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POVERTY-REDUCING IMPACTS OF IRRIGATION: EVIDENCE AND LESSONS†

INTIZAR HUSSAIN*

International Network on Participatory Irrigation Management (INPIM), Islamabad, Pakistan
(Formerly Senior Economist, International Water Management Institute (IWMI), Colombo, Sri Lanka)

ABSTRACT

This paper is part of the multi-country study on ‘‘pro-poor intervention strategies in irrigated agriculture in Asia’’ carried out by the author at the International Water Management Institute (IWMI) in collaboration with national partners in six Asian countries, namely Bangladesh, China, India, Indonesia, Pakistan and Vietnam. The study is largely based on primary data collected from over 5400 households in 26 irrigation systems during 2001–2002. This paper summarizes the findings of the study, and further extends the results (as presented in the sister paper in this Special Issue) on direct and indirect benefits and disbenefits of irrigation in terms of their poverty alleviation impacts. The paper examines evidence on poverty-reducing impacts of irrigation in local settings as well as at broader regional levels, and also looks into key factors influencing these impacts, and attempts to answer the following key questions: (i) what is the magnitude of impact of irrigation on poverty reduction; (ii) what is the response of poverty reduction to irrigation or irrigation-induced expansion in agricultural output across various settings; (iii) do poverty-reducing impacts of irrigation vary across systems, and if so, why? Or what are the conditioning factors that determine the anti-poverty impacts of irrigation? The paper offers insights into these questions with analyses and findings from our studies and with review and referencing of other related topical studies on the subject. Finally, the paper draws some generic lessons that could be useful in irrigation investment decisions. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: poverty; irrigation; impacts; poverty elasticity of irrigation; upstream–downstream; Bangladesh; China; India; Indonesia; Pakistan; Vietnam; Asia

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RÉSUMÉ

Cet article traite de l’étude internationale sur les stratégies d’intervention « pro-pauvres » en agriculture irriguée en Asie effectuée par l’auteur à l’Institut International de Gestion de l’Eau (IWMI) en collaboration avec des partenaires nationaux dans six pays asiatiques (Bangladesh, Chine, Inde, Indonésie, Pakistan et Vietnam). L’étude est en grande partie basée sur des données brutes collectées auprès de plus de 5400 ménages dans 26 systèmes d’irrigation en 2001–2002. Cet article récapitule les résultats de l’étude, et leur donne un certain prolongement (comme indiqué dans le papier « jumeau » de ce numéro spécial sur cette question) sur les avantages et les inconvénients directs et indirects de l’irrigation sur la réduction de la pauvreté. Il examine les preuves de réduction de la pauvreté du fait de l’irrigation dans les petits systèmes irrigués comme dans les plus grands systèmes régionaux, et considère également les facteurs principaux qui influencent ces impacts, pour tenter de répondre aux questions principales suivantes: (i) quelle est l’importance de l’impact de l’irrigation sur la réduction de la pauvreté; (ii) quels sont les impacts de cette réduction de la pauvreté sur la production agricole dans différents contextes; (iii) les effets de l’irrigation sur la réduction de la pauvreté sont-ils différents selon les systèmes irrigués, et si oui pourquoi? Ou

* Correspondence to: Dr Intizar Hussain, Executive Director, International Network on Participatory Irrigation Management (INPIM), Islamabad, Pakistan. E-mail: ihussain@inpim.org
† Irrigation et lutte contre la pauvreté: preuves et enseignements.

quels sont les facteurs qui déterminent ces effets ? L'article propose quelques ouvertures sur ces questions, à partir des analyses et des résultats des études de l'auteur et de la littérature existante sur le sujet. En conclusion, le papier esquisse quelques recommandations génériques qui pourraient être utiles dans les décisions d'investissement en irrigation.

MOTS CLÉS: pauvreté; irrigation; impacts; élasticité de la pauvreté par rapport à l'irrigation; amont–aval; Bangladesh; Chine; Inde; Indonésie; Pakistan; Vietnam; Asie

INTRODUCTION

As explained in the sister paper (on direct and indirect benefits and potential disbenefits of irrigation), irrigation generates a variety of direct and indirect benefits (and any potential dis-benefits) through several processes and mechanisms, that can lead to varying degrees of net impacts on poverty reduction. This paper examines evidence on the poverty-reducing impacts of irrigation in local settings, and also looks into key factors influencing these impacts. The key questions answered herein are: (i) what is the magnitude of impact of irrigation on poverty reduction; (ii) what is the response of poverty reduction to irrigation or irrigation-induced expansion in agricultural output across various settings; (iii) do poverty-reducing impacts of irrigation vary across systems, and if so, why? Or what are the conditioning factors that determine the anti-poverty impacts of irrigation? We answer these questions with analyses and findings from our studies and with review and referencing of other related recent studies.

There are two main channels through which irrigation impacts poverty, direct and indirect. The direct channel means that irrigation directly reduces poverty in local settings with various types of direct net benefits. The indirect channel implies that irrigation contributes to broader agricultural and economic growth that in turn contributes to overall poverty reduction at meso/regional and macro/national levels. Hussain and Hanjra (2003) describe the transmission of the poverty-reducing impacts of irrigation through the following inter-linked pathways:

- micro-pathway: through increasing returns to physical, human and social capital of the poor households (productivity pathway);
- meso-pathway: through integrating the poor into factor-product and knowledge/information markets (market participation pathway);
- macro-pathway: through improving national growth rates and creating second-generation positive externalities (economic growth pathway).

