Irrigation and Income-Poverty Alleviation: A Comparative Analysis of Irrigation Systems in Developing Asia

Intizar Hussain and Deeptha Wijerathna

International Water Management Institute (IWMI)

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Summary

This study forms part of the ADB-funded multi-country project on 'Pro-poor intervention strategies in irrigated agriculture in Asia' implemented by the International Water Management Institute (IWMI) in collaboration with national partners in six Asian countries: Bangladesh, China, India, Indonesia, Pakistan and Vietnam. These are among the top few countries where substantial investments have been made in the development of large- and medium-scale canal irrigation systems, where irrigated agriculture provides livelihoods to hundreds of millions of rural people. These countries together account for over 51 percent of global net irrigated area and over 73 percent of net irrigated area in Asia, with most of this area located in China, India and Pakistan.

The study addresses some of the key questions in relation to irrigation and rural poverty: Does irrigation reduce poverty? What is the magnitude of the poverty problem and what are the key determinants of poverty in irrigation systems? Do inequities in land and water distribution and their differential access have impacts on poverty in irrigation systems? Are there any spatial patterns in poverty in irrigation systems? What are the system-level characteristics that help improve performance and enhance antipoverty impacts of irrigation? In addition to synthesizing the review of past work on irrigation-poverty linkages, the study assesses poverty performance of irrigation systems, quantifies key causes and determinants of poverty, and identifies conditions for greater antipoverty impacts of irrigation. Comparative assessments and analyses of poverty are undertaken in 26 selected large- and medium-scale canal irrigation systems. Analysis is based on primary household-level data collected for the 2001-2002 agricultural year from selected irrigation systems, and adjoining rain-fed areas. The selected systems vary in terms of size, water supplies and distribution, infrastructural condition, irrigation management, cropping patterns, crop productivity, level of crop diversification and size of landholdings.

The study findings suggest that irrigation has strong linkages with poverty. Irrigation impacts on poverty alleviation both directly and indirectly. Direct impacts are realized through land augmentation impacts of irrigation resulting in improved productivity, employment, incomes, consumption and other social aspects at micro or household level. Poverty incidence is 20-30 percent less in settings with irrigation compared to those without irrigation. Indirect impacts are realized through expansion in economic activities and welfare of population at wider regional or macro levels. However, antipoverty impacts of irrigation vary across irrigation systems.

The results indicate that in the studied systems in South Asia, average land size is relatively large, distribution of land and water is highly inequitable and overall productivity is lower compared to those in Southeast Asia and China. In the former (South Asian) systems, the average productivity per hectare varies from US$230 to US$637 (with the lowest productivity in Pakistan systems), while in the latter (the systems of Southeast Asia and China), the average productivity level varies from US$665 to US$1444 (with the highest productivity level in China). In general, productivity benefits of irrigation are lower and poverty is higher in those systems where average landholding size per household is relatively large, distribution is inequitable, crop productivity is low and cropping patterns are least diversified. In the studied systems, poverty incidence varies from 6

percent to 77 percent, with poverty much lower in South East Asian and Chinese systems than in South Asian ones. Poverty incidence is the lowest in Chinese systems and the highest in Pakistani systems. Analysis of key determinants of poverty suggest that higher crop productivity, diversified agricultural-dependent nonfarm sources of income, and equity in land distribution are important negative determinants of poverty in irrigation systems.

Further, the study finds that the poverty situation tends to worsen in reaches of the systems where surface-water availability is low, groundwater quality is poor, agricultural productivity is low and opportunities in the nonfarm sector are limited. In general, poverty incidence and severity are higher at tail reaches of the systems, and inter-reach differences in poverty are more pronounced in relatively larger-size systems where inter-reach inequities in canal water distribution and resulting differences in productivity are high, implying that targeted approaches can be adopted to address the poverty problem in irrigation systems. The analysis indicates that if land (and water) distribution is made more equitable (as it is, for example, in China) poverty incidence in the systems could be reduced by over 20 percent. Elasticity of poverty incidence with respect to crop productivity, land distribution, and noncrop farm and nonfarm sources is estimated at -0.31, -0.48 and -0.79, respectively. These values suggest that each US$100 per increase in crop productivity over the present productivity level would reduce poverty by 2 percent.

The results of the study imply that, while irrigation is an important contributor to poverty alleviation, the magnitude of antipoverty impacts of irrigation varies greatly across systems and depends on a range of factors. These include size and distribution of landholdings (equity in land), distribution of available water across farm households and across upstream-downstream locations (equity in water distribution) with proper maintenance of irrigation infrastructure (good infrastructural condition), cultivation/production technology (improved cultivation technology), cropping patterns, and level of crop diversification supported by market infrastructure to facilitate marketing of inputs and outputs. In the studied systems, where all these conditions prevailed, access to irrigation has strong direct antipoverty impacts. The antipoverty impact of irrigation decreases as one or more of these conditions do not hold. In short, investments in irrigation sectors may not reduce poverty directly in any significant way unless accompanied by other complementary interventions. Overall, the findings of the study imply that improving performance of irrigation systems by improving land and water productivity of crops, diversifying cropping patterns, improving infrastructure and water distribution across locations would help reduce poverty in presently low-productivity-high-poverty parts of the systems.

Acknowledgements

This report is part of the output of the ADB-financed research project on "Pro-poor intervention strategies in irrigated agriculture in Asia." The project is being implemented by the International Water Management Institute (IWMI) in collaboration with key national partners in six countries: Bangladesh, China, India, Indonesia, Pakistan and Vietnam. Analyses and assessments in this report are based on primary data collected by the country-study teams, and on estimates presented in the draft final country reports prepared by the country teams in collaboration with IWMI. Cooperation and dedication of the country-study teams for the successful implementation of the project are highly appreciated. Special thanks are due to Dr. Q.K. Ahmed and Mr. K. Raman (BUP-Bangladesh), Drs. Jikun Huang and Jinxia Wang (CCAP-China), Drs. Chris Scott and S.K. Sivamohan (IWMI-India); Drs. Sigit Arif and Muhammad Maksum (CRRD-UGM, Indonesia); Drs. Waqar Jehangir and Muhammad Ashfaq (IWMI-Pakistan); and Drs. Eric Biltonen and Doan Doan Tuan (CIWSR, Vietnam). Thanks are also due to other study-team members in each country. Financial support from the ADB for this project is gratefully acknowledged. Valuable comments and suggestions during the early phase of the project from the ADB, particularly from Messrs. Wouter Lincklean Arriens, Kenichi Yokoyama and Toru Shibuchi are highly appreciated. Finally, thanks are due to our Director General, Professor Frank Rijsberman; Director, Finance and Administration, Mr. Gerard O'Donoghue; Director, Asia, Dr. Sarath Abewardena, and Theme Leader for the WRIP theme, Dr. Madar Samad for their continuous support and encouragement for this project.

Introduction

With the advent of the Green Revolution in the mid-1960s, irrigated agriculture in Asia experienced significant expansion. Irrigation has been regarded as a powerful factor in increasing crop productivity, enhancing food security, expanding opportunities for higher and more stable incomes and employment and for increasing prospects for multiple cropping and crop diversification. Massive investments have been made in the development of irrigation infrastructure in Asia, with irrigated areas expanding from 90.17 million hectares (M ha) in 1961 to 190.39 M ha in 2001. As a result, there have been dramatic increases in aggregate agricultural production. For example, cereal production in developing Asia increased from 309 million tons in 1961 to 962 million tons in 2001. The expanded production has greatly improved incomes and welfare of producers, and benefited the overall population by providing more food at reduced prices.

However, despite these achievements, there remain vast areas in established irrigation systems where productivity and incomes of farmers remain low and highly variable (Hussain et al. 2001). This is attributed to a number of factors including poor performance of irrigation systems, which causes low, inequitable and unreliable water supplies, and physical, sociocultural and economic constraints. It is widely acknowledged that actual irrigated areas in many irrigation systems are much smaller than planned. Large areas within the irrigation systems suffer from severe water shortages, resulting in productivity levels much lower than the achievable potential. Molden et al. (1998), comparing performance of a number of irrigation systems, report that gross value of production per unit of cropland varies from as low as US$384 (Chistian, Pakistan) to as high as US$2615 (Mexico) for systems using surface water and groundwater. Also, studies indicate significant intra-system variations in productivity (see Hussain et al. 2003). Low productivity areas are characterized by lower incomes and higher poverty.

Importantly, past agricultural policies in Asia, driven by notions of food self-sufficiency, were largely focused on aggregate food production. Investments in irrigation were often determined on economic indicators, such as benefit-cost ratio and internal rate of return. Poverty concerns were rarely considered in such investment decisions, and investments in irrigation were not necessarily targeted to the poor areas. There is evidence to suggest that strategies exclusively focused on growth do not necessarily reduce poverty, unless they are accompanied by deliberate measures that ensure a good degree of equity in access to, and control over, resources. In projects lacking a specific poverty focus, benefits to the poor have often been insufficient to significantly improve their living standards. This is particularly so in South Asian countries, specifically Pakistan and India, where there is relatively greater inequity in distribution of resources. In these countries, the efforts by the governments and other agencies to address poverty reduction, especially in low productivity areas, have been limited and largely ineffective not only due to lack of effective policies and actions but also due to lack of knowledge on the magnitude of the poverty problem, its causes and interventions that can reduce poverty more effectively.

Past irrigation-related research has largely been focused on general agricultural productivity increases and improvement of irrigation system performance through technical and physical interventions. Not only does poverty performance, particularly of medium- and large-scale canal irrigation systems, remain largely unknown, but little scientific knowledge exists on key determinants of poverty and interventions to enhance antipoverty impacts of irrigation. This study aims to contribute to filling this gap. Since many developing countries in the Asian regions are initiating major policy reforms to improve the management of their water resources in the face of increasing water scarcity and ever-increasing demand for food, the findings of this study are expected to provide timely input into the reform initiatives.

This study focuses on some of the fundamental questions in relation to irrigation poverty linkages: irrigation is generally perceived to play an important role in improving productivity and aggregate food production; Does it also reduce poverty? What is the magnitude of the poverty problem? What are the key determinants of poverty in irrigation systems? Do inequities in land and water distribution and their differential access have impacts on poverty in irrigation systems? Are there any spatial patterns in poverty in irrigation systems? What are the system-level characteristics that help improve performance and enhance antipoverty impacts of irrigation?. Answers to these basic questions would provide an important input for the management of irrigations systems that focus on the poor. This paper builds on our recent paper on irrigation and poverty (Hussain and Hanjra 2003) by providing empirical evidence and systematic quantitative analysis of the key issues related to irrigation and poverty. Further, it expands the scope of work offered in the earlier paper with recent data from 26 irrigation systems in six countries, through rigorous micro-econometric analysis of impacts of irrigation on income-poverty.

Objective

The objective of this study is to assess poverty performance of irrigation systems, quantify key causes and determinants of poverty and identify conditions for enhanced antipoverty impacts of irrigation through a comparative analysis of selected large- and medium-scale canal irrigation systems in the abovementioned six Asian countries. This study is unique in three respects: a) it offers a comparative analysis of why poverty is very high in some irrigation systems and low in others, b) it identifies generic conditions for realizing greater antipoverty impacts of irrigation, and c) it is based on primary data collected from a fairly large sample of households across 26 medium- and large-scale irrigation systems.

The rest of the paper is structured as follows. The next section highlights some of the key linkages between irrigation and poverty and presents a brief review of the recent empirical evidence on antipoverty impacts of irrigation. Section 3 describes our study settings and characteristics of the irrigation systems selected for comparative analysis. Section 4 elaborates data and methods, including sampling procedures and measurement of poverty. Section 5 briefly compares land, water and productivity across systems. Section 6 presents a comparative assessment of poverty, including an analysis of aggregate and disaggregated poverty determinant functions and the last section summarizes the key findings and major conclusions drawn from the study.

