Optimum Farm Ditch Density for Irrigating Diversified Crops

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Abstract

Regression models were developed to determine the optimum farm ditch density for irrigating diversified crops. Size of turnout service area, shape factor, orientation of main farm ditches, average farm size, and farms with direct access to farm ditches were the physical factors that exhibited significant effects on the length of farm ditches. Optimum farm ditch density in two study sites had an average of 100 meter/ha, regardless of size of turnout service area. Since models are subjective, physical and field observations have to be employed.

Preliminary results of this study indicate the need for providing on-farm facilities if dry season diversified cropping is to be undertaken in gravity-type rice-based imgation systems.

Introduction

Farm ditches are terminal facilities, densities of which are expressed in linear length per hectare and estimated in general component studies of existing irrigation systems (Wickham and Valera, 1976). Farm ditches from 10 to 100 meter/ha were found limiting in different areas. A joint IRRI-NIA study (1984) determined the optimum turnout service area for irrigated rice in two gravity-type irrigation systems. Moya (1985) found that terminal facilities like farm ditch density influenced the allocation and uniform distribution of water in gravity-type systems serving rice. However, the relationship of farm ditch density with some physical water control parameters that dominate the use of water in irrigated fields planted to diversified crops is not yet well understood. This is especially true where irrigation flows from the farm ditches cause waterlogging or are inadequate, hence partial changes have to be made most especially in irrigating diversified crop. Tahbal, et al. (1983) found that terminal facilities like farm ditches were affected adversely, if inappropriately located.

Imgated diversified croplands in the Ilocos Region are small and fragmented. Also, over-crowding of farms at the turnout service areas coupled with high degree of land utilization are the main sources of conflict among farmers. Svendsen (1985) characterized the building and destroying tertiary-level farm ditches as hysteresis and considered this an inefficient approach to the design process.

Therefore, irrigation planners must provide adequate on-farm facilities to avoid possible conflicts among farmer-irrigators. There is then a need to understand the intensity of facilities that will provide an efficient water allocation and distribution.

Objectives

The study aimed to determine the optimum farm ditch density for irrigating diversified crops. It also aimed to determine the how physical factors of turnout service area affect the total length of farm ditches.

Study Sites

The study was conducted under two irrigation systems in Luzon:

Laoag Vintor River Irrigotion System *(LVRIS).* LVRIS is one of the eight imgation

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systems under the llocos Norte Irrigation Systems (INIS) in the province of llocos Norte. The system is a run-of-the-river type serving 2377 hectares.

Upper Talavera River Irrigation System (UTRIS). UTRIS is also a run-of-the-river type irrigation system which is served by a dam in Tayabo, San Jose City, Nueva Ecija. It is part of the Upper Pampanga River Integrated Irrigation System (UPRIIS). During the dry season, only about *500* hectares are programmed for diversified crops.

Methodology

Selection *of* turnout service area. Sample turnout service areas (TSAs), lengths of which are oriented either parallel or perpendicular to the lateral canal, were used as units for observation and analysis. Physical engineering survey was done at selected turnouts in each system that were partially or fully planted to diversified crops during the dry season. TSA's selected were representative of the head, middle, and tail sections of the irrigation systems.

Determination *of physical factors* and analysis. An engineering field survey was conducted at each sample TSA. Boundaries served by each turnout were properly delineated. The following were determined at each TSA. total service area (SA) delineating the area planted to rice (R) and non-rice crops (NR) onspecific farm plots; orientation and layout of main farm ditches (MFD's) and supplementary farm ditches (SFD's); main farm ditch gradient (MFDg); general land slope (GLs); average farm size (FSa); shape factor (SF); and percent of farm with direct access to the farm ditches (PF).

To evaluate the effects of the TSA physical variables on farm ditch length, multiple linear regression analysis was used. The functional relationship was expressed as:

$$FDL = f(Or, MFDg, GLs, R, NR, SA, FSa, SF, PF)$$

where:
FDL = farm ditch length, (meter);
Or = orientation of main farm ditch to supply canal (dummy variable, equal to zero when MFD is parallel to lateral canal or equal to one when it is perpendicular);
MFDg = main farm ditch gradient, (%);
GLs = general land slope, (%);
R = rice farm plots, (%);
NR = non-rice farm plots, (%);
SA = effective turnout service area, (ha);
FSA = average farm size, (ha);
SF = shape factor, (m/m); and
PF = percent of farms with direct access to farm ditches, (%).

