THE IMPACT OF IRRIGATION ON POVERTY.

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1. INTRODUCTION AND OVERVIEW.

Poverty reduction is now one of the main goals of development yet progress against poverty 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 PPP), three-quarters live in rural areas. Reviving the fight against poverty requires action on many fronts (see IFAD, 2001), too numerous to address in one paper, but a review of the evidence of past poverty reductions suggest that one important weapon is investment in agriculture research and technology. This paper focuses on one aspect of agricultural technology: irrigation.

We justify our choice quite simply. There are huge regional differences in the proportion of cropland that is irrigated and these 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 and Pacific and 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 is 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, fertilisers and pesticides – that further reduced poverty (Ray, Rao and Subbarao 1988).

TABLE 1: POVERTY INCIDENCE AND IRRIGATION IN DEVELOPING REGIONS

	$1-a-day poverty [a] 1998			% Irrigated area per Ha cultivated area (arable + permanent cropland) 1999
	Incidence (millions)	% of total Population	% Change in incidence 1987-98	
E Asia and Pacific	**278 [b]**	**15 [b]**	**-33 [b]**	**20%**
Latin America and the Caribbean	**78**	**16**	**22**	**12%**
N Africa & M East	**5**	**0.04**	**-44**	**27%**
South Asia	**522**	**39**	**10**	**6%**
Sub-Saharan Africa	**291**	**44**	**34**	**3%**

[a] People living on less than $1 per day in 1998 (1993 PPP $US) (Estimates)
[b] East Asia
Sources: Poverty figures from World Bank (2000, 2001), Irrigated land from FAO Statistical Database
www.apps.fao.org/default.htm.

This paper aims to provide a framework for analysing the (positive and negative) impact of irrigation on poverty and to 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 evidence is patchy, and usually not gathered in such a way as to allow easy conclusions to be drawn.

Irrigation may lead to poverty reduction via increased yields, increased cropping areas and higher value crops (all favouring initially farmers, including poor small deficit and surplus farmers), by these means raises employment (directly of farmworkers, indirectly of other workers if wages are bid up) and maybe cuts prices in an imperfectly open economy or if there are high transport costs. Increased mean yields can mean increased food supplies, higher calorie intakes and better nutrition levels. There are also stability effects because of reduced reliance on rainfall – hence irrigation lowers the variance of output and employment and yields, and helps to reduce adverse consequences of drought (Dhawan, 1988). However irrigation may increase the covariance by crowding larger proportions of total output into nearby irrigated areas (because even these depend partly on rainfall and its variation).[1]

All irrigation benefits (also to poor) must be offset against costs. These include not just the direct costs of irrigation projects themselves, or the costs of some of the negative impacts but also the opportunity costs of irrigation investments, i.e. opportunities foregone of cutting poverty in other ways. The Green Revolution period is “odd” in the sense that complementarities among irrigation, extension, rural roads, seed research, fertilisers etc were exceptionally high, obscuring the normal trade-offs between one type of investment and another. Perhaps, however, this very

[1] Hazell (1992) showed that the effect of increased covariance can outweigh the effect of falling variance, so variability of total output allegedly increased in 1970s in India, though farm-specific and small-region-specific variance fell.

complementarity provides further justification for the need for extra investment in irrigation.

Some of the most visible and politically sensitive costs are environmental and affect the sustainability of irrigation projects: big changes to the water table, salinity, waterlogging – the latter reducible by intelligent but costly drainage planning, destruction of natural habitats all receive much press. Other costs may include widening of income and wealth disparities between dry and irrigated tracts, or between farm classes within an irrigated region, the reappearance of malaria in virulent form in irrigated areas; adverse output impact of irrigation on growth of staples such as pulses, oilseeds and coarse grains. Yet Dhawan (1988) argues that these problems are not caused by irrigation alone. Waterlogging, for example, is also caused by floods and construction of roads and railways.

Before we begin to assess how irrigation affects poverty we need to consider different meanings of poverty and different types of irrigation. The impact of irrigation on poverty may vary by what we mean by poverty and how we measure it. Firstly the indicator of poverty needs to be chosen. Narrow or one-dimensional indicators include income and consumption, or calorie intake or anthropometric measures, while broader measures may include several dimensions such as access to a range of goods and services including health, education, public transport and utilities, ownership of land and other assets, political freedom and human rights. One might reasonably expect irrigation projects to impact on some of these different indicators (e.g. income via higher yields, calorie intake by better food security) but access to education, or respect for political and human rights may not be affected, or only in the long-run. In addition, irrigation may have a positive impact on some dimensions of poverty but a negative impact on others. For example, irrigation may raise land prices in irrigated areas, out of reach of the landless poor or poor small farmers, but increase their incomes and employment opportunities.

Secondly poverty can be defined in absolute or relative terms, depending on how we define the poverty line or the threshold that separates the poor from the non-poor. Absolute concepts define a threshold fixed in real terms, for example an income level, that provides a given standard of living or welfare, while relative concepts adjust the threshold to reflect levels of consumption and welfare in society as a whole, which may therefore change over time as the societal level and distribution of welfare (and perceptions of what is adequate) change. Irrigation might raise incomes of the poor sufficiently to guarantee sufficient food consumption, but its ability to affect relative poverty will depend on not only whether the poor benefit directly proportionately more than the non-poor but also on the poor’s access to other inputs, assets, technology, markets and institutions.

Finally there is the time dimension of poverty to consider. Not all of the poor will be poor all year, or all their lives and there may be considerable movement in and out of poverty across seasons and across years. Irrigation may remove part of the variance of incomes across seasons and years, and so reduce the incidence of spells of poverty among those that flip in and out of poverty but it is unclear that the permanently poor will be lifted out of poverty by irrigation alone.

Irrigation may take many different forms from large dams and canals to small systems of shallow tube well, small sprinkler systems and porous pots. Often irrigation projects have several aims, not necessarily explicitly or directly orientated towards poverty reduction (electricity generation for example).[2] 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. tailenders), 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, fertiliser 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. These differences also vary across regions, countries and states within countries. Irrigation may affect different types of poor people in different ways: perhaps impacting on small farmers first by boosting yields and income levels, then impacting on landless labourers through increased demand for agricultural labourers, and then on the urban poor via lower food prices and possibly reduced migration of the rural poor to urban areas.

Given these potentially large poverty impacts of irrigation across a wide range of poor people, it is alarming that investment in irrigation has been falling. Section 2 of this paper presents some of the evidence and possible reasons for declining investment in irrigation and examines the case for extra irrigation. Sections 3 and 4 review the theory and evidence respectively on the links between irrigation and poverty. Section 5 sets out a framework for assessing the poverty impact of irrigation projects by technology type and by different groups of poor people. Section 6 concludes and provides a number of policy recommendations.

2. INVESTMENT IN IRRIGATION

The Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR) estimated that the average annual value of all crop production in developing countries for the years 1987 to 1989 was $364 billion (Yudelman, 1993; Wallingford, 1997). Of this, $104 billion worth of crops or 28.5% was produced on irrigated land. About 2.4 billion people of the developing countries depend directly on irrigated agriculture for food and employment. Even though the importance of irrigation seems obvious, there has been a decline in investment in irrigation.

Irrigated agriculture produces 40% of food and agricultural commodities from 17% of agricultural land. Thus, food security is critically dependent on irrigation, particularly in Asia where about 60% of the food production is from irrigated land. Table 2 presents the relative contribution from irrigation across regions. (World food Summit 1996; Wallingford 1997).

[2] Of the 37 irrigation projects evaluated for this paper, only 5 cited poverty reduction as an explicit goal.

TABLE 2: FOOD PRODUCED FROM IRRIGATED LAND

Region	Food produced from irrigated land (%)
Asia	60
Pakistan	80
China	70
India	50
Indonesia	50
Middle east and north Africa	33
Egypt	98
Iran	50
Latin America	10
Chile and Peru (food crops for export)	50
Sub-Saharan Africa	9

Source: Wallingford, 1997.

During the past three decades Africa's food production has grown at the rate of 2% per year, whilst its population growth has been 3%. The number of malnourished children is expected to increase by 14 million during the next 25 years. According to IFPRI (2020 vision), given these trends Sub-Saharan Africa would need to triple its import of cereals from 9 million tonnes in 1990 to 29 million tonnes in 2020. [3]One way in order to do this would be to expand irrigated area. At the same time, however, Africa faces a water scarcity problem. Africa is a dry continent and receives unstable rainfall. Costs of irrigation in Africa are also higher than in other parts of the world (FAO, 1986). Inter-regional comparisons made by the World Food Conference in 1974 estimate that new schemes in Africa cost 64% more than in the Far East, 55% more than in Latin America but 3% less than in the Near East. Rehabilitation is estimated to cost 20% more than in the Far East and Latin America but 11% less than in the Near East.

Yet given these alarming statistics, evidence from two 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 (Mark and Svendsen 1993). However, linking evidence on irrigated areas to irrigated investments is difficult as one needs to take account of proportions of INITIAL cropland irrigated. Diminishing returns to irrigation investment are surely less likely if these proportions are very small to start with. Also, one needs to distinguish between GROSS and NET change in irrigated area. Quite a lot of once-irrigated area

[3] Rosegrant and Pervez (1995) show that investments in new irrigation and an improvement in existing facilities can reduce the projected demand for cereal imports.

becomes unirrigated due to (a) 'losing ground' from agriculture to urban and other uses - cities often built near rivers, even confluences, so it is irrigated land that gets built over; (b) losing water - falling water-tables, deteriorating management (more seepage etc) of dam systems, and increasing pressure to divert water from agriculture to urban-domestic and industrial uses; (c) possibly the effect of global warming in increasing evaporation rates (as well as increasing variability of rainfall in the inter-tropical convergence zone). For all these and other reasons annual GROSS growth of irrigated area much exceeds NET, especially in countries with much and/or old irrigation systems. Globally irrigated area rose at an annual average rate of 1.97% in the 1960s, of 2.41% in the 1970s and fell to 0.94% in the 1980s. Regional figures, with the exception of Africa, show a similar pattern of growth of irrigated area peaking in the 1960s and 1970s, and declining in the 1980s.

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 South-east Asia, since the late 1970s and early 1980s, when it peaked. By 1986-87 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. Annual expenditure in China and Sri Lanka was cut by nearly 50% between the late 1970s and 1980s. In the Philippines the level in the late 1980s was only 1/3 of that in the early 1980s. Expenditures peaked later in Bangladesh, Indonesia and Thailand, but these countries also show a decline in investment in irrigation. In India, public sector investment in irrigation has been stagnant or declining since the mid-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 percent of Bank lending, with a peak of 10 percent 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 billion (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 considerably fallen. During the financial years, 1995-99, there were only 39 irrigation projects with an average annual lending of $ 750 million (http://wbln0018.worldbank.org/essd/essd.nsf/). This is during a period of declining lending for agriculture and rural development, which suggests that investment and lending for irrigation is not being substituted by lending for other inputs or activities.

What of private sector irrigation? Much groundwater is privately owned e.g. India, Mexico – 2/3 is privately owned, so monitoring both use and development of groundwater sources is difficult. 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 (Johnson, 1997; Ringler, Rosegrant and Paisner, 2000). 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 (CNA 1995; Ibid.). In Chile, with one of the most privatised irrigation sectors in Latin America, farmers have to, by law, contribute as much as 75% to new pumping and channel irrigation projects, with the result that only the most profitable schemes are built. But the extent of private sector involvement in the approval, funding and operation, management and maintenance of irrigation projects has increased water efficiency (see Box 1 for definitions) with booms in agricultural exports despite a small decline in irrigated area per capita (Gazmuri Schleyer, 1997; Ringler, Rosegrant and Paisner, 2000).

