IRRIGATION AND DRAINAGE
Irrig. and Drain. **53**: 1–15 (2004)
Published online in Wiley InterScience (www.interscience.wiley.com). **DOI**: 10.1002/ird.114

IRRIGATION AND POVERTY ALLEVIATION: REVIEW OF THE EMPIRICAL EVIDENCE†

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ABSTRACT

The purpose of this study is to clarify the linkages between irrigation and poverty by offering an objective review of recent research on the subject. The key questions addressed herein are: (1) what is the role of irrigation development and management in poverty alleviation? (2) what are the linkages and pathways through which irrigation contributes to poverty alleviation? (3) what is the magnitude of anti-poverty impacts of irrigation? and (4) what are key determinants of anti-poverty impacts of irrigation? Our review focuses on topical empirical research studies in Asia.

The extensive review suggests that there are strong linkages between irrigation and poverty. These linkages are both direct and indirect. Direct linkages operate via localized and household-level effects, and indirect linkages operate via aggregate or subnational and national level impacts. Irrigation benefits the poor though higher production, higher yields, lower risk of crop failure, and higher and year-round farm and nonfarm employment. Irrigation enables smallholders to adopt more diversified cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production. Increased production makes food available and affordable for the poor.

The indirect linkages operate via regional, national, and economy-wide effects. Irrigation investments act as production and supply shifters, and have a strong positive effect on growth, benefiting the poor in the long run. Further, irrigation benefits also accrue to the poor and landless in the long run, although in the short run relative benefits to the landless and land-poor may be small, as the allocation of water often tends to be land-based. Despite that, the poor and landless benefit, in both absolute and relative terms, from irrigation investments. Recent advances in irrigation technologies, such as micro-irrigation systems, have strong anti-poverty potential.

Ongoing studies in Asian countries document strong evidence that irrigation helps to alleviate both permanent and temporary poverty. Further, it helps to alleviate poverty in its worst forms, namely chronic poverty. In general, irrigation is productivity enhancing, growth promoting, and poverty reducing. Instances of negative externality effects associated with large and medium-scale irrigation systems point to management issues, and therefore call for more comprehensive response mechanisms from the planning and the political community alike. The anti-poverty impacts of irrigation can be intensified by creating conditions or enabling environments that could achieve *functional* inclusion of the poor. These include: (1) equitable access to land; (2) integrated water resource management; (3) access to and adequacy of good quality surface and groundwater; (4) modern production technology, (5) shift to high-value market-oriented production; and (6) opportunities for the sale of farm outputs at low transaction costs. The benefits of irrigation to the poor can be intensified by initiating broader level and targeted interventions simultaneously. Copyright © 2004 John Wiley & Sons, Ltd.

KEY WORDS: irrigation; agriculture; chronic poverty; transient poverty; pro-poor interventions; India; Pakistan; Sri Lanka; Asia

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† Irrigation et réduction de la pauvreté: une revue des faits empiriques.

Received 19 February 2002
Revised 9 October 2003
Accepted 15 November 2003

RÉSUMÉ

L'objectif de cette étude est de clarifier les relations entre l'irrigation et la pauvreté en offrant une revue objective de la recherche récente sur le sujet. Les questions clés abordées ici sont: (1) quel est le rôle du développement et de la gestion de l'irrigation sur la réduction de la pauvreté? (2) quels sont les articulations et chemins par lesquels l'irrigation contribue à réduire la pauvreté? (3) quelle est l'ampleur des impacts anti-pauvreté de l'irrigation? et (4) quels sont les facteurs clés des impacts anti-pauvreté de l'irrigation? Notre revue se focalise sur des études empiriques d'actualité en Asie.

La revue approfondie entreprise suggère qu'il y a de fortes connections entre l'irrigation et la pauvreté. Ces connections sont à la fois directes et indirectes. Les connections directes agissent à travers des effets localisés et à l'échelle des foyers, tandis que les connections indirectes opèrent à travers des impacts collectifs ou à l'échelle sub-nationale et nationale. L'irrigation bénéficie aux pauvres par le biais d'une production accrue, de rendements plus élevés, d'un plus faible risque d'échec cultural et d'une meilleure situation de l'emploi tout au long de l'année, dans les exploitations comme en dehors. L'irrigation permet aux petits producteurs d'adopter des cultures plus diversifiées et de passer d'une production de subsistance, de faible valeur, à une production de forte valeur, orientée vers le marché. L'augmentation de la production donne accès aux pauvres à une nourriture abordable.

Les connections indirectes opèrent à travers des effets à l'échelle régionale, nationale et de l'économie. Les investissements en irrigation agissent comme des modificateurs de production et d'approvisionnement, et ont d'importants effets positifs sur la croissance, bénéficiant aux pauvres sur le long terme. Au-delà de ceci, les bénéfices de l'irrigation reviennent aussi aux pauvres et sans-terres sur le long terme, malgré le fait que, sur un plus court terme, les bénéfices vers ceux qui n'ont pas ou peu de terres peuvent être faibles du fait que l'allocation de l'eau tend à être basée sur les terres. En dépit de cela, les pauvres et sans-terres bénéficient, à la fois en termes absolus et relatifs, des investissements en irrigation. De récentes avancées dans les technologies d'irrigation, par exemple les systèmes de micro-irrigation, ont un fort potentiel anti-pauvreté.

Des études en cours dans des pays asiatiques supportent fortement le fait que l'irrigation aide à réduire à la fois la pauvreté permanente et temporaire. Au-delà de ceci, l'irrigation aide à alléger la pauvreté dans ses pires formes, nommément la pauvreté chronique. En général, l'irrigation augmente la productivité, favorise la croissance et réduit la pauvreté. Des exemples d'effets d'externalités négatives associés à des systèmes irrigués de grande et moyenne échelle pointent vers des problèmes de gestion, appelant par conséquent à des mécanismes de réponse plus englobants de la part des communautés politiques et de gestion. Les impacts anti-pauvreté de l'irrigation peuvent être intensifiés en créant les conditions ou les environnements qui permettraient de réaliser une inclusion *fonctionnelle* des pauvres. Ces conditions et environnements comprennent: (1) un accès équitable à la terre; (2) une gestion intégrée des ressources en eau; (3) un accès à de l'eau de surface et souterraine de bonne qualité et en quantité adéquate; (4) une technologie moderne de production; (5) un passage à une production à forte valeur ajoutée, orientée vers le marché; et (6) des opportunités pour la vente des produits agricoles à faibles coûts transactionnels. Les bénéfices de l'irrigation aux pauvres peuvent être intensifiés en initiant simultanément des interventions ciblées et à plus large spectre. Copyright © 2004 John Wiley & Sons, Ltd.

