The effects of irrigation on poverty:
a framework for analysis

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Abstract

Irrigation projects have been the subject of much bad press coverage because of the sometimes very damaging environmental and social impacts associated with large-scale projects such as dams, declining aid to agriculture and falling rates of economic returns to irrigation since the heyday of the 1970s. Yet irrigation remains one of the most crucial inputs into farming and therefore a potentially important poverty reduction tool for the 21st century. We review some of the evidence surrounding trends in investments in irrigation and the reasons behind the decline. We also provide a framework for analysing the positive and negative impacts of irrigation on poverty, how these might differ by the type of irrigation technology and review some of the evidence of these impacts. We reach a number of conclusions about the conditions under which irrigation is most likely to have a positive impact on the poor, but we also report that the evidence is patchy, and usually not gathered in such a way as to allow easy conclusions to be drawn.

Keywords: Developing countries; Irrigation; Poverty

1. Introduction and overview

Poverty reduction is now one of the main goals of development, yet progress against poverty was stalled in many countries during the late 1990s and early 2000s. Of the 1.2 billion people defined as dollar-poor (i.e. with a per capita household income or consumption level below US$1-a-day in 1985 Purchasing Power Party (PPP)), three-quarters live in rural areas. Reviving the fight against poverty requires action on many fronts (see IFAD, 2001). A review of the evidence of past poverty reductions suggests that one important weapon is investment in agriculture. This paper focuses on one aspect of agricultural technology: irrigation.

The choice can be justified quite simply. There are huge regional differences in the proportion of...
cropland that is irrigated and these differences coincide with successes or failures in poverty reduction (see Table 1). In Africa, only around 3% of cropland is irrigated and the region has experienced very little reduction in poverty in the 1990s (sub-Saharan Africa had an estimated poverty headcount of 47.7% in 1990 and 46.3% in 1998 (World Bank, 2000)). In contrast, those regions that have the greatest proportion of cultivated area irrigated (namely East Asia, Pacific, North Africa and Middle East) have experienced the greatest poverty reduction. In addition, 35–40% of cropland in Asia is irrigated and poverty reduction in the 1970s, the period immediately following the Green Revolution in which much initial investment in irrigation was made, was substantial. We argue in this paper that this is no mere coincidence; rather, that differences across regions, countries and states within countries in irrigation are an important factor in determining rates of poverty reduction. The significant poverty reduction in many parts of India, for example, is attributed to the availability of irrigation, which not only boosted agricultural production but also made possible the adoption of modern farming technology – seeds, fertilizers and pesticides – that further reduced poverty (Ray et al., 1988).

Irrigation may take many different forms, from large schemes to small systems of shallow tube wells, and from surface irrigation to small sprinkler or drip systems. Often, irrigation projects have several aims, not necessarily explicitly or directly oriented towards poverty reduction dams. Perhaps more importantly, however, irrigation may impact differently on the poor depending on the irrigation technology itself, their position along the distribution system (e.g. tail enders), the institutional rules governing access to water and maintenance of water systems and their ability to complement irrigation with other agricultural inputs (which includes access to land, credit, seeds, fertilizer, etc.). Furthermore, the poor are not a homogenous group of people defined uniformly by a set of characteristics. Instead they are much more heterogeneous, comprising different ages, gender, ethnicity, education, different economic activity and location. Irrigation may affect different types of poor people in different ways, perhaps impacting on small farmers first by boosting yields and income levels, then by impacting on landless labourers through increased demand for agricultural workers, and last by impacting on the urban poor via lower food prices and possibly reduced migration of the rural poor to urban areas.

Table 1. Poverty incidence and irrigation in developing regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>1-a-day povertya 1998</th>
<th>Total population (%)</th>
<th>Change in incidence 1987–98 (%)</th>
<th>% Irrigated area per ha cultivated area (arable + permanent cropland) 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Asia and Pacific</td>
<td>278b</td>
<td>15b</td>
<td>−33b</td>
<td>20</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>78</td>
<td>16</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>North Africa and the Middle East</td>
<td>5</td>
<td>0.04</td>
<td>−44</td>
<td>27</td>
</tr>
<tr>
<td>South Asia</td>
<td>522</td>
<td>39</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>291</td>
<td>44</td>
<td>34</td>
<td>3</td>
</tr>
</tbody>
</table>

a People living on less than $1/day in 1998 (1993 PPP US$) (Estimates). b East Asia.
2. Investment in irrigation