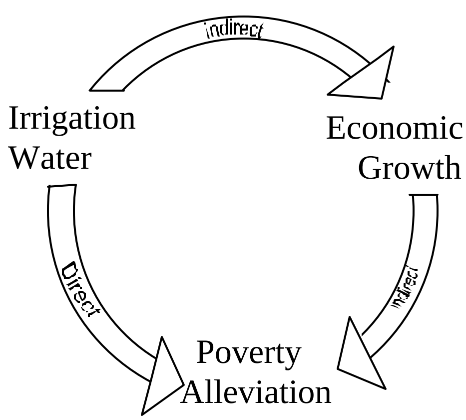
Irrigation-Poverty Alleviation Nexus

Over the past three decades, an enormous amount of research work has been carried out to understand the poverty problem in developing countries. One of the key lessons from this work is that poverty is complex and multidimensional and is the result of myriad interactions between resources, technologies, institutions, strategies and actions, and that there is no single solution to this problem. The multidimensional character of poverty has been reflected in a wide array of papers, poverty reduction strategies and policies (UNDP 1997; ADB 1999; DFID 1999; World Bank 2000; Narayan et al. 2000a,b; DMFA 2001; OECD-DAC 2001; IFAD 2001; Narayan and Petesch 2002). It is now acknowledged that poverty is caused by lack of access to resources, opportunities, information, technologies and socioeconomic and demographic factors, and that it is also deep-rooted in other important factors, such as global-level policies and actions, national-level historical factors and government policies, institutions and actions at various levels, and community-level power structures and informal institutions.

In relation to the water and poverty nexus, it should be mentioned at the outset that water is only one of the several complex variables in the poverty equation, but it plays a disproportionately powerful role in influencing poverty, whether it is in the drinking-water-supply sector, the production sector or environment sector and whether it relates to quantity or quality dimension of water. There are two sides to the water-poverty nexus: water can help alleviate poverty, but if ill-managed or abused it can also create poverty. Our focus here is on the positive side of how access to water can help alleviate poverty in the irrigation sector, which remains the largest user of water in developing countries.

As an important production resource in irrigated agriculture, irrigation water contributes to agricultural development and overall economic growth. Benefits of irrigation are realized through improvements in agricultural productivity and overall production, employment and wages, incomes, consumption, food security and other social impacts. These benefits tend to be interrelated and to reinforce the impacts of each other. With these benefits, irrigation water is linked to poverty alleviation both directly and indirectly (figure 1). Direct impacts are realized through improved welfare of water users or agricultural producers having access to land, water and other production inputs—household or micro pathway of the irrigation-poverty alleviation link. Indirect impacts are realized through expansion of economic activities in both agricultural and agricultural-dependent nonagriculture sectors through backward and forward linkages, resulting in improved economic growth, which contributes to poverty alleviation—community or meso pathway and national or macro pathway of the water and poverty alleviation link.

Figure 1. Irrigation-poverty-alleviation linkage.



There is a plethora of literature on growth-promoting and poverty-reducing impacts of irrigation. No attempt is made here to review all the available literature. Hussain and Hanjra (2003) provide a very detailed review of recent studies on the subject. The review includes an empirical evidence based on comparisons of poverty with and without irrigation, and econometric evidence on the nature, direction and magnitude of impacts of irrigation on poverty alleviation. The review covers assessments made at micro, meso and macro levels.

The extensive review of past work on the subject suggests that there are strong linkages between irrigation, growth and poverty alleviation. The empirical evidence from the studies implies that irrigation has a strong land-augmenting impact, with cropping intensity and overall crop productivity much higher in irrigated settings than in rain-fed settings. In most situations, the value of crop production under irrigated settings is almost double that under rain-fed settings. This simply means that one hectare of land with irrigation produces a yield almost equivalent to that from two hectares of land with no irrigation. Providing adequate irrigation to a poor small farmer with one hectare of land would enable him to harvest as if s(he) has two hectares of land with no irrigation. Similarly, comparisons of labor employment per hectare and wages indicate that these are much higher in irrigated than in nonirrigated settings. Quantitative evidence shows that household income and consumption are much higher in irrigated settings than in rain-fed settings, and a 50 percent point gap is not uncommon (see Agrawal and Rai 2002, Gomti basin in the Gangetic plains, UP, India; Estudillo et al. 2001, Philippines; Fan et al. 1999, India; Huang et al. 2002, China; Hussain et al. 2002, 55 villages in Sri Lanka; IPC 1998, All India (before-after focus); IRRI 2002, Comilla (irrigated) vs. Rajshahi (rain-fed) districts, Bangladesh; Jatileksono and Otsuka 1993, Indonesia; Parthasarthy 1996, India; Rahman 1999, Bangladesh; Samarasinghe and Samarasinghe 1984, Thalpotha area in the dry zone, Sri Lanka; and Thapa et al. 1992, villages in Nepal Terai; Shand 1987, Kemubu project, Malaysia).

Almost all reviewed studies using econometric techniques show that irrigation is a positive determinant of incomes and expenditures and a negative determinant of poverty. The probability of households with access to irrigation water being poor is significantly less than those without access to water. The abovementioned studies provide evidence on this finding.[1]

Studies comparing with and without irrigation settings show that poverty is much higher in settings without irrigation. For example, evidence from recent studies show that poverty incidence varies from 16 percent to 58 percent in irrigated settings and 23 percent to 77 percent in adjoining rain-fed settings (see table 1 for study sources). In most settings, poverty incidence is 20-30 percent higher in rain-fed settings than in irrigated settings (table 1). The studies using a dynamic concept of poverty such as those by Hussain et al. (2002) also show that incidence of chronic poverty is significantly lower in irrigated than in rain-fed settings. The empirical evidence presented so far indicates that irrigation has significant impacts on poverty. However, as will be shown in the next sections, antipoverty impacts of irrigation vary across systems and depend on a number of factors.

[1] For more details also see Balisacan 1992, 1993, The Philippines; Binswanger et al. 1993, India; Datt and Ravallion 1996, 1997, 1998), India; dela Cruz-Dona 2000, 73 out of 75 provinces in the Philippines; Faki et al. 1995, Irrigated schemes, Sudan; Fan et al. 1999, India; Fan et al. 2000, India; Fan et al. 2002, China; Hanrahan and McDowell 1997, Bolivia; Hassan et al. 2000, Gezira irrigation scheme, Sudan; Hassan et al. 1989, Rahad irrigation scheme, Sudan; Hossain et al. 2000, Philippines; Hossain et al. 2000, Bangladesh; Jagaich 2000, Punjab, India; Joshi et al. 1981, East and West Uttar Pradesh, India; Karunakaran and Palanisami 1998, Tamil Nadu, India; Kurosaki 2003, West Punjab, Pakistan, 1903-1992; Looney 1994, the Indus basin, Pakistan; Mann 1989, India; Minot 2000, Vietnam; Nagarajan 1999, Erode district, Tamil Nadu, India; Narayanamoorthy 2001, Indian states; Narayanamoorthy and Deshpande 2002, Indian states; Orr 2000, Malawi; Shah and Singh 2002, Gujrat, India; Singh and Binswanger 1992, Three villages in semiarid tropics, India; Srivastava 1998, Assam, India; Thiruvengadachari and Sakthivadivel 1996, Bhadra Project, Karnataka, India; Ut et al. 2000, Vietnam; van de Walle 2000, Vietnam; and van de Walle and Gunewardena 2001, Vietnam.

Table 1. Estimates of poverty in irrigated and unirrigated settings in selected countries.

Country	Year	Poverty headcount (%)		
		Irrigated	Unirrigated	% Difference
Vietnam	1996	17.9	60.6	42.7
Philippines	1997	30.0	39.0	9.0
Thailand	1998	20.8	55.8	35.0
India-Bihar	1996	34.3	65.7	31.4
India-Chattisgarh	1996	38.0	55.0	17.0
Bangladesh-G-K	2002	35.0	55.0	20.0
Bangladesh-Pabna	2002	58.0	77.0	19.0
India-AP-NSLC	2002	33.0	63.0	30.0
India-AP-KDS	2002	16.0	23.0	7.0
Pakistan	2001	45.0	47.0	2.0
Sri Lanka	2001	34.0	49.0	15.0
Indonesia-Yogyakarta	2002	37.0	59.0	22.0

Sources:

Vietnam 1996: Ut et al. 2000; Philippines 1997: Hossain et al. 2000; Thailand 1998: Isvilanonda et al. 2000; India-Bihar 1996: Thakur et al. 2000; India-Chattisgarh 1996: Janaiah et al. 2000; Bangladesh-G.K (Ganges Kobadak) 2002: Ahmad et al. 2003; Bangladesh-Pabna 2002: Ahmad et al. 2003; India-AP (Nagar Juna Sagar, Andhra Pradesh) 2002: Sivamohan et al. 2003; India-AP (Krishnia Delta System, Andhra Pradesh) 2002: Sivamohan et al. 2003; Pakistan (Upper Indus Basin) 2001: Hussain et al. 2002a; Sri Lanka (Udawalawe Left Bank system) 2001: Hussain et al. 2002b; Indonesia-Yogyakarta 2002: Arif et al. 2003.

The Settings

This study forms part of the ADB-funded multi-country project on 'Pro-poor intervention strategies in irrigated agriculture in Asia' implemented by IWMI in collaboration with national partners in the abovementioned six Asian countries. These are among the top few countries where substantial investments have been made in the development of large- and medium-scale canal irrigation systems, where irrigated agriculture provides livelihoods to hundreds of millions of rural people. According to recent FAO statistics, these countries together account for over 51 percent of global net irrigated area and over 73 percent of net irrigated areas in Asia, with most of this area located in China, India and Pakistan (table 2).

Table 2. Net irrigated areas, 2001.

	Net irrigated area (000 ha)	% of world net irrigated area	% of all Asia net irrigated area
World	273,052		
All Asia	190,385	69.7	
- Bangladesh	4,421	1.6	2.3
- India	54,800	20.1	28.8
- Pakistan	17,820	6.5	9.4
- China	54,831	20.1	28.8
- Indonesia	4,815	1.8	2.5
- Viet Nam	3,000	1.1	1.6
Total	139,687	51.2	73.4

Notes: Net irrigated area (defined by the FAO as area developed using appropriate methods to irrigate crop fields. It includes areas with partial control irrigation, spate irrigation areas, and equipped wetland or inland valley bottoms).

Source: Based on the data set from FAO 2001.

In this project, 26 medium- and large-scale irrigation systems, and their peripheral rain-fed areas were selected from the six countries. The selected irrigation systems vary in terms of size, canal water supplies, groundwater use, condition of irrigation infrastructure, irrigation-management patterns, crop productivity, level of crop diversification, land quality and size of landholdings. Table 3 provides details on key characteristics of the selected systems.

Table 3. Salient features of the selected irrigation systems.