POVERTY IN IRRIGATED AND NON-IRRIGATED SETTINGS

There are several studies examining the poverty-reducing impacts of rural–agricultural development interventions, including irrigation. Most of these studies assess poverty impacts using ''with and without'' frameworks, often combined with econometric estimations. The studies comparing poverty measures across ''with and without'' irrigation situation show that poverty is much higher in settings without irrigation. For example, evidence from studies shows that poverty incidence varied from around 17 to 64% in irrigated settings and from 23 to 77% in adjoining non-irrigated settings. On average, poverty incidence is over 21% less in irrigated than in non-irrigated settings, with substantial variation in poverty incidence across systems (Table I). Further, the studies indicate that intensity of poverty is also significantly higher in non-irrigated settings than in irrigated settings. Similarly, the studies using econometric techniques show that irrigation and agricultural output are positive determinants of incomes/expenditures and negative determinants of poverty. Households and communities having access to irrigation are less likely to be poor compared to those with little or no access to irrigation.

The studies using a dynamic concept of poverty such as those by Hussain *et al*. (2002) in the Udawalawe system in Sri Lanka show that incidence of chronic poverty is significantly lower in irrigated (32%) than in non-irrigated settings (65%). These studies further show that the average period the poor households experience temporary poverty is shorter (5.85 months per year) than that in non-irrigated settings (8.44 months per year). These findings imply that irrigation reduces not only chronic poverty but also the duration of temporary poverty. The empirical evidence presented so far clearly suggests that irrigation has significant impacts on poverty reduction, however, the strength of the relationship and the magnitude of response of poverty reduction to irrigation or farm output vary considerably across settings.

Table I. Estimates of poverty in irrigated and non-irrigated settings in selected countries

Country/location	Year	Poverty headcount (%)			Source
		Irrigated	Non-irrigated	Difference (%)	
India-Bihar	1996	34.3	65.7	31.4	Thakur *et al.* (2000)
India-Chattisgarh	1996	38.0	55.0	17.0	Janaiah *et al.* (2000)
Rural India	2000	28.0	39.0	11.0	Fan and Hazell (2000)
UdaWalawe system, Sri Lanka	2004	32.0	65.0	33.0	Hussain *et al.* (2004)
Vietnam	1996	17.9	60.6	42.7	Ut *et al.* (2000)
Philippines	1997	30.0	39.0	9.0	Hossain *et al.* (2000)
Thailand	1998	20.8	55.8	35.0	Isvilanonda *et al.* (2000)
India-NSLC	2001–2002	35.0	70.0	35.0	This study
India-Harsi	2001–2002	44.0	71.0	27.0	This study
BangladeshG-K	2001–2002	35.0	55.0	20.0	This study
Bangladesh-Pabna	2001–2002	58.0	77.0	19.0	This study
Indonesia	2001–2002	41.0	59.0	18.0	This study
India-Halali	2001–2002	64.0	74.0	10.0	This study
India-KDS	2001–2002	17.0	23.0	6.0	This study
Pakistan	2001–2002	40.0	44.0	4.0	This study

POVERTY IN IRRIGATION SYSTEMS

Not only does poverty differ across irrigated and non-irrigated settings, there are even large differences in poverty across irrigation systems (Figure 1). Among the 26 systems studied, poverty incidence varies from as low as 6% to as high as 65%. Average poverty incidence across all the systems is estimated at 33.5%, with lowest poverty in Chinese systems and highest poverty in Pakistani systems. As expected, overall poverty incidence is much higher in South Asian systems than that in the Chinese and Vietnamese systems studied. Also, not only are there inter-country differences in poverty in irrigation systems, there are significant intra-country differences in poverty and these differences are much larger among South Asian systems.

Poverty across upstream and downstream reaches of canals

Further, the study findings show that there is generally more poverty at downstream than at upstream reaches of irrigation systems (Table II). However, the upstream–downstream poverty differences are more pronounced for systems in India and Pakistan than those in China, Vietnam and Indonesia where such differences are small. Among all the systems studied, downstream poverty is higher in more than half of the systems. Further, these locational

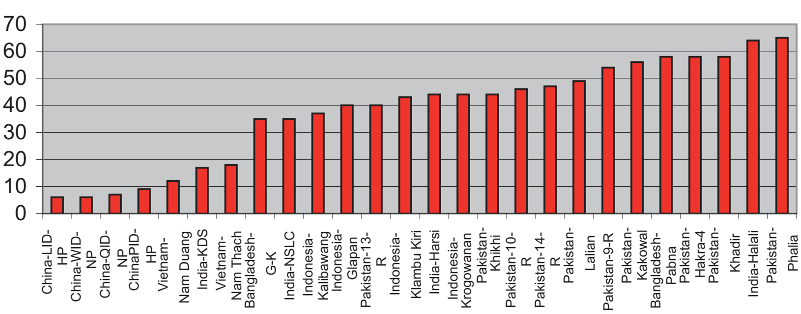

Figure 1. Poverty headcount (%) in selected irrigation systems Bangladesh, China, India, Indonesia, Pakistan and Vietnam. This figure is available in colour online at www.interscience.wiley.com/journal/ird

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Table II. Poverty incidence across upstream–downstream reaches

Country/reach	Upstream	Downstream
India	23.0	34.0
Pakistan	49.0	55.0
Vietnam	12.0	14.0
China	6.4	7.5
Indonesia	37.0	41.0

Source: based on field data.

differences in poverty are more apparent in those downstream areas where access to canal water is least, alternative source of water is limited or of poor quality and or alternative sources of employment/livelihoods are very limited. While there is significant upstream–downstream inequity in access to canal water in almost all the South Asian systems studied, downstream poverty is not higher in systems where there is access to good quality groundwater or where there are alternative sources of employment/livelihoods (especially in situations where downstream reaches are closer to the cities). The poverty situation becomes worse in those downstream reaches where there is no or little access to canal water, groundwater quality is poor and access to alternative sources of livelihoods is limited. Also, in such situations the poor tend to be poorer than the poor at upstream reaches (see Jehangir *et al.*, 2004 for more details).

