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Economic Returns to Irrigation in India

by

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Executive Summary

The purpose of this study is to review available data on the economic returns to irrigation investment in India. We found many ex-ante project appraisal estimates of rates of return, but few studies which contained ex-post field survey evidence of actual results. We were able to locate ex-post field survey studies of actual economic benefits from irrigation for fifty three separate irrigation projects.

We have organized these estimated rates of return into three major categories, (1) public surface systems, (2) groundwater systems, (3) improvement interventions in existing surface systems. These estimated ERR's for the 53 projects we have reviewed are contained in Table 1. All of the estimates except those marked with * are based on ex-post field surveys of the on-farm benefits resulting from irrigation either using before and after or control group samples.

Table 1
Estimated Economic Rates of Return to Irrigation in India

Public Surface Systems		System Improvements		Groundwater Systems	
Large Scale		**Operations Impr.**		**Private Tubewells**	
Murkar. Kar.	18.7	Tawa MP	46.4	Baroda Guj.	228
Fatewadi Guj	15.7	Vanivilas Kar.*	45	Aligarh UP	167
Palamau Bihar	11.8	Sathanur TN*	43	Kapurthala	89
Girna Mah.	10.7	Rajolibanda AP*	29	Ahmedabad Guj.	82.4
Panam Guj.	9.8			Ludhiana	51
Watrak Guj.	9.2	**On-Farm Water Mang.**		Nadia WB	34-50
Sarda UP	7.6	Mahandi Orissa	121.4	Etah UP	33
Dantiwada Guj.	7.3	E. Gandak, Bihar	81.8	Mahi-Kadona Guj.	33
Cauvery-Mettur TN	7.1	W. Gandak UP	31.2	Patiala	16
Ghod Mah.	6.9	Chambal MP	9.5		
Pochampad AP	6.2	Chambal Raj.	6.2	**Public Tubewells**	
Tarai UP	4.8			West Bengal	25-60
Salwa UP	4.6	**Conjunctive Use Impr.**		Baroda Guj.	26.8
Tawa MP	-1.4	Gomti-Kal. UP	124	Orissa	7.2
		Adhala, Mah.	120		
Medium Scale		**Conveyance & Applic.**		**Priv. Hardrock Dugwells**	
Adhala Mah.	16.0	Adhala + Sprink.*	74	Ahmedn. Mah.	12-87
Bhimsagar Raj.*	11.3	TN Tank Imprv.	25	Kar. over 5Ha.	50
Panchana Raj.*	8.2	Periyar TN*	18	Kerala	35-50
Som Kagdar Raj.*	5.6	Salwa UP	12	Kar. under 5Ha.	22.7
				Tamil Nadu	18
Minor Scale		**Coop & AgInd Systems**			
Sukhaomajri, UP	9.8	Sangli Mah.	68.5		
		Kolhapur Mah.	45		
		TN Kar. AP AgInd	30.8		
		River/Canal Lift Sys.			
		Pune Mah Private	24		
		Orissa Public	5.9		
		East UP Public	-5		

It appears that most investments in existing large scale public surface systems have had rather low economic rates of return in the range of 4-12%. Medium and minor scale projects appear, with only one ex-post study in each category as a basis, to be in the 10-16% range. Private groundwater rates of return are considerably higher, between 20-90%, while public tubewells appear less attractive in the range of 7-30%. Most interventions aimed at improving existing public surface systems have high incremental rates of return in the range of 20-120%.

1. Rates of Return to Existing Public Surface Systems.

Most public surface systems for which ex-post impact studies are available have rates of return less than the apparent opportunity cost of capital in India. A few oft cited reasons are usually given for the somewhat disappointing returns to public sector surface irrigation. Construction delays often result in distancing investment from benefit which results in lower rates of return. Required design changes often result in higher costs. The widespread "under-utilization" problem arises because systems frequently irrigate significantly smaller areas than initially projected. Under-utilization results in an increase in the cost of an irrigated hectare even if the system cost does not increase. Short-falls in yield response and crop mix change are also frequent reasons for reduced rates of return.

The rather low estimated rates of return to existing public surface irrigation systems should give rise to serious concern about how to improve that performance, but there is little doubt that irrigation development has been and will continue to be THE single most important element in Indian rural production, employment and income. The high rates of return to system improvements and groundwater development underscore the inherently profitable potentials of irrigation in India. Attribution is difficult to assign but few analysts would give irrigation less than half the credit for the progress agriculture has made in India during the last three decades. The options for future agricultural and rural development appear to depend just as centrally on future irrigation development and improvement.

2. Options for High Return Investments in Irrigation.

The vast Indian investment in surface irrigation since independence has created two major types of opportunities for high return irrigation development. The first is the opportunity to make marginal improvements in existing systems, the second is to tap the added groundwater which these systems have made available. Aside from exploiting the potentials of existing projects there are two other high rate of return irrigation opportunities; (1) exploiting groundwater acquifers which are naturally recharged from rainfall and; (2) construction of new systems with high return improvements already designed in.

A final type of investment whose ERR is hard to measure, but whose returns are almost certainly high, would be to invest in institutional improvements which would spread the proven high return concepts into new designs, project renovations, and system operations. The challenge appears to be to skew that development in the direction of the high return strategies and away from relatively low ones.

3. Improvements in Existing Public Surface Systems.

Conjuntive Use Improvements. The data appear to support the position that the highest return possibility (50-100%) for improving the economic performance of existing surface systems would be conjunctive use of groundwater recharge. To a large extent this is taking place naturally through private investment in wells inside surface system command areas. Public credit for wells and groundwater surveys are the principal public mechanisms for support of conjunctive use improvements. Operations of surface systems can be managed to push farmers to exploit underground recharge by restricting surface supplies during certain periods or for certain high profitability crops.

Perhaps the major reason for the very high profitability of conjunctive use interventions is that the water is under the farmer's independent control. The surface system essentially assures the year round availability of water in the aquifer, but the farmer controls its delivery. There is a close and sometimes inverse relationship between conjunctive use and other possible system improvements, particularly canal lining. In many cases it is cheaper and creates increased benefits to allow earthen canals to leak and then pump the resulting groundwater than it is to save the water from leakage by canal lining.[1]

The Adhala command in Maharashtra is one example of relative contributions of surface and groundwater in an integrated ERR computation. Seventy eight percent of the total benefit of irrigation in the Adhala command came from the wells which were privately developed in the command and only 22% from surface irrigation. All of the well irrigation did not result from the Adhala recharge, one third of the well irrigation was functioning before the Adhala dam was constructed. It is impossible today to tell how much margin there would have been for additional well development without the Adhala project, but it is clear that the stability of the aquifer was substantially increased. If all well development since the dam is credited to the Adhala account the project would have an ERR or 15-16%, without the costs and benefits of wells Adhala is a 8.5% project. The incremental ERR of the well development on the existing Adhala base is over 120%.

Operations Improvement. The principal factor which system managers operate is the temporal and spacial distribution of the water in the system. By fine tuning and strategic improvement in the timing of water release major increases in system profitability can be obtained. This is a complex and demanding task since there are many alternatives which change from year to year depending on rainfall amounts and timing, crop mix in the different seasons and distribution timings aimed at pushing farmers to use recharged groundwater. Ex-post field survey measures on the Tawa project confirm World Bank ex-ante estimates of the potential of investments in operations improvement to reach incremental rates of return over 40%.

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[1]/ In the Salwa command in U.P. the cost of saving a cubic meter of water from leakage through canal lining was .19 Rs, while the cost of pumping the leaked cubic meter from the recharged aquifer was only .12 Rs. See section III 3 below. Raghuvanshi, C.S. and Sojwan, K.S. (1987), *Socio-economic Constraints in Irrigation Management: An Empirical Study in Salawa Command*, Proceedings of the Asian Regional Symposium on Irrigation Design for Management Organized by Hydraulics Research Centre, Sri Lanka on February 16-18, 1987, p. 233-246.

On-Farm Water Management. The rate of return picture for on-farm water management and on-farm works is a somewhat confusing one. On-farm water management investments involve land levelling, on-farm channels, farmer training and similar "below the outlet" activity. A number of general studies have suggested that the benefits of these investments (often referred to in India as Command Area Development) have been relatively disappointing. This position appears consistent with two ex-post fields surveys which estimated rates of return about 8%. The opposite conclusion appears to emerge from preliminary analysis of data from wells designed before/after and control group surveys of water management investments in three projects where rates of return from 30-121% were measured. Pending further analysis the only safe conclusion would be that on-farm investments appear to have widely varying but occasionally very high rates of return.

Conveyance and Application Technologies. Conveyance losses may be reduced by investments in canal lining and closed pipe conveyances. Field application efficiencies may likewise be increased though investments in sprinkler or trickle equipment. ex-post measures of the return to canal lining investments suggest rates from 12-23%. In the Salwa project case with an estimated return to lining of 12%, the analysis suggested that it would have been cheaper and more profitable to have left channels unlined and invested in pumping the lost water from the shallow aquifer. Canal lining should always be considered in conjunction with groundwater options.

The high rate of return (74%) suggested for sprinkler investment from ex-ante analysis comes from the fact that sprinklers can irrigate roughly double the area with the same volume of water. Installation of sprinklers on existing systems at a cost of less than $1,000/Hectare would double the reach of an irrigation system built at a cost of $2,000-5,000/Ha. The result would be a 100% increase in benefits with a 20-50% increase in costs, and hence a very high incremental return. Sprinkler technology is also less demanding of farmer management skills and forgiving of irregularities in land contours. Its adaptability to uneven farmer management skills and uneven terrain make it a good possibility for small farmers.

Commodity Cooperative and Agroindustry Linked Irrigation

The major driving force in recent high profitability irrigation appears to be a shift in the mix of crops from lower value to higher value crops. Since most high value crops involve special marketing or processing facilities, the realization of major crop mix shifts in irrigation commands are also accompanied by the presence of agroindustry. Two alternative approaches to improving irrigation systems by linking them to agro-industry have demonstrated very high ex-post rates of return. The first approach is to place irrigation water under the control of a farmer "lift" society which is in turn aimed principally at producing, marketing and/or processing a high value product. This was the case in two ex-post studies with 45-69% rates of return. The second approach is to make complementary agroindustrial investment in the irrigated area. Data from a fifteen village ex-post study in Andhra Pradesh, Tamil Nadu and Karnataka indicate an incremental rate of return to irrigation plus agroindustry of approximately 31%. In that study, irrigation without such investment in these village areas had a rate of return of only about 3.2%.

River and Canal Lift Systems

Farmer control over water supply appears to be a major source of profitability. Allowing farmer groups to lift water directly from system channels (either canals or from timed releases into the original river channel) is an option for accomplishing this. The ex-post evidence suggests that this has a high rate of return (around 24%) when it has been managed by private farmer lift societies and very low (5.9%) and even negative (-5%) returns when managed by public agencies.

4. Groundwater Development

Except for a few cases of low returns to public tubewells, groundwater irrigation has consistently high rates of return predominantly in the 30-200% range. An important part of the groundwater supply results from recharge provided by public surface systems and should justly be credited in part to the surface systems as discussed above. However, there are substantial areas in India (particularly in the East) where groundwater recharge is predominantly natural and vast aquifers exist. Even in those areas where the stability of groundwater is substantially due to surface irrigation, there are now large untapped potentials. The issue of whether nature or the Irrigation Department should be credited with the creation of the potential may be less important than getting on with the investments to effectively exploit it. Statistics at the national level suggest that groundwater irrigation already accounts for 75-80% of the value of irrigated production in India which is unusually close to the ex-post ratio of surface and groundwater benefits measured by Ralegaonkar in the conjunctive use study of the Adhala command.

Public tubewells appear to have inferior rates of return when compared to private ones but are still generally superior to public surface irrigation ERR's. Deccan hardrock dugwells in areas where groundwater has been stabilized by surface irrigation have rates of return between 50-87% in most areas. The profitability of groundwater development is strongly effected by the costs of electric or diesel energy yet the high average rates over years with highly fluctuating energy costs attests to the robust forces creating the high returns. Farmer control over a reliable water source appears to be the major benefit of groundwater. This reliability provides the confidence level necessary to undertake potentially high value and in some cases high risk crop mix changes.

5. Investment in Institutional Improvement

Estimating the economic rate of return to investment in institutional improvement is extremely difficult. We have identified two ex-post impact studies which suggest that institutional investments in irrigation related areas can have high rates of return. Puttaswanamaiah and Vena using data by Deepak Lal computed an ERR for a groundwater study of 140-316% under varying assumptions. Based on ex-post data generated by a Ford Foundation supported study on the Tawa command, we estimated that the study had a rate of return of around 46%. The difficulties in extending these high rates to institutional development in general are obvious. All these two studies indicate is that some specific institutional activities have had very high rates of return. It is possible that though these two study activities had high rates of return, they were not caused by or even related to "improvements" in the institutions which undertook them.

Introduction

This study is an analysis of the available studies and data on the economic returns to irrigation investment in India. The intent is to examine the available empirical evidence of economic returns using two rather independent approaches. The first approach is a traditional benefit/cost approach in which the returns to irrigation are expressed in the form of an economic rate of return computed by discounting cost and benefit streams to farmers using estimated "economic" prices.

The second approach taken in Section IV of this document is a broader one exploring the past contribution and future potentials of irrigation to the overall factor productivity and employment.

We are particularly appreciative of the considerable assistance we were provided by many university and public officials in the gathering of the data and sources we have utilized in this study. Charles Antholt, Robert Thurston and Glen Anders at AID New Delhi have provided critical guidance and ongoing support for our work. Jeremy Berkhoff of the World Bank's New Delhi office provided useful comments and we have relied heavily on the findings of the NMW project study he prepared in our formulation of our Section II and our analysis of operations improvements in Section III. Anthony Bottrall of the Ford Foundation and the Tawa study Ford supported were drawn upon heavily as the only ex-post field measurement of the impact of operations improvement. We have utilized Dr. B.D. Dhawan's many papers in various parts of the study and benefitted from his comments during the early stages of our work. The ex-post evaluations of NABARD and comments of its Deputy General Manager, Mr. S.P. Sanghal were among the most useful we encountered. Our short visit with Dr. Dandekar in Pune and the information we obtained have been most helpful, and we hope to extend this brief collaboration to other related research.

In addition to those mentioned by name above, we wish to acknowledge the assistance and cooperation of the many institutions in Maharashtra, Gujarat, Uttar Pradesh, Bihar, Karnataka and Tamil Nadu who were visited in the course of the research.

We remind our readers that while we appreciate the assistance and comments we have received we are alone responsible for the conclusions and content of this study. The study does not bear or imply the approval of any of the above mentioned individuals or agencies.

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Methodology

As a review study rather than an original research project, this paper inevitably makes comparisons of estimated rates of return derived from widely varying and hence partially incomparable methods and assumptions. An example of this comparison difficulty is the case of the difference between financial rate of return (IRR) and economic rate of return (ERR). The preferable measure from the point of view of the study is to compare ERRs. The difficulty is that most of the available ex-post studies lack clear explanations or differentiated data which would allow for an unambiguous determination of "economic" measures. Where we were unable to obtain more than one valid ex-post estimate for a particular category we have added the best ex-ante data we could find, these are marked with an * in Table 1.

In some cases we have found acceptable ex-post measures of project impact on net farmer income but without either time discounted ERR analysis or incomplete cost accounting. In other cases the cost and benefit data have been present in the reviewed study but the data had never been subjected to a formal time discounted ERR computation. Our objective in reworking the various data sources has been to bring the final ERR estimates as far as is possible onto similar methodological footing to make the results comparable.

Our own judgement is that our study falls short of much real comparability in the individual estimates. With one exception we think that we have overcome this difficulty by grouping the estimates into the general categories which make up the outline of the study and are presented in Table 1 above. We think there is sufficient consistency in the general magnitudes of the estimates in each group to allow us to reach some overall conclusions about the **relative** positions between the groupings. The exception to the rough consistency of groupings is the case of On-Farm Water Management interventions where there is an almost bi-modal distribution of estimated ERR's.

In the majority of studies we have reviewed there was either no ex-post data or insufficient ex-post data to conduct a time discounted formal ERR computation. We have cited these studies in our list of studies reviewed but have not utilized them in the body of the report. A study reached our threshold criterion for use as an "ex-post" study if it contained at least a minimum of field survey data estimating the net income benefit to farmers of the irrigation system or system improvement analyzed. To be considered as a valid "ex-post" study, the income impact data should have been obtained on a "before & after" or "with & without" sample basis. In a few unusual cases, notably in three on-farm water management interventions studies, the samples contained both cross sectional (with vs. without) and longitudinal (before vs. after) control groups. We have been relatively more demanding of the existence of ex-post farm level cost and benefit measures than of system cost measures. System cost data are both more available and more easily completed from sketchy data than farm level costs and benefits. The methodological complexities and field logistics problems associated with farmer control group sample surveys do not arise in the case of system cost estimates. Where we found useable ex-post farmer control group survey data we tried very hard to complete the system cost information using best available estimates in order to compute a time discounted ERR. In a few isolated cases we felt that the methodology used in a study which had already computed a rate of return was divergent enough from the methods we have used for other studies in the same grouping that a recomputation was neces-

sary. For example, the Mukarthihal study estimated a rate of return of 16%, our re-estimate of 18.7% is more comparable to our other large system estimates.

I. Investment in Public Surface Systems

Section I examines available estimates of the economic rate of return to the total investment in public surface irrigation systems. Section II explores a possible framework for understanding the underlying sources of high returns in irrigation investment. Section III examines the incremental returns to specific types of improvements in existing surface systems. Section IV deals with the returns to groundwater investment and Section V to employment and productivity impacts of irrigation. This first section deals with estimating the economic returns to "total" investment. Most international donor activity in irrigation in India has involved a partial investment in a "time slice" or alternatively in a specialized component of irrigation systems, and economic analysis has frequently assessed the return estimated to flow from that "partial" investment. Section III will address estimated returns to partial or incremental investments, while section I concentrates on developing a picture of returns to total system investment.

Most public surface systems for which ex-post impact studies are available have rates of return less than the apparent opportunity cost of capital in India. A few oft cited reasons are usually given for the somewhat disappointing returns to public sector surface irrigation. Construction delays often result in distancing investment from benefit which results in lower rates of return. Required design changes often result in higher costs. The widespread "under-utilization" problem arises because systems frequently irrigate significantly smaller areas than initially projected. Under-utilization results in an increase in the cost of an irrigated hectare even if the system cost does not increase. Short-falls in yield response and crop mix change are also frequent reasons for reduced rates of return.

The rather low estimated rates of return to existing public surface irrigation systems should give rise to serious concern about how to improve that performance, but there is little doubt that irrigation development has been and will continue to be THE single most important element in Indian rural production, employment and income. The high rates of return to system improvements and groundwater development underscore the inherently profitable potentials of irrigation in India. Attribution is difficult to assign but few analysts would give irrigation less than half the credit for the progress agriculture has made in India during the last three decades. The options for future agricultural and rural development appear to depend just as centrally on future irrigation development and improvement.

A. Large Public Surface Systems

Table 2 presents ex-ante, revised, and ex-post estimated ERRs for public surface systems divided by scale. As anyone familiar with the practice of benefit cost analysis would expect, there are sizeable differences between ex-ante and ex-post estimates of rates of return. Some of this is the inevitable product of uncertainty which characterizes any predictive analysis. Some of these differences also may be explained by differences in methodology and assumptions used. The methodology used to obtain ex-ante estimated ERR's varies widely between agencies. For many years the Government of India did not use time discounted cash flows in benefit-/cost analysis. Annual benefit/cost ratios using interest rates and depreciation conventions continues to be standard procedure in many states. The evolution of economic analysis of irrigation projects in India is traced in two recent papers by Daines (1985)[2] and Rogers (1983). The following short extract from Rogers suggests that before the advent of "protective" irrigation there was a surprisingly adequate level of economic analysis.

> "Despite some ambiguity with regard to discounting, the discussion (prior to 1880) in ... Indian engineers' writing show a great concern with the economics of projects and the need to assess correctly the attributable costs and benefits. The discussion has a very modern sound to it. ... About this time (1879) the British also introduced the concepts of "productive" (and) unproductive "protective" works. A "productive work is one that the net revenue derived from the project within ten years after the date of completion is more than a definite percentage of total capital outlay. This percentage was fixed by the central government from time to time. An unproductive work was on that did not meet these criteria. After the great famine of 1877-78 the concept of "protective: works was introduced. ... The projects that were taken up in the 20th century did not match the economic performance of some of the earlier canals."[3]

The absence of estimates in Table 2 at certain stages reflects the very spotty availability of economic return studies we have reviewed so far.

The last generalized dictum on recommended methodology for benefit/cost analysis methodology is that contained in the 1972 Government of India Irrigation Commission Report. Rather than explore this method in detail here, we have included a short description and critique of the method by Mande[4] as Annex C.