MOTS CLÉS: irrigation; agriculture; pauvreté chronique; pauvreté transitoire; interventions en faveur des pauvres; Inde; Pakistan; Sri Lanka; Asie

BACKDROP

Irrigated agriculture has expanded significantly over the past five decades. World irrigated areas have almost doubled from 139 million ha in the 1961 to over 273 million ha in 2001. Much of this expansion has taken place in developing Asia, with India, China and Pakistan accounting for around 48% of the total irrigated area (IWMI, 2002). While investments in large-scale canal irrigation systems have slowed down after peaking in the 1970s, private investments in groundwater increased significantly during the 1980s and 1990s. Much of the growth in groundwater development has taken place in areas of canal irrigation development, generally referred to as favored areas.

Past interventions in irrigated agriculture have yielded immense benefits to those societies. In Asia, cereal production has more than doubled, between 1970 and 1995, from 300 million tons to 650 million tons. This

remarkable growth in food production was largely attributed to the growth in irrigated agriculture, coupled with the use of high-yielding varieties and fertilizers. At present, about 40% of the cropland in Asia is irrigated and accounts for about 70% of total cereal production. Irrigation is believed to have benefited the population by providing more food at reduced prices.

Despite these achievements, there are vast irrigated areas where agricultural productivity levels continue to remain low, notably in South Asia. Such low productivity areas are characterized by persistent rural poverty. There seems to be a general consensus that improving agriculture and enhancing agricultural productivity will remain a key strategy for rural poverty alleviation in most of the low income counties, where the majority of the rural poor depend directly or indirectly on agriculture. Improved access to food by the poor through their own increased production or enhanced purchasing power and economic ability to buy food would be the most effective way to move poor people out of poverty, particularly in low productivity areas.

Consequently, attention is now being drawn to poverty-stricken agricultural areas, where productivity level is low but potential for increasing productivity is high. Recent analyses of returns to public investments in less favored areas in China and India suggest that attractive opportunities exist for reducing poverty through investments in these areas. These investments would offer win–win opportunities for achieving more production growth and greater poverty reduction (Fan *et al.*, 2002; Fan *et al.*, 2000a,b).

Many of the low productivity areas may be classified as ''economically'' water-scarce areas (areas where water is not a limiting factor but they lack financial means to develop the available resources), and irrigation development is being suggested as a key strategy to enhance agricultural productivity. Examples of high potential areas include the Indo-Ganges basin, home to over 500 million people (many of whom are the among the poorest in the world), and many areas in sub-Saharan Africa (Molden *et al.*, 2001; Shah *et al.*, 2000).While the debate on such investments is underway, fundamental questions are being raised over the role of irrigation development in poverty alleviation.

OBJECTIVES

The objective of this paper is to contribute to resolving the debate on development and management of water resources by clarifying the linkages between irrigation and poverty and by offering an objective review of recent research on the subject. The key questions addressed in the paper include: (a) what is the role of irrigation development and management in poverty alleviation? (b) what are the linkages and pathways through which irrigation contributes to poverty reduction? (c) what is the magnitude of anti-poverty impacts of irrigation? and (d) what are the key determinants of anti-poverty impacts of irrigation or what are the conditions for enhancing the anti-poverty impacts of irrigation?

The paper is organized as follows. After the background and study objectives, the second part presents an overview of the role of irrigation in poverty alleviation, identifies key linkages, pathways and mechanisms through which irrigation contributes to poverty reduction—offering a framework for looking at the irrigation–poverty nexus. A review of the empirical evidence on the impacts of irrigation on poverty with a focus on recent research work is presented in part 3, followed by summary of conclusions and implications.

WATER–POVERTY NEXUS

Land and water are two key natural resources upon which poor people depend for their livelihoods, and often more heavily than the non-poor. Poverty is an outcome of complex interactions of these and other resources, institutions, actions and policies and their ultimate outcomes. It would be naïve to perceive that all rural poverty problems could be solved through improving the poor's access to water alone. However, though water is only a single element in the poverty equation, it plays a disproportionately powerful role through its wider impacts on such factors as food production, hygiene, sanitation, food security, and the environment. Indeed, development agencies, groups, and experts worldwide are increasingly recognizing the important impact that water can have on poverty.

Various uses of water, for domestic, industrial and commercial, agricultural and environmental uses, are linked to each other, and water use for one purpose often conflicts with use for others. The conflicts and competition

across these uses are growing with increasing populations, rapid urbanization and expanding economic activities. This is why the Integrated Water Resources Management (IWRM) approach has been greatly emphasized in recent years. In this paper, we do not go into the details of sectoral competition for water use which can be found elsewhere (GWP, 2000), but rather focus on establishing linkages between these uses and poverty.

Within the water and poverty debate, irrigation water holds a unique place. While solutions to other dimensions of the water and poverty problem such as sanitation, hygiene, and potable supplies generally call for increased expansion of services, the agricultural water/irrigation problem requires drastic improvements in existing services.

Irrigation–poverty linkages

Within agriculture, irrigation water is a vital resource for many productive and livelihood activities. As a production input in agriculture, irrigation water is an important socioeconomic ''good'', with a positive role in poverty alleviation. Irrigation water can also become a socioeconomic ''bad'' when it leads to problems such as waterborne diseases (malaria, schistosomiasis), and land degradation including waterlogging and salinity, water pollution and associated destruction of living beings and natural ecosystems (negative externalities associated with irrigation). The poor population, which with limited resources remain unable to adopt preventive or defensive measures, are most affected by consequences of water as a socioeconomic ''bad''.

Access to reliable irrigation water can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, overall higher production, and greater returns from farming. This, in turn, opens up new employment opportunities, both on-farm and off-farm, and can improve incomes, livelihoods, and the quality of life in rural areas. Overall, irrigation water, like land, can have an important income-generating function in agriculture specifically, and in rural settings in general.