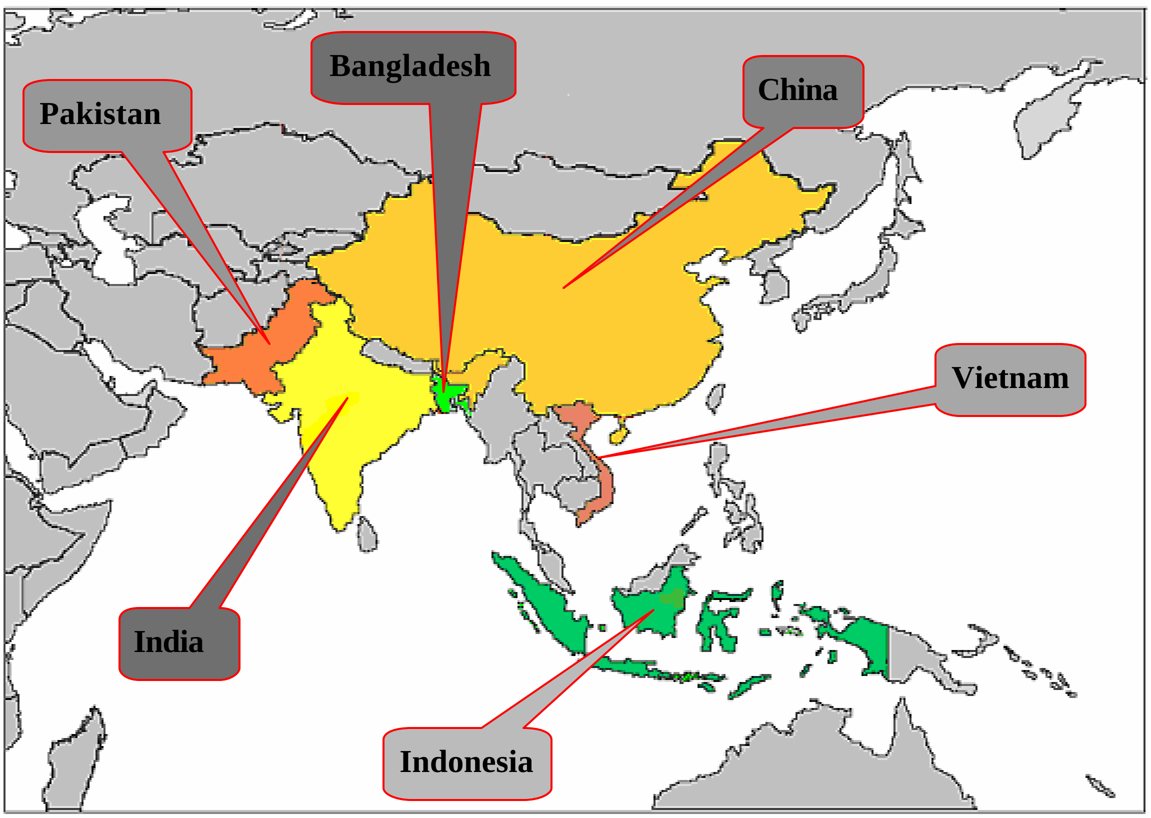
Country	System name	Location	Date of construction	Management	Size (ha)	Annual rainfall (mm)	Major crops	Source of water	Water availability	Sample size
Bangladesh	G-K	South-western Bangladesh	1969	Agency-managed	142,000	1,500	Rice, pulses, oilseeds, tobacco	Both SW and GW	Water-short	400
	Pabna	West-central Bangladesh	1992	Agency-managed	145,300	1,900	rice, pulses, vegetables	Both SW and GW	Water-adequate	400
India	NSLC	Andhra Pradesh/Krishnia River- Upstream	1955	Transferred	246,,000	750	Rice-groundnut	Mainly SW	Water-short	300
	KDS	Andhra Pradesh/ Krishnia River-Downstream	1852	Transferred	508,,000	900	Rice, pulses, vegetables	Mainly SW	Water-Adequate	240
	Halali	Madhya Pradesh	1973	Transferred	23,,500	1,050	Wheat, soybean, pulses	SW	Water-short	217
	Harsi	Madhya Pradesh	1925	Transferred	41,,500	850	Wheat, rice, gram	Both SW and GW	Water-short	205
Pakistan	9-R	Upper Jehlum canal	1915	Agency-managed	5,950	644	Rice-wheat	Both SW and GW	Water-short	90
	10-R	Upper Jehlum canal	1915	Agency-managed	4,370	644	Rice-wheat	Both SW and GW	Water-short	90
	13-R	Upper Jehlum canal	1915	Agency-managed	2,870	644	Rice-wheat	Both SW and GW	Water-short	90
	14-R	Upper Jehlum canal	1915	Agency-managed	22,180	644	Rice-wheat	Both SW and GW	Water-short	90
	Kakowal	Upper Jehlum canal	1915	Agency-managed	9,270	644	Mixed-wheat	Both SW and GW	Water--short	90
	Phalia	Upper Jehlum canal	1915	Agency-managed	26,910	644	Mixed-wheat	Both SW and GW	Water--short	90
	Lalian	Lower Jehlum canal	1901	Agency-managed	44,480	413	Mixed-wheat	Both SW and GW	Water-short	171
	Khadir	Lower Jehlum canal	1901	Agency-managed	47,430	413	Mixed-wheat	Both SW and GW	Water-short	171
	Khikhi	Lower Chenab canal	1892	Agency-managed	32,940	372	Mixed-wheat	Both SW and GW	Water-short	171
	Hakra-4	Hakra System	1937	Transferred	17,850	196	Cotton-wheat	Both SW and GW	Water-short	171
										Table Conti.
China	WID-NP	Ningxia Province-Northwestern China (upper YRB)	B.C	Village cooperatives	56,000	200	Wheat-rice-maize-other	SW	Water-short	34
	QID-NP	Ningxia Province-Northwestern China	B.C	Village cooperatives	304,000	195	Wheat-rice-maize-other	SW	Water-short	95

		(upper YRB)								
	PID-HP	Henan Province-Eastern China (Lower YRB)	1952	Village cooperatives	99,000	620	Wheat-rice-maize-other	Both SW and GW	Water-short	66
	LID-HP	Henan Province-Eastern China (Lower YRB)	1967	Village cooperatives	31,000	639	Wheat-rice-maize-other	Both SW and GW	Water-short	36
Vietnam	Nam Duang	Red river delta	1962	Village cooperatives, IDMCs	16,775	1,700	Rice and upland crops	Mainly SW	Water-short	480
	Nam Thach Han	North Central Region	1978	Village cooperatives, IDMcs	7,657	2,609	Rice	Mainly SW	Water-adequate	480
Indonesia	Klambu Kiri	Central Java	1987	Agency-managed	21,475	2,092	Rice, mungbean, soybean	SW	Water-short	300
	Glapan	Central Java	1930	Agency-managed	18,284	2,458	Rice, mungbean	Mainly SW	Water-short	250
	Kalibawang	Yogyakarta	1940	Transferred	6,454	2,291	Rice, vegetables	Mainly SW	Water-adequate	250
	Krogowanan	Central Java	1976	Transferred	813	2,065	Rice, soybean, maize, vegetables	SW	Water-abundant	101

Notes:
IDMCs = Irrigation and Drainage Management Companies.
G-K = Ganges Kobadak; NSLC = Nagarjuna Sagar Left Bank canal; KDS = Krishna Delta Systems; WID-NP = Weining Irrigation District in Ningxia Province; QID-NP = Qingtongxia irrigation district in Ningxia Province; PID-HP = People's Victory Irrigation District in Henan Province; LID-HP = Liuyuankou Irrigation District in Henan Province. SW = surface water; GW = groundwater.

As mentioned earlier, the selected systems represent medium- and large-scale canal systems in the selected countries. Locations of the systems are shown in figure 2. The Ganges Kobadak and Pabna systems are located in the southwestern and west-central parts of Bangladesh, along the Ganges and Brahmaputra rivers, respectively. The Nagarjuna Sagar and Krishna delta systems are located in Andhra Pradesh along the upstream and downstream, respectively of the Krishna river. The Halali and Harsi systems are located along the Halali and Parvati rivers in the Vidisha and Gwalior districts, respectively, in Madhya Pradesh. The selected systems in Pakistan are located in the upper Indus basin. In China, the Weining and Qingtongxia systems are located in the northeastern province of Ningxia along the upstream of Yellow river; the People's Victory and Liuyuankou systems are located in the eastern province of Henan along the downstream of the Yellow river. The Nam Duong and Namthach Han systems are located in the Red river delta region and the North Central Coastal region, respectively, of Vietnam. In Indonesia, selected systems are located in the Central Java and Yogyakarta provinces.

Figure 2. Study locations.



The selected systems vary greatly in age, some systems in China and Pakistan being very old (table 3). Also, selected systems vary in size/command area from 813 hectares to 21,475 hectares in Indonesia to 23,500 hectares to 508,000 hectares in India. In general, the selected systems in South Asia are much larger than those in Southeast Asia. The selected systems fall into regions with varying degree of rainfall. Rainfall is the lowest in selected systems in China and Pakistan ranging from 200 to 650 mm, moderate in selected systems in India from 750 to 1,050 mm, and high in selected systems in Bangladesh, Indonesia and Vietnam of over 1,500 mm. Cropping patterns in low and high rainfall areas are dominated by wheat and rice cultivation, respectively. Rice-wheat rotations are commonly practiced in Chinese and Pakistani systems. In other systems, rotations of rice, pulses and other high-value crops are common. The level of crop diversification varies from one system to another and depends on a range of factors such as soil quality, cultivation practices, market infrastructure and, most importantly, on the availability of water from rainfall, surface water and groundwater sources. Out of 26 selected systems, surface water is the only or major source of water supplies for crop production in 11 systems. In other systems, conjunctive use of surface water and groundwater is common (this is especially so in the selected systems in South Asia).

Data and Methods

Sampling

This study is based on primary data collected from the selected irrigation systems and from adjoining rain-fed areas through household-level surveys. Consistent procedures were adopted for developing a sampling framework and for sample selection across selected systems in the six countries. For each irrigation system, samples were drawn using a multistage sampling method.

In the first stage, each selected system was purposively divided into three strata (e.g., head, middle and tail sections). The stratification helped in classifying a system into smaller areas that are homogenous in terms of cropping patterns, access to water and irrigation infrastructure.

In stage two, each stratum was divided into a number of clusters (in irrigated and rain-fed areas, a distributary canal and a village were together defined as a cluster). One to two representative clusters were selected along each of the three reaches at head, middle and tail of a system. Where the main canal was classified as a system, the distributary canal was taken as a cluster as in small and medium systems. However, where the distributary was classified as a system (as in large systems), watercourses along the three reaches were classified as clusters. Stratified-cluster sampling helped in obtaining smaller, but more representative, samples and facilitated implementation of surveys over wider geographical areas.

In stage three, a sample of households was selected from each cluster. At this stage, a complete sampling frame (i.e., list of all households) for each of the selected representative clusters was developed. A systematic random sampling was used to draw sample households from the sample frame. Given the variations in size of the selected systems, some strata and some clusters within a stratum were larger than others. The general rule adopted was that the smaller the variation in parameters of interest across clusters in a stratum, and households in a cluster, the smaller the sample size of selected clusters and households, and vice versa. If there were no significant intra-stratum and intra-cluster variations in the parameters of interest, an equal allocation method was applied, i.e., an equal number of clusters from each stratum and equal numbers of households from each cluster were selected, regardless of the size of a stratum/cluster. Given the differences and complexity of systems across countries, there were some minor variations in procedures adopted according to local conditions, but overall sampling procedures were fairly consistent across systems.

The total survey sample size was 5,408 households in 26 selected systems. The distribution of sample sizes of households across systems and countries are shown in table 3 (last column). For each country, the sample size was as follows: Bangladesh, 900; India, 1,092; Pakistan, 1,224; China, 231 [in addition, a sample size of 1,199 households from six provinces in China (Hebei, Liaoning, Shananxi, Zhejiang, Hubei and Sichuan) was also used in the study]; Vietnam, 960; and Indonesia, 1,001 households. The selected households were interviewed with a pretested, structured questionnaire to gather information on various aspects of household economies including demographics, landholdings and agriculture, irrigation, costs and returns of crop cultivation, household assets, employment and earnings from the nonagriculture sector, credit, total incomes and expenditures of households and other related variables. The survey covered all cropping seasons during the 2001-2002 agricultural year.