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[2]/ Daines, S., *Background on Socio-Economic Analysis of Irrigation in India*, SRD Research Group, for USAID and WMS-II USU, Logan, Utah, 1986, 65 pp.

[3]/ Rogers, P., *Irrigation and Economic Development: Some Lessons from India*, Division of Applied Sciences, Harvard University, Cambridge, Mass., 1983, 148 pp.

[4]/ See, Mande, O.D. (1980), *Evaluation of Social Benefits and Costs of Conjunctive Use of Surface and Ground Waters in Gomti Kalyani Doab*, Technical Report, Water Resources Development Training Centre, University of Roorkee. Discussion of benefit cost analysis methodology at pages 7-13.

Table 2
ERR Estimates for Large Scale Public Surface Irrigation Projects at Different Project Stages

Project	Appraisal Stage ERR	Revised Estimate Mid-Course or Project Completion	ex-post Field Sample
Ex-Ante Estimates Only			
Rajasthan Canal	30		
Karnataka Tanks	20		
Auranga Bihar	21.5		
Maharashtra II (IBRD)	15		
Nalanga & Bor River, Mah.	6-8%		
Ex-Ante &/or Revised ERR's			
Gangapur Dam, Mah.		43.5	
Malampuzha		22	
Tungabhadra		21.7	
Kukrupar		12.2	
Kadana	12	12	
Hirakud, Orissa		12	
Subernarekha (IBRD)	16	10.1	
Kallada (IBRD)	14	7.0	
Karnataka (IBRD)	16	9.5	
Ex-post Data Based ERRs			
Pochampad, Andhra Pradesh	14	14	6.2
Mukarthihal, Karnataka			18.7
Fatewadi, Gujarat			15.7
Palamau Bihar			11.8
Girna, Maharashtra			10.7
Panam, Gujarat			9.8
Watrak, Gujarat			9.2
Sarda U.P.			7.6
Dantiwada, Gujarat			7.3
Cauvery-Mettur, Tamil Nadu			7.1
Ghod, Maharashtra			6.9
Tarai U.P.			4.8
Salwa U.P.			4.6
Tawa M.P.			-1.4

DATA SOURCES: See Bibliography of Sources Reviewed for each Project.

Four reasons are most frequently cited for the well recognized unsatisfactory large system irrigation returns. These are construction delays, unanticipated costs, under-utilization and a slump in commodity prices.

The first two of these reasons deal with the cost side of benefit cost ratios and are rather simple to quantify and understand. Construction delays are not always damaging to ERR's, their impact depends on when the delays occur with relation to investments. Delays after substantial investments are very damaging, delays in getting started with construction may be neutral or even in some cases, favorable.

1. Cost Escalation in Major Systems

The overall costs of irrigation construction for Major and Medium scale irrigation have been growing in real terms as cheaper sites have been used up and as the objectives have been gradually shifting away from extensive irrigation of the type normally called "protective" in India to a more productive and intensive kind of system. Sawant in his 1986 study brings us up to date on this general rise in cost:

> "As the earlier irrigation works were mostly diversion works--intended to be mainly of protective type--for irrigating flat lands, they were relatively inexpensive. But gradually, the expenditure per hectare of irrigation potential created through major and medium schemes increased and has more than doubled during the three decades, i.e. from 1950 to 1980. At 1970-71 prices the expenditure per hectare of potential created was Rs. 2,770 for the First Plan, Rs. 5,880 for 1979-80 and Rs. 6,696 as the anticipated expenditure for the Sixth Plan."[5]

Individual systems experience cost escalation in large part because of income or inaccurate original plans and cost estimates. Revisions in the location and specifications of component works are common. The Pochampad command is an illustration of a rather serious example of these revisions and delays. It was initially designed to irrigate 800,000 Ha. in the extensive or "protective" mode in the 1950's. In 1963 it was approved with a redesign which would irrigate 228,000 Ha. at an estimated cost of 400 million Rupees. It was expected to complete in six years. After commencement it was discovered that the planned canal would only reach 140,000 irrigable hectares due to hilly terrain. The canal was extended from 112 km to 197 km and the redesign in was expected to irrigate 264,000 Ha.. The ex-post evaluation in 1983 found that 973 million Rupees had been expended and that field

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[5]/ Sawant, S.D. (1986), *Irrigation and Water Use in Indian Agricultural Development Since Independence*, Indian Society of Agricultural Economics, Oxford & IBH Publishing Co., Bombay, 1986, p. 107-139. at page 131. Sawant is quoting Abbie et al for the later figure. See Abbie, L., Harrison, J.Q. and Wall J.W. (1982), Economic Return to Investment in Irrigation in India, World Bank Staff Working Paper No. 536, The World Bank, Washington D.C., U.S.A., 1982.

channels constructed by 1980 (last year for which data were then available) reached only 80,640 hectares.[6]

While the Pochampad example may be worse than many projects it serves as a good illustration of the various elements of the cost problem. The revised designs and increased total cost exceeded general inflation rates. The largest part of the problem, however, which accounts for the largest shortfall in ERR is related to the drop in expected area irrigated, rather than in the rise in costs.

2. The Underutilization Problem and Cost Escalation

The under-utilization problem is at once complex and illusive and we along with many others have analyzed its causes at considerable length elsewhere[7]. The implication of under-utilization for the cost/ha irrigated and hence for ERRs is rather obvious. If a system is designed to irrigate 228,000 hectares as Pochampad was, and it ends up irrigating only half of that area, then the cost per irrigated hectare will double7 even if the estimated costs do not escalate one rupee. The average utilization rate for Indian public surface irrigation is estimated at 40-45%. Without any cost escalation, this shortfall in area irrigated would translate into a drop in ERR by more than half.

The under-utilization problem appears to be the largest single reason for the significant drop in ERRs from appraisal to ex-post evaluation. It therefore bears examination here in some detail. Rather than to divert our whole analysis into an examination of the complexities of under-utilization we will present a few paragraphs here and then include the 1985 analysis as an annex.

The under-utilization problem is much more than simply a short-fall in achievement of project objectives. The problem goes much deeper into the basic conflict between "protective" and "productive" irrigation strategies and design policies. There are many separate reasons for under-utilization but the most important appears to be the over-extension of designed command areas through the use of planning assumptions evolved to implement the protective strategy.

In a recent memo, Anders appropriately suggests four major causes for under-utilization as follows:

"--over-extended command areas
--irregular operations

6/ Govt. of India (1983), *Evaluation Report on Pochampad Irrigation Project (1980-82)*, Planning Commission, Govt. of India, New Delhi, November, 1983. at pages 31

7/ S. Daines, *The Under-Utilization Problem: Public Policy Meets Local Management*, Chapter Six in Daines, S. (1985) *Famine Protection and Irrigation in India: A Public Policy Analysis*, SRD Research Group Inc., Logan Utah, 148 pp., at pages 70-90. Two major Indian Government irrigation commissions have examined the under-utilization problem in depth in recent years. See Hashim, A. S., *Report of the Commission for Irrigation Utilization*, Government of Andhra Pradesh, Hyderabad, Government Secretarial Press, 2 Vols., November 1982; and also, Government of Maharashtra, *Report of the High Power Committee*, Bombay, 1981.

--low distribution efficiency
--lower than predicted catchment yields"[8]

The last three of Anders suggested "causes" of underutilization are easier to understand and deal with. Irregular operations may be improved by the interventions discussed in section III below. Inaccuracy in predicting catchment yields may be addressed through better training in the WALMI's and through better meteorological data from new equipment such as that included in the AID Maharashtra Minor Project. Low distribution efficiency may be dealt with by canal lining and improved application technologies such as sprinkler. Perhaps the most difficult cause to deal with both conceptually and operationally is the over-extension of commands since it is imbedded deeply in the planning and policy framework evolved over many decades in India and now linked inseparably with notions of Social Justice and Equity.

Table 2
Irrigated Area, Yield and Crop Mix Targets & Actual
Chambal Project in Madhya Pradesh

	Appraisal	Ex-Post
Area Effect	(Hectares)	(Hectares)
Irrigated Area	270,000 Ha.	142,000 Ha.
Yield Effect	(QQ/Ha.)	(QQ/Ha.)
Paddy	40	12.3
Jowar	20	11.2
Maize	20	12.5
Bajra (HYV)	10	9.0
Groundnut	15	8.0
Wheat (HYV)	30	15.1
Gram	20	7.9
Rapeseed	15	3.5
Crop Mix Effect	(% area)	(% area)
Paddy	19.9%	2.5%
Sugarcane, Fruit & Veg.	5.0	0.0
Wheat	70.0	20.4
Other	5.0	82.6

8/ Anders, G. Unpublished Memorandum to authors on draft *Economic Returns to Irrigation in India*, USAID April 8, 1987, at page 3.

3. Benefit Shortfalls

An examination of the evidence we have seen so far suggests that in addition to substantially increased costs, appraisal benefit estimates are often higher than ex-post measurements. There appears to have been substantial slippage in all three major anticipated impact categories, area, yield and crop mix changes. The Chambal project in M.P. illustrates these three areas of slippage. As discussed above, the area effect short-fall also fundamentally affects cost per irrigated hectare.

B. Medium and Small Scale Public Systems

AID's irrigation investment in India has been concentrated in the improvement of medium and minor scale irrigation systems. It is therefore useful to separate these projects from the large or Major scale projects. Expost impact studies on medium and minor projects is rare, but we have been able to identify one expost study for each size and three partially expost studies on medium projects in Rajasthan.

1. Medium Scale Systems

As indicated in Table 4, the only expost study we have reviewed for a medium project suggests an ERR of about 16% for the Adhala project in Maharashtra[9]. In addition to this single measurement we also identified three partially ex-post studies on mediums in Rajasthan. The data in these studies appears to contain ex-post impact data on yields and net incremental income per hectare in the project areas even though the projects are not fully operational and the studies are called "baseline" studies.[10] To estimate comparable ERR's we have put these "with" and "without" survey measurements one equal cost footing.

The Adhala project was studied on an ex-post basis to investigate the implications of conjuntive use planning.[11] The 16% ERR was computed by the authors based on the assumption that costs and benefits of well development in the command after the establishment of the dam should be credited to the Adhala project. Using energy and other costs associated with electric pumping the result

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[9]/ It is possible that some of the project studies which we have identified as "major" or large scale are actually medium scale by strict Govt. of India standards. Some of the studies we reviewed did not identify the project as a Major or Medium and we are not personally acquainted with the official classification of all of these projects.

[10]/ N.C.A.E.R., *Socio-Economic Baseline Study: Selected Medium Irrigation Projects in Rajasthan*, p. 61-90.

[11]/ The Adhala medium command was one of two irrigation areas surveyed in the following study: Ralegaonkar, G.P. (1983), *Conjunctive Use of Ground Water for Canal Development: A Case Study of Pravara Canal System*, Symposium on Water Management: Experiences of the Past and Directions for Future, Central Board of Irrigation and Power, New Delhi,1983, p. 35-54.^

is approximately 16%. The completeness of the Adhala study with regard to conjunctive use benefits puts it on a different footing from the other estimates in this and Table 2 above. It is likely that were conjunctive use benefits included in the ERRs for the other projects they might likewise be increased. A more complete discussion of this issues may be found in the conjunctive use section below.

Table 4
Estimated ERRs for Medium and Minor Projects

Project	Ex-Ante	Partial Ex-Post	Ex-Post
Medium Scale Projects			
Gujarat Medium (AID)	13		
M.P. Medium (IBRD)	18		
M.P. Medium (AID)	15		
Rajasthan Med. (AID)	11		
Maharashtra Med. (AID)	14		
Bhimsagar Med., Raj.		11.3	
Panchana Med., Raj.		8.2	
Som Kagdar Med., Raj.		5.6	
Adhala Med. Maharashtra			16
Minor Scale Projects			
Himachal Minor (AID)	14		
M.P. Minor (AID)	13		
Sukhaomajri Minor, U.P.			9.8

SOURCES: See Annex B, Bibliography of Sources Reviewed.

In the absence of other ex-post studies of medium projects it is difficult to generalize on the Adhala case. It may well be that medium projects have higher returns than Major projects. One reason often given for a frequently held presumption that mediums and minors probably have higher ERRs is because of the shorter construction periods the time lag between costs and benefits.

The data base for ex-post evaluation of medium projects is being laid in a much more careful and systematic basis than was the case for Major projects. AID has supported a number of well designed and effectively administered base-line studies on medium projects in Maharashtra which will permit reliable ex-post

measurement of actual impacts and serve as instruments for adjusting future design and implementation strategies.[12]

2. Minor Surface Irrigation Projects

We were able to identify only one minor surface irrigation project ex-post study. "Minor" irrigation is often used to include well irrigation, and many ex-post studies are available on groundwater projects. The discussion in this section relates only to surface irrigation projects. Recent AID minor irrigation projects in Himachal Pradesh, Madhya Pradesh and Maharashtra all have ex-ante estimated ERRs in the 10-16% range. The normal AID procedure for estimating these ERRs is to use a series of four or five representative minor projects selected as representative of the type of systems the project will eventually finance. An analysis of benefits and cost analysis issues in minor projects from the AID point of view is contained in Sen's recent papers.[13]

Seckler and Joshi (1982) conducted an ex-post benefit cost analysis of a representative system in the Sukhomajri rural development program. The minor system they analyzed was a small tank system serving 78 acres. They did a careful job in assessing both financial and social or economic prices relative to many other project analyses we reviewed[14]. Placing their benefit and cost measures in a discounted framework yields an ERR of 9.8% and an IRR of 5.2%.

This single ex-post measure is hardly sufficient data to generalize upon for minor irrigation. AID projects in Maharashtra and Himachal Pradesh are currently laying a critically needed set of base-line studies which will expand the base of ex-post analyses on minors from one or two to over 30 in the course of the next five years.

12/ The following is one example of one of the AID financed base-line studies: Dhongade, M.P. and Dangat, S.B.(1985), *Socio-Economic Bench-Mark Survey of the Sina, Medium Irrigation Project Command Area in Maharashtra*, Department of Agricultural Economics Mahatma Phule Agricultural University, Maharashtra, January, 1985.^

13/ Sen, B. (1986), *Economic Appraisal of Small Irrigation Projects in Himachal Pradesh*, Occasional Paper for USAID, New Delhi.^ and also; Sen, B. (1985), Benefits from Surface Irrigation Projects, USAID, AR/RD, New Delhi,January, 1985

14/ See, Seckler, David and Joshi, Deep (1982), *Sukhomajri - A Rural Development Program in India*, Proceedings of the International Workshop on Modernization of Tank Irrigation System - Problems and Issues, Organized by Centre for Water Resources, Anna University, Madras on February 10-12, 1982, p. 203-213.

II. Understanding the Sources of High Rates of Return

Irrigation is undertaken to achieve increased incomes from added gross crop area, from increased yields and from shifts to higher value crops. Higher rates of return must come from increases performance on one or more of these effects. There appears to us to be a rough pattern and trend in the relative importance and potential of these three potential irrigation effects. From 1950 to the mid sixties most of irrigation's contribution came from expanded food grain area irrigated. From the mid sixties, with the advent of HYV, into the late 70's the major contribution appears to have been in yield increases in food grains. There is reason to believe that the potential of food grain yield increases from irrigation has played most of its potential role, and that irrigation's contribution in the 80's and beyond will depend principally on shift in the irrigated crop mix form food grains to higher value crops.

Mody points us in this direction with his tracing of irrigation's role ion the historical development of Indian agriculture in the last decades:

> "To understand ... the reasons for growth in the fifties, it is necessary to go beyond the proximate sources of growth. ... In the fifties, increase in area under irrigation provided the main impetus for growth. More than 3/4 of the increase in area under irrigation was accounted for by government canals and tanks. Canals and tanks provide, in general, extensive irrigation, ie, irrigation of the type that implies 'light irrigated crops, and 'wide distribution of water."
>
> "In the 1960's ... irrigation in general supported the more intensive application of modern inputs. It may be noted, ... that the use of fertilizers and HYV seed required controlled and intensive irrigation, ie, a given volume of water concentrated in a relatively narrow area."

If Indian irrigation is indeed operating in a kind of post-HYV era, an important question is what is the relative difficulty of achieving increased returns through improvement in each of the three sources of irrigation benefit. The world bank staff appraisal of the India National Water Management Project contains a series of estimates which directly address this issue. These estimates provide a kind of empirical framework for understanding the relative potential of different improvements in existing irrigation systems in India.

Table 5 outlines World Bank estimates of the potential of area, yield and crop mix changes to increase the returns from three existing irrigation projects. The numbers in the Table represents the percent of the existing commands that would have to be affected by the particular change in order to justify an expenditure of Ra. 1000/hectare in improvement costs.

Table five suggests that a shift of one percent of the three examined commands from paddy to cash crops would achieve the same improvement in returns that reaching target yields in33% of the command in paddy. This does not necessarily prove that such a crop mix shift is "easier" to achieve, but it does suggest the empirical magnitudes of alternatives for improving irrigation returns in the current market environment.

Table 5
Percent of Command that Needs to be Affected
to Justify Improvement Costs of Ra. 1000/He.

Yield Effects	(% of Command)
Irrigated Paddy	33%
Irrigated Grains	13
Arrogated Cash Crops	9
Area effects	
Rainfed Grains to Irrigated	8
Crop Mix Shifts	
Paddy to Irrigated Grains	7
Irrigated Grains to Cash Crops	3
Paddy to Irrigated Cash Crops	

It would appear that the highest potential changes are those which facilitate or even directly cause crop mix shifts from grains to high value cash crops. High value crops include short season crops with demanding irrigation schedules and perennial intensive irrigation reliability and year round supplies have important meaning for high return irrigation improvement investments.

III. Review of Possible Options for High Rate Return Investments

The vast Indian investment in surface irrigation since independence has created two major types of opportunities for high return irrigation development. The first is the opportunity to make marginal improvements in existing systems, the second is to tap the added groundwater which these systems have made available. Aside from exploiting the potentials of existing surface projects there are two other high rate of return irrigation opportunities; (1) exploiting groundwater acquifers which are naturally recharged from rainfall and; (2) construction of new systems with high return improvements already designed in.

A final type of investment whose ERR is hard to measure, but whose returns are almost certainly high, would be to invest in institutional improvements which would spread the proven high return concepts into new designs, project renovations, and system operations. The institutional challenge appears to be to skew that development in the direction of the high return strategies and away from relatively low ones.

This section examines the available ex-post estimates of the economic returns to various specific irrigation systems which have adopted one or more of these specific "high return" strategies. In a few cases we have supplemented scarce ex-post studies with ex-ante and revised estimates.

A. Improvements in Existing Surface Systems

Inside the general category of improvement in existing surface systems, we have made six sub-groups:

- -- Improved System Operations (water release timing etc)
- -- On-Farm Water Management & CADA Improvements (leveling, field channels etc)
- -- Conjunctive Use Improvements (well development etc.)
- -- Conveyance and Field Application Improvements (lining, piping, sprinkler etc)
- -- Commodity Coop and Agroindustry Linked Improvements
- -- River/Channel & Reservoir Lift Systems

1. Rate of Return to Improved System Operations

The principal factor which system managers operate is the temporal and spacial distribution of the water in the system. By fine tuning and strategic improvement in the timing of water release major increases in system profitability can be obtained. This is a complex and demanding task since there are many alternatives which change from year to year depending on rainfall amounts and timing, crop mix in the different seasons and distribution timings aimed at pushing farmers to use recharged groundwater. Ex-post field survey measures on the Tawa project confirm World Bank ex-ante estimates of the potential of investments in operations improvement to reach incremental rates of return over 40%.

Estimating the potential rate of return to improvement in system operations would be a difficult task even if the appropriate data were available due to the

difficulty of separating causal attribution between the many different possible causative factors. Before proceeding to examine the available estimates of these rates of return it may be useful to outline some examples of possible improvements in operations which could increase the returns to irrigation.

The World Bank's NWM project contains a good description of specific operations improvements which would be included in this investment category. In this case of the Nagarjunasagar command operations were changed to carry-over a substantial water reserve for the following Kharif, changes in the timing of water release, and intermittent supplies. In the upper Krishna command an altered water release schedule was the basis of the operations changes. Another kind of operating change is to alter the basis on which farm level water allocation and deliveries are made such as introducing fixed turn systems like warabundi or removing the crop sanction procedures imposed by Shejpali. These are a few types of changes in the way the system is operated are examples of what would be considered operations improvements.

The World Bank ex-ante estimates of anticipated rates of return to these improvement for three sample projects is as follows:

Rajolibanda Diversion Scheme	29%
Vanivilas Sagar Scheme	45
Sathanur Scheme	43
All Three Schemes	37%

These are very high anticipated rates, and even though they are ex-ante and might decrease during implementation, their magnitude makes it unlikely that they would drop to unattractive levels.

