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DIRECT AND INDIRECT BENEFITS AND POTENTIAL DISBENEFITS OF IRRIGATION: EVIDENCE AND LESSONS[†]

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ABSTRACT

This paper is a part of the multi-country study carried out by the author at the International Water Management Institute (IWMI) in collaboration with national partners in six Asian countries (Bangladesh, China, India, Indonesia, Pakistan and Vietnam) during 2001–2002. Based mainly on primary data collected from 5400 households in 26 irrigation systems, the study examines in detail the benefits and potential disbenefits of irrigation. The results indicate that irrigation benefits vary widely across systems, and depend on a range of factors including local conditions, system management, irrigation policy, and broader economic and political factors. The study suggests that indirect irrigation benefits could be larger than direct benefits through the multiplier effect. The distribution of irrigation benefits also varies widely by type of the benefit and the socio-economic status of the beneficiaries. The direct benefits generally accrue to landholders while a significant part of the indirect benefits accrue to the landless and small farmers, positively contributing to their livelihoods. Further, the overall benefits of irrigation are large when irrigation-improving interventions, investments in infrastructure, improvements in system management and service delivery to farmers, are implemented in an integrated manner.

On the other hand, the paper also suggests that irrigation can also lead to some negative or adverse social, health and environmental impacts. Such potential disbenefits of irrigation include displacement of people as a result of new irrigation development, public health risks from water-related diseases, irrigation-induced land and water degradation, loss of biodiversity and river health risks from increased river water withdrawals for irrigation. Often, negative social and environmental consequences adversely affect the poor more than the non-poor people. Most potential adverse impacts of irrigation are not due to irrigation water per se, but due to inadequacies and ineffectiveness of institutions and management to address them. Moreover, many of the potential adverse impacts can be avoided or minimized with effective planning, design and management of the projects.

This paper develops and offers a generic typology of direct and indirect benefits and potential disbenefits of irrigation that can be used to identify and influence different types of irrigation benefits and disbenefits for enhancing net benefits to the poor. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: irrigation; benefits; potential disbenefits; landless; landholders; irrigation benefit typology; Bangladesh; China; India; Indonesia; Pakistan; Vietnam; Asia

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RÉSUMÉ

Cet article est un élément de l'étude internationale effectuée par l'auteur à l'Institut International de Gestion de l'Eau (IWMI) en collaboration avec des partenaires nationaux de six pays asiatiques (Bangladesh, Chine, Inde, Indonésie, Pakistan et Vietnam) en 2001–2002. Basée principalement sur des données primaires collectées auprès

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[†]Bénéfices, directs et indirects, et coûts potentiels de l'irrigation: preuves et leçons.

de 5400 ménages dans 26 systèmes d'irrigation, l'étude examine en détail les bénéfices et les coûts potentiels de l'irrigation. Les résultats indiquent que les bénéfices de l'irrigation diffèrent considérablement selon les systèmes, et dépendent d'une gamme de facteurs comprenant les conditions locales, la gestion du périmètre, la politique d'irrigation, et d'autres facteurs plus vastes d'ordre économique et politique. L'étude suggère que les avantages indirects de l'irrigation pourraient être supérieurs à ses avantages directs du fait de l'effet multiplicateur. La répartition des bénéfices de l'irrigation diffère également considérablement selon le type de bénéfice et le statut socio-économique des bénéficiaires. Les avantages directs vont généralement aux propriétaires fonciers tandis qu'une partie significative des avantages indirects va aux paysans sans terre et aux petits agriculteurs, avec un impact positif sur leurs modes de vie. De plus, les avantages globaux de l'irrigation sont grands quand les actions d'amélioration de l'irrigation, les investissements en infrastructure, les améliorations de gestion des périmètres et de prestation de services aux irrigants, sont mis en application d'une façon intégrée.

L'article suggère d'autre part que l'irrigation peut également avoir des impacts négatifs sur le plan social, sur la santé et sur l'environnement. Ces désavantages potentiels comprennent le déplacement des personnes causé par le nouveau projet d'irrigation, les risques de santé publique venant des maladies liées à l'eau, la dégradation des terres et de l'eau, les pertes de biodiversité et les risques sanitaires dans les cours d'eau du fait de prélèvements accrus pour l'irrigation. Souvent, les conséquences sociales et environnementales négatives frappent davantage les pauvres que les non-pauvres. La plupart des impacts défavorables potentiels de l'irrigation ne sont pas dus à l'eau d'irrigation proprement dite mais aux insuffisances et à l'inefficacité de l'organisation et de la gestion nécessaires pour les contrer. D'ailleurs, la plupart de ces impacts défavorables potentiels pourraient être évités ou minimisés avec une planification efficace, une bonne conception de projets et une gestion adéquate des systèmes irrigués.

Cet article développe et propose une typologie générique des avantages directs et indirects et des désavantages potentiels de l'irrigation qui peut être employée pour identifier et influencer différents types de bénéfices et de coûts de façon à augmenter les bénéfices nets allant aux pauvres. Copyright © 2007 John Wiley & Sons, Ltd.