The explanatory power of the model developed was tested using the F-statistic and the significance of each regression coefficient was tested using the T-statistic.

Results of the physical survey were drawn into scale to visualize the physical factors at each TSA.

Results and Discussion

Laoag Vintar River Irrigation System (LVRIS)

The LVRIS network consists of a 27.5-km main canal. It has seven main laterals and five sub-laterals. The total canal length is 72.98 km. There are about 396, 30-cm diameter, single-gated operational turnouts serving the command area (Table I). Thirty-five percent of these turnouts are in Division IV, where most diversified crops are planted. Forty-seven TSA's were selected within irrigation canals scheduled for irrigating diversified crops during the dry season.

Table 1. Distribution of turnouts in each division of LVRIS, 1987/88 dry season.

Division	Canal Section	No. of Turnouts	% of Total Turnouts	Service Area (ha)
I	Main canals 1-5, lat A, B, E and G	108	27	658
II	Main canals 6-8, lat H, G-1	75	19	685
III	Lat H	16	19	381
IV	Lat F, sub-lat F-lc, F-ld	137	35	653
TOTAL		396	100	2371

Physical Factors and Regression Models. A multiple linear regression analysis was used to evaluate the relationship between physical features of TSA (independent variables) and farm ditch length (dependent variable) to determine the optimum farm ditch density used in irrigating diversified crops.

Five regression models were developed (Table 2). Regression analyses of these models show that physical factors such as size of turnout service area (SA), shape factor (SF), farm size (FSa) and farms with direct access to farm ditches (PF) significantly influenced the farm ditch length (FDL).

Individual effects show that turnout service area **(SA)** and shape factor (SF) significantly affected farm ditch length (Table 2, Model la): both having positive coefficients. The model show that the narrower the farm was, the longer were **the** farm ditches. Results were consistent with field observations on long and narrow TSA (Figure l).