We identify five key dimensions of how access to good irrigation water contributes to socioeconomic uplift of rural communities and alleviates poverty. These are production, income and consumption, employment, food security, and other social impacts contributing to overall improved welfare. These poverty-reducing variables are interrelated. In general, access to good irrigation allows poor people to not only increase their production and incomes, but also enhances their opportunities to diversify their income base, and to reduce their vulnerability to the seasonality of agricultural production and external shocks. It should be noted that the poor also use water for other farm and non-farm production activities, particularly small-scale rural enterprises such as livestock rearing, fish production, brick making and so on. These enterprises are part of the poor's livelihood strategies and contribute to poverty alleviation. Thus, access to good irrigation water can contribute to poverty reduction, and to moving people from ill-being to well-being as shown in Figure 1.

Further, we identify three main pathways through which irrigation impacts poverty. These are:

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

These pathways are very much interlinked. What happens on one particular pathway does have impacts on others.

Micro-pathway

Irrigation enables the poor and smallholders to achieve higher yields. The productivity of crops grown under irrigated conditions is often substantially higher than that of the same crops under unirrigated/rainfed conditions. Higher productivity helps to increase returns to farmers' endowments of land and labor resources. Apart from yield improvements, higher productivity partly stems from higher land use intensity and cropping intensity. Irrigation affects cropping intensity positively (Dahawan and Datta, 1992). Farmers in many parts of India and Bangladesh

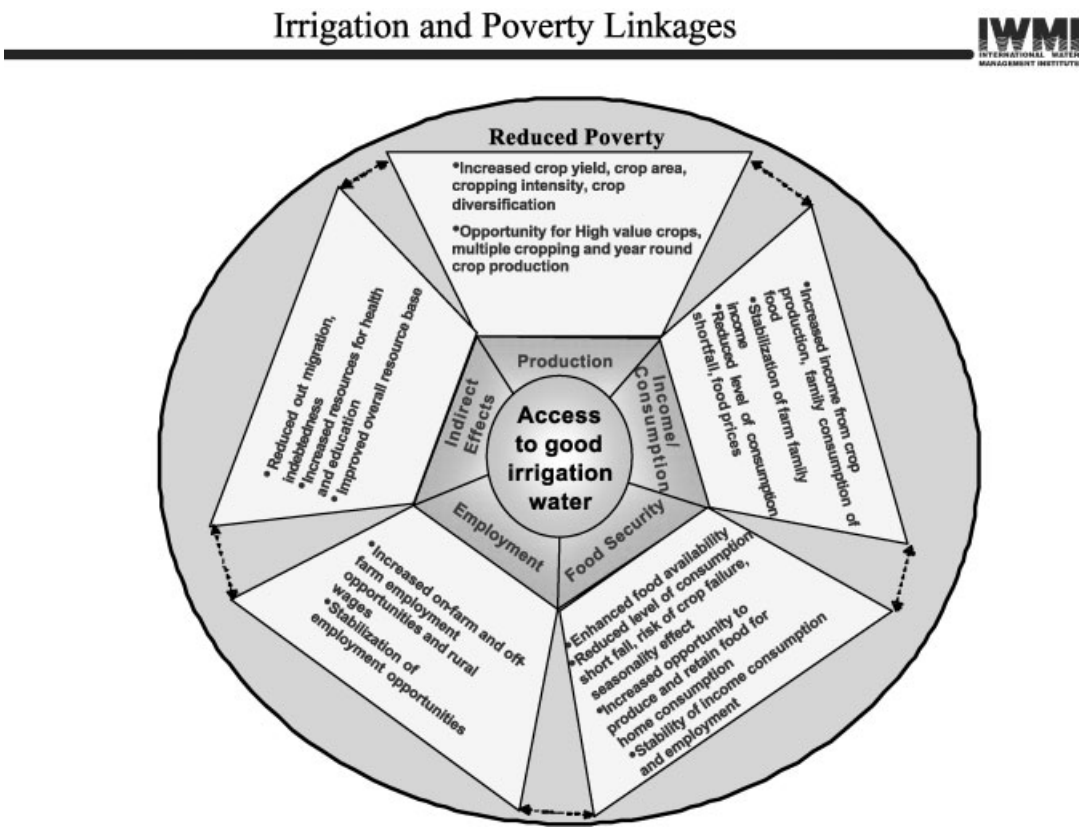

Figure 1. Agricultural water and poverty linkages

are known to raise three irrigated rice crops per year (namely *boro*, *aman*, and *aus* rice), unlike their rainfed counterparts who can hardly grow one crop. High cropping intensity implies land augmentation by the poor, i.e., they can grow several crops per year from the same plot of land under irrigated conditions. Access to good irrigation enables *crop-switching*: substituting low-yielding and low-profitable crops with *new* high-yielding and more profitable crops. Implicitly, this implies switching from subsistence production to market-oriented production. Further, crops can be grown year-round. Thus irrigation culminates in what is commonly known as crop diversification, and enables the poor and smallholders to spread risk more evenly over the course of a year (Reardon and Taylor, 1996). In fact, crop diversification is both an income maximization and risk minimization strategy. The role of irrigation in enabling the adoption of green revolution technologies, including modern varieties of rice and wheat in Asia, and their effects on income, employment, prices, food security and overall growth, are well documented in the development literature.

Increased employment for the poor may originate from the labor-intensive nature of irrigation developments/construction and subsequent maintenance, and from intensive cultivation both on their own farm, as well as on the farms of other large farmers who may find it difficult to provide extra labor from family resources during peak times. Additional employment opportunities may come from nonfarm activities generated through increased demand for inputs and increased supply of outputs. This helps to improve and stabilize wages, and in particular enables the poor to negotiate their wage terms with their employers. The poor can garner opportunities by participating in the local labor and goods markets—the transition to the market economy places the poor on a level playing field with the others (presumably the non-poor), and also enables them to participate effectively in nonlabor markets and earn higher nonfarm incomes. Rising wage incomes are particularly important for the landless. These mechanisms may result in higher permanent incomes for the poor. Higher permanent incomes help to reduce chronic poverty, while stable incomes help to reduce transient poverty that arises from income

fluctuations. These direct effects of irrigation may, however, be distributed inequitably at least initially. As the benefits of irrigation infrastructure are closely tied to the ownership of land, the first-generation beneficiaries tend to be large, medium, and small landowners respectively. The landless may benefit in the long run in several other forms, through increased employment, higher and stable wages, and lower food prices.