Box 1: Measuring water use efficiency

IFAD (2001:148) defines *water-use efficiency* (WUE) as "the proportion of irrigation system water that reaches the crop root zone." It is measured by the product of *conveyancing efficiency* (ratio of irrigation water that reaches cropped fields to total irrigation system water) and *field efficiency* (ratio of water applied to the field that reaches the cropped zone to the total applied to the field). However, this measure is imperfect both for technical and economic reasons: the latter because it does not account for costs of obtaining extra water, the former because it does not account for 'unobserved' factors that reduce conveyancing efficiency (polluted water) and those acting to reduce field efficiency (the proportion of water that is absorbed by weeds and transpired).

The *economic efficiency of water* (EEW) measures the ratio of value added to output by water to the costs of obtaining it. However, *private EEW* may differ from *social EEW* if the private optimum does not account for externalities, e.g. down-stream farmers that benefiting from the project without paying, or lose due to water pollution, salinity or flooding. Yet even if they are both increased (by growing crops with higher returns to water), the poor may not benefit, particularly where capital-intensive systems of water conservation (e.g. centre-pivot systems) are applied, which render poor farmers, who cannot afford the technology, uncompetitive, and dislodge poor workers.

Nevertheless, where there exist large differences in WUE and there is knowledge of any under-performance, mismanagement or corruption, WUE is likely to be a useful indicator of EEW and equity, and therefore possible welfare implications for poor people.

Source: IFAD (2001).

What are the reasons for the decline in investment?

The decline in investment in irrigation is largely ascribed to the falling economic rate of return (ERR) to irrigation projects, both new and existing making other sorts of investment better options for scarce resources. This may be because of technical reasons, i.e. higher-returns works are usually built first (e.g. the best sites for dams have already been chosen) leaving less good ones for later, or because of rising costs of construction, or falling recovery of costs from users; sustainability reasons, i.e. declining agricultural prices, declining water-use efficiency; or 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 (ERR) effect of investments in irrigation is only part of the story about the impact on returns to the poor, or for poverty reduction. Falling ERRs may mean that the amount of total resources available to the poor 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 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.* (1999:46) argue that Government spending in 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, Hazell et al. show that some rainfed or "backward" regions show higher ERRs 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/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 works expands and/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 non-agricultural 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 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 agricultural 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 1960s and 1970s – despite exhaustion of new Green Revolution uptrends on basic yields[4]. There is no reason why irrigation investments are any different. The relatively constant ERR is despite falling world agricultural prices (about 0.5% per year relative to manufactures) and 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. This may well be the case in some areas (see Table 3). In India and Indonesia the real costs of new irrigation have more than doubled since the late 1960s and early 1970s; in the Philippines real costs increased by more than 50%; in Thailand by 40%, and in Sri Lanka, costs tripled. The result is lower returns to investment. This has been shown by Aluwihare and Kikuchi (1991) for Sri Lanka where the benefit cost ratio for new construction declined from 2.1 in 1970-74 to 0.7

[4] Though this was increasingly 'defensive', i.e. the new research achieved its returns increasingly by preventing bugs and water shortages from reducing yields, rather than by increasing yields per se.

in 1985-89. But these data relate to countries where irrigation has long been intense. In other regions – notably sub-Saharan Africa – costs of construction are falling, and so invalidating some of the old arguments against irrigation expansion.

TABLE 3: REAL CAPITAL COSTS FOR CONSTRUCTION OF NEW IRRIGATION SYSTEMS, 1966-88 (US$/ HA)

	India (1988 prices)	Indonesia (1985 prices)	Philippines (1985 prices)	Sri Lanka (1986 prices)	Thailand (1985 prices)
1966-69	2698	1521	1613	1470	1419
1970-74	2368	1681	1882	256	2584
1975-80	1656	3187	2263	2909	2366
1981-85	4033	3283	2688	5288	2276
1986-88	4856	4096	Na	5776	2812

Source: Mark and Svendsen 1993, page 21 Table 9.

Cost recovery

Poor and/or declining cost recovery could be another factor that explains declining trends. Public irrigation projects "have been an enormous drain on government budgets" mainly because cost recovery falls short of covering the actual costs (Johnson 1990). For example, in Pakistan in 1984 approximately Rs 1 billion were collected in payment for public irrigation services. Operation and Maintenance costs were about Rs 2 billion and annualised charges for past irrigation investments were Rs 5.9 billion. Small et al (1986) studied cost recovery for five South and South-east Asian countries (Indonesia, Korea, Nepal, Philippines, and Thailand) and found that actual government receipts covered less than 10% of the full irrigation costs. Increased fiscal pressure to recover costs or to reduce subsidies may also make irrigation projects less attractive other things being equal, but presumably cost recovery problems will affect all public investments. Given the growing demand for domestic and industrial water, and other sources of water squeeze tightening, this argument becomes less defensible.

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 raising 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 now are a consequence of rising irrigated area and hence higher global yields, and even more 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 relative to farm input prices - fertiliser 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 ERR can be maintained at acceptable levels (Carruthers, op cit).

Technical efficiency

A fourth reason behind declining investments in irrigation is declines in other aspects of irrigation performance in, for example, water use efficiency or conveyancing efficiency. Misincentives, such as poorly targeted subsidies, or inappropriate water pricing systems can induce overuse or wastage of water and eventual water table depletion (IFAD, 2001). Inefficient irrigation is cited as one of the main reasons for low returns to investment in Latin America. With the possible exception of Chile (where water use efficiency has improved due to the establishment of water markets and tradable water rights, and where cost recovery is very high (Hearne and Easter, 1995; Ringler, Rosegrant and Paisner, 2000)), inefficient irrigation damages the performance of projects. Estimates from Brazil found excess irrigation time, pipe leakage and surface runoff to be the main culprits (Alfar and Marin, 1994; Ibid.). Exogenous factors, such as global warming that increases loss of water through evaporation, may also have effected technical aspects of projects.

Health and Environment impacts.

Declining ERR of investments in irrigation may be due to either 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. Resettlement of enormous numbers of people,[5] sometimes with compensation too small to purchase land equivalent to their original land-holding, and negative environmental effects[6] that are difficult to identify let alone value, create adverse publicity and weakens political support for such projects, despite the fact that, even with adequate compensation systems, benefits may still outweigh costs. The World Bank in its study of 50 large dams estimated that only 26% of the 50 projects had an unacceptable social and environmental impact that could not be mitigated through compensation packages etc without jeopardising the economic returns to the projects. The remainder of the projects could still make adequate compensation or investments in technology to avoid associated environmental effects and have acceptable ERR (World Bank, 1996).

3. THE EFFECTS OF IRRIGATION ON POVERTY: A FRAMEWORK FOR ANALYSIS.

Why is the decline in investment in irrigation important for poverty reduction? While the answer may be obvious to some given the importance of water as an input in agricultural and other productive processes, in reality the channels that transmit effects of irrigation through to poor households are many and complex. This section lays out a conceptual framework for analysing the transmission mechanisms between irrigation and poverty, whilst the following section reviews some of the country and regional evidence that sheds light on the relative importance of different channels. 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, management and maintenance mechanisms of irrigation projects.

[5] An estimated 830,000 were displaced by 50 large dams evaluated by the World Bank (World Bank, 1996); a staggering projected figure of between 1.2 and 2 million people by the Yangtze/Three Gorges dam (Siebert, 2001).
[6] Such as water-logging, sedimentation, salinisation, over extraction of groundwater, loss of natural habitats and pollution of surface and groundwater with nitrates, phosphates, ammonium compounds.

3.1. The impacts of irrigation on poverty via output, employment and prices.

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.

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 with a fixed amount of rainfall through reduced crop loss due to erratic, unreliable or insufficient water supply. Secondly, irrigation allows for the possibility of double-cropping, and so an increase in annual output.[7] Thirdly, irrigation allows a greater area of land to be used for crops. 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 poor's income, and labourers are growing share of the poor. Finally, output may be increased because irrigation enables the use of complimentary inputs, such as modern seed varieties (MVs). In fact there was an initial emphasis on using MVs on better-watered areas, and on wheat and rice regions, which tended to leave out the poorer areas. MVs (and irrigation complements the use of MVs) increased surpluses so that the prices of cereals were lower than what they would otherwise have been. In the areas that gained from the use of MVs the decline in prices was outweighed by an increase in yields, but in areas that did not benefit from MVs, the restraint on cereals prices harmed farm sales and there was little or no yield compensation (Lipton and Longhurst, 1989). Thus, incomes reduced in these areas. The landless and the food deficit farmers gained through a decline in the cost of food purchases. Lipton and Longhurst (1989) argue that the problem of 'regions left out' should not be over-generalised for the following reasons:

(1) In some cases such as India and West Malaysia, inequality among rural areas is associated with only a small proportion of either poverty or national inequality (Malone, 1974 and Anand, 1984; Lipton and Longhurst, 1989:16);

(2) In other cases, some of the regional bias in benefits from MV research corrects earlier research biases towards regions suitable for major export crops, especially within West Africa;

(3) To some extent, migration from non-MV areas to MV areas could reduce the bias;

(4) Finally, net food buyers would gain in any case in all regions.

Regional distribution has actually improved in some countries. In Taiwan, most of the cropland is in irrigable MV rice so that there has been an improvement in regional

[7] Note, however, that Dhawan (1988) argues against sole use of measures of land use efficiency such as cropping intensity (i.e. ratio of gross cropped area to net sown area – a simple indicator of the extent of multiple cropping or number of crops being raised in a sequence) to measure the 'success' of irrigation, since if the main aim of irrigation is to protect or enhance the yield of the main wet season crop, it is futile to expect any beneficial impact on intensity of cropping.

income distribution. In Pakistan, 40% of the cropland is in irrigated wheat and there has also been a spread of MVs to rainfed and *barani* areas (Rochin, 1973; Lipton and Longhurst 1989). This helped in reducing inequality among rural regions in Pakistan (Chaudhry, 1982; Ibid.). In India (excluding the Eastern rice states and Kerala) MVs did not increase inter-district inequality.

Binswanger and Quizon (1986) use a general equilibrium model of India's agricultural sector post-Green Revolution to consider the effect of expanding the irrigated area by 10% on the rural poor. The effect is to increase aggregate output by 2.7% and decrease the aggregate price level by 5.8%. Since irrigation requires labour, labour employment and real wages rise slightly. But this labour demand effect on irrigation is not very strong due to the inelastic final demand, which curtails output. Residual farm profits therefore decline by 4.8% due to higher labour costs and lower output prices associated with domestic absorption. Incomes of the landless are predicted to rise modestly from this (2.9%), whilst large farmers lose (-0.7%). All urban households gain substantially with the poorest showing the largest gain (6%).

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 on-going 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 seasonal excess labour. 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 numbers of workers required and length of 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.

The third direct effect on poverty is via *food prices*. If irrigation leads to increases in staples or non-staple food output then this may result in lower prices for staples and food in imperfectly open economies or if there are significant transport costs internationally or 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 share of food expenditure on staples and the share of expenditure on food tend to fall as expenditure rises, and the majority of the rural poor are net food purchasers, receiving large proportions of their income from off-farm employment activities. Hence the fall in the staple price is likely to be poverty reducing. However some low-income and possibly poor, small-farmers in areas NOT affected by extra irrigation – unirrigated 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 price fall. Waged agricultural labourers, in addition to increased employment, will benefit from lower prices. Wage labourers will find their wage buys more food, 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 and/or countries with high transport costs where, pre-irrigation project, food deficit had to be purchased from other regions; ii) areas with a comparative advantage in food production which can respond more strongly to the availability of irrigated land (e.g. if have surplus land and/or labour) and iii) areas with high surplus output levels which can be traded in wider markets.