In the South Asian systems, there is generally a consistent pattern of increasing poverty towards downstream reaches of canals and their peripheral non-irrigated areas except where there is good quality groundwater or alternative sources of livelihoods in the nearby areas. A recent study by Rajagopal *et al*. (2002) on tail-end derivation in irrigation systems in Tamil Nadu, Karnataka and Maharashtra also conclude that: (i) tail or lower reaches of canal are disadvantageous locations; (ii) upper-reach farmers are powerful in terms of social and economic conditions – the living standards of the upper-reach farmers are better in terms of food, clothing, transport, electronics and luxury equipment, whereas the people at the tail ends are just surviving; (iii) the extent of tail-end deprivation is unequal and varies across the systems and is directly related to the size of the systems, participation of users and system managers. Further, the study also indicates that the deprivation is more pronounced in the *rabi* season when a large part of the distributary goes out of irrigation due to non-availability of irrigation. The main reasons that lead to the poor water supply at tail reaches include the following: (i) the powerful farmers at the head reaches gain more access to water by influencing the irrigation bureaucracy and other means; (ii) inefficient methods of water allocation; (iii) poor maintenance of the systems; and (iv) extension in irrigated areas/command over and above the original design of the systems.

FACTORS INFLUENCING POVERTY-REDUCING IMPACTS OF IRRIGATION

The magnitude of anti-poverty impacts of irrigation depends not only on the availability of irrigation but also on the productivity performance of the systems and, importantly, on the distribution pattern of land and irrigation water. Where land distribution is relatively equitable, irrigation water distribution in terms of total amount per household also becomes inequitable. From a poverty alleviation perspective, both productivity performance of the systems (size of the pie) as well as distribution of land and irrigation matter (distribution of the pie).

As shown in Table III, our systems across countries differ significantly in terms of households' access to land/ water, their distribution pattern, farm sizes and productivity performance of the systems. Average landholding size varies from as low as 0.40 ha per household in Vietnam to as high as 4.3 ha per household in Pakistan. Average landholdings are much smaller (less than 1 ha per household) in Chinese, Vietnamese and Indonesian irrigation systems than in Indian and Pakistani systems. Unlike in South Asian systems, there is generally no landlessness in the Chinese and Vietnamese systems studied and overall land distribution is fairly equitable as indicated by low

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Table III. Land and water-related factors across countries

	Farm size (ha)	Gini coefficient	Crop intensity	Productivity in SGVP (US$ ha^{-1} yr^{-1})	Irrigation benefit (US$ ha^{-1} yr^{-1})	Non-crop income (%)	Poverty headcount (%)	Landlessness
Bangladesh	0.9	0.66	196.0	692.5	157.0	76.9	46.5	15.0
India	2.4	0.46	99.0	985.5	180.5	59.3	40.0	37.5
Pakistan	4.3	0.44	153.6	448.5	94.1	63.2	51.7	27.7
China	0.7	0.19	177.0	1661.3	477.5	64.1	7.0	0.0
Vietnam	0.4	0.25	196.5	1577.0	264.0	73.5	15.0	0.0
Indonesia	0.7	0.48	238.5	1001.8	375.8	41.8	41.0	19.8
Average	1.6	0.41	176.8	1061.1	258.1	63.1	33.5	16.7
Bangladesh– rainfed						88.5	66.0	18.5
India –rainfed						55.0	59.5	29.8
Pakistan – rainfed						98.0	44.0	40.0
Indonesia –rainfed						52.0	59.0	10.0
Average						73.4	57.1	24.6

Source: Based on primary data.

Gini coefficients. This is basically an outcome of land equity policies adopted in these countries over past decades. Given that the system-level irrigation distribution generally follows land distribution patterns, water distribution also tends to be equitable or even pro-poor in these countries. Our study of the Chinese system 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 (see Wang *et al.*, 2004).

The study findings indicate that irrigation systems vary significantly in terms of their productivity performance. The estimated elasticity of poverty reduction with respect to the system productivity performance varies across countries from −0.15 to −4.42, indicating that a 1% increase in productivity performance reduces the poverty incidence from 0.15 to 4.42% (with average value of elasticity estimated at −0.29). The elasticity estimate here measures poverty reduction (average) response to productivity improvements in the *local settings* through *direct productivity benefits* (type 2) only. The elasticity estimates are much higher for China (−4.42) followed by Vietnam (−0.91) and much lower for systems in South Asian countries (from −0.15 to −0.28). Our findings are consistent with those from the broader literature in that poverty elasticities are higher where poverty and inequities in asset/ land distribution are relatively low. Land distribution pattern has relatively stronger impacts on poverty, with average response/estimated elasticity of 0.38 indicating that a 1% decrease in land Gini coefficient would reduce poverty by 0.38%. This effect captures the effects of both land and irrigation distribution as the two broadly move together. Overall, our results suggest that access to, and distribution of, land and irrigation, and productivity performance of irrigation systems have significant impacts on the incidence of poverty in local settings. The anti-poverty impacts of land and irrigation distribution are stronger than that of productivity performance of the systems. The poverty reduction impact is much greater in systems where there is greater equity in land and irrigation distribution and productivity performance is better and vice versa. The disaggregated analyses for countries suggest that households' demographic and locational characteristics are also important in influencing their poverty. The probability of being poor is significantly higher for households with larger families than for smaller families. Similarly, the probability of households located at middle reaches of the systems being poor is much lower than those at the tail ends.