MOTS CLÉS: irrigation; bénéfices; coûts potentiels; sans terre; propriétaire foncier; typologie des bénéfices de l'irrigation; Bangladesh; Chine; Inde; Indonésie; Pakistan; Vietnam; Asie

DIRECT AND INDIRECT BENEFITS OF IRRIGATION

As a vital resource in agriculture, irrigation generates a variety of benefits contributing to many productive and livelihood opportunities in rural settings. The benefits are generated through several processes, mechanisms and pathways. These include benefits from irrigation-induced crop intensification and diversification towards high-value crops leading to increased crop productivity and overall crop production; benefits derived through non-crop farm and non-farm uses of water including non-consumptive uses of water supplied by irrigation infrastructure; benefits arising from improved employment opportunities and higher wage rates; benefits through improved incomes and consumption expenditures, and enhanced food security; social benefits such as improved health and education; and benefits from expansion in economic activities in related sectors resulting in overall improved growth of regional and national economies. A part of these benefits is realized at the local level, while the other part occurs at the broader regional and national economy levels through what are generally referred to as *backward and forward* linkages of agriculture with other economic sectors (Figure 1). The degree and form of these linkages across settings are influenced by a range of factors, such as extent of rural infrastructure development, rural population density, the degree of local processing of farm produce, the nature of technical change in farming, and tradability of farm outputs. The total benefits of irrigation include direct or primary benefits occurring in local settings, indirect or secondary benefits occurring at the local and broader levels, and induced or tertiary benefits occurring in other sectors at the local and broader levels. The indirect and induced benefits together are generally referred to as *multiplier* benefits.

Direct production benefits

The direct productivity-related benefits derived from increases in average crop yield, ability to increase cropping intensity (the number of cropping per year per unit of land), and reductions in climatic risk which make investments in other inputs more profitable and allow selection of higher-yielding over drought-tolerant crop varieties.

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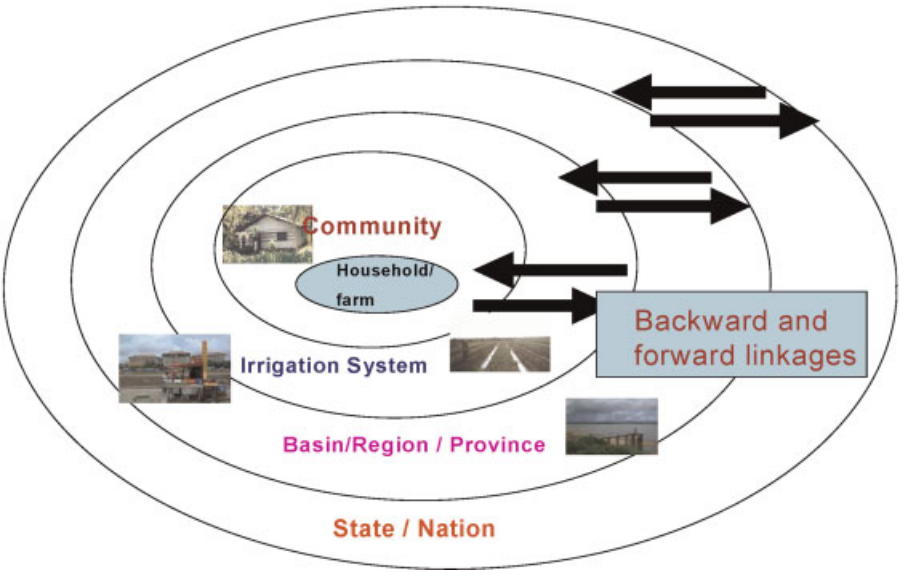

Figure 1. Backward and forward linkages in irrigated agriculture. This figure is available in colour online at www.interscience.wiley.com/journal/ird

Numerous studies provide evidence of the direct productivity-related benefits of irrigation (see Hasnip *et al*., 2001; Hussain and Hanjra, 2003 and 2004 for a detailed review of related studies). Our multi-country studies (China, Bangladesh, India, Indonesia, Pakistan, and Vietnam) showed that irrigated lands were twice as productive as non-irrigated reference areas,[1] the net productivity benefits (defined as the difference in net output values between irrigated and non-irrigated lands) varied widely across settings from US$23 to US$600 ha^{-1}, with benefits much lower in South Asian systems compared to those in China and Vietnam (Figure 2).

A range of factors can influence the net productivity benefits of irrigation. These can be categorized as: (a) farm-level factors (i.e. crop yield differences, differences in production methods and technologies; land quality, types of cropping patterns, and degree of diversification towards high-value crops and other farm enterprises; and farmers' access to support measures such as information, input and output marketing); (b) system-level factors (i.e. condition of irrigation infrastructure and its management/maintenance, irrigation water allocation and distribution procedures and practices and related institutions); and (c) related policies (i.e. policies that influence land distribution patterns

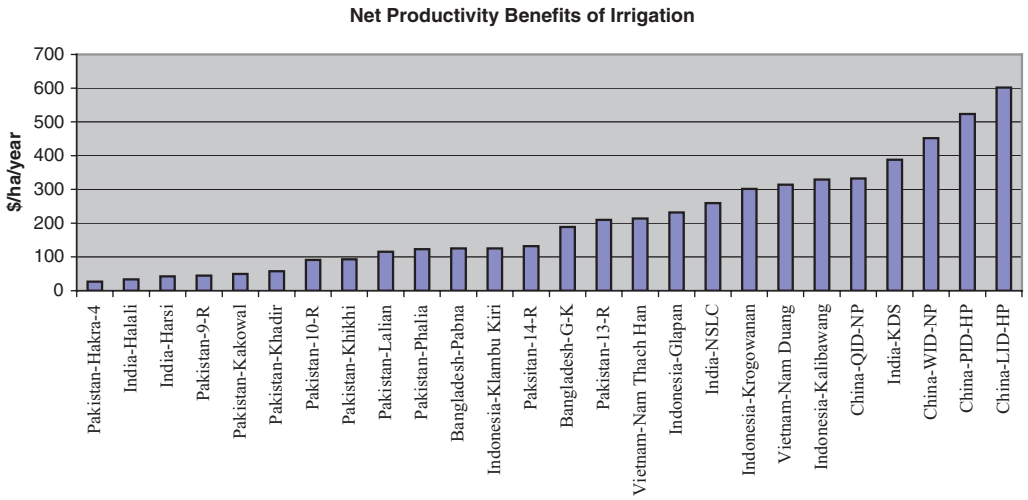

Figure 2. Net productivity benefits of irrigation. This figure is available in colour online at www.interscience.wiley.com/journal/ird

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(equitable/inequitable) and size of farms, and broader agricultural policies that influence access to agricultural support services and diversification of farm enterprises). In the 26 systems studied, irrigation benefits are generally large where crop productivity is higher due to higher yields and higher cropping intensity, farmers have better access to production inputs, management and maintenance of irrigation systems is relatively better, and where there is greater equity in land and water distribution across households and locations (as in Vietnam and China).