Crop intensification, diversification, and market-oriented production make food available and affordable for the poor and rich alike. Nevertheless, the main beneficiaries of low and stable food prices are the poor and landless households in rural areas and the urban poor, as they tend to be net buyers of food and spend a major part of their monthly expenditure, up to three-quarters, on basic food. Due to poverty-related resource constraints, nonfood expenditure, recreation, health, education, and the environment tend to be reflected in decreasing order in the poor's budget calculus. Better and affordable food improves nutrition and health, which in turn has a favorable impact on learning capabilities and skills of the poor. Higher incomes improve human capital formation, which in turn improves productivity and returns to human capital and physical endowments.

Meso-pathway

The micro-pathway operationalizes the meso- and macro-pathways. The meso-pathway works at the local, community and regional levels and refers mainly to the secondary benefits of irrigation. For example, the effects of additional employment may spill over to landless workers in adjoining rainfed areas, who may migrate to irrigated areas to take advantage of the employment opportunities. Landless households in Bihar are known to be a major source of labor for Punjabi agriculture in India. Similarly higher wage and lower food prices benefit the general community, let alone the irrigated community. Further, development of irrigation infrastructure eventuates in supply and provision of other infrastructure. For example, an irrigation infrastructure funding decision influences both government and private sector decision making. Governments tend to allocate more resources and infrastructure facilities to high-potential favored areas to enhance their political interests. Financial institutions, such as banks, respond to similar incentives and tend to open their branches to these high-potential areas, which in turn may become nuclei of growth. This sets into motion a *process* of market integration and technological transformation, which makes modern infrastructure and financial services accessible to the poor. Access to low-cost institutional credit has strong productivity-enhancing and consumption-smoothing effects, which has significant influence on poverty.

Access to irrigation facilities helps improve participation and decision making by the poor, at both micro- and meso-levels. This is particularly true in settings with farmer-managed irrigation systems. Farmers' involvement in irrigation management and decision making delivers direct benefits at farm household level, and indirect benefits at system level. Household-level benefits accrue in terms of higher water productivity, profitability, and labor savings due to higher water use efficiency, improved maintenance, and accountability in system management. These effects may translate into system-wide benefits, thereby improving the overall performance of irrigation systems and promoting its sustainability. The decentralization of authority, and user participation in irrigation management, may help improve productivity, efficiency, and equity. This in turn encourages institutional change, improves decision making, and promotes transparency and accountability. Even partial reforms can deliver sizable monetary gains. For example, Svendsen (1993) shows that the removal of the operating subsidy in the canal irrigation system in the Philippines helped to reduce staffing levels, lower operating costs with no rise in fees, increased the billable area and revenue, and saved financial resources (subsidy payments) that could be spent elsewhere, say on poverty alleviation programs. Further, it improved equity in irrigation distribution equivalent to a 13% increase in irrigated area, all with attendant effects on productivity and sustainability of the irrigation system.

Multiple uses of irrigation water and irrigation infrastructure provide significant benefits to the landowners and land poor alike at the community/regional level. For example, in canal command areas of Pakistan, canal water is used as a source of domestic water supply, and this is particularly the case in parts of Punjab and Sindh provinces where groundwater is brackish and a public water supply network is not available (Jensen *et al.*, 1998). People in these areas depend upon irrigation water for all their requirements, including agriculture, domestic, and livestock water uses. Several other studies, including those in Sri Lanka, have hinted at multiple uses of irrigation water (Meinzen-Dick and van der Hoek, 2001; Bakker *et al.*, 1999; Meinzen-Dick and Bakker, 1999; van der Hoek *et al.*, 1999).

Macro-pathway

The macro-pathway works at the national and transnational or global level. It is widely acknowledged that economic growth is important for poverty alleviation. As long as irrigation infrastructure development can induce technological change and trigger economic growth, it should contribute to poverty alleviation. Economic growth helps to raise long-term or permanent incomes, and is therefore a necessary condition to pull poor people out of poverty permanently, although it is by no means a sufficient condition. For example, the poverty impact of growth could be eaten up if population growth rates are very high. As most of the poor live in rural areas, growth must be in those areas and activities that directly benefit the poor.

There is a considerable body of literature that suggests that agricultural growth serves as an ''engine'' of economic growth, and irrigation-led technological changes are the key driver behind productivity growth in the agriculture sector in Asia and elsewhere. This is due to its potential to increase overall food grain productivity, employment and income, and thereby alleviate poverty and hunger. The productivity growth can help to alleviate poverty via (1) a growth component and (2) a distribution component. The growth impact of technological change is well accepted, however, the distributional impact of technological change is controversial. There are studies which contend that green-revolution technology has been distributional neutral, while others contend that technology is inherently biased against the poor and landless. The distributional impacts of modern agricultural technology become clear from Freebairn (1995), whose synthesis of the results of 307 studies undertaken during 1970–89 reveals that about 80% of the studies conclude that new technology widened both intrafarm and interregional income inequalities. However, the conclusions reached by those studies are influenced by methodologies employed and study settings, etc. Asian authors using case study methodologies in India, Bangladesh or the Philippines are more likely to conclude that increasing income inequality is not associated with new technology. New technology may benefit the poor in the long run in two ways. First, by reducing the cost of production and lowering food prices, on which poor spend most of their income, and second by generating more nonfarm employment opportunities by suppressing real wages and stimulating demand for nonfarm goods and services. The poor may enter into these new markets both as purchasers of goods and services or sellers of their products and surplus labor to other sectors.

