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A PRELIMINARY REPORT

IRRIGATION SYSTEMS IN DHADING DISTRICT

BY

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This is an initial draft of this report for discussion with members of the Dhading Development District staff and other interested colleagues. Please do not quote from this version. Comments and criticisms are welcome. Further analysis and a more extended report will be completed in the fall of 1992 and made available to anyone who requests it.

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Introduction

In 1988 as part of an effort to locate irrigation systems in the Dhading District that could benefit from external assistance, the Dhading Development District [funded by Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ)] contracted to have a census of irrigation systems conducted in the Dhading District. Information about the engineering aspects of irrigation systems, labor mobilization, water adequacy, and farmers' enthusiasm for external assistance was gathered from 3,000 irrigation systems.

This data was made available to the Nepal Institutions and Irrigation Systems (NIIS) project at the Workshop in Political Theory and Policy Analysis for secondary data analysis in conjunction with a larger study of Nepal irrigation systems being conducted by the Workshop with financial assistance from the Ford Foundation, from the National Science Foundation, and from USAID. The data has been sent to the Workshop in several installments and the current analysis is based on the first two installments that include 2501 systems. A third installment with data on about 300 systems recently arrived and is being prepared for merging with the first two installments. We have also received xerox copies of original field collection instruments for an additional 55 systems and hope to enter this data in the fall of 1992. The current report must therefore be viewed as an initial report of analysis in progress rather than as a final report.

Since the initial purpose of the census of irrigation systems was to produce a description of each system in the Dhading District, many variables were entered in text or combined together in a single field. For the purposes of analysis, however, it is important to have structured data (i.e., data that has been converted into categories or numbers) and to have one variable contained in one field. A considerable amount of the Workshop's efforts so far have been devoted to a systematic recoding of information contained in the original census. We are particularly appreciative of the efforts of Corey Alexander and Todd Walker during this past year. They have worked very hard to keep the integrity of the original data set intact while helping to extract a series of categorical variables that could be used in analysis. Gopendra Bhattrai has helped in the interpretation of textual variables given his engineering background in Nepal. Sharon Huckfeldt has provided considerable input in the programming involved in the development of this data set.

In order to have a workable set of variables the original dataset was scrutinized carefully and then reorganized. Some of the original variables were transformed into two or more new variables such that where originally only textual information was available, we now had numeric data that was statistically usable. The final result of this reorganization was that the dataset used for the purposes of this study had 2501 systems with the variables listed in the Appendix. Further, a more limited dataset was created from the original dataset by eliminating all cases that had at least one missing variable so that a cross-tabulation exercise using key variables could have the same number of cases for each variable (see Tables 4a through e). This dataset had a reduced N of 2096, down from the original 2501. The purpose of the limited dataset is to carry out a cross-tabulation that illustrates the differences in standardized versus unstandardized measures using labor days.

In this initial report we compare the physical variables characterizing irrigation systems in Nepal by whether the systems are managed by the farmers themselves (either in private, family irrigation systems or in larger, communal irrigation systems) or are managed by a government agency which is usually the Department of Irrigation. Further, we examine physical characteristics by the age of the irrigation system and whether there has been any external assistance. Then, we report on an effort to understand better the relationships among diverse measures of labor input. Finally, we present a preliminary multi-variate analysis of variables affecting labor input and whether water supplied from an irrigation system was adequate for different seasons of the year.

Eventually, analysis of this data will be included in a monograph entitled *Institutions, Incentives and Irrigation in Nepal* by Elinor Ostrom, Paul Benjamin, and Ganesh Shivakoti and the NIIS Project Team. An initial draft of the entire monograph will be completed by December 1992 and a one-day seminar will be conducted on this draft in Kathmandu by Ganesh Shivakoti (IAAS) and Elinor Ostrom (Indiana University).

A **Description** of **the** Irrigation Systems in **the Dhading District;**

This section uses cross-tabulations to examine some of the potentially meaningful bivariate relationships that can be found amongst the variables characterizing irrigation systems in the Dhading dataset. The findings are presented in the form of tables with brief descriptions that follow each set.