Direct employment benefits

The construction and maintenance of irrigation systems provide direct employment benefits, typically to those living in or near the systems. While employment related to construction can be considered a one-time impact for labourers and suppliers of construction inputs, employment benefits related to maintenance continue for the life of any system. The exact nature and magnitude of the benefits for local labour, of course, depend on how and from where financing is obtained, and the degree of labour intensity of methods of works carried out, which would vary from one setting to another.

Indirect employment and consumption benefits

Indirect local benefits from irrigation are primarily related to increased labour demand. Over the past three decades, a substantial body of empirical evidence has emerged on the relationship between irrigation-induced increases in agricultural production and employment. Silliman and Lenton (1985) and Chambers (1988) showed that irrigation raises employment by increasing the number of days of work per hectare, per crop season and per crop year. They further show that irrigation-induced employment increases help to smooth seasonal troughs in agricultural employment and improve and stabilize wage rates for agricultural labourers. Numerous other recent studies showed that labour employment per hectare is significantly higher in irrigated settings than in non-irrigated settings (e.g. Hussain *et al*., 2002; Brabben *et al*., 2004). While sometimes it is argued that mechanization associated with irrigation can actually displace labour, however, the net employment effects of irrigation-induced production increases are generally positive.

Our country case studies provide further evidence on the significant contribution of irrigation to employment generation in agriculture. For example, annual labour work per hectare in the Ganges-Kobadak irrigation system of Bangladesh is around 100 days more than that in nearby non-irrigated areas. This additional labour demand translates not only into fuller employment for available on-farm labour but also employment of hired labour. For example, hired labour use in Sri Lanka's Uda walawe system is double that in nearby non-irrigated areas and the wage rate is 15% higher in the former than in the latter areas.

The productivity and employment benefits contribute to improved household incomes and consumption expenditures. Evidence from empirical studies shows that average household incomes and consumption can be up to 100% higher in irrigated than non-irrigated settings. Our study in the Uda walawe irrigation systems and its surrounding non-irrigated areas showed that average household monthly (real) consumption was significantly higher in irrigated settings for each of the 24 months of the study period (Figure 3).

Local indirect benefits

In addition to its use in crop production, irrigation water is also used by rural communities for a variety of other purposes. These ''multiple uses'' of canal water, often neglected in the design and evaluation of irrigation systems, include: (a) domestic supply – drinking, washing, bathing, homestead gardening/trees; (b) urban water supply; (c) livestock raising – animal drinking and bathing; (d) fish farming; (e) rural enterprises and industries – brick making, water-powered grain milling, micro-hydropower generation; and (f) transportation – use of canal embankments for transportation of goods and people, especially in areas with low road coverage. Many studies have highlighted the significant benefits and contributions to livelihoods, especially for poor households, afforded by these multiple uses (see e.g. Jensen *et al*., 1998; Barker and van Koppen, 1999; Bakker *et al*., 1999; Meinzen-Dick and Bakker, 1999; van der Hoek *et al*., 1999; Meinzen-Dick and van der Hoek, 2001; Pariyar, 2003). Further, many of these uses are

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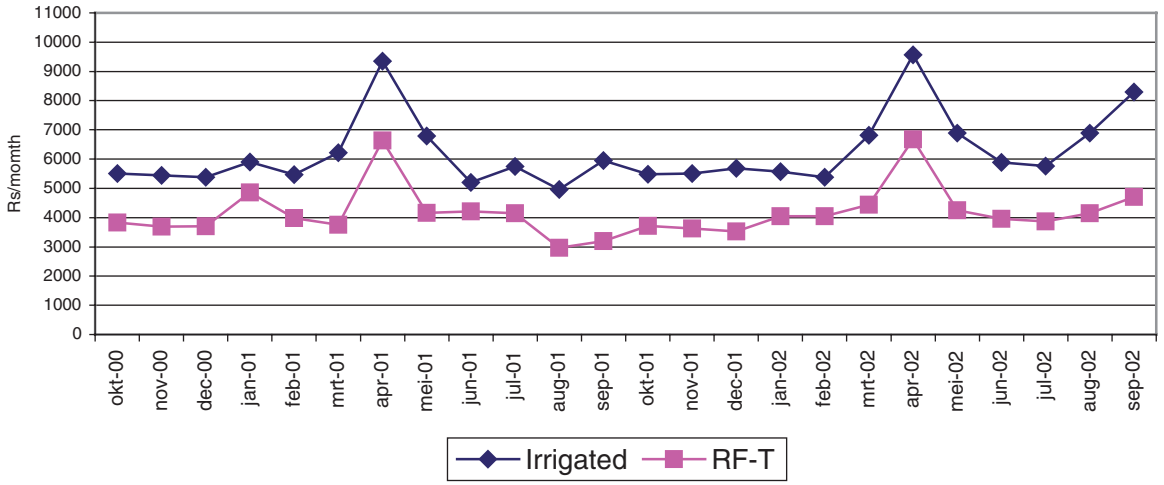

Figure 3. Household average monthly consumption expenditure (real) in Uda walawe irrigation system, Sri Lanka. This figure is available in colour online at www.interscience.wiley.com/journal/ird

non-consumptive or consume only small quantities of water and so do not usually degrade the irrigation function of systems.