Net food BUYERS, including landless and urban, gain in all areas. However, surplus producers in unirrigated areas and also in areas already irrigated – a bigger effect there, since they are likelier to be in surplus, or to produce traded crops – are likely to suffer a fall in demand for their products, so reducing income and employment opportunities. In non-remote areas this may not be a problem if cheaper food can be transported at relatively low unit-cost from irrigated areas, but not if the effect of food price falls outweighs the employment effect. Where transport and/or storage costs are high – e.g. in remote, inaccessible areas - then cheaper food prices elsewhere are not likely to benefit the poor, and so poverty may actually increase in some areas. Evidence from the green revolution suggests that poorer rural regions do, in general, lose through lower farm-gate prices due to surpluses generated elsewhere through the use of MVs. This is likely to be the case for irrigation too. Owners of land bear more of the initial losses than workers since workers can migrate or shift jobs – though many poor farmers and workers are not able to move readily from land in poorer regions and have lost absolutely from MVs (Binswanger and Ruttan 1977; Binswanger, 1980; Binswanger and Ryan, 1977; Lipton and Longhurst, 1989)

Hence, examining the direct first-round effects, irrigation is likely to reduce poverty via increased food output, higher demand for employment and higher farm real incomes among a) net food purchasers in irrigated areas, b) net food purchasers in non-remote unirrigated areas and c) the urban poor. Positive effects may be experienced by net food producers and waged labourers if effects of, respectively increases in output and employment outweigh effects of price falls. This is increasingly likely with liberalisation of food trade, with falls in growth rate of irrigated area and with better transport and falling transport-cost/production-cost ratios. Negative effects might be experienced by surplus producers in remote, unirrigated areas but net food buyers there – who are usually among the poorest – gain from price falls.

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 may encourage farmers to adopt or increase their use of fertilisers, pesticides, improved seeds and other agricultural inputs, and provide 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 probably switches 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, 1988:42). As long as the rural poor can access appropriate new technologies, possibly also requiring access to credit markets, then poverty among small producers and landless labourers is likely to fall. Irrigation does not, however, necessarily imply the production of non-foodgrains at the expense of foodgrains. While irrigation is a necessity for raising some non-grain crops (e.g. sugarcane and vegetables), many others (e.g. oilseeds and fibres) are raised in many parts of India under rainfed conditions. Moreover, the introduction of HYV seeds for cereal crops has in fact tilted the scales in favour of cereal crops to the extent that irrigation is a must for these. Punjab and Haryana, the Green Revolution states, exemplify this.

The switch of crops in irrigated areas may also create or expand demand for the crops of unirrigated areas, so leading to poverty reduction in those areas. Examples of this can be seen in the context of modern seed varieties. In India the shift from rice to groundnuts and sugar in North Arcot, Tamilnadu and from wheat to mustard, rapeseed and groundnuts in parts of Gujarat is seen as a result of shifts into rice and wheat by lead areas in the adoption of modern varieties, which led to a reduction in supply of groundnuts etc and hence an increase in price (Lipton and 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). Under certain types of irrigation technology beneficial external effects on unirrigated areas may occur. The introduction of surface irrigation through canals and tanks raises the groundwater table since a substantial portion of the surface irrigation water seeps through the ground, improving ground water availability, which 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 semi-arid areas of low uncertain groundwater availability and is why canal lining may not be regarded favourably (e.g. by the Maharashtra Irrigation Commission). However, continuous seepage without adequate measures to drain withdrawal of water through wells and tubewells or through a network of drains could make the water table rise to the crop root zone level leading to problems of water logging and land salinisation (Dhawan, 1988:35-36). This highlights the point that in many cases negative consequences of one type of irrigation could be counteracted by a mix of technologies.

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

Perhaps the biggest long-run 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 fertilisers are highly complementary with water and hence the demand for these inputs is influenced by 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 in a year when soil moisture is adequate and the ground water table favourable due to good rainfall, use of inputs like fertilisers increases crop yields, but in bad years crop yields decline sharply, hence widening year to year differences in yields (Rao, Ray and Subbarao, 1999:15);

(ii) Relative price of inputs – changes in the prices of inputs (like fertilisers) 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 and /or modern inputs are introduced (ibid.).

Irrigation not only raises crop output levels but usually cuts VARIANCE over seasons – because of double cropping for example – and over years as reliance on rainfall is reduced, at least as a percentage of the mean.[8] Ray, Rao and Subbarao (1988:35) argue that, in comparison to unirrigated conditions, the expansion of irrigation has

[8] And even if it does not, the same or even a slightly higher variance, as a proportion of a much larger mean, because of irrigation, means a bigger floor on food output and/or employment

contributed to a substantial extent in reducing instability in the output of foodgrains 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 non-farm activities.

By making employment and incomes more reliable (as well as higher) irrigation protects farmers from loss of assets and also prevents peasants from getting into debt-traps. In a bad monsoon, while rainfed crops may fail, crops irrigated using groundwater usually yield well, even if the groundwater table falls. Thus, irrigation acts as a buffer against bad years and hence the deprivation and indebtedness that these years may entail. Risk of disposing of assets such as mortgaging or selling land to buy food or meet debts, are reduced. Howes (1985: 114; Chambers, Saxena and Shah, 1989:18) describes how irrigation by poor families with handpumps has prevented them from becoming landless. Irrigation also liberates people from maintaining demeaning social relations such as with money-lenders. Chambers, Saxena and Shah (1989:18) state that "[f]or RPFs (resource poor farmers) and landless labourers alike, it ceases to be so necessary to 'touch the shoes of the rich' as insurance against those dreaded bad seasons or bad times of a year when food runs out and loans are needed to survive. Irrigation thus supports self-respecting independence."

But these effects can be eroded, even reversed, by the imperfectly predictable decline of irrigation services from existing schemes, or as schemes are expanded into new and less safe areas. Corruption can greatly increase uncertainty and so can bad management or maintenance, but EXTRA irrigation increases strains on overview and administration systems. Spending to increase outreach of existing irrigation schemes can increase (or, probably more rarely, decrease) variance due to headender-tailender conflict and uncertainty. Any irrigation system that experiences water shortage contains inherent conflict between 'upstream' and 'downstream' farmers. Upstream farmers have first access and can enjoy relatively abundant supplies. However, downstream locations do not always have water scarcity – they may get too much water if it is not wanted upstream.[9] The behaviour of upstreamers determines when and how much water the downstreamers will get. Without rules restraining access, conflict and crop loss are likely when water is scarce (Wade, 1988). A final point to note is that more irrigation in the SAME area as regards rainfall, or crop type, increases COVARIANCE and this may outweigh effect of reduced VARIANCE, leaving national employment or income or output LESS stable (see for example Hazell 1992).

To the extent that poor farmers do have access to irrigated land and other agricultural inputs, then the effects of irrigation via output, employment and prices, stabilisation and risk reduction are likely to be positive in both irrigated areas and unirrigated but non-remote areas. Remote unirrigated areas are likely to experience negative effects if transport or other market transaction costs are significant. Finally, the greater availability of food output, lower prices and reduced pressure on urban resources is likely to be good for the urban poor.

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[9] Also, the degree of locational disadvantage depends on the type of water control system: tail-end areas are less disadvantaged with a 'downstream controlled' system (found in France and French-influenced parts of Africa) than with conventional 'upstream' control.

3.2. Socio-economic impacts of irrigation.

Irrigation projects do not only effect economic outcomes, but may have wider socio-economic effects. Two very visible effects of irrigation projects, particularly large-dams and canal systems are the displacement of large numbers of people and negative health effects associated with increases in malaria incidence.

Michael Cernea who has drawn up the World Bank's guidelines for dam-driven relocations indicates that "(f)orced population displacement cause by dam construction is *(its) single most serious counter-development consequence* (Cernea, in Horowitz, 1991:168, emphasis in Cernea). While there is no doubt that both of these effects carry heavy private and social costs, insufficient attention to the 'without irrigation scenario' in programme evaluation gives rise to a devaluation of the positive economic and social impacts of irrigation works (Blackman, 2000:5, Carruthers, 1996:35, Carruthers, *et al.,* 1997.)

The impact of groundwater and surface irrigation on physical well-being, including beneficiaries' health, nutrition and sanitation is multi-faceted (Lipton and 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 to ensure that not only calorie intake is sufficient but that also diets are better balanced, with adequate intake of micro-nutrients.

However, irrigation, particularly involving canals, reservoirs and tanks, has a downside in terms of health as it encourages waterborne diseases due to inadequate drainage and renders the microenvironment hospitable to *anopheles* 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-borne diseases: they are likely to be more exposed to sources through their work and in their homes (e.g. living beside rivers and canals, or on rivers), they are less likely to be able to prevent infection by properly sterilising water and water utensils, plus they are less likely to have access to prompt, appropriate medical treatment when they are infected, because they live in remote areas and/or they cannot afford the medical fees.

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 so is not a serious problem. In addition, tubewells can mean cleaner drinking water than before, though pollution problems (nitrate and nitrite from fertiliser) need watching.

3.3. The impact of irrigation on the environment.

Another potentially large source of negative effects of irrigation are the environmental impacts of irrigation schemes. The construction of some schemes – large dams and canal systems – are associated with particular environmental problems such as loss of natural habitat, diversion of rivers but generally irrigation projects beyond the construction phase have further detrimental impacts on the environment. Water loss through evaporation, seepage and percolation, plus problems of salinisation and water logging have been found to be important consequences of irrigation schemes.

Are the poor more likely to suffer from these effects than the non-poor? Possibly if they are the ones who are more likely to face resettlement, without adequate compensation, and if as in some countries, they are resettled in areas where they become an ethnic minority.

3.4. Summary

In summary there are a mixture of short-run and long-run economic, socio-economic, environmental and political effects of irrigation that may have adverse or positive effects, and may affect different types of poor people (landless labourers, small farmers and the urban poor) in different ways. It is likely that cheaper, more abundant and stable food supplies, more farm employment, stabilisation and risk reduction, and spill-over effects to non-farm activities will be poverty reducing for large categories of the poor, although some groups, such as small food surplus farmers in very remote rural poor, may be negatively affected. However, the negative externalities of irrigation – on health and the environment – may be locally very damaging. We present some evidence below that illustrate the gains and losses from irrigation and describe the circumstances under which gains to poor farmers are less than those that accrue to other farmers and land-users.

4. A REVIEW OF THE EVIDENCE

4.1 Farm output, rural employment and prices.

According to the FAO world agricultural crop production in the thirty-four year period from 1996 to 2030 is projected to increase by only 57%, against 117% in the previous thirty-four years (FAO, 1995:95). However in the case of developing countries the predictions during these two periods is much higher, at 70% and 175% respectively. This means that by 2030 developing countries will account for a massive 75% of world crop output.

In comparison with rainfed farming, irrigation involving double cropping and Green Revolution technologies may increase the area cultivated, output per acre and farm incomes. Under ideal conditions, in tandem with increased agricultural output and efficiency, irrigation and water management aims for an equitable distribution of water supply to farmers both upstream and downstream. However, irrigation may affect rich and poor farmers differently, because of differences in access to water.

A key factor in analysing the impact of irrigated agriculture on the incidence of rural poverty is the extent to which productivity gains ‘trickle down’ through increases in income and employment for all categories of the poor. In most cases there is an inverse correlation between output and income on the one hand, and rural poverty, on the other (Fan, *et al.,* 1999:3). However the situation is not always clear-cut. The choice of crop also affects employment in irrigated areas, as crops such as chillies, rice and cotton may require more labour days in comparison with sugarcane (Chitale, 1994:388). While NHYVs and irrigation technology have been major ‘engines of growth’ in rural India, for example, there are major inter-state variations. Richer states such as Punjab and Andhra Pradesh have higher adoption rates of NHYVs, while poorer states such as Orissa and Bihar have lower adoption rates, and arguably as a result, a higher overall rate of rural poverty (Sen, Tendulkar, *et al.,* in Fan, *et al.,* 1999).

