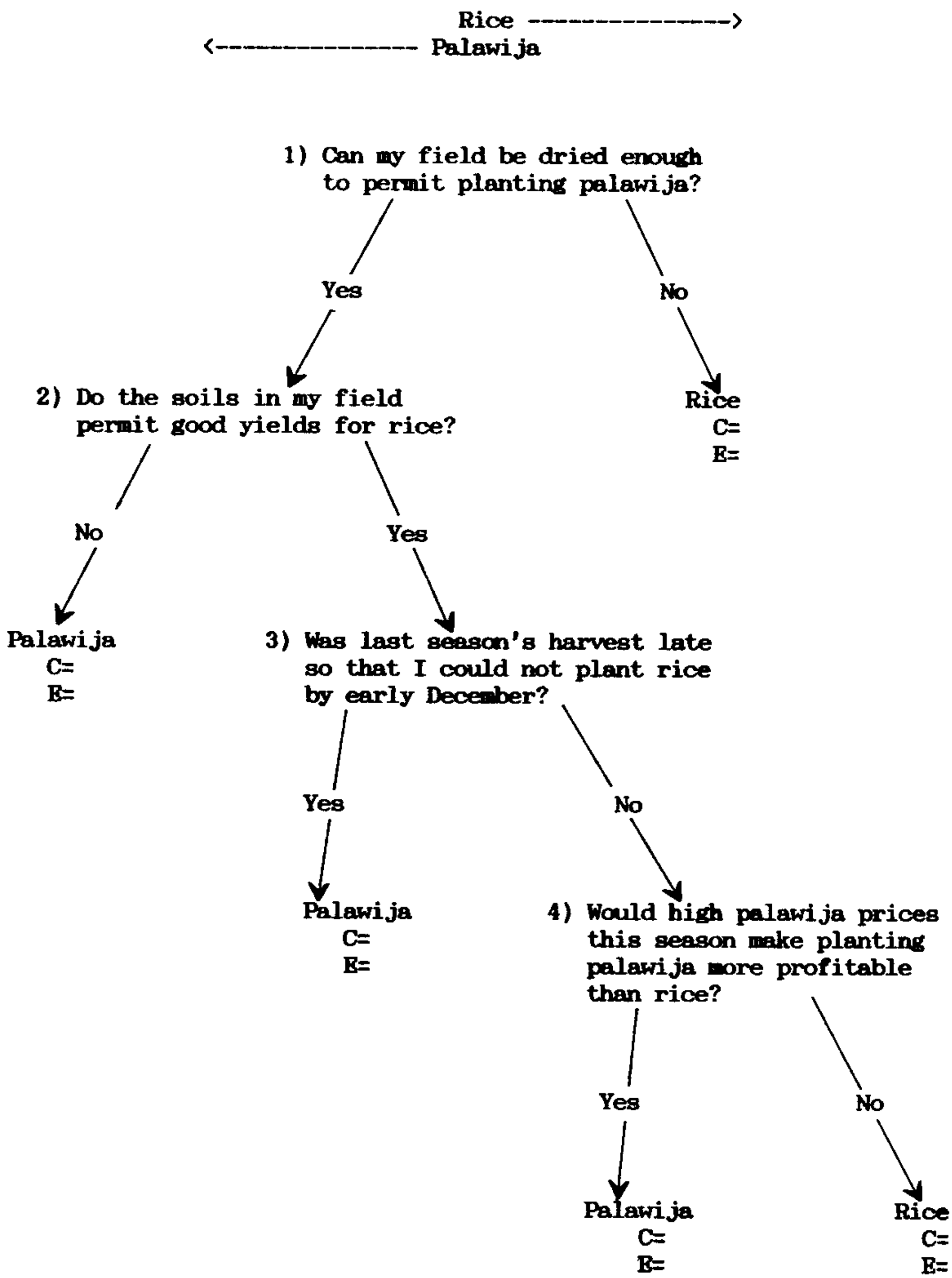
Farmer Decision Model For Planting Rice or Non-rice Crops (Palawija), Cirebon-Kuningan Section, West Java: First Planting Period, Dry Season (Gadu I)