However, irrigation systems vary in terms of the multiple use benefits they provide. For example, in Pakistan's Punjab and Sindh provinces canal water is commonly used for domestic and livestock purposes in areas of brackish groundwater. In Sri Lankan canal irrigation systems, canal water uses for washing, bathing, homestead plots and fishing (in tanks) are quite common. Water mills are commonly used for grain milling in Nepal, making a significant contribution to livelihoods of poor families. For instance, our recent study in Nepal notes that a small watermill can grind 300–400 kg of cereals per day and generate a daily income of NRs 90–120 for a family (Pariyar, 2003). While some of multiple uses of irrigation water, for example fish and livestock production and the grinding mill just mentioned, can be relatively easily quantified, and benefits monetized, valuing other uses can be more difficult due to data constraints and, more importantly, methodological complexities. However, it is important that such uses of water and their benefits, including their multiplier benefits, are recognized, identified and accounted for in designing irrigation interventions.

Broader-level multiplier benefits

The impact of irrigation in expanding local production and employment and increasing possibilities for non-agricultural water uses also has knock-on benefits for the wider regional and national economy. These benefits are typically referred to as multiplier effects. Examples of multiplier effects include the increased demand for farm inputs and stimulation of markets and industry to supply these inputs and reduction in food prices, improving consumer welfare and encouraging purchases, and production, in the non-agricultural sector. A multiplier, which can be estimated using a variety of methods,[2] is a measure of relative importance of direct to indirect benefits and is expressed as a ratio of total to direct benefits. As multiplier estimation is an involved task, relatively few studies related to agriculture in developing countries are available. The values of multipliers vary widely across settings, from as low as 1.22 for a small-scale irrigation system in India to as high as 6.0 for New South Wales, Australia. In general, multipliers are higher in developed than in developing economies. At the same time, there is also wide variation between estimates for given countries and regions within a country. For example, multiplier estimates for India range from 1.22 to 3.15, though several studies estimate values around 2 (Appendix, Table AI). While multiplier estimates vary widely due to differences in methodologies, underlying differences in regional economic structures, and the degree of rural–urban links, it is clear that multipliers are generally substantial and often larger, sometimes significantly larger, than direct benefits. Thus they are a critical factor in understanding the overall impacts of irrigation on both economic growth in general and on poverty reduction in particular.

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Who gains from irrigation benefits?

There is a common perception that the benefits of irrigation accrue primarily to landholders, in particular large landholders. While this is true in relation to the most direct productivity-related benefits, a different and more nuanced picture emerges when a broader view of the wide range of irrigation benefits described above is considered. The full range of beneficiaries can be classified as:

1. the landless dependent on the non-agricultural sector;
2. the landless dependent on agriculture (i.e. agricultural labourers);
3. marginal and small landholders who both farm and sell labour;
4. large landholders;
5. other economic agents (e.g. businesses, input suppliers, transporters, agro-industrialists).

In general, the direct benefits of irrigation in terms of increased agricultural output accrue in proportion to landholdings, with large benefits accruing to large landholders. However, indirect employment benefits accrue primarily to those who sell labour, in particular the landless. Benefits from the multiple uses of irrigation water also likely fall primarily on smallholders and the landless, since most additional uses of irrigation water are of a small or micro-scale nature and are part of the informal water economy upon which low-income households depend the most. The distribution of multiplier benefits is more difficult to generalize. Purchasers of foodstuffs, in particular the landless, smallholders and urban consumers, clearly benefit from lower prices caused by increased production. The nature of other benefits and beneficiaries may vary substantially by country and region depending, for example, on the nature of rural–urban linkages and degree of development of the non-agricultural economies.

LESSONS AND IMPLICATIONS

Most discussions of irrigation benefits focus on direct production effects. While these effects may be large, they ignore a much wider array of benefits ranging from increased labour demand, to new opportunities for non-irrigation water use, to economy-wide impacts such as decreases in food prices. In fact, evidence shows that the indirect benefits of irrigation are larger, and probably substantially larger, than direct benefits. And just as there are a range of irrigation benefits beyond farm-level production, there are also a range of beneficiaries beyond merely agricultural producers. This range of beneficiaries must be considered in any calculus of irrigation benefits and the magnitude and social impacts of those benefits. Based on the analysis and discussions in this chapter, we develop the following typology of irrigation benefits (see also Table I and Table II):

Type 1: direct benefits related to expansion in employment from construction, rehabilitation and maintenance of irrigation systems;
Type 2: direct benefits related to irrigation-induced expansion in crop productivity;
Type 3: localized indirect benefits related to productivity-induced benefits from increases in employment, wages, income and consumption in local settings;
Type 4: other localized benefits from multiple uses of water;
Type 5: broader-level multiplier benefits from linkages with non-agricultural sectors.

In developing a fuller understanding of both irrigation benefits and their particular relation to poverty reduction, a number of key lessons emerge: (1) direct and indirect *benefits of irrigation vary greatly across systems*, and depend on a range of factors including local conditions, system management, irrigation policy, and broader economic and political factors; (2) the *indirect irrigation benefits are larger, and often substantially larger, than direct benefits*; and (3) the *distribution of irrigation benefits varies greatly by type of benefit and the socio-economic status of the*

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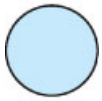
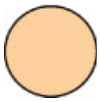
Table I. Direct and indirect benefits of irrigation. This table is available in colour online at www.interscience.wiley.com/journal/ird

	Landless – A (not dependent on agriculture)	Landless – B (dependent on agriculture)	Small and marginal landholders	Large landholders	Other (including urban consumers)
Type- 1					
Type 2					
Type 3					
Type 4					
Type 5					

beneficiary. Direct benefits generally fall to landholders while indirect benefits are more concentrated on the landless and those outside of the agricultural sector.

