PN-ACH-935

WORKING PAPERS ON IRRIGATION PERFORMANCE 2

ASSESSING EFFECTS OF POLICY CHANGE ON PHILIPPINE IRRIGATION PERFORMANCE

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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International Food Policy Research Institute
Washington, D.C.

December 1992

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FOREWORD

The Working Papers on Irrigation Performance series was initiated by the International Food Policy Research Institute (IFPRI) in early 1992 to promote research, discussion, and thought on issues relating to the effectiveness and efficiency of irrigation systems in the developing world. This is not a new topic, but much of the work in this area is marked by a wide diversity of definitions, assumptions, approaches, and methodologies, which has rendered results incommensurate and nonadditive.

The purpose of this series is to provide a venue for more coherent and focused efforts to characterize irrigation performance and to understand its determinants and its impacts on national food production systems. The series consists of concept papers that provide a framework for approaching irrigation performance issues and case studies that represent applications of these principles to field situations.

The series is rooted in an activity carried out in conjunction with the International Irrigation Management Institute (IIMI) to develop a framework and methodology for assessing irrigation performance. Several of the papers in the series had their origin in that activity, though other papers are being included as well. A fundamental criterion for inclusion in the series is consistency with the definitions and concepts presented in the first paper, which articulates a framework for assessing irrigation performance and provides the overall conceptual basis for the series.

The case study presented here brings together two important sets of issues of considerable current interest in the irrigation management field. The first of these relates to the methodological problems involved in usefully and reliably assessing irrigation system performance, a topic with which this series is centrally concerned. The second set of issues relates to the application of policies and rules by governments that try to elicit enterprise-like behavior from irrigation agencies. This paper assesses the irrigation performance impacts of Philippine government policy changes that shifted the public irrigation agency to a "quasi-private" organizational mode in 1981. It is adapted from a larger study documenting the institutional transformation of the irrigation agency over a 22-year period and assessing its causes and impacts. The present paper focuses explicitly on the effect of the transformation on the output performance of irrigation systems in the country. Its approach to performance assessment is derived from the framework presented in the first paper in this series and draws on the limited set of secondary data routinely collected by the irrigation agency. This limits the precision and depth of the analysis but enhances the broader relevance of the approach.

Mark Svendsen
Series Editor

ACKNOWLEDGMENTS

The author would like to thank Leslie Small and Jeremy Berkoff for helpful comments on an earlier unpublished version of this paper, and Charles Rogers for his careful and creative work on the analysis.

1. INTRODUCTION

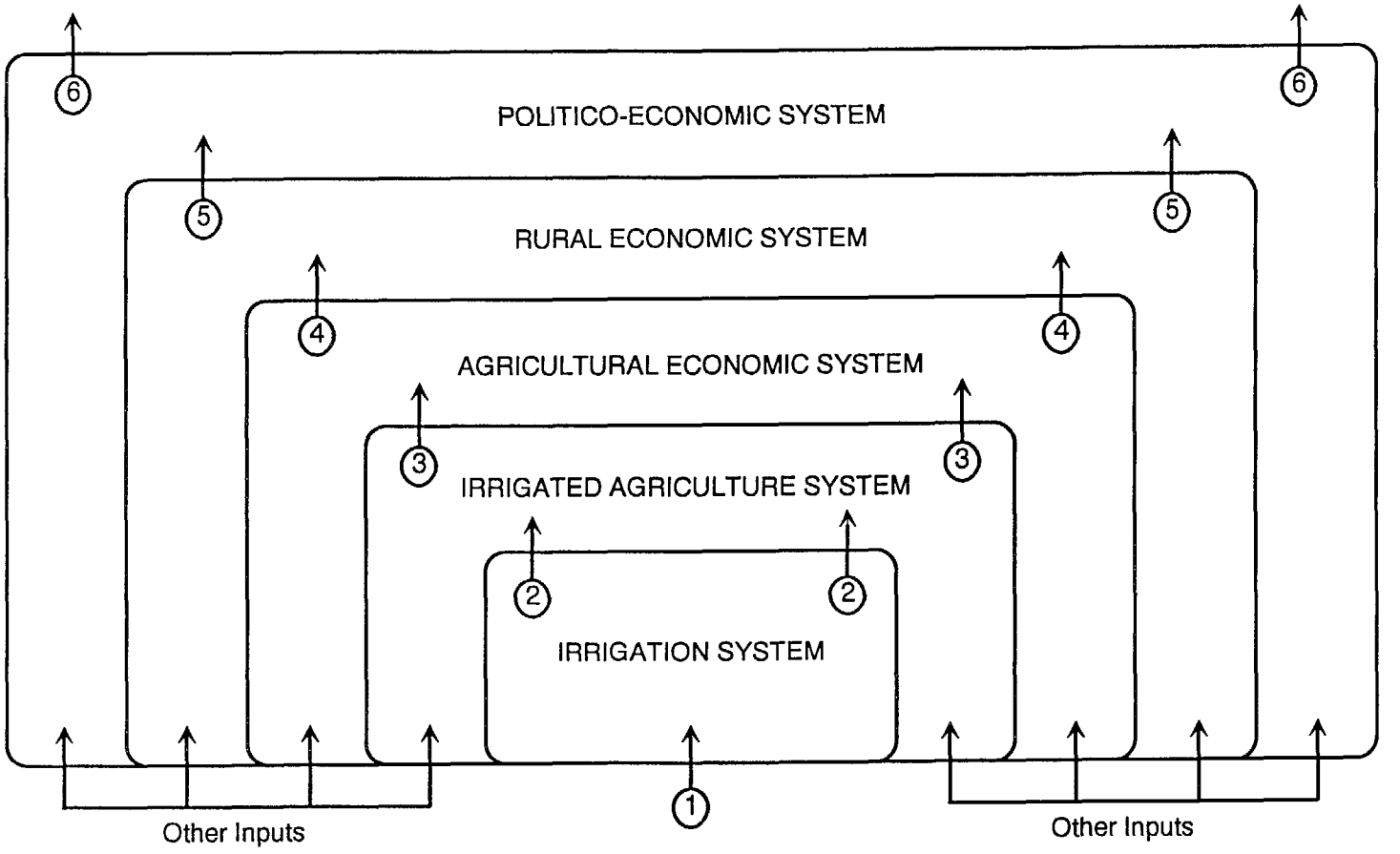
The disappointing performance of many developing-country irrigation systems has led to the development and application of a variety of measures intended to improve performance in these schemes. These efforts have demonstrated some successes but on balance have themselves been disappointing, and system operating performance has generally remained far below potential. Particularly disappointing has been the short effective life span of many of the improvements.

One of the fundamental difficulties experienced in attempting to develop more productive interventions results from a lack of effective means of assessing the changes wrought by the interventions and of comparing intervention outcomes with those planned (Biswas 1990). This deficiency has hampered the ability to assess the success of project improvements, design subsequent improvements, and learn from past mistakes.