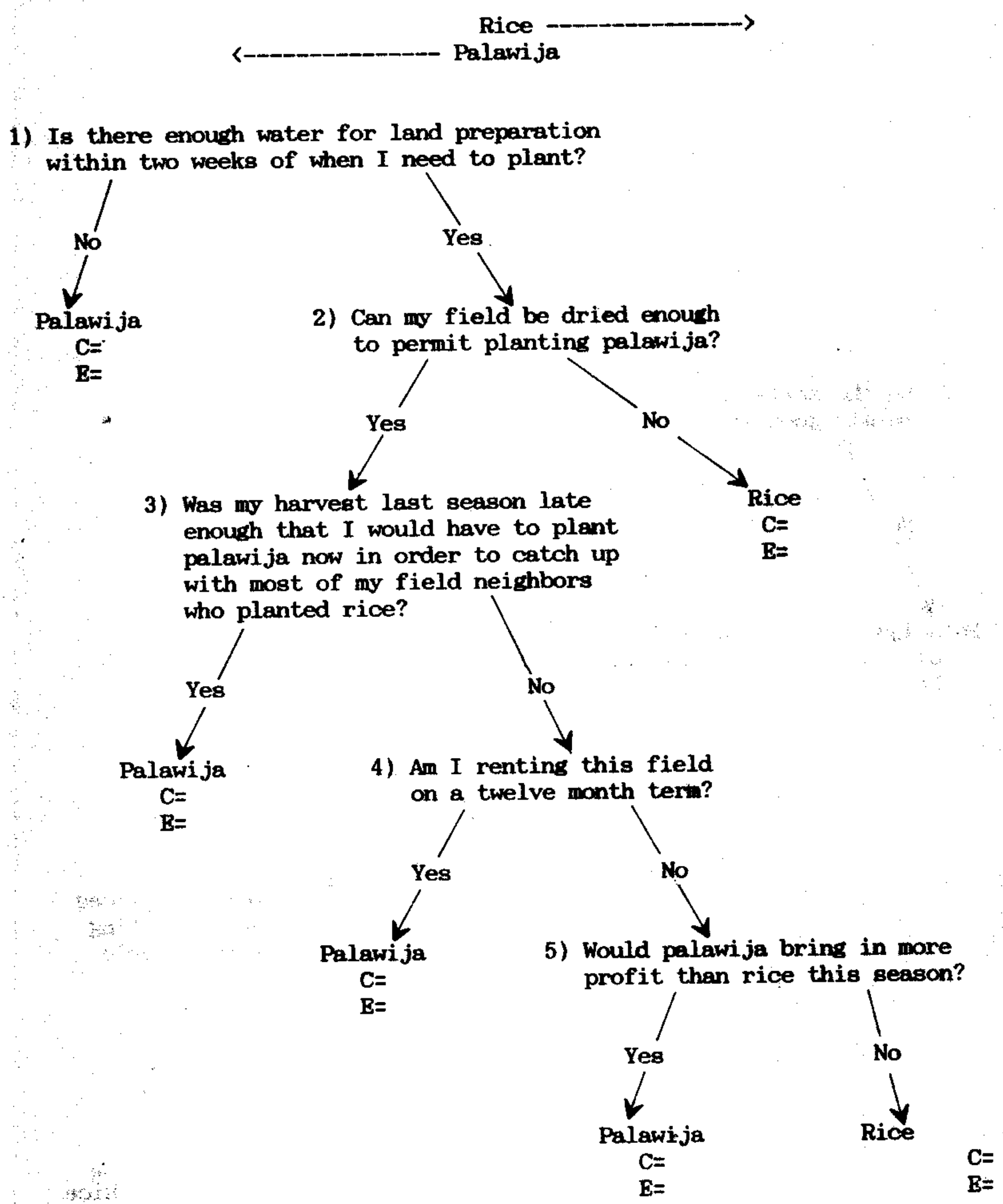
Farmer Decision Model For Planting Rice, Palawija or Leaving Fallow Cirebon-Kuningan Section, West Java: Second Planting Period, Dry Season (Gadu II)