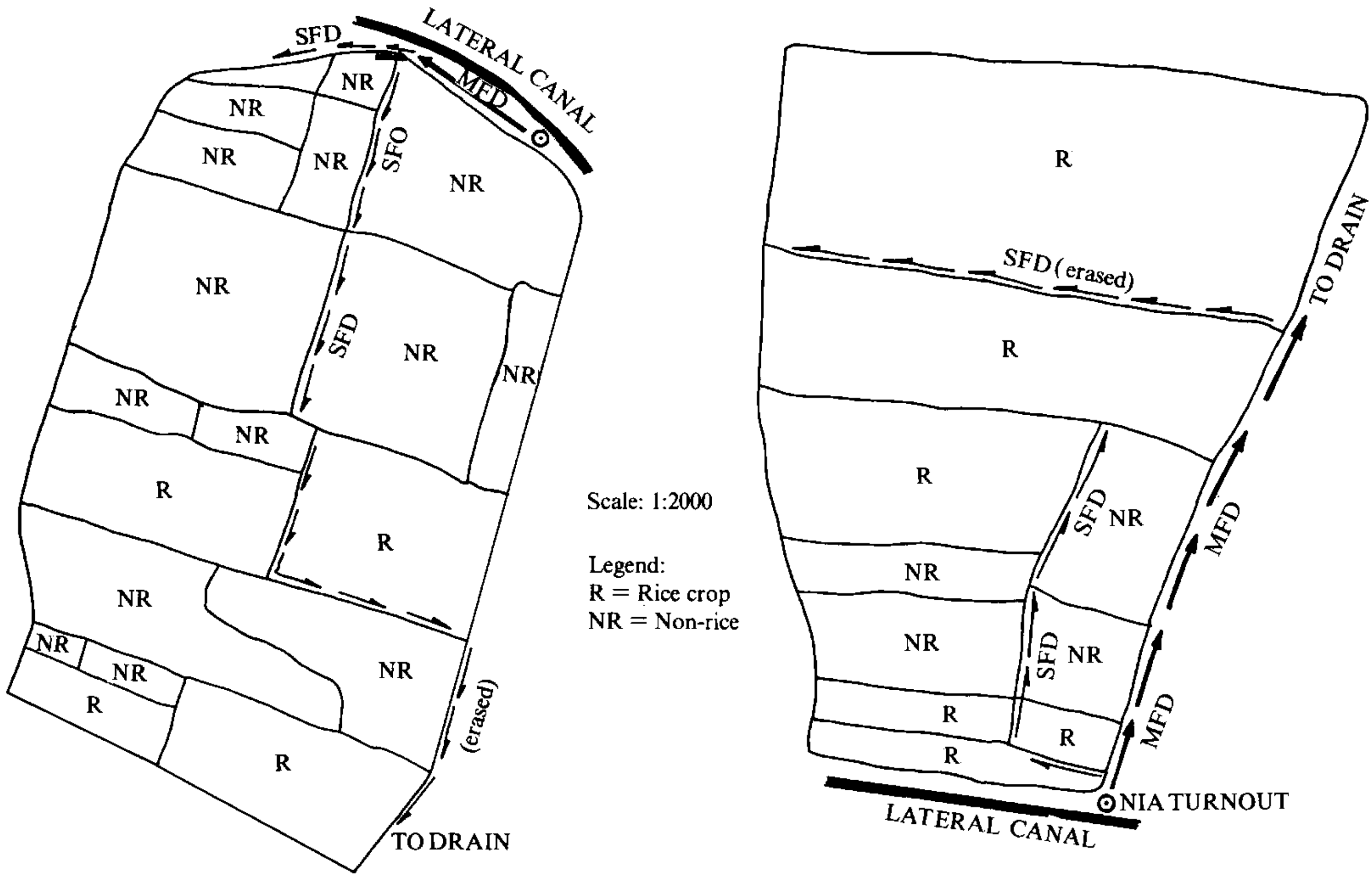
Relaxing **SA** and SF which are significant variables in Model Ia resulted to a reduced Model IIa. However, the average farm size (FSa) and percent of farms with direct access to farm ditches (PF) significantly affected the lengths of farm ditches. These two physical factors influence the

Table 2. Parameters of five regression models relating farm ditch length (FDL) to physical variables. LVRIS. **1987188** drv season.

Physical Variables	Regression coefficients (T-values in parenthesis)				
	Model la	Model IIa	Model IIIa	Model IVa	Model Va
Intercept	-3184.13	- 3277.10	- 4065 59	-3011.67	- 2025.01
Or	12.80	- 24.69	6.34	7.77	9.86
	(0.42)	(0.71)	(0.21)	(0.26)	(0.33)
MFDg	- 4.34	- 13.52	- 1.40	- 2.77	- 3.14
	(0.25)	(0.65)	(0.08)	(0.16)	(0.19)
GLs	11.56	26.91	6.98	7.57	10.60
	(0.67)	(1.31)	(0.38)	(0.41)	(0.62)
R	30.11	31.09	38.55	28.24	17.87
	(0.67)	(0.57)	(0.85)	(0.64)	(0.41)
NR	31.10	32.10	39.58	29.30	19.06
	(0.69)	(0.59)	(0.88)	(0.67)	(0.44)
SA	57.33		140.25	177.60*	207.23**
	(2.78)		(1.67)	(2.36)	(2.88)
FSa	273.50	596.7**	186.22		
	(1.55)	(3.36)	(0.99)		
SF	40.16**		27.56	21.57	37.16**
	(3.23)		(0.65)	(0.51)	(3.02)
PF	0.49	1.64	0.49	0.37	0.34
	(0.72)	(2.15)	(0.72)	(0.55)	(0.52)
[SA*SA]			- 28.76	- 34.99*	- 31.36*
			(1.59)	(2.07)	(1.87)
[SF*SF]			- 7.67	- 7.15	
			(1.23)	(1.15)	
[SA*SF]			27.54	28.49	
			(1.31)	(1.36)	
R^2	0.55	0.29	0.60	0.59	0.57
F -value	5.09**	2.26**	4.29**	4.59**	5.35**
N	47	47	47	47	47