Often the difficulties experienced in assessing interventions are blamed on a dearth of adequate data at the project level. This is indeed a serious problem, and more and better-quality data are needed for this purpose. Equally responsible, though, is the absence of a sound conceptual basis for designing assessments and effective and practical methodological tools for carrying them out (Abernethy 1987). Small and Svendsen (1992) address the first of these issues in offering a framework for making explicit the choices inherent in any assessment situation. Central to that framework is the conception of irrigation as a system occupying a place in a nested hierarchy of systems (Figure 1). Each system is seen as being the supplier of a critical input to a higher-level system, where it is combined with other inputs and transformed into higher-level outputs, which, in turn, are inputs to still higher-level processes. For example, an irrigation system supplied with a natural source of water, physical facilities, personnel, and operating funds produces irrigation services that are supplied to an irrigated agricultural system in which the irrigation system is embedded. The irrigated agricultural system produces crops that are an input to an agro-economic system producing farm income, and so on. The utility of this conception is the guidance it offers in the selection of suitable boundaries at which to measure performance and assess an intervention.

In evaluating the results of interventions designed to improve the functioning of irrigation systems, far more attention is usually paid to the *impacts* of the system's performance — crop yields and changes in household income, for example — than to the direct *output* of the irrigation system itself — the quality of irrigation service it provides. The difficulty this causes is significant and pervasive. The higher-level systems, which are assessed by measuring crop output and agricultural income, receive and utilize a multitude of inputs other than irrigation water in making transformations and producing outputs. In the case of the irrigated agricultural system, these include such things as fertilizer, agricultural chemicals, seeds, labor, and management skills. All of these things can vary in quality and quantity over the time period being assessed independently of the intervention being evaluated and can have significant influence on the higher-level outputs being measured.

Figure 1—Inputs and outputs: irrigation in the context of nested systems



Key to Inputs/Outputs:

1. Operation of irrigation facilities
2. Supply of water to crops
3. Agricultural production
4. Incomes in rural sector
5. Rural economic development
6. National development

To isolate and assess the result of the irrigation intervention itself, the assessment should be made at the interface between the irrigation system and the irrigated agricultural system in which it is embedded. Of course, higher-level impacts can and often should be assessed also, since intervention-project objectives are frequently framed in terms of the agricultural and economic impacts of the intervention. To be a useful diagnostic tool, however, the evaluation should separate the results that are directly attributable to the change caused by the intervention and those secondary or downstream impacts that are influenced by a large number of unrelated inputs and conditions in addition to those stemming directly from the intervention.

The intervention that this study tries to assess is a national-level policy shift intended to place medium- and large-scale irrigation in the Philippines on a self-financed footing. The model chosen employed linkages and incentives that were felt to involve improved farmer satisfaction as a necessary condition for achieving financial self-reliance, making improved performance of the agency-operated irrigation schemes in the country an essential part of the strategy. In contrast with interventions that attempt to improve irrigation performance through rehabilitation of physical facilities or modified operating rules and practices, this change effort attempted to modify the larger environment in which irrigation systems operate, presumably addressing more fundamental underlying causes of poor performance. This paper attempts to evaluate the immediate outcomes of that policy shift in terms of the operational performance of irrigation systems operated by the agency. In the process, it illustrates difficulties involved in working at the irrigation/agriculture interface and demonstrates approaches for dealing with them.

The next chapter gives a brief background on irrigation in the Philippines and describes the policy change introduced and the resulting institutional impacts. The following chapter then describes a methodology for analyzing the impacts of these institutional changes on system hydrologic performance and presents the results of the analysis. The final two chapters discuss the implications of these findings for irrigation in the Philippines and present conclusions regarding the methodology employed.

2. THE PHILIPPINE EXPERIMENT

IRRIGATION IN THE PHILIPPINES

The irrigation sector in the Philippines is divided between two major surface-water components — communal irrigation systems and national irrigation systems. Groundwater irrigation in the Philippines has been of relatively minor importance, currently comprising about 10 percent of the sector. Communal irrigation is an ancient practice in the Philippines and is the more important segment in terms of net area irrigated, currently covering about 48 percent of the nation's irrigated area of 1,488,000 hectares. It is made up of generally small systems, managed by farmers, which are usually constructed by them as well. Since the mid-1970s, the National Irrigation Administration (NIA) has been actively involved in innovative efforts to assist and improve communal irrigation systems without compromising farmer ownership and management.

The other major component of the irrigation sector, national irrigation systems, comprises about 42 percent of total irrigated area and consists of larger systems, developed and operated by NIA. Operating these systems consumes by far the largest share of NIA's operating budget and constitutes its largest potential source of revenue. NIA's efforts to manage itself center on these two salient features of its financial picture, which are described briefly in the following section.

EVOLUTION OF A NEW INSTITUTIONAL FORM

In a major departure from regional norms, the Philippine Irrigation Department was abolished in 1964 and a public corporation created in its stead. During the first decade of its existence, NIA operated in a way that differed little from regular government departments. A major overhaul of its charter in 1974, however, led to far-reaching changes in NIA's organizational values, structure, and operations. At the core of these values was the presumption that, to be successful, NIA must be financially viable, taking in more income than it spent. By 1979 it had achieved the goal of overall financial viability, and in 1981 the last operating subsidy paid out from the national treasury was received.

Policy Shift

The major thrust of the 1974 charter amendment was to allow NIA to retain all revenues generated by it, including irrigation-fee collections. Heretofore all collections had been immediately turned over to the treasury in exchange for an annual appropriation for operating expenses unrelated to NIA's self-generated revenues. The annual appropriation that NIA received had always exceeded, by a significant margin, the collections that it remitted. Accompanying this shift, however, was an agreement that all government operating subsidies to NIA were to be phased out over the ensuing five-year period. At the end of that

period, NIA's operating budget would be completely self-financed.

NIA Response

NIA management responded to these charter changes with a four-part strategy aimed at bringing its costs and revenues into balance. The strategy comprised actions to

- Devolve responsibility for certain operational, maintenance, and fee-collection tasks to farmers;
- Increase corporate revenues by raising fees, improving collections, and generating secondary income from ancillary activities;
- Reduce operating costs through a series of minor economies and through major cuts in the personnel budget; and
- Provide financial incentives for superior performance to outstanding field units and to individuals in them.

In 1980, following earlier successes in organizing farmers in the communal irrigation sector, NIA began experimenting with ways to organize farmers in its larger systems into effective irrigators' associations, which could assume responsibility for some canal-maintenance, water-allocation, and fee-collection functions. By 1986, the area under various forms of farmer management in the national irrigation systems had reached about 100,000 hectares out of a total of about 600,000 hectares in the country. Depending on the specific type of devolution, reductions in NIA's staffing levels in a sample of affected systems ranged from 13 to 75 percent (Svendsen, Adriano, and Martin 1990).

Immediately following the 1974 charter amendment, NIA obtained permission to increase its fees for irrigation service. At the same time, fees were indexed for inflation by denominating them in measures of paddy and NIA was authorized to collect fees in paddy, just as village moneylenders do. Since that time, the agency has made strenuous efforts to increase its fee collections. The net effect has been to hold fee revenues per hectare constant in the face of a national rice support price that has steadily declined relative to more general indices of inflation.

At the same time, NIA also took steps to reduce its operating expenses. Although a number of minor measures of economy were mandated initially, more than three-quarters of the operating budget was devoted to personnel costs, which meant that any real savings would require reductions in staffing levels. Voluntary reductions were carried out in the late 1970s and early 1980s, resulting in a decrease in the number of staff per hectare and a reduction of the personnel share of the budget from 80 percent in 1976 to about 74 percent in 1986.