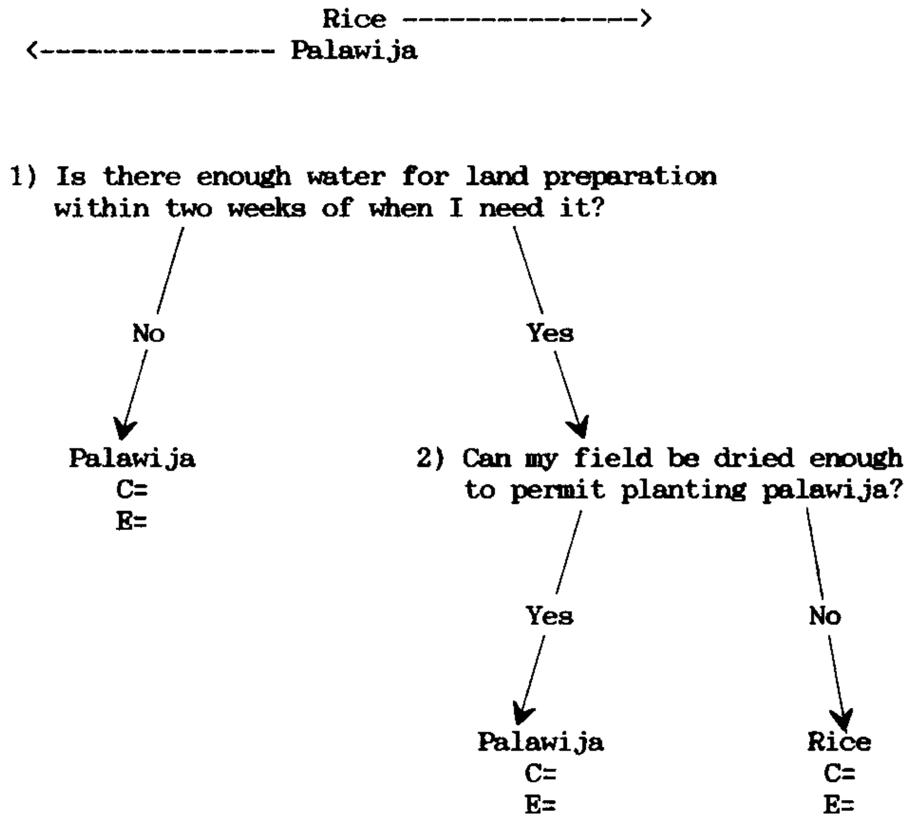
Farmer Decision Model For Planting Rice or Palawija, Gung Section, Central Java: Rainy Season



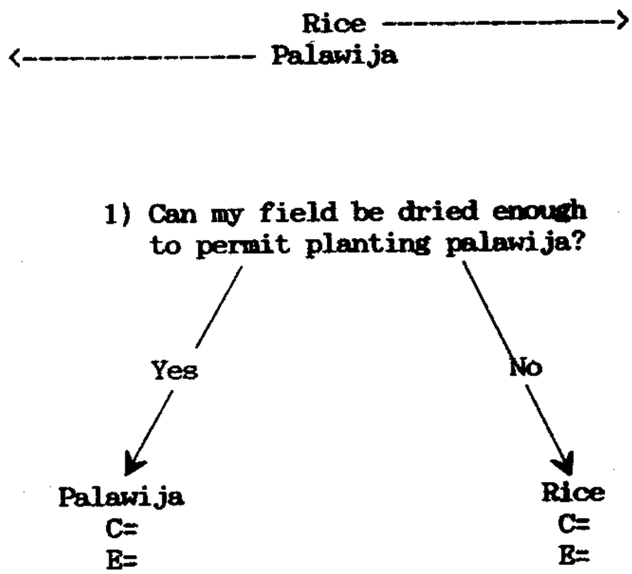
Farmer Decision Model For Planting Rice or Palawija, Gung Section, Central Java: First Planting Period, Dry Season (Gadu I)



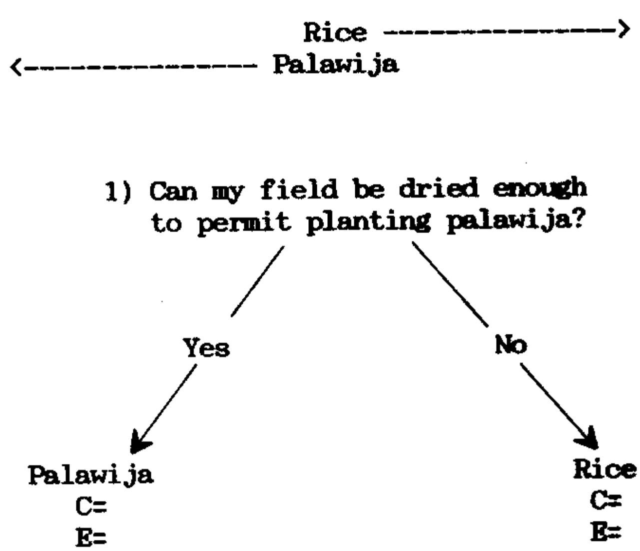
Farmer Decision Model For Planting Rice or Palawija, Gung Section, Central Java: Second Planting Period, Dry Season (Gadu II)