Irrigation can make a big contribution to output and incomes. In the case of the FAO second irrigation system rehabilitation project in Pakistan, over a five-year period farmers on the rehabilitated distributory canal maintained cropping intensities and farm incomes, while those on the non-project distribution suffered an 8% reduction in cropping intensity and output (FAO, 7 August 1996:2). However in the absence of adequate monitoring and baseline data, project achievements in terms of equitable water supply and poverty impact were at times unclear.

In recent attempts to rejuvenate the ancient tank networks, Sri Lanka's Mahaweli programme increased total food production by 550,000 metric tons annually, and virtually doubled the country's total power-generating capacity (613 megawatts compared to 325 megawatts from other sources) (Mahaweli Authority of Sri Lanka, 1992a and 1992b). Although precise figures are unavailable, it is argued that the programme also eased the unemployment situation in the country (Dunham, 1983).

Dhawan (1988) finds that by the late 1970s income in irrigated areas had risen across India, though not uniformly. In the Indus basin average income rises from about Rs 350 to about Rs 1 830 (1970-71 prices); in the Gangetic basin from Rs 440 to Rs 2200; in the southern peninsula from Rs 530 to Rs 2225; and from Rs 260 to Rs 4550 in the Deccan plateau. He also finds evidence for yield and output stability and drought proofing effects of irrigation, which too varied across states (see below).

Use of irrigation may also have (positive and negative) external effects on unirrigated farming. Gadgil (1948; cited in Dhawan (1988)) found some negative external effects of irrigation on unirrigated yield. Introduction of canal irrigation in a tract of western Maharashtra, India, led to a steep rise in the demand for farm-yard manure. This was due to a change in the crop pattern to sugarcane – a heavily manured crop – that resulted from canal irrigation. The rise in demand for manure by sugarcane growing farmers was met by purchases from dryland farmers located outside the canal command which had an adverse impact on yield levels in dry areas. Scarlett Epstein (1962 cited in Dhawan 1988:33) analysed socio-economic changes in two adjacent villages in southern Karnataka, one receiving canal water and the other continuing traditional dry farming. Farmers in the irrigated village took to sugarcane cultivation, increasing demand for male labour, met by the dry farming area. While this created new employment opportunities, farming was neglected in the dry area and there were adverse impacts on land productivity. The author ascribes greater dependence on female labour as the cause – one presumes was because women had limited knowledge of this non-traditional activity, or because farming implements were unsuitable for them.

However, the impact on output will also depend on the type of technology implemented. Dhawan (1988:27) reports that groundwater irrigation performs better than surface water because farmers have better control over supply. Individually owned tubewells in Punjab and Haryana enhance farm output by about 28 quintals/ha, which is twice the 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 quintals in case of tanks; 15-21 in case of canals; and 34-36 in case of wells (primarily dugwells equipped with pumpsets). Over time, the productivity of groundwater-irrigated land has risen faster than surface irrigated.

Dhawan (1985 cited in Chambers, Saxena and Shah, 1989) shows that in four Indian states the output impact of groundwater per net irrigated hectare was roughly double that of canals (see Table 4). Among lift irrigation systems, own tubewells ranked the highest in terms of quality of irrigation service. Other options such as depending on other private tubewell owners or on state tubewells are inferior.

TABLE 4: OUTPUT IMPACT OF GROUNDWATER, CANALS AND TANKS, INDIA 1977-79

Tonnes of food grain per net irrigated hectare additional to rainfed yield			
State	Groundwater	Canals	Tanks
Punjab	4.4	2.1	–
Haryana	5.3[a]	2.0	–
Andhra Pradesh	5.2	2.9	1.5
Tamil Nadu	6.0	2.1	1.8

[a] The groundwater impact of Haryana is higher than for Punjab partly because unirrigated yields were lower. Haryana figures are for 1976-77 and 1978-79.

Sources: Dhawan (1985: 11 and 13), Chambers, Saxena and Shah (1989:36).

However, the effect on yield will depend on ownership status. Lowdermilk *et al.* (Tiffin and Toulmin (1987:6); Chambers, Saxena and Shah, 1989:37) have shown in a study of lift irrigation systems in Pakistan that wheat and paddy yields rise as farmer control over supply improves (see Table 5).

TABLE 5: AVERAGE YIELDS PER HA UNDER FOUR WATER SUPPLY SITUATIONS IN PAKISTAN, 1978

Water supply situation	Average yield per ha kg			
	No. of farms	Wheat (kg/ha)	No. of farms	Paddy rice (kg/ha)
No control (no tubewell)	170	1681	75	1308
Fair control (public tubewell)	33	1868	13	1775
Good control (purchase from private tubewell)	133	1962	35	1962
Very good control (tubewell owner)	42	2242	9	2148

Source: Lowdermilk et al. (Tiffin and Toulmin 1987; Chambers, Saxena and Shah 1989:37).

The ability to extract and appropriate groundwater depends on rights and access to the land above it. However, it is not a restricted private resource and can be appropriated by lift irrigation (as well as by crops and trees). In the absence of a clear law defining and enforcing ownership and use rights, groundwater is appropriated by those who command the land over it and who have the means to lift it. Complications also arise from links between groundwater and surface flows. Surface flows replenish groundwater. Thus, groundwater and lift irrigation often gain from canal irrigation (Chambers, Saxena and Shah, 1989:28). Seepage and recharge have increased with new canal irrigation. In Punjab, in 1934 rainwater contributed 80% of total recharge. By about 1980, the percentage contribution of rainfall dropped to 51% – of the rest, 39% was from return seepage from canal irrigation and 10% from return flows from irrigation by groundwater (Sangal 1980:8; Chambers, Saxena and Shah; 1989:29). Thus, a rapid spread of canal irrigation led to a rapid rise in groundwater potential. This indicates that it might be better to use a mix of technologies in order to gain most from irrigation.

Intra-rural production linkages are created by measures, such as irrigation, that raise crop production and incomes. Johnston and Kilby (1975; Haggblade, Hazell, and Brown, 1987) highlight the potential importance of production linkages for India, Pakistan, and Taiwan. In addition to farmer demand for fertiliser and production input they emphasise the importance of other backward linkages from small farm agriculture to local blacksmiths and equipment suppliers. Mellor (1976; Ibid.) also talks of the potential power of agricultural consumption linkages since farmers also purchase consumer goods. Using Indian data they conclude that middle-sized peasant farmers (as compared to large or urban farmers) spend incremental income on labour-intensive rurally produced goods, hence generating important second-round demand multipliers.

Several empirical studies have documented the power of farm-nonfarm linkages in Asia. Based on data from India, Rangarajan (1982; Ibid.), Mellor and Lele (1973; Ibid.) and Mellor and Johnston (1984; Ibid.) estimate economy wide agriculture-to-non-farm income multipliers in the range of 0.7. Haggblade, Hazel and Brown (1987) estimate rural agricultural growth multipliers to be of the order of 1.5 – in other words a dollar increase in agricultural income will generate an additional 50 cents in rural non-farm goods and services. However they find that African multipliers are lower than those in Asia, attributable to the combination of different policies and natural environments. The nature of African rainfall patterns and geology of river basins preclude cost-effective irrigation on a scale as large as Asia. Thus, backward linkages into pump supply, canal construction and maintenance, that are important in Asia, are not available in Africa. Population density is also lower in Africa requiring large geographic catchment areas to support minimum viable scales for business. This diminishes the competitiveness of rural non-farm producers competing with large urban suppliers. In addition, African consumption patterns are less diversified into non-foods than in Asia (Haggleblade, Hazell and Brown, 1987).

Irrigation also has an important effect on stability of output and employment, and thus income. Dhawan (1988) and Ray, Rao and Subarao, (1988:45) compare fluctuations of irrigated and rainfed farming for 11 Indian states 1971-84. The calculations (presented in Table 6) indicate that the state-wise net effect of irrigation – net of possible effects of correlated movements between outputs of crops within and across states – is to stabilise crop production: the standard deviation of annual aggregate crop (foodgrains and all crops) yield and output growth rates under irrigation is less than half of that under unirrigated. Inter-state comparisons show a gain in output stability in 9 out of 11 states. The stability gains from irrigation however are mainly confined to areas with low and medium rainfall, as for example in the case of Andhra Pradesh, where the irrigated section achieved a 35% lower coefficient of variation of output and yield than the unirrigated segment. The study also indicates irrigation's significant 'drought-proofing' consequences – the reduction in irrigated output during the drought of 1972-73 was only 7% below trend level in contrast to 20% in the unirrigated segment. In 1979-80, irrigated crop output fell one-tenth below its trend magnitude while the unirrigated fell one-fifth (Dhawan 1988: 27-28).

Dhawan (1988:159) states that one reason for stability of area and yield of irrigated farming in Punjab is the central price support for wheat and paddy, the two principal crops that predominate irrigated agriculture in the state. He further suggests that farm output stabilisation 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. Additionally, substantial additions to crop output, resulting from an accelerated expansion of irrigated capacity, are likely to reduce prices of crops that experience growth faster than their demand and, in the absence of price support and cost-reducing technological change, provide disincentives to intensify farming under irrigated conditions, lowering the potential of investments in irrigation to further expand output. Since the unit cost of establishing and maintaining irrigation capacity is tending to rise faster than the rise in farm product prices, returns to irrigation investments are likely to diminish unless the output impact of irrigation rises to compensate for the rising cost. In other words, one needs to improve the general environment under which the farmer practices irrigation, rather than simply improving management of irrigation (Dhawan (1988: 239).

TABLE 6: INSTABILITY [a] IN IRRIGATED AND UNIRRIGATED FARMING, INDIA 1971-84

	Irrigated	Unirrigated
Foodgrains		
Area	2.42	5.30
Yield	6.72	14.85
Output	8.37	19.50
All crops		
Area	2.40	4.95
Yield	5.87	14.48
Output	7.34	18.99

[a] As measured by standard deviation in annual growth rates

Source: Dhawan (1988; Ray, Rao and Subarao, 1988:45)

There is evidence that the degree of stability is affected by the type of irrigation. Haryana and Punjab, in particular, experienced large gains due to extensive development of private tubewell irrigation. Relatively small gains in Tamil Nadu and Andhra Pradesh can be linked to dependence on tanks which are sensitive to rainfall variations.

In addition, some positive externalities were noted. Irrigation development has had a positive external effect on the stability of the rainfed segment in some areas (by improving soil moisture through seepage of water) such as in Punjab, whose rainfall segment appears to be stable despite a natural environment that is unfavourable for stable agriculture.

There is some evidence that corrupt practices can reduce beneficial output and stabilisation impacts of irrigation, particularly for tailenders. Based on a study of a village in Andrha-Pradesh, India, Wade (1988) describes some of the ways in which farmers can try to get an assured supply of water for paddy. These, very often illegal, means may involve enlarging the official canal outlets, breaking off gates so the outlets cannot be shut, cutting extra outlets in the canal banks, blocking the flow of water immediately downstream of an outlet to force more water through, or bribing officials to force more water along the distributary. Use of some of these methods in upstream villages squeezes water supply to villages downstream, so that farmers lower down have to exert themselves even more to protect their supply.

Wade argues that locational advantage is difficult to overcome. If farmers near the outlet wish to use more water for their paddy, farmers further down, on the same field channel may find their crops getting very little water and too late and thus have lower yields. One response could be to shift out of water intensive crops like paddy, but since small farmers seem to prefer to continue to grow staples even if they are grwoing cash crops as their main source of income. Another is to organise irrigation through common irrigators, i.e. a collective farmer-controlled organisation that enforces farmers to clear their field channels by refusing to deliver water down an ill-kept tract.