With an eye on its bottom line, NIA also instituted a system of performance grants, called Viability Incentive Grants, for all field units and the individuals in them. To facilitate this, each large irrigation system in the country was made a separate cost center to allow costs and revenues to be accounted for on a system-by-system basis. This program provided that once a unit achieved a net excess of revenues over operating costs in a given year, a fraction of the surplus would be shared among the unit's personnel. Five of the 11

irrigation regions of the country were receiving these incentive payments by 1986, as were 53 of the 120 individual systems included within the 11 regions.

Effects

The financial results of these efforts are shown in Table 1. If subsidies are not considered, NIA first achieved net profitability in 1979 and retained it through the end of the period studied, except for a small deficit incurred in 1981. Subsidies were eliminated in 1982 (except for occasional small calamity grants following typhoons). Although revenues have declined in recent years, due largely to decreases in interest earnings and construction management fees, expenses have declined more rapidly, resulting in a series of net positive balances.

Achieving a financially viable position is an important accomplishment; few other irrigation agencies in the developing world have been able to do this. However, there is some risk that such an achievement occurs at the expense of the quality of service provided to clients. Some of the most interesting and important consequences of the new cost-recovery policies, therefore, relate to the physical performance of the irrigation systems NIA operates. It is here that the end objectives of the irrigation investments are realized and where the lives of the farmers who till system lands are affected. In Chapter 3, the impact of these policy changes on irrigation system output performance will be examined and an attempt will be made to quantify that impact.

Table 1—National Irrigation Administration revenues and expenditures, 1976-86

Item	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
					(P million, in 1972 prices)						
Revenues											
Irrigation fees collected	12.73	14.83	17.13	18.31	20.70	16.68	16.99	18.93	17.28	21.29	25.46
Other income	7.15	7.37	24.20	55.91	26.31	59.90	77.83	66.38	56.99	49.32	29.34
Total direct revenue	19.88	22.20	41.33	74.22	47.01	76.58	94.82	85.31	74.27	70.61	54.80
Expenses											
Total expenses	48.25	57.16	50.39	63.29	38.21	77.55	61.66	47.49	43.48	42.59	49.59
Excess (deficit)	(28.37)	(34.96)	(9.06)	10.93	8.77	(0.97)	33.16	37.82	30.79	28.02	5.21
Subsidies											
Government operation and maintenance subsidies	25.21	27.41	27.99	18.17	13.98	6.33	0.00	0.00	0.00	0.00	0.00
Calamity fund payments	5.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00	1.42
Total subsidy	30.69	27.41	27.99	18.17	13.98	6.33	0.00	0.00	1.19	0.00	1.42
Total excess (deficit)	2.31	(7.54)	18.93	29.10	22.75	5.36	33.16	37.82	31.98	28.02	6.63

Source: IFPRI analysis of National Irrigation Administration data.

3. IMPACTS ON SYSTEM PERFORMANCE

STUDY METHODOLOGY

Unfortunately, the kinds of changes in hydrologic system output and the impact on agricultural performance that might be expected to result from improved institutional performance are difficult to capture and quantify. There are a number of reasons for this. First, there is the year-to-year variability of system performance caused by variable rainfall, which feeds rivers, fills reservoirs, and supplements irrigation water in supplying crop requirements. Second, there is the difficulty of defining just what performance is and specifying how to measure it. Third, and most important, the regularly collected data from which indicators can be constructed are limited in type, number of measuring points, and period of record and are sometimes of doubtful reliability.

These difficulties notwithstanding, an attempt was made to determine the impact that changes in operating procedures, staffing levels, and incentive programs had on system performance. Because the effects that are being assessed here resulted from changes that affected all of the systems under NIA's direct authority, there are no "control" systems that can be used as standards. The choice was made, therefore, to employ an interrupted time series analysis in which values of selected performance indicators before and after the date of the major structural and procedural changes, taken to be 1981, are compared.

To accomplish this, secondary data were assembled for five systems in National Administrative Regions 3 and 6, which had not undergone significant physical changes during the period of analysis. Time series data were collected for service area and benefited area for wet and dry seasons, for yields in wet and dry seasons, for monthly main canal discharge at the system headworks, and for monthly precipitation. The general period of availability for this data is 1966-86, though for systems that began operation after 1966 the period of record is shorter. The records of some systems contain missing values. These five systems, their 1986 service and benefited areas, and other descriptive data are shown in Table 2.

The principal problem with using a "before and after" approach, rather than one that considers comparable systems "with" and "without" the innovation, is that some of the measured differences in effects may have resulted from causes that are independent of the ones being studied. These causes can be specific, in which case they may be relatively easy to identify and accommodate, or more general and diffuse, and therefore more difficult to control for. In the present case — that of changes in the performance of NIA irrigation systems resulting from the major organizational changes in 1981, two principal external factors can be identified that might be expected to affect differences in measured levels of irrigation performance between the two time periods. These are rainfall and level of use of other agricultural inputs. Since our interest is in systems' managerial responses to these changes, and since there is no reason to believe that the relative magnitudes of the responses are dependent on the size of the system, the five systems are treated as equal in the analysis. That is, changes in measured values relating to the smallest system are

Table 2—Descriptive characteristics of selected National Irrigation Administration systems

Item	Region 3			Region 6	
	UPRISS[a]	Angat-Maasim[b]	Santo Tomás[c]	Sibalom-San José	Aganan-Santa Barbara
Average service area (hectares)	102,272	31,462	3,522	5,282	8,703
Average irrigated area (hectares)					
Wet season	83,768	23,454	3,007	4,410	8,300
Dry season	64,587	27,639	1,781	2,801	2,770
Average benefited area (hectares)					
Wet season	77,605	22,908	3,007	4,369	7,698
Dry season	62,478	27,396	1,781	2,769	2,997
Average rainfall (millimeters)[d]					
Wet season	1,685.5	857.6	3,051.0	2,473.1	2,000.1
Dry season	75.6	33.3	32.2	282.8	302.5
Average discharge (liters/second)					
Wet season	46,501	14,792	1,692	2,353	4,984
Dry season	78,091	22,812	2,014	1,276	2,315
Average water delivery (millimeters/day)					
Wet season	5.22	5.48	4.87	4.62	5.71
Dry season	10.89	7.15	9.95	3.98	6.86
Average yield (metric tons/hectare)					
Wet season	3.45	4.19	3.22	3.95	4.35
Dry season	4.03	4.51	4.12	3.99	4.26
Average yield per unit of water (kilograms/cubic meter)					
Wet season	0.373	0.440	0.373	0.538	0.443
Dry season	0.248	0.400	0.279	0.690	0.428
t-statistic, difference in mean rainfall, 1978-81 and 1982-86[e]					
Wet season	0.432	0.713	-0.567	1.169	1.169
Dry season	0.519	-0.230	-0.523	1.187	1.187
Annual	0.460	0.707	-0.686	1.445	1.445

Source: IFPRI analysis of National Irrigation Administration data.
Note: Summary numbers are averages for the period 1982-86, except as noted.
[a] UPRIIS is Upper Pampanga River Integrated Irrigation System.
[b] Water delivery, discharge, and yield per unit discharge are four-year averages, 1982-85.
[c] Water delivery, discharge, and yield per unit discharge are four-year averages, 1983-86.
[d] For Angat, the five years are 1981-85, for Santo Tomás, 1979-83, for Sibalom, 1971-75.
[e] No significant differences at 95 percent confidence.

considered to be as important as changes in values for the largest, with no area weighting applied.