Datt and Ravallion (1998) show that higher agricultural productivity has delivered both absolute and relative gains to the rural poor in India. A share of these gains was via the growth component or wages and lower food prices rather than improved distribution. The benefits of higher yields and productivity growth to the poor were not confined to those near the poverty line but reached deeper. Further, the study finds that due to wage price stickiness short-term gains to the poor are far lower than the long-term gains. In fact, short-term effects operating via wages and prices are minor compared to those emanating through other pathways (meso and macro). Overall, long-term elasticity of poverty to yield increase is five times higher than short-run values. Clearly the study documents empirical evidence, using data for the 1958–94 period, that higher real wages and higher farm yields reduce poverty, and with about the same effect. This implies that it is higher yield (food security) combined with higher wages (supplemental income security) that matters for poverty alleviation. Thirtle *et al.* (2001) found that for a sample of 40 countries, the elasticity of incidence of poverty to agricultural productivity growth was about 1%, that is, the percentage of those living below the dollar a day poverty line fell by close to 1% for every percentage increase in agricultural productivity. These empirical analyses help to establish an inverse relationship between poverty and agricultural productivity growth.

How well the benefits of productivity growth are spread across other sectors depends on linkages with rest of the economy and the magnitude of national multipliers. Higher real agricultural income generates demand for goods and services both within and outside this sector. Higher agricultural output/supply stimulates the creation of nonfarm employment, through backward and forward linkages, to services and manufacturing sectors, etc. Thirtle *et al.* (2001) categorize these linkages into: (a) production linkages—higher demand for agricultural inputs and services, including processing, storage, and transportation; (b) consumption linkages—higher demand for consumer goods backed by higher ability to spend and willingness to spend (higher real disposable incomes); and (c) human capital linkages—higher income and food consumption culminating in better nutrition, health, and human capital formation.

Economy-wide farm to nonfarm income multipliers vary considerably. Haggblade *et al.* (1991) cite an income multiplier of 1.71 for the Muda Valley irrigation development project in Malaysia (Goldman and Squire, 1982),

which implies that a dollar increase in agricultural income will generate an additional 71 cents in rural nonfarm goods and services. Bhattarai *et al.* (2002) estimate that the aggregate irrigation multiplier operating in India is about 3.15, which means that each US$100 benefit generated by irrigated cropland will generate another US$215 in the local economy as an induced effect. While the irrigation multipliers may vary from country to country, it helps to make the point that agricultural productivity growth delivers large benefits to the rural communities, including the poor, and a large share of these benefits accrues via indirect channels and in the long term.

IRRIGATION AND OTHER INFRASTRUCTURE—COMPLEMENTARITIES

There exist strong complementarities between irrigation and other forms of rural infrastructure. Recent analyses of poverty and inequality indicate strong interactions that exist between physical infrastructure and human capital. A strand of literature has established links between physical infrastructure, productivity, and welfare levels of households. Canning and Bennathan (2000) explicitly show that there are strong complementarities between physical and human capital investments, and the former face rapidly diminishing returns if increased in isolation. Using Indian state-level time-series data for the period 1957–91, Datt and Ravallion (1998) demonstrate that states with higher initial investments in physical and human infrastructure have performed better in promoting growth and alleviating poverty than poorly endowed states. They note that differences in trend rates of poverty reduction (measured as squared poverty gap) are attributed to differing growth rates of yield per acre, an indicator for technological progress in agriculture, and differing initial conditions. Post-independence or initial endowments of physical infrastructure and human capital appear to have played a major role in explaining the intertemporal trends in poverty: higher initial irrigation intensity, higher initial literacy, and lower initial infant mortality rates *all* contributed to higher long-term rates of poverty reduction. For example, states with smaller irrigated areas such as Maharashtra achieved lower reduction in poverty than states with greater irrigated areas such as Punjab and Haryana. Evidently, the differences in poverty outcomes are due to differences in initial conditions of physical and human capital resources, or past spending priorities, rather than inequitable growth and distributional outcomes. The authors contend that states with low levels of initial rural development were not well suited to achieve large reductions in poverty through economic growth (Datt and Ravallion, 1997, 2002).

Binswanger *et al.* (1993) show that there are complementarities among investment decisions of government, financial institutions, and farmers and these in turn affect growth rates and aggregate agricultural output. Investments in canal irrigation, primary education, rural electrification and commercial banks have all contributed to increased crop output over the 1971–81 decade in India. This study helps us to move further on the learning curve by showing that agricultural output, and therefore income level, is determined by a complex interactive process where the agents (state–public–markets) respond to the same set of incentives; while farmers respond to infrastructure investments, the governments in turn allocate infrastructure investments in accordance with the agroclimatic potential of the districts (but hardly on equity grounds), and banks locate their branches where agroclimate and infrastructure conditions are favorable for their financial operations. Then there is the question of strong complementarities between public and private investments in irrigation infrastructure and the agriculture sector which do have strong equity implications for the poor. Using area under canal irrigation as an indicator of public investment, Rao (1998) established that the complementarities between public and private investments stand out prominently.

The strong complementarities between returns to irrigation and household education, particularly adult primary education, have been uncovered by van de Walle (2000) in the case of rural Vietnam. The study hints at the pro-poor character of irrigation investments, given the right economic environment. It shows that increased investments in adult education would generate gains accruing primarily to the poor and would have a strong equalizing effect on returns to irrigation investments, that is, returns to irrigation would be higher for the poor than non-poor, given the right level of adult education. Therefore, a properly targeted adult education program in Vietnam would have a ''substantial equalizing effect'' through its impact on returns to irrigation investments. Conversely, in the presence of inequalities in educational endowments, returns to irrigation for the poor are likely to remain lower: knowledge-poor will remain income-poor.

In a state of the art study Mundlak *et al.* (2002) analyzed the effect of infrastructure variables, inputs, and price incentives on agricultural growth in Indonesia (1971–98), the Philippines (1961–98), and Thailand (1971–95). The infrastructure variables included in the growth model are roads, representing physical infrastructure, and indicators of education and health, representing human capital endowments. The education variable is given by thepercentage of agricultural workers with no schooling for Indonesia and Thailand and as the mean accumulated school years of the total labor force (% schooling) for the Philippines. The infant mortality rates capture the level of health. The input variables include irrigated land, rainfed land, fertilizers, capital, and labor. The incentive variables are prices and shadow prices. The dependent variable is the log of value added. The results show that roads infrastructure accounted for 11–15% of the output growth in Thailand and Indonesia. Schooling and infant mortality had a similar contribution, with some variability over time. The infrastructure variables together accounted for a large proportion of total factor productivity growth in all three countries, which should have significant anti-poverty impacts. Further, the second-generation or multiplier effects should generate higher employment and incomes for the poor and non-poor. The analysis shows that irrigated land contributed between 10 and 16% of output growth.