Type of Canals

On the data compilation form, surveyors used a series of phrases to describe the type of canal (or absences of a canal) for each system. Phrases were entered such as "simple unlined earth canal." These phrases were coded in Bloomington into the seven categories shown on Table la. Most of the farmer managed irrigation systems are unlined (92.83%) whereas nearly two-third of the government managed irrigation systems are unlined (62.96%). On the other hand, only 0.29% of the total farmer managed irrigation systems are partly lined as compared to 25.93% of the government managed irrigation systems being partly lined. Farmers have not approached the government for assistance for the systems that are without canal or are terraced field channels. Table la presents a more detailed overview of the variety of types of irrigation canals found in the Dhading District and Table lb collapses that information into two categories, used in later analysis, depending on whether the canal is lined or not. Table la: Type of Canal

Summary of Canal Type	Type of Irrigation System	
	Farmer Managed	Government Managed
No type specified	1.19% (29)	0.0% (0)
Unlined	92.83% (2265)	62.96% (17)
. Partly lined	0.29% (7)	25.93% (7)
Without canal	1.56% (38)	0.0% (0)
Terraced	1.48% (36)	0.0% (0)
Canal in rocky area	2.13% (52)	3.70% (1)
Other	0.53% (13)	7.41% (2)

Table lb Is the Canal Lined

Is the canal lined?	Type of Irrigation System	
	Farmer Managed	Government Managed
No	99.69% (2265)	70.83% (17)
Yes (Partly)	0.31% (7.)	29.17% (7)

Presence of Masonry in the Headworks

The data collection team was asked to describe the type of head work or diversion structure that characterized an irrigation system. Phrases such as "dry stone masonry" were entered as answers to this question. Given the importance of masonry in hill irrigation systems to bring water from the rocky cliffs, these descriptions were coded to reflect the presence or absence of masonry. As shown in Table 1c nearly two-thirds of the farmer managed canals have masonry work; and 55% of the government managed systems also have headworks composed of masonry work. Table 1c : Type of Headworks

Do the Headworks have masonry work?	Type of Irrigation System	
	Farmer Managed	Govt. Managed
No	31.83% (755)	45.00% (9)
Yes (Partly)	68.17% (1617)	55.00% (11)

Age of Irrigation Systems

Information was also collected in the census regarding the age of the irrigation systems. Data was entered as "traditional" or the year of construction was given where known. Eighty seven percent of the farmer irrigation systems were constructed before 1931 or coded originally as "traditional" whereas eighty five percent of the government managed irrigation systems were constructed *after* 1931. The findings are summarized in table 1f.

Table If Age by Type of Irrigation System

Age of irrigation system	Type of Irrigation System	
	Farmer Managed	Govt. Managed
Traditional (pre-1931)	87.03% (2094)	14.81% (4)
Recent (post-1931)	12.97% (312)	85.19% (23)

Farmer Enthusiasm

In response to a question concerning the farmers' enthusiasm and willingness to raise local resources and utilize grant or loans received to increase or enlarge capacity, nearly two-thirds of system users in farmer managed systems were coded by the fieldworker as not enthused about participating in raising further resources while in the case of government managed irrigation systems, 70% of the system users were willing to put forth more effort to raise resources. The findings are presented in table lg. Table lg: Farmer Enthusiasm by Type of Irrigation System

Users' Enthusiasm To Raise Further Resources	Type of Irrigation System	
	Farmer Managed	Govt. Managed
Not Enthused	68.95% (1670)	29.63% (8)
Enthused	31.05% (752)	70.37% (19)

Water Adequacy

When the original data was collected, fieldworkers were asked to answer yes or no to a question whether there was "enough water" and if not, in which months was water adequate. The dichotomous answers to this question were coded into numeric form (0 and 1) to obtain a variable called Watersum. Further text was entered in many descriptions and questions were also answered about the crops grown in summer, winter, and spring seasons. From this we could derive a second variable, **Waterseasons,** that described the adequacy of water season-by-season in the annual cycle. Its values represented single seasons as well as combinations of seasons resulting in a variable with multiple categories ranging from 0 to 8 (see Appendix). Because of the distribution of responses to this variable, it could not be used as a useful categorical variable nor as a scalable variable. For the purposes of this analysis the variable Waterseasons has been recorded to obtain a scale of adequacy ranging from 1 to 4 (see Table 2a) and called **Enough.** **Watersum** was left as a dichotomous variable with 0 representing not adequate for all seasons and 1 representing adequate for all seasons.