Since rainfall can substitute for irrigation water supplies, and since it affects the supply of water available in rivers for irrigation, it may exert some independent influence on various performance indicators. To test the strength of the relationship for the period being analyzed, simple correlations were run between rainfall and benefited area for one system in each region. Benefited area was used in this analysis because it is the variable deemed most likely to be influenced by year-to-year changes in rainfall. Weather data from Cabanatuan City were used for the Upper Pampanga River Integrated Irrigation System (UPRIIS) that surrounds it, and Iloilo City data were used for the nearby Aganan-Santa Barbara system. For UPRIIS, all of the r^2 values for these correlations were less than 0.005, suggesting that rainfall has almost no impact on area harvested in this large reservoir-based scheme. For Aganan-Santa Barbara, wet-season rainfall was related to wet-season benefited area ($r^2 = 0.16$) and to benefited area during the following dry season ($r^2 = 0.24$). Signs of the simple correlations were in the expected directions, that is, wet-season rainfall increased benefited area during both the wet and the subsequent dry seasons. These connections are understandable but weak.

Another possibility is that there were longer-term differences in rainfall received in the two regions. If this were the case, a comparison of performance during two different time periods would have to take this difference into account. Differences in average precipitation during the two periods were examined for the four stations used in the analysis (see Table 2). In no case were differences in seasonal or annual mean rainfall statistically significant.[1]

Nevertheless, in the regression approach adopted to analyze the data, rainfall was included in each equation to control for its possible effect on the particular dependent variables being analyzed. In doing this, wet-season rainfall was used in analyzing wet-season performance indicators, while annual rainfall was used in analyzing dry-season data. The rationale for this is that while dry-season rainfall cannot possibly influence the wet-season crop, the dry-season crop is affected by both the rainfall received directly and the rain falling during the preceding wet season, through its effect on river discharge, reservoir storage, and antecedent soil-moisture conditions.

The level of agricultural production is also an often-used indicator of an irrigation system's performance. Its major weakness is that a number of factors other than irrigation service, such as labor inputs, relative prices, and fertilizer use, influence it. It is necessary, therefore, either to control for changes in the levels of these inputs or to assume that they are constant across the two periods being compared. In the present case, the most important of these factors is the level of application of chemical fertilizer. Because fertilizer use by farmers is responsive to the relative prices of fertilizer and rice, it also includes, to some extent, input and output price effects. Since reliable data on fertilizer use for individual systems were not available, estimates derived from FAO fertilizer and cultivated rice area data were used to control for the effect of changes in the use of this input over time.[2] This

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[1] For Cabanatuan City, the longer period of record available, that is, 1904-86, was divided into two equal periods and tested for difference in means to test the observation by farmers that rainfall today is lower than it used to be. Mean precipitation after 1947 was actually about 3 percent higher than before, but the difference was not significant ($t = 0.7$).

[2] The procedure used was to take time-series data on total nitrogen fertilizer consumption in the Philippines, multiply it by the ratio of N fertilizer used on rice to total N consumption and divide the product by the rice harvested area to obtain an estimate of N use per hectare. Values of the ratio of N use on rice to total N use were taken from IRRI (1988, 150) with interpolation used to fill in gaps in the series.

variable was included in any of the regression equations in which agricultural production was used as the dependent variable. Other factors, such as labor use, genetic potential of varieties sown, and pesticide applications, are assumed to be constant across the two periods.

The analytic approach employed is to fit linear regression equations to pooled data from the five systems covering an 11-year period, 1976-86. A dummy variable is used to check the impact of pre- and post-1981 periods on differences in the dependent variable after the effects of factors such as rainfall and nitrogen fertilizer use have been removed. In addition, because the data set was created by pooling data from five different systems, a set of four site dummies was included in the basic model to control for system-specific differences caused by variables that were not measured. For some runs, these were replaced with dummies that separated reservoir and nonreservoir systems, though equations using the reservoir dummy were consistently inferior to those using the complete set of site dummies. Several different dependent variables were created to index the quality of irrigation service and were tested using this approach. Regression results are given in Tables 3 and 4 and are discussed below.

PERFORMANCE INDICATORS

A variety of indicators have been used in evaluating irrigation performance in various contexts. The selection of appropriate indicators depends on a number of factors, including the purpose of the evaluation, the audience for its results, the way in which the boundaries of the irrigation system are defined, and the kind and quality of data available to the evaluators. The current analysis is designed to evaluate the impact of a set of management changes on system hydrologic performance. The audience for this analysis comprises top-level managers of the irrigation agency and policymakers at higher government levels. Boundary definition is an important analytic problem here, as evident from the subsequent discussion relating to the choice of the appropriate area values to use in scaling system inputs and outputs. This issue is also related to the data quality and availability problems that have already been mentioned.

Three fundamental indicators have been proposed for assessing the effectiveness of irrigation services to cultivators (Abernethy 1990). These are the *adequacy* of water supplies, the *equity* of their distribution across the command area of the system, and the *timeliness* of the supplies. Computation of adequacy measures requires information on the total quantity of water delivered to the system over a season on a per hectare basis. Equity and timeliness measures require information on the spatial and temporal distribution, respectively, of those supplies. Where appropriate discharge information is not available, proxies can be employed by making suitable assumptions. Standards must also be selected against which the magnitude of the indicators can be judged (Small and Svendsen 1992).

The task in the present case, however, is somewhat different. Here the need is to evaluate changes in selected variables between the pre-1981 and post-1981 periods. Hence the absolute values of variables selected are less important than their relative magnitudes and the statistical significance of the differences in magnitudes between the two periods. A distinct limitation is imposed by the data series available for the five sample systems. Since discharge and yield data are available only on a whole-system basis, it is impossible to develop measures of equity and timeliness directly. However, the analysis will be extended