A Ford Foundation/AFC field survey evaluation of operations interventions in the Tawa command in Madhya Pradesh which was completed recently in 1986 provides some very useful cross checks on these estimates. The Ford/AFC financed study and improvement implemented selected changes on two distributaries, The effect of these changes was measured at the end of the second year.

The difficulties in attributing change to the improvements are not easily overcome, and the Tawa study does not present clear and unambiguous data. It does however contain actual field sample data on a "before and after" basis which are rare. The attribution of impact to the operations improvement is as strong in the introduction of the report as is wise to infer:

> "It is observed that the performance has shown improvement in the second year (1984-85) as is evident from the reports on the various aspects of irrigation,its utilization and drainage because of interventions on the basis of first year studies. Similar Evaluation and Intervention studies can be replicated in other command area projects in the country with a view to achieving desired benefits of irrigation, as well as improving the efficiency of the system."[15]

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[15] / Agricultural Finance Corporation Limited, *Evaluation and Intervention Studies in Tawa Irrigation Project*, Hoshangabad, Madhya Pradesh, (Financed Jointly by Ford Foundation and AFC), 1986, at page ii of Study 2.

The Tawa study measures the changes and benefits which might be associated with the operations improvements. Using the basic data in the study we have put these measurements in a benefit cost framework and computed an ERR. The improvement effort cost Ford and AFC approximately $236.000. The resulting benefits in the 2,270 Ha. distributaries where the interventions were implemented results in an ERR of 25.2% to this intervention cost.

If we assume that over a five year period these benefits would spread to the whole command with the same impact that they have had of the intervened distributaries, the rate of return rises to 67.6%. While this appears on its face to be too optimistic an assumption, it is not improbable that a rate of return somewhere between the 25% and 67% could be achieved. This would place the field measured benefits in a similar range to those estimated by the World Bank in its appraisal report. Another way of stating the economic value of the Ford/AFC Tawa effort is that it could have cost them $1.5 million instead of $256.000 and still have been an investment with an ERR of over 12%.

Both the ex-ante and ex-post estimates for operations improvements suggest that the rate of return to these investments is likely to be very high. While this is an attractive possibility, it should be remembered that the opportunity for high returns is created by the rather poor performance of the existing systems.

2. On-Farm Water Management and CADA Type Investments

The rate of return picture for on-farm water management and on-farm works is a somewhat confusing. On-farm water management investments involve land levelling, on-farm channels, farmer training and similar "below the outlet" activity. A number of general studies have suggested that the benefits of these investments (often referred to in India as Command Area Development) have been relatively disappointing[16]. Saksena's evaluation of the first decade of CADA projects in Majors concludes as follows:

> "It is a very difficult task to evaluate in real terms the benefits as a result of CAD activities only. For this actual at site evaluation studies are needed where there should be a control area to evaluate the benefits only because of CAD activities. No such evaluation study has been reported so far. In absence of these, the only two indicators are the increase in utilization or irrigation potential and that of increase in agricultural production.
>
> "In respect of individual projects, Ramanujam (1983) made a study of 27

16/ Mr. Saksena was the director of the CADA organization for many years and has reported his rather pessimistic view on the performance of the program in a number of articles and speeches. Representative of these is Saksena, R.S. (19--), *Command Area Development in Irrigation Projects - Case Studies*, Paper No. 24, Irrigation Design Organization, Roorkee.^

projects which revealed that only in 12 projects, the percentage of utilization has been better in 1982-83 than it was in 1973-74."[17]

This position appears consistent with two ex-post fields surveys which estimated rates of return about 8%. The opposite conclusion appears to emerge from preliminary analysis of data from well designed before/after and control group surveys of water management investments in three projects where rates of return from 30-121% were measured. Pending further analysis the only safe conclusion would be that on-farm investments appear to have widely varying but occasionally very high rates of return.

We computed ERRs using data from two field studies on CADA investments in the Chambal command in Madhya Pradesh and Rajasthan.[18] These two studies provide reasonable cost data and considerable evidence on ex-post benefits. Putting this data into a cost-benefit framework involved more than simply discounting field estimated flows, but the estimates are based on reasonably good ex-post benefit and cost data and should therefore be useable as comparisons.

The CADA package of investments in the surveyed segment of the M.P. part of the Chambal cost $73 per hectare and involved some drainage, field channel construction and minimal land shaping. In the Rajasthan project the CADA investments studies were considerably more expensive and involved considerable land levelling for an average cost of $375 per hectare. The resulting benefits are estimated to create an ERR of 9.5% for MP Chambal and 6.2% for Rajasthan Chambal.

During the period 1978-80, the Programme Evaluation Organisation of the National Planning Commission financed a series of ex-post studies of soil and water management pilot projects. During the early seventies pilot water management projects had been undertaken in a fairly large group of major irrigation projects. The objective of the pilot projects was to see if the performance of large irrigation systems could be improved by on-farm development and farmer training. Seven[19] of these pilots were selected in 1978 for in-depth evaluation.

The general design of the evaluations was excellent from a methodological point of view. Before and after intervention data was sought on a recall basis, with follow-up visits made in two successive seasons. A three level control group sample was drawn including the test group of farmers who were directly involved in the on-farm pilot, an intermediate control group of irrigating farmers who were

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[17]/ R.S. Sakasena, *A Decade of Command Area Development in Major Irrigation Projects*, Roorkee, 1985, p. I-42.

[18]/ HAQ Consultants, *A Study on Water Resources Management, Impact and Evaluation of Command Area Development Programmes (Pre & Post Conditions)*, Volumes I-III, M.P. Chambal Ayacut Development Authority, Gwalior, 1981. and Asopa, Bhamagar, Desai, Kalro & Shingi, *Irrigation System, On-Farm Development, and Extension Services in Chambal Project Rajasthan*, Indian Institute of Management, Ahmedabad, 1978, p. 267.

[19]/ The seven selected pilot on-farm water management projects were, West Gandak (Uttar Pradesh), East Gandak (Bihar), Mahanadi Delta (Orissa), Neyar (Kerala), Pochampad (Andhra Pradesh), Ukai-Kakrapar (Gujarat) and Navalgund (Karnataka).

inside the command but not involved directly in the pilot, and a final control group of matched farmers who were not irrigating nor intended beneficiaries of the command. The sample sizes were too small for highly reliable statistics but the data appear to be superior to any other ex-post evaluation of on-farm water management interventions we have seen.

To date we have only been able to obtain summary data from these studies which is incomplete in a number of important respects which would have allowed a much fuller analysis. The incompleteness of data reported in the final documents prevented usable ERR computations for four of the seven evaluations. The three evaluations which were analyzed provided results surprisingly different from the Chambal estimates and from Saksena's generally negative conclusions.

The Uttar Pradesh pilot involved an irrigable area of 247.4 hectares. The interventions were undertaken by a staff of full time agronomists, engineers and a group of ten "assistants". This team consumed about 2/3 of the total pilot budget in salaries and support costs during the five years the project continued. Detailed soils surveys were conducted on 280 hectares, 17 km of farm channels were constructed, and 16 km or field drains were installed. Forty three hectares of land were leveled and crop production and irrigation demonstrations were conducted on 46 hectares or about 1 out of every six hectares in the pilot project area.

The total cost of these interventions was Rs. 5,577 per hectare or roughly one third the per hectare cost of an average large scale irrigation system.

The incremental benefits which resulted are measured by taking the before vs. after results on the test farms
and deflating these changes by the changes that were occurring on the control group farms. It is interesting to note that at the same time that the area actually irrigated in the test farms increased, so did the area irrigated in the non-pilot control group of farmers inside the command. That implies that at least during the period of the test, most farmers in the command were increasing the areas they irrigated either because it was a good water year or because the project was moving forward in reducing under-utilization generally.

The last paragraph illustrates the need for carefully constructed control group samples in order to be able to adjust for possibly erroneous attribution of impact.

After appropriate deflation of impacts, the pilot interventions are associated with sufficient benefits to make the Rs. 5,577 investment an excellent one with an ERR of 31.1%. It is interesting to divide the total impact by its three components; area effect, crop mix effect, and yield effect:

Area effect	15%
Yield effect	85%
Crop Mix effect	(slightly negative but not quantifiable)

The Uttar Pradesh case is essentially one of improved yields through better managed and more reliable water through a mix of channels, drainage and land levelling.

The Bihar case is almost the exact opposite in impact pattern, though the interventions were similar. Soil surveys, contour surveys, farm channels, field drains and extensive on farm crop production and irrigation demonstrations were undertaken. In the Bihar case, however, there was a significantly larger land-levelling component with 2/3 of the total pilot area receiving some kind of levelling activity. The total cost per hectare was about 40% of the UP case but the benefits were significantly higher. The estimated ERR was 81.8%.

In the Bihar case there was a positive impact on crop mix with vegetables entering in significant quantities. The crop mix contribution was significant but we were unable without access to the original data to separate it out quantitatively. The bulk of the total impact, however, was due to area effect which accounted for about 91% of the non-crop mix benefits. Yield impacts accounted for only 9% of the residual benefit.

It appears that the UP case is applicable to situations in which water is - reaching farmers but being used inefficiently with low levels of crop technology and with poor planning and drainage. The Bihar case is the more common classic problem of under-utilization where large areas of the command have not been brought under irrigation. Both of these cases are relatively high cost and "construction" intensive compared to the final case of the Mahandi Delta in Orissa.

The pilot on-farm water management case in the Mahandi Delta addressed an area more than ten times as large as the other cases with 5,600 hectares. Roughly the same size of staff attempted to improve water management in an a flat delta area. Surveys of almost the total area were conducted for both soils and contours, a few km of field channels were constructed and even fewer drains and other works were installed. The project focused on training, with 458 farmers trained on a rather intensive basis.

The cost per hectare was less than 5% of the UP case and less than 8% of the Bihar case. This is a training intensive water management case with a relatively small construction input and a very large and somewhat thin coverage. Crop mix was probably somewhat negative since the training focused on a narrow range of production and irrigation technology packages for cereals, but the yield effect was substantial accounting for 73% of the total benefit and area (multiple cropping) effect 27%.

The estimated ERR of the small Rs. 230/ha. investment was estimated at 121.4-%.

The five estimated ERRs we have computed for on-farm water management and CADA type investments are therefore clumped in a bi-modal fashion at the top and bottom end of the return range. Without access to the original data for the Planning Commission studies were are unable to explain this bi-modality. Without further analysis we can only conclude that on-farm water management and CADA investments can have very high rates of return in certain situations.

3. Investments in Conveyance and Application Technologies
Conveyance and Application Technologies.

Conveyance losses may be reduced by investments in canal lining and closed pipe conveyances. Field application efficiencies may likewise be increased though investments in sprinkler or trickle systems. Ex-post measures of the return to canal lining investments suggest rates from 12-25%. In the Salwa project case with an estimated return to lining of 12%, the analysis suggested that it would have been cheaper and more profitable to have left channels unlined and to have invested in pumping the lost water from the shallow acquifer. Canal lining should always be considered in conjuction with groundwater options.

The high rate of return (74%) suggested for sprinkler investment from ex-ante analysis comes from the fact that sprinklers can irrigate roughly double the area of traditional irrigation with the same volume of water. Installation of sprinklers on existing systems at a cost of less than $1,000/Hectare would double the reach of an irrigation system built at a cost of $2,000-5,000/Ha. The result would be a 100% increase in benefits with a 20-50% increase in costs, and hence a very high incremental return. Sprinkler technology is also less demanding of farmer management skills and forgiving of irregularities in land contours. Its adaptability to uneven farmer management skills and uneven terrain make it a good possibility for small farmers.

a. Canal Lining

Canal lining can have a high rate of return by saving water which is then applied to increase the area or reliability of the system. An estimate of the rate of return to this kind of improvement is contained in the project completion report of the World Bank Periyar Vaigai project in Tamil Nadu.

The initial appraisal ERR for the water saving investment was between 17-23%. The revised estimates contained in the project completion report are 25% for saved water utilized inside the existing command and 15% for water saved in the extended command. A similarly designed project in Tamil Nadu depended largely on canal lining for modernizing and improving tank irrigation[20]. The estimated ERR for the Tamil Nadu Tank Improvement project is 25%.

Taken together the Periyar Vaigai and TN Tank estimates suggest with revised cost and partially ex-post impact data that canal lining and complementary water saving improvements have rates of return in the range of 18-25%.

Two main questions are left unanswered by these two studies. There is the lingering concern that there may be slippage between the revised estimates and true ex-post impacts and costs. Secondly, there is the persistent issue of conjunctive use. It may be more cost effective in the long run to allow surface systems to "leak" in order to recharge groundwater sources. It may be that the high

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[20]/ Sakthivadivel, R. et. al. (1982), *A Pilot Study of Modernization of Tank Irrigation in Tamil Nadu*, Proceedings of the International Workshop on Modernization of Tank Irrigation System - Problems and Issues, Organized by Centre for Water Resources, Anna University, Madras on February 10-12, 1982, p. 1-18. The estimated rate of return for this project is based partially on ex-post measurements and partly on projections. Since roughly 2/3 of the estimates are ex-post we have used it as a check on the revised estimates of Periyar. The case study conducted by Sakthivadivel was the Padianallur tank in Chengalpattu district.

profitability of groundwater is sufficient to overcome the added costs of pumping the water. This is a complex issue since irrigation itself is also a way of "leaking" the surface water into the aquifer minus the ETP of the crops irrigated in the process.

The MS thesis of Singh (1983) is an excellent answer to both of these issues. It was undertaken on the much studied Salawa distributary and addresses the costs and benefits of canal lining in conjuction with alternative groundwater implications[21].

On the first issue of the separate true ex-post rate of return to lining, Singh's data when analyzed in a time discounted framework gives a rate of return of about 12%. This is roughly half the revised rate of return in the Tamil Nadu lining studies. There is great variation in the particular situations of different irrigation commands and there is no stable basis for treating the ex-post Salawa estimate as if it represented what the Tamil Nadu studies would be if they were conducted with ex-post data. However, the Salawa ex-post estimate is the only one we have been able to find as yet which directly addresses the issue and we are left with 12% as the best rough preliminary guesstimate of what lining will return.

The more interesting part of Singh's data are the implications it holds for the complicated consideration of lining in the context of conjunctive use alternatives. Singh's data indicate that each cubic meter of water saved through lining costs approximately .19 Rs. He then estimates that the average cost of pumping out of the aquifer where the leaked water would go is .12 Rs. per cubic meter. This suggests that on balance in the Salawa case it would have been cheaper to have "saved" the leaked water through pumping out of the aquifer than by lining. The margin of increased efficiency on the cost side is 58%, but this is not the complete picture.

Groundwater has a higher net farmer incremental return per cubic meter than surface water due to the increased level of control and timing flexibility that the farmer has. Not only would it have been 58% cheaper to obtain an added cubic meter of water from a well than from the lined canal, but that cheaper unit of water would have also created a substantially larger net value of product in its final farm application.

Taken together, these findings suggest that even when lining shows a reasonably high rate of return when analyzed separately, it is not likely to be a good alternative when conjunctive use is fully analyzed.

b. Sprinkler and Trickle Application Systems

The installation of sprinkler systems on existing surface commands has the effect of increasing the effective reach of the water by 2-3 times. Such an installation would require pressurization of the water supply in closed pipe systems and a total cost of between $500-1000 per hectare. During the last five years there

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[21]/ Singh, Indramani Th. (1983), *A Study of Canal Lining With Special Reference to Salawa Distributory*, Research Dissertation submitted to University of Roorkee.

has been a relatively rapid expansion of these systems on private wells in the Deccan, many of them by small farmers.

Since the sunk cost of obtaining enough water to actually irrigate one hectare using traditional gravity flow techniques in India is from $2000-4000, an added investment of $1000 per hectare in application technology which effectively spreads that water over twice the area will obviously have a very high rate of return.

Recent sprinkler technology utilizing low pressure sprinkler heads makes gravity pressurization practical for many areas of existing commands, thus avoiding the costs of energy in pressurization. A common misunderstanding about sprinkler technology is that it is a "high tech" irrigation option demanding high level management skills from farmers. The widespread use of sprinkler technology in extremely backward small farmer areas of other LDC's have proven the robustness of sprinkler technology[22]. The most important advantage of sprinkler technology for small farmers has to do with its simplicity and flexibility in undulating and broken terrain. The cost of land levelling can be subtracted (not added) to the cost of sprinkler installations.

To explore the rate of return implications of sprinkler installations on existing surface commands we have conducted an ERR computation using data from the Adhala medium command in Maharashtra. This ex-ante analysis suggests that the Adhala command without sprinklers or conjunctive use has an ERR of 8.5%. With sprinkler installation the overall ERR would rise to 28.1% including the sunk costs. The incremental ERR of the sprinkler investment alone would be approximately 74.5%.

Since the incremental benefits measured for surface water on an ex-post basis are extended to the sprinkler irrigation, this computation appears to have a considerable conservative bias. It is very likely that sprinkler irrigation would have a higher benefit per irrigated hectare due to the increased application control which it permits.

While installation of sprinklers on surface commands would appear to have a very good rate of return, that return would likely be considerably higher if combined with conjunctive use inside the command. The Adhala command provides a good example of this potential. If sprinklers were added to the wells developed in the Adhala command, the added energy costs of pressurization would be substantially less than for sprinklers installed on the surface canals since most small wells utilize oversized pumps. To add an additional 8-10 meters of head to the pumped well water would be a much smaller cost than to install pressurized closed pipe systems on surface canals.

It would therefore appear that the highest return configuration for improving existing commands would be well development inside the command linked with sprinkler application on the pumped water. The incremental ERRs of these separate

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22/ There is considerable expansion of trickle irrigation in many areas of India (for example in the Sangli area of Maharashtra), but we have not included any analysis of rate of returns because we are not aware of widespread small farmer experience proving the technological "robustness" of trickle.

improvements is estimated at 74% and 124%. The incremental ERR of the combined strategy could be in the 200% range.

4. Commodity Coop & Agroindustry Linked Irrigation

The major driving force in recent high profitability irrigation appears to be a shift in the mix of crops from lower value to higher value crops. Since most high value crops involve special marketing or processing facilities, the realization of major crop mix shifts in irrigation commands are also accompanied by the presence of agroindustry. Two alternative approaches to improving irrigation systems by linking them to agro-industry have demonstrated very high ex-post rates of return. The first approach is to place irrigation water under the control of a farmer "lift" society which is in turn aimed principally at producing, marketing and/or processing a high value product. This was the case in two ex-post studies with 45-69% rates of return. The second approach is to make complementary agroindustrial investment in the irrigated area. Data from a fifteen village ex-post study in Andhra Pradesh, Tamil Nadu and Karnataka indicate an incremental rate of return to irrigation plus agroindustry of approximately 31%. In that study, irrigation without such investment in these village areas had a rate of return of only about 3.2%.

a. Commodity Cooperative Controlled Lift Societies.

In the late 50's sugar cooperatives in the Sangli and Kolhapur areas of Maharashtra organized lift cooperatives to utilize existing water from nearby irrigation project channels. In some cases these lifts operated from water released by dams into the original river bed channels during the dry season. These lifts gave the cooperative growers effective control over the water and provided the basis for the development of a highly profitable agroindustry. This same model was followed a decade later by grape growers cooperatives. This approach provides grower cooperative control over an existing supply of water either through lift technologies or other mechanisms. This approach seeks to implement high value crop mix change through a combination of irrigation changes which assure a reliable supply and coordinated cooperative production and marketing to remove marketing and production technology constraints.

The importance of crop mix change to high value crops focuses attention on marketing as a critical constraint on the development of high value and often perishable crops. By attempting to facilitate this shift not only through increasing farmer control over irrigation, but also through direct private sector marketing interventions appears to have considerable potential.

Two recent studies have produced field survey evaluations of the costs and benefits of these types of lift schemes. Patil (1986) evaluated schemes in the Sangli and Satara districts and computed an IRR of 68.5%[23]. Laud (1982) led a NABARD evaluation team that analyzed ex-post data on a river lift scheme in the Kolhapur

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[23]/ Patil, F.T. (1986), *Economics of Lift Irrigation in Krishna Valley Area of Maharashtra*, Department of Agricultural Economics, Mahatma Phule Agricultural University, 1986.*

district of Maharashtra. The IRR their data suggests is approximately 45%[24]. Since both of these computations are financial rates of return the ERRs would probably be 5-10% higher.