Note: Or = orientation of main farm ditch (dummy variable); equal to zero when MFD is parallel or equal to one when it is perpendicular; MFDg = main farm ditch gradient (%); GLs = general land slope (%); R = rice farm plot (%); NR = non-rice farm plot (%); **SA** = size of turnout service area (ha); SF = shape factor (m/m); PF = percent of farms with direct access to farm ditches (%)

* and ** denote significance at **5%** and 1% levels, respectively.



a. TSA with MFD 11 to lateral canal

b. TSA with MFD 1 to lateral canal

Figure 1. **Layout of two turnout service areas (TSA's) exemplifying parallel and perpendicular orientations between MFD and supply canal at LVRIS, Ilocos Norte, 1987-88 dry season.**

need, location, and layout of farm ditches as well as the intensity and need of farm level facilities for allocation and distribution of water to farmers sharing a turnout (Tabbal et al., 1983). Farm size determines the number of farmers who will share water delivered through a common turnout. The accessibility of the farm plots to farm ditches reflects the need for additional farm ditches to serve farms which are far from the source. This is consistent with field observations that farmers construct additional farm ditches because of relative need (Svendsen, 1985).

A regression model was developed to show interaction of the significant variables (Table 2, Model IIIa). The interaction [SA*SA] shows the possibility of expanding the service area if farm ditches are adequate. The interactions [SF*SF] and [SA*SF] indicate the relative shape and orientation of the farms to the service area boundaries.

Regression Model IIIa explained 60% of the variations in farm ditch lengths. No single or interaction variables significantly affected the length of farm ditches. However, the model is statistically significant at 1% level.

Relaxing FSa resulted to an alternative Model IVa. The model explained 59% of the variations among samples. The turnout service area (SA) and interactions [SA'SA] significantly affected the length of farm ditches, implying the expansion of the turnout service area, if farm ditches are adequate.

An alternative model which relaxes the interaction variables [SF*SF] and [SA*SA] which were not significant in Model IVa was developed. The alternative model explained 57% of the variation in thelength of farm ditches (Table 2, Model Va). The SA and SF yielded significant effects at 1% level. Moreover, the interaction variable, [SA*SA] was significant only at 5% level.

However, other physical factors, although insignificant in the models, should not be overlooked in the design of terminal facilities (Table 2). The negative coefficient of main farm ditch gradient (MFDg) implies a decrease in the length of farm ditches as the slope increases. Results are consistent with the findings of Levine (1980) that flat areas require longer farm ditches than slopping areas. IRRI-NIA (1984) also found that MFD gradient and land slope greatly influence the flow of irrigation water and thus the duration of water distribution. Murray-Rust et al., (1983) also found that MFDs running perpendicular to the supply canal were easier to maintain than parallel ones.

Optimum Farm Ditch *Density* for ***LVRIS.*** Among the five models developed, the alternative Models IVa and Va were selected to determine the optimum farm ditch density. By taking the derivative of FDL with respect to the significant variable, SA and equating it to zero, the optimum value of SA was obtained. The average values of the non-significant values were then substituted to the equation to determine the optimum farm ditch length. The optimum farm ditch density was obtained by dividing the optimum FDL by the average turnout service area in each orientation category. This procedure was similar to the method used by IRRI-NIA (1984) and David (1974).

Applying the procedure to Model IVa, the optimum FDL obtained was 202 and 210 meters for parallel and perpendicular orientations, respectively (Model IVa, Table 3). Dividing the optimum FDL values by the average SA on each orientation, resulted in the approximate farm ditch density of 110 meter/ha for parallel and 114 meter/ha for perpendicular MFDs, with an average of 112 meter/ha. Optimum density was 4% higher than the mean density of 107 meter/ha.

Using the alternative Model Va, optimum FDL was *268* meter for parallel and 278 meter for perpendicular orientation (Table 3). The optimum farm ditch density was 145 and 151 meter/ha for parallel and perpendicular orientations, respectively, with an average of 148 meter/ha (28% higher than the mean).