Measuring Poverty

There are many different concepts of poverty in various disciplines. In recent years, it has been increasingly realized that poverty is a multidimensional concept, extending from low levels of incomes and expenditures to lack of education and poor health, and includes other social dimensions, such as powerlessness, insecurity, vulnerability, isolation, social exclusion and gender disparities. Similarly, the concepts of livelihoods, basic capabilities and entitlements have broadened the concepts of poverty. While these concepts are very useful in understanding poverty from various dimensions, most empirical work on poverty measurement is based on incomes or consumption expenditures, and poverty is defined as a situation where a household's or a person's income or consumption level falls below some minimum level necessary to meet basic needs. While acknowledging the importance of nonmonetary dimensions of poverty, our focus in this study is on income/expenditure poverty. A poor household is defined as one with income/expenditure less than a specified level to meet basic food and nonfood needs. We employ the most commonly used Foster-Greer-Thorbecke (FGT) class of measures for estimating incidence and depth of poverty across selected systems. These measures are Headcount Index and Poverty Gap Index, estimated as:

$$P_{\alpha} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right)^{\alpha} \qquad \text{.......... (1)}$$

where,

y_i is the income of the individual i or household i, and z is specified poverty line. When parameter $\alpha = 0$, it gives the Headcount Index (HCI). HCI estimates the share or proportion of the population, which is poor or whose income is below the specified poverty line. This is a measure of incidence of poverty. If in a population of size n, there are q number of poor people whose income y is less than the poverty line z, then the Headcount Index is simply $HCI = q/n$. When the value of parameter $\alpha = 1$, the index becomes a measure of poverty gap, defined as the mean distance separating the population from the poverty line.

$$\text{Poverty Gap Index} = \frac{1}{n}\sum_{i=1}^{n}\frac{z - y_i}{z} \qquad \text{.......... (2)}$$

where,

y_i is the income of the individual i or household i, and the sum is taken only of those individuals who are poor (below poverty line). The Poverty Gap Index is a measure of depth of poverty. Those not poor are given a distance of zero.

Measurement of poverty using the above indices involves specification of a) the poverty line and b) the indicator of well-being and standard of living such as income or expenditure. The standard of living varies not only from country to country but across regions/communities within a country. Considering these variations, there is no unique poverty line that can be applied to all systems. The international poverty line of US$1/day has its own limitations, as it often tends to overestimate poverty. A poverty line estimated for a country/region or community should provide a more realistic estimate of poverty. Therefore, in this study we use secondary estimates of poverty lines commonly employed by the national/regional statistical agencies. These national poverty lines are based on per capita incomes or expenditures needed for required food and nonfood basic needs. These are: Bangladesh, Tk 833/capita/month; India, Rs 311/capita/month for Madhya Pradesh and Rs 263/capita/month for Andhra Pradesh; Pakistan, Rs 730/capaita/month; China, yuan 50.1/capita/month; Vietnam, VND 100,000/capita/month; Indonesia, Rp 74007 to 84062/capita/month (for various regions).

There is no consensus on whether household income or expenditure is a better measure to be used in estimating poverty. Each measure has its own limitations. Households usually tend to understate their incomes and overstate their expenditures. However, there are a large number of empirical studies that use either incomes or expenditures. As long as data are reliable and of good quality, and there is consistency in estimation, use of either incomes or expenditures should not be of much concern. In this study, we used household incomes to estimate poverty across systems (except for systems in Pakistan, where data on expenditure were used).

The concept of income used in the study is quite comprehensive. Household total income is defined as the total income received in both cash and kind in a given season/year. Income received in kind is imputed in monetary value using prevailing prices. The total income used is net of all cash expenses but excludes the imputed value of all resources owned by the household (family labor, draft animals, etc.). The total income is disaggregated by its source of origin as follows: a) income from crop production includes incomes from the sale of all crop outputs (including grains, vegetables and fruits), imputed value of all crop outputs retained for household consumption, and imputed value of crop byproducts. The income is calculated net of all cash expenditures on production inputs (seeds, fertilizers, chemicals), hired labor and rental payments for farm machinery; b) income from noncrop agriculture includes incomes from livestock, fisheries and forest products and their byproducts. This includes the imputed value of the produce retained for household consumption; c) income from agricultural wages includes incomes from working in agricultural activities on others' farms; d) incomes from trade, services and other nonagricultural sources includes incomes from shopkeeping, petty trade, business and market intermediation, self-employment, salaried services, earnings from manual labor employed in rural processing and industrial activities, transport operations, housing and road construction and other similar activities.

The total expenditure of a household comprises expenses incurred on items in the following four categories, purchased from the market or the village shopkeeper on a loan basis. The items included in Category I were wheat, flour, rice, pulses, maize flour, potato, vegetables, mutton, beef, chicken, fish, eggs, milk, yogurt, fruit and bread. Category II included items such as tea, soft drinks, squashes, syrups, cooking oil, ghee, sugar, salt, spices, gur, jawar flour and suji. Category III included items such as tobacco for huqqa, cigarettes, soap, shampoo, electricity charges, telephone charges, cow dung, wood, gas, lighting fuel and water charges. Category IV included items such as clothing, shoes, medical care, treatment for sickness, education, recreation, expenses for ceremonial occasions, transportation and communication, remittance to family members or relatives, house rent, loan payment, tax, usher, deposit to banks, charities, funerals, legal disputes, rent for a shop, salary of house servants and other similar expenses.

Land, Water and Crop Productivity in Selected Systems

Average landholding size per household in selected systems varies from 0.25 hectares (Indonesia) to 6.54 hectares (Pakistan). Landholdings are of much smaller size in selected systems in Southeast Asia (SSSEA) than in selected systems in South Asia (SSSA). Across SSSEA,[2] the majority of households own less than 1 hectare, with those in Vietnam owning less than 0.5 hectare. Among SSSA, landholding size is the lowest in Bangladesh (average less than 1 ha) and highest in Pakistan (2.49 to 6.54 ha). While average landholding size is higher in SSSA, its distribution is highly inequitable with the highest inequity in Pakistan followed by Bangladesh. In Pakistan, 75 percent of sample households owned around 40 percent of land, and 25 percent owned 60 percent of land. Average Gini coefficient for land across selected systems in Pakistan varies from 0.31 to 0.56, with an average value of 0.49. In Bangladesh (G-K system), the lower 71 percent of sample households owned 25 percent of land, the middle 27 percent owned 32 percent of land, and upper 2 percent owned 43 percent of total land, indicating significant inequity in land distribution.

Across SSSEA, though average landholding size per household is very small its distribution is fairly equitable (except in some systems in Indonesia). Unlike South Asia, equity in land distribution is a typical characteristic of agricultural economies of China and Vietnam. Our study in China shows that the size of farms in terms of cultivated area is very similar among various income groups and between the poor and the nonpoor. Such an equitable distribution of land, an outcome of equity policies adopted in these countries, has played an important equity increasing and poverty reducing role in rural economies of these countries (see Wang et al. 2003).

In all the systems studied, irrigation water is allocated to farm households based on size of landholdings, that is, land and water rights tend to be coupled. Where land distribution is inequitable, as in SSSA, water distribution when measured in terms of total amount allocated per farm household also becomes inequitable, and vice versa. In China and Vietnam, where land distribution is fairly equitable, water distribution also tends to be equitable or often pro-poor. The study in Chinese systems shows that the poorest farmers, who rely more on farming, have the greatest access to water when measured in terms of per capita or per household use.

Also, head-tail inequities in water distribution are greater in SSSA than those in SSSEA. Inequities are more pronounced in relatively larger size systems, where the tail ends often receive little or no water (see Hussain et al. 2003 for detailed analysis of head-tail inequities in water distribution in India and Pakistan).

In the studied systems, cropping intensity varies from 68 percent to 296 percent. In general, cropping intensity is much lower in SSSA than in SSSEA, and smaller the average landholding size, the greater the intensity of cropping. In Javanese irrigation systems, cultivation of three crops per year (during rainy season, dry season-1 and dry season-II) is not uncommon. Similarly, overall productivity per unit of land varies significantly across systems. In general, productivity level is low in SSSA, where it varies from US$230/ha to US$637/ha, with productivity in India higher than that in Pakistan and Bangladesh. On the other hand, productivity is relatively high in

[2] Geographically China lies in East Asia. In this report, China is included in the South East Asia Region, for the sake of convenience in interpretation.

SSSEA, where average productivity ranges from US$665/ha to US$1444/ha, with productivity in China higher than in Vietnam and Indonesia. As for cropping intensity, productivity levels are higher where average landholding size is smaller. Comparison of productivity levels of individual crops shows that rice productivity varies from as low as 1,348 kg/ha up to 5,416 kg/ha in SSSA (with the lowest productivity level in Pakistan from 1,348 kg/ha to 3,278 kg/ha). In SSSEA, rice productivity varies from 3,365 kg/ha to as high as 7,396 kg/ha (with highest productivity achieved in Chinese systems (6,097 kg/ha to 7,396 kg/ha). Similarly, wheat productivity in selected Chinese systems (4,527 kg/ha to 5,295 kg/ha) is almost double that in most systems in Pakistan (1,822 kg/ha to 3,471 kg/ha). Why is productivity level so low in SSSA? Hussain et al. 2003 undertook a detailed analysis of causes of low productivity in Indian and Pakistani systems. They found inequity in the distribution of canal water, poor quality of groundwater (especially at tail- end areas where the availability of canal water is less), and farm-level practices, such as sowing of older varieties, delay in timing of sowing and application of production inputs, as the key factors influencing productivity levels. A recent study by the Word Bank (2002) in Pakistan indicates that inequity in land distribution is also one of the causes of low agricultural productivity.

As a result of the above factors, net productivity benefit of irrigation (defined as net value of output from irrigated crop production minus net value of output from rain-fed crop production) varies significantly across systems. As shown in table 4, net productivity benefit of irrigation (NPBI) across systems varies from as low as US$23/ha to US$478/ha. NPBI is much higher in SSSEA (US$214/ha to US$478/ha) than in SSSA (US$23/ha to US$ 206/ha). NPBI is higher for irrigation systems where cop productivity is high and cropping patterns are diversified with high-value crops (i.e., the Krogowanan system in Java). In general, NPBI is lower in systems where average land size is relatively large, crop productivity is lower and cropping patterns are least diversified with high-value crops. Overall, in several cases, NPBI is small in South Asia, particularly in Pakistani systems. This is due to overall lower productivity in these systems, caused not only due to significant inequity in land and water distribution, but also due to lack of access to key production inputs other than water (see Hussain et al. 2003).

Table 4. Land, water, productivity and poverty across selected irrigation systems.

Country	Name of system	Family size	Farm size (ha)	Land distribution	Head-tail equity ratio	Crop intensity	Productivity (US$/ha/yr.)	Irrigation benefit (US$/ha)	Noncrop income (%)	Poverty headcount (%)
Bangladesh	G-K	6.00	0.93	Skewed	1.47	212	448	127	73.5	35
	Pabna	6.00	0.92	Skewed	0.63	180	293	151	75.0	58
India	NSLC	4.63	3.03	Moderately skewed	3.0	89	524	145	64.0	33
	KDS	4.19	1.31	Moderately skewed	2.7	127	637	194	63.1	16
	Halali	7.40	2.9	Fairly skewed	Skewed	112	323	35	50.3	73
	Harsi	8.03	2.1	Fairly skewed	Skewed	68	231	37	47.1	62
Pakistan	9-R	6.49	2.83	Moderately skewed		152	230	42	86.1	42
	10-R	6.71	2.49	Moderately skewed	1.8	162	360	87	78.8	40
	13-R	7.06	3.62	Moderately skewed		183	500	206	61.2	42
	14-R	7.52	3.38	Moderately skewed		164	430	127	69.0	51
	Kakowal	4.48	3.44	Moderately skewed	1.23	153	282	46	80.1	43
	Phalia	7.37	4.84	Moderately skewed		170	413	120	61.2	50
	Lalian	7.92	4.96	Moderately skewed	2	138	404	112	53.1	63
	Khadir	7.84	5.66	Highly skewed	2.5	124	276	54	60.1	77
	Khikhi	9.8	5.16	Highly skewed		137	481	89	70.3	69
	Hakra-4	8.28	6.54	Highly skewed	1.09	152	362	23	75.3	71
China	WID-NP	4.22	1.03	Fairly equal		156	1,319		69.6	6
	QID-NP	4.22	0.79	Fairly equal		160	1,141		68.8	7
	PID-HP	4.16	0.45	Fairly equal		194	1,444		63.7	9
	LID-HP	4.16	0.5	Fairly equal		198	1,417		54.1	6
										Table Conti.
Vietnam	Nam Duang	4.8	0.28	Fairly equal	3.1	209	1,250	314	76.0	12

	Nam Thach Han	5.6	0.3	Fairly equal	0.9	186	974	214	71.0	18
Indonesia	Klambu Kiri	4.97	0.77	Skewed	1.07	253	729	357	40.1	43
	Glapan	4.94	0.73	Skewed	3.01	275	665	292	50.7	40
	Kalibawang	4.47	0.25	Fairly equal	1.45	296	749	376	58.8	37
	Krogowanan	4.31	0.35	Fairly equal		264	851	478	62.1	44

Notes:

Head-Tail Equity Ratio: Head-tail equity ratio is defined as the ratio of average delivery performance ratio (DPR), which is the ratio of actual discharge to target discharge) of the upper 25 percent of the systems to the average DPR of the tail 25 percent of the system.