Enhancing benefits of irrigation

The key factors influencing direct production benefits of irrigation (such as crop productivity, irrigation system/infrastructure management and maintenance, access to production inputs and services and equity in land and water distribution) could be influenced by policy and management interventions. Further, large benefits could be achieved where such interventions are implemented simultaneously in an integrated manner. Numerous other studies support this conclusion. For instance, a recent study in Vietnam assessed the relative impacts of irrigation improving interventions – infrastructure rehabilitation only, management improvement only, and both infrastructure rehabilitation and management improvement (combined impact) – in three selected schemes where these interventions were undertaken. The study showed that the direct benefits to farmers from increases in farm output were much larger where infrastructure rehabilitation/improvement was combined with management improvements compared to schemes where either infrastructure or management improvement was undertaken (Janaiah, 2004). Further, the direct benefits of irrigation could be increased through integrated approaches to management of surface water and groundwater. Our in-depth study in a typical canal in the Chaj sub-basin in Pakistan showed that the direct benefits of irrigation can be significantly increased through improved canal water allocations that account for availability and quality of groundwater across locations, and concluded that joint management of the two resources is important in order to realize these benefits (see Hussain *et al.*, 2003 for more details). Similarly, the direct productivity-related benefits could be enhanced through integrated approaches to provision of non-water production inputs/technologies and services that help reduce transaction costs of access to them by farmers (Hussain and Perera, 2004, provide a review of case studies demonstrating benefits from integrated service provision in agriculture).

Further, local level direct and indirect benefits of irrigation can be enhanced through promoting labour-intensive production methods (e.g. diversification towards high-value crops); improving access to land and water by

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promoting equity in distribution of these resources; and promoting system designs that account for multiple uses of water in an integrated framework. Our study in Kavre district in Nepal shows that income benefits to households are almost twice for households having good access to water for drinking as well as for irrigation compared to those having poor access to them. The broader-level multiplier benefits can be increased through other infrastructure development and with increased value addition to agricultural produce through development of agri-industries.

Targeting irrigation benefits to the poor

As highlighted already, the distribution of irrigation benefits can vary widely by both benefit type and the socio-economic status of possible recipients. For poverty reduction, our typology of irrigation benefits adjusted to particular local and regional conditions can provide a valuable framework for developing strategies to target irrigation investments and develop irrigation policy. While any specific strategy for targeting irrigation interventions in support of poverty reduction necessarily requires an understanding of the relative magnitudes of each of the various benefits, use of the general typology presented here helps to ensure that the main issues are not forgotten and allows some general suggestions which can form the basis of decision making. For targeting irrigation benefits to the poor, lessons from the paper suggest that: (a) irrigation project appraisals and evaluations need to take into account the full range of benefits identified here; (b) in the construction and management of irrigation systems, explicit consideration of the relationship between irrigation benefits and socio-economic status can help to ensure that benefits accrue to those most disadvantaged. In general this means designing hardware and management systems which enhance the direct benefits of irrigation for smallholders and/or the indirect irrigation benefits to the landless; (c) similarly, the poverty-reducing potential of irrigation can be increased when irrigation and related policies explicitly take into account the full range of both irrigation benefits and the relationship with those benefits and the poor; and (d) the benefits of irrigation can be increased when improvements include both infrastructure and management in an integrated fashion.

DIRECT AND INDIRECT DISBENEFITS OF IRRIGATION

As shown and discussed in the previous section, irrigation generates a variety of direct and indirect benefits. But all is not good. Irrigation can also lead to social, health and environmental problems. The potential adverse impacts of irrigation include displacement of people, public health risks from water-related diseases, irrigation-induced land and water degradation, loss of biodiversity and river health risks from increased river water withdrawals for irrigation. There has been wide publicity of these potential negative impacts of irrigation over the past decade, especially with the publication of the report of the World Commission on Dams (WCD) in 2000. This section aims to provide an objective review of various potential negative impacts of irrigation and their implications for the poor, and also attempts to explore avenues for minimizing them.

Irrigation and people (dis)placement

Large-scale irrigation projects oftentimes involve some form of displacement of people either in terms of location or livelihoods or both. This could have a multitude of adverse impacts on the people and communities affected. However, the scale of displacement and its impacts would vary from one project to another depending on a range of factors including the size of the project and population density in the project area. The WCD surveys of dams reported physical displacement in 68 of the 123 dams surveyed. This has led to controversy over irrigation development, particularly large dams, with the main focus on the large projects in developing countries of the regions including Asia. The Three Gorges in China, Sardar Sarovar in India and the Selangor in Malaysia are some of the classical examples of this controversy.

There are arguments for and against large-scale irrigation and dam development. The opponents argue that large-scale irrigation development leads to serious negative and unjust outcomes and marginalization of the poor. The proponents argue that in the present situation of mass poverty, deprivation and suffering, human needs must

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have priority. The gains for millions of beneficiaries have to be traded against losses to a few thousands, but the few thousands who bear the burden of suffering and pay the price of development must be properly compensated for their losses.

Hardly anyone would disagree that people displacement is a serious issue in large-scale irrigation projects, affecting lives and livelihoods of people who are often poor. For example, Tarbela dam in Pakistan led to displacement of around 96 000 people from 120 villages, with many more indirectly affected. There were serious issues related to lack of involvement of those affected in decision-making processes, lack of information sharing, and inadequate compensation and re-settlement of the affected people. Some of the those affected who held valid allotment letters have not been given land due to its unavailability or some other reasons (Asianics Agro-Dev, 2000).