2.1. Trends

Evidence from key sources indicates that investment in irrigation has begun to decline. Data on irrigated areas, globally and across regions, show that the rate of growth in irrigated area has declined and has been accompanied by a decline in lending for irrigation by international donors (Rosegrant & Svendsen, 1993). Globally, irrigated area rose at an annual average rate of 2.0% in the 1960s, at 2.4% in the 1970s but fell to 0.9% in the 1980s. Regional figures, excepting those of Africa, show a similar pattern of growth of irrigated area, peaking in the 1960s and 1970s, and declining in the 1980s. In the forthcoming decades, this trend will continue and it is expected that annual growth of irrigated land will be around 0.7% (FAO, 2002).

There has been a large decline in real lending by major donors (World Bank, Asian Development Bank, Japanese Overseas Development Fund) for irrigation projects in South and Southeast Asia since the late 1970s and early 1980s, when it peaked. By 1986–87, the World Bank lending was only around 40% of peak lending, and lending by other donors shows similar trends. Trends in public expenditure on irrigation in selected Asian countries also show a decline in real irrigation expenditure in the late 1980s.

It is clear from this evidence that lending for irrigation projects and actual investment in irrigation has been declining across and within regions. The World Bank Operations Evaluation Department (OED) determined in its 1993 Irrigation Review that irrigation accounted for 7% of Bank lending, with a peak of 10% during the 1970s and 1980s – more than any other single sector – but since then Bank lending for irrigation projects has declined. From 1950 to 1993, the Bank lent roughly US$31,000 million (in 1991 dollars) for various forms of irrigation in 614 projects. Investment in irrigation reached a peak in the 1970s and 1980s with lending to over 250 projects in the 1970s at a total cost of US$1120 million (1991 prices). Since then, lending for irrigation has fallen considerably.

What of private sector irrigation? Typically, monitoring both use and development of private irrigation is difficult. In India and Mexico for example, two-thirds of groundwater development is privately managed and is often mixed in with surface-irrigation schemes, resulting in a mosaic of largely unregulated conjunctive use. In Latin America, private sector investment has historically been important and only gave ground to public sector investment during the 1970s. In Mexico, a substantial number of irrigation units covering a large proportion (around 40%) of irrigated area were privately owned, even before reforms of publicly funded irrigation districts shifted control to water user associations (Ringler et al., 2000). During the reform, increases in private sector investment in irrigation infrastructure have been dramatic and have helped compensate for the 41% decline in federal government investment between 1991 and 1995. In many countries, the trend is towards increased involvement of the private sector both in investment and management of irrigation. In Chile, with one of the most privatised irrigation sectors in Latin America, farmers have to contribute, by law, as much as 75% to new pumping and channel irrigation projects, with the result that only the most profitable schemes are built.

2.2. Reasons for the decline in investment

The decline in investment in irrigation is largely ascribed to the falling economic rate of return (ERR) of irrigation projects, both new and existing, making other sorts of investment better options for scarce
resources. This is, in part, due to declining agricultural prices, but it may also be because of technical reasons. Higher-return works are usually built first (e.g. the best sites have already been chosen), leaving less good ones for later building, or because of rising costs of construction, or because of a better assessment of externalities, i.e. increasing negative impacts (e.g. on health and the environment). We evaluate each of these in turn. However, it must be stressed that the growth effect of investments in irrigation is only part of the story about the impact on returns to the poor, or for poverty reduction. Falling ERR may mean that the amount of total available resources declines, but distribution changes could amplify, reduce or even reverse the effect of ERR falls on poverty. Poverty-reduction impacts of projects may not come about through significant increases in yields or output alone, but through improving the distribution of access to irrigation by the poor. Hence, project evaluations of poverty impacts need to evaluate not just the ERR but the impact on poverty reduction for each marginal dollar of investment.