Productivity: is gross value of output per hectare in US dollars.

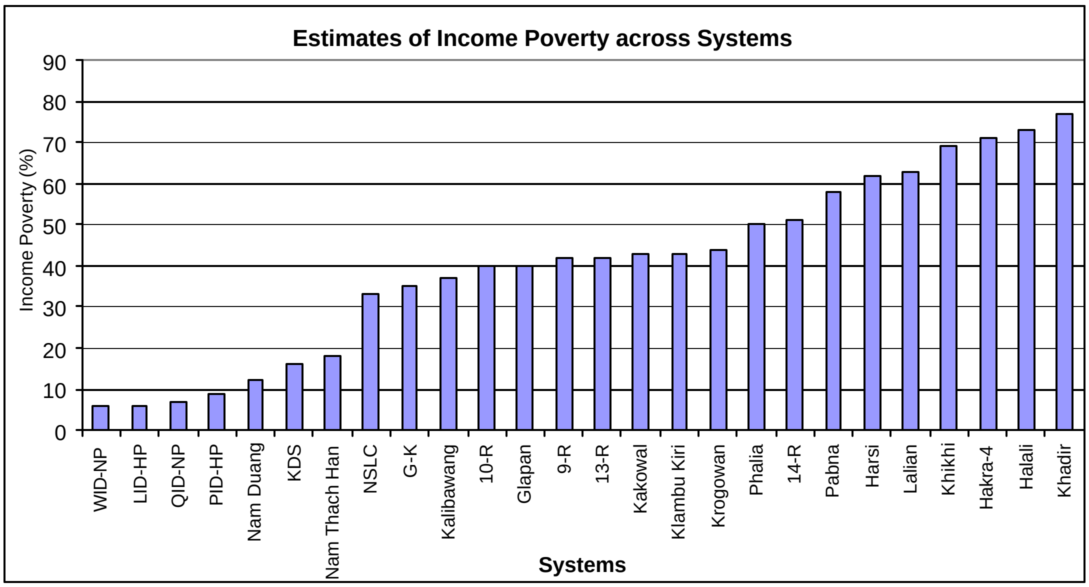
Cropping Intensity: Cropping intensity is defined as the ratio of gross cultivated area in a year to design command area.

Irrigation Benefit: Irrigation benefit per unit area is defined as the net value of farm production per unit area from irrigated settings minus net value of farm production per unit area from adjoining rain-fed settings.

Income-Poverty across Irrigation Systems

The estimates of poverty are reported in table 4 (last column). For all systems studied, around 40 percent of households have incomes below the specified poverty line. However, there are significant variations in poverty across systems. The headcount index shows that the incidence of poverty varies from 6 percent to 77 percent (figure 3). The poverty gap index shows that the depth of poverty varies from 3 percent to 68 percent. As one would expect, poverty is lower in SSSEA than in SSSA, with the lowest poverty in selected systems in China and Vietnam and the highest in the case of Pakistan. In general, poverty is higher in those systems, where land distribution is highly inequitable, productivity is low, and overall benefits of irrigation are low. We test the significance of these and other factors by estimating the poverty-determinant function, as defined below.

Figure 3. Estimates of income-poverty across systems.



Aggregate Level Poverty-Determinant Function

The aggregate level poverty determinant function is specified as follows:

$$HCI \quad = \quad \beta_0 + \beta_1\, PROD + \beta_2\, SNCI + \beta_3\, LDIST + \beta_4\, PFSIZE + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where,

HCI = income-poverty headcount (%)
PROD = average crop productivity per hectare (US$/ha)
SNCI = average share of noncrop income in total income
LDIST = land distribution index (index varies from 1 to 6, with 1 indicating highly skewed distribution, and 6 indicating fairly equitable distribution)
FSIZE = average family size
$?_i$ = coefficients to be estimated

e = error terms

The estimated coefficients indicate the significance of variables in influencing the income-poverty headcount. If the sign of the estimated coefficient for a particular variable is negative and significant, that variable contributes significantly to income-poverty alleviation. The results of estimations are presented in table 5. Coefficients of all the specified variables carry expected signs and are statistically significant. Adjusted R^2 of 0.853 indicates that over 85 percent of variation in the dependent variable is explained by the variables included in the model. A negative and significant coefficient of productivity indicates that the higher the productivity level the lower the incidence of income-poverty in a system. This suggests that the incidence of income-poverty would be lower in those systems where agricultural performance is relatively better. The noncrop income is also a significant negative determinant of poverty, with impacts on poverty even higher than that of crop productivity. It should be noted that rural noncrop income sources such as livestock and livestock products, agricultural labor, renting out of agricultural equipment and similar other services constitute significant part of noncrop income in addition to income from nonfarm sources. Increase in crop productivity reduces poverty directly (as estimated with the PROD variable) and also indirectly by contributing to expansion in noncrop activities (as estimated by the SNCI variable).

Similarly, land distribution has significant influence on income-poverty. The estimated coefficient suggests that greater the equity in land distribution, the lower the incidence of poverty. Each one unit increase in equity index will reduce poverty incidence by over 5 percent. As discussed earlier, inequity in water distribution is associated with inequity in land distribution and, therefore, the coefficient of LDIST captures the influence of (in)equity in both land and water distribution. Coefficients of demographic variables, such as family size, indicate that the larger the family size, the higher the incidence of poverty.

Table 5: Results of Regression Estimations

Variable	Coefficient (b)	t-statistic	Elasticities*
Constant	81.9467	3.5662	-
PROD	-0.0196	-2.2353	-0.313
SNCI	-0.4930	-3.0707	-0.792
LDIST	-5.3601	-1.8396	-0.481
FSIZE	3.7161	2.0268	0.552

Dependent variable = poverty headcount (%)
Number of observations = 26
Adjusted R-Square = 0.853
*Elasticities are calculated at average values of independent variables.

These coefficients indicate the marginal impacts on poverty of the variables included in the model. To transform the estimated marginal impacts to easily interpretable measure, the elasticities of poverty incidence are calculated at average values of the independent variables, reported in the last column of table 5. The estimated elasticities indicate that, on average, a 1 percent increase in productivity level will reduce incidence of poverty by 0.31 percent (at average values of dependent and independent variables). However, the impact will vary across systems depending on the average values for dependent and independent variables. Similarly, a 1 percent increase in equity index for land distribution will reduce poverty by 0.48 percent. These values suggest that more equitable land and water distribution will have significant impact on poverty, which is even greater than the antipoverty impact of increases in productivity. The impact of increased noncrop farm and nonfarm income share has the highest antipoverty impact, as a 1 percent increase in noncrop income share will reduce poverty incidence by 0.79 percent.

In rural agricultural settings, a significant part of noncrop activities depends on cropping activities, indicating that productivity increases will not only reduce poverty directly but also indirectly through expansion in noncrop activities (such as livestock, agro-based industries). Therefore, poverty impact of SNCI should not be interpreted as the impact of only nonfarm services, as a large part of SNCI comes from agriculture-dependent nonagricultural activities. PROD thus captures direct impacts on poverty of productivity increases and SNCI captures both direct and indirect impacts on poverty of incomes from noncrop sources, and indirect impacts on poverty of incomes from crop sources. In the absence of crop-productivity-induced incomes from noncrop sources, the coefficient and elasticity of SNCI would be very small. The combined impact of PROD and SNCI on poverty headcount is 1.1 percent, which indicates that a 1 percent increase in income from crop productivity and associated sources of income would reduce poverty by 1.1 percent. The elasticity estimate here is comparable to the estimate of the elasticity of incidence of poverty to agricultural productivity growth, based on a sample of 40 countries, of about 1 percent (Thirtle et al. 2001). These results also indicate that direct impact on poverty of income from crop productivity is only one-third of total impacts on poverty from agricultural and agricultural-dependent nonagricultural incomes. Overall, the empirical analysis in this section helps us to clearly establish that there is an inverse relationship between agricultural productivity growth and rural poverty; and also that an inverse relationship exists between equity in distribution of land (and associated water) and rural poverty.

Based on the estimates of equation (3), it may be interesting to see how the estimated model performs in terms of predicting the incidence of income-poverty for 26 systems. Actual and predicted values are shown in figure 4. On an overall basis, the specified model predicts income-poverty across systems fairly accurately.

Using equation (3), antipoverty impacts of productivity increases and equity in land distribution are predicted. These are shown in figures 5 and 6. As can be seen, almost 20 percent of income-poverty can be reduced by increasing productivity level from US$200/ha to US$1,000/ha. Equitable distribution of land and water resources would have even greater poverty-reducing impacts. Improving on equity index from 1 (highly inequitable) to 6 (fairly equitable) would reduce income-poverty index from over 50 percent to less than 30 percent. It should be noted that equity in land distribution here means promoting redistribution of land to the extent that land size units remain economically viable and is according to a threshold level of land size that generates livelihoods for households to be able to move out of poverty. Of course, this threshold level would vary across countries and depend on land quality, level of productivity per unit of land and livelihood opportunities in the nonfarm sector. In Pakistani Punjab settings, for example, an average land size of little over 2 hectares per household contributes farm income to total household income such that households are no longer income-poor. In China, such a threshhold level would be much low because of higher productivity per unit of land and relatively more opportunities available in the nonfarm sector.

Figure 4. Actual and predicted level of income-poverty across systems.

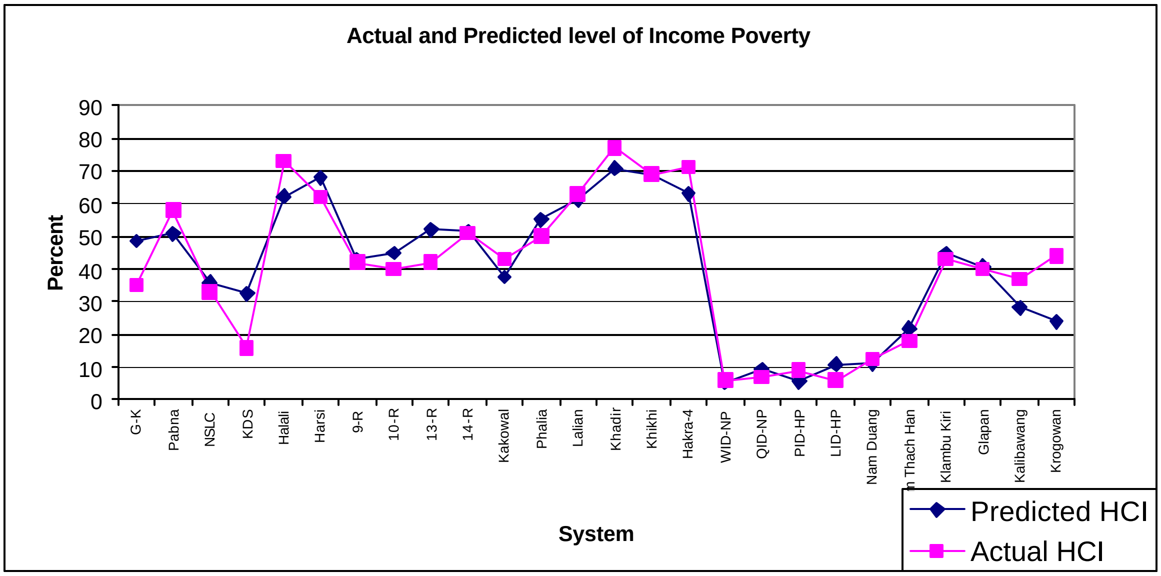


Figure 5. Predicted impact of productivity increases on income-poverty.