According to Shah and Raju (1998), referring to tank irrigation systems in Rajasthan, "tail-enders often have problems in receiving water particularly in years of low rainfall when tanks have filled only partially and the need for irrigation is acute. At such times, the problems of equitable distribution of water between head reaches and tail farmers worsen. In an average year tailenders hardly manage to irrigate once while head-reach farmers are able to irrigate three times" (Shah and Raju, 2001:9)

Just as irrigation can generate a stable flow of income through increased intensity of cropping and improved yields and more stable yields across seasons and years, it may also augment employment opportunities, in-migration and real wage rates. This is the case in both surface and groundwater irrigation via tubewells. For example, although the FAO groundwater development project in Indonesia had a very low ERR of just 5%, the project had positive impacts on employment and income generation through increased agricultural production including NHYVs and as a consequence, increased food security (FAO, 4 February 2000:3). Although the ERR was low it is likely that the poverty impact was much higher.

Further evidence of the beneficial effects of irrigation on employment can be found. The ILO's Bhorletar project in Nepal led to an intensification in production of rice and wheat in hills through an increased cropping index and to employment to reduce out-migration (Martens, 1989b). At the pre-project stage demand for agricultural labour was a mere 24,104 labour days year, but with project implementation this increased to 105,000 labour days per annum, absorbing 25% of the employment among smallholders. Moreover, the 21% deficit in rice was eradicated.

Irrigation facilities also require labour and other domestic inputs for their construction and maintenance. 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, January 1999:3). Increased government investment in infrastructure facilities such as roads and dams also increased *non*-agricultural employment and real wages in 'irrigated' areas, contributing to poverty reduction. However, even in large-scale multi-purpose irrigation and resettlement schemes construction is encapsulated into 3-4 years, an employment 'boom' that gives rise to massive under- and unemployment once dam construction is finally complete. In light of this, employment generation also needs to be *actively* promoted along with irrigation. Granted, it is sometimes argued that increases in the real wage rate in fact outstrip increases in agricultural labour productivity, at times even rising when productivity is on the decline (Bhalla, 1997; Fan, *et al.,* 1999:4). Yet even in India the increase in real agricultural wages is mainly due to the share of the rural populace employed in *off*-farm activities (Mukherjee, 1996 and Sen, 1997; Ibid.).

When two or three cultivators a year replace one, the need for labourers and resource-poor farmers to migrate diminishes and may disappear. Irrigation ends the need to migrate and families can stay together; it also makes it less difficult to send children to school. According to IFAD (1984; Chambers, Saxena and Shah, 1989) in one part of Maharashtra it was possible to send girls to school for the first time. There may also be indirect gains to other poor people in areas which absorb the outmigrants as the competition for work reduces and wages may even rise (Chambers, Saxena and Shah, 1989).

However, over time the higher demand for labour in irrigation schemes may therefore prompt a higher supply of labour, in turn pushing down real agricultural wage rates. As Lipton (1994:2) points out, population growth increases the supply of labour as well as demand for food relative to labour demand and output, prompting nominal wages to decline, and food prices to rise. Higher population pressures in irrigated areas also make land costs higher, and increase farmgate prices (Lipton and Longhurst, 1989:216).

The impact of irrigation on poverty via employment will depend on the type of irrigation system used. For example, centre-pivot sprinkler systems – often hundreds of yards long – are a classic big-farm-biased, capital-intensive means to water control; but the same effect can be attained more labour-intensively through gravity-flow. The aim in both cases is to achieve better crop per drop, to save water – the former with capital, the latter with labour. Price is one means to influence this choice, research and extension, another and land reform, a third.

Turning to groundwater irrigation it has also been observed that when there is short-term drought investments in labour and related inputs will not be lost (Burke and Moench, 2000:23). Shallow tubewells specifically target the poor relative to deep tubewells (that are more costly to sink) but less well compared to shallow dug wells. In areas of relatively high water tables the relatively low cost contributes to garden irrigation in large parts of the developing world, and evidence from agro-pastoral communities in arid parts of Africa indicates that villagers rely entirely on groundwater development. Moreover although recent techniques of drilling are increasingly *less* labour intensive, due to additional indirect employment created, groundwater irrigation has ripple effects and augments employment throughout rural and peri-urban areas (Burke and Moench, 2000, 29-31).

In considering the causal connections between output, prices, consumption and well-being it is useful to distinguish between producer or wholesale prices on the one hand, and retail prices, on the other. The prices of commodities consumed by the rural poor are a significant contributing factor in explaining variations in rural poverty (Fan, *et al.,*1999:3) and even though irrigation leads to increased output the link to increased food security is not unambiguous as abundant food supplies, even at modest prices, do not guarantee food security at the household level if those households are unable to work or produce in order to purchase food. The very poor spend in the range of 50-80% of their income on food and water (World Bank, 1996, Lipton, 1983; IPTRID, January 1999:1). Below the dollar poverty line, typically 70-80% of consumption (including the value of self-consumed farm produce) is for food and 50% of total self-consumption is for staples. According to global food projections in the next three decades food prices will be either stable or decline. Rosegrant and Perez (September 1997:23-24) argue that irrigation investment in Africa may have a significant impact on increased food production and lower world commodity prices and thus poverty.

In practice few projects and project evaluations refer to *poverty reduction* as an overarching goal or purpose, or attempt to evaluate the impact of the irrigation project on poverty. Perhaps an exception to this is the World Bank's salinity control and reclamation project in Pakistan that aimed to privatise tube wells. Although actual economic rate of return (ERR) was lower than anticipated and stood at 18% (compared with a projected ERR of 23%), tube well owners received higher returns than others. Further, there were increases in high value crops, and while wheat and rice predominated, there was a discernible shift towards fodder and sugarcane cultivation. Cropping intensities in smaller farms (under 2 hectares) were *higher than* in larger farms (over 10 hectares), standing at 118% and 105% respectively[10]. The project also conceived equity as a major concern, hence introduced subsidies for smallholders only. Albeit only mildly positively, actual equity was improved as purchasers of groundwater who did not control wells were able to benefit through the lower water price prompted by the high number of wells now available. But subsidies are not always a good idea, even if carefully targeted. Corruption can mean subsidies fall into the wrong hands and subsidising extra use of groundwater, and hence lowering the water table – including denial of water to poor existing users with shallow-draft tubewells – may be neither pro-poor nor sustainable. The IFAD-led Jahally-Pacharr smallholder rice project in The Gambia aimed to simply ensure the cultivation of two crops per year, yet failed to conceptualise equity in a purposive manner (von Braun, *et al.,* 1989). The overarching goal of the ILO Mnenia project in Tanzania is quite similar in terms of overall purpose of allowing double-cropping and aims to build a new main canal to provide supplementary income for the dry season, but has little explicit reference to poverty (Martens, 1989a).

4.2 Socio-economic impacts: resettlement and health

Experiences with involuntary resettlement in India, Thailand and Ghana (but not only) found that these projects and programmes generally failed to comply with eligibility and entitlement criteria, the 'acid test' of all recent irrigation projects (World Bank, 06.02.98:1). With the exception of Pak Mun (Thailand) which enjoyed exceptionally generous land compensation rates, the majority of settlers were dissatisfied with compensation for lost assets and resettlement to new homes, farms and off-farm work. In the case of Karnataka (India) the water reached families before the new sites were ready to receive them, requiring boats and helicopters to evacuate large numbers of people. Meanwhile, in Kedung Ombo (Indonesia) a significant minority of people refused to vacate, and there were protests in Narmada (India) (World Bank, *op cit.,* 2 and Drèze, *et al.,* 1997:47). However with time relocation has proved to be more satisfactory. Regional growth and job creation often buttresses the negative impact of resettlement, as income levels increase above the pre-dam levels for the majority of displaced families. This has been noted in project evaluations with three resettlement programmes in China (Shuikou, Pak Mun and Kedung Ombo), as well as a programme in Brazil (Itaparica) and Togo (Nangbeto).

The irrigation project on the Yangtze river in China is mainly concerned with the diversion of water from the Yangtze river basin in south China to the north. This requires three main routes. The western section requires tunnelling through mountains to link the headwaters of the Yangtze and Yellow rivers. The central route involves building a canal and aqueduct about 1240 km long to the Beijing area. The eastern route, about 1150 km would follow existing water courses. The central route involving the construction of a canal would cause displacement of 200,000 people. Many of them would need to move into the hills, which is likely to cause deforestation as ground is cleared for agricultural land (The Economist, Aug. 18th 2001:53).

[10] This finding - greater cropping intensity on smaller farms - is almost universal, but there is a problem pertaining to the direction of causation

Turning to health impacts, there are both negative and positive impacts. The biggest negative impact is via water-borne diseases, especially malaria. For example, when the Karnataka Irrigation Project was approved in 1978 the river valley was malaria free, yet owing to massive vegetation which choked drainage canals, and seepage that caused pools of standing water malaria returned (Jones, 1995:54). There is often inadequate baseline data from which to make accurate assessments of project impact over time (Kerr and Kohlavalli, 1999:148). There appears to be information on differential exposure and susceptibility to water- borne diseases but it seems likely that those living and working closest to surface water irrigation sources will face higher risks. If these people form a large proportion of the poor, and this too seems likely, then the poor may bear the brunt of the negative health impacts. However, irrigation may also have positive impacts on health. Higher yields and lower prices mean greater calorie and micro-nutrient availability to households; higher incomes, whether through output increases or increased demand for labour, mean more resources are available for prevention of disease, through safer and better storage and preparation of drinking water and food, and resources for prompt, appropriate health care (see Lipton and de Kadt, 1991). These positive effects are likely to be felt by the poor only to the extent that their yields, outputs and incomes rise with irrigation. If the irrigation technology bypasses the poorer residents and workers in the area, or they are excluded because they are tail-enders in a system or they do not have adequate access to the decision-making institutions that control water use and distribution, then they will only experience the negative impacts. The difficulty is that the negative effects are *public bads* while the positive effects of irrigation on health are to a large extent *private benefits*.

4.3. Environmental impacts.

FAO estimates that around 60% of irrigation water does not reach the fields due to seepage, evaporation and percolation (FAO 1996b; Blackman 2000:6). Surface irrigation may also cause water levels to rise, causing water logging and salinity. Drainage problems are concentrated in dry areas where there is salinity and, in alternative seasons, waterlogging. In Egypt, the construction of the Aswan High Dam in the 1960s resulted in high water tables and salt damage once farmers took advantage of the abundant water supply. Moreover, since groundwater is either saline away from the riverbed or acts as a lens of freshwater overlying deeper saline aquifers near the river, a limited supply of irrigated water and negligible rainfall results in a potential ecological disaster (Jones, 1995:53). Sprinkler irrigation is useful when surface water is available as water is diverted underground, reducing the chance of evaporation. It is more efficient (70-80%), along with drip irrigation (90%) (Wolff and Stein, 1998; Blackman, 2000:7). However its impact on poverty is questionable, as it is costly for the poor.

Drainage problems affect large areas of land in Latin America and in many cases these problems are compounded by salinisation. Improper agricultural water use in Latin America is salinising, waterlogging, and eroding agricultural lands and polluting water for agricultural use. In 1982, salinisation affected about 1,291,630 or 7.6% in South America and about 560,000 ha or 12.4% of Mexico’s irrigated acreage, were wholly or partially affected by salinisation in 1980 (Alfaro and Marin, 1994; Ringler, Rosengrant and Paisner, 2000). Most salinisation problems originate in inefficient use of water – for example, in Brazil 40% of the irrigated land in the north east is affected by salinity as a result of improper irrigation.

Groundwater irrigation tends to be susceptible to salinity[11] unless such irrigation occurs at higher elevations or in wet zones. During monsoon and flash floods landslides at times dam riverbeds, and when these are breached destruction could occur. But because prior to flooding the area may experience extreme aridity fish may die. As mentioned above, the *anopheles* mosquito may also thrive, as eggs are laid in the dried up riverbeds and imprints of hooves made by livestock. Further, sedimentation and debris can flush pumps in lift irrigation, and much scientific documentation of the links between ground and surface water (e.g. sprinklers, water harvesters) is needed.