POVERTY ELASTICITY OF IRRIGATION/ FARM OUTPUT

As mentioned earlier, our findings on elasticity of poverty reduction with respect to productivity increases are consistent with those from the broader development literature in that poverty elasticities are much lower in settings where initial levels of poverty and inequities in resource distribution (land and water) are high. Our comprehensive

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review of related literature on estimates of elasticity of poverty reduction with respect to irrigation/farm output (see Table AIII) suggests the following lessons:

- the poverty elasticities of irrigation or farm output vary widely across various settings, across countries and regions within countries from as low as 0.1% to as high as 1.34%. The elasticity estimate for farm output (i.e. direct benefit of irrigation) from several studies is closer to −0.35, indicating that a 1% increase in farm output leads to poverty reduction by 0.35%;
- the poverty elasticity estimates vary with poverty measure employed. Among most commonly used measures, elasticity estimates for headcount are generally lower than those for poverty gap and squared poverty gap measures (Datt and Ravallion, 1996). These findings imply that the poverty-reducing impact of irrigation-induced expansion in farm output is larger in terms of reducing depth and severity of poverty than in terms of incidence, that is, a larger impact on those deeper down the poverty line;
- the elasticities of poverty reduction are significant in relation to both direct and indirect benefits of irrigation. However, the poverty-reducing response to indirect benefits is larger than that from the direct benefits in the long run than in the short run. This is because a significant part of the indirect benefits, especially through employment and price effects, goes to the poorest socio-economic class, generally the landless. De Janvry and Sadoulet (2002) show that a 1% increase in land productivity increases total real income of the landless by 0.75% and of small farmers by 0.50%, with indirect benefits contributing to total income gains by 92.5% for the landless and 56.4% for small farmers. Under certain conditions, the poverty impacts of direct productivity benefits of irrigation could also be very strong. For instance, Van de Walle (1996) shows that in Vietnam converting 10% of unirrigated land to irrigation leads to increases in crop incomes that are equal to 0.1–4.52% of household average expenditures, with the largest impact on the lowest expenditure group and vice versa. Targeting the irrigation expansion to households with small per capita landholdings produces the most progressive incidence of gains as well as the largest absolute benefits to the poor. Further, he suggests that benefits of irrigation would be higher and well distributed for the poorest regions of Vietnam (northern upland and north coastal region);
- the poverty elasticity with respect to irrigation or farm output is low where asset distribution (particularly land) is inequitable. In the context of broader growth and development issues, a growing body of research work suggests that income and asset inequality have negative impacts on income growth of the poor. Birdsall *et al*. (1995) show that the elasticity of poverty reduction with respect to growth declines sharply with increasing inequality. With a very low Gini coefficient of 0.25, the elasticity is very high at 3.33, while it drops by almost half to 1.82 with a Gini coefficient of 0.59. Adams and He (1995) find that an increase in crop income tends to be inequality-increasing in Pakistan because of the skewed distribution of land, while increases in livestock incomes are equalizing. Timmer (1997) estimates the ‘‘elasticity of connection’’ between the poor and the rest of the economy (i.e. the extent to which the poor share in overall income growth). His findings suggest that in developing countries with highly unequal income and asset distribution, the poor are substantially disadvantaged in the growth process. He finds that in countries with highly unequal income distribution, the elasticity of connection for the poorest quintile is 0.257 for agriculture and 0.449 for non-agriculture. In contrast, for those economies with better income distribution, the elasticity of connection for the poor is 1.146 and 1.018 for the agriculture and non-agriculture sectors, respectively. The study basically suggests that the contribution of agriculture productivity to poverty reduction is a function of the income inequality in a country, with unequal countries having a low elasticity of connection. Datt and Ravallion (1997) also suggests that high inequality provides lower growth and even lower reduction of poverty. Datt and Ravallion (1998) examine the effects of inequality on the elasticity of poverty reduction and conclude that inequalities can severely impede the prospects for poverty reduction. Bourguignon and Morrison (1998) suggest that international differences in income can be at least partially explained by land per capita, the share of land cultivated by small and medium-size farmers, and the relative productivity differentials between agriculture and the rest of the economy, and that the inequalities particularly penalize the poor. Deininger and Squire (1998) show, by using the initial distribution of land as a proxy for the asset distribution, that asset inequality has a significant negative effect on subsequent growth and this effect is stronger in low-income countries than in high-income countries. Similarly, Sarris (2001) argues that initial inequitable land distribution makes the relationship between agricultural growth and the overall growth much weaker. Further, Heltberg (2001) shows that poverty elasticity depends on the degree of inequality and falls

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quite strongly as the Gini coefficient increases; also poverty elasticity is low where the initial level of poverty is high. A cross-country study by Jalilian and Weiss (2004) further confirm that countries that start with a higher level of inequality suffer more poverty;

- the studies also suggest that the poverty reduction response could be much higher when interventions are implemented with a package approach. For example, Van de Walle (2000) shows that there are strong complementarities between education and the gains from irrigation in Vietnam. Similarly, Jalilian and Weiss (2004) show for developing countries that an increase in human capital (schooling) by 25% would increase poverty elasticity with respect to infrastructure by around 8% on average. A combination of an increase in human capital investment and infrastructure could therefore have a stronger impact on poverty reduction than either alone. Their results provide further support for the widely held view that infrastructure as a direct poverty tool will work best when it is part of a package approach. Furthermore, the studies suggest that the productivity impact of rural infrastructure accounts for around one-third of total impacts on poverty, non-agricultural employment and rural wages account for two-thirds of impacts on poverty via indirect impacts.