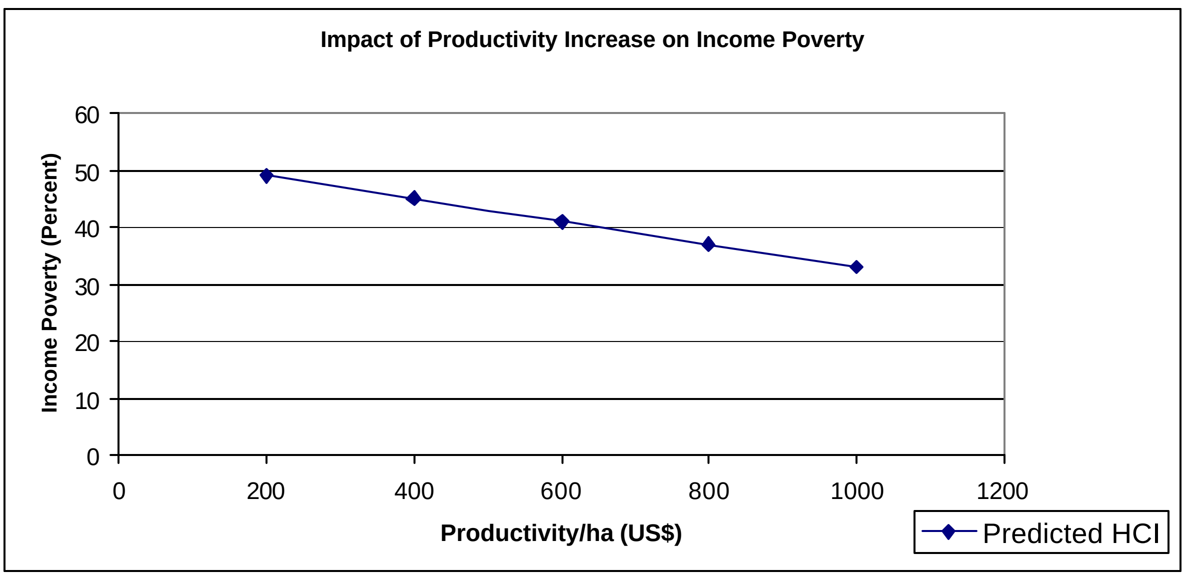
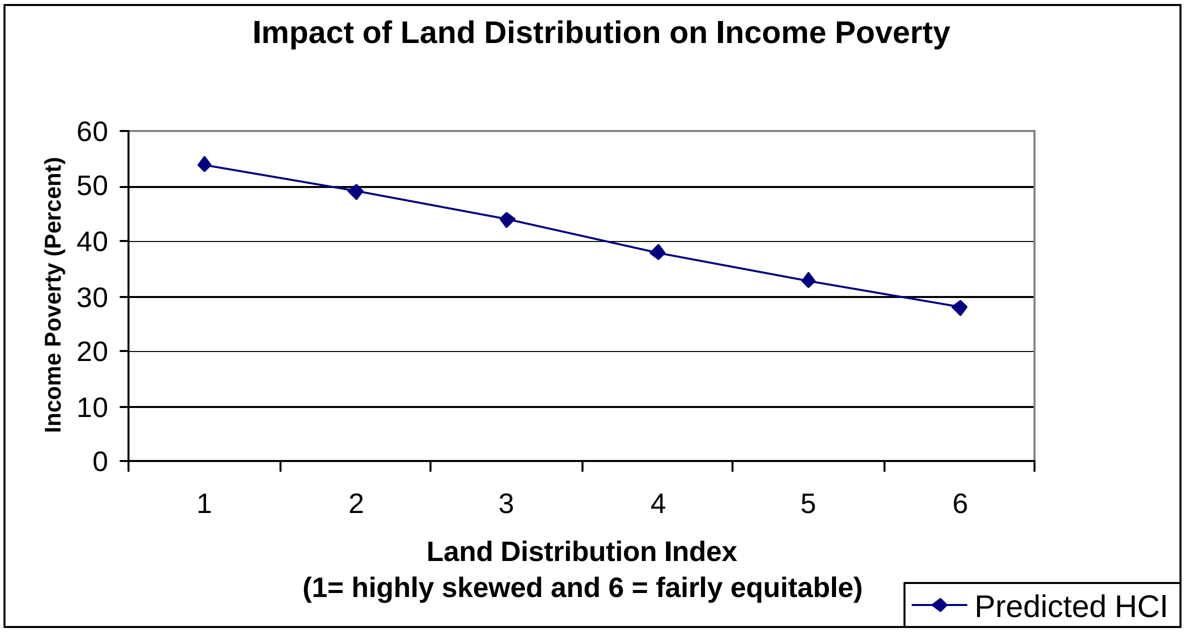


Figure 6. Predicted impact of equity in land distribution on income-poverty.



Disaggregated Poverty Determinant Function

The above analysis uses system-level aggregate data to identify key factors influencing poverty. However, the aggregate-level analysis does not capture the intersystem differences in poverty and its determinants (including locational differences across head, middle and tail reaches of systems) within a country. We now analyze the significance of these and other related determinants of poverty, using disaggregated household-level data. The disaggregated analysis will allow us to explicitly analyze the significance of intersystem and inter-reach differences in poverty and, more importantly, whether irrigation is one of the key determinants of poverty. Without going into a detailed analysis of all systems in the six countries individually (which can be found in individual country reports, available on request), we focus on systems in two countries, Indonesia and Pakistan.

Before analyzing disaggregated the poverty-determinant function, we present disaggregated poverty estimates for individual systems in tables 6 and 7 for Indonesia and Pakistan. For Indonesia, estimates indicate that there are differences in poverty across systems and across head, middle and tail locations within each system. Incidence of poverty is relatively higher at tail reaches of Klambu Kiri and Kalibawang and head reaches of Glapan and Krogowanan. Overall, the incidence of poverty is relatively less at middle reaches of the systems where crop productivity is high.

Table 6. Estimates of poverty across reaches of selected systems, Indonesia.

Poverty criterion	Klambu Kiri			Glapan			Krogowanan			Kalibawang		
	H	M	T	H	M	T	H	M	T	H	M	T
Headcount (HC) (%)	36.7	36.4	56.3	46.4	32.4	35.3	47.1	45.5	29.4	36.5	33.3	40.5
Poverty gap (PG)	0.51	0.68	0.67	0.67	0.68	0.71	0.57	0.55	0.77	0.41	0.51	0.41
Poverty gap sq. (PGS)	0.41	0.75	0.76	0.89	0.70	071	0.39	0.36	0.72	0.25	0.39	0.25

Note: H, M, T denote head, middle and tail, respectively.
Source: Primary data 2002.

Table 7. Estimates of poverty across reaches of irrigation systems, Indus Basin, Pakistan.

	Headcount			Poverty gap			Squared poverty gap		
Distributary	Head	Middle	Tail	Head	Middle	Tail	Head	Middle	Tail
9-R Khoja	0.48	0.38	0.40	0.31	0.27	0.26	0.13	0.09	0.09
10-R Dhup Sari	0.44	0.50	0.27	0.27	0.36	0.26	0.11	0.15	0.09
13-R Saroki	0.40	0.57	0.29	0.26	0.24	0.34	0.11	0.07	0.13
14-R Maggowal	0.60	0.37	0.57	0.21	0.32	0.29	0.10	0.12	0.13
Phalia	0.63	0.46	0.39	0.29	0.26	0.30	0.11	0.11	0.11
Kakowal	0.37	0.59	0.35	0.29	0.29	0.35	0.11	0.12	0.17
Lalian	0.69	0.51	0.69	0.46	0.43	0.48	0.26	0.21	0.27
Khadir	0.77	0.70	0.86	0.51	0.45	0.55	0.29	0.23	0.33
Khikhi	0.81	0.53	0.74	0.45	0.47	0.47	0.24	0.25	0.26
Hakra 4-R	0.68	0.68	0.75	0.51	0.46	0.49	0.29	0.26	0.28
Table total	0.64	0.55	0.59	0.41	0.39	0.44	0.21	0.19	0.24

Source: Primary data 2002.

Similarly, in Pakistan, poverty varies across systems and across reaches within systems. Poverty incidence is relatively low at middle reaches compared to head and tail reaches. The depth and severity of poverty are lower at middle reaches, and higher at tail reaches. Are these differences significant? We test this using a disaggregated poverty determinant function as defined in equations 4 and 5 below.

Disaggregated Poverty-Determinant Function

We model household-level poverty as a function of demographic variables, farm productivity/income, nonfarm income, assets (such as landholdings) and availability/access to irrigation. The specified models are estimated using a Logit regression specification. The Logit specification is a standard econometric specification and is used where the dependent variable is the dichotomous variable of whether a household is poor or nonpoor.

The explanatory variables used are family size, dependency ratio, productivity per hectare, noncrop income and size of landholdings. The impact of difference in availability and access to water on poverty is captured using dummy variables. Similarly, locational differences within irrigation systems are incorporated by locational dummies (using tail areas as the base case). Estimated coefficients indicate the significance of variables affecting the probability of households being poor. If the sign of the estimated coefficient for a particular variable is negative and significant, that variable contributes significantly to poverty alleviation. Estimated Logit regression models are given below:

Indonesia

The models are specified as follows:

$$\log\left(\frac{p(poor)}{p(nonpoor)}\right) = ß_0 + ß_1\,FSIZE + ß_2\,DRATIO + ß_3\,PROD + ß_4\,PEREINC$$
$$+ ß_5\,NCRINC + ß_6\,NLAND + ?_7\,D_G + ?_8\,D_{KB} + ?_9\,D_{KK} + ?_{10}\,D_H +$$
$$?_{11}\,D_M + e \ldots\ldots (4)$$