Similar issues have emerged in the recently completed Chashma Right Bank Irrigation Project-III (CRBIP-III) in Pakistan, which covers a 144 km long canal with a command area of 135 000 ha. The post-project surveys and estimates by local NGOs indicate that significantly more than the initially estimated people/villages faced displacement. Land acquired under the project for various purposes (reported to be over 7600 ha (19 000 acres)) affected livelihoods of small and marginal farmers and tenants in the absence of adequate compensation. The project is also reported to have adversely affected the traditional irrigation system (locally known as *rowd kohi*) which utilized the natural flood flows of numerous hill torrents. Irrigation development in CRBIP-III is also reported to have caused other common problems such as deforestation, loss of biodiversity, waterlogging and salinity problems. Here too, there have also been issues regarding lack of community involvement, and inadequate compensation for lost land and livelihoods (Bank Information Center, 2003). In the Sardar Sarover project in India, estimates suggest that the project will lead to total or partial submergence of around 240 villages and nearly 100 000 people will have to be rehabilitated and resettled (Sabnis, 2001).

The most critical issues in relation to displacement of people, apart from displacement itself, have been the lack of involvement of those affected in decision-making processes, inadequate compensation and lack of effective resettlement plans. In cases where those affected have been involved and compensation packages well negotiated with them, the process has led to better outcomes for resettlement (World Commission on Dams, 2000). However, there are no systematic studies assessing the post-displacement and resettlement impacts in terms of whether displacement and resettlement have actually led to making the displaced and resettled people and communities worse off or better off.

Irrigation and people placement

However, on the other hand, there are also examples where development of irrigation systems has actually led to placements of the (displaced) poor people from overcrowded urban areas or from marginal areas to provide them sustainable livelihood opportunities. Resettlement schemes developed with medium- and large-scale irrigation development in Sri Lanka are good examples of such placements – where by 2000, the Mahaweli Authority of Sri Lanka have settled 131 640 families or around 673 000 people in its schemes (the number of families that have been allocated lands and settled in all schemes in the country as a whole is much larger than this number).

Irrigation and human health risks

It is widely known that irrigation can introduce diseases, as adding water to the drier areas can create environments favourable to vectors and pathogens. Some 30 diseases have been linked directly or indirectly to irrigation projects, including diseases that are water-borne, water-washed, water-based and water-related insect vectors (Olivares, 1994). Among the most important ones are malaria, schistosomiasis, cholera and diarrheas, with malaria having the larger risks and impacts. A study in south Punjab in Pakistan investigated the potential linkages between irrigation and malaria transmission and found that major malaria vectors were in irrigated and waterlogged sites and were directly and indirectly linked to canal irrigation systems. The study suggested that vector breeding can be reduced through improved canal water management (Mukhtar *et al*., 2002). Similarly, a detailed study investigating mosquito breeding in nine small irrigation reservoirs or tanks in north central Sri Lanka found that

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major malaria vectors did not occur frequently in the small irrigation tanks. However, important secondary vectors that were involved in malaria transmission were found to occur frequently. The study concluded that irrigation tanks certainly contributed to malaria risk in Sri Lanka, and suggested that both rehabilitation and continuing management (such as selective desiltation to remove depressions, seepage proofing of tanks and the management of vegetation) are necessary to maintain tanks in a condition in which they pose minimum disease risks that affect the lives and livelihoods of the poor rural communities (Amarasinghe *et al*., 2001).

On the other hand, there is evidence that irrigation can actually reduce the malaria risk by improving the socio-economic status of households. A recent study of the International Water Management Institute (IWMI) compared malaria in irrigated and nearby non-irrigated/rainfed/*chena* areas. The results showed that an increased malaria risk was found in areas with more than average rainfall or large areas under forest cover or in *chena* cultivation (i.e. slash and burn cultivation) areas. Irrigated areas had a low risk of malaria. People in the irrigated areas had a higher socio-economic status than those in the *chena* areas and therefore lived in better constructed houses, made more use of bed nets and medication, and had a generally higher nutritional (health) status. The study showed that the malaria risk was higher outside the irrigated areas and was associated with lower socio-economic status, *chena* cultivation and presence of abandoned tanks (Klinkenberg *et al*., 2003).

Further, most work on irrigation and human health risk linkages suggests that irrigation systems can be designed and managed to reduce or even eliminate negative health risks and impacts. A number of case studies in Asian countries, including India, Indonesia and China, have shown that irrigation management interventions could be designed to lower the incidence of water-related diseases. For example, the studies suggest that the alternate wet/dry irrigation (AWDI) method in rice cultivation could lead to a lower incidence of malaria and Japanese encephalitis. These studies conclude that in certain areas and under the right conditions, AWDI is a promising method in irrigated rice cultivation with dual benefits of water saving and human disease control, while maintaining rice yields at least at the same level (van der Hoek *et al*., 2001). Moreover, more effective disease control, particularly malaria, can be achieved with better planning towards health before implementation of the projects and with improved coordination between irrigation authorities and malaria control agencies (Fernando, 2002). It is, therefore, important to identify critical human health risks right at the beginning of project initiation and measure the cost of irrigation water-related diseases for incorporation in the cost–benefit analysis.

Irrigation-induced land and water degradation

Irrigation can also cause degradation of land and water resources in the long term. The expansion in irrigated agriculture could lead to salinity and waterlogging, soil erosion, pollution of surface and groundwater from irrigation-linked excessive chemical and fertilizer use in crop production, and increased nutrient level in the irrigation and drainage water resulting in propagation of aquatic weeds. Among these, land degradation in the form of waterlogging and salinity have serious long-term adverse impacts and could threaten the sustainable use of soil and water resources and overall food production systems. Irrigation-induced land degradation is particularly severe in South Asia and China. The problem is more severe in highly populated agriculturally intensive areas. A study by UNDP, FAO and UNEP (1993) estimated that 73% of agricultural land in South Asia was degraded by one form of land degradation or another, and it was estimated to cost US$9.8 billion per year in the region.