SOME ISSUES

There are some critical issues related to irrigation development and management, which are important to be highlighted here. Upstream developments and overabstraction of water supplies can affect the welfare of downstream users negatively. Taking the case of the Dalia barrage (Bangladesh), Higano and Islam (2002) show how the operation of the Gazoldoba barrage upstream (India) has affected the livelihoods of farmers in Bangladesh. Cross-boundary coordination failure is causing a reduction in agricultural production/land, loss of fish, flash floods, and transportation problems in the short run. This situation is compounded by poor canal design and faulty structures, inequity in water distribution, untimely water deliveries, and insufficiency of irrigation water, with consequent loss of agricultural productivity and livelihood for the poor. The long-term impacts may include conversion of fertile land to wasteland, annual economic loss of over half a billion dollars in agricultural production, fisheries, and navigation and use of arsenic contaminated groundwater for irrigation which could create serious health hazards. Overall, an estimated 21 million people would be affected through economic and environmental ruin of this ''*man-made disaster*''.

Some studies have highlighted negative environmental externality effects of irrigation. The main concerns are related to poor drainage, waterlogging and salinity in large irrigated systems, which have the potential to cause loss of soil fertility and productivity with consequent adverse impacts for the poor and regional economies. Taking the case of the Indira Gandhi canal command areas in Rajhastan, India, Jaglan and Qureshi (1996) document evidence of rising water tables and high incidence of irrigation-induced alkalinity. Soil salinity poses real constraints on agricultural productivity and economic livelihoods of Pakistani farmers. However, existing soil reclamation technologies are more traditional and costly, and during recent decades new technologies to combat soil salinity have not been widely disseminated.

Irrigation-induced green-revolution technology, due to its labor-saving and capital-intensive nature, is sometimes perceived to disfavor the poor. However, a more serious concern relates to inequity in irrigation water distribution and its impacts on productivity and livelihoods for the tail-end farmers in large-scale canal irrigation systems. Using panel data from wheat farms in canal command areas of the Chaj sub-basin of the Indus basin, Pakistan, Hussain *et al.* (forthcoming) document the existence of large head–tail inequities in irrigation distribution. Less access to surface water and poor quality of groundwater at the tail-ends reduce productivity and consequently have negative welfare impacts for the wheat farmers. Reallocation of canal water to areas with a deficit water supply, and in particular to tail-end locations with poor quality groundwater, is considered a poverty-reducing intervention.

In general, the distribution of benefits of irrigation among various socioeconomic groups is determined by the distribution of land resources. Where the distribution of land is skewed, as in India and Pakistan, large farmers benefit relatively more. On the other hand, if the distribution of land is relatively equal, for example irrigated land settlement schemes in Sri Lanka or the land distribution pattern in Chinese irrigation systems, the distribution of irrigation benefits tends to be more or less equal. The land poor also benefit, as the case studies by IDE (2002) in Bangladesh, India, Nepal, and in African countries show, that micro-irrigation technologies such as sprinkler, drip,

and trickle irrigation, self-target the poor, and empower them by enabling them to raise their incomes permanently. With modest investments of as little as US$15–25 per household, landless households can produce fruits and vegetables for family consumption or sale (Shah *et al.*, 2000). Landless households benefit indirectly through increased employment opportunities, both on-farm and in agribusiness enterprises and nonfarm.

These arguments serve to make the point that irrigation does offer opportunities for benefiting the landless and resource-poor households, although the incidence of these benefits may not always fall squarely on these households, due mainly to policy issues often unrelated to irrigation. This points out that pro-poor and anti-poverty impacts of irrigation infrastructure can be intensified through provision of complementary infrastructure and inputs and by adopting an all-inclusive approach in other policy areas.

There is some evidence that corruption can militate against the benefits of irrigation to small and poor farmers, particularly those located at the tail-ends. Wade (1982) in India, and more recently Rinaudo (2002) in Pakistan, provide a graphic account of how corruption can determine the allocation of water in large, public canal irrigation systems.

Taking the case of tank irrigation systems in Tamil Nadu, India, Brewer *et al.* (1997) show that *inflexibility* in water allocation rules, on the part of government agencies, goes against the economic and financial interest of the tail-end farmers, who in turn are obliged to undertake a variety of measures, varying from public agitation to political influence to bribery, thereby badly affecting the performance of irrigation system, agency in charge, and water users' associations alike. Making water allocation rules more responsive to seasonal crop water requirements and emerging needs, and farmer involvement in decision making, would help to resolve these issues and optimize the benefits of tank irrigation. These instances, whether sporadic or endemic, show that irrigation can be used as a pro-equity instrument if management is honest, adequately funded, and fair to all segments of society or by having water user associations with similar attributes.

Finally, the impact of irrigation on poverty also depends on how poverty is defined and measured. It is important to distinguish that even within ''*the poor*'' all poor are not the same: some are poor occasionally while others are often poor; and for each category of the poor, their distance from the poverty line is not the same; some are only marginally poor while others are severely poor, and often the former outnumber the latter. In other words, it is important to distinguish which component of poverty is chronic and what is transitory. Chronic poverty refers to a situation where an individual is poor as a result of long-term structural factors. Transient poverty refers to a situation where an individual is poor because of some temporary shocks which could be reversed over time. Often transient poverty constitutes a large proportion of total poverty. For example, Jalan and Ravallion (2000) found that 49.39% of the squared poverty gap in China is transient, while Gaiha and Deolalikar (1993) found that over nine years, chronic poverty accounted for only one-fifth of the total poverty in ICRISAT VLS panel of rural south India. In China, in some provinces, for example Guangdong, transient poverty accounts for 84.21% of total poverty. In estimating the impacts of irrigation on poverty, most studies define the poor in terms of numbers only, and estimate poverty at a single point in time. Such estimates mask the impacts of irrigation on the dynamics of poverty, including inter- and intraperiod income/expenditure-smoothing impacts of irrigation on temporary and permanent poverty.