Using Indian data from 1970–93, Fan et al. (1999, p 46) argue that government spending on different investments, including rural infrastructure and agricultural research and extension, contributed to agricultural growth, but the effects on poverty and productivity increase differed markedly. Investment in rural infrastructure and agricultural research and extension were definite “win–win” situations and had the highest impact on productivity and output. However, investment in irrigation had only the third largest impact on agricultural productivity and a smaller impact on rural poverty reduction.

But these rankings of investment types, and the returns to each type, differ hugely among regions. Fan et al. (1999) show that some rain-fed or “backward” regions show higher ERR and higher poverty impact per marginal dollar for a wide range of types of investment than already advanced irrigated areas. Furthermore, even if it is found that in some countries or regions new works have lower economic returns than other projects, investment in new works may have higher poverty impacts than other investments. Finally, while it may be the case that marginal physical returns from old works are falling (as irrigated area from a particular work expands or for ecological or management reasons as time passes), rehabilitation of existing irrigation systems may have higher ERR than either new irrigation or other types of investment.

Carruthers (1996) argues that the returns to irrigation are comparable to alternative investments in agriculture and nonagricultural projects. In an evaluation of 192 World Bank-funded irrigation projects implemented between 1950 and 1993, 67% received an overall satisfactory rating, with an average internal rate of return (IRR) of 15% at evaluation (as opposed to on appraisal or completion). This average is quite high, given the large initial investments required in irrigation projects, the long gestation periods before benefits start trickling in and accounting for inflation. Moreover, this was achieved in a period when the domestic terms of trade, due to overvalued exchange rates, and various indirect taxes or subsidies to competing urban interests, worked against the agriculture sector. When irrigation projects were weighted by area served, the average evaluation IRR increased to 25%. Hence, the decline in investment in irrigation should not be ascribed to a real decline in the rate of return to such investments.

There was no downtrend in ERR to agricultural research in the 1980s or early 1990s as compared with the 1960s and 1970s – despite the exhaustion of new Green Revolution upward trends on basic yields. There is no reason why irrigation investments are any different. There is a relatively constant ERR despite falling world agricultural prices (about 0.5% per year relative to manufacture) and this should carry through to, and parallel results for, trends in returns to irrigation.

Construction costs. There is an argument that investment in irrigation is falling because of rising costs of construction. The result is lower returns to investment. This has been shown by Aluwihare & Kikuchi
(1991) for Sri Lanka where the benefit–cost ratio for new construction declined from 2.1 in 1970–74 to 0.7 in 1985–89. But these data relate to countries where irrigation has long been intense, but nothing indicates that this is a worldwide trend.

Cost recovery. Poor cost recovery could be another factor that explains declining trends in irrigation investment. Public irrigation projects have been an enormous drain on government budgets, mainly because cost recovery falls short of covering the actual costs (Johnson, 1990).

Prices. The biggest surge in investment in irrigation occurred in the 1970s, leading some to argue that this was due to the rise in agricultural prices, due in turn to the two oil crises that raised the prices of inputs and transport, and unfavourable weather conditions, and to argue further that declines in agricultural prices make future investment in irrigation unwarranted (Repetto, 1986). If these events were perceived to be significant and likely to extend into the long run, then this argument may have some merit. It is possible, however, that falling agricultural prices are now a consequence of rising irrigated area and hence higher global yields, and even more so if extra irrigation creates incentives for green revolutions in seed–fertiliser use, and if these eventually raise yields (more accurately, net value added) more slowly than they depress farm prices (more accurately, farm output prices – fertilizer prices may be bid up, as well as crop prices down). However, even if agricultural prices continue their downward trend, there is sufficient evidence that the ERR can be maintained at acceptable levels (Carruthers, 1996).

Technical efficiency, health and environmental impact. Disincentives, such as poorly targeted subsidies or inappropriate water-pricing systems, can induce overuse or wastage of water (IFAD, 2001). Inefficient irrigation is cited as one of the main reasons for low returns on investment in Latin America, for instance. Declining ERR of investments in irrigation may also be due either to increased negative impacts of irrigation or increased value being ascribed to such costs. It is certain that there has been more vocal and visible concern over the social and environmental impacts of irrigation projects, particularly, but not exclusively, large-scale irrigation projects.