Table 3 — Results of pooled regressions, water-delivery indicators

Independent variable	Dependent variables[a]							
	Water Delivery in Wet Season		Water Delivery in Dry Season		Benefit/Service Area Ratio in Wet Season		Benefit/Service Area Ratio in Dry Season	
	(millimeters/benefited hectare)							
Equation number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	6.799*	6.189*	13.102*	2.411	0.743*	0.800*	0.129	0.258*
	(9.98)	(10.19)	(10.93)	(1.54)	(11.86)	(11.65)	(1.31)	(3.29)
System 2 indicator	0.173		-3.743*		-0.063*		0.200*	
	(0.29)		(-3.63)		(-2.19)		(5.05)	
System 3 indicator	0.698		0.163		0.085*		-0.046	
	(0.85)		(0.12)		(2.08)		(-0.97)	
System 4 indicator	-0.514		-7.011*		0.080*		0.169	
	(-1.07)		(-8.03)		(3.40)		(1.87)	
System 5 indicator	0.177		-5.049*		0.174*		0.051	
	(0.33)		(-5.38)		(6.03)		(0.58)	
Reservoir indicator		0.327		5.703*		-0.126*		0.156*
		(0.78)		(5.43)		(-5.10)		(2.61)
Period indicator[b]	-0.808*	-0.771*	-1.214*	-1.309	-0.036	-0.025	0.071*	0.030
	(-2.40)	(-2.29)	(-2.09)	(-1.62)	(-1.92)	(-1.12)	(2.39)	(0.77)
Water delivery (millimeters)[c]								
Wet season					0.015	0.023*		
					(1.59)	(2.15)		
Dry season							0.070*	0.046*
							(6.13)	(3.71)
Precipitation (millimeters)								
Wet season	-4.6E-4	-1.9E-4						
	(-1.25)	(-0.82)						
Annual			-4.3E-4	2.0E-3*				
			(-0.77)	(3.85)				
Average daily rainfall (millimeters)								
Wet season					-0.001	0.001		
					(-0.04)	(0.21)		
Dry season							-0.017	0.010
							(-0.58)	(0.33)
R^2 (adjusted)	0.156	0.133	0.711	0.434	0.693	0.556	0.865	0.730
Number of observations	43	43	41	41	42	42	40	40
Degrees of freedom	36	39	34	37	34	37	32	35

Source: IFPRI analysis of National Irrigation Administration data.
[a] Coefficient, (t-statistic).
[b] 1982-86 = 1.
[c] Delivery per hectare of service area.
* Significant at 95 percent confidence.

Table 4—Results of pooled regressions, yield indicators

Independent variable	Dependent variables[a]							
	Yield in Wet Season		Yield in Dry Season		Specific Yield in Wet Season		Specific Yield in Dry Season	
	(metric tons/hectare)				(1,000 kilograms/cubic meter of water)			
Equation number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	1.967*	3.747*	1.991*	2.800*	0.084	0.441*	0.049	0.876*
(2.86)	(5.80)	(2.93)	(4.60)	(0.41)	(2.29)	(0.23)	(3.43)	
System 2 indicator	0.400		0.525*		0.057		0.115	
	(1.55)		(2.26)		(0.85)		(1.95)	
System 3 indicator	0.466		-0.029		-0.016		0.006	
	(1.39)		(-0.10)		(-0.18)		(0.08)	
System 4 indicator	0.980*		0.090		0.176*		0.391*	
	(4.70)		(0.49)		(3.33)		(8.27)	
System 5 indicator	1.221*		0.256		0.104		0.224*	
	(5.70)		(1.38)		(1.74)		(4.40)	
Reservoir indicator		-1.033*		-0.063		-0.146*		-0.326*
		(-5.78)		(-0.39)		(-3.10)		(-5.69)
Period indicator[b]	0.163	0.231	0.161	0.199	0.082*	0.092*	0.032	0.052
	(1.03)	(1.42)	(1.18)	(1.43)	(2.00)	(2.23)	(0.93)	(1.12)
Precipitation (millimeters)								
Wet season	-2.9E-4	-5.8E-4*			5.7E-6	-6.1E-5*		
	(-1.82)	(-6.06)			(0.13)	(-2.32)		
Annual			9.2E-5	-6.4E-5			2.9E-7	-1.2E-4*
			(0.72)	(-0.84)			(0.01)	(-4.14)
Nitrogen application (kilograms/hectare)	0.025*	0.021*	0.025*	0.020*	0.003	0.002	0.003	-0.002
	(2.54)	(2.11)	(2.74)	(2.27)	(1.05)	(0.43)	(1.01)	(-0.52)
R^2 (adjusted)	0.553	0.516	0.251	0.198	0.309	0.262	0.713	0.445
Number of observations	50	50	49	49	42	42	40	40
Degrees of freedom	42	45	41	44	34	37	32	35

Source: IFPRI analysis of National Irrigation Administration data.
[a] Coefficient, (t statistic).
[b] 1982-86 = 1.
* Significant at 95 percent confidence.

to a discussion of equity by indirect inference. Levine and Coward (1986) have argued that equity ought to be considered the paramount objective in managing large public irrigation systems. They base their conclusion on an analysis of eight small community-managed systems and five larger public systems (including UPRIIS) in which equity appears to be the most important operational objective in the successful systems. It may be appropriate, therefore to give success in improving equity of distribution added weight in assessing overall performance.

Area Estimates

Because measures of system agricultural output and water supplied are typically reduced to a unit area basis before being used, much depends on the area values that are used to standardize them. Two different area measures are available. The first is service area, which is defined as the irrigable portion of the command area that is provided with physical facilities for water delivery. This represents the area that could conceivably be irrigated in a given season if water supply were not constraining. This value may change somewhat from year to year in response to urban encroachment on irrigated command, minor remodeling and repair, and refinements in area estimates. In the present case, though, the systems selected for analysis were chosen to avoid those that had undergone more extensive rehabilitation or modification.

The second measure is benefited area, which is the area billed for payment of irrigation service fees. It is the irrigated area harvested that did not have yields so low that the farm was exempted from payment of fees in a given season. This threshold value has been approximately 2 tons of paddy per hectare. Benefited area varies more than does service area, particularly during the dry season when available water supply may seriously constrain the area that can be planted. Its magnitude is a function of system managers' actions in authorizing the amount of land to be planted in a given season, farmers' decisions regarding whether to plant or not, and the combined ability of system managers and farmers/irrigators subsequently to distribute water. Both of these area measures will be used in the analysis to standardize other variables for particular purposes, as well as being combined to form a separate indicator by themselves.

Adequacy

The most direct measure of the adequacy of irrigation water supply to the agricultural system is the quantity of water applied to the system command area on a per unit area basis, relative to some standard. In this case, since the present interest is in differences in water adequacy between two time periods, and since the systems being assessed have been, and continue to be, almost entirely devoted to rice cultivation during both cropping seasons, depth measures for the two periods may be compared directly, assuming the seasonal crop demand for water to be unchanged. Although dry-footed crops can suffer yield losses from overapplication of irrigation water, rice is largely insensitive to this effect. In addition, water can substitute for other inputs that the farmer would otherwise have to provide, such as weed control and more careful (and costly) water management. It is assumed, therefore, that other things being equal, larger values of depth applied are better than smaller values in terms of meeting crop water demands and reduce the cost of cultivation. At the same time, it is recognized that high levels of water adequacy can affect

the values of other performance measures — particularly equity.

When the regression model is run for quantity of water diverted at the system headworks divided by benefited area, hereafter termed "depth," the period dummy in the regression equations is negative and significant at the 95 percent confidence level for both wet and dry seasons (see Table 3, equations 1 and 3). Since the overall explanatory power of the wet season model is very weak, however, the focus will be on the dry season. This result indicates that, after adjusting for rainfall differences, significantly less water was delivered to the command per unit of benefited area following 1981 than before, suggesting that performance, in terms of water adequacy, deteriorated following financial self-sufficiency. This conclusion needs to be examined more carefully, however.