In sum, while the importance of negative externality effects cannot, and should not, be underestimated, these have to be interpreted with care. It bears emphasizing that irrigation development, like all other development programs, has its spillovers and unintended negative impacts. These unintended impacts per se do not discount the effectiveness of irrigation developments in alleviating poverty, rather they point to the operational or *software* issues in irrigation management, and call for a more focused and informed response from the planning community and political governments alike.

EMPIRICAL EVIDENCE[1]

In this part, we provide a synthesis of empirical evidence on the impacts of irrigation on poverty. While the focus is on large and medium-scale irrigation systems, reference is also made to small-scale irrigation. An enormous

[1]This section is based on a comprehensive review of literature on irrigation and poverty. For details on numbers and quantitative evidence for the studies reviewed see Hussain and Hanjra (2003).

amount of literature exists that is directly or indirectly related to our subject. No attempt is made in this paper to review all the available literature, but rather we focus on more relevant recent material, covering mainly topical Asian studies.

The literature on the impacts of irrigation on poverty alleviation can be classified into three broad categories: (1) systematic empirical research measuring impacts with rigorous methods using primary or secondary data and information, focusing on specific locations; (2) general articles and papers based on common perceptions and logic; and (3) appraisals, evaluations, and assessments of projects, mostly undertaken by the funding agencies. Our review focuses on the first category, i.e. empirical research studies. Impact studies differ in terms of geographic coverage, scale of analyses, and approach adopted in measuring impacts. The scale of analyses varies in studies, ranging from household to village, region, national to international levels. The approaches adopted in various studies can be classified into three major categories: (1) ''before and after'' comparisons; (2) ''with and without'' comparisons; and (3) ''more and less'' comparisons—with econometric methods applied in most studies in all three categories. It should be noted that studies documenting concrete linkages between irrigation and poverty are rare, and more so in case of studies documenting indirect linkages between irrigation and poverty. Simultaneity and the concurrent nature of interventions and multiplicity of linkages pose methodological problems in assessing and separating impacts of irrigation interventions.

For brevity, we present here a synthesis of key findings and conclusions emerging from the review of the studies. For a more detailed review of empirical evidence on the impacts of irrigation on poverty reduction, based on (1) ''with'' and ''without'' comparisons of intermediate poverty-reducing indicators/variables—cropping intensity, crop productivity, and employment generation; (2) ''with'' and ''without'' comparisons of poverty-related indicators—employment, incomes, income inequality, and incidence of poverty; (3) econometric evidence on the nature, direction and magnitude of impacts of irrigation on poverty; and (4) evidence from earlier reviews and synthesis papers, see Hussain and Hanjra (2003).

As mentioned earlier, micro-level impacts are realized at farm, household, and local level, and these affect intermediate variables of poverty including cropping intensity, land and water productivity of crops, labor employment, and household income. A number of studies conducted in various settings and countries show that cropping intensity, crop productivity (principally rice, as per these studies) and per hectare employment are higher in irrigated than in rainfed settings. A comparative review of the studies shows that:

(a) cropping intensity, one of the intermediate indicators of poverty, is higher in the irrigated setting than the rainfed setting. Cropping intensity ranges between 111 and 242% in irrigated and 100 and 168% in the rainfed setting. The availability of irrigation facilities has therefore enabled farmers to raise nearly an extra crop a year, with consequent implications for household food security;
(b) irrigation has contributed to increase land productivity of major crops, including rice and wheat, the main staple foods of Asian rich and poor alike. For example, rice yields fall in the vicinity of 3.0–5.5 t ha^{-1} in irrigated settings, while the upper bound corresponding figure in rainfed settings is around 4.0 t ha^{-1}, implying that farmers can harvest an extra tonne per hectare of rice due to access to good irrigation water. Similarly, wheat yields are higher in the irrigated than the rainfed setting;
(c) labor employment per hectare, and wage rates, are higher in irrigated than nonirrigated settings. Further, the former serves as an employer of surplus labor of adjoining nonirrigated areas.

Although some studies have hinted at labor displacement under the influence of mechanization, these studies measure direct employment effects only, though indirect employment effects of irrigation may be much larger and often sufficient to counterbalance these *adjustments*.

Similarly, there is a body of empirical studies that show that household income is higher in the irrigated than the rainfed setting, and poverty is lower. Review of these studies shows that:

(a) although these studies do not use common income categories and yardsticks to allow meaningful comparisons, whatever the units used, income in irrigated settings is higher than in the rainfed, and a 50% point gap is not uncommon;

(b) also income inequality is lower in irrigated than rainfed settings, at least for these studies. The lower bound was almost the same, the upper bound Gini values are 0.53 and 0.61 for irrigated and rainfed settings, respectively;
(c) the studies unfailingly document evidence of lower poverty rates in irrigated than rainfed environments. For example, poverty head count ranges from 18 to 53% in irrigated and 21–66% in rainfed settings. Poverty incidence is 20–30% lower in most irrigated settings compared to that in rainfed settings. Studies using a dynamic concept of poverty, such as those by Hussain *et al.* (2002), show that the incidence of chronic poverty is 10% (5%) lower for irrigated areas in Sri Lanka (Pakistan) than adjoining rainfed areas. The extent of poverty, measured by the poverty gap index, where reported in these studies, is found to be much higher in rainfed than irrigated settings. This shows that the poor in rainfed areas are located relatively further below the poverty line, which implies that rainfed poor's income has to grow relatively faster and in many folds in order for them to catch up with the irrigated poor or escape poverty.

A number of studies have used econometric models to establish a irrigation–poverty nexus. Although irrigation infrastructure variables are defined differently (for example, as the ratio of irrigated area to cultivated/command area, access to irrigation, and modern variety–irrigation interaction term), almost all of these micro- and econometric studies show that irrigation is a positive determinant of income, a negative determinant of poverty, and households having access to irrigation (and complementary inputs) are less likely to be poor. While irrigation is a negative determinant of poverty, magnitude of the anti-poverty impact of irrigation varies across locations.