POVERTY-REDUCING IMPACTS OF IRRIGATION: SMALL-SCALE VS LARGE-SCALE

The question is often raised as to whether small-scale irrigation reduces more poverty than does large-scale irrigation. The irrigation systems can be distinguished in terms of: (i) ownership and management of systems – public, private and communal; (ii) size of systems – small, medium and large; (iii) source of water supply – surface/canal water or groundwater; and (iv) technology of irrigation application. Publicly managed irrigation systems include both small- and large-scale systems, where water usually flows by gravity from a reservoir or river diversion through a network of canals. The management performance of large-scale systems is often below expectations because of their large size and complexity of operations, productivity performance is generally lower and head–tail inequity is a typical problem in these systems. Privately owned and managed systems are mostly groundwater systems. Where groundwater quality is good and recharge is sufficient, productivity of these systems can be much higher (than canal systems) because of greater reliability of water and better overall control over water supplies. Communal irrigation systems are those owned and managed by farmers and their local associations. They are of generally small size and usually consist of small diversion structures and earthen distribution channels. Small-scale irrigation technologies usually referred to as micro-irrigation technologies are irrigation application technologies where the source of irrigation could be surface water or groundwater such as drip irrigation, bucket irrigation, etc.

The irrigation systems studied differ significantly in size, varying from as low as 813 ha to as high as 508 000 ha. These systems are administered by public sector agencies, though lower-level management has been transferred to users in some of these systems. Comparison of these systems does not show any systematic pattern of increasing or decreasing poverty with the size of the systems. Poverty outcomes are mixed for systems of varying sizes. However, as discussed earlier, our comparative analysis of systems does indicate a consistent pattern of increasing poverty towards downstream/tail-end areas (with the poverty situation worsening in those downstream areas where access to canal water is least, groundwater quantity/quality is poor and alternative sources of livelihoods are limited), and this is more pronounced in relatively large-size systems than in small-size systems. This finding is also confirmed from recent studies in irrigation systems in Tamil Nadu, Karnataka and Maharashtra, suggesting that ‘‘the magnitude and distribution of deprivation varies across the systems and is directly related with the size of the system and participation of users and system managers in management’’ (Rajagopal *et al*., 2002).

Past studies by the Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP) in Bangladesh, India, Nepal, Pakistan and Sri Lanka and recent studies by the Department for International Development (DFID) in Bangladesh on assessing the impacts of small-scale irrigation show that livelihood-improving and poverty-reducing impacts of irrigation vary significantly across schemes in each country (Hasnip, 2002; Brabben *et al.*, 2004). These studies suggest that the development of small-scale schemes owned and managed by farmers has been an effective tool for poverty alleviation provided certain preconditions are met (access to land and water, access to credit and markets, farm enterprise diversification). The review of these case studies implies that while the impacts of irrigation on poverty alleviation across small- and large-scale systems may show some quantitative differences, the mechanisms for poverty alleviation are similar, and that there is no conclusive evidence on whether small-scale is better than large-scale for poverty reduction. More research is needed in this area.

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Impact of canal water vs groundwater

The output and farm income impacts of surface/canal water irrigation vs groundwater irrigation could differ significantly due to differences in reliability and degree of control over water supplies – which are generally better for the latter than the former source of irrigation. The results and conclusions of most studies comparing canal water and groundwater impacts are mixed and mostly location specific, with several studies concluding that groundwater has relatively greater poverty-reducing impacts. However, an important aspect that is often ignored is that canal irrigation creates favourable conditions for attracting private investments in groundwater by providing an important source of groundwater recharge. A recent study in India estimated that a 1% increase in crop area under canal irrigation increases crop area under private groundwater irrigation by 0.22% in irrigated areas and by 0.58% in high potential rainfed areas (Fan and Hazell, 2000). When these benefits of canal water are also accounted for, its total impacts on poverty may well outweigh the impacts from groundwater especially in areas where canal water plays important role in groundwater recharge.

POVERTY-REDUCING IMPACTS: IRRIGATION VS OTHER INTERVENTIONS

Another often raised important question is which of the various alternative rural interventions are more effective in reducing poverty – such as irrigation, research and development (R&D), roads, electricity, education, health and so on – and where should investments be made for larger poverty impacts. There are onlya few studies analysing poverty-reducing impacts of alternative interventions, and our review of these studies suggests that there is no general consensus on whether a particular intervention is more poverty reducing. The overall outcomes and conclusions of various studies on the relative effectiveness of various interventions in reducing poverty are mixed (Table AIV). The main lessons that emerge from the review are that: (i) no single intervention is sufficient for effective poverty alleviation; (ii) irrigation is identified as one of the important interventions for large poverty-reducing impacts along with land, education and roads; and (iii) there are strong complementarities across various interventions in that poverty impacts are large when interventions are carried out in an integrated framework. The results of the various studies enhance the case for integrated and multi-sector approaches to poverty alleviation.