The NABARD study is particularly useful since it permits us to estimate what these systems would be if the agroindustry component were separated. This is a somewhat strained and inaccurate exercise since the farm level production benefits are inseparably linked to the agroindustrial and marketing outlet for the high value product. It is interesting, however, to note that approximately 25% of the total 45% may be reasonably associated with the agroindustrial activity in the Kolhapur analysis. This appears roughly consistent with the implications of the Nadkarni data presented in the next section.

b. Agroindustrially Linked Irrigation Investment

The second case situation is where agroindustrial investment is made in the same area as a surface irrigation command but without any special or changed irrigation works to link the irrigation with the agroindustry. Nadkarni (1984) conducted detailed control group surveys in 15 villages in Andhra Pradesh, Tamil Nadu and Karnataka to measure the impact of irrigation and complementary agroindustrial investments on farmer income[25].
The selection of the villages was carefully undertaken to provide comparisons between villages without irrigation, those with irrigation but without agroindustrial investment, and those with both interventions.

By analyzing Nadkarni's impact data in a time discounted framework with average costs of irrigation we computed the
implied ERR of irrigation alone and the combined irrigation and agroindustry investment. The average investment in agroindustry was standardized to assure comparability of the results. The different data base and assumptions make it difficult to compare these ERRs with the lift society measures.

Nandkarni's article in the Economic and Political Weekly which reports his data is entitled "Irrigation and Rural Development: A Skeptical View". Part of his skepticism arises from the very low rate of return which irrigation alone demonstrates in the sample. Our estimated irrigation "alone" ERR
using Nadkarni's data is low indeed, around 3.2%. Nadkarni's concern is that irrigation alone has not really even stabilized yields and has in many cases widened income disparities.

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[24]/ Laud, P.R., Shaligram, R.G. and Tankhiwale, N.R. (1982), *River Lift Irrigation Scheme in Kolhapur District Maharashtra: An Ex-Post Evaluation Study*, National Bank for Agriculture and Rural Development, Bombay, 1982.*

[25]/ Nadkarni, M.V. (1984), *Irrigation and Rural Development - A Skeptical View*, Review of Agriculture, June 1984, A-67-A-73. Also see, Nadkarni, M.V. (1985), *Socio-economic Conditions in Droughi-Prone Areas*, Concept Publishing Co., New Delhi, 1985, p. xx+236.*

When we recomputed the ERR of irrigation plus agroindustrial investment we obtained an estimate of 30.8% suggesting that the two together have had substantial and highly investable returns. The data base generated by Nadkarni was both ingeniously designed and contained sample sizes large enough to provide statistically reliable findings on an ex-post basis. We think his data and the conclusions we have drawn from them are among the most stable in our review.

5 River and Channel Lift Improvements

Lifts from existing project channels without any agroindustrial linkage constitute a sixth alternative improvement or alternation in surface systems. In the last few years irrigation systems in Maharshtra have also begun authorizing private lift societies pumping directly from project reservoirs. The main potential benefit of these lifts appears to be that farmers gain control over a reliable source of water. We have identified three ex-post evaluations of these types of lifts. The fact that lifts from river channels are only partially dependent on seasonal operation of irrigation works up-stream somewhat clouds the connection of these lifts as "improvements" or alternations in those systems.

Farmer control over water supply appears to be a major source of profitability. Allowing farmer groups to lift water directly from system channels (either canals or from timed releases into the original river channel) is an option for accomplishing this. The ex-post evidence suggests that this has a high rate of return (around 24%) when it has been managed by private farmer lift societies and very low (5.9%) and even negative (-5%) returns when managed by public agencies.

The 24% private rate was measured by a NABARD team evaluating a lift scheme near Pune in Maharashtra[26]. The 5.9% rate of return for a public system was measured by a NABARD team in Orissa[27], and the negative 5.9% rate for a public system in Eastern U.P. was measured by Prasad and a team from the University of Patna[28]. Though a three sample case hardly proves a hypothesis, these measur-

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[26]/ Nachane, S.P. (1982), *River Lift Irrigation Schemes in Pune District Maharashtra: An Ex-Post Evaluation Study*, National Bank for Agricultural and Rural Development Economic Analysis & Publication Department, Bombay, 1982.*

[27]/ Sarmah, B. (1984), *Public Tubewells and River Lifts in Orissa: An Ex-Post Evaluation Study*, National Bank for Agriculture and Rural Development, Bombay, 1984.*

[28]/ Singh, M.L. and Prasad, P.K. (1973), Evaluation of Irrigation Schemes in Palamua District (Bihar): A Case Study, Indian Journal of Agricultural Economics, October-December 1973, p. 235-236. See also, Sharma, Indradeo (1985), Benefit-Cost Analysis of Surface Irrigation Schemes in a Drought Prone Area: Palamau, Proceedings of the national Symposium on Formulation and Appraisal of Irrigation Projects held on March 28-30, 1985 by Water Resource Studies Programme, Patna University, Patna, Bihar, p. v1-v16.*

6 Conjunctive Use Investments

The data appear to support the position that the highest return possibility (50-100%) for improving the economic performance of existing surface systems would be conjunctive use of groundwater recharge. To a large extent this is taking place naturally through private investment in wells inside surface system command areas. Public credit for wells and groundwater surveys are the principal public mechanisms for support of conjunctive use improvements. Operations of surface systems can be managed to push farmers to exploit underground recharge by restricting surface supplies during certain periods or for certain high profitability crops.

Perhaps the major reason for the very high profitability of conjunctive use interventions is that the water is under the farmer's independent control. The surface system essentially assures the year round availability of water in the aquifer, but the farmer controls its delivery. There is a close and sometimes inverse relationship between conjunctive use and other possible system improvements, particularly canal lining. In many cases it is cheaper and creates increased benefits to allow earthen canals to leak and then pump the resulting groundwater than it is to save the water from leakage by canal lining.[29]

The Adhala command in Maharshtra is one example of relative contributions of surface and groundwater in an integrated ERR computation. Seventy eight percent of the total benefit of irrigation in the Adhala command came from the wells which were privately developed in the command and only 22% from surface irrigation[30]. All of the well irrigation did not result from the Adhala recharge, one third of the well irrigation was functioning before the Adhala dam was constructed. It is impossible today to tell how much margin there would have been for additional well development without the Adhala project, but it is clear that the stability of the aquifer was substantially increased. If all well development since the dam is credited to the Adhala account the project would have an ERR or 15-16%, without the costs and benefits of wells Adhala is an 8.5% project.

Though the Adhala command presents an interesting case of a rough doubling in the ERR of a project through conjuntive use, the Adhala data do not permit an estimation of the incremental ERR to the conjunctive use investment by itself.

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[29]/ In the Salwa command in U.P. the cost of saving a cubic meter of water from leakage through canal lining was .19 Rs, while the cost of pumping the leaked cubic meter from the recharged aquifer was only .12 Rs. See section III 3 below.

[30]/ Ralegaonkar, G.P. (1983), *Conjunctive Use of Ground Water for Canal Development: A Case Study of Pravara Canal System*, Symposium on Water Management: Experiences of the Past and Directions for Future, Central Board of Irrigation and Power, New Delhi,1983, p. 35-54.*

Such a study was undertaken for conjunctive use in the Gomti Kalyani Doab[31]. This study examined ex-post costs and benefits for conjunctive use which provides the data for an ERR computation. We analyzed these data using the higher diesel costs of pumping to assure a wider applicability of the finding. The study included two different crop mixes which represent frequently encountered patterns. The result was an ERR of 124% for the higher value crop mix and 100.5% for the lower value mix.

Dhawan has conducted a number of studies relevant to the consideration of the analysis of conjunctive irrigation[32]. In his analysis of the rates of return to hard-rock Deccan dugwells he reviewed estimates indicating that while the return to dugwells outside commands had rates of return around 12%, those inside commands were about four times as high, at 50%. The format of Dhawan's data did not permit us to make a computation of the incremental ERR implications of this finding, but it is fair to conclude that it would be well over 100%.

All of the studies we have reviewed have dealt with informally developed conjunctive use situations. We have not found any ex-post study of a situation in which the surface and groundwaters were "managed" and "developed" together with a unified strategy. There is considerable discussion of conjunctive use strategies for operating surface projects which involve managing the discharge of surface waters so as to hold back surface supplies during periods when groundwater is readily available thus "forcing" farmers underground. A second way of managing surface system which is thought to have substantial effect on "forcing" exploitation of recharged groundwater is to restrict surface water use for the most productive crops. This, it is thought "forces" farmers with the resources to take advantage of high profitability crops to use groundwater to do it with. The idea has been that these high profitability crops are less "socially" important from a nutritional point of view and that therefore private individuals should develop them on their own out of groundwater leaving the cheaper surface water for food grain production.

Unfortunately this approach lumps together all high value crops and gives them all the same reputation as sugarcane for which argument is fairly accurate. Sugarcane has a relatively low water productivity ratio and hence might be viewed as a less than optimal use of scarce water. That is not the case for almost any others of the high value fruits, vegetables and specialty crops. Thus an argument which

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[31]/ Mande, O.D. (1980), *Evaluation of Social Benefits and Costs of Conjunctive Use of Surface and Ground Waters in Gomti Kalyani Doab*, Technical Report, Water Resources Development Training Centre, University of Roorkee.

[32]/ Dhawan, B.D. (1985), *Improving Economic Returns from Well Irrigation in Hard Rock Areas - the Maharashtra Case*, Proceedings of the Seminar on Groundwater Development Organized by the Indian Water Resources Society at Roorkee on December 19-20, 1983, p. 429-436. Dhawan, B.D. (1982), *Development of Tubewell Irrigation in India*, Agricole Publishing Academy, New Delhi, 1982, p. xviii+208. Dhawan, B.D. (1987), *Water Management in the Mula Command: A Study in Productivity Impact of Canal Waters*, Indian Journal of Agricultural Economics, Vol. 12, No.I, Jan.-Mar. 1987, p. 37. Dhawan, B.D. (1986), *Economics of Groundwater Irrigation in Hard Rock Regions - with special reference to Maharashtra State*, Agricole Publishing Academy, New Delhi, India.

which originated in the context of sugarcane is applied to limit access of all high value and perennial crops.

Both the seasonal and crop mix restrictions which evolved in many Deccan areas, and the "localisation" restrictions which grew up in the South are very crude tools to deal with the complicated and critical issue of husbanding and supporting the development of conjunctive use. P.R. Gandhi sees the informal conjunctive use situation in the Deccan as one which appropriately evolved in reasoned response to an important need:

> "Restriction on perennial crops under canal irrigation loan them to use their well waters and waters of nallas and drains (by lifting) to raise such crops for their own benefit. Thus developed an irrigation model of the Deccan Commands in which canal irrigation, well irrigation and nalla and drain lift irrigation co-exist. In essence, regenerated waters from the irrigated area percolating to ground and drains were used again. ... In such an irrigation model the overall efficiency is maximum and optimum production results. Intermixing of well and canal waters is not permitted. The situation is thus fraught with all possibilities and hence rigid rules are framed for canal irrigation. However, in the final analysis, the State stands to achieve the most with limited water resources spread over larger areas with the mixed model of irrigation."[33]

This rather rosy view that Deccan systems have achieved maximum production and optimum water use by the rather crude but extremely complex system of crop restrictions and water spreading procedures does not appear to square with the rather low rates of return of projects, even if the total informally developed well benefits are accounted to the projects. Gandhi's last few sentences hint that the "intermixing" of surface and well waters is impossible to prevent in practice and that the restrictive procedures of crops and waters creates a system "fraught" with all kinds of unmentioned and highly "informal" possibilities. The "rigid" rules meant to control all of these possibilities are themselves "fraught" with their own possibilities[34].

Perhaps the largest difficulties in conjunctive use planning are institutional problems. Farmers currently have more or less unhampered control over groundwater from a legal point of view. When they tap it they can use it for whatever crops and in whatever seasons they find most profitable. That is clearly not the case with surface water. There are those who would like to suggest that the way to make conjuntive use work is to give the government additional control over the regulation of groundwater so that its development can be planned along with and inside of surface irrigation projects. The evidence we have seen of the substantial margin of superiority in private managed water over public managed

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[33] Ghandi, P.R. (1983), *Evolution of Management System on Deccan Canals, Symposium on Water Management: Experiences of the Past and Directions for Future*, Central Board of Irrigation and Power, New Delhi,1983, p. 1-10.*

[34]/ see discussion of evasion of crop restrictions in Annex B on the under-utilization problem.

water suggests that this is exactly the wrong strategy for conjunctive use development.

It would appear to us that the best way to develop conjunctive use is to leave surface canals unlined and provide direct financial and technical support to the development of private wells inside irrigation commands through institutional mechanisms such as NABARD financing, groundwater studies and institutional support of the state level groundwater agencies.

B. Investment in Institutional Improvement

Estimating the economic rate of return to investment in institutional improvement is extremely difficult. We have identified two ex-post impact studies which suggest that institutional investments in irrigation related areas can have high rates of return. Puttaswanamaiah and Venu[35] using data by Deepak Lal computed an ERR for a groundwater study of 140-316% under varying assumptions. Based on ex-post data generated by a Ford Foundation supported study on the Tawa command[36], we estimated that the study had a rate of return of around 46%. The difficulties in extending these high rates to institutional development in general are obvious. All these two studies indicate is that some specific institutional activities have had very high rates of return. It is possible that though these two study activities had high rates of return, they were not caused by or even related to "improvements" in the institutions which undertook them.

Institutional development is at once an obviously high potential investment and a potential morass in which large expenditures over long periods of time may not yield desired results. Our data are not really much help in evaluating this option except to suggest that under certain conditions the rate of return can be very high because of its multiplier effect across many projects.

C. Investing in Groundwater

Except for a few cases of low returns to public tubewells, groundwater irrigation has consistently high rates of return predominantly in the 30-200% range. An important part of the groundwater supply results from recharge provided by public surface systems and should justly be credited in part to the surface systems as discussed above. However, there are substantial areas in India (particularly in the East) where groundwater recharge is predominantly natural and vast aquifers exist. Even in those areas where the stability of groundwater is substantially due to surface irrigation, there are now large untapped potentials. The issue of whether nature or the Irrigation Department should be credited with the creation of the potential may be less important than getting on with the investments to effectively exploit it. Statistics at the national level suggest that groundwater irrigation

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35/ Puttaswamakah, K. and Venu, S. (1984), *Cost-Benefit Analysis*, Nrusimha Publications, Bangalore, 1984.*

36/ Agricultural Finance Corporation (1986), *Evaluation and Intervention Studies in Tawa Irrigation Project*, Hoshangabad, Madhya Pradesh, prepared by A.F.C., Bombay, Maharashtra, India.*

already accounts for 75-80% of the value of irrigated production in India which is unusually close to the ex-post ratio of surface and groundwater benefits measured by Ralegaonkar in the conjunctive use study of the Adhala command.

Public tubewells appear to have inferior rates of return when compared to private ones but are still generally superior to public surface irrigation ERR's. Deccan hardrock dugwells in areas where groundwater has been stabilized by surface irrigation have rates of return between 50-87% in most areas. The profitability of groundwater development is strongly effected by the costs of electric or diesel energy yet the high average rates over years with highly fluctuating energy costs attests to the robust forces creating the high returns. Farmer control over a reliable water source appears to be the major benefit of groundwater. This reliability provides the confidence level necessary to undertake potentially high value and in some cases high risk crop mix changes.

1. Public and Private Tubewell Irrigation

Tubewell Irrigation from shallow aquifers is largely limited to the Gangetic plain, though tubewell projects exist in other areas such as Gujarat. The rate of return to private tubewells is generally very high. Dhawan's survey of tubewell studies found consistently very high ex-post impacts and rates of return.[37] Many of the returns to tubewells in Dhawan's study and in Gujarat are over 100%[38], and most of them were in the range from 30-90%. A few cases exist where private tubewells had returns between 12-25, but most were in the higher ranges.

A recent study of the Mahi-Kadona[39] tubewell projects in Gujarat based on ex-post field survey data has tentatively indicated a 30% rate of return. Even small manual lift tubewells have high rates of return, a study in Orissa measured impacts indicating a 34.4 ERR.[40]

There appears to be little slippage in ex-ante and ex-post estimates of tubewell returns. The U.P. Tubewell project had an estimated 36% ERR at appraisal, and the project completion estimate was 26-30%.

37/ Dhawan, B.D. (1982), *Development of Tubewell Irrigation in India*, Agricole Publishing Academy, New Delhi, 1982, p. xviii+208.*

38/ Aligarh UP 167%, Baroda Gujarat 228%. For Gujarat estimates see, Pathak, M., Patel, A. and Patel, H. (1985), *Economics of Tubewell Irrigation in Gujarat*, Agro-Economic Research Centre, Sandar Patel University, Vallath Vidyanagar, Gujarat, India.*

39/ Asopa, V.N. and Tripathi, B.L., *Command Area Development in Mahi-Kadana*, Indian Institute of Management, Ahmedabad, Monograph 76.

40/ Tripathy, D. (1982), *Social Benefits of Small Holder Wells-A Study from Orissa*, Arth Vijnan, Vol. 24, No. 2, June, 1982, p. 101-119.*

Public tubewells do not appear to have nearly as high an average rate of return, though their returns are higher in almost all cases than public surface systems. Dhawan, Pathak and a NABARD study of public tubewells in Orissa[41] together can be read to suggest that the rate of return is in the range from [illegible]-30% with a few exceptional projects as high as 60%. When compared with private tubewells which are predominantly in the range of 30-90 suggests at least a 30% differential in favor of private systems.

2. Deccan Hardrock Dugwells

There are few shallow or even deep true aquifers in the Deccan, most groundwater is from hard-rock dugwells tapping very small basaltic traps. Inside command areas and down stream for irrigation projects these traps have abundant and seasonally stable water. Outside commands these wells have very limited and seasonally unstable water supplies.

Notwithstanding the difficulties of Deccan groundwater exploitation, the water has a high economic value and their returns are relatively high. Dhawan's major study of ex-post returns suggests that dugwells inside or near commands have a rate of return of 50%, while those outside these areas return about 13%. Other studies suggest higher rates of return to non-conjunctive dugwells. In Karnataka, ex-post studies indicate rates of return from 35-50%[42] Other studies indicate similarly high rates of return in other parts of the Deccan such as the Copestake study in Tamil Nadu[43] Dugwells in other areas such as Kerala with somewhat different sub-soil conditions than he Deccan show similarly high returns.[44]

It would appear that almost all types of groundwater development have high rates of return. There appears to be considerable existing groundwater which could be exploited without further surface irrigation supplementation of the supply. This is not to take away any of the credit due surface irrigation for assisting in the creation of the existing supply, it is only to suggest that at the current time groundwater development could proceed based on already existing supplies for the next 3-5

41/ Sarmah, B. (1984), *Public Tubewells and River Lifts in Orissa: An Ex-Post Evaluation Study*, National Bank for Agriculture and Rural Development, Bombay, 1984.*

42/ Deshpande, R.S. et. al., (1986), *Ex-Post Evaluation of Dug-Well Investments in Hard Rock Areas of Karnataka-Mandya Report* (unpublished), Institute for Social and Economic Change, Bangalore, 1986.*

43/ Copestake, James (1986), *Finance for Wells in an Hard Rock Area of Southern Tamil Nadu*, ODA/NABARD Research Report No. 11, June, 1986.*

44/ Narayana Kurup, T.V. (1986), *Dugwell Irrigation in Palghat District-Kerala: An Ex-Post Evaluation Study*, National Bank for Agriculture and Rural Development, Bombay, 1986.*

decades without running out of water. Recent Government of India estimates[45], conservative when compared to many other recent assessments of supply for individual states[46] indicates that existing groundwater has only been 43% exploited.

This would suggest a vast potential for groundwater development with very high rates of return. As irrigation options are analyzed this dominating reality should not be pushed into a back seat position, in our view it is the major opportunity facing rural India during the next few decades.

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[45]/ Govt. of India (1986), *Water Resources of India*, Central Water Commission, Govt. of India, New Delhi, 1986.*

[46]/ Karkare, B.S. (1986), *Groundwater Exploration, Development & Research in Maharashtra*, All India Conference on Artificial Recharge Techniques, Related Subjects of Development & Management, Directorate of Groundwater Surveys & Development Agency, January 23, 1986.*

IV. Employment and Productivity Impacts of Irrigation

Rate of return analysis inside a benefit cost framework began as a technique for analyzing private investment options. The focus initially was on the narrow private profitability of a particular project. Economists broadened the technique to include both indirect benefits to the wider region and society, and the use of social pricing to reflect the differences between private and social objectives. In a theoretical sense it would be possible to look at all of society's local and national objectives in a social benefit cost framework, but the task is computationally and conceptually far beyond the reach of any existing analysis we have been able to locate for India. This kind of massive general equilibrium model may not even be cost effective to create and would almost certainly be to unwieldy to utilize in the give and take of policy making.

While such a general analysis is not available, there is a need for looking at a larger picture than that presented by the partial project oriented measures which are reported in the first three sections of this paper. It is rather obvious that the underlying motives of undertaking irrigation projects by the Government of India, and for AID's support, go beyond what is effectively measured by the ERRs and IRRs presented above.