Considering cost, labor and time, Model IVa is more appropriate to describe the optimum farm ditch density of LVRIS.

Preliminary results, however, do not imply that the regression models developed were the best regressions. Since best regression is subjective, physical and field observations has to be employed.

Upper *Talavera* River *Irrigation* System ***(UTRIS)***

At UTRIS, 24 TSA's weresurveyed. The sizes of the TSA ranged from 3.4 to 41.2 hectares. Combining the physical factors at each TSA, five regression models were also developed (Table 4). Results of the regression analysis showed that physical factors such as orientation (Or), size of turnout service area (SA), average farm size (FSa), and farms with direct access to farm ditches (PF) significantly affected the total farm ditch length (Table 4, Model Ib). The wider range of values in

Table 3. Optimum farm ditch density, length, and turnout service area, for two different main farm ditch (MFD) orientations, LVRIS, 1987/88 dry season.

	MFD Orientation		Average
	Parallel	Perpendicular	
	MODEL IVa[1]		
Farm ditch density, m/ha	110	114	112
Farm ditch length, m	202	210	206
Turnout service area, ha	1.82	1.85	1.84
	MODEL Va'		
Farm ditch density, m/ha	145	151	148
Farm ditch length, m	268	278	273
Turnout service area, ha	1.82	1.85	1.84

'Regression Model IVa:

FDL = −3011.67 + 7.77 (Or) −2.77 (MFDg) + 7.57 (GLs) + 28.24 (R) + 29.30 (NR) + 177.60 (SA) −34.99 (SA*SA) + 21.57 SF −7.15 (SF*SF) +28.49 (SA*SF) + 0.37 (PF)

'Regression Model Va:

FDL = −2025.01 + 9.86 (Or) −3.14 (MFDg) + 10.60 (GLs) + 17.87 (Rj + 19.06(NR) + 207.23 (SA) −31.36 (SA*SA) + 37.16 (SF) + 0.34 (PF)

Note: Computed based on average values of MFDg = 0.94%, GLs = 1.58%, R = 25.5%, NR = 74.45%, SF = 11.49, PF = 50.91%.

each unit of observation resulted to a coefficient of determination equal to 87%.

***Optimum* Farm *Ditch* Density *for UTRIS*.** Among the regression models developed, Model Ib described best the farm ditch density characteristics for UTRIS. Substituting the average physical values at each orientation, the optimum farm ditch density was 117 and 94 meter/ha for parallel and perpendicular orientations, respectively (Table 5).

Combination *of* Physical Parameters of LVRIS and UTRIS

The combined effect of the physical parameters at each TSA in both sites was tested to determine which variables caused the variation in farm ditch length. The regression model developed explained 80% of the variation of the FDL with respect to the combined factors considered (Table 6). Physical factors such as orientation (Or), size of turnout service area (SA), shape factor (SF) and farm with direct access to farm ditches (PF) appeared to he significant when the average farm size (FSa) was dropped. Notwithstanding the combined effects of the samples from LVRIS and UTRIS, the values of the factors of UTRIS samples biased the model. Thus, it would he misleading to interpret the results of this model without considering physical observations,

Length of farm ditches, average farm size, turnout service area and degree of land utilization under LVRIS and UTRIS differed (Tables 7 and 8). Farm ditches at LVRIS were shorter than at UTRIS. Results were consistent with field observations that some farmers under LVRIS practiced paddy to paddy irrigation and that some supplementary farm ditches were not used to the extent that they were nonexistent.

Field observations at UTRIS showed that the total length of farm ditch oriented parallel to the supply canal were longer than those that were perpendicular (Table 7). Difference in length with respect to orientation was due to factors such as MFD gradient (Model IIb) and general land slope (GLs). At parallel orientation, a shorter MFD was observed due to steeper slopes (MFDg) while a longer SFD was found at flat slopes.

Average farm size and turnout service area were smaller at LVRIS than at UTRIS (Table 8). However, the degree of land utilization at LVRIS was higher than at UTRIS. These differences explain the varying results obtained in the analysis of farm ditch lengths.