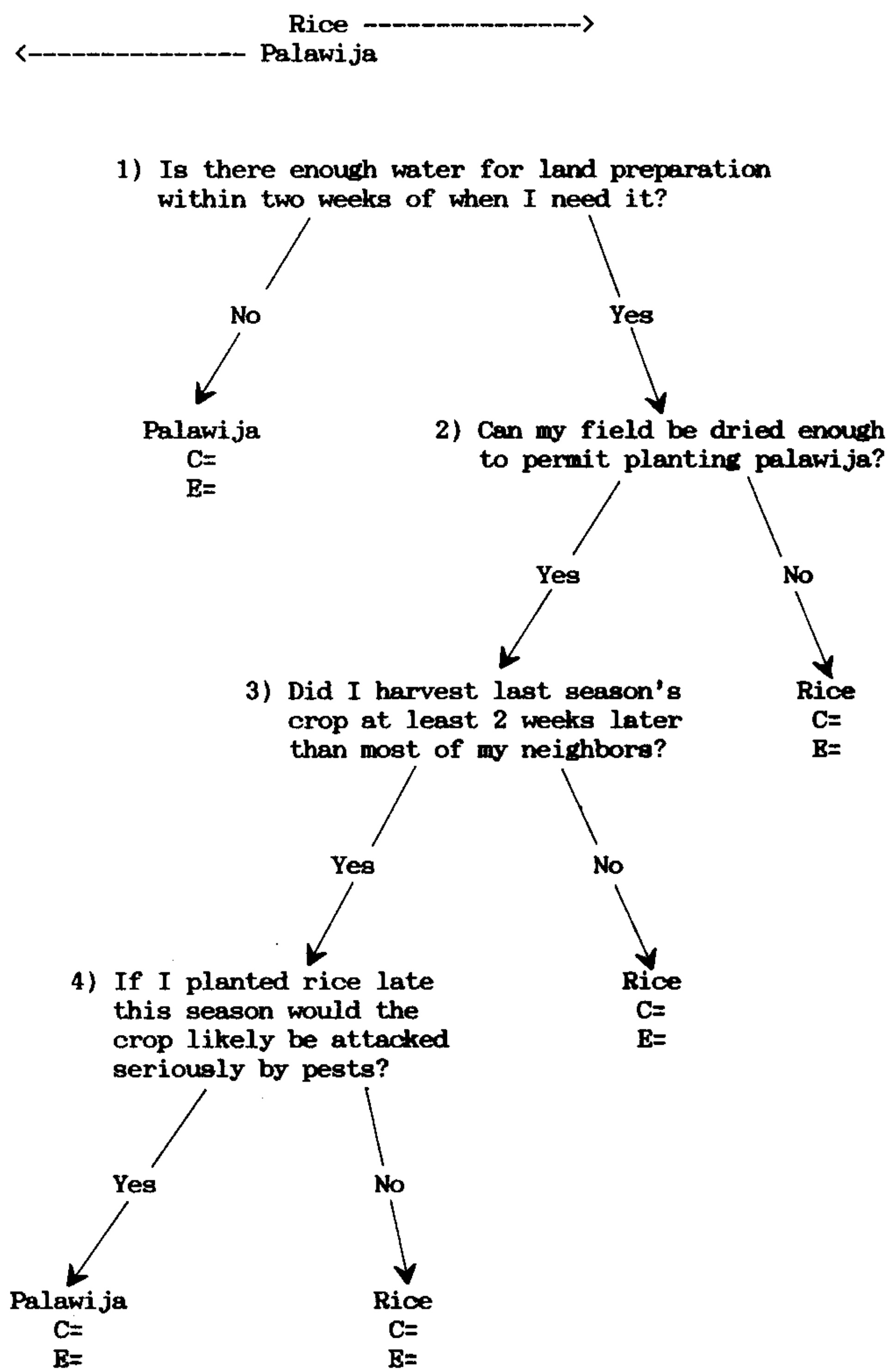
Farmer Decision Model For Planting Rice Palawija, Desa Mojokendil, Nganjuk Section, East Java: First Planting Period, Dry Season



Farmer Decision Model For Planting Rice or Palawija, Nganjuk Section, East Java: Second Planting Period, Dry Season



Farmer Decision Model For Planting Rice or Palawija, Desa Barong, Nganjuk Section, East Java: First Planting Period of Dry Season (Gadu I)



DISCUSSION: RESULTS OF ON-GOING RESEARCH

M.R. Biswas wondered why the price of corn was lower than that of rice, as shown in Figure 15 in the Cablayan and Valera paper. **Alfredo Valera** explained that the figure reflected actual farm gate prices in Isabela which were determined by the forces of supply and demand. But in certain parts of Isabela, the corn prices were higher than rice prices, suggesting the lack of an established market. He cautioned, however, that this price difference did not reflect the overall country situation.