3. The effects of irrigation on poverty: a framework for analysis

This section lays out a conceptual framework for analysing the transmission mechanisms between irrigation and poverty, illustrated by some country and regional evidence. We attempt to examine how the size of different effects of irrigation on the transmission mechanisms to poverty varies by characteristics of the irrigation project, such as type, scale, water source and management and maintenance mechanisms of irrigation projects. We begin to identify the impact of irrigation by considering a partial equilibrium scenario with a hypothetical, unspecified irrigation project in one location and farmers producing one farm product, for example a staple grain, and then consider secondary, general equilibrium effects by allowing for multiple farm products.

3.1. Direct impact on output levels

The first direct impact is on output levels. Irrigation boosts total farm output and hence, with unchanged prices, raises farm incomes. Increased output levels may arise for any of at least three
reasons. Firstly, irrigation improves yields through reduced crop loss due to erratic, unreliable or insufficient rainwater supply. Secondly, irrigation allows for the possibility of multiple cropping, and so an increase in annual output. Thirdly, irrigation allows a greater area of land to be used for crops in areas where rain-fed production is impossible or marginal. Hence, irrigation is likely to boost output and income levels. If there is no price effect (i.e., through higher output levels) and no effect on employment or stability of food availability, only “small farmers” among the poor—or, more precisely, only the own-farm incomes of the poor—are affected by this. If the output effect is the only effect that irrigation has then its poverty impact will be limited, given that labour income is a growing part of the income of the poor and labourers are a growing share of the poor. Finally, output may be increased because irrigation enables the use of complementary inputs, such as high-yielding varieties (HYVs). In the areas that gained from the use of HYVs the decline in prices was outweighed by an increase in yields, but in areas that did not benefit from HYVs, the restraint on cereal prices harmed farm sales and there was little or no yield compensation (Lipton & Longhurst, 1989). Thus, incomes were reduced in these areas.

The special role of groundwater. The impact on output will depend on the type of technology implemented. As an example, Dhawan (1988, p 27) reports that groundwater irrigation performs better than surface water because farmers have better control over supply. Individually owned tube wells in Punjab and Haryana enhance farm output by about 28 quintals/ha, which is twice the output level for public-canal irrigation. In Tamil Nadu and Andhra Pradesh, the additional output due to the introduction of one hectare of irrigation facility varies from 12–16 q in the case of tanks, 15–21 q in the case of canals and 34–36 q in the case of wells (primarily dug wells equipped with pump sets). Over time, the productivity of groundwater-irrigated land has risen faster than that of surface-irrigated land.

Dhawan (1985, cited in Chambers et al. (1989)) shows that in four Indian states the output impact of groundwater per net irrigated hectare was roughly double that of canals (see Table 2). Among lift irrigation systems, one’s own tube wells ranked the highest in terms of quality of irrigation service. Other options, such as depending on other private tube-well owners or on state tube wells, are inferior.

3.2. Direct impact on employment

The second direct effect on poverty is via employment. There are two sources of additional demand for labour created by irrigation projects. Irrigation projects firstly require labour for construction and the ongoing maintenance of canals, wells and pumps, etc. This is likely to be an important sector of employment for the poor, especially the landless rural poor or rural households with excess labour or

<table>
<thead>
<tr>
<th>State</th>
<th>Groundwater</th>
<th>Canals</th>
<th>Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punjab</td>
<td>4.4</td>
<td>2.1</td>
<td>–</td>
</tr>
<tr>
<td>Haryana</td>
<td>5.3</td>
<td>2.0</td>
<td>–</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>5.2</td>
<td>2.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>6.0</td>
<td>2.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*The groundwater impact of Haryana is higher than for Punjab partly because nonirrigated yields were lower. Haryana figures are for 1976–77 and 1978–79.*

seasonal excess labour. A project in Nepal that used labour-intensive construction to provide irrigation increased production potential by over 300% and income by over 600%, contributing immensely to food security (IPTRID, 1999, p 3).

Secondly, increased farm output as a result of irrigation will stimulate demand for farm labour both within the main cropping season and across new cropping seasons, increasing both the numbers of workers required and the length of the employment period. Rural poverty levels may therefore be reduced by increased employment opportunities. In addition, there may be effects that extend to other areas if irrigation projects reduce migration to urban areas, and so reduce the pool of job seekers and relieve the downward pressure on urban wages and the upward pressure on prices of housing and other urban infrastructure.