In India, 42 irrigation systems are reported to be affected by salinity problems. The total area adversely affected by irrigation-related problems (particularly waterlogging and salinity) has been estimated at 5.743 million ha, and a decline of 30–50% in the yields of crops has been registered on the farms affected by waterlogging and salinity – leading to a total loss of Rs 61 560 million (Rs 6156 *crores*)[3] per annum in the country due to these problems (Shishodia, 1996). The adverse impacts of resource degradation problems are realized not only at the farm level in terms of reduced resource productivity and returns to farming, but also at the regional level in the form of displacement of labour from agriculture resulting from reduced production, and at the national level in terms of reduced agricultural contribution to national income. A study by Joshi *et al*. (1994) assessed the adverse effects of salinity and waterlogging in selected irrigation projects in Uttar Pradesh, Rajasthan, Haryana and Gujarat. The effect of salinity in declining yield ranged from a low level of about 3% for sugarcane to a high level of 74% for paddy. The effect of waterlogging in declining yields ranged from less than 1% to about 64%. Further, the study

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estimated the land degradation led to a labour demand cut back from 5% to about 62% in parts of the systems, leading to underemployment and unemployment in the regions. The study cautioned that failure to take any measures to minimize these problems could negate irrigation benefits.

In Pakistan, secondary salinity associated with a high water table resulting from irrigation is a particular problem. According to official estimates, around one-tenth of country's best agricultural land is affected by salinity. These problems are particularly acute in Punjab and Sindh. In Sindh, about half of the soils are saline, of which 18% are strongly saline (Mustafa and Pingali, 1995). The studies estimate that waterlogging and salinity have led to 30% decline in yields of major crops in Pakistan (Barghouti and Le Moigne, 1991 as cited in Pinstrup-Anderson and Pandya-Lorch, 1994).

Salinity and waterlogging are very complex problems. Some of the impacts of these problems are direct and highly visible while others are indirect and more insidious in nature. In the past, these complex problems were addressed in two ways. First, scientific research was directed to improve understanding of the biophysical processes involved. Second, two broad approaches were adopted to deal with salinity-related problems: (i) an engineering approach (which is often very costly), and (ii) agronomic and reclamation approaches. Governments and international donors have invested considerable funds to implement these approaches to solve the salinity and waterlogging problems in irrigated areas in the region. More recently, saline agriculture has been recommended as a more sustainable solution to the problems of salinity and waterlogging.

The evidence on the effectiveness of the first two approaches suggests that while there have been successes in some areas, the extent and severity of salinity and waterlogging-related problems have continued to worsen in many areas. For example, installation of tubewells under salinity control and reclamation projects (SCARPs) has increased cropping intensities and decreased severe waterlogging in some areas in Pakistan. However, it has been found that over 70% of tubewells in the country are pumping water of marginal and hazardous quality and very large areas of previously salt-free lands are being damaged through the use of tubewell water (Qureshi and Barrett-Lennard, 1998).

The impacts of irrigation-induced land degradation are not confined to a plot, farm or boundaries of a private property, but spread over a wider scale. Consequently, there can be a range of off-farm impacts, including displacement of labour, outmigration, income disparity, and overall reduction in food output. These off-site costs or negative externalities have important policy implications regarding land and water resources use and management, and how scarce public finances are deployed to create optimum benefits for society at large.

In sum, most of the above problems related to land and water degradation emerge from poor management of irrigation and irrigated agriculture. These problems affect the poor marginal and small farm households, who often lack financial and other means to take preventive measures, rather than non-poor households. There are a range of intervention options to minimize them such as improving irrigation management, establishing proper drainage systems, promoting conjunctive use of surface and groundwater, and improving on crop management and selection of crops depending on their suitability to different salt levels.

Other negative impacts

There are a number of other known negative impacts of irrigation such as: (1) irrigation-led mechanization of farming (particularly on large farms with increased use of tractors, combines, threshers and cotton pickers) which may displace the labour and can have negative effects on employment in the absence of alternative employment opportunities. This can have potential adverse impacts on the livelihoods of the poor landless and tenants; (2) irrigation can adversely impact the quantity and quality of downstream water resulting from excessive use of water and pollution upstream, affecting the livelihoods of downstream water users. For example, Bundala National Park in Sri Lanka, which is of great ecological significance and the only area in Sri Lanka listed under the International Convention on Wetlands, has been affected by the drainage flow from the Kirindi Oya Irrigation and Settlement Project (KOISP) and the Badagiriya Irrigation Scheme. After KOISP was implemented, salinity of the lagoons in the park has dropped due to inflow of upstream irrigation water, which has adversely affected the population of water birds and the overall ecology of the lagoons. Prawn fishing, which previously contributed to the livelihoods of the poor families, has almost disappeared from the lagoons (van der Hoek, 1998); (3) irrigation development and

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poor management can lead to loss of biodiversity and altering of the natural environment; and (4) at the broader level, irrigation development can lead to important trade-offs between water needs for the environment and water use for irrigation. Excessive water withdrawals for irrigation could adversely affect health of rivers with adverse impacts on the livelihoods of communities that derive a range of benefits from the river systems.

LESSONS AND IMPLICATIONS

Irrigation can lead to considerable disbenefits or adverse socio-environmental impacts. Often, negative social and environmental consequences adversely affect the poor more than the non-poor people. However, many of the potential adverse impacts can be avoided or minimized with effective planning, design and management of projects. Based on the review and discussion in this paper, we develop the following typology of direct and indirect disbenefits of irrigation:

Type 1: direct disbenefit related to displacement of the poor households, and potential for land encroachments;
Type 2: direct disbenefits related to land degradation from salinity, waterlogging, overuse of chemicals resulting in reduced agricultural productivity;
Type 3: localized indirect disbenefits due to irrigation-induced land degradation resulting in labour displacement; irrigation-led mechanization and use of labour-saving methods of cultivation – leading to unemployment;
Type 4: other localized disbenefits – public health risks, loss of biodiversity, water pollution;
Type 5: broader-level disbenefits – water transfer for irrigation with potential negative impacts on health of rivers and sustainability of river systems with potential adverse impacts on the livelihoods of river-dependent poor communities.