The impact of irrigation on the most pressing problems of India, **employment and poverty**, are not easily or perhaps even best addressed by project level benefit cost analysis. A broader evaluation is required if we are to be able to assess irrigation's past impact and future potential on these central issues. An adequate analysis of this subject is beyond the scope of this paper, but the urgency of such an analysis suggests that a brief introduction to the issues and an admittedly uneven review of available data and studies will serve to point directions for further work.

Part IV is divided into four sections. The first section outlines a conceptual framework for examining the role of irrigation in poverty, unemployment, and hunger problems. The second section explores irrigation impacts on employment, the third on productivity and the last on equity.

A. The Role of Irrigation in Solving Hunger, Poverty and Unemployment Problems.

Poverty, unemployment and hunger appear to most observers to be the three most important names which India's most serious problem is alternatively and some times jointly called. Often these three titles are seen as different positions on a vicious circle. While the literature is immense on these issues, we will draw principally on four recent papers to outline a framework for our discussion of irrigation's role and potential in these matters. The first is V.M. Dandekar (1986), *Agriculture, Employment and Poverty*; the second, Seckler & Sampath (1985) *Production and Poverty in Indian Agriculture*; the third, Poleman (1981) *A Reappraisal of the Extent of World Hunger*; and the fourth, Evenson (1986) *Food Consumption, Nutrient Intake and Agricultural Production in India.*

1. Dandekar: Market Price and Employment Options to the Poverty Problem

Fifteen years ago Dandekar and Rath dimensioned the general size of the Indian poverty problem in a seminal article[47]. Last year Dr. Dandekar updated his earlier estimates in the context of an article on agriculture, employment and poverty[48]. By his latest estimate, 44.4% of the rural population were below the poverty line in 1983. Dandekar suggests the gravity of the problem and looks to two alternative types of solutions, natural workings of market prices and direct employment generation options:

> "What needs to be emphasized is that to alleviate poverty of this dimension, with almost half of the rural population or the population of the unorganized sector living below the poverty line, will require substantial transfer of incomes from the urban to the rural ... or from the non-agricultural to the agricultural sector. ... The present transfers of large incomes from the agricultural to the non-agricultural sector are taking place through the price mechanism. Hence, it may be suggested that this could be stopped or even reversed by means of a comprehensive price support to agriculture. But experience shows that, in the absence of demand support, price support involves large subsidies which benefit naturally only the agricultural producers with a marketable surplus while higher food prices affect adversely the poor sections.
>
> "The (direct employment generation) programmes as we have seen are mainly of two kinds. One seeks to promote self-employment by providing the poor households with productive assets financed by subsidies or credit. The other seeks to provide wage employment and in the process create community assets."

Dandekar's framework points to two general approaches, first, natural price mechanisms, and the second a more direct employment generation approach with two sub-variants. These are public support for putting productive assets like irrigation in the hands of the poor from which they can generate their own employment, and second, the provision of wage employment on the construction of community productive assets such as irrigation.

For our purposes we will rephrase Dandekar's options as follows:

--Income transfers to the rural poor from natural workings of price mechanisms which in turn depend on the structure of market demand for agricultural products.

--Employment generation for the poor through making productive assets

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47/ V.M. Dandekar and N. Rath, *Poverty in India*, Economic and Political Weekly, Vol VI, Nos 1 & 2, January 2-9, 1971 and Indian School of Political Economy, Pune.

48/ V.M. Dandekar, *Agriculture, Employment and Poverty*, Economic and Political Weekly, Vol XXI, Nos. 38 & 39, September 2027, 1986 pages A90-A100

available to them or those who would employ them though credit or direct subsidies.

--Direct public employment generation through wage work on public infrastructure like irrigation.

We will leave Dandekars formulation and return to it after revisiting Malthus in the context of discussion by Seckler/Sampath, Evenson, and Poleman.

2. Malthus and the India Poverty/Population Dilemma.

Seckler and Sampath (1985) start their discussion of production and poverty in agriculture with examination of the "two Malthusian races". We adopt this "two race" framework for our discussion and enlist Poleman to assist us in interpreting its meaning in the context of irrigation and India. First to Seckler/Sampath and the definition of Malthus' two races:

> "There are to important races in Malthusian theory, with population growth a major competitor in each. The "First Malthusian Race", as we call it, is the familiar one between the growth of population and food production. The "Second Malthusian Race" is less commonly known, but is just as important. This is the race between the growth of the labor supply and labor demand. Both races are of fundamental importance to Malthus' theory and, we believe, to India."[49]

a. The First Malthusian Race: Is it between Production & Population or Demand and Population and are there Two Races or Only One?

In the first Malthusian race Seckler and Sampath see a picture of a century of a long term loss for India at least for the last century or so:

> "Perhaps the best introduction to the First Malthusian Race in India is through the historical perspective ...[of] population growth in relation to gross per capita foodgrain (cereals and pulses, which provide over 80% of the energy intake of the Indian population) through this century. It must surely be a sobering experience for technological enthusiasts, as it was for us, to see that per capita production of foodgrain in the second decade of this century, in the pre-technological era of agriculture, was at least 25% more than it is today, in the full flush of the Green Revolution. ...the degree and severity of rural poverty in India has undoubtedly worsened from its state in the early part of this century."[50]

Writing just eight months before Seckler, Daines (April 1985) reached the similar, though even more disconcerting conclusion that the decline has been roughly continuous at least since 1890 and the percent drop in per capita foodgrain

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[49]/ Seckler, D. and Sampath, R.K. (1985), *Production and Poverty in Indian Agriculture*, Report to India Mission of USAID, November 25, 1985.

[50]/ Seckler & Sampath, p.1-2

availability from the 1890's to the 1980's has been on the order of 43%. Table 6 outlines Daines' estimates based on Bhatia and GOI data.

TABLE 6
FOODGRAINS AVAILABILITY PER CAPITA IN INDIA

Year	Grams/Capita/Day
1893-1896	731
1896-1906	698
1906-1916	681
1916-1926	670
1926-1936	574
1936-1946	496
1951-1952	390
1953-1956	438
1956-1966	451
1966-1976	438
1976-1981	450
1981-1984	511*

* Provisional estimate
Sources: 1893-1946 from Bhatia, *Famines in India*, New Delhi 1974, 1951-1981 from Directorate of Economics and Statistics, *Bulletin on Food Statistics*, New Delhi 1982 at page 141.

As initially stated by Seckler/Sampath, and roughly by Malthus, the first race is between production and population. On closer examination the race between population and production is only a kind of "straw man" for a race between market demand and population. Examined further, we think that the illusion of two races dissolves essentially into the single second named race between employment and population.

Seckler and Sampath lead us to this closer examination as follows:

"The relationship between production and poverty in Indian agriculture has resulted in the peculiar situation that India now has a substantial foodgrain surplus problem on its hands. ... The cause of this surplus problem is clear, even if the solution is not. The 40% of the population who need and want this food are too poor to purchase it: the problem is deficient effective demand."[51]

Evenson reaches the same ground without Malthusian imagery:

[51] / Seckler & Sampath, p. 2-3

"...foodgrain production in India has increased at such a rate in the 1970's and early 1980's that by early 1986 substantial stocks of foodgrains (approximately 30 million tons) were being held. This means that the supply of foodgrains had increased more rapidly than demand *at the prices prevailing to consumers.....* [52]"

Evenson asks and a few pages later answers the poverty and nutritional question raised by this point:

"Should the favorable production performance have been expected to markedly change the dimensions of the poverty-undernutrition problem of India? ... the favorable agricultural performance has not fundamentally altered the nature of the poverty-undernutrition problem in India. Some improvements have taken place and it is of great importance that the decline in average food consumption has been halted. But for millions of low income people in India, income levels are too low to provide dietary adequacy even if food prices were to fall further. The percentage of the population in the poverty-food inadequacy class (by any of a number of definitions of poverty) probably has not fallen in recent years."[53]

The conclusion to our discussion of the first race is that it is not really a race between production and population, but rather a race between effective demand and population. To understand the structure and dynamics of this first race, one would logically turn to a discussion of the structure and dynamics of its two elements, demand and population. The dynamics of population growth in India are rather well known and abundantly documented.[54] The issue of the structure and dynamics of demand for food is less discussed and documented though there are a number of consumer expenditure studies and some particularly useful recent studies[55]. While it might seem that this is the appropriate point to explore the structure and dynamics of demand, we prefer to explore the implications of the second Malthusian race first, returning thereafter to explore the implications of food demand for both races.

b. Irrigation and the First Malthusian Race

Irrigation has played, and will likely continue to play, a vital role in the first Malthusian race if we characterize it as a race between production and population. Since we see the first race as essentially a race between effective demand for food and population, the role of irrigation in that more important race is only a marginal

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[52]/ Evenson, Robert E. (1986), *Food Consumption, Nutrient Intake and Agricultural Production in India*, USAID/India Occasional Paper No.3, October 1986.

[53]/ Evenson p. 9 & 21

[54]/ Kantner, John (1986), *Population in India's Development*, USAID/India Occasional Paper No. 1, January 1986.

[55]/ A good bibliography of consumer expenditures studies can be found in Evenson p. 25.

one. Where irrigation appears to us to be a critical factor is in the second race to be examined below. However, this mischaracterization does not diminish in any way the importance of the production expansion which has arrested the decline in pre-capita grain consumption. It is therefore useful to make a quick assessment of the importance of irrigation in foodgrain production.

Seckler/Sampath provide an adequate treatment of the contribution of irrigation to the growth of foodgrain production over the last few decades as follows in this rather long quote:

> "the Green Revolution in India is not just biochemical technology; it is mainly the application of this technology to *irrigated land*. Except in rare and limited areas with naturally favorable agro-climatic conditions, there has been *no* Green Revolution in India on unirrigated land. ... All of the increase in total foodgrain area in the early period was from irrigation development. ... Unfortunately it is very difficult to quantify the relative contributions of irrigation and biochemical technology on foodgrain production in India. First, irrigation and biochemical technology constitute a "basket" of inputs that vary together. ... However, the analysis in Chapter 4 indicates that irrigation accounts for one half to two-thirds of the increase in foodgrain production in India over the past three decades; and without the indirect effect of irrigation development enabling the use of HYVs and NPK, most of the remainder would not have occurred. Irrigation is the *sine qua non* of Indian foodgrain production."[56]

3. Malthus Second Race between Employment and Population.

In the most common interpretation of Malthus first race of production against population, irrigation has been the most important single factor in bringing these two racers into a stalemate and arresting the century long losing position of production. While this is an important conclusion, we must not lose sight of the fact that this common interpretation has mis-identified the racers, it is <u>effective demand</u> and not production that is the important runner in the race against population, the baton was passed some time ago from production. The evidence that "production" is losing to "effective demand" is the foodgrain surplus alongside persistent malnutrition. The central question is not how can production be increased to win the race, but rather how can effective demand be increased to keep pace with population? The question is not, how can India produce sufficient food to feed her growing population, but rather how can India produce sufficient paying employment to expand the *effective demand* to feed its population.

There is little doubt that supply can meet effective demand, the big question is whether effective demand can expand rapidly enough to feed the population. While it requires a bit of vital abstraction, if we are to accurately visualize these races for India we must come to see **effective demand** as the "thing" that "feeds" people rather than **production**. If Indians continue to go hungry in the future it will not be because Indian land and water cannot produce enough food to keep

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[56]/ Seckler p. 3-4

ahead of Malthus' race, it will be because **effective demand** has been unable to run fast enough.

In our view of these races, the proper identification of the runners is the key to understanding the problem. We have suggested in the last few paragraphs that **effective demand** not production is the real runner in the first race, but we questioned whether there are really two races or just one with a confusion of the identity of runners. We come now to an examination of Malthus' conception of the second race. Having identified **effective demand** as the runner against population in the first race, we suggest that this self same runner is the main player in the second race simply running under the banner of **employment.** It is our suggestion that **effective demand** is essentially determined by productive employment and that it is most useful to see **employment as the main runner in both races against the same competitor,** *production*, and therefore to consolidate the two races into one.

Not only is the proper identification of racers important to understanding Malthus' races, it is also critical to properly understand the nature of the track they are running on. Seckler and most other observers have identified the track as **foodgrains** since hunger/nutrition is the issue and foodgrains provide most of nutrition[57]. This would make sense if "production" was the runner. The difficulty with this view is that while foodgrains do provide about 80% of the caloric intake, they provide less than half of agricultural incomes and less than half of rural employment. Thus while foodgrains are the big "nutrition" players they are not the big **effective demand** nor **employment** players and hence are not the racers to watch.

Poleman leads us through a logical chain of thinking about this second race and back to irrigation, but when we come back to irrigation Poleman will help us see that we are not watching a race on the foodgrain track since the race is an employment/effective demand one and not a production/nutrition one.

a. Poleman's Thesis on Hunger and Poverty: Employment Shortage vs. Food Shortage.

In 1981 Thomas Poleman published a provocative article reappraising the extent and causes of world hunger. His article was prompted by the 1980 Report of the Presidential Commission on World Hunger, of which he was critical. The data and analysis contained below seem to support many of Poleman's hypotheses, and it is therefore worth exploring his positions in some detail before proceeding.

In criticizing the Commission's report for perpetuating the historic pattern of "persistent exaggeration" in "world hunger pronouncements" Poleman stated:

> "We were, after all, assured 30 years ago by Lord Boyd-Orr, the first Director General of FAO, that "a lifetime of malnutrition and actual hunger is the lot of at least two-thirds of mankind". ... A further turn-off in the case of the Presidential Commission's Report was the

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[57]/ It seems logical in the Seckler/Sampath paper to equate **foodgrains** with **agriculture** as the "race track" for Malthus first race because, as they state "cereals and pulses ... provide over 80% of the energy intake of the Indian population". See Seckler & Sampath p. 2.

enormity of the measures recommended by it to alleviate hunger. Hardly anything was left untouched: ... commodity agreements should be negotiated; tariffs should be reduced; food reserves should be established; food aid should be increased; development assistance should be liberalized; and, the LDC's should be encouraged to promote equitable growth by emphasizing land reform, the small farmer, the basic needs of all."

"But if the Commission took the path of idealism and political naivety, it does not follow that it failed to pinpoint the causes of hunger. It did so with admirable clarity: "... they are hungry because they are poor, and they are poor because they do not have jobs that provide a decent income." This statement may sound trite, but it is not. To have said it 20 years ago was to risk derision. When I said it in 1975 in an article in Science, a number of people wrote to say that for them it was an utterly new idea. This is because it flies in the face of the notion -- erroneous but still widely held-- that there is not enough food to go around, and that current world hunger is simply a sign that mankind is losing the race between food production and population growth first visualized nearly 200 years ago by Robert Malthus."

"That there is a race, no one questions. But it is not the mindless one foreseen by Malthus in which food and population push relentlessly toward some saturation point and ultimate mass starvation. Rather it is a ... race ... in which more and better jobs and the elimination of poverty act as the equilibrating mechanism.

"Employment -- the elusive equilibrator ... consider the outlook for full employment in the developing world. The prospect is anything but good ... Between 1970 and 2000 it is expected that the LDC labour force will double from about one billion to two billion people. In terms of just one country, it means that during the remainder of the century Mexico will need to add to its labour force each year about the same number of new entrants as the USA and Canada together were able to absorb during the boom years of the 1950's and 1960's."[58]

Poleman's diagnosis of unemployment as the principal proximate cause of both poverty and hunger provide the organizing thread for the analysis which follows.

b. Poleman's Prescription on the "*Irrigated Labor Intensive Other Crops*" Track

Poleman then focuses on an examination of viable strategies for finding or creating the necessary number of jobs as follows:

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[58]/ Thomas Poleman, "A Reappraisal of the Extent of World Hunger", *Food Policy*, November 1981 p. 236-237. The sources cited in this quote by Poleman are: Lord John Boyd-Orr, "The Food Problem", *Scientific American*, August 1950, p. 11; Presidential Commission on World Hunger, *Overcoming World Hunger: The Challenge Ahead*, Washington D.C. March 1980 p. 49.

growing, and as industry then had high labour requirements, virtually all who left the land found jobs. (In LDC's) though industry is growing, the bulk of it is capital --not labour demanding. Jobs are fewer than people in search of them. ... Not only must (rural populations) be persuaded that their future lies in the countryside, not town, but their growing affluence ... (must be) the driving force behind transformation of the whole economy.

"Have such strategies a chance of success? There are some grounds for optimism. We sometimes forget how recent is the application of scientific method to farming in the Third World, ... improvement ... until just a year or two ago concentrated on wheat, rice and maize ... There is every reason to believe that other crops ... which are smallholder crops **par excellence,** offer similar possibilities. ...

"...the Chinese experience is certainly suggestive of the extent to which agriculture can productively absorb more labour. According to Rawski, agriculture in 1957 employed about 230 million, ... by 1975 ... 100 million more were working usefully on the land. This remarkable achievement was possible, according to Rawski, because of ... support ... of agriculture, which most of us would equate more with gardening than with farming. Improved irrigation systems permitted the spread of multiple cropping and labor intensive practices.."[59]

A series of specific "prescription" items begin to emerge in Poleman's narrative which we will re-emerge in the analysis below. These simple items are rather constant and important themes. The first is the importance of creating productive jobs in rural areas. The second is importance of "gardening" type agriculture characterized by "garden" crops and "gardening" labor intensive methods of production. The "garden" crops roughly include everything but the grains, Poleman calls them the "other crops which are smallholder crops **par excellence**". They are presumably smallholder crops **par excellence** because they are efficiently and competitively grown with large labor inputs and absorb the high amount of family labor which small-holdings have available. The great majority of farms in India, indeed in the world, are really garden sized plots. The third theme is the importance of irrigation as the enabling mechanism which, as Poleman puts it, "permitted the spread of multiple cropping and labour intensive practices".

4. A Proposed Framework for Understanding the Poverty/Hunger Problem and the Role of Irrigation in its Possible Solution

The earlier discussion lays the groundwork for a proposed framework in which to understand the poverty/hunger problem and the role of irrigation in its possible solution. We summarize this proposed framework in a simplified diagram consisting of two alternative ways of viewing the poverty/hunger problem and its solution. The first is the simple, and we believe, incomplete view of hunger as a lack of

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[59] Ibid. p. 245-246. The cited study on China is T. G. Rawski, *Economic Growth and Employment in China*, Oxford University Press for the World Bank, 1979 pp 123-26.

production problem which has gave rise to and has grown out of Green Revolution thinking. In Table 7 we have labeled this view as the Foodgrain/Production view. The second is our proposed framework which takes a somewhat circuitous, but we feel accurate, track to irrigated other crops as the solution to the underlying effective demand and employment problem. In Table 7 this view is called the Demand/Employment (other crops) view.

Figure 1
Proposed Framework for Understanding the Poverty/Hunger Problem

Logical Sequence	Foodgrain/Production View	Demand/Employment (other Crops) View
The Problem	Most Indians are underfed	Most Indians are underfed
The Problem Causation Chain	India does not produce enough foodgrain (Production)	The poor lack income to buy enough food (Effective Demand) The poor lack income because they are largely unemployed (Unemployment)
The Solution	Produce more foodgrains (Production strategy)	Generate more paying employment for the poor (Employment strategy)
The Solution Causation Chain	Produce more foodgrains India by increased irrigation, more chemicals & spread HYV technology	Generate more paying employment for the rural poor by producing more labor intensive "other" crops
The Major Factors Constraining the Solution	Irrigated area Fertilizer supply Institutional capability to spread HYV technology	Reliable irrigation Market demand for labor intensive crops Marketing infrastructure for labor intensive crops

The two alternative scenarios both have a rather simple sequence though the Demand/Employment view has a few more steps. In sentence form the two views contain the following elements and sequences. The foodgrain/production view sees hunger as the result of insufficient foodgrain which can be solved by expanding irrigated area, fertilizer supply and the spread of HYV varieties and technology. The demand/employment view is a four sentence version. The poor are hungry because they lack income to buy the food they need. They lack the income because they lack gainful paying employment most of the year. Given India's resources the best hope of generating gainful paying employment is in labor intensive irrigated "other crops". The main factors which limit increased production of these labor intensive other crops are the reliability of irrigation, the limited domestic and international market demand for these crops and the lack of cooling, packing and transport infrastructure to get these products to domestic and international markets.

B. Analysis of the Role of Irrigation in A Market-Demand Driven Employment Strategy.

The analysis underpinning the foodgrain production view is simple and well known and will not be repeated here. The various elements which comprise the demand/employment view are not so well known and will be summarized in the next section. Even from the brief discussion so far, it is obvious that the demand/employment view involves irrigation as a major element in a somewhat complicated system. Irrigation is a critical component in a demand/employment strategy for India since the "other crops" are much more demanding of irrigation than foodgrains, in fact most foodgrains in the world are produced without irrigation. It may come as some surprise to Green Revolution enthusiasts that the highest yields recorded for wheat in the U.S. are not irrigated yields, they are recorded for dryland production in arid conditions. The demand/employment view of irrigation's potential contribution would see a major shifting of irrigation design and operation oriented away from grains toward irrigation for "other crops". To state the case in the extreme it would be to allow the market to move grains off of India's high quality irrigated land resource to more marginal dry lands and put those lands to high labor crops as far as the markets will carry them.