Groundwater overdraft and water contamination is often associated with water scarcity, and is specific to over-pumping, though some agro-ecological zones suffer more than others do. Prior to the development of mechanised pumps the extent to which groundwater could be exploited was 'capped', so to speak, by an elaborate system of water-share and the sheer limitations set on draught power. Deep and shallow tubewells with or without pumps are now more common with the results that over-pumping is a growing problem, though the deeper wells with pumps remain the prerogative of the well-off. The situation is compounded by water salinity in the wells within arid areas, and in the case of Bangladesh seepage of naturally occurring arsenic in domestic wells (Nishat, 2001:7).

In Latin America and the Caribbean over 50% of the renewable water supply is concentrated in the Amazon which is subject to major environmental degradation. Environmental impacts may be avoided or reversed under different management systems. In Mexico, the increase in private sector investment has led to improvements in performance of some irrigation systems. Removal of sediment from canals and drains, irrigation budgets and user contributions have all increased dramatically after irrigation management transfer from the public to the private sector (Johnson, 1997; Ringler, Rosegrant and Paisner, 2000). Increased water efficiency in Chile is largely attributed to the increase in private sector involvement. However private sector investment, especially by the poor, relies upon access to credit facilities and technical assistance, yet subsidies for infrastructure investments can create incentives to invest in non-viable projects or in projects with relatively low rates of return.

4.4. Irrigation, power structures and the poor.

According to Kähkönen (May 1999:2) homogeneous Water User Associations (WUAs) have a positive impact on co-operation as users share social norms and characteristics. Community managed irrigation systems are more efficient, better maintained than state managed initiatives, constrain free riders, promote leader accountability and follow more equitable distribution patters. Similarities in caste, ethnicity, kinship, cultural norms and economic status may promote cohesion, mutual trust and better managed irrigation structures. For instance, in the case of Senegal heterogeneity of irrigators with regard to caste contributed to disputes. In Pakistan where kinship groups *(biradaris)* are the prevailing group for collective action polarised groups were less effective than homogeneous settlements. In Nepal and Peru irrigators of different ethnic groups were often reluctant to work together in irrigation associations (Kähkönen, May 1999:7-9).

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[11] So are to some extent canals. The canal colonies dug by the Royal Engineers 1850-90 in India came with quite accurate timed forecasts of when the area irrigated would go saline. All agreed the extra food (employment-based entitlements to food) in the meantime was worth it.

Both surface irrigation as well as groundwater development have become sources of inequality and conflict. As Janakarajan (1999) and Maskey *et al.* (1994) have documented, when water tables recede competition may arise between owners and users of wells. This is also the case between well owners who own wells of different depth since wealthier owners have the capacity to deepen wells and adopt electric pumps with high capacity and quality. Problems may also arise between shareholders of wells, even if these are 'community' owned and managed. Thus for instance, there are restrictions on using wells delineated for potable (drinking) water for bathing purposes, owing to the aforementioned scarcity of clean water and possible cross-contamination from domestic soap and other detergents.

Several factors curtail poor people's access to lift irrigation. For one, capital investments to establish lift irrigation systems (LISs) are high, and these are still higher in water-scarce regions. Further, there is risk of capital loss from well failure. Large overheads give rise to economies of scale in LIS operation which resource-poor farmers with small fragmented holdings find hard to exploit. Thus, group organisation is often a good way of improving poor people's access to water from lift irrigation. There are three types of groups that could be formed: i) public tubewells established and operated by many State governments; ii)NGO-induced lift irrigation groups, particularly in water scarce regions – these groups generally help promote equitable distribution of water where it is scarce and is likely to be controlled by the rural élite; and, iii) spontaneous lift irrigation groups – these are small, informal, and under-perceived, but the most extensive (Chambers, Saxena and Shah, 1989:79).

Bangladeshi case studies suggest that the implications of irrigation for small farmers' survival strategies is that in both private and public schemes the landless have not been able to regain lost land in the aftermath of irrigation (Wood, *et al.,* 1991:74). Rather, they may continue to lose through the sale, mortgage, leasing and sharecropping of land to farmers who have the requisite inputs including credit. Hence the FAO-initiated National Minor Irrigation Development Project in Bangladesh (Cr.2246-BD) may have paid insufficient attention to group formation and subsequent reduced demand for Deep Tubewells and in turn, project impact (19 March 1998:iii-iv). In the case of the FAO Private Tubewell Development Project in Pakistan (13 March 1995:iv-v) considerable investment to integrate private tubewell development with electricity distribution would have been all but lost, if not for the existence of alternative *village* electrification. Ironically, agricultural production and equity measures could also have improved through less costly introduction of Deep Tubewells. However evaluation of the FAO Second Irrigation Systems Rehabilitation Project in Pakistan (7 August 1996:iii) reveals that the agro-ecological impact and equity of supply to watercourses by those at the tail end have improved.

Research conducted in the farmer-constructed and managed Thulotar Kulo irrigation system in Nepal focuses on water rights and dispute management in terms of the relationship between customary laws and state laws as they pertain to land and water rights. Water and land disputes may range from simple social turmoil to civil strife. Such disputes are limited under farmer managed irrigation systems, although it does not necessarily follow that the outcome of disputes is negative. WUAs are sufficiently informal to enable localised conflict to be managed by farmers, yet 'unperceived injurious experiences' are equally responsible for hindering farmer participation in irrigation projects (Poudel, 2000:4). Differences in gender, caste, age, economic status and normative rights may result in variations in dispute management techniques, speed and cost. However disregard to hidden power structures within the village microcosm could result in injustice being unnoticed by observers, including policy makers, non-governmental organisations and other civil society organisations, allowing adverse situations of disadvantaged groups (most likely the poor as a whole but also women and landless) to perpetuate.

4.5. Pricing of water.

It is increasingly argued (IFAD, 2001, African Development Bank, Ringler, Rosengrant and Paisner, 2000) that water markets and water pricing are necessary to for equity and sustainable poverty reduction, particularly in drylands, but also in areas of relative abundance. For example, despite the relatively high endowment of water resources in Latin America and the Caribbean (30.8% of the available global water supply is concentrated in this region, with only 8.6% of the world's population), water resources are unequally distributed. Population growth and urbanisation are putting considerable pressure on water available for irrigation. Ringler, Rosengrant and Paisner (2000) conclude that new water development is not the primary solution to water resource challenges in the region. One needs to instead focus on water policy and management to improve the efficiency and equity of irrigation and water supply systems. They suggest integrated water management at the river basin level, and market-based water allocation, emphasising policies that transfer management responsibilities from agencies to farmers.

The poor depend on water vendors, and may even pay *up to ten times more for water* than the middle classes that enjoy piped water. It is therefore believed that cross-subsidies whereby the richer customers cover part of the cost of servicing the poor can be achieved by incorporating a 'progressive block tariff schedule', but in practice subsidies are often poorly targeted.

Many countries are also adopting water-pricing mechanisms to regulate the allocation and consumption of irrigated water. Recently, loans for investment in irrigation often includes a component calling for some form of water pricing. Equity in the allocation of irrigation water touches on long term fixed costs and the 'fairness' in allocating this scarce resource across economically disparate groups (Johansson, September 2000:vi, 7). The concept of fairness is aimed at increasing the welfare of the least powerful, and it is sometimes argued that in the case of groundwater and surface irrigation water pricing is not effective in redistributing income (Tsue and Dinar, 1995; Johanssen, *op cit.,* 7). In the case of drinking water, the poor who must rely on water vendors may also pay many times more than the well off. In irrigated agriculture markets in tradable water rights already exist and the value of usufructory water rights may be capitalised into the value of irrigation land. In groundwater development a range of interventions have been employed to influence demand, such as pumping quotas and charges, and transferable rights.[12] Groundwater subsidies, as with credit for irrigation purposes, also disproportionately favour the rich.

Private lift irrigation systems (LISs) are considered to be the most successful form of irrigation where access to water is through markets (Chambers, Saxena and Shah, 1989). Moreover, in India at least, LISs are dominated by private owners – in 1988, private LIS owners accounted for over 95% of the groundwater development. Their number has increased since then at the rate of 100,000 per year (Kolavalli and Chicoine 1987; Chambers, Saxena and Shah, 1989:98). Chambers, Saxena and Shah argue that while it may be important to reform the public tube well programme and to encourage and support NGO experiments with LIS groups, it is important to realise that neither of these offer the speed or the scale necessary to achieve major

[12] Ringler, Rosegrant and Paisner (June 2000:79-84) give an insightful discussion *in favour of* tradable water rights under surface and groundwater irrigation.

impacts on rural poverty. Thus, it is important to devise policies that influence the actions and decisions of private LIS owners and hence ensure equitable access to groundwater – one way of doing this is through pricing of water.

Private water markets supply many resource poor farmers. Across India water prices with diesel operated pumps can vary by a multiple of three (Dhawan, 1988). This is explained not by aquifer conditions but by degrees of water sellers' monopoly power and by incremental costs. With electric LISs, water prices are much lower in States with flat electricity tariffs, since these reduce incremental pumping costs close to zero, and would therefore tend to be more pro-poor. Although the private initiative gives inequitable direct access to irrigation water, the landless poor and the resource poor farmers have benefited through increased labour demand and wages, opportunities to buy water, and appreciation of land values (Chambers 1986; Shah and Raju 1988; Chambers, Saxena and Shah, 1989). Small and marginal farmers also sell water to make their LISs viable.

5. ASSESSING IRRIGATION PROJECTS

There are many different types of irrigation, ranging from small scale micro-irrigation (water harvesting, tube wells) to large scale (canals, dams). 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 operations 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 the scarce capital resource are better suited for large farmers (Dhawan 1988:215).

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 if 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, 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 increase in agricultural labour needed because of increase in cropping intensity);
- extent of increase in yields/marketable surplus/incomes;
- distributional issues, 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);

5.1. Differential effects by technology type

We discuss the above points with respect to four types of irrigation technology:

canals, dams, tube wells and tank irrigation systems.

(i) Canals

Canal projects are large-scale, expensive forms of irrigation. This section compares two main canal projects, in Tanzania and Nepal (taken from Martens, 1989). Mto wa Mbu, Tanzania has a command area of 800 ha with 54 km of canals. The total construction cost (including labour costs) in current prices was US$ 2,034,198 (US$ 926,075 excluding labour costs). Bhorletar, Nepal (Martens 1989) is a much smaller project, with a command area of 200 ha gross. It has a 5km long canal and the cost of construction is US$ 812,378 including labour (excluding labour the cost is US$ 455,812).

At Mto wa Mbu overall cropping intensity increased from 122 in 1980 (before project) to 141 at full development of the project. Crop production over the same period also showed an increase (e.g. for maize from 1,013 metric tonnes to 1,587 in 1985 and was expected to rise to 2,378 with full development). Crop production in case of Bhorletar increased by 232% – from 363 metric tonnes pre-project to 1,205 post-project. The total marketable surplus was estimated at about 800 metric tonnes post-project and was expected to cross 1000 metric tonnes once the full potential was developed. However, lack of markets made it difficult for farmers to sell this.

Incomes in agriculture in Mto wa Mbu showed an increase from T. Sh 33,382 per hectare to 38,008 between 1980 and 1985. In case of Bhorletar, the total revenue generated from crop production pre-project was estimated at NR 1,281,000 and post-project, NR 4,289,000. The financial surplus per hectare was NR 3,032,000 pre-project and NR 18,277,000 post-project. This shows the enormous income-generating potential of the canals. However, the gains were not evenly distributed because of land inequality – gains to small farmers were limited in Bhorletar since 45% of farms have less than 0.5 ha. However, because of employment generation, in the end small farmer incomes rose by almost as much as rich farmers - per capita incomes increased by 3.1 for the former and 3.2 for the latter (and middle classes benefited the least). Per capita income for small farmers was brought above basic food requirements after two years of project operation.