The following interventions and actions could help avoid or minimize these potential dis-benefits of irrigation:

- the people displacement and its adverse impacts could be avoided or minimized through: (a) exploring the options for minimizing people displacement at the time of project preparation /initiation; (b) developing legal frameworks for addressing the displacement issues: (c) involving communities in decision-making processes right from the planning stage of the project, and establishing effective mechanisms for information sharing and hearing of complaints; (d) developing compensation and resettlement plans; discussing compensation and resettlement packages with affected communities, through participatory consultation processes; including the landless and tenants in the compensation and resettlement plans; and providing fair and adequate compensation to those affected, particularly poor households including small and marginal farmers, tenants, and landless labourers; (e) involving NGOs in negotiation of compensation packages and implementation of resettlement plans; and (f) including resettlement costs as a part of the project cost or loan package;
- establishing effective mechanisms to ensure that environmental impact assessment (EIA) and health impact assessment (HIA) guidelines are followed in implementing the projects;
- establishing effective mechanisms for post-project monitoring and impact assessments to identify opportunities to minimize negative impacts, such as land and water degradation, water quantity and quality impacts on downstream users, through involvement of communities and maximize positive impacts; and
- developing pre-project knowledge base on social, ecosystem and environmental parameters to establish a benchmark for assessing performance of irrigation.

CONCLUSIONS

Irrigation generates a variety of direct and indirect benefits. The benefits vary widely across systems, and depend on a range of factors including local conditions, system management, irrigation policy, and broader economic and political factors. The indirect irrigation benefits are generally larger than direct benefits. The distribution of

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Table II. Typology of irrigation benefits and disbenefits

Type of (dis)benefit	Benefit	Disbenefit
Type 1	Direct benefits related to expansion in employment from construction, rehabilitation and maintenance of irrigation systems, placements of poor people	Direct disbenefit related to displacement of the poor households, and potential for land encroachments
Type 2	Direct benefits related to irrigation-induced expansion in crop productivity	Direct disbenefits related to land degradation from salinity, waterlogging, overuse of chemicals resulting in reduced agricultural productivity
Type 3	Localized indirect benefits related to productivity-induced benefits from increases in employment, wages, income and consumption in local settings	Localized indirect disbenefits due to irrigation-induced land degradation resulting in labour displacement; irrigation-led mechanization and use of labour-saving methods of cultivation – leading to unemployment
Type 4	Other localized benefits from multiple uses of water, groundwater recharge, increased private investments in irrigated agriculture	Other localized disbenefits–public health risks, loss of biodiversity, water pollution
Type 5	Broader-level multiplier benefits from linkages with non-agricultural sectors	Broader-level disbenefits–water transfer for irrigation with potential negative impacts on health of rivers and sustainability of river systems with potential adverse impacts on the livelihoods of river-dependent poor communities

irrigation benefits also varies widely by type of benefit and the socio-economic status of the beneficiary. The direct benefits generally accrue to landholders while a significant part of the indirect benefits accrue to the landless and small farmers, contributing positively to their livelihoods. Further, the overall benefits of irrigation are large when irrigation-improving interventions, investments in infrastructure, improvements in system management and service delivery to farmers, are implemented in an integrated manner.

But it is not all good – irrigation can lead to considerable negative or adverse social, health and environmental impacts. The potential disbenefits of irrigation include displacement of people as a result of new irrigation development, public health risks from water-related diseases, irrigation-induced land and water degradation, loss of biodiversity and river health risks from increased river water withdrawals for irrigation. Often, negative social and environmental consequences adversely affect the poor more than the non-poor people. Most potential adverse impacts of irrigation are not due to irrigation water per se, but due to inadequacies and ineffectiveness of institutions and management to address them. Moreover, many of the potential adverse impacts can be avoided or minimized with effective planning, design and management of the projects. The study develops a generic typology of direct and indirect benefits and disbenefits of irrigation (as shown in Table II) that can be used to identify and influence different types of irrigation benefits and disbenefits for enhancing net benefits to the poor.

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APPENDIX

Table AI. Estimates of multipliers from increase in agricultural output to other sectors

Study location	Multiplier estimate	Study/author
India (1982)	1.70	Rangarajan (1982)
North Arcot District, Tamil Nadu, India (1982–83)	1.87	Hazell and Ramasamy (1991)
India (2002)	3.15	Bhattarai *et al*. (2004)
India (2003), Bhakra system	1.86	Bhatia *et al*. (2003)
India (2003), (small dam in Bunga village)	1.22	Bhatia *et al*. (2003)
Muda Valley, Malaysia (1972)	1.83	Haggblade *et al*. (1991)
Various Asian settings (mostly covering 1970s and 1980s)	Range from 1.3 to 4.3	Haggblade *et al*. (1991) based on review of past studies
New South Wales, Australia (1985)	6	Powell *et al*. (1985)
Alberta and Saskatchewan, Canada 1994	5	Hill and Tollefson (1994)
Sierra Leone, rural (1974–75)	1.35	Haggblade *et al*. (1991)
Burkina Faso (1984–85) Niger (1989–90) Senegal (1989–90) Zambia (1985–86)	Range from 1.31 to 4.62	Delgado *et al*. (1994a, b)
Kenya (1995)	1.64	Block and Timmer (in Timmer 1995)

NOTES

[1]Non-irrigated areas had an average net product value of US$153 ha^{-1} compared to US$360 ha^{-1} for irrigated settings. However, at least some of the difference is related to the fact that currently irrigated lands were likely more productive than non-irrigated lands even before irrigation was introduced.

[2]For example, input–output (I–O) models, models based on social accounting matrices (SAMs), and computable general equilibrium (CGE) models.

[3]Rs = Indian rupees; 1 US$ = Rs 49.11

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