This section reviews four major elements in the demand/employment strategy. First is looks at the question of the labor intensity of foodgrain and other crops to see how much difference there really is in their employment capacity. Second it looks at the domestic and international market demand for these high labor crops to see how large the market really is. Third, it summarizes the marketing infrastructure constraints in India. Lastly it explores the irrigation needs of the strategy which is oriented at other crops.

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1. Labor Intensity and Rural Employment.

A major misconception which has become institutionalized in India is the equating of agriculture and food with "foodgrains". Frequently in the literature one will encounter a book, a paper, a seminar or a speech which has "agriculture" or "food" in the title and purports therefore to deal with "agriculture" or "food" as a whole, but which proceeds to deal exclusively with "foodgrains". The tendency to equate "food" with "foodgrains" may make some sense in a caloric sense since foodgrains account for about 3/4ths of caloric intake, but when the subject shifts from nutritional intake to agricultural income, poverty, employment or most other topics such a generalization is inaccurate.

Since our tracing of the two Malthusian races focuses us on rural income, effective market demand and employment such a generalization would be fatal. Table 7 below outlines the relative crop shares in agricultural value and agricultural employment

Table 7
Estimates of Crop Shares in Area, Production, Employment and Ag. Value
(Estimates for 83-84)

Crop	Area 000 Ha.	Production 000 MT	Value 000 US$ 84	Emply Mill PD	Value % Share	Emply % Share
Food Grains	123,318	128,[illegible]6	26,963,237	6,289	47.10%	42.99%
Oils/Grdnut	17,857	15,393	5,387,457	679	9.41%	4.64%
Milk	1,466	32,985	8,279,235	880	14.46%	6.02%
Meat/Fish/Eggs	5,271	5,149	1,803,945	633	3.15%	4.33%
Tubers/Pot.	1,522	19,311	1,040,395	365	1.82%	2.49%
Sugar	3,364	16,719	3,093,030	1,177	5.40%	8.05%
Vegetables	1,859	14,995	1,649,450	1,208	2.88%	8.26%
Fruits/Spice	2,340	9,818	4,411,027	1,170	7.71%	8.00%
Fibers	10,130	3,980	4,616,800	2,229	8.07%	15.24%
Total	167,127	246,706	57,244,576	14,630	100.00%	100.00%

SOURCES: See footnote [60]

[60]/ Area and production figures based on Government of India, *Area and Production of Principal Crops in India 1981-84*, Directorate of Economics & Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi, 386 pp.. We valued major internationally traded commodities at World Bank estimates of US$ 1984 international prices. This should give a more realistic equilibrium estimate free of subsidy bias. For non-traded commodities we used prices principally from, Government of India, *Indian Agriculture in Brief*, Directorate of Economics & Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi, pp. 374. Employment demands are based on the 38 individual commodity studies for Maharashtra reviewed and statistically summarized in Daines, S., & Pawar, J.R. Pawar, *A Statistical Profile of Agriculture, Nutrition, and Development Trends in India: A Case Study of Maharashtra State*, SRD Research Group, Logan, Utah 1984, pp. 38.

Table 7 indicates that while foodgrains occupy three fourths of the crop area and supply roughly the same proportion of caloric intake, they account for only 43% of agricultural employment and 47% of agricultural income.

a. Unemployment and Under-Employment

If we assume that the available work year for workers in agriculture in India is 300 days there is a supply of approximately 54 million person days for the agricultural work force. Table 7 indicates that roughly 14.6 million days of this available supply would be demanded in direct productive labor in crop, livestock and fish production. Based on Daines & Pawar estimates of indirect employment required in marketing, processing and transport to support direct production (See footnote 60), there might be as much as another 2 million person days of productive employment. This suggests that even including indirect agricultural employment the rural workforce is productively employed only about one third of its capacity. This suggests an "under-employment" rate of about 66 percent in rural India. This figure is not really comparable methodologically to published estimates of "unemployment",[61] but we feel our figure is more useful and accurate for planning purposes.

The critical question then is how to productively employ a pool of some 35 million person days that is growing by about 2.8% per year. Recent Chinese experience suggests the unusual dynamism and labor absorptive capability of intensive irrigated non-grain "other crops" mostly comprised of fruit and vegetable products but also including some fiber and specialty products.

61/ Most published "unemployment" statistics relate to the work "status" of surveyed individuals in the economically active workforce. Thus the percentages published deal with job status rather than with the percentage of hours gainfully working in productive activities. There are additional differences between the method used in Table 7 and this section for employment and unemployment estimates. Most under-employment estimates attempt to include "productive" household and service activities such as cooking, fuel gathering, and societal "maintenance" work. The reason we have not included these is that the productivity of these activities is hard to measure on an hourly basis. Fuel gathering for example may take more or less time depending on the availability of competing productive employment options. We prefer to use an estimate of productive employment demand as the implied "employment" rate realizing that it may somewhat overestimate true employment slack. We think that the over-estimation bias is more than adjusted for by under-estimates of the work force implied by the computation of "economically active population" and the 8 hour 300 day work year. If there were highly productive employment options these two numbers would likely increase in response and overcome any over-estimation bias in our labor slack estimates.

b. Labor Intensity and Employment Impact

Table 8 outlines the on and off farm employment generated by both irrigated and rainfed crops in person days per hectare cultivated for a single crop cycle. The range in the table represents the majority of small and large farm practices in Maharashtra.

Table 8
Employment Generated by Irrigated and Rainfed Crops
Person-days per Hectare per Crop Cycle
(Farm and Off Farm Employment)

Crop	Rainfed Employment Per Ha.	Irrigated Employment Per Ha.
	Person Days/Ha.	Person Days/Ha.
Fodder Crops	12-44	28-55
Rice	32-54	53-80
Jowar	22-50	37-64
Bajra	22-44	27-54
Wheat	22-33	27-39
Pulses	22-33	32-53
Oilseeds	22-33	32-43
Cotton	95-240	125-350
Groundnuts	60-120	100-190
Spices	120-190	240-320
Sugarcane		450-750
Bananas & Other Fruits		360-480
Onions & Potatoes		385-550
Vegetables		300-425
Grapes & Flowers		2,250-3,300

Sources: See Daines & Pawar footnote 60

Figure 2 illustrates the employment generation relationships by crop in graphic form. In the figure, the vast differences in employment potential of the different crops is obvious. While irrigation does increase the labor required by crops when compared with the same rainfed crop, these small differences are dwarfed by the very large differences are between the low income grain crops as a group and all of the others.

The length of crop cycle varies from short season 3 month crops to crops like sugarcane which take 18 months to mature, and therefore a "crop-cycle" employment indicator such as that presented in Table 11 and Figure 8, therefore, is a distorted view. Figure 3 adjusts crop employment to a common base 12 mo. period.

Figure 2

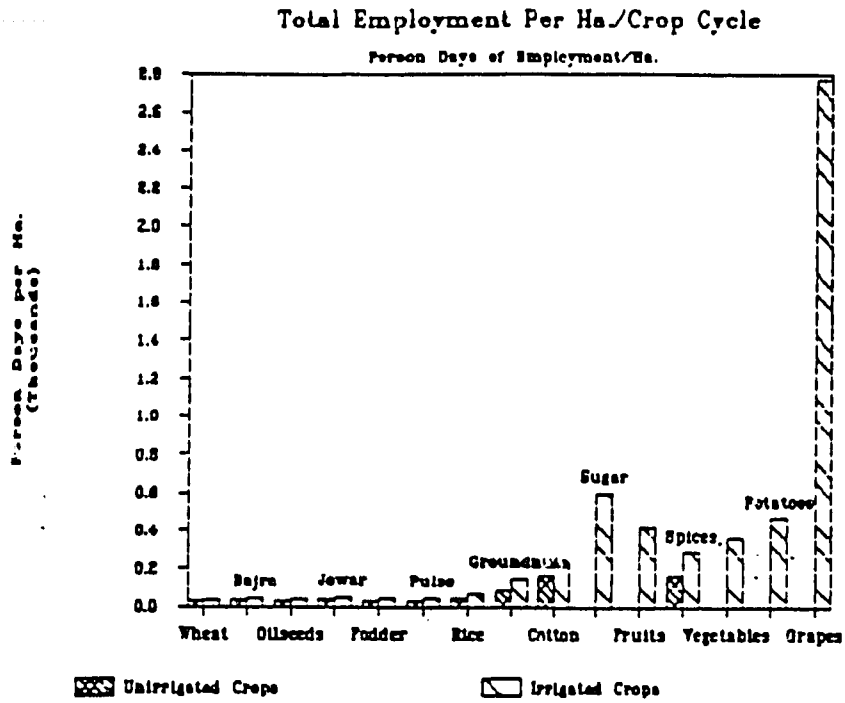
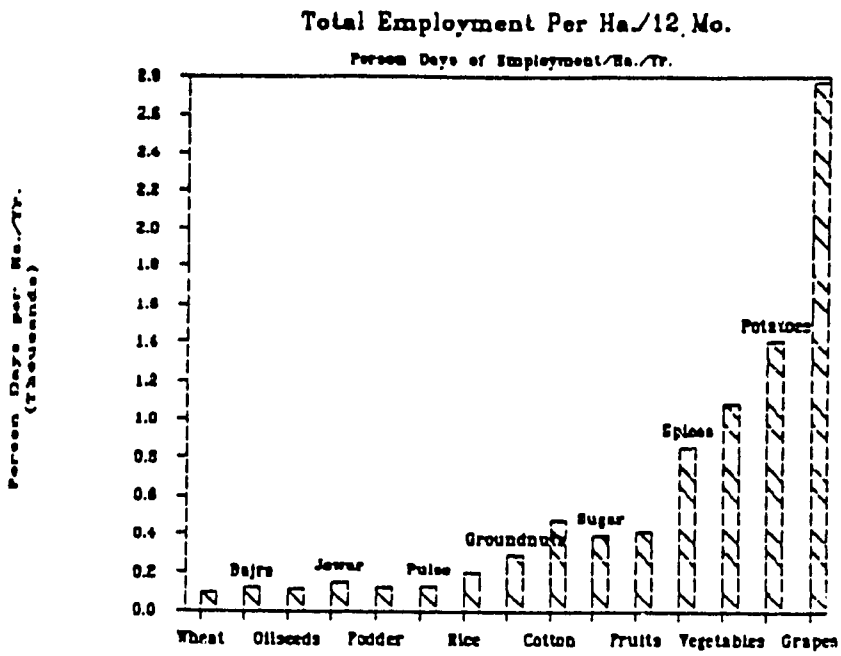


Figure 3



The employment figures given above overestimate the net contribution of irrigation since they fail to account for the employment which would have taken place even without irrigation. Figures 4 and 5 subtract out the employment of alternative rainfed crops and present the net contribution of irrigation in land and water terms. The low productivity position of sugarcane and bananas which are longer standing and more water demanding is clearer using the "incremental" measures of Figures 4 and 5, than it was in Figures 2 and 3. The very strong employment impacts of spices, potatoes, vegetables, grapes and flowers becomes very clear in Figures 4 and 5.

Figure 4

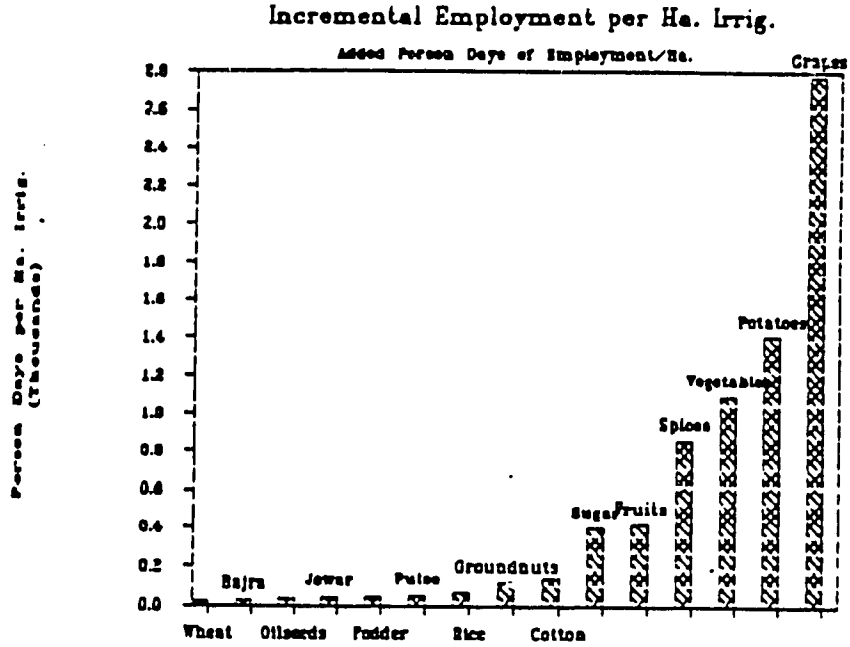
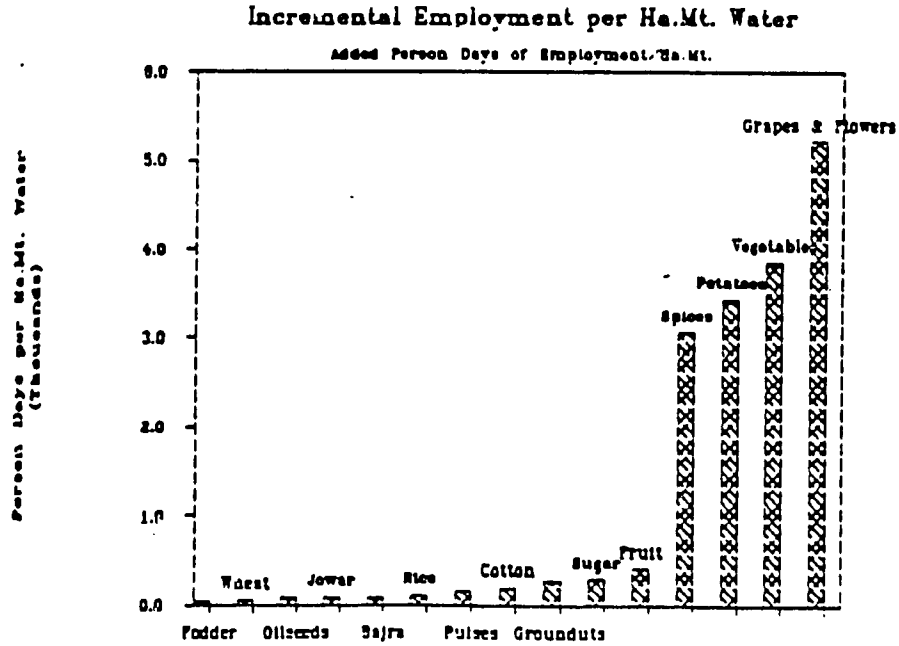


Figure 5



c. Small Farm Employment and Income Patterns in A Typical Command

Figures 6 and 7 present small farm crop area and crop income shares. Small farms (under 2Ha.) dedicated approximately two-thirds of their crop area to irrigated grains, with another one-fourth remaining in rainfed traditional grains and, about 10% in intensive irrigated crops such as sugarcane, vegetables, groundnuts and spices. Figure 8 illustrates the substantial importance of sugarcane as an income source. Even though sugarcane occupies only 4.6% of cropped area in small farms, it contributes one-third of the on and off-farm income generated by small farms. Irrigated and rainfed grains, occupying 90% of cropped area, contributed only 56% to the income generated by small farms.

Figure 6

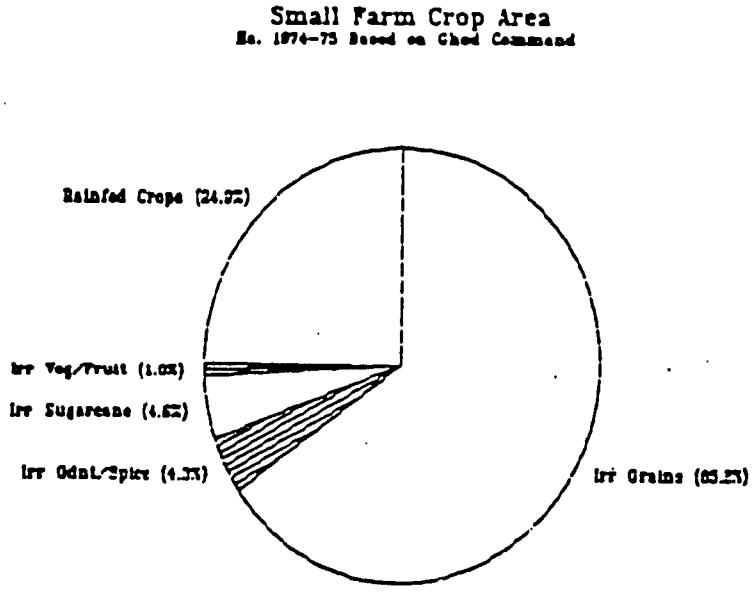
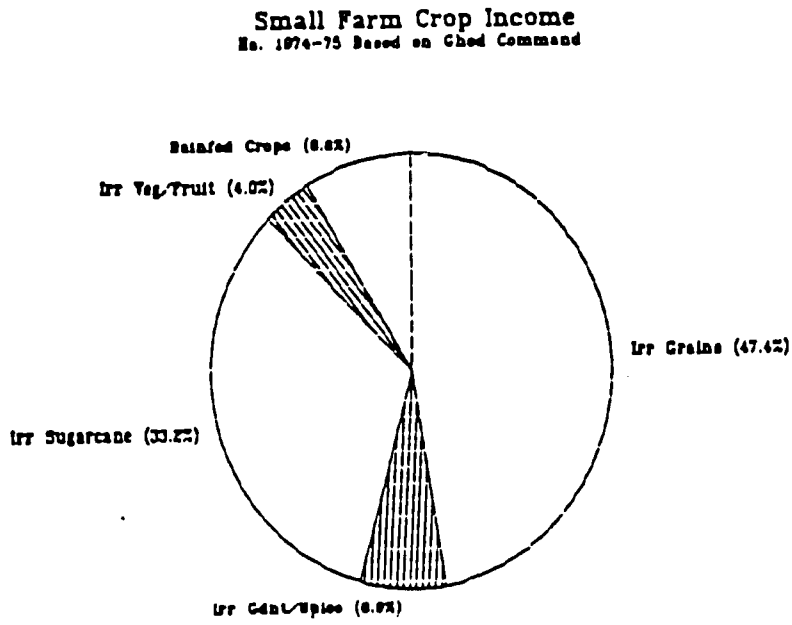


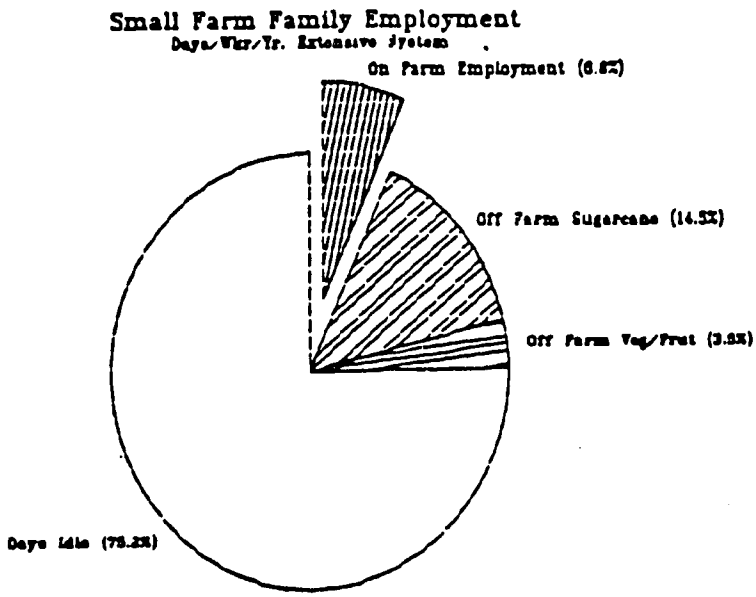
Figure 7



Small farm families, even those who are fortunate to live inside the commands of irrigation projects, are seldom gainfully employed. The most common measures of employment in India fail to capture the very high levels of economic idleness which predominates in rural areas.

Figure 8 outlines the average use of available adult person days in the Ghod command, which is characteristic of the dominant "extensive" type irrigation system. Adults in small farm families, even those with some sugarcane, are actively working in crop production on their own farms for only about 7% of the work year.