Recent studies on poverty distinguish between chronic or permanent poverty and transient or temporary poverty – with the former indicating a more severe poverty situation than the latter. The studies suggest that the causes of two types of poverty are different; therefore, different types of interventions are needed to address them. Chronic poverty is associated with lack of assets (both physical and human), low level of productivity, disadvantageous demographic characteristics (e.g. large families and high dependency ratios), and location in more remote and backward areas. Transient poverty, while also related to lack of assets, is more typically associated with households' inability to insure themselves against fluctuations due to either external factors such as prices, climate or job availability or household-level shocks such as serious illness or death of family members. Interventions that lead to improvements in physical infrastructure reduce both chronic poverty and transient poverty. However, interventions that improve access to land, crop productivity, education level and health reduce chronic poverty. On the other hand, interventions that help improve seasonal public works and credit programmes reduce transient poverty (Jalan and Ravallion, 2000; McKay and Lawson, 2002). It can be concluded from the above discussion that irrigation is one of the most effective interventions for poverty alleviation, and its poverty-reducing impacts can be enhanced through simultaneously implementing other complementary interventions.

LESSONS AND IMPLICATIONS

The study findings lead to the following conclusions, lessons and implications:

1. Irrigation significantly reduces income poverty. Poverty outside of irrigation systems in nearby non-irrigated settings is much higher (almost twice) than that within irrigation systems. In absolute terms, poverty is still high in irrigation systems, estimated at 33.5%. There are significant inter- and intra-country differences in

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poverty incidence in irrigation systems. As expected, poverty is higher in South Asian systems than in South-East Asian and Chinese systems, with inter-system differences in poverty much higher in the former than in the latter;

2. In South Asian systems, poverty is generally higher at downstream/tail reaches, particularly in areas where access to canal water is least, groundwater is of poor quality and alternative sources of livelihoods are more limited. In these systems, poverty is lower at middle reaches than at head and tail reaches. In Chinese and Vietnamese systems, head–tail differences in poverty are not as pronounced as in South Asian systems;
3. Poverty is high among landless households, followed by marginal landholders. Unlike Chinese and Vietnamese systems where there is no landlessness, around one-third of households in the Indian and Pakistani systems studied are landless (and generally waterless). The landless households account for the majority of the poor who depend on non-crop sources of income including on-farm and off-farm wage labour;
4. Poverty is significantly related to productivity levels, the distribution pattern of land and irrigation water and locational factors. Poverty is low in settings with better productivity performance, equitable distribution of land and irrigation water and vice versa;
5. The elasticity of poverty reduction with respect to equity in land and water distribution is higher than that with respect to crop productivity. Further, the elasticity of poverty reduction with respect to productivity is much higher in systems with greater equity in land and water distribution and lower initial level of poverty, as in Chinese and Vietnamese systems. On the other hand, the elasticity of poverty reduction with respect to productivity is low in settings with unequal land and water distribution and higher initial level of poverty, as in Pakistan. Inequity in land and water distribution is bad for both productivity increases and poverty reduction;
6. In systems with unequal land and water distribution, local-level direct productivity-related benefits of irrigation account for around one-third of total impacts on poverty, and two-thirds of impacts are realized through indirect benefits such as through expansion in non-agricultural activities and increase in wages;
7. Poverty outcomes for canal irrigation systems of varying sizes are mixed. There is no systematic pattern of poverty increasing or decreasing with size of systems. However, the pattern of increasing downstream/tail-end poverty is more pronounced in larger-size systems than in smaller-size systems. While tail-end poverty performance is better in smaller systems, overall mechanisms for poverty alleviation and constraints therein are similar across large- and small-scale systems;
8. Groundwater irrigation has relatively greater impact on output levels and poverty reduction because of its greater reliability and better control over water supplies, but this is only in settings where groundwater is of good quality. In settings where groundwater is of marginal quality, the impact of canal water on output and poverty is much larger than that of groundwater irrigation. Further, canal water attracts private investment in groundwater (and other factors of production); overall benefits of canal water are large when groundwater recharge benefits of canal water are also accounted for;
9. No single intervention is sufficient for effective poverty alleviation. Irrigation is found to be one of the important interventions for poverty alleviation along with land, education and road infrastructure. Poverty reduction impacts of irrigation are large when these and other complementary elements such as market systems are in place. The poverty-reducing impacts of irrigation can be enhanced through simultaneously implementing complementary interventions in an integrated framework. However, different strategies are needed for different settings (i.e. settings with greater or lesser equity in land and water distribution, settings with different patterns of upstream–downstream poverty);
10. There are different causes of chronic and transient poverty; therefore, different interventions are needed to address the two types of poverty. Land and water-related interventions contribute to reducing both chronic and transient poverty.

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APPENDIX

Table AI. 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
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 (upper YRB)	B.C.	Village cooperatives	304 000	195	Wheat–rice–maize–other	SW	Water-short	95
	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

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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.