One difficulty is that the measured quantity of water diverted at the source is largely a function of the supply available in the river, rather than of system management. This is particularly true during the dry season and in nonreservoir systems. Thus, while the depth of water supplied to the system is a measure of the adequacy of the system's service, it is to some extent beyond the control of the managing agency. To better understand the factors behind this decline in water availability, simple unadjusted index values for several of the key variables are examined. Table 5 shows annual values of total volume of water delivered in each season, service area, and benefited area in both wet and dry seasons and shows the results of t-tests on the means of a set of indicators before and after 1981. Indicators are used, rather than the actual values, to weight each of the systems equally, regardless of its size. The table shows that both the average wet season benefited area and the average discharge are significantly lower during the second period as compared with the first. For the dry season, too, the discharge index is lower after 1981 than before, but this difference is not significant. At the same time, the dry season benefited area index rose slightly, but again the change was not significant. Since there is not a clear pattern of relative movement of discharge and benefited area during the respective seasons, no simple interpretation of these index value changes is possible. What stands out is that both discharge and benefited area declined across periods during the wet season, while during the dry season there was no significant change in either indicator across the two periods. It seems clear that the decline in water adequacy must be evaluated together with other measures of performance in drawing conclusions about the overall impact of the 1981 changes on the quality of system management.

Another measured variable, per hectare yield, can be used as a proxy for water adequacy. It has the advantage of partially reflecting the impacts of the dimensions of timeliness[3] and equity[4] of distribution as well, integrating all three effects into a combined impact on aggregate crop production. Table 4 (equations 1 and 3) shows that the period dummy in the yield regressions has a positive sign in both seasons after controlling for nitrogen application and precipitation, though the t-values are not significant. Treating yield

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[3] This assumes that timeliness is evaluated against a standard based on the physiological demand for water generated by the rice crop and the varying sensitivity of the crop to stress at different growth stages. In such a case, a poor timeliness rating for irrigation service will result in reductions in yield.

[4] Because rice yields are insensitive to water applications that exceed potential evapotranspiration (PET) values, a redistribution of water from water-excess to water-short portions of the command area will usually result in higher aggregate output and higher average yields. Exceptional scenarios can be constructed in which this general rule would be violated, but such scenarios are unlikely to play out in practice.

Table 5 — Indices of service area, benefited area, and average seasonal discharge

Index	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average, 1977-81	Average, 1982-86	t-Statistic
					(index: 1983-85 average = 100)								
Service area index													
UPRIIS[a]	88.2	91.9	92.0	91.5	95.1	95.1	100.0	100.0	100.0	100.0	91.7	99.0	5.53*
Angat-Maasim River	95.9	99.4	99.7	99.6	99.6	99.6	100.0	100.0	100.0	100.0	98.8	99.9	1.63
Santo Tomás	106.3	106.3	101.9	102.9	103.0	99.8	100.0	100.0	100.0	111.0	104.1	102.2	-0.89
Sibalom-San José	95.0	87.2	94.2	93.3	94.2	94.2	102.8	102.8	94.4	101.7	92.8	99.2	2.92*
Aganan-Santa Barbara	108.3	109.1	106.0	103.0	96.1	100.5	99.6	100.8	99.6	99.6	104.5	100.0	-2.11*
Average	98.7	98.8	98.7	98.1	97.6	97.8	100.5	100.7	98.8	102.5	98.4	100.1	1.23
Wet-season benefited area index													
UPRIIS[a]	110.0	100.7	114.4	105.5	113.8	117.4	95.1	107.7	97.1	115.8	108.9	106.7	-0.47
Angat-Maasim River	97.9	97.4	92.0	98.3	102.8	100.8	99.7	102.1	98.2	93.1	97.7	98.8	0.54
Santo Tomás	116.3	115.9	112.3	107.5	108.0	103.9	98.1	97.8	104.1	103.9	112.0	101.6	-4.88*
Sibalom-San José	113.5	103.8	101.1	93.7	93.4	90.6	100.7	97.5	101.8	99.8	101.1	98.1	-0.80
Aganan-Santa Barbara	108.5	110.5	107.4	106.8	100.1	104.2	99.8	101.5	98.7	61.0	106.7	93.0	-1.84
Average	109.2	105.6	105.4	102.4	103.6	103.4	98.7	101.3	100.0	94.7	105.3	99.6	-2.32*
Dry-season benefited area index													
UPRIIS[a]	...	140.4	155.0	158.0	155.8	161.7	128.0	57.2	114.8	157.4	152.3	123.8	-0.94
Angat-Maasim River	90.3	93.0	103.2	106.1	104.2	106.9	98.8	99.2	102.1	99.6	99.3	101.3	0.61
Santo Tomás	105.7	122.7	122.5	96.1	99.9	115.9	101.7	91.0	107.3	121.2	109.4	107.4	-0.28
Sibalom-San José	66.5	62.6	67.4	50.1	47.2	76.6	85.6	107.0	107.4	111.6	58.8	97.6	5.35*
Aganan-Santa Barbara	95.8	63.2	111.4	108.1	115.1	93.3	94.3	94.8	110.9	158.6	98.7	110.4	0.83
Average	89.6	96.4	111.9	103.7	104.4	110.9	101.7	89.8	108.5	129.7	101.7	108.1	0.82
Wet-season discharge index													
UPRIIS[a]	132.9	72.7	142.5	118.8	120.4	98.8	105.8	106.3	87.9	96.4	117.5	99.1	-1.65
Angat-Maasim River	...	129.7	135.2	134.5	125.8	127.0	117.0	120.3	62.7	...	131.3	106.8	-1.89
Santo Tomás	...	147.1	155.0	141.6	...	...	104.0	72.5	123.5	112.3	147.9	103.1	-4.48*
Sibalom-San José	96.8	73.3	111.5	92.2	90.7	47.1	102.3	85.7	112.0	42.2	92.9	77.9	-1.09
Aganan-Santa Barbara	...	...	...	87.9	86.3	68.1	92.5	96.8	110.7	70.5	87.1	87.7	0.09
Average	114.9	105.7	136.1	115.0	105.8	85.3	104.3	96.3	99.4	80.3	115.5	94.0	-2.85*

(continued)

Table 5 — Continued

Index	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average, 1977-81	Average, 1982-86	t-Statistic
						(index: 1983-85 average = 100)							
Dry-season discharge index													
UPRIIS[a]	42.5	130.9	153.3	142.8	180.6	148.0	125.8	56.3	117.9	146.6	130.0	118.9	-0.43
Angat-Maasim River	...	122.6	161.6	153.0	139.2	128.5	100.8	103.3	95.8	...	144.1	107.1	-3.80*
Santo Tomás	...	116.4	148.2	155.7	...	...	79.9	97.1	123.0	126.5	140.1	106.6	-2.44*
Sibalom-San José	...	48.6	71.5	78.2	62.9	78.9	64.5	116.9	118.6	80.1	65.3	91.8	2.36*
Aganan-Santa Barbara	...	...	...	62.0	81.5	94.7	89.7	122.0	88.2	123.6	71.8	103.7	3.23*
Average	42.5	104.6	133.6	118.4	116.1	112.5	92.2	99.1	108.7	119.2	114.0	105.5	-0.75

Source: IFPRI analysis of National Irrigation Administration data.
[a] UPRIIS is Upper Pampanga River Integrated Irrigation System.
* Significant at 95 percent confidence.

adjusted in this way as a proxy for quality of irrigation service leads to the conclusion that, by this more comprehensive measure, quality of service held constant across the two periods in the dry season. Because of the large yield component accounted for by rainfall during the wet season, no such judgment is possible for that season.