We now examine which variables (if any) are associated with varying levels of adequacy. According to the response of the key informants (in Table 2b), 70% of the government managed irrigation systems have adequate water all year round as opposed to only 36% of the farmer managed irrigation systems. This might be due to the fact that many of the government managed irrigation systems have been partly lined along critical sections of the canals whereas many farmer managed irrigation systems lack resources and the technical wherewithal required for such construction. However, as shown in Table 2a, 62% of the farmer managed irrigation systems have adequate water all year or two of the three seasons as compared to 74% of the government managed irrigation systems. Thus, it is possible that most of the government irrigation systems have perennial sources where water is available during the whole year. In the case of many farmer managed hill irrigation systems in Nepal, the sources are seasonal which means that they usually dry up during the spring time. This seems true for Dhading district as well. Table 2a Water Adequacy by Type of Irrigation System

Water Adequacy	Type of Irrigation System	
	Farmer Managed	Govt. Managed
Scarce all year	11.33% (274)	3.7% (1)
Adequate only in monsoons	26.46% (640)	22.22% (6)
Adequate in two of three seasons	26.33% (637)	3.7% (1)
Adequate all year	35.88% (868)	70.37% (19)

Table 2b Water Adequacy for All Three Seasons by Type of Irrigation System

Summary of Water Adequacy	Type of Irrigation System	
	Farmer Managed	Govt. Managed
Not adequate in all seasons	64.12% (1551)	29.63% (8)
Adequate in all seasons	35.88% (868)	70.37% (19)

External Assistance

The original data collection form asked whether any external assistance has been utilized in building or improving the irrigation system. Only 114 systems (or, about 5%) appear to have had external assistance. Of those systems that have received external assistance 60.5% do have adequate water in all three seasons while only 35% of the systems not receiving assistance have adequate water in all seasons. However, 27% of the systems not receiving assistance have adequate water in two of the three seasons as compared to only 16.7% in those systems receiving assistance. Thus, external assistance has helped farmers to increase water adequacy (See Tables 2c and 2d).

Table 2c; External Assistance and Water Adequacy in Diverse Seasons

Water Adequacy	External Assistance	
	Not Received	Received
Scarce all year	11.71% (275)	5.26% (6)
Adequate only in monsoons	26.87% (631)	17.54% (20)
Adequate in two of three seasons	26.36% (619)	16.67% (19)
Adequate all year	35.05% (823)	60.53% (69)

Table 2d: External Assistance and Water Adequacy in All Seasons

Summary of Water Adequacy	External Assistance	
	Not Received	Received
Not adequate in all seasons	64.95% (1525)	39.47% (45)
Adequate in all seasons	35.05% (823)	60.53% (69)

Water Adequacy and Farmers' Enthusiasm about Mobilizing Resources

The level of water adequacy appears to be related to the enthusiasm that farmers exhibit in regard to the mobilization of resources to increase or enlarge the capacity of their system. The majority of users (74%) who had inadequate water in all seasons were unenthusiastic about working to raise more resources. This might be due to the lack of water at the source during dry seasons. In case of those systems where water was adequate all seasons, more than half (58%) of the systems' users were enthusiastic about raising additional resources for further improvement of the systems. In future analysis we will explore whether the different levels of water adequacy in farmer managed and government managed systems helps to explain the differences shown in Table lg above. Table 3a: Water Adequacy by Farmer Enthusiasm

Water Adequacy	Summary of Enthusiasm	
	Not enthused	Enthused
Scarce all year	15.11% (254)	3.59% (28)
Adequate only in monsoons	30.76% (517)	17.33% (135)
Adequate in two of three seasons	28.20% (474)	21.05% (164)
Adequate all year	25.94% (436)	58.02% (452)

Table 3b

Summary of Water Adequacy	Summary of Enthusiasm	
	Not Enthused	Enthused
Not adequate in all seasons	74.60% (1245)	41.98% (327)
Adequate in all seasons	25.94% (436)	58.02% (452)

Labor Mobilization in Dhading Irrigation Systems

In most irrigation systems in Nepal, farmers contribute a rather amazing level of labor to keep their systems maintained. Fortunately, among the information collected in the original census was the number of hours (which we have converted to days) contributed by farmers during the past year to keep their system in good repair. A variable **AveRepair** was gleaned from the text variable **RepairSpent** in the original dataset which contained the information on hours contributed. This variable was then converted into the variable **Laborday,** which is the result of dividing **AveRepair** by eight to arrive at the average workday.