3.3. Impact on food prices

The third direct effect on poverty is via food prices. If irrigation leads to increases in staples or nonstaple food output then this may result in lower prices for staples and food in imperfectly open economies or if there are significant transport costs from food-surplus areas to towns or food-deficit areas. Rural net purchasers of food will therefore gain from cheaper food, as will urban consumers. The fall in the staple price is likely to be poverty reducing. However, low-income and possibly poor small farmers in areas not affected by extra irrigation – nonirrigated or already irrigated areas – may be net producers so harmed by falling prices and may even become poor, unless the increase in output offsets the fall in prices. Waged agricultural labourers, in addition to increased employment, will benefit from lower prices. Wage labourers will find that their wage buys more food, and hence will benefit from falling prices, apart from employment changes.

The effect of irrigation on prices, and therefore on poverty, may be particularly strong in: (i) remote areas or countries with high transport costs where, prior to an irrigation project, the food deficit had to be compensated for by purchases from other regions; (ii) areas with a comparative advantage in food production, which can respond more strongly to the availability of irrigated land (having a surplus of land or labour); and (iii) areas with high surplus output levels, which can be traded in wider markets.

Hence, examining the direct first-round effects, irrigation is likely to reduce poverty among (a) net food purchasers in irrigated areas, (b) net food purchasers in non-remote nonirrigated areas, and (c) the urban poor. Positive effects may be experienced by net food producers and waged labourers if the effects of increases in output and employment, respectively outweigh the effects of price falls. This is increasingly likely with liberalisation of the food trade, with falls in growth rate of irrigated area and with better transport and falling transport/production cost ratios. Negative effects might be experienced by surplus producers in remote, nonirrigated areas.

3.4. Second-round effect on outputs

But the availability of irrigation also has second-round effects via output, employment and prices on poverty. In the longer run, and in a dynamic, general equilibrium scenario with multiple farm outputs, irrigated land usually encourages farmers to adopt or increase their use of fertilizers, pesticides, improved seeds and other agricultural inputs, and provides the stimulus for further research into
improved plants and technology that lead to increased output, and so employment and incomes, with possible further price reductions. This “Green Revolution” style virtuous circle is likely to lead to further poverty reduction.

Furthermore, irrigation gives the opportunity to switch farm use away from staples to higher-value, market-oriented products, since not all the additional output due to irrigation is likely to be absorbed in self-consumption, except by very small farmers (Dhawan, 1988, p 42). As long as the rural poor can access appropriate new technologies, also possibly requiring access to credit markets, then poverty among small producers and landless labourers is likely to fall.

The switch of crops in irrigated areas may also create or expand the demand for the crops of nonirrigated areas, so leading to poverty reduction in these areas. Examples of this can be seen in the context of HYVs. In India, the shift from rice to groundnut and sugar in North Arcot, Tamil Nadu and from wheat to mustard, rapeseed and groundnut in parts of Gujarat is seen as a result of shifts into rice and wheat by leading areas in the adoption of modern varieties, which led to a reduction in the supply of groundnut, etc., and hence an increase in price (Lipton & Longhurst, 1989). Remote areas are, however, likely to remain negatively affected in this longer-run scenario by high transport costs and difficult access to markets for credit, labour, inputs and outputs (IFAD, 2001).

3.5. Effect on non-farm rural output and employment

A second, longer-run effect on poverty is via nonfarm rural output and employment. As farm output and incomes rise and food prices fall, enriched farmers and workers will increase their expenditure on nonfood products, leading to increased demand for nonfood goods and services and so increased employment opportunities in nonfarm-income-generating activities. These may include transportation, construction, food preparation and trading.

3.6. Stabilization of outputs and income

Perhaps the biggest long-term effect on rural poverty is via effects on variance of output or employment or income at farm or small-area level. Two factors contribute to output fluctuations:

(i) Natural factors (rainfall) – crop output, particularly that of food grains, is sensitive to variations in rainfall. Modern inputs like fertilizers are highly complementary to water and, hence, the demand for these inputs is influenced by the availability of water. In areas without assured sources of irrigation, the sensitivity or elasticity of output with respect to variations in rainfall tends to rise with growth since the use of inputs like fertilizers increases crop yields in a year when soil moisture is adequate, while in bad years crop yields decline sharply, hence widening year-to-year differences in yields (Kumari et al., 1999, p 15).