Equity

As noted earlier, no reliable data are available for subdivisions of the five sample systems, making direct computation of equity measures impossible. Some judgments about changes in the equity of water distribution can be made, however, by examining changes in the ratio of two area measures given for each system — service area and benefited area. Since service area is the area that theoretically can be supplied with irrigation water by the system, and benefited area is the area that actually receives a quantity of water adequate to produce a remunerative crop, the ratio of the two provides a measure of the percentage of the potential service area that was irrigated to a particular standard. The larger this percentage, the more equitable is the distribution.[5] This, of course, assumes that the quantity of water available to the systems is constant across the two periods.

Since the condition of constancy of water supply is not generally satisfied, a regression was run in which the total quantity of water diverted at the headworks of each system divided by the system's potential service area was included in the regression to control for changes in the water supply available to the system (see Table 3, equations 5 through 8). The average daily rainfall received directly on the system service area during the season was also included as an independent variable. The regression was run separately for wet and dry seasons. The sign and t-statistic of the period dummy should then show whether or not equity, as reflected in the benefited area/service area ratio, increased, decreased, or remained unchanged across the period divide.

Both equations are reasonably good, as indicated by the R^2 values, though the dry season equation is considerably better, as would be expected. For the wet season, both the water-delivery term and the rainfall term in equation 5 are of positive sign but are nonsignificant at the 95 percent confidence level, indicating that wet-season irrigated area does not change appreciably in response to level of wet-season rainfall or the available irrigation water supply. The period dummy was negative but not significant, indicating that equity of distribution, as reflected in the benefited area/service area ratio, was similar during the two periods.

For the dry season, the water-delivery term in equation 7 is positive and strongly significant, indicating a close relationship between the fraction of potential area actually irrigated and the water supply available at the headworks. In addition, however, the period dummy is positive and significant, suggesting that, once the influence of water supply is

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[5] There are many standards for judging "equity" that could be used here. The most common one is equality of per hectare water deliveries. In the present case, the implicit standard is equality of water supply utility in producing a crop. Thus if two areas received equal amounts of water on a per hectare basis, but one had such high seepage and percolation losses that the crop failed to produce a harvest (and was therefore exempted from irrigation fee payment), the water supply to the combined area would be judged inequitable. Because such radical differences in seepage and percolation rates are unlikely on puddled rice soils in the lowland Philippines, and because the definition of benefited area accommodates a wide range of acceptable yields, these two definitions are largely indistinguishable at the current limits of data resolution.

removed, the benefited area/service area ratio was significantly higher in the period following 1981 than it was before.

This is an important finding, for it reflects significantly improved performance in terms of a factor — equity of water distribution — that is under the control of the managing entity, an entity that here comprises both NIA and irrigators' associations. Interpreted in these terms, NIA and allied farmers' associations were able to spread a given amount of water more widely across the potential command area of the five sample systems after 1981 than before. Moreover, they did this in a way that did not decrease average system yields, as discussed earlier. This interpretation suggests that there was some redistribution of water from better-watered areas to fringe areas that would otherwise not have received irrigation water, and that this redistribution was a direct response to the change in NIA priorities and operating policies and rules occurring around 1981.

It is difficult to prove conclusively the assertion that water was in fact redistributed, with a resulting increase in directly measured equity. Without access to reliable discharge data broken out by system section, it can only be assumed, in the absence of a plausible alternative explanation, that it was such a redistribution that made the increase in the benefited area/service area ratio possible. In a larger sense, it is difficult to prove conclusively that any outcome in a "before" and "after" analysis was the result of a particular independent causative factor. In this case, an effort has been made to remove the influence of other potential causative factors where feasible, but the possibility remains that some combination of unmeasured factors is responsible for the difference in the benefited area/service area ratio found. It is noted, however, that this type of response is exactly the type that would be expected to follow from an emphasis on increased farmer satisfaction and cooperation and increased fee revenues. Because the fee schedule is tied to benefited area, the only ways NIA can increase its revenue from that source are to expand benefited area and to increase collection efficiencies. The former depends on redistributing a fixed supply of water over a larger portion of the command, while the latter requires that farmers be satisfied with the irrigation service they are receiving together with the commitment of the local irrigators' association to assist in the task of collecting the amounts due. The evidence, while not conclusive, is highly suggestive that this is exactly what has happened.

Efficiency

In addition to measures that reflect the levels of adequacy and equity of irrigation service, available data allow the calculation of a measure of operating efficiency. The term efficiency usually denotes the relationship between inputs to a process and its outputs, often expressed as a ratio. The output measure employed here is aggregate system rice output, and the input is quantity of irrigation water turned into the system. Dividing the first by the second gives a measure of agricultural production per unit of water — here termed "specific yield." This is a highly integrated measure that evaluates the combined efficiency of the irrigation and agricultural processes. As such, it is a function of the managerial and other inputs supplied both to the irrigation system and to the agricultural operation. Regarding one important input to the irrigation system, NIA per hectare field-operating expenses were about 29 percent lower, in real terms, in the 1982-86 period compared with the 1976-81 period, although this drop may have been partly offset by increases in farmer-supplied labor inputs. Other things being equal, one would thus expect to find a decline in output efficiency.

The regression analysis shows positive signs for the period terms in both wet and dry

season equations (see Table 4). In the case of the wet season, the period dummy in equation 5 is significant but the overall explanatory power of the model is quite low. For the dry season (equation 7) the coefficient is positive but nonsignificant. This means that after taking rainfall and fertilizer use into account, data do not indicate a lowering of specific yield in the wake of funding reductions and the strong emphasis on financial viability beginning in 1981. This result provides evidence that the efficiency of the overall irrigation delivery/agricultural production process relative to the system water input did not fall off as a result of the changes implemented, at least over the short run.

IMPACT MAGNITUDE

The preceding analysis has shown that some indicators of irrigation performance changed significantly following the managerial changes of 1981, while others did not. However, it has not provided a sense of the size of the changes that occurred. To determine the magnitude of these changes, the regression model is used to predict the response of the composite system to the managerial changes, given a common set of input and environmental factors. To do this, average values of the independent variables from the entire eleven-year period 1976 to 1986 are put into the model, together with the previously determined coefficients, to generate predicted average values of the various dependent variables used in the earlier analysis with and without the period dummy. This procedure produces a pair of estimates for each dependent variable under the same conditions — one in which the system responds as it did after the managerial changes were implemented, and one in which it responds as it did prior to their introduction. The differences between these two values thus indicate the magnitude of the changes occurring in the various indicators of performance discussed above.

The results of this exercise are shown in Table 6. The table shows that water availability decreased by about 13 percent in both wet and dry seasons when the period dummy was included, and while the coefficients responsible were significant in the earlier analysis, this difference cannot be easily connected with levels of system management, as discussed earlier. For rice output per hectare, although the coefficients were not very significant, it is interesting to note that yield increases by 163 kilograms per hectare for the wet season and by 101 kilograms for the dry season when the period dummy is included, in spite of the reduced water supply available. Keep in mind that the predicted yield values have already been adjusted for differences in nitrogen fertilizer use and rainfall. This suggests that timeliness and equity of distribution of water supply to farmers may have increased following the changes, contributing to the higher predicted yields.