Pakistan

$$\log ? \frac{p ? poor ?}{p ? nonpoor ?} ? = ?_0 + ?_1\, FSIZE + ?_2\, DRATIO + ?_3\, PROD_{+} + ?_4 NCRIN + ?_5 NLAND + ?_6\, D_{KHO}$$

$$+ ?_7\, D_{DHU} + ?_8\, D_{SAR} + ?_9\, D_{MAG} + ?_{10}\, D_{PHA} + ?_{11}\, D_{KAK} + ?_{12}\, D_{LAL} + ?_{13}\, D_{KHA} + ?_{14}\, D_{KHI} + ?_{15}\, D_H + ?_{16}\, D_M + e \ldots\ldots (5)$$

where,

Poverty	=	Poor = 1, nonpoor = 0: according to national poverty line
P(poor)	=	Probability of being poor
FSIZE	=	Family size
DRATIO	=	Dependency ratio (no. of dependents/no. of independents)
PROD	=	Annual productivity of field crops per hectare ('000 Rs or Rp)
PEREINC	=	Annual household income from perennial crops ('000 Rs or Rp)
NCRINC	=	Annual household noncrop and nonfarm income ('000 Rs or Rp)
NLAND	=	Net landholding of a household
D_{GL}	=	Dummy for Glapan irrigation system (D_{GL} = 1, 0 otherwise)
D_{KB}	=	Dummy for KaliBawang irrigation system (D_{KB} = 1, 0 otherwise)
D_{KK}	=	Dummy for Klambu Kiri irrigation system (D_{KK} = 1, 0 otherwise)
	=	[*Krogowanan irrigation system as the base category = 0*]
D_{KHO}	=	Dummy for 9-R Khoja distributary (D_{KHO} =1, 0 otherwise)
D_{DHU}	=	Dummy for 10-R Dhup Sari distributary (D_{DHU} =1, 0 otherwise)
D_{SAR}	=	Dummy for 13-R Saroki distributary (D_{SAR} =1, 0 otherwise)
D_{MAG}	=	Dummy for 14-R Maggowal distributary (D_{MAG} =1, 0 otherwise)
D_{PHA}	=	Dummy for Phalia distributary (D_{PHA} =1, 0 otherwise)
D_{KAK}	=	Dummy for Kakowal distributary (D_{KAK} =1, 0 otherwise)
D_{LAL}	=	Dummy for Lalian distributary (D_{LAL} =1, 0 otherwise)
D_{KHA}	=	Dummy for Khadir distributary (D_{KHA} =1, 0 otherwise)
D_{KHI}	=	Dummy for Khikhi distributary (D_{KHI} =1, 0 otherwise)
	=	[*Hakra -4-R system is the base category = 0*]
D_H	=	Dummy for head reach of an irrigation system (D_H = 1, 0 otherwise)
D_M	=	Dummy for middle reach of an irrigation system (D_M = 1, 0 otherwise)
	=	Tail reach – the base category = 0
? i	=	Coefficients to be estimated
e	=	Error term

The results of the analysis for Indonesia are presented in table 8. Coefficients of all the specified variables have expected signs and are significant. Coefficients of family size and dependency ratio are positive and significant. This indicates that the greater the number of family members (with larger number of dependents), the higher the marginal effect on the probability of that household to remain poor compared to a household with a smaller number of family members (and lesser number of dependents). The negative and significant coefficients for crop productivity of both perennial and non-perennial crops indicate that improving productivity would contribute to poverty alleviation. Income from noncrop and nonfarm sources is also an important determinant of poverty. A negative marginal effect on the probability of a household being poor is significant for those households deriving a greater income share from noncrop sources. Similarly, the size of landholding has a significant impact on poverty. This implies that a higher land size has a significant negative effect on the probability of a household to be poor. In simpler words, the results imply that poverty would be higher among households with a larger number of dependents. Incidence of poverty would be lower among households with higher levels of crop productivity, having a greater share of noncrop income through household diversification of income sources, and among those with relatively larger-size holdings. Higher crop productivity, diversification of income towards noncrop sources (including livestock rearing) and larger size landholdings are important poverty-reducing variables.

The negative and significant coefficients for system dummies indicate that there are differences in the significance of poverty across systems. The coefficient of middle area dummy is negative and significant, indicating that the negative marginal effect of middle location on the probability of households being poor in the middle section of systems is significant, when compared with those located at tail section. However, the marginal effect on probability for head location, though negative, is not significant, indicating no significant differences in poverty across head and tail reaches. In simple words, these results imply that overall, poverty incidence is lower at middle reaches, where productivity is relatively higher. On the other hand, poverty incidence is higher at tail reaches, where productivity is lower. Contrary to common perceptions, the results suggest that poverty is not necessarily lower in locations in canal systems that are closer to the source of water, that is at the head reaches.

Table 8. Results of estimated regressions, Indonesia.

Variable	Coefficient (b)	Marginal effect on probability of (Y=1)	b/SE
Constant	0.6159	0.06608	1.4750
FSIZE	0.5207	0.05587	6.2160
DRATIO	0.3425	0.03675	2.6990
GVPFIELD	-0.0001	-0.00001	-4.3160
PEREINC	-0.0006	-0.00006	-2.1670
NCRINC	-0.0006	-0.00006	-12.0880
NLAND	-1.2042	-0.12920	-5.6410
D_{GL}	-0.7815	-0.08385	-2.2490
D_{KB}	-0.2058	-0.02208	-0.6240
D_{KK}	-0.6586	-0.07066	-2.0270
D_H	-0.2792	-0.02995	-1.2540
D_M	-0.5847	-0.06274	-2.3380

Dependent variable – poverty (1 = poor, and 0 = nonpoor)
Number of observations = 901; Log likelihood ratio = - 608.6; Base categories – Krogowanan system, and tail reach are dummy variables. The base category allows capturing the additional impact of nonbase categories over the base category. For example, the coefficients of D_H and D_M variables would estimate the additional impact of head and middle locations over the tail location which is a base category. For b/SE, b is the respective estimated coefficient and SE is the standard error, and b/SE indicates the significance of the estimated coefficient.

For Indonesia, we also compared the significance of poverty in irrigated systems with that in the adjoining rain-fed areas. The results (reported in appendix table 1) indicate that negative marginal effect on the probability of a household being poor is significant for those households located in irrigation systems compared to those located in rain-fed areas. These findings suggest that irrigation has a significant impact in reducing poverty, and the impacts vary across systems. In sum, it can be concluded from the above findings that improving crop productivity, access to land and water, and improving opportunities in the nonfarm sector will have significant impacts in reducing poverty.

Estimated results for Pakistan are presented in table 9. The coefficients of the specified variables carry expected signs, and most of them are significant at 95 percent of significance level. As expected, coefficients of family size and dependency ratio are positive and significant indicating that marginal effect on probability of a household with larger family size and with more number of dependents to remain poor is significant when compared to that with smaller number of family members and dependents. Crop productivity is a significant negative determinant of poverty. Similarly, landholding size is also a significant negative determinant of poverty, that is, a larger land size has a negative effect on the probability of a household to be poor. Coefficients of dummies for systems (distributaries) indicate significant differences in income-poverty across systems. In general, the incidence of poverty is significantly lower in systems located in upper and middle sections of the upper Indus basin (except for the Khadir system) when compared with the Hakra system (base case) located at the lower part of the upper Indus basin. These findings suggest that at the basin level, incidence of poverty increases towards downstream areas where access to canal water is less and cropping intensities and crop productivities are lower.

Table 9. Results of estimated regressions, Pakistan.

Variable	Coefficient (b)	Marginal effect on probability of (Y=1)	b/SE
Constant	-0.2654	-0.0620	-0.9080
FSIZE	0.3183	0.0744	11.3660
DRATIO	0.2071	0.0484	2.7050
GVP	-0.0083	-0.0019	-1.8920
NCRIN	-0.0012	-0.0003	-1.2160
NLAND	-0.2108	-0.0493	-9.8890
D_{KHO}	-1.7604	-0.4114	-5.5150
D_{DHU}	-1.8158	-0.4244	-5.7050
D_{SAR}	-1.7249	-0.4032	-5.4920
D_{MAG}	-1.4313	-0.3345	-4.5850
D_{PHA}	-1.5515	-0.3626	-4.7920
D_{KAK}	-1.7946	-0.4195	-5.6320
D_{LAL}	-0.5085	-0.1188	-1.8640
D_{KHA}	0.3952	0.0924	1.3400
D_{KHI}	-0.7201	-0.1683	-2.5640
$D2_{H}$	-0.1367	-0.0320	-0.7910
$D2_{M}$	-0.3516	-0.0822	-2.0640

Dependent variable – poverty (1= poor, and 0= nonpoor); Number of observations = 1,204
Log likelihood ratio = - 621.20; Base categories – 1. Hakra-4-R system, and tail reach.

Further, as for Indonesia, the coefficient of the middle area dummy for Pakistani systems is also negative and significant, indicating that the negative marginal effect on probability of households being poor in the middle sections of the systems is significant when compared to those located at the tail sections. However, the marginal effect on probability for the head location though negative is not significant, indicating no significant differences in poverty across head and tail reaches. These findings suggest that poverty is not necessarily lower in locations within canal systems that are closer to the source of water, that is, head reaches compared to tail reaches. However, further inter-reach analysis indicates that, though poverty incidence may be similar at head and tail reaches, but depth and severity of poverty is higher at tail reaches.

Summing up, the results indicate that, for all systems in both Indonesia and Pakistan, in addition to demographic variables, crop productivity, nonfarm income, landholding size, performance and location of individual systems are significant determinants of poverty. In both cases, probability of households being poor is high in systems where land and water distribution is skewed (that is mostly in larger-size systems), cropping patterns are less-diversified, and performance of systems in terms of overall productivity is low. Overall, poverty is lower at middle reaches (where productivity is relatively higher), and poverty is higher at tail reaches. Contrary to common perceptions, the results for both Indonesian and Pakistani systems suggest that poverty is not necessarily lower in locations within canal systems closer to the source of water (i.e., head reaches).

While in aggregate terms, poverty performance at middle locations is generally better, disaggregated analysis for each system indicates that inter-reach or inter-locational differences in poverty within systems are not significant for all systems. Inter-reach differences in poverty are more pronounced in larger systems, where inter-reach inequities in canal water distribution, and resulting differences in productivity, are high. Also, variations in groundwater quality contribute to such differences. The poverty situation tends to worsen in reaches/locations where surface water availability is low, groundwater quality is poor, agricultural productivity is low and opportunities in nonfarm sector are limited. This situation is quite common in large scale systems in Pakistan.

Summary, Conclusions and Implications

This study assesses poverty performance of irrigation systems, quantifies key causes and determinants of poverty and identifies conditions for enhancing antipoverty impacts of irrigation. Comparative assessments and analyses of poverty were undertaken in 26 selected large and medium-scale canal irrigation systems in the abovementioned six countries. Analysis was based on primary household-level data collected for the 2001-2002 agricultural year in selected irrigation systems, and adjoining rain-fed areas. The selected systems vary in terms of size, water supplies and distribution, infrastructural condition, irrigation-management patterns, cropping patterns, crop productivity, level of crop diversification and size of landholdings. Overall findings and conclusions of the study are summarized as follows:

Irrigation has strong linkages with poverty. Irrigation impacts on poverty alleviation both directly and indirectly. Direct impacts are realized through land augmentation impact of irrigation that translates into improvements in productivity, employment, incomes, consumption and other social aspects at micro or household level. Studies comparing irrigated and nonirrigated settings indicate that poverty is 20-30 percent less in settings with irrigation compared to those without irrigation. Indirect impacts are realized through expansion in economic activities and welfare of population at wider regional or macro levels.

Average landholding size per household is much smaller in the studied systems in Southeast Asia (less than 1 ha) compared to that in the studied systems in South Asia. Land distribution is fairly equitable in the former, and highly inequitable in most systems in the latter, particularly in the systems studied in Pakistan. Given that water distribution is based on landholding size in all systems, water distribution per household is highly inequitable in South Asian systems. Also, head-tail inequities in water distribution are high in South Asian systems, with inequities more pronounced in larger-size systems, than in Southeast Asian systems. Cropping intensity, crop productivity and net productivity benefits of irrigation are much higher in Southeast Asian systems than in South Asian systems. In the former, average gross value of product per hectare varies from US$665 to US$1444 (with the highest productivity being achieved in Chinese systems), while the average productivity level in the latter varies from US$230 to US$637 (with the lowest productivity in Pakistani systems). In general, productivity benefits of irrigation are lower in systems where average landholding size per household is relatively large, distribution is inequitable, crop productivity is low and cropping patterns are least diversified.