(ii) Relative price of inputs – changes in the prices of inputs (like fertilizers) relative to crops influence the demand for inputs resulting in variations in output. Thus the elasticity of output with respect to prices is likely to rise as new technology or modern inputs are introduced. Irrigation not only raises crop output levels but also usually reduces the variance over seasons – because of double cropping, for example – and over the years as reliance on rainfall is reduced, at least as a percentage of the...
mean. Ray et al. (1988, p 35) argue that, in comparison to nonirrigated conditions, the expansion of irrigation has contributed to a substantial extent in reducing instability in the output of food grains as well as of other crops. Because of this, the poor are less likely to need to borrow to smooth subsistence consumption levels and so avoid the high capital-market access costs that they usually face. In addition, less risky production of staples or other crops allows them to take more risks with other activities, encouraging diversification into higher-risk, but potentially higher-income, activities, such as cash crops for export or new nonfarm activities.

But stability cannot be achieved through irrigation only. Dhawan (1988, p 159) states that one reason for stability of the area and the yield of irrigated farming in Punjab is the central price support for wheat and paddy, the two principal crops, which predominate irrigated agriculture in the state. He further suggests that the stabilization of farm output cannot be achieved merely through a reliable system of irrigation. In the absence of an adequate price support, fluctuations in the irrigated output can be quite high as farmers adjust their area and input allocations in a regime of uncertain farm-product prices. In other words, one needs to improve the general environment under which the farmer practices irrigation, rather than simply improving the management of irrigation.

3.7. Socioeconomic impacts of irrigation

Irrigation projects affect not only economic outcomes, but may have wider socioeconomic effects. A very visible effect of irrigation projects is the negative health effects associated with increases in the incidence of water-related diseases. When irrigation is associated with the construction of large dams, additional impacts include the displacement of large numbers of people and negative environmental effects of dam construction.

The impact of groundwater and surface water irrigation on the physical well-being, including the beneficiaries’ health, nutrition and sanitation, is multifaceted (Lipton & de Kadt, 1988). Access to irrigation may have very positive impacts on nutritional outcomes, through the availability of increased and more stable food supplies and, sometimes, cleaner water. In addition, increased income levels will allow rural producers, assuming transport costs are not prohibitive, to purchase a wider variety of foods. This should help ensure not only that calorie intake is sufficient but also that the diet is better balanced, with adequate intakes of micro-nutrients.

However, irrigation, particularly involving canals, reservoirs and tanks, has a downside in terms of health as it encourages water-related diseases due to inadequate drainage and renders the microenvironment hospitable to mosquitoes and snails that spread malaria and schistosomiasis. Untreated contaminated water is also responsible for causing serious diseases, from diarrhoea (one of the main proximate causes of child mortality) to cholera. It is likely that the poor are more vulnerable to such water-related diseases. However, some recent studies report that, thanks to the increased purchasing capacity of farmers following irrigation projects, they can afford to pay for the medical treatment they need to combat water-related diseases.

These problems are much less serious with some sorts of irrigation. For example, field-to-field water in paddies (such as *liyaddes* in Sri Lanka) does not stagnate and is therefore not a serious problem. In addition, tube wells can mean cleaner drinking water than before, though pollution problems (nitrates and nitrites from fertilizer) need watching. Finally, it should be noted that in many places, in particular...
in humid regions, the condition for the propagation of water-related diseases already existed well before the development of irrigation.

3.8. The impact of irrigation on the environment

Another potentially large source of negative effects of irrigation is the environmental impact of irrigation schemes. The construction of some schemes – large dams and canal systems – is associated with particular environmental problems, such as loss of natural habitat. Generally, irrigation projects have also further detrimental impacts on the environment beyond the construction phase. Water loss through unproductive evaporation, seepage and percolation, possibly inducing problems of waterlogging and salinisation, have been found to be important potentially negative consequences of irrigation. The issue of whether the poor are more likely to suffer from these effects than the non-poor depends very much from one case to another.