Sunil Dimantha was confused by the term "land shaping." In the Sri Lanka Country Paper and the Concept Paper by IIMI, the term indicated on-farm activities to prepare the land for irrigated agriculture. This involved forming bench terraces, graded terraces, or basins, which was generally a one-time operation. However, the Indonesia paper referred to "land shaping" raised beds, ridges, furrows, or basins at the beginning of every season. This was referred to as "on-farm irrigation layout" in the Sri Lanka paper. **Douglas Vermillion** said that "irrigation layout" meant the network of channels in the main system. On-farm land preparation for planting was referred to as "land shaping." **Dimantha** contended that the channel network in the main system should be called the "system irrigation layout." The furrows and basins that distribute water within the farm would then be the "on-farm irrigation layout," and would not pertain to land shaping. **Senen Miranda** agreed with **Dimantha** that "land shaping" should refer to the initial operations when the original surface features of the land are changed to create uniform surfaces at pre-determined grades.

Kapila Gunasekera pointed out that Table 9 from the IIMI Status Research Report showed that Dewahuwa labor requirements in 1986 were much higher than in 1985, and he wondered why. **Edward Martin** replied that exact ratios relating to rice were presented in Table 9 and showed no significant difference between the two years. Although 1985 was the first year of IIMI's field research, data collection actually began after the season started. He felt that some data may have been lost, accounting for the lower values. Furthermore, farmers' responses were less consistent in 1985. In 1986, farmers were more confident of increased water supplies, and records of farmer responses were more consistent and covered the full season from planting to harvest.

1977 studies showed, according to **Gunasekera**, that chilli gave the highest net returns per unit of water and this resulted in widespread chilli cultivation. Since 1977, production costs increased, especially labor. Farmers who diversify must be aware of increased labor requirements. Although weeds in rice can be controlled by flooding, weeding needs labor for other crops. Irrigation management for diversification should emphasize soil moisture conservation; after all, he observed, soil is in reality a huge reservoir.

R.D. Wanigaratne, referring to Table 5 of the Sri Lanka paper, wished to know the basis for listing soil and water as constraints, and minimizing the importance of costs and risks. The basis, according to **Martin**, was a strong correlation between other food crops (OFC) and well-drained areas, and rice and poorly-drained soils. The average area planted by individual farmers to input-intensive OFCs was not significantly different from the average area planted to rice, which requires less cash input, suggesting that costs were not as constraining to cultivation of OFCs as poor soil conditions.

Shawki Barghouti wondered how the data and study results should be used to improve crop diversification. Without a framework within which variables can be tested, research simply accumulates unfocused data from diverse situations. According to Thomas Wickham, this should be treated as two issues: to develop a strategy of overall purpose, and, within it, to produce a separate framework for each study. Although IIMI had hoped to do this at all its research sites, financing and other problems forced a variety of strategies. Nevertheless, IIMI's goal is to identify, document, and field test management techniques that make diversification profitable. Thus, the common theme at all sites is to search for innovative irrigation management technologies and practices. Barghouti asked if IIMI was applying new irrigation management practices developed by the Institute. Wickham replied that they did not feel they could add new ones but would borrow from one area and apply to another. Miranda commented that all disciplines generally manifest their biases, and that, although this was reflected in the presentation of the respective program reports, it should be noted that they had common objectives. The workshop was trying to learn if these objectives were still viable. Similarly, IIMI is trying to develop methodologies that would be common across sites. Roberto Lenton emphasized that commonalty should be the guide for the working groups.

David Groenfeldt pointed out that researchers had to address a variety of information all under the rubric of "crop diversification." To do so, they had to approach the research in a new way to demonstrate the interrelationships between constraints and diversified agriculture. For example, the complexity of institutional constraints had to be recongized.

There was consensus that it was important to develop a consistent framework for research in diverse settings to synthesize data generated. The participants concluded that IIMI should focus on:

1. Conducting studies with common objectives and methodologies.

2. Conducting research in relatively similar environments, especially similar market conditions.

3. Systematically applying proven agricultural technology and irrigation practices, rather than developing new technology.

4. Emphasizing an interdisciplinary framework that recognizes interrelationships and the complexity of constraints to diversified cropping.

IIMI's work should be more in the realm of farmers' decision making than in that of national policy making. There was scope, everyone felt, for further research within the farmer environment by an international institute like IIMI. Research still required a socio-economic perspective on crop diversification that takes into account, among others, consumers' acceptance of OFCs and the per capita consumption of non-rice crops.