Poverty performance of irrigation systems varies significantly across countries. In the studied systems, poverty incidence varies from 6 percent to 77 percent, with poverty much lower in Southeast Asian systems than in South Asian systems. Poverty incidence is the lowest in Chinese systems and the highest in Pakistani systems. Aggregate-level poverty determinant analysis indicates that higher crop productivity, greater share of noncrop income in household incomes, and equity in land distribution are important negative determinants of poverty in irrigation systems. Overall, the study findings suggest that poverty incidence is high in those systems where land and water distribution is highly inequitable, crop productivity is low and cropping patterns are least diversified. The analysis indicates that if land (and water) distribution is made more equitable (as it is, for example, in China) poverty incidence could be reduced by over 20 percent. While we know that land reform is politically sensitive and problematic to implement (especially in countries like Pakistan as previous attempts at land reforms undertaken during the regimes of Ayub Khan (1962) and Zulfiqar Ali Bhutto (1972) have been largely ineffective) we need to acknowledge that if land reforms could be implemented effectively, it would be one of the effective instruments to make a significant dent in rural poverty in Pakistan. A recent World Bank study in Pakistan attributes land inequality as a primary cause of rural poverty (World Bank 2002). The Bank's study also suggests that inequality in landownership has significant negative impacts on agricultural productivity (as productivity on large-size farms is generally lower than on smaller- size farms as high labor supervision costs encourage large farmers to reduce cropping intensity, and also prevalence of share tenancy reduces the incentives to invest in land improvement and resource conservation).

Our results also suggest that increasing average gross crop income from US$200/ha to US$1000/ha would lead to poverty reduction by almost 20 percent through its direct impacts (however, it should be noted that the overall impacts on poverty alleviation would be greater if poverty impacts of productivity-induced expansion in the noncrop sector are also accounted for). In Pakistan, for example, a 20 percent reduction in rural poverty would require gross crop income increases across systems between US$1281/ha (from US$281/ha) and US$1500/ha (fromUS$500/ha). These figures are comparable to the actual productivity levels being achieved in Chinese systems.

Elasticity of poverty incidence with respect to crop productivity, land distribution, and noncrop farm and nonfarm sources is estimated at -0.31, -0.48 and -0.79, respectively. These figures suggest that each US$100/ha/year increase in crop productivity over the present productivity level would reduce poverty by 2 percent. The key question is how can we achieve such large increases in productivity? Productivity enhancements would require improvements not only on the technological side but also on the institutional side. Molden et al. (2001) summarize several ways of improving land and water productivity. Hussain et al. (2003) undertook a detailed study on analyzing constraints to crop productivity in India and Pakistan. Their study suggests that large increases in productivity are feasible through conjunctive management of surface water and groundwater, canal water reallocations to tail ends of the systems and farmers' improved access to other production inputs (such as good quality seeds and fertilizers). Their study shows that access to improved varieties of seed alone has the potential to increase crop productivity by almost one ton per hectare (of wheat). How can farmers' access to these inputs be improved? Hussain and Perera (2003) argue that access to production inputs can be enhanced with integrated services provision (ISP) through public-private partnerships. Based on examples from several countries, they develop a framework for implementing ISP intervention.

Disaggregated analysis shows that poverty varies not only across systems but also across locations within systems. Demographic variables such as family size and dependency ratio are important positive determinants of household poverty. Productivity performance, income from crop-dependent noncrop sources, and size of landholdings are found to be important negative determinants of household poverty. Poverty is found to be lower at middle reaches of the systems, where productivity is high, and poverty is higher at tail reaches. Contrary to common perceptions, the findings suggest that poverty is not necessarily lower in locations within systems that are closer to the source of water, that is head reaches, compared to tail reaches. Inter-reach differences in poverty are more pronounced in larger size systems where inter-reach inequities in canal-water distribution, and resulting differences in productivity, are high. Variations in groundwater quality also add to such differences. The poverty situation tends to worsen in reaches of the systems where surface water availability is low, groundwater quality is poor, agricultural productivity is low and opportunities in the nonfarm sector are limited. Overall, the study suggests that the incidence and severity of poverty are relatively higher at the tail reaches compared to the middle reaches of the systems, implying that targeted approaches can be adopted to address the poverty problem in irrigation systems.

To sum up, the results of the study imply that while irrigation is an important contributor to poverty alleviation, the magnitude of antipoverty impacts of irrigation varies greatly across systems and depends on a range of factors. These include the distribution of land and irrigation water, productivity performance, cropping patterns and level of crop diversification supported with market infrastructure. Overall, the findings of the study imply that improving performance of irrigation systems by improving land and water productivity of crops, diversifying cropping patterns, improving infrastructure and water distribution across locations would help reduce poverty in presently low-productivity-high-poverty sections of the systems.

Poverty is relatively higher in rain-fed areas than in irrigated settings, and efforts are needed in both areas. The former areas require hardware interventions (investments) in the development of irrigation infrastructure, while the latter requires mostly software type of interventions that enhance equity in resource distribution and improve farmers' access to services and inputs.

This study provides significant insights into key determinants of poverty in irrigation systems, and it clearly brings out reasons why poverty is high in some systems and low in others, and highlights conditions under which irrigation has greater antipoverty impacts. The findings in this study are relevant to decisions regarding future investments in water-resources management and development for poverty alleviation. While this study has focused mainly on analyzing direct impacts of irrigation on income-poverty, further research is needed to quantify indirect or broader-level impacts of irrigation on income and other dimensions of poverty.

Appendix – 1

Table A-1. Results of regression estimations, Indonesia (irrigation systems vs.rain-fed areas).

Variable	Coefficient (b)	Marginal effect on probability of (Y=1)	b/SE
Constant	1.031497	0.116506	2.945
FSIZE	0.528916	0.059740	6.862
DRATIO	0.368087	0.041575	3.003
GVPFIELD	-0.000107	-0.000012	-4.679
PEREINC	-0.000599	-0.000068	-2.408
NCRINC	-0.000630	-0.000071	-13.124
NLAND	-1.271579	-0.143622	-6.024
D_G	-1.412771	-0.159570	-3.851
D_{KB}	-0.697143	-0.078741	-2.079
D_{KK}	-1.248705	-0.141039	-3.626
D_{KR}	-0.628163	-0.070950	-1.595

Dependent variable is poverty (1= poor, and 0= nonpoor)
Number of observations = 1,001
Log likelihood ratio = -409.15
Base category, rain-fed

Crop Diversification and Poverty Alleviation in Indonesian Systems

These graphs provide an example of how increased land and water productivity through diversification of cropping patterns towards high-value crops can reduce poverty even in settings where the average landholding size is small as in Indonesia. The crop diversification index (CDI) here is defined as CDI for household i = (total number of crops grown by household i/maximum number of crops grown in a system).

Figure A-1. Crop diversification index in irrigated and rain-fed settings, Indonesia.

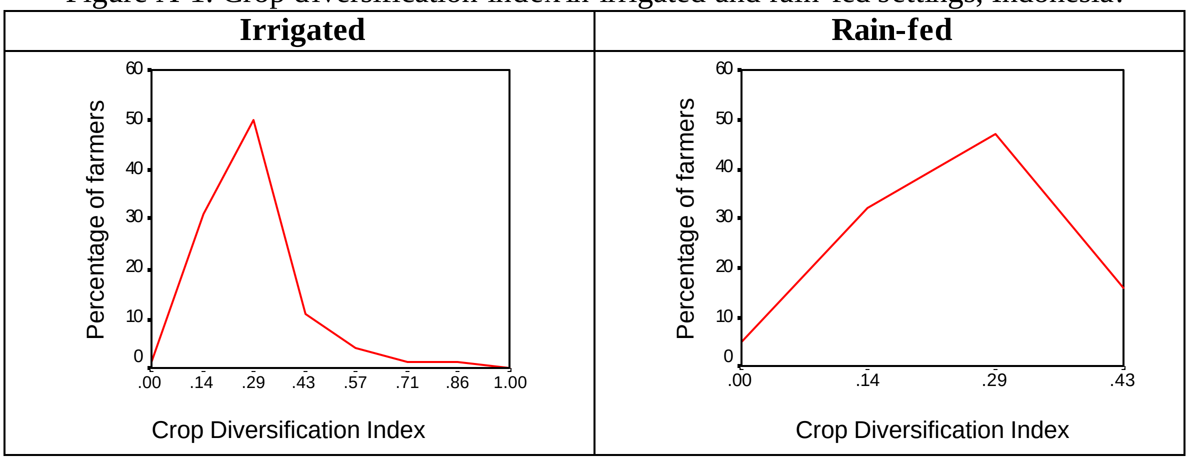
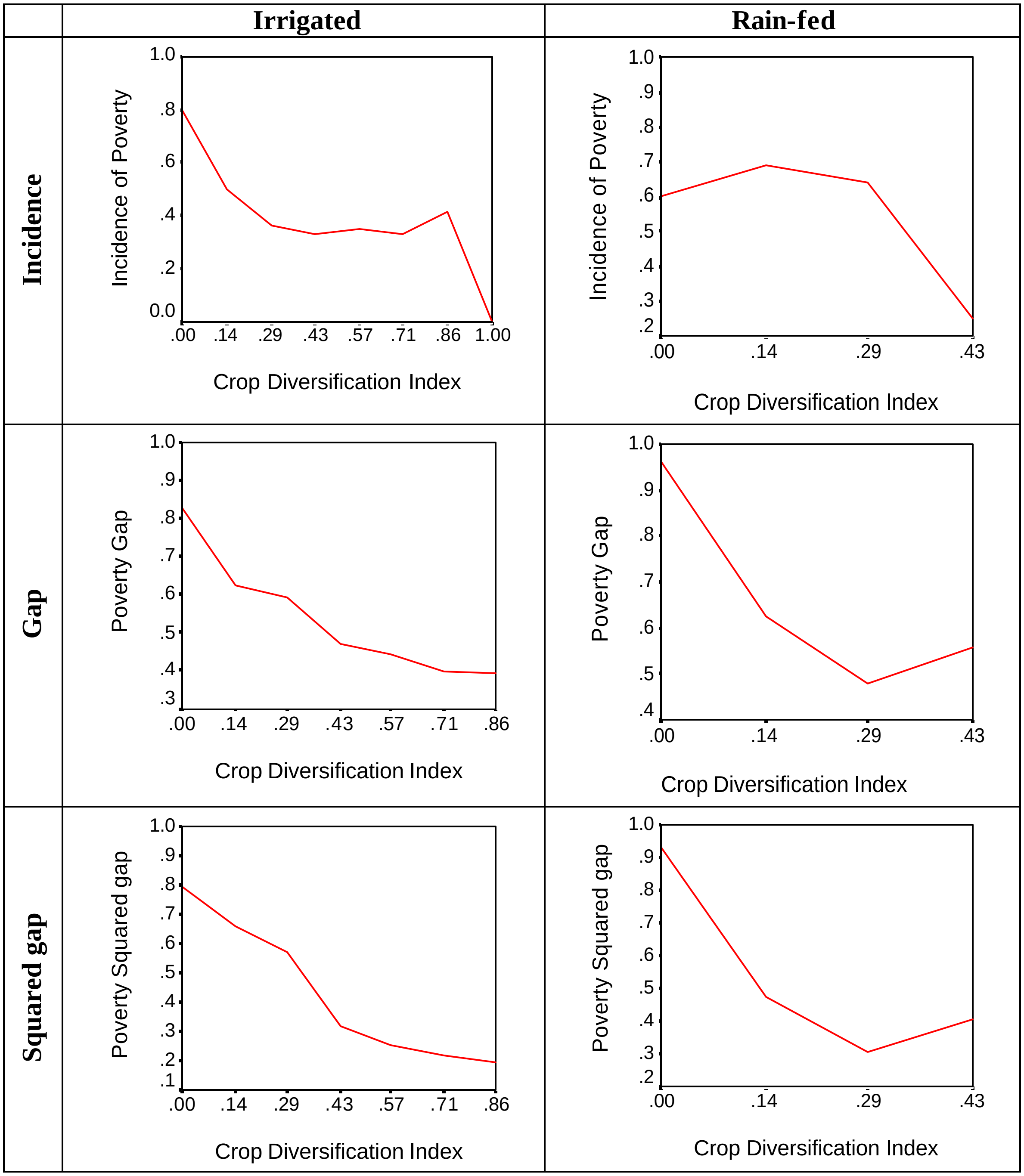


Figure A – 2. Poverty and level of crop diversification in irrigated and rain-fed settings, Indonesia.



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