Certain types of irrigation technology may have beneficial environmental effects on nonirrigated areas. In some cases, the introduction of surface irrigation through canals and tanks may raise the groundwater table since a substantial portion of the surface-irrigation water seeps through the ground, improving the availability of groundwater that, in turn, improves the water yield of the nearby wells. This, in turn, enhances the farm output of their owners when well water is a binding constraint on their expanding farm production. This type of positive externality is a boon in semiarid areas of low, uncertain groundwater availability and is why canal lining or adoption of highly efficient irrigation technologies may not always be regarded favourably. However, continuous seepage without adequate measures to drain excess water can lead the water table to rise to the crop-root zone level, leading in places to problems of waterlogging and land salinisation. This example highlights the complexity of the interactions between water users inside and outside irrigation schemes and calls for a comprehensive approach to water management in irrigation.

4. Assessing the impact of irrigation projects on poverty

4.1. Factors affecting the impact of irrigation projects on poverty

There are many different types of irrigation. Each has the potential for poverty reduction, but will also entail different social, environmental and economic costs, which may differ across different groups. For example, among private means of irrigation, the comparative advantage of small over large farmers may be viewed as follows: small-scale irrigation works are heavily reliant on family labour in their construction and operation, and are therefore better suited to the resource endowment of small farmers; irrigation works that require minimal use of human or animal labour but make a heavy demand on scarce capital resources are better suited for large farmers (Dhawan, 1988, p 215).

Given the previous discussion, we propose that appraisal of irrigation for poverty reduction should account for each of the following (in no particular order):

- cost of construction/installation (affordability),
- the land area required to install/construct the project and whether it involves huge displacement,
- participation of the communities that are likely to benefit from the project; and thus whether the
project addresses issues of empowerment and capacity building by training villagers to maintain the irrigation systems, etc.,
- the extent of employment the project generates at the time of construction, in maintenance and post-project (in terms of increases in agricultural labour needed because of increases in cropping intensity),
- the extent of increases in yields/marketable surplus/incomes,
- distributional issues and equity, e.g. head-ender/tail-ender problems,
- environmental impacts associated with a particular type of project (since they may affect the sustainability of the livelihoods of the poor).

4.2. Impacts of irrigation on specific groups of poor

Most of the world’s poorest live in rural areas – mostly small farmers and landless workers. Hence, agricultural development is the key to reducing poverty, and in particular rural poverty. Our framework, described above, allows us to set out the likely impacts of irrigation on different types of poor people, summarized in Table 3.

In most of sub-Saharan Africa, since most of the poor are small farmers, increasing farm efficiency (by making irrigation, fertilizer inputs and new technology available) enables them to expand their sales and produce their own subsistence with less effort and less cash costs, thus stimulating poverty reduction. The issues are more complicated when the poorest groups are landless, as in South Asia, since development efforts in agriculture do not affect the welfare of workers directly but only through the impact on demand for labour and on the level of output prices (Binswanger & Quizon, 1986).

Measures of agricultural development enhance the efficiency of resource use. Thus, they reduce labour input per unit output. How much this is reduced depends on the source of productivity gain – for example, the reduction is larger for machines than for added irrigation. Labour demand can only rise if the enhanced profitability of farming leads to an output increase, which is sufficiently large to compensate for the initial reduction in labour requirements. The output expansion depends on the nature of demand for agricultural output and on the elasticity of supply of the agricultural output. The demand for agricultural output is price-elastic for small, open economies but inelastic for closed or state-trading economies. If output expansion is limited from the demand side, agricultural growth will lead to reduced agricultural labour demand, but will also lower food prices. Thus, the poorest rural groups will lose as workers but gain as consumers. The question is: which effect will be more important (Binswanger & Quizon, 1986).

Both small and large farmers can benefit to the same degree from irrigation per unit of irrigated area – that is, benefits need not rise with the size of a farmholding. This is so if there is equality in fertilizer use, which is a major source of increasing crop yield in modern agriculture. However, if this equality is absent, benefits from each unit of irrigated area are positively associated with farm size.