Examining the impact of increased equity of distribution by looking at the ratio of benefited area to service area, recall that the change was positive and significant for the dry season and negative and not significant for the wet. Table 6 shows that the dry-season benefited area/service area ratio increases by 7 percentage points when the dummy is included, a 13.1 percent increase. Other things being equal, this should result in a 13.1 percent increase in system output due to the expansion of benefited area, constituting a major impact on production.

Table 6—Summary of estimates, performance indicators

Dependent Variable	Variable Description	Period Coefficient	Predicted 1976-86 Indicator=0	Predicted 1976-86 Indicator=1	Period Effect[a]
	(units)				(percent)
Benefited/service area ratio	Ratio				
Wet season		-0.036	0.853	0.817	-4.25
Dry Season		0.071	0.539	0.610	13.13
Delivery	Millimeters of water				
Wet season	per benefited hectare	-0.808	6.003	5.195	-13.46
Dry season		-1.214	9.083	7.869	-13.37
Rice yield	Metric tons per hectare				
Wet season		0.163	3.578	3.741	4.56
Dry season		0.161	3.905	4.066	4.12
Specific yield	Kilograms of rice				
Wet season	per cubic meter of	0.082	0.348	0.430	23.53
Dry season	water delivered	0.032	0.378	0.409	8.37

[a] Percentage changes between periods.

4. POLICY IMPLICATIONS

The Philippine experiment to transform the national irrigation agency into an "enterprise" has undoubtedly been successful in reducing system operating expenses, bringing revenues and costs into line, and eliminating the recurrent cost burden imposed by large-scale irrigation systems on the national budget. Evidence presented here indicates that in the process, equity of water distribution across systems also improved. In the five years following the cessation of operating subsidies from the government, an index of equity of distribution improved by about 13 percent. At the same time, yields per hectare, adjusted for rainfall and nitrogen application, held constant.

There is a strong logical connection between the achievement of financial viability and improved equity of water distribution across the command. Because increasing irrigation fees is a political decision lying largely beyond NIA's control, expanding the area that can be billed for service is one of the few revenue-increasing measures available to the irrigation agency that does not involve major additional investment. In the face of constant or shrinking water supplies, this can be achieved only by redistributing water from areas receiving excessive supplies, usually near the head ends of canals and laterals, to areas receiving no supplies or inadequate supplies, often located near the tails of canals. Although data are not available that would allow the direct examination of this hypothesis, the two outcomes are logically consistent with each other.

Data also show that per hectare water deliveries declined significantly in the five sample systems after 1981, even though rainfall did not differ appreciably between the two periods. This decline averaged about 13 percent for both wet and dry seasons and is interpreted as a decline in water availability in the supplying rivers rather than a conscious reduction in withdrawals by system managers. Such declines could result from changes in watershed runoff characteristics, as caused by deforestation, or from increased upstream abstractions from supplying rivers.

After adjusting for rainfall and nitrogen application, per hectare yields increased only marginally in the post-1981 period. Projected area served, on the other hand, increased by about 13 percent after adjusting for water-supply availability, indicating that the area benefited by irrigation in the sample systems would have increased by this amount if water supply had held constant. Since water supply declined by a similar amount, the area irrigated remained approximately the same.

If the missing water was abstracted upstream, additional benefits would have been realized from its use there. If, on the other hand, the observed declines in river diversions were a result of watershed changes, the benefits that would have resulted from the potential expansion of irrigated area represent the opportunity cost of failure to control watershed degradation. In either case, a 13 percent increase in system output represents a significant benefit (or benefit forgone) resulting from operational changes that required no additional capital outlay.

5. CONCLUSIONS

Despite limitations on the amount and type of data available, it was possible to evaluate jointly the performance of five Philippine irrigation schemes at the point of interface between the irrigation and agricultural systems. Seasonal data available from the irrigation agency included service area, benefited area, and system-wise yield. Monthly data on main-canal discharge at the headworks and precipitation were also available. The average period of record was about 20 years. In addition, secondary information on nitrogen fertilizer application rates was obtained from other sources. The availability of rainfall data and discharge data at the system level was critical to the evaluation in that it allowed performance scenarios from different years to be put on a common hydrologic footing and compared. Moreover, it allowed the use of a common pool of data, cutting across both systems and years, greatly increasing the degrees of freedom available in the analysis and providing for integration of the results.

The choice of the "evaluation point" is a significant decision in an evaluation. In this case the interface between the irrigation system proper and the irrigated agricultural system was selected. This allowed conclusions to be drawn about the performance of the irrigation system separately, and consequently about the performance of the organizational entities responsible for managing irrigation — NIA and affiliated farmers' associations. It was a "bottom-line" assessment, providing information relating to the achievement of NIA's principal output goal of supplying irrigation service to farmers. In that sense, it was a substantially different type of assessment than ones that might (1) yield information on NIA's internal processes, reporting such measures as fee collection rates, staff/area ratios, or vehicle serviceability percentages, or (2) provide information on the combined performance of irrigation and irrigated agricultural systems, which would include consideration of the agricultural extension service, the rural credit banks, pricing policies, and a host of other institutions and systems.

Another important feature of the assessment was the use of the standard dimensions of adequacy, equity, and timeliness to assess the irrigation service supplied. Adapting analytic procedures to the limited amount of time-series data available, these dimensions were used as a conceptual guide, together with knowledge of the physical and institutional environment in the Philippines, to develop indicators for the standard dimensions that could be computed with available data. In another country setting, or in Philippine systems with more extensive data, indicators might have been developed that were different from those used here but that still represented the basic dimensions of adequacy, equity, and timeliness.

Yield was used as an integrated measure of quality of irrigation service in one portion of the analysis. An attempt was made to remove the confounding influence of nonirrigation inputs from the yield figures by controlling for use levels of nitrogen fertilizer and rainfall. Because data on use of other inputs were not readily available, however, control for nonirrigation factors was incomplete. The inclusion of levels of labor and agricultural chemical use and choice of variety in the analysis and the use of system-specific fertilizer-

use data would have been desirable; however, the approach taken would have been similar.

The use of interrupted time-series analysis has both drawbacks and advantages in this application. A principal drawback is the attendant uncertainty relative to unmeasured secular changes that may have taken place coincidentally with the effect to be measured, which might either mask or exaggerate the influence of the effect on the dependent factors in the analysis. A thorough reconnaissance is one safeguard against such unconsidered changes, since once such changes are identified, statistical control may be possible.

An important advantage of this type of assessment is that standards are needed only to indicate the desired direction of change, but absolute values are not necessary to serve as benchmarks for success, assuming that objectives have not changed between the two time periods. This eliminates a major difficulty that must be confronted when making cross-sectional comparisons. In general, the fewer the changes in such things as system and national objectives, relative prices, and cropping patterns, the more significant this advantage is. When significant changes of this type have occurred, it may be necessary to treat the "before" and "after" cases as independent systems, and to undertake a more formal process of goal assessment and quantification as part of the assessment.

A major limitation was imposed on the assessment by the absence of reliable discharge data for subdivisions within sample systems. This type of information is essential for direct assessment of distributional equity and is a useful check on adequacy measurements as well. The quality of this type of an appraisal would be significantly enhanced by the availability of reliable water-delivery information for even a small number of internal subdivisions of the systems being assessed.

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