Total labor days contributed gives us one view of labor mobilization but not the only relevant view. We have also examined three ways of standardizing labor mobilization: (1) labordays per household served by the irrigation system, (2) labordays per length of the canal (in meters), (3) labordays per hectare of land served by the canal. On Table 4a through 4e, we display all four measures of labor mobilization by various physical and other variables related to an irrigation system.

Table 4a : Comparison of Standardized vs. Unstandardized Measure of Labor

TYPE OF SYSTEM	Frequency	Labordays	Labordays per Household	Labordays per unit length (meter)	Labordays per unit area (hectares)
Farmer Group Managed	*1922*[1]	**35.60**[2] 69.60[3]	**4.14** 5.58	**.0998** .2730	**.7615** .9644
Govt. Managed	*17*	**294.4** 956.7	**7.18** 15.90	**.1154** .3144	**.7655** 1.222
Govt. Planned	*5*	**13.75** 15.40	**1.05** 1.26	**.0154** .0191	**.1151** .1296
Individual or Family Managed	*150*	**19.96** 21.23	**9.16** 12.64	**.1863** .6595	**.8767** .7747
Govt. under Construction	*2*	**81.25** 97.22	**1.56** .4419	**.1109** .1461	**.1845** .0925

Table 4b

TYPE OF CANAL	Frequency	Labordays	Labordays per Household	Labordays per unit length (meter)	Labordays per Hectare
Missing	*3*	**26.04** 31.91	**1.57** 1.41	**.2960** .1981	**.6045** .8298
Unlined	*2016*	**32.20** 58.27	**4.42** 6.31	**.2960** .3098	**.7560** .9267
Partly Lined	*11*	**45.88** 42.75	**8.56** 16.39	**.2731** .7586	**.6615** .5922
Without Canal	*2*	**9.37** .8838	**.529** .0757	**.0430** .0274	**.1151** .0391
Terraced	*3*	**6.66** 4.38	**1.38** .6364	**.0589** .0638	**.3275** .1519
Canal in Rocky Area	*51*	**212.7** 578.0	**8.69** 11.99	**.2108** .4501	**1.423** 1.685
Other	*10*	**26.75** 33.94	**1.09** .9414	**.1525** .1861	**.2045** .2017

N = 2096

[1] *Bold Italic type numbers are frequencies,*

[2] **Bold type numbers are** means, and

[3] Ordinary type numbers are standard deviations.

Table 4c

TYPE OF HEADWORK	Frequency	Labordays		Labordays per Household		Labordays per Meter		Labordays per Hectare	
Missing	7[1]	**25.44**[2]	23.41[3]	**10.28**	20.34	**.1219**	.1706	**.6956**	.5868
Temporary	***614***	**37.43**	55.62	**5.28**	6.61	**.1375**	.3688	**.9772**	1.064
Semi-Permanent, Stone Masonry/Wall	***1457***	**36.18**	126.2	**4.18**	6.48	**.0928**	.2942	**.6826**	.8951
Permanent	***4***	**57.03**	49.89	**3.25**	3.26	**.0426**	.0139	**.3718**	.2976
Other	***14***	**39.93**	79.79	**3.80**	3.38	**.1025**	.1401	**.5772**	.4578

Table 4d

WATER ADEQUACY	Frequency	Labordays		Labordays per Household		Labordays per Meter		Labordays per Hectare	
Not Adequate in all seasons	***1301***	**29.08**	55.94	**4.13**	5.40	**.1060**	.2928	**.7253**	.8682
Adequate in all seasons	***795***	**48.84**	162.4	**5.15**	8.17	**.1059**	.3535	**.8370**	1.075