Table 4. Parameters of five regression models relating farm ditch length (FDL) to physical variables, UTRIS. 1987/88 drv season.

Physical Variables	Regression coefficients (7-values in parenthesis)				
	Model Ib	Model IIb	Model IIIb	Model IVb	Model Vb
Intercept	-8701.14	- 13945.00	- 6864.44	.3002.91	- 3621.35
Or	–1086.16'.	–637.96	–1021.16	–1050.23*	–1045.64
	(2.50)	(0.79)	(2.20)	(2.19)	(2.04)
MFDg	1455.02	3374.13*	986.29	779.64	1036.47
	(1.85)	(2.48)	(1.02)	(0.79)	(1.11)
GLs	687.91	–504.80	464.94	157.10	581.82
	(1.09)	(0.47)	(0.60)	(0.21)	(0.77)
R	41.27	102.88	34.79	16.28	8.48
	(1.84)	(2.03)	(1.17)	(0.60)	(0.29)
NR	53.33	110.07*	46.80	28.42	19.77
	(1.84)	(2.13)	(1.58)	(1.05)	(0.68)
SA	133.06**		105.30	84.15	97.42
	(6.27)		(0.99)	(0.77)	(0.93)
FSa	863.45**	1524.03*	613.22		
	(2.30)	(2.26)	(1.34)		
SF	–15.61		–30.30	–135.42	–27.28
	(0.35)		(0.17)	(0.84)	(0.52)
PF	41.89**	44.19*	31.87*	23.24	35.55*
	(4.02)	(2.50)	(2.40)	(1.94)	(2.97)
[SA*SA]			2.43	3.69	0.60
			(0.94)	(1.49)	(0.27)
[SF*SF]			14.02	21.61*	
			(1.31)	(2.30)	
[SA*SF]			–12.82	–16.35	
			(1.56)	(2.04)	
R^2	0.87	0.50	0.90	0.88	0.83
F-value	11.12**	2.36**	8.28**	8.32**	7.69**
N	24	24	24	24	24

Note: Or = orientation of main farm ditch (dummy variable); equal to zero when MFD is parallel or equal to one when it is perpendicular; MFDg = main farm ditch gradient (%); GLs = general land slope (%); R = rice farm plot (%); NR = non-rice farm plot (%); SA = size of turnout service area (ha): SF = shape factor (m/m); PF = percent of farms with direct access to farm ditches (%)

* and ** denote significance at 50, and 1% levels, respectively.

Table 5. Optimum farm ditch density', length, and turnout service area. for two different main farm ditch (MFD) orientations, UTRIS, 1987/88 dry season.

	MFD Orientation		
	Parallel	Perpendicular	Average
Farm ditch density, m/ha	117	94	104
Farm ditch length, m	2013	1848	1924
Turnout service area, ha	17.20	19.60	18.50

'Regression Model Ib:

$$FDL = -8701.14 - 1086(Or) - 1455.02(MFDg) + 678.91(GLs) - 41.72(R) + 53.33(NR) + 113.06(SA) + 863.45(FSa) - 15.61(SF) + 41.89(PF)$$

Note: Computed based on the average values in each orientation.

Table 6. Coefficient of regression[a] relating farm ditch length (FDL) to combined physical variables of LVRIS and UTRIS, 1987/88 dry season.

Physical Variables	Regression Coefficient	Std Error Of Est.	T-value
Intercept	-717.09		
Orientation of MFD[b] (Or)	-405.83*	1699.78	2.36
MFD gradient (MFDg)	-13.34	171.71	0.11
General land slope (Gls)	43.63	120.51	0.36
Percent of farms planted to rice (R)	-1.55	16.86	0.09
Percent of farms planted to non-rice (NR)	4.15	16.86	0.24
Average farm size (SA)	132.23**	35.46	3.73
[SA*SA]	0.07	0.86	0.08
Shape factor (SF)	-74.83**	26.83	2.70
Percent of farms with direct access to FD (FF)	12.50**	3.77	3.31

Coefficient of determination, R^2 = 0.80
F-value = 26.96**
N = 71

[a]Regression model:
FDL = -717.09 -405.83 (Or) -13.34 (MFDg) + 43.63 (GLs) -1.55 (R) + 4.15 (NR) + 132.23 (SA) + 0.07[SA*SA] -74.83 (SF) + 12.50 (PF)

[b]Dummy variable: 1 if the MFD is perpendicular lo supply canal and 0 if it is parallel.