In addition, because of market bottlenecks large farmers were not able to get rid of the surplus and were reluctant to increase their cropping density, reducing potential employment opportunities for landless and/or surplus-labour farmers. At the same time however, crop prices were likely to fall if the area was opened up to major market centres: net effects on farmer income were of uncertain sign (Martens, 1988).

Because canals (and, more generally, large-scale irrigation) have the potential to greatly improve cropping intensity and incomes over a wide area, effects on employment are also likely to be large. For example, Mto wa Mbu created 572,000 work-days for unskilled and 7,700 for skilled labourers (masons, carpenters) in the construction phase of the project and Borletar, in its four years of construction, required 225,279 work-days of unskilled labour and 31,596 work-days of skilled labour. This increase in employment benefited mostly the poor small farmers – during 1981-82, when the project was initiated, unemployment for this group dropped by nearly 14%, increasing again when construction came to an end. Because canals (as well as rivers and drains which are a part of the irrigation network) require regular maintenance the project was also expected to generate much post-construction employment – for example cleaning of the canal before the rainy season and prior to the start of a new agricultural season was estimated to generate employment in the order of 30,600 work-days per year (Martens 1987; Martens 1989:89).

Permanent on-farm (and non-agricultural) employment stimulated by large-scale irrigation is likely to be the most important from the perspective of rural poverty reduction. For example, Bhorletar contributed to an increase in total annual employment in agriculture of 92% as compared to pre-project employment. This was even before the project was fully developed and is attributed to the change in cropping patterns that resulted. Pre-project total labour demand was 24,104 workdays; once the project was in operation, and under the new cropping patterns, it was 46,383. At the completion of the project, these figures were expected to rise to 57,522 workdays. The increase in employment in agriculture absorbed about 25% of unemployed poor small farmers. The same trend, though observed, was less pronounced for the middle class and the large farmer groups. Martens (1989) argues that the total effect on employment was even greater because of stimulation of non-agricultural sectors.

Given the scale of the projects it is perhaps unsurprising that displacement issues – in terms of numbers of households – were important. However, there were striking differences between the two in methods of obtaining land. In Bhorletar there were voluntary contributions of land since the project involved participation from the local community in decision making. On the other hand, land contributions in Mto wa Mbu were neither voluntary nor were they paid for. Many farmers were not even informed that project activities would take place on their land.

By not involving local farmers the Mto wa Mbu project did not address empowerment issues. A project committee, where villagers could voice their opinion, was not established, meaning that they were not actively involved in the design and planning of the canal network, even if it concerned their own fields. This is often the case in large-scale projects – perhaps because their sheer size and distances involved make it more difficult involve the communities. Such a lack of participation has a negative influence on the villagers' sense of autonomy and commitment to the project with the result that farmers would also not feel responsible for maintenance. Although there was local participation at Bhorletar the canal required continued support for maintenance from DIHM or ILO, organisations that funded the project and were involved in the construction of the canal, because villagers could only provide unskilled maintenance.

(ii) Dams

Dams have great potential development benefit in terms of power generation, flood control, water provision for urban populations as well as for industrial development and rural irrigation and employment generation. The review of Operations and Evaluation Department of the World Bank indicates that the 50 large dams reviewed created an installed power generation capacity of 39,000 MW, replacing about 51 million tonnes of fuel in electric energy produced annually, and expanded total irrigated area by about 1.8 million hectares. Although dams generate temporary employment expansion in their construction, and then more permanent, but smaller, increases because of maintenance, probably the largest benefits are in on-farm employment, e.g. because of multiple cropping as in Tungabhadra project in South India (Kallur 1988; Chitale 1994). In Pakistan, the direct benefits from two irrigation projects, Tarbela and Mangla, were estimated at about $260 million (annual) and the added supplies of irrigation water made it possible to grow the equivalent of two wheat crops a year on 400,000 hectares of previously irrigated land and 400,000 hectares of previously rainfed land. According to an impact evaluation, farmers with irrigated land have had increases in income which are spent on consumer goods and on education. Increased farm activity also increased demand for the fertiliser and agricultural output processing industry (OED 1996 – OED Precis. No 125. Operations

Evaluation Department, World Bank. Sep 1996).

However, social and environmental costs of large dams may be huge. Dams are responsible for huge displacement. The 50 dam projects reviewed by OED have displaced about 830,000 people, and only half showed a satisfactory resettlement outcome. Hirakud dam, India, built over 1948-57, displaced 100,000 persons and submerged 167,376 acres of land (Cernea, 1997). Sardar Sarovar, India is expected to displace about 100,000 people (30,000 from Gujarat and Maharashtra and 70,000 from Madhya Pradesh) (Alvares and Billorey, 1988:16). In some cases landholders have not been compensated, for example farmers were stripped of their land during the Semry I project in Cameroon (Brown and Nooter, 1992).

There are serious issues regarding the impact of large dams on deforestation. For example, the forest area lost to hydro-electric projects in the state of Karnataka was about 41,068 hectares, 18.4% of the total area (Ray, Rao and Subarao, 1988). Building of dams can also cause watershed degradation leading to sedimentation of the reservoir. New dams can create health problems in tropical areas that often have outbreaks of waterborne diseases, although as OED (1996) argues, the World Bank projects reviewed successfully controlled these problems. Many dam projects have created new fisheries within the reservoirs, thus mitigating losses to fisheries, and potentially provided some (possibly landless) poor with a source of livelihood.

(iii) Tube Wells/Groundwater

Tube wells are small-scale forms of irrigation and have much lower costs of construction/installation relative to dams and canals. In Bangladesh the command area for each deep tube well (DTW) is in the range of 50 acres, the procurement price of which was Tk 640 000 and rental charges Tk 5000 per year (Wood and Palmer-Jones, 1991:135). The main benefits of tube wells are to farm income. Installation of shallow tube wells in Terai, Nepal, led to a net increase in income from cultivation by Rs 15,224 for paddy, Rs 1,793 for wheat, Rs 736 for maize and Rs 3,502 for other crops. The corresponding net increases for those who were not (direct) beneficiaries of this scheme, were Rs 8,616, Rs 1,736, Rs 579 and Rs 2,981. Although it is not clear where the majority of poor farmers were situated and what crops they harvested, and thus what effect on income inequality there was, the spillovers implied by these figures demonstrate that, on average, farmers in both areas stood to gain from the project.

Tube well installations are not large-scale projects so they do not generate employment during construction. However, post-installation, they show an increase in seasonal employment, related to increase in cropping intensity. Minor irrigation, by creating a winter rice season and contributing to wheat and supplementary irrigation of the *aman* crop in Bangladesh, enhances both the productivity of land as well as increases the opportunities for employment of landless workers (Wood and Palmer-Jones 1992:148). Unfortunately employment figures pre- and post-project not available to verify this claim. Murshid (1995:20) reports that irrigation generates higher-skilled salaried employment (as manager, linesmen, etc). It also enables fuller utilisation of family labour through sharecropping opportunities for members and provides more post harvest processing opportunities for both men and women.

Unlike large-scale projects, micro-irrigation works may be designed to promote equity since it is possible to have the landless manage them. For example, in Bangladesh, Murshid (1995) reports that assigning property rights of DTWs to landless empowers them and also promotes skill development both directly through training as well as indirectly from interaction with local bureaucracy, farmers, and NGO officials. This helps them to develop bargaining and negotiation skills, provides employment in the fields and in operation and maintenance of the tubewell and finally it gives them status.

However, the poverty-alleviating potential for small farmers may be limited since tube wells and pumpsets are indivisible investments and prove uneconomic for farms below a certain size. One solution is for them to enter into a co-operative agreement (Dhawan, 1988). The spread of tube wells over the last 25 years has also led to a steady drop in the water table level and rise in salinity levels – in Pakistan the depth of the water table fell from 8.1 feet to 11.3 feet over 1961-1965 (Ibid.) – which presents sustainability issues for poverty reduction in areas affected.

The Grameen Bank of Bangladesh has diversified into many activities, including management of irrigation. The number of deep tube wells acquired by the Grameen Bank are about 805 (managing them under the name of a separate institution – the Grameen Krishi (Agricultural) foundation (GKF)). The GKF's approach to irrigation management differs from that of public agencies in Bangladesh. This is because GKF has an explicit poverty alleviation objective. Its activities are aimed at helping the poor, the landless, and asset less and poor women and enable them to get access to resources so that they can be self-employed. It thus encourages a staff intensive policy of management of deep tube wells. They also provide thorough staff training in order to make the schemes effective. Such investment in human resources has resulted in committed and hard working people. Moreover the GKF charges a non-subsidised fee in the form of a share of the crop from farmers who make use of their irrigation facilities (Jordans and Zwarteveen, 1994).

Box 2: The impact of irrigation on poverty: a case-study

Von Braun, Puetz, and Webb (1989) study a new rice irrigation project involving 7,500 farmers in The Gambia. The technology was in the form of mechanical pump irrigation and improved drainage for rain-fed and tidal irrigation. Its expansion pulled labour away from other crops, reducing output of the latter, but increasing net calorie production overall. The project was likely to benefit excess farm-household or landless labour since 24% of the work is carried out by hired labour, which played a marginal role in rice production before the project. Average labour productivity was greatest in the fully water-controlled rice fields (ones with pump irrigation). In partly water-controlled fields (tidal irrigation or improved rain-fed cultivation and drainage) labour productivity was only half of that in the fully water-controlled, though 30% higher than that in swamp rice.

At the sample average, the irrigation project increased real incomes by 13% per household. Moreover, since rice production contributed 43% of per adult equivalent income to the bottom income quartile and 26% to the top quartile, poor households gained disproportionately, and thus the new rice technology to a more equal distribution of income in the area (at least in the short run). However, the study predicts that the poorest are also likely to be most adversely affected in case there is deterioration in project yields. The gains to household income raised calorie consumption, in turn improving the nutritional status of children. Mothers' weight loss in the wet season, not only a health and nutrition problem for them but also indirectly for the children as it relates to low birth weight, was found to be reduced with increased access to the new rice land. Unfortunately without supplementary programs for child-support, the greater the access to the rice project, the more frequently mothers took their smallest children with them to the swamps, which increased their susceptibility to disease.

The introduction of the new technology led to a transformation of the status of rice, traditionally a women's crop grown to a large extent on private farms, to communal crop under the authority of the male compound head. Thus female farmers, despite being previously allocated formal land titles, now controlled only 10% of their pump-irrigated plots. This change increased the burden of communal agricultural work disproportionately for women (though men's burden increased also), thus reducing women's opportunity to grow private cash crops and receive independent incomes, as well as limiting the beneficial calorie consumption effect of higher household income. However, women were not necessarily dispossessed of all individual farming rights or of an independent income. They organised private production of upland crops (such as groundnuts and cotton) and many were paid for work on the new rice fields by the compound head (von Braun and Webb, 1989; von Braun, Puetz and Webb, 1989:68).

(iv) Water Harvesting

Rural areas of Rajasthan have small dams called *johods* or *paals* with water spread areas of a few acres. They also have minor irrigation tanks with command areas of 1000 ha or more. Shah and Raju (1998) call Rajasthan's tanks "a socio-ecological and economic marvel (since) (a)t a low opportunity cost, they perform many useful functions… First, they help capture, conserve, and store what little rainfall the region receives and in the process reduce soil erosion by cutting the pace and momentum of run-off waters. Second, they provide low-cost flow irrigation. Third, they help recharge groundwater aquifers, which provide a stable and reliable source of irrigation and domestic water supply. Fourth, they reduce the intensity of flash floods and droughts… Fifth, tanks concentrate silt and minerals contained in rain water run-off in tank beds and in the command area and fertilise the soil. Sixth, …unlike large reservoirs and tanks in South India which take land in the submergence areas away from other uses, tank-beds in Rajasthan are used both for water storage as well as for cultivation" (Shah and Raju 1998:7). However, the main problems are in terms of maintenance since, as mentioned above, there may be health problems (spread of water-borne diseases) if tanks are left unclean or uncovered.