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

Country	Name of system	Family size	Farm size (ha)	Land distribution Gini coefficient	Head–tail equity ratio	Crop intensity	Productivity in SGVP (US$ ha^{-1} yr^{-1})	Irrigation benefit (US$ ha^{-1} yr^{-1})	Non-crop income (%)	Poverty headcount (%)
Bangladesh	G-K	6.00	0.93	0.52	1.47	212	823	189	72.2	35
	Pabna	6.00	0.92	0.80	0.63	180	562	125	81.5	58
India	NSLC	4.19	1.95	0.25	3.0	89	1290	259	64	35
	KDS	7.56	1.31	0.44	2.7	127	1874	388	63	17
	Halali	8.02	3.75	0.58	Skewed	112	376	33	57	64
	Harsi	4.33	2.41	0.58	Skewed	68	402	42	53	44
Pakistan	9-R	6.71	2.83	0.46		149	302	45	84	54
	10-R	7.06	2.49	0.31	1.8	161	452	91	77	46
	13-R	7.52	3.62	0.38		183	652	210	56	40
	14-R	7.48	3.38	0.34		164	536	132	58	47
	Kakowal	7.37	3.44	0.38	1.23	158	380	49	73	56
	Phalia	7.92	4.84	0.52		170	508	123	60	65
	Lalian	7.84	4.96	0.44	2	138	421	116	45	49
	Khadir	9.8	5.66	0.56	2.5	124	331	57	49	58
	Khikhi	8.28	5.16	0.51		137	511	92	65	44
	Hakra-4	7.01	6.54	0.49	1.09	152	392	26	65	58
China	WID-NP	4.22	1.03	0.19		156	1678		69.6	6

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Table AII. (Continued)

Country	Name of system	Family size	Farm size (ha)	Land distribution Gini coefficient	Head–tail equity ratio	Crop intensity	Productivity in SGVP (US$ ha^{-1} yr^{-1})	Irrigation benefit (US$ ha^{-1} yr^{-1})	Non-crop income (%)	Poverty headcount (%)
	QID-NP	4.22	0.79	0.19		160	1452		68.8	7
	PID-HP	4.16	0.45	0.19		194	1837		63.7	9
	LID-HP	4.16	0.5	0.19		198	1678		54.1	6
Vietnam	Nam Duang	4.8	0.25	0.22	3.1	204	1770	314	76.0	12
	Nam Thach Han	5.6	0.52	0.27	0.9	189	1384	214	71.0	18
Indonesia	Klambu Kiri	3.97	0.99	0.49	1.07	238	976	357	40	43
	Glapan	4.82	1.08	0.58	3.01	223	890	292	38	40
	Kalibawang	3.45	0.30	0.46	1.45	245	1002	376	42	37
	Krogowanan	3.47	0.39	0.37		248	1139	478	47	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% of the systems to the average DPR of the tail 25% 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.
Poverty lines (per capita income/ month); Bangladesh = BTK 833, India = Rs 311 (AP) & Rs 263 (MP), Pakistan = PRS 530, China = Yuan 52.08, Vietnam = VND 100 000, Indonesia = Rp 74 007).
SGVP- Standardized value of gross product; value of output generated by different crops was estimated as value of wheat equivalents.

Table AIII. Elasticities of poverty reduction with respect to irrigation and farm output

Study location	Elasticity estimate	Description	Authors
India	Short run: −0.177 [via direct effect: −0.119 via wage rate effect: −0.014 via food price effect: −0.044] Long run −0.875 [via direct effect: −0.239 via wage rate effect: −0.237 via food price effect −0.400]	A 1% increase in farm yields leads to 0.177% reduction in rural poverty in the short run, with direct productivity effects larger than indirect effects via wages and food prices. In the long run, a 1% increase in farm yields leads to poverty reduction by 0.875%, with indirect effects via wages and prices more than twice of that via direct effects	Datt and Ravallion (1998)

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Developing countries	−0.299 to −0.910 [estimates differ across different specifications as −0.229, −0.370, −0.621, −0.720 and −0.910]	A 1% increase in land productivity or yields reduces the proportion of people living on less than 1 dollar a day by 0.299–0.910%	Thirtle *et al*. (2001) and Irz *et.al*. (2001)
Developing countries	0.35	A 1% increase in infrastructure stock per capita reduces poverty ratio of 1 dollar day by 0.35%	Jalilian and Weiss (2004)
Gujrat, India	−0.10	A 1% increase in the average gross farm income per rural person of the state reduces poverty headcount ratio by 1%	Shah and Singh (2002)
India	−0.27	A 1 % increase in gross cropped area under irrigation reduces poverty by 0.27%	Bhattarai and Narayanamoorthy (2003a)
India	Punjab: −1.34 Haryana: −1.00 Gujrat: −0.40 West Bengal: −0.40 Uttar Pradesh: −0.25 Andhra Pradesh: −0.21 Himachal Pradesh: −0.20	A 1% increase in gross irrigated area leads to poverty reduction from 1.34% in Punjab to 0.20% in Himachal Pradesh [Note: the study finds insignificant impacts of irrigation in other states such as Madhya Pradesh, Bihar, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Karnataka]	Bhattarai and Narayanamoorthy (2003b)
India	Elasticity of poverty reduction with respect to yield growth: Headcount: −0.38 Poverty gap: −0.55 Squared poverty gap: −0.70	A 1% increase in agricultural yield growth reduces poverty by 0.38% (headcount), 0.55% (poverty gap) and 0.70% (squared poverty gap)	Datt and Ravallion (1996)
India	Production growth: – irrigated area: −0.160 – high potential rainfed areas: −0.170 – low potential rainfed areas: −0.310 Wage rate: +0.201 −0.157	A 1% increase in production growth reduces poverty by 0.16% in irrigated areas, 0.17% in high potential rainfed areas and 0.31% in low potential rainfed areas A 1% increase in production growth increases wage rates by 0.21%, and a 1% increase in wage rates reduces poverty by 0.157%	Fan and Hazell (2000)
China (2002)	0.41 −1.31	A 1% increase in irrigation is associated with a 0.41% rise in agricultural output per worker, resulting in a 1.31% drop in poverty incidence	Fan *et al*. (2002)
Vietnam	0.01 to 0.452	Conversion of 1% of non-irrigated land to irrigation produces an increase in crop income equal to around 0.01–0.452% increase in mean household expenditures with largest impact on the poor smallholders	Van de Walle (1996)