**Significant at 1% level
*Significant at 5% level

Table 7. Mean main (MFD) and supplementary SFD farm ditch lengths in meters for two different orientations of main farm ditches, LVRIS and UTRIS, 1987/88 drv season.

Location	Orientation	Farm Ditch Length MFD	SFD	Average
LVRIS	Parallel	144	38	196
	Perpendicular	125	48	197
Average		135	43	196
UTRIS	Parallel	499	1514	2013
	Perpendicular	750	1099	1848
Average		635	1289	1924

Table 8. Average farm size in hectares by main farm ditch (MFD) orientation, LVRIS and UTRIS, 1987/88 dry season.

Location	MFD Orientation Parallel	Perpendicular	Average
LVRIS	0.31	0.32	0.31
UTRIS	1.44	1.27	1.35

Results of the combined model in conjunction with field observations indicate that two sets of values must be considered in designing systems for mixed cropping during the dry season. For areas where the average farm size is less than 0.50 hectare, the optimum turnout service area should be less than 3 hectares. For areas with average farm size of less than 2 hectares but larger than 1 hectare, the turnout service area should be less than 20 hectares. Furthermore, regardless of the differences in sizes of areas, the farm ditch density for both cases will have to be 100 meter/ha, on the average.

Conclusion and Recommendation

On-farm ditches are indispensable in water distribution. Adequate farm ditches facilitate equitable water distribution.

Lengths of farm ditches are generally affected by physical factors such as size of turnout service area, orientation of main farm ditch, shape factor, farm with direct access to farm ditches, main farm ditch gradient and land slope. Preliminary results showed that the regression models signify dependence of farm ditch density on the explanatory variables.

The regression models developed illustrated the effects of the factors considered based on actual conditions under LVRIS and UTRIS. However, the equations could not be used to predict the needed farm ditch by substituting values obtained from a certain area.

Factors like land slope, shape and orientation entail costly modifications to conform with an optimum value.

Each area has its own peculiarities and in most cases it is desirable to establish farm ditches at proper boundaries.

Compared to the optimum farm ditch density found by the IRRI-NIA study for rice areas (1984), the values obtained for the study sites were much higher, indicating a higher farm ditch density for diversified crops areas. Optimum turnout service areas for the study sites were also less than the value obtained by IRRI-NIA.

References

David, Isidoro. 1974. Response surface analysis for factorial experiments. A lecture handout, UPLB, Los Baños, Laguna.

IRRI-NIA. 1984. On-farm facilities study: A Final Report. National Irrigation Administration, Quezon City.

Levine, G. 1980. Hardware and software: An engineering perspective on the mix for irrigation management. Paper presented during a Planning Workshop on Irrigation Management, IRRI, Los Baiios, Laguna.

Moya, T. 1985. An evaluation of water distribution within tertiary areas of the Lower Talavera River Irrigation System. Paper presented during the Seminar on Irrigation Management: Research for South Asia.

Murray-Rust, et al. 1983. Evaluation of irrigation system design. Water Management Dept. IRRI, Los Baños, Laguna.

Svendsen, M. 1985. Group behavior of farmers in three types of Philippine irrigation systems. Paper presented during the seminar on Irrigation Management: Research from Southeast Asia, sponsored by ADC, Inc.: T. Wickham (ed), Thailand, 1981.

Tabbal, D.F., S.I. Bhuiyan, and A. M. Mejia, 1983. Irrigation system design and operation: Some problems that impede efficient water management. Paper presented during the Symposium on Water Resources Research in the 80's, 20-22 June 1983, Quezon City.

Wickham, T. and A. Valera. 1976. Practices and accountability for better water management. Paper presented at the West Africa Rice Devt Assoc, Water Management Workshop. 8-10 June 1976, Dakar, Senegal.