Figure 8

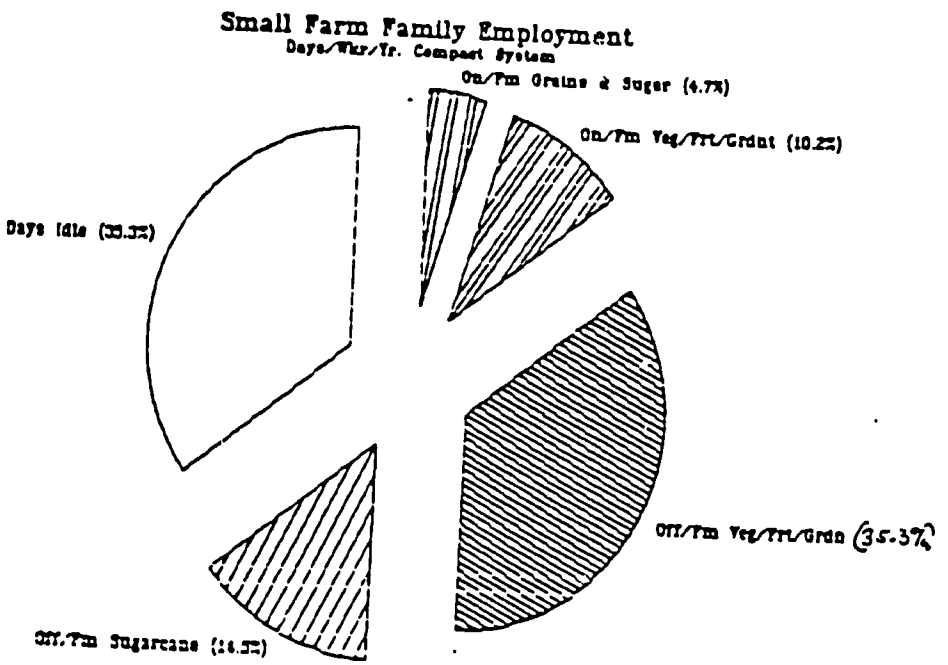


The seasonal demands of land preparation, sowing and threshing prevent small farm families from distributing their labor demand over a long period of time. During peak labor demand periods, small farmers even hire outside labor to complement family labor availability. Small farm families join the landless laboring pool during the vast majority of the year, and in the Ghod command, they are employed more than twice as much on neighboring large farms as they are on their own plots. Sugarcane on other farms is the dominant employment activity of even small farm families. Small farm adults spend about 75% of the available working year in economic idleness, relief works, or informal activities.

d. Possible Employment Patterns in Improved Reliability Systems

The basic configuration of an improved reliability system was used to compute the implied employment patterns for small farm families and for landless laborers. The results of this simple model may be seen in Figures 9, 10 and 11. In Figure 9, the implied employment patterns of small farm families in the alternative improved reliability system are displayed. The under-employed or relatively idle period in the improved reliability system has been reduced to 35% compared with the extensive system 75%. Most of this added employment was caused by a substantial increase in off-farm employment on large farms in vegetable, fruit and groundnut crops.

Figure 9



Employment on the small farms themselves doubled from 7% of the available labor days to 14%. Sugarcane has been held constant. Employment patterns like those seen in Figure 9 closely approximate some irrigated situations in Jalgaon, Sangli and Nasik districts in Maharashtra.

From an equity point of view, one should not fail to notice how the employment of small farm families depends on the type of crops grown, not so much of their own farms, but that of neighboring larger farms which provide needed employment.

e. Irrigation and the Employment of the Landless.

The weakest group in the "weaker" sector is the landless group. In irrigated areas there is substantial employment for at least a part of this severely disadvantaged group. Figure 10 outlines employment patterns of landless rural workers in extensive systems such as the Ghod command. Only 4% of the employment of landless workers is provided by small farms. Sugarcane and irrigated large farm grain crops dominate in the employment pattern of landless workers. More than two thirds of the total person days of available adult labor of landless families is spent in marginal economic activity or idle.

Figure 10

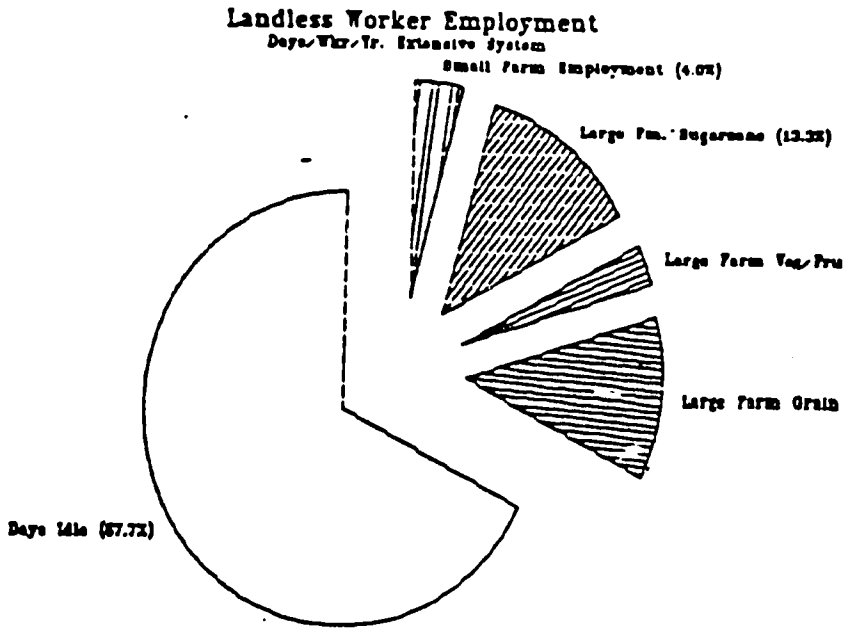
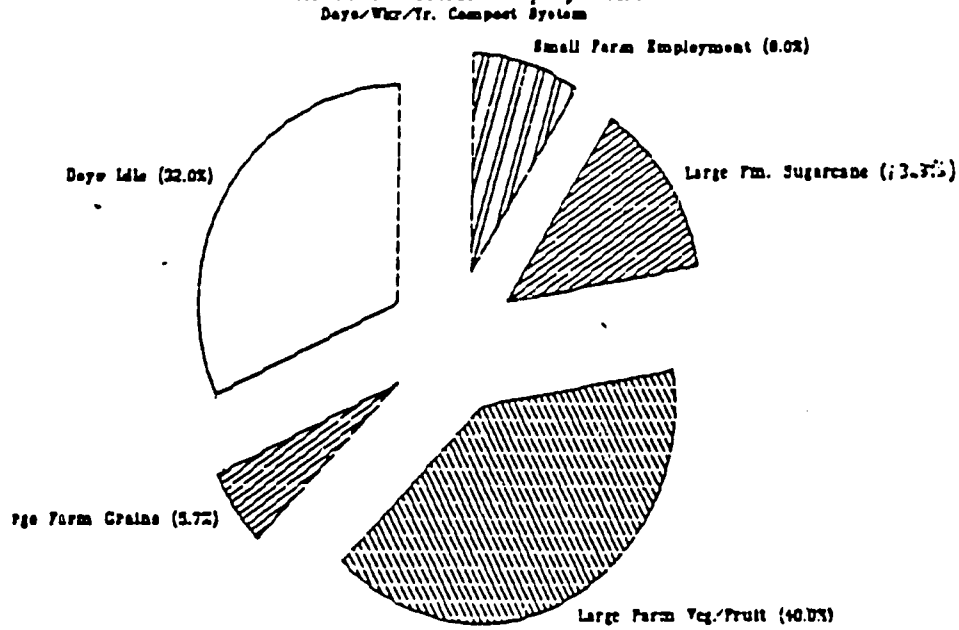


Figure 11 presents projected employment patterns of the landless in a improved reliability system. Small farm employment more than doubles with the increased crop intensity allowed by a improved reliability system, but is still a small part of overall employment. Like the small farm families, landless workers in a improved reliability system would be able to employ almost one third of their available work days in large farm fruit, vegetable, spice, cotton and groundnut crops. The total under-employment or economic idleness would drop for landless workers from about 67% in extensive systems to around 32% in a improved reliability system.

Figure 11
Landless Worker Employment



2. Market Demand Constraints for Labor Intensive Agricultural Products.

The above discussion highlights the importance of irrigation to labor intensive crops and overall employment and income of the poor through an employment and effective demand strategy. Improved reliability irrigation is clearly a necessary but not really a sufficient condition for the expansion of labor intensive crops. Most of these "other" crops are high income elastic products and effective market demand is limited in low income families.

This section explores the structure of market demand in India for labor intensive products. The authors are involved in an ongoing collaborative study between researchers at Harvard, USU, and Cambridge Universities and the Indian School of Political Economy in Pune to analyze domestic and international market potentials for these and similar products. The initial results of this effort are reported at the beginning of section B above. They suggest that there is considerable potential in both evolving domestic urban markets in India and in high income countries to which India could export these products. India has a strong international comparative advantage both from its low labor cost and from its flexible capacity to produce these products during almost all seasons of the year. The subsections which follow explore both nutritional and market demand trends inside India.

a. Nutritional Supply and Demand

i. Nutritional Supply & Demand for Foodgrains

Table 6 presented above outlines the availability of foodgrains per capita during the last century. The table suggests dividing the last hundred years into three periods from the point of view of foodgrain availability. The first period, from the 1890's to the 1920's, was a high availability period with foodgrain availability nearly 700 grams/capita/day.The second period was one of declining per capita availability resulting from steady absolute production in the face of rapidly expanding population. During this period of some thirty years, per capita availability dropped from nearly 700 grams/day before 1920 to a low of 385 in 1952. The third phase since 1953 has seen an erratic but slowly growing trend in per capita

foodgrain availabilities in the face of continuing rapid population growth.

The first part of the growth phase from 1951-1968 appears to have been caused by an expansion in the area cultivated associated with increases in surface irrigation. From 1968 forward the increases appear were caused by the yield increases generally known as the "green revolution" which was supported mostly by the expansion in groundwater based irrigation.

It was thought by many that the growth trend in output of foodgrains had stagnated in the late 70's. Analysis of detailed production data appears now to question the stagnation hypothesis[62], and recent studies now suggest that the growth trend since 1953 has continued to date around a reasonably continuous trend. If this position is correct, as we think it is, it would imply that the "green revolution" did not have any impact on the rate of foodgrains growth. It simply allowed the growth rate to continue based on increased yields after the area for expanding cultivation ran out in the sixties.

ii. Nutritional Supply & Demand for All Food Products

There is a tendency in India to equate "food" with "foodgrains". Though foodgrains provide a large part of the calories in the Indian diet, the other food items must be included in an overview of the nutritional supply and demand picture. - Table 8 presents an overview of "nutritional" supply and demand based on production in 1980-81 and the nutritional requirements of a "least cost" average diet for the Indian population in that year.

From Table 8 it would appear that there is a discontinuity between the pattern of foods being produced and the pattern that would be demanded by the least cost adequate diet. It would appear that India is already producing more foodgrains than would be required by a least cost average diet to feed its population. Fruits and vegetables constitute about 55% of the nutritional deficit, with milk at about 30% of the deficit.

Perhaps the most important implication of Table 8 is that even if all food was equally distributed, India would need to expand production by approximately one third to feed its population a "least cost" adequate diet. When the realities of unequal distribution are accounted for, it appears probable that food production would have to increase by perhaps half to provide a least cost minimum diet to the existing population.

It is useful to note that all of the increased production to satisfy the nutritional demand of the average least cost diet are in non-foodgrains categories. Averages in nutritional matters are often deceptive. Since foodgrains are not equally distributed there are large populations in India who have not yet reached even the least cost diet levels of foodgrain consumption. Increased production of foodgrains would be required to lift these populations to the least cost diet levels, and still more to supply foodgrains to the additional population that is added yearly. It is

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62/ See, T.N. Srinivasan, "Trends in Agriculture in India, 1949-50-- 1977-78, *Economic and Political Weekly*, August 1979, p. 1283.

also generally true that foodgrains supply

Table 8
Food Production and Food Requirements in India
(food balance 1980-81 in millions of metric tons)

Food Items	Actual Production 1980-81	% 1980-81	Nutritional Requirement Deficit-	% Deficit	Surplus+	% of
	(mmt)	(%)	(mmt)	(%)	(mmt)	(%)
Foodgrains	129.9	59.2%	123.9	42.7%	+ 6.0	0.0 %
Other Foods	89.5	40.8%	166.5	57.4%	-77.0	100.0 %
Other Foods						
Fruits & Veg.	37.9	17.2%	80.1	27.6%	-42.2	54.8 %
Milk	30.2	13.8%	53.0	18.3%	-22.8	29.6 %
Fats & Oils	2.2	1.0 %	11.0	3.8%	- 8.8	11.4 %
Meats & Fish	3.8*	1.7 %	10.8	3.7%	- 5.5	7.0 %
Sugar	15.4	7.0 %	11.6	4.0%	+ 3.8	0.0 %

* Provisional Estimate
SOURCES: Least cost diet pattern per capita from Gopalan, "Some Aspects of Nutrition in India." In: Population in India's Development, New Delhi, 1976 pp. 101-102. Production 1980-81 from Directorate of Economics and Statistics, Bulletin on Food Statistics 1981-82, New Delhi 1982. Population 1980-81 from Census of Population 1981, New Delhi 1983.

a larger number of calories per unit of weight than do other food items and therefore their relative importance from the point of view of energy (which is the most pressing nutritional deficit in India) is understated by the weight units used in Table 8.

The implication of Table 8 isn't that foodgrain production wouldn't need to increase over time to supply an adequate diet, such an increase would be necessary and appears to be happening. The implication of the Table is rather that the major nutritional deficits in the current production pattern are in non-foodgrains categories dominated by fruits, vegetables and milk.

iii. Summary of Nutritional Supply and Demand.

It appears that food production would need to increase by perhaps 50% in order to feed the population a least cost adequate diet. India does not appear from the data we have seen to be nearing nutritional self sufficiency. The major deficits are in fruits, vegetables and milk, not in foodgrains, though increased foodgrain production would also be necessary. Foodgrain production appears to have expanded slightly faster than population in a somewhat erratic trend since 1953 with no noticeable change at the time of the Green (or perhaps more accurately "grain") revolution.

b. Market Supply & Demand

In India subsistence and market driven agricultural production exist side by side in most rural areas. The transition to a predominantly market agricultural economy has not been rapid. Income per capita is rising, albeit slowly in towns and cities, and even in rural areas. This accumulating income exerts pressure on production through market mechanisms. The most obvious of these pressures comes from the large urban areas. Food consumption by income levels for Calcutta, presented in Table 9, provide a good example of the directions of this market demand pressure.

TABLE 9
PER CAPITA CONSUMPTION OF FOOD PRODUCTS BY FOOD EXPENDITURE LEVEL
CALCUTTA 1970
EXPENDITURE LEVEL (Rupees/Month/Capita)

Food Item	Exp. Level 1 > 20 Rs/mo.	Level 2 20-40	Level 3 40-60	Level 4 60-100	Level 5 100 +	Ratio of level 3/1
	grams/day	gr/day	gr/day	gr/day	gr/day	(3)/(1)
Food Grains	328	368	392	398	392	1.2
Milk & Eggs	20	39	87	133	238	4.4
Fruits	6	12	28	46	80	4.7
Vegetables	100	158	206	247	276	2.1
Oils	10	15	21	27	35	2.1
Meat & Fish	19	25	38	45	69	2.0
Sugar	21	25	30	36	43	1.4

Source: Computed by S. Daines based on data from A Study of Food Habits in Calcutta, U.S. Agency for International Development, New Delhi, 1972, 166 p.

Table 9 indicates that market forces are pulling production in roughly the same directions that nutritional demand would dictate. The market pull on food grains appears to stagnate at relatively low levels of income, just slightly above the average Indian income level of 1970. This implies that those Indians below that level will continue to purchase additional foodgrains as their incomes approach the 1970 average. Since average income per capita is rising at about 1.3% per year, the population which has reached the foodgrain demand stagnation level is increasing each year by about that same margin. Substantial populations still lie below this food grain demand stagnation level of about US$ 200 income per capita in 1982. For these families, increases in income will still be spent partly for additional foodgrains. To this incremental demand for foodgrains from increased income we must add the incremental demand which arises from added population.

It is interesting to note that the two commodities (foodgrains and sugar) which Gopalan's least cost diet indicated are already over produced on the average are also the same two items which Table 2 indicates have the lowest income elasticity of demand.

Market demand pressure appears to be strongest in milk and fruit categories with strong demand for vegetables (including potatoes), oils and meat/fish. Purchases in the milk/fruits groups increase by more than four fold as incomes increase from the lowest group to the slightly above average income group in 1970.

It would appear that the long term trend driven by internal markets would be to a gradual shift in product composition from 60% grains and 40% other products, to the reverse with 40% grains and 60% other products.

External markets could have some impact on the shift in product composition of the agricultural sector. The basic factor endowment pattern of India, scarce land and capital and abundant labor, make India a poor competitor in international grain, milk and meat markets. That same factor endowments linked with India's seasonal advantages could place India in a good competitive position in many fruit and vegetable products. However, poor marketing/processing technology and marketing infrastructure appear to be major constraints on rapid export expansion in fruit and vegetable products as discussed below.

3. Marketing Infrastructure and Technology Constraints on the Expansion of Irrigated Labor Intensive Crops.

Marketing infrastructure and technology is a major constraint on the expansion possibilities for labor intensive irrigated crops. The cases of grapes and bananas in Maharashtra are good examples. There are good markets for grapes and bananas in Bombay, but substantial expansions of banana and grape acreages in Maharashtra would need to tap other more distant markets. Marketing losses from spoilage of these products is substantial even for sale in the Bombay[63] market and the problems and losses multiply as more distant domestic markets are sought. Current packaging would be largely unacceptable in the very attractive European and Pacific Rim markets such as Hong Kong and Singapore and the capability of the Indian industry to put a high quality product that far away is severely limited. Port cooling and handling facilities are almost non-existent for this kind of high perishability trade and substantial post-harvest handling technology would be needed at all stages from field harvest to final export market delivery.

4. Reliable Irrigation Constraints on an Employment Strategy

Reliable year round irrigation is a necessity for most labor intensive crop expansion. Many of the products are perennial crops which require year round irrigation, and even short season vegetable crops are most profitable when undertaken as year round production systems. The seasonality of markets and packing facility amortization both make year round production an economic necessity in most cases. Many surface systems cannot assure this kind of seasonal reliability. There is also the issue of irrigation scheduling. During the early months of onion production, for example, irrigation is required on onion starts every 2-3 days. A

63/ see price impacts of perishability in J.R. Pawar & S. P. Patil, "Price Spread in Marketing of Important Fruits in the Bombay Market", *Indian Journal of Marketing*.

rotation pattern of 14 day irrigation intervals is impossible to work with even if it is 100% reliable.

These factors are explored at length in other parts of the paper but need to be re-emphasized at this point in the discussion to highlight that the critical irrigation need of an employment strategy is **reliable** and **flexible** irrigation, not more area under irrigation.

B. Productivity Impacts of Irrigation.

1. Definitions & Concepts of "Productivity"

The purpose of this first section is to explore the measurement of productivity of irrigation in India. The first two subsections examine alternative concepts and definitions for "productivity" in the context of irrigation. The third subsection presents estimates of productivity ratios for rainfed vs. irrigated crops and examines differences in overall productivity between different types of irrigation, such as wells, tanks and canals.

While there are many possible definitions of productivity, the general concept which will be used here is the most common definition which suggests that "productivity" is a measurement of the quantum of some desired output per unit of some scarce input. Productivity by this definition is a ratio with a numerator measuring or estimating the amount of output obtained per unit of input. The productivity of irrigation would be a ratio measuring or estimating the increase in some desired output per unit of some scarce input. Rao outlines some of the alternative choices of numerator and denominator in irrigation productivity ratios as follows:

> "The definition of efficiency in irrigation system could be broadly characterized either in terms of hydrogeological (ie water use efficiency or irrigation efficiency) or socio-economic (productivity/growth and social justice) parameters. In a National Seminar at the Administrative Staff College of India on Multi-disciplinary Organisation Structure for Irrigation Projects (October 1981), it was recommended; "In the ultimate analysis irrigation efficiency is to be measured with reference to the primary objective of irrigation, namely, irrigated agriculture which is the end product of a long process. Thus, the efficiency of the system as a whole can be measured via efficiency of irrigated agricultural production. The latter can be expressed in terms of output per unit of the scarce factor, which may be land in some cases and water in others."[64]

Rao's productivity and social justice concepts are used as the analytical framework for this document. Using this framework carries the discussion away from water delivery and into examining irrigation in terms of its impacts on irrigat-

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[64] P. K. Rao, in Niranjan Pant Ed, *Productivity and Equity in Irrigation Systems*, Ashish Publishing, New Delhi, 1984, 276p, at page 5.

ed agricultural production. Following the Rao approach to the analysis of irrigation efficiency seems logical enough, but has rarely been done in India due to the dominance of engineers in irrigation matters. Engineers in India tend to see irrigation systems in "water" terms rather than in "crop" terms. Wade characterizes this water myopia as follows:

> "A ... significant feature of irrigation projects is that engineers dominate in their design and operation... Today one of its consequences is that irrigation engineers tend to view the output of a canal system as water, not the additional crops which that water should allow." [65]

Following the causation chain for irrigation into its productivity and equity impacts begins with a crop orientation rather than a water orientation. This document will therefore concentrate on irrigated crops rather than irrigation per se.