(*Continues*)

Table AIII. (Continued)

Study location	Elasticity estimate	Description	Authors
Philippines (2002)	0.31	A 1% increase in irrigation leads to 0.31 % rise in income of the poor	Balisacan and Pernia (2002)
Philippines (1991)	0.80	A 1% increase in farm output in irrigated areas leads to 0.8% increase in the incomes of landless labourers	Coxhead and Warr (1991)
Asian developing countries	Small farmers: 0.50 Landless: 0.72	A 1% increase in land productivity increases total real income of small farmers by 0.50% and the landless by 0.75% (with indirect benefits contributing 56.4% for small farmers and 92.5 for the landless)	De Janvry and Sadoulet (2002)
Asian developing countries	1.36	A 1% increase in land productivity will increase employment in agriculture and non-agriculture sectors by 1.36%, with largest impacts on landless people	De Janvry and Sadoulet (2002)

Table AIV. Poverty-reducing impacts of alternative interventions

Interventions ranking	Description/conclusions/remarks	Authors
1. Rural roads; 2. Ag R&D; 3. Education; 4. Rural development; 5. Irrigation; 6. Electricity/power; 7. Soil and water conservation; and 8. Health	India: Investments in roads have the largest impacts and health smallest impacts on poverty reduction	Fan *et al*. (2000)
1. Rural roads; 2. Irrigation; 3. Electicity	Various Asian developing countries [based on review of econometric studies]	Ali and Pernia (2003)
1. Urbanization and industrialization 2. Schooling/education 3. Productivity/farm income	Gujrat, India Urbanization/industrialization has the largest impact on poverty followed by investments in primary schooling, agricultural productivity enhancement programmes	Shah and Singh (2004)
1. Irrigation 2. Education	India Irrigation has the largest impact on poverty followed by education. Poverty-reducing impacts of roads were not obvious	Bhattarai and Narayanamoorthy (2003b)
1. Combined physical infrastructure (roads) and education (schooling) 2. Physical infrastructure 3. Education (schooling)	Developing countries A combination of increase in investments in physical infrastructure and education have stronger impact on poverty than either alone	Jalilian and Weiss (2004)
1. Irrigation and education	Rural Vietnam	Van de Walle (2000)

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2. Other infrastructure	There are strong complementarities between the returns to irrigation and household education, particularly primary education in rural Vietnam. The full returns to irrigation will not be realized by the poor without concomitant investments in education. There are important synergies between human and physical capital. The knowledge poor will have lower returns to investments in physical capital. The study enhances the case for multi-sectoral approach to development projects	
1. Irrigation and roads 2. Other infrastructure and services	Nepal and Bangladesh The case studies note that "given the high proportion of national population living in rural areas, there are very limited options for the majority that can bring the same scale of improvements in incomes as can irrigation, in a relatively short period". Besides irrigation, road improvements have made the largest contribution to the development of villages. Road development has greatly complemented irrigation, maximizing its benefits by improving access to markets for both inputs and outputs. Irrigation has larger poverty reduction impacts if complementary elements are in place – market system, roads, schools and extension services. Therefore, in order to generate optimum benefits from irrigation, there is a need to plan integrated packages of rural support, which include complementary drivers of development	
1. Irrigation 2. Other interventions	Chambers *et al*. (1989) argue that support to irrigation (small-scale privately managed groundwater irrigation) targets the rural poor better than other poverty reduction interventions	Chambers *et al*. (1989 as cited in Hasnip *et al*., 2001)
Investments in several areas [in order] 1. Irrigation 2. Land reforms 3. Modern technology 4. Non-farm employment 5. Family planning	Chhattisgarh, India The study concludes that poverty can be alleviated by development of reliable irrigation, effective implementation of land reforms and redistribution of surplus land to the landless and poor, modern technology suited to rainfed ecosystems, creation of non-farm employment opportunities, and effective implementation of family planning	Janaiah *et al*. (2000)
Investments in several areas [not in order/rank] – population control – agrarian/land reforms – education – modern technology – irrigation	Bihar, India The study concludes that poverty can be alleviated by effective population control in rural areas, effective implementation of various agrarian reforms to make cultivated land accessible to marginal and landless households, improving education, development and diffusion of modern technology and development of better infrastructure, especially reliable irrigation	Thakur *et al*. (2000)

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Table AIV. (Continued)

Interventions ranking	Description/conclusions/remarks	Authors
Investments in several areas [not in order/rank] – population growth – intensification of rice – irrigation – other infrastructure – education	Rural Vietnam: They suggest that rural poverty can be alleviated by controlling population growth, intensifying rice farming, developing irrigation and other infrastructure and developing human capital (education)	Ut *et al*. (2000)
Investments in several areas [not in order/rank] – education – irrigation – land reforms – non-land asset base	Rural Philippines The study concludes that rural poverty can be reduced by more investments in education and reliable irrigation infrastructure, effective implementation of land reforms to enable the landless and tenants to have access to land, and by strengthening the non-land fixed asset base of rural households	Hossain, Gascon and Marciano (2000)

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