Table 4e

EXTERNAL ASSISTANCE	Frequency	Labordays		Labordays per Household		Labordays per Meter		Labordays per Hectare	
Not Received	***2010***	**31.56**	54.31	**4.43**	6.31	**.1062**	.3186	**.7627**	.9332
Received	***86***	**153.6**	460.8	**6.52**	11.39	**.1006**	.2810	**.8838**	1.340

N = 2096

[1] ***Bold Italic type numbers are frequencies,***
[2] **Bold type numbers are means,** and
[3] Ordinary type numbers are standard deviations.

Tables 4a through 4e help us address a question of considerable importance with reference to the study of irrigation systems i.e. whether or not to standardize labor contributions. And does standardization make a difference? We can now see that there are significant differences seen between an unstandardized variable and a standardized variable as well as between different standardized variables.

The strength of this dataset lies in the large number of cases available for statistical analysis and consequently, an enhanced ability to make some definitive findings. To get a complete set of coherent cross-tabulations that could be consistently interpreted across and down the table, the original dataset was subjected to some cleaning up prior to analysis. Each of the variables used in these cross-tabulations, whether standardized or unstandardized, were included in a transformation that got rid of problems such as blank spaces and null values. The dataset thus obtained had 2096 observations as compared to 2501 observations in the original dataset. This new dataset was now ready for analysis and we could be assured of consistency in frequency across the table.

The very nature of irrigation systems compels any analysis to include many variables that may be significant in their impact on performance. Variables such as service area, households in service area, length of system, type of headwork, type of capital resources available, type of institutional arrangement, labor mobilization, etc make significant contributions in explaining the variation in performance of an irrigation system. Consequently, incorporating these variables in cross-tabulations and any other statistical exercise is important. Equally important is the decision to use one standard of measurement over another. The cross-tabulations presented in Tables 4a through 4e use number of households in service area, length of system, and service area of system as three different measurement standards for labordays spent in maintaining/building a system. The variable labordays is an important intermediate in explaining the effectiveness of collective action in enhancing the performance of an irrigation system, the underlying premise being that better organized systems are capable of higher labor mobilization and hence better maintenance and therefore better performance. The cross-tabulations show that indeed there are considerable differences in measurement from one standard to another. The decision to use a particular standard then depends on the theory underlying the analysis.

At least two kernels can be gleaned from the analysis in this section. The first is that the cross-tabulations in this section support the findings from the cross-tabulations in the earlier section. As one example, the number of labordays, standardized or unstandardized, with one exception, was more in systems where water was adequate in all three seasons. The exception to the effect of water adequacy on labor mobilization is for the variable where labor input is standardized using length of canal. The second interesting fact gleaned from these tables is that the standard deviations for labor per household consistently showed lower standard deviations than any of the other standardized measures. It could be that this particular standardized variable turns out to be most useful for the analysis of this dataset.

Evaluating Performance

A central question of the NIIS project is what various combinations of institutional, physical, and cultural factors affect the performance of irrigation systems. Since the Dhading data was collected for an entirely different purpose, we do not have available the full array of institutional variables that we have collected in the much more limited set of irrigation systems in the NIIS data set itself. Nor are there a full array of performance measures. One way of gauging performance, however, is the adequacy of water made available to the farmers. And some information about adequacy was collected in the Dhading census of irrigation systems.

The analysis contained in this section has its strengths and weaknesses. The strengths stem from the fact that there are a large number of cases to work with and this allows for a fair amount of confidence as far as the findings are concerned. The weaknesses arise out of the extreme skewness of the data and the relative narrowness of the range in the variety of variables available. These two characteristics combined together make for a very tentative preliminary analysis.