There is a set of selected synthesis articles and reviews focusing on the irrigation–poverty nexus. These include: David and Otsuka (1994), a synthesis of eight village-level studies from seven Asian countries including Bangladesh, China, India, Indonesia, Nepal, Philippines, and Thailand, using cross-sectional village- and household-level data collected during 1985–88; DFID (2001) reviews studies from South Asia, and particularly from Bangladesh and Nepal; FAO (1999), a conceptualization of benefits of irrigation to the poor with selected examples from global empirical literature, and a succinct menu of how to increase the benefits of irrigation to the poor; Freebairn (1995), an analysis of the results of 307 empirical studies undertaken during the period 1970–89 (post-green revolution) to investigate the effects of the green revolution; IDE (2002), a summary of research documents available from IDE (India), including studies conducted in Aurangabad and Bijapur, Cooch Bihar, Deccan Plateau, Gujarat, Himachal Pradesh, North Bihar, Uttar Pradesh, Orissa in India, Nepal Terai, and Bangladesh; Jayaraman and Lanjouw (1999), a review of 35 longitudinal village-level studies from Andhra Pradesh, Bihar, Gujarat, Karnataka, Kerala, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal in India; Kishore (2002), empirical studies on the socioeconomic impacts of canal irrigation in India, covering studies conducted over the past 30 years; Lipton *et al.* (2002), an extensive review of empirical studies on the direct and indirect impacts of irrigation on outputs, employment, prices, health, the environment, resource allocations, and its equity and poverty implications at micro- and macro-level; Silliman and Lenton (1985), a review of evidence from 45 micro-level irrigation studies, with 25 of these from India; Songco (2002), a survey of evaluations in subsectors of rural roads and transport, water supply and sanitation, energy, and irrigation, augmented by a case study conducted in two provinces in the Central Highlands of Vietnam; and von Braun (1995), a synthesis of long-term (1988–94) multi-country studies, conducted largely by IFPRI, in Bangladesh—Food-for-Work Program, China—Yigong-daizhen Program, India—Employment Guarantee Scheme of Maharashtra, and Botswana, Ethiopia, Tanzania, Niger, and Zimbabwe in Africa, and Bolivia, Chile, Costa Rica, Honduras, Mexico, and other countries in Latin America. These reviews and synthesis papers reaffirm the role of irrigation in enhancing crop intensification and productivity, generating employment, promoting growth, and enhancing and sustaining rural livelihoods.

SUMMARY, CONCLUSIONS AND IMPLICATIONS

The extensive review suggests that there are strong linkages between irrigation and poverty alleviation. These linkages are both direct and indirect. Direct linkages operate via localized and household-level effects, and indirect

linkages operate via aggregate or national level impacts. Irrigation benefits the poor though higher production, higher yields, lower risk of crop failure, and higher and year-round farm and nonfarm employment. Irrigation enables smallholders to adopt more diversified cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production. The transition to the market economy integrates the poor into land, labor, commodity, and information markets, and it empowers them. Increased production makes food available and affordable for the poor. The poor and landless are the main beneficiaries of low food prices as they are net buyers of food. The indirect linkages operate via regional, national, and economy-wide effects. Irrigation investments act as production and supply shifters, and have strong positive effects on economic growth, benefiting the poor in the long run. The magnitude of indirect economy-wide benefits could be even more than the direct and local and household-level benefits. Further, irrigation also benefits the poor and landless in the long run, although in the short run relative benefits to the landless and land-poor may be small, as the allocation of water often tends to be land-based. Land-based water allocation is inherently biased against the landless. Despite that, the poor and landless benefit, in both absolute and relative terms, from irrigation investments. Recent advances in irrigation technologies, such as micro-irrigation systems, have strong anti-poverty potential.

A comparative review of quantitative evidence gleaned from empirical studies on the poverty–irrigation nexus, leads us to conclude that cropping intensity, crop productivity, labor productivity and employment, and household income are all higher in irrigated than rainfed settings. More importantly, irrigation is a negative determinant of poverty, and incidence, depth, and severity of poverty are lower in irrigated than rainfed settings. For example, poverty head count ranges from 18 to 53% in irrigated and 21–66% in rainfed settings, with poverty incidence 20–30% less in irrigated settings. The picture regarding income distribution outcomes remains mixed, however, with inequality generally being lower in irrigated than rainfed areas, but with instances of rising income inequality, mainly in irrigated areas with high land inequality. Recent studies document strong evidence that irrigation helps to alleviate both permanent and temporary poverty. Further, it helps to alleviate poverty in its worst forms, namely chronic poverty. This supports the view that irrigation is productivity enhancing, growth promoting, and poverty reducing. Sporadic instances of the negative externality effects of irrigation point to the management or *software issues*, and call for a comprehensive response mechanism from the planning and political community alike.

We contend that the impact of irrigation on poverty will vary by agroclimatic conditions and institutional settings, and the magnitude of the impact of any irrigation intervention on poverty will depend on: (a) (in)equity in land distribution; (b) irrigation infrastructure condition/management; (c) irrigation water management/allocation, and distribution policies, procedures and practices; (d) quality of irrigation water; (e) production/cultivation technologies; cropping patterns, extent of crop diversification; (f) type of irrigation technology and (g) support measures (e.g. input and output marketing, information).

The anti-poverty impacts of irrigation can be intensified by creating conditions or enabling environments that could achieve *functional* inclusion of the poor. These include: (1) equitable access to land; (2) integrated water resource management; (3) access to and adequacy of good quality surface and groundwater; (4) modern production technology; (5) shift to high-value market-oriented production; and (6) opportunities for the sale of farm outputs at low transaction costs. To the extent that these conditions or enabling environments are lacking or imperfect, on-ground benefits of irrigation to the poor would continue to be discounted. In short, it is the ''package'' that matters for effective poverty alleviation, and not the mere supply of irrigation water. The benefits of irrigation to the poor can be enhanced by affecting broader-level and targeted interventions simultaneously. The interventions should focus on reaching out to the poor through improved economic, policy, institutional, and governance measures in irrigation and other sectors. Generating a knowledge base through multi-country studies on identifying and developing pro-poor interventions in irrigated agriculture is the first step to help identify the opportunities to serve the poor.

ACKNOWLEDGEMENTS

Special thanks go to Mr Nicolas Roost (International Water Management Institute) for French translation.

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