**Impact on resource-poor farmers.** According to Chambers et al. (1989) “the subsistence and income effects of new irrigation for resource poor farmers (RPFs) and for landless labourers are usually strongly positive, but they differ in form.” For the RPFs, the effects are in terms of increased production, whether for subsistence or for sale. This implies higher incomes (unless prices for produce fall so much as to offset gains). For the RPFs, irrigation means more productive work on their land. This increases intensities associated with irrigation and helps to give them productive work on more days of the year. With irrigation, the resource-poor family may not have to engage in part-time work any more. Production and income are therefore generally higher and also more stable.
Landless labourers. It is likely that landless labourers would also have a net positive benefit from irrigation. For example, Kallur (1988, cited in Chitale (1994)) reports that the Tungabhadra project in Southern India showed an improvement in the condition of agricultural labourers. Murshid (1995) reports that landless labourers could benefit if they are made owners and managers of micro-irrigation.
works. They also gain through an increased demand for post-project employment. Chambers et al. (1989) argue that the most obvious subsistence and income gains from new irrigation come from work on more days of the year, especially where a second or third cultivation season is added.

5. Conclusions

Irrigation affects poverty via a variety of different transmission effects that vary by technology type and by the characteristics of different types of poor. The chief effects are via increased employment and lower food prices: most of the poor (even the rural poor) gain an increasing share of their income from employment and are net food purchasers. As well as raising mean levels of employment, output and incomes, irrigation can also help reduce the variance of each, although there may be increased covariance. However, the distribution of ownership of, and benefit from, water and water-yielding assets, e.g. between large and small farms, is an important issue. As some of the studies above have suggested, increases in mean yields, output and incomes are not always replicated across the distribution of farms. Although few project evaluations explicitly address the equity issue of irrigation projects it is possible to draw a number of tentative conclusions.

We conclude that irrigation in itself is an important tool in poverty reduction. It is no coincidence that regions with the best poverty-reduction performance have greater proportions of irrigated land, which has complemented advances in other areas of agricultural production. There are important potential benefits of irrigation through increased yields, higher and more stable outputs, lower consumer prices and greater demand for labour that arise solely through the adoption of irrigation but can be magnified when used in combination with other inputs.

However, the poverty-reduction impact of irrigation is not a foregone conclusion and much depends on the details.

First of all, technology matters. Small-scale, low-cost and labour-intensive irrigation techniques are likely to be more important for poverty reduction. Irrigation techniques that can be accessed by small, capital or credit-constrained farms, that use additional labour beyond the initial construction phase (either family labour or generate demand for hired labour) are more likely to be of benefit to the poor than large-scale, capital-intensive technologies.

But this may not be appropriate for all regions. Substantial poverty reduction in sub-Saharan Africa is unlikely to be achieved without some new small- and large-scale irrigation projects. The high costs of this, combined with future increasing pressures on water use (e.g. subsidised agricultural water use, growing domestic and industrial use), will see big shifts of costly intensive irrigation from cereals and staples to high-value crops. This requires more water control in semiarid areas, and lower-cost irrigated areas, for the production of staples and for employment.

Secondly, institutions matter. In areas of extreme land inequality, such as Southern Africa and maybe Latin America, irrigation inequality is even more extreme. Giant farms have secured free water for capital-intensive use, leaving almost no water control for the labour-intensive poor small farmer. Poverty reduction demands attention to this issue. Distribution issues are central to assessing the poverty impact of irrigation. Small users and those in the tail-ends of systems need to be able to secure access to water in appropriate quantities and at appropriate times. Water markets and water pricing may be methods of ensuring equitable access, as well as transparent, accountable, decision-making institutions. Studies of the successes and failures of irrigation in sub-Saharan Africa show that a combination of
supply augmentation and demand management will be required. Effective demand management will require water-resources policies involving, in part, cost recovery, transfer of management responsibility and institutional change. Both the infrastructure and farming experience to exploit this potential are currently missing in Africa.

Thirdly, access to complementary inputs matter. Irrigation has the strongest effect on poverty if the poor also have access to agricultural inputs, such as fertilizers, pesticides and appropriate seeds, and to credit. Just as access to irrigation needs to be equal so too does access to these inputs.

Finally, the negative externalities of irrigation – on health and the environment – may be locally very damaging, with variable impacts on the poor. This conclusion, showing the variety of possible situations, calls for special attention in developing irrigation projects. In a “pro-poor” approach to irrigation development, a careful review of all possible impacts on the poor should help enhance the positive impacts and mitigate possible negative impacts.

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