Rao's quote further sets the conceptual framework for our discussion of productivity and irrigation by suggesting the measurement technique which should be used to quantify productivity for irrigation systems. Rao suggests that productivity:

> "... can be expressed in terms of output per unit of the scarce factor, which may be land in some cases and water in others."[66]

Rao's proposed measurement for the productivity of irrigation is a conceptually very simple ratio with crop output as the numerator, and one unit of either land or water as the denominator.

2. Crop Output: The Numerator in the Irrigation Productivity Ratio

a. Value vs. Quantum of Output

If irrigated agriculture were comprised of a single crop, it might be possible to use the physical quantum of production as the numerator. Since many crops are involved, it is necessary to use agricultural prices as a mechanism for adding apples and oranges together in a single measure of output. For the purpose of this document, farm gate producer prices are used to value both home consumed and marketed products.

b. Net vs. Gross Value to Farmers

Two further refinements in the measurement of the numerator are helpful in fine tuning the ratio to represent a more accurate indication of the desired output of irrigation. The first adjustment reduces the gross value of output by the paid out costs which farmers incur in the production process. The objective of this adjustment is to avoid over-estimating the value of production which comes to the farming sector and stays in the rural areas. The idea is to count only that part of the value of production which does not "leak" outside the irrigated area. To

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[65] / Robert Wade, "The Performance of Irrigation Projects", *Economic and Political Review*, January 17, 1976.

[66] / Rao, op.cit. p. 5.

accomplish this objective, I have reduced the value of production by subtracting certain selected cost items which are likely to "leak" outside the farming sector.The most prominent of these are chemical fertilizer, fuels and mechanical costs.

A more difficult issue is raised with reference to animal power and farm yard manure. Since draft animals must be fed even when not productive, they represent a significant "cost" in real terms to the farm family. It is easier from a computational point of view to add in the forage value of crop residues and then subtract a reasonable cost of animal power than it is to treat animal costs as a part of the farm value of production.

The resulting measure of farm value of production which is used in this document represents a rough estimate of the part of production value which remains in the hands of farmers and farm laborers.

c. Direct vs. Indirect Output

Irrigated agriculture not only benefits farmers and farm laborers, but creates additional value added in marketing and processing of the agricultural products it generates. In order to provide useful productivity estimates these forward linkages need to be added. Ideally, one would use a formal Input/Output model to estimate these indirect impacts as has been done in other more extensive studies.[67] Formal input/output modeling would include estimates of all economic forward and backward linkage effects but is unfortunately beyond the reach of this particular document. As a second best alternative I have included estimates of the first and second forward linkage impacts, which roughly correspond to wholesale marketing and first stage processing. In a formal input/output model, almost all impacts are covered when five to six forward and backward linkage "rounds" are included. Including the first and second forward "rounds" probably captures about three fourths of the indirect impacts. In the tables which follow direct on-farm and indirect off-farm impacts have been added together.

67/ see S. Daines, et al, *Input/Output Matrices for Employment and Income Distribution Analysis (76 Sectors)*, Sector Analysis Division, Agency for International Development, Washington D.C. 1972, 120 p.

3. Scarce Resources: The Denominator in Irrigation Productivity Ratios

Rao correctly suggests the appropriate denominator for irrigation productivity ratios as follows:

> "(Productivity) can be expressed in terms of output per unit of the scarce factor, which may be land in some cases and water in others."[68]

The idea of productivity is that it measures the amount of some desired output gained per unit of some scarce resource. It is important to have a correct scarce resource in the denominator in order to obtain the most meaningful productivity ratio. Rao suggests two scarce resources as the most appropriate for irrigation productivity measurement, land and water.

a. Capital and Energy Productivity of Irrigation

Before refining Rao's suggested denominators, we should examine alternatives. Two other basic resources are obviously scarce in India, capital and energy. There is some evidence that another type of "capital" is very scarce and constrains the productivity of irrigation systems. The type of capital referred to, is farmer production credit. It may be that the scarcity of production credit to farmers prevents full and efficient utilization of irrigation water and irrigable land and should constitute an additional denominator for irrigation productivity ratios which is inadequately captured in benefit cost analysis. In any case, an analysis of "credit" productivity ratios is beyond the reach of the data I have gathered for this paper.

The "energy" productivity of irrigation is a vital issue which needs further analysis in India similar to that undertaken elsewhere,[69] but is beyond the reach of this particular paper.

b. Land and Water Productivity Ratios

The most common traditional unit used as the denominator in productivity measurements for agriculture has been land. Almost all "yield" estimates for agriculture are reported in terms of output per acre or hectare. Recent irrigation commissions have questioned land ratios as the most appropriate measure of productivity on the basis that land is less scarce than water in India. This is not an easy issue to deal with since the scarcities of these two resources are interrelated and difficult to separate.

A partial alternative to separating the analysis into two separate ratios is to conceptually see the scarce resource as "irrigable land" -- land **with** water. While this approach may well produce the best single combined productivity ratio, it lacks precision where water is concerned. Such a combined ratio assumes a more or less

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[68]/ Rao, op.cit. p. 5

[69]/ see S. Daines et al, *Energy in the Food System: Dominican Republic*, Brookhaven National Laboratory, Upton N.Y., and Agency for International Development, Washington D.C., 1980, 213 p.

fixed water allocation per unit of irrigated land which fails to account for differences in crop water requirements.

Rao argues for using two ratios to account for the fact that in some cases in India irrigable land is the scarcest resource, and in others water is the scarcest. For this analysis, I have estimated two productivity ratios, the first is a combined "irrigated land" ratio and the second is a pure "water" ratio.

The productivity analysis which follows examines irrigation productivity at two levels: the crop level, and the irrigation system or command level. This analysis commences with estimates of productivity ratios at the "crop" level. Next we examine irrigation productivity at the irrigation system level in the Deccan Plain based on detailed farm level survey data from Maharashtra.

4. Land Productivity Ratios at the Crop Level

Table 10 outlines the crop level "land" productivity ratios for irrigated crops based on micro-data in Maharshtra state. The specific crop surveys were principally conducted by Mahatma Phule Agricultural University and are described in a separate document.[70] Rather than estimate an "average" productivity ratio, I have preferred to estimate a range which captures the predominant prevailing agricultural practices. While the micro studies from which the data are drawn are not always comparable, I have attempted to select from these sources, upper and lower bounds for ratios which would represent approximately 90% of prevailing farming situations. Eliminated from this range are both the very best growers and the very worst growers of a particular crop.

The first two columns in Table 10 are computed per crop cycle which creates a distorted picture of true land productivity since there is considerable variation in the number of months a particular crop takes to mature. For example, most vegetable crops take less than four months per crop cycle and three crops may usually be cultivated in a year if irrigation water is available. Sugarcane, on the other hand, usually takes 18 months per cycle. Column three in Table 10 adjusts all crops to a 12 month equivalent productivity basis.

Column three also computes the additional product value created by irrigation by subtracting the rainfed yield from the irrigated yield. Since some crops are not usually cultivated without irrigation in the Deccan, the rainfed yield is zero.

Column three is, therefore, an estimate of the net added productivity of land with irrigation in the various crops. Table 10 suggests three different sources of increased productivity which are associated with irrigation. The first of these is

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[70] / S. Daines, *A Statistical Profile of Agriculture, Nutrition and Development Trends in India: A Case Study of Maharashtra State*, SRD Research Group Inc., Logan Utah 1984, 38 p. (Prepared under subcontract to USU-WMSII & CID). Some of the estimates in these studies have been modified based on the irrigation studies conducted in the Ghod & Girna Commands and in Karnataka referred to in the farm level analysis section of this document.

the obvious increase in productivity for all crops when rainfed land is given supplemental irrigation. The second source of increased productivity is illustrated by the range in yields which is unlocked by irrigation from non-irrigation factors such as high yielding varieties, fertilization, and other improved practices. The range in yields inside irrigated crops is much larger in column two than for rainfed crops in column 1. The third source of productivity increase is in the cropping pattern allowed by irrigation. It will be noted that the most productive crops are not even possible without irrigation. Irrigation makes it possible to grow more productive crops.

Table 10
Land Productivity Ratios at the Crop Level
(On & Off Farm Value Product per Hectare Irrigated)

Crop	Rs. 000/Ha. /Crop Cycle Rainfed	Rs. 000/Ha. /Crop Cycle Irrigated	Added 000 Rs./Ha. Irrigated, Adjusted to a 12mo. Cycle
Pulses	0.6-0.9	0.7-2.2	1.5-5.5
Oilseeds	0.5-1.4	0.7-2.7	1.6-6.6
Jowar	0.9-2.2	1.4-3.7	3.3-8.8
Wheat	0.8-2.3	1.8-3.8	4.5-9.2
Rice	0.9-2.2	2.0-4.3	5.1-10.7
Fodder	0.9-1.4	2.2-3.8	5.7-10.0
Cotton	1.6-3.3	3.3-6.5	5.0-9.7
Groundnuts	2.2-4.3	4.8-8.3	7.4-12.3
Spices	2.2-4.6	4.6-7.0	11.6-16.4
Sugarcane		11.0-34.0	7.3-22.5
Onions/Potatoes		8.0-14.0	24.0-42.0
Vegetables		11.5-19.0	34.5-57.0
Fruit		33.0-49.0	33.0-49.0
Grapes & Flowers		62.0-96.0	62.0-96.0

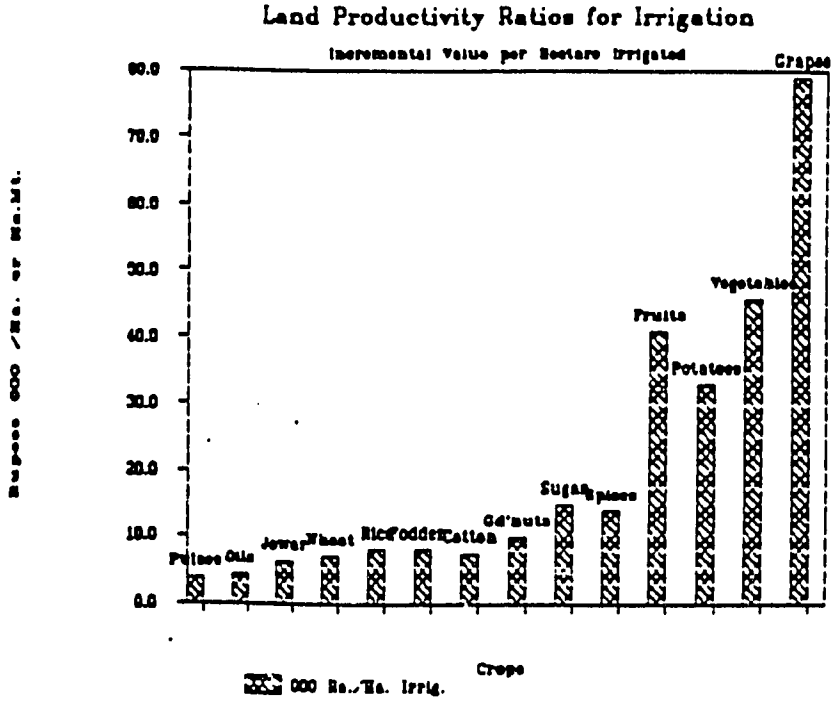
Sources: S. Daines, with the Assistance of J.R. Pawar, *A Statistical Profile of Agriculture, Nutrition and Development Trends in India: A Case Study of Maharashtra State*, SRD Research Group Inc., Logan Utah, 1984, 38 p. at pages 19 & 20.

In Table 10 it is clear that there are two irrigation associated "ladders" or routes to increased productivity and income. The first of these "ladders" is the "yield ladder" which has about five rungs on it of about one thousand rupees each. Climbing the yield ladder involves a farmer in mastering the practices associated with high yielding varieties. The yield ladder is the heart of the so called "green revolution". The other ladder associated with irrigation is a cropping pattern ladder in which a farmer diversifies out of lower value crops into higher value crops. The

"diversification" ladder has about one hundred rungs on it. The absolute magnitudes of these two ladders may be inferred from Figure 12 where the added value of irrigation is shown for each crop on an annually adjusted basis.

The alternative yield and diversification ladders correspond visually to a farmer climbing from the base line to the top of the crop columns in the left half of Figure 12 (yield ladders), or of stepping from the top of one column to the top of another from the left part of the graph to the right of the graph (diversification ladders).

Figure 12



5. Water Productivity Ratios by Crop

Table 11 presents crop productivity per hectare-meter of irrigation water as contrasted to land as in Table 10. The estimates are based on climatic conditions in Ahmednagar district of the state of Maharashtra which is taken to be roughly representative of the arid Deccan plain areas.[71] The individual crop coefficients were obtained from FAO sources.[72] Since climates vary widely in the Deccan Plain, these computations are most useful for comparisons between crops rather than absolute levels of water productivity. Table 2 was calculated in a computer model which also contains data for many other Deccan Plain locations. When climatic data for other locations is used there are no important shifts in the relative position of crops, and few important shifts in the absolute magnitudes of water productivity. One reason for this is that while a smaller quantum of water is required in wetter areas which tends to increase the apparent productivity of a smaller volume of irrigation water, this increase is compensated for by the higher rainfed productivities which must be subtracted to arrive at net incremental benefit. Because of these partially compensating tendencies, the use of the ratios contained in the Table may be less limited than otherwise.

With the single important exception of sugarcane, the relative positions and relative magnitudes of differences between crops is the same for water productivity as it was in Table 1 for land productivity. This indicates that, with the exception of sugarcane, the criteria for allocation of scarce land and scarce water would not vary much depending on which is the scarcest.

a. The Water "Stress Sensitivity" Ladder.

Table 12 (with the exception of sugarcane) presents a new kind of productivity ladder, which Wade has correctly sensed is characterized by the relative water stress sensitivity of various crops. He states:

> "Without water, a switch from stress-resistant but low-income crops to stress-sensitive but high-income crops is simply not possible."[73]

Those crops which can be grown without irrigation are in the "stress-resistant" category and roughly include all of the crops in the first section of table 2. There are two exceptions to this categorization. First, and most important, is sugarcane

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71/ The basic agroclimatic data for potential evapotranspiration in millimeters (ETo) and mean monthly precipitation were obtained from G. Hargraves, et al, *Water Requirements and the Water Balance for India*, Utah State University, Logan Utah, 1984, 88 p. at page 50. The methodology used in compiling these water balance tables may be found in G. Hargraves, et al, *A Crop Water Evaluation Manual for India*, Utah State University, Logan Utah, (Unpublished) 1983, 131 p. plus maps.

72/ The crop coefficient (kc) was obtained from J. Doorenbos & W. Pruitt, *Guidelines for Predicting Crop Water Requirements*, Food and Agriculture Organization, Rome, 1975, 179 p. at page 60.

73/ Robert Wade, "Performance of Irrigation Projects", *Economic and Political Weekly*, New Delhi, January 17, 1976.

which shows both a low return to water and yet is stress-sensitive. The other exception is spice crops which show a high return to water but are also stress resistant.

Table 12
Total Productivity per Hectare-Meter of Irrigation Water
(Rs. 000/Ha.Mt.)

Crop	Value Product per Ha.Mt. Irrigation Water/Crop Cycle	Incremental Value (Irrig.- Rainfed) per Ha. Mt. Irrig. per 12 mo. period.
	(Rs.000/Ha.Mt.)	(Rs.000/Ha.Mt.)
Fodder Crops	1.8-3.1	4.5-8.0
Sugarcane	7.8-24.2	5.2-15.9
Oilseeds	1.7-6.5	4.7-18.2
Pulses	2.5-7.6	6.9-21.9
Cotton	4.6-9.0	7.6-14.7
Rice	2.9-6.3	7.8-16.5
Jowar	2.9-7.8	8.1-21.1
Wheat	5.2-11.1	14.8-30.0
Groundnuts	11.8-20.4	21.4-36.0
Fruits (Bananas, Citrus etc)	32.0-47.5	32.0-47.5
Spices	16.3-24.9	46.8-70.0
Onions & Potatoes	19.7-34.4	59.0-103.0
Grapes & Flowers	116.6-180.6	116.6-180.6
Vegetables	40.9-67.5	122.6-208.0

Sources: See footnotes 8, 9 & 10.

Setting aside sugarcane and spices, the balance of the stress-resistant crops are also low-income crops, as Wade suggests. The higher income crops are also stress-sensitive. The incremental returns from adding one Ha.Mt. of irrigation water to the stress-resistant crops is between Rs. 5,000-36,000. One Ha.Mt. of water allocated to the stress-sensitive crops returns Rs. 32,000-208,000. The magnitude of the economic pressure pulling farmers to make what Wade calls the "switch" from stress-resistant to stress-sensitive crops may be seen in Table 4. As a group, the stress-sensitive crops (without sugarcane) return almost ten times as much to water as do the stress-resistant crops. The fact that the returns to land follow essentially the same pattern reinforces this economic pressure.

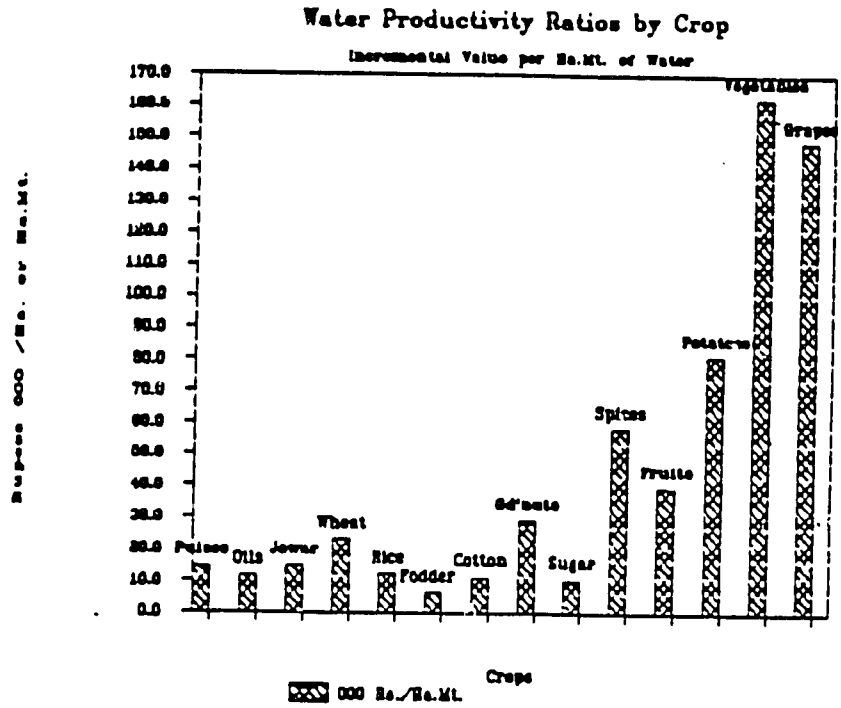
b. The Sugarcane Case

Sugarcane is a unique crop in that it has high land productivity but low water productivity. It is the most important exception to a general pattern of consistency between land and water productivity. The indictment of "thirsty" sugarcane by the Dandekar Commission[74] as a wastage of Maharashtra's scarce water seems to be generally supported by the data in this study.

c. Wheat and Groundnut Cases

Wheat and groundnuts have the highest returns to water of the stress-resistant group of crops and bear a closer examination. At the upper yield levels these two crops bridge the gap between the two groups. In the Deccan plain less than 10% of all foodgrains were irrigated in 1981, but well over 20% of wheat was irrigated. It would appear that farmers, pulled in part by the high water return of wheat are preferentially allocating this scarce resource to wheat among foodgrains. The recent surge in cultivation of summer groundnuts in Maharashtra may be partially explained by the high water return of this crop.

Figure 13



74/ In 1983 an irrigation commission led by Dandekar released its findings to the Government of Maharashtra. The report was not circulated to the public at large, and I have yet to obtain and review a copy. It is widely known, however, that one of the main conclusions of the commission report is that sugarcane is a poor use of Maharashtra's scarce water. Sugarcane is characterized as a "thirsty" crop which diverts scarce water from nutritionally important foodgrains.

Annex A
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