In this analysis, we will use multiple regression techniques to ask whether the number of labor days per household, the length of an irrigation canal, the number of hectares contained in an irrigation system, an interaction term representing the product of labor days per hectare and length of canal, and the enthusiasm of the farmers for contributing resources help to explain the number of seasons during which water is adequate. The model constructed for the purposes of regression is :

$$\mathbf{Enough} = a + \mathbf{b_1\, Inter1} + \mathbf{b_2 Labor/HH} + \mathbf{b_3 Length} + b_4 \text{Landarea} + b_5 \text{Enthsum} + e$$

where

Enough, the dependent variable has values ranging from 1 to 4 and represents the adequacy of water;

Inter1, the interaction term is the product of **Labor/HH** and **Length;**

Labor/HH, is a standardized independent variable that is obtained by dividing number of households into labordays per system yielding labordays per household;

Length, is an independent variable representing the length of a system with meters as the unit of measurement;

Landarea, is an independent variable representing the service area of a system with hectares as the unit of measurement; and

Enthsum, is an independent dichotomous variable representing the enthusiasm of farmers towards participation in efforts to raise local resources and use capital to increase the capacity of a system. This variable is coded zero for not enthusiastic and one for enthusiastic.

This model incorporates variables characterizing the physical system and those characterizing the resource mobilization capabilities of the farmers in attempting to explain the variability in the water adequacy of an irrigation system. **Length** and **Landarea** are the physical variables used in the model on the theoretical premise that the length and size of a system should have a negative relationship with adequacy. We would expect greater difficulty in organizing to maintain a longer and/or bigger system as well as less efficiency in water delivery over large areas or long distances.The variable **Labor/HH** represents the idea of labor mobilization, i.e. people have to mobilize to participate in the maintenance of a common resource such as an irrigation system. The variable Enthsum is a proxy for the stake that a farmer might have in participating in collective efforts to maintain, protect and enhance the resource. The interactive term Interl gives the change in the relationship between **Labor/HH** and **Enough** that accompanies a unit change in **Length.** This would also be true for the change in the relationship between **Length** and **Enough** for a unit change in **Labor/HH.**

Each variable has statistical significance at the .01 level and this also implies that the variables are jointly significant as well. The results of the regression are summarized in Table 6.

Table 6 : Ordinary Least Squares Estimates for Adequacy Model

Variable	Coefficient	Std. Error	t-value	Proba
Interl	-4.87	2.06	-2.367	0.018
Labor/HH	.0102448	.0037	2.768	0.006
Length	.0001717	.00003	5.568	0.000
Landarea	-.0003111	.00011	-2.640	0.008
Enthsum	.5791682	.04601	2.587	0.000
Intercept	2.5866			
Number of cases	2282			
R-square	0.10			

The predicted value for **Enough** can be calculated from the equation:

Enough = 2.58 **- 4.**87**(Interl) +** .010**(Labor/HH)** + .0001 **(Length)** - .0003 **(Landarea) + .579 (Enthsum)**

The signs of the relationship indicate that adequacy of water is positively related to the quantity of labor per household mobilized, the enthusiasm that the farmers have for raising resources, and the length of the canal. The first two relationships are expected. The direction of the relationship of **Length** with **Enough** is not what was expected. This could be because length in this context could include branches as well, which could then mean that water delivery is more efficient. The slope of **Inter1** gives the value of the slope shift of **Labor/HH** for every unit change in length of the system. The R-square of .10 tells us that this particular model is only able to explain ten percent of the variance in the dependent variable **Enough.**

A more significant finding is that these variables are non-trivial in explaining the variability of water adequacy in a system and the direction of all but one of the relationships is as expected. In the fall of 1992 after merging the last of the data from the original data set, we intend to examine several alternative multi-variate models and include an analysis of the level of rainfall in this analysis.

Conclusion

This preliminary study used data provided by GTZ on irrigation systems in Dhading district, Bagmati, Nepal. Cross-tabulations of theoretically meaningful variables were undertaken to describe the behavior of bivariate relationships between them. Further, another set of cross-tabulations was conducted to provide a comparison of measurements that were standardized using different bases. A significant difference in values is observed for each of the standardized measures and bivariate relationships examined previously were supported by the findings. The regression conducted to estimate the adequacy of water for a system yielded statistically significant variables that had been used to represent physical variables and the willingness of farmers to mobilize resources. Given the skewed nature of the data and the relatively modest analysis conducted, the findings at this stage cannot be considered as formally tested. Further analysis at a later stage will continue from where this initial working paper has ended.