In recent years, Latin American and Caribbean countries have tapped non-traditional sources of water for both irrigation and non-agricultural water uses. *Rainwater harvesting* in the form of rooftop catchment is undertaken in several countries in the region including Argentina, Barbados, Brazil, Chile, Costa Rica, the Dominican Republic, Mexico, and Peru. Costs of water harvesting are estimated at US$3 per cubic metre in Chile. This type of water is mainly used for domestic purposes. In situ rainwater harvesting (the use of natural or artificial depressions to store rainwater) is carried out in Argentina, Brazil, and Paraguay for crop and livestock production. *Fog collection* has also been used in the mountainous coastal regions of Chile, Peru, Ecuador, and Mexico, which have high levels of fog and recurring winds. Fog collectors are made of fine nylon net strung between poles. Water droplets in the fog condense on the net and, when enough have gathered, coalesce and run off into a conveyance system, which carries the water to a storage area. *Runoff collection*, captured from roads, can be collected in drainage ditches or street gutters and then transported to cultivator areas. This has been used in semi-arid areas of Argentina, Brazil, and Venezuela. In Ecuador, costs have been estimated at between US$0.10 and US$2 per cubic metre of water stored and in Argentina between US$0.60 and US$1.20; in Brazil a project of 3000 cubic metres cost US$2000. *Flood diversion* in the forms of transverse dikes, small-scale diversion structures (*toroba*), and water traps have been used in Sao Paulo State, Brazil, state of Falcon, Venezuela, and

Province of Mendoza, Argentina, (Ringler, Rosengrant and Paisner, 2000).

Water harvesting offers both agricultural and ecological benefits: they are cheap and thus available to poor farmers, and sustainable, having limited adverse environmental consequences.

5.2. Impacts 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, especially rural poverty, and especially, in light of the (often) hard budget constraints faced by Government, because of strong linkages both within the rural economy and to the economy as a whole (e.g. in terms of cheaper food for poor net consumers, reduced rural-urban migration pressure etc).

In most of Sub-Saharan Africa since most of the poor are small farmers increasing farm efficiency (by making irrigation, fertiliser inputs and new technology available) enables them to expand their sales and/or 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 the landless, as in South Asia, since agriculture development efforts do not affect the welfare of workers directly but through the impact on demand for labour and on the level of output prices (Binswanger and Quizon, 1986).

Agricultural development measures enhance 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 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 and Quizon, 1986).

Binswanger and Quizon (1986) look at what happened to income of different income groups in two decades of agricultural growth in India. Then they look at technical change in different crops under alternative trade assumptions and consider the effects of expanding irrigation, declining fertiliser prices and removing trade restrictions on rice. The results indicate that consumer benefits are more important than employment effects for the welfare of the landless. They can benefit from agricultural growth only if food prices decline. However, declining prices is bad for he rural sector as a whole. The authors therefore suggest food rations and direct income transfers to assist poverty groups.

Small and large farmers, per unit of irrigated area, can benefit to the same degree from irrigation – that is, benefits need not rise with the size of a farm holding. This is so if there is equality in fertiliser 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.

<u>Impact on resource poor farmers</u>: According to Chambers, Saxena, and Shah (1989)

"the subsistence and income effects of new irrigation for resource poor farmers[13] (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 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 is therefore generally higher and also more stable.

<u>Landless labourers</u>: It is likely that landless labourers would also have a net positive benefit from irrigation. For example, Kallur (1988; Chitale 1994) reports that the Tungabhadra project in S 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 employment post-project.

Chambers, Saxena, and Shah (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. Reliable and adequate irrigation raises employment." Silliman and Lenton (1987 in Chambers, Saxena and Shah 1989) report from evidence collected from 45 micro-studies, 25 of which are form India, that there is a positive relationship between irrigation and employment, especially from increased cropping intensity. Mehra (1976; Chambers, Saxena and Shah, 1989) disaggregated the employment effects of irrigation and of high-yielding varieties. He found that irrigation contributed more to employment than high-yielding varieties.

Ghosh (1984, 1985 in C, S, and S 1989) found a sharp contrast between irrigated and unirrigated conditions for male labourers in two West Bengal villages. In the irrigated village there was work all year round with additional immigration of seasonal labourers at the peak periods. In the unirrigated village there were two periods with almost no work, implying that labourers would either have to seek low paid local work, or migrate, or suffer serious deprivation. In contrast, high intensities of irrigation appear livelihood-intensive for labourers, filling in the slacks providing for a continuous flow of cash and food to the household (CSS 1989: 16).

According to CSS (1989:17) among some common benefits of irrigation to labourers is a rise in daily wage rates; more reliable employment and income; and where labourers have to buy food, lower food prices when higher production from irrigation brings prices down.

<u>Impact on women.</u> Women are disproportionately represented in poverty statistics (IFAD, 2001). Failure to recognise the importance of women in agricultural activities often worsens the position of women as well as negatively affects project outcomes (Zwarteveen, 1994; Jordans and Zwarteveen, 1997). Although there is now increased recognition of the importance of gender relations for planning, designing and managing irrigation, there are few documented examples of irrigation

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[13] Resource poor is a term used for farms, farmers and farm families that do not have farm resources that currently permit a decent and secure family livelihood. Such families include many of those who are marginal (0-1 ha) and small (1-2 ha) farm holdings, and many others with more than 2 ha but whose land is infertile, vulnerable to floods or erosion, or subject to low and unreliable rainfall (p 263, Chambers, Saxena, and Shah 1989)

approaches that consciously incorporate gender issues.

In Bangladesh, women's on- and off-farm incomes have risen. The increase in labour opportunities generated by irrigation has been higher for female labour as compared to male labour. Of the women belonging to landless and marginal farmer households 67% reported a higher income through increased wage labour opportunities in irrigated production (Jordans and Zwarteveen, 1997). Increases in income from animal production increased incomes of both male and female workers and women reported that caring for livestock (which is primarily their role) became easier with irrigation since it increases water availability for bathing cows in the dry season. Additionally, irrigation reduces the general work burden of women because it increases access to water close to home, since water collection is primarily an activity of women.

However, whilst livestock care is easier (as mentioned above), feeding of livestock has become more time consuming – again a task that women are involved in. This is because there is a decline in fallow land – more and more land is brought under cultivation because of irrigation. In the villages from which the above observations have been drawn, irrigation has made rice cropping possible. This means an additional amount of straw is available for the livestock. The disadvantage is that it is not as nutritious as grass. However, fresh grass grows near the bunds around the rice fields and in the earthen channels. Women either lead their cows to these areas or cut the grass and stall-feed the cattle at the house. Leading the cattle to the bund sites could have a negative effect in that the earthen channels may get damaged by the cattle. Hence women generally cut these grasses and carry them. This implies increased work burden for them even though they do not report any shortage of fodder.

Irrigation also changes labour relationships. Prior to availability of irrigation, women often worked for rich households, receiving food in return. With irrigation, opportunities for income generation such as crop processing, agricultural production or working as agricultural labourers have increased. During interviews with women from middle and large land-owning families, 45% reported increasing difficulty in obtaining wage labourers – both male and female at peak times. Introduction of irrigation also changes labour relationships within households – female family labour is increasingly used for own irrigated production especially among poorer households.

The increased contribution to household income has resulted in greater power of women in the household. This is not only equitable but also will have functional consequences – for example, women have different priorities such as a clear preference for education of their daughters. Jordans and Zwateveen (1997) argue that women could be empowered by involving them in cultivating land in the command areas of deep tube wells (DTWs) and participating in water management; by allowing them to fully or partially manage DTW equipment, and in constructing earthen irrigation channels in the DTW command area.

6. Conclusions and Recommendations

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 that has complemented advances in other areas of agricultural production. There are important potential benefits of irrigation through increased yields, higher 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 detail.

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 and/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 large scale irrigation projects. The high costs of this, combined with future increasing pressures on water use (e.g. subsidised agriculture 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 semi-arid areas, and lower-cost irrigated areas, for staples production and 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 farmers have secured free water for capital-intensive use, leaving almost no water control for the labour-intensive small-farm poor. Poverty reduction demands attention to this issue. Distribution issues are central to assessing the poverty impact of irrigation. Small users and those in tail-ends of systems need to be able to secure access to water in the appropriate quantities and at the appropriate times. Water markets and water pricing may be methods of ensuring equitable access, as well as transparent, accountable decision making institutions. Studies of successes and failures of irrigation in Sub-Saharan Africa show that a combination of supply augmentation (new development of surface and groundwater water, reuse of agricultural drainage water, industrial recycling, waste water use, water harvesting, and desalination) 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 as well as farmer experience to exploit this potential is currently missing in Africa.

We have a number of recommendations about further research and policy making in this area.

1. Project evaluations of irrigation projects funded by donors with poverty reduction

objectives need to cover not just economic and technical impacts but broader impacts on the poor. In particular project evaluations should examine the impact on yields, output, crop mix etc on different types of irrigation beneficiaries, perhaps classified by farm size or income group. Employment effects need to be separated into short-run construction related effects and longer-run agricultural related effects. Similarly effects on surrounding non-irrigated areas should be investigated. Ideally a before and after evaluation should be conducted, either using two surveys or recall techniques.

2. Agricultural research needs to prioritise poverty reduction objectives as much as average increases in yield and outputs. Hence research needs to focus on the types of technology most appropriate for different types of poor users and poor beneficiaries. Technology that creates demand for labour rather than replacing it is likely to be the most appropriate.

3. Project choice criteria should include not just comparisons of ERR or other efficiency indicators but also equity issues by examining the poverty reduction impact per dollar of investment, estimated using the framework sketched in this paper, or something similar. This applies to irrigation and non-irrigation projects alike.

4. Much more research is needed into the poverty impacts of irrigation projects to provide more detail on which types of irrigation are of greatest benefit to different types of poor people in different agro-ecological regions and institutional settings.

7. ANNEX: PROJECT EVALUATIONS

The database of irrigation project evaluations comprises of 27 projects, mainly funded by a combination of private donors, some in conjunction with national or federal governments (in one case the source of funding was not reported). 16 of these had World Bank and/or IBRD donations, 9 IDA and 2 ILO.

In total there are 14 canal projects under review (mainly in Asia), 7 wells (of which 6 are specified as tubewells and 1 as deep wells and conduits), 2 combined tubewell and canal projects, 1 pump and tidal irrigation project, 1 resettlement project, 1 irrigation rehabilitation project and 1 water-use efficiency project.

They are distributed among developing regions rather unevenly. 15 of the projects evaluated were situated in South Asia (1 Bangladesh, 3 India, 3 Nepal, 6 Pakistan and 2 Sri Lanka), comprising of a range of canal, well and tubewell projects with a wide range of costs and command areas. 5 in East Asia (China, 2 Indonesia and 2 Philippines) were relatively large projects involving costs of between US$33 and US$220 million and command areas between 22,000 ha and 160,000 ha. 5 projects were in Sub-Saharan Africa (The Gambia, Nigeria, Senegal, Sudan and Tanzania) and involved a range of mainly tubewell but also canal and tidal technologies. The largest in this region, the Gezira Rehabilitation project in the Sudan, had the greatest overall command area (924,000 ha) and cost $US191m. Of the 2 remaining, 1 was a deep well project in North Africa (Tunisia) costing US$24m; the other, the Itaparica Resettlement and Irrigation project in Brazil, incurred the greatest costs (US$738m).

Efficiency outcomes:

Most studies report an economic rate of return (EER) – i.e. the ratio of value added by irrigation water to its costs (see Box 1 in the text) – in their analyses (however, 3 do not). EERs range from less than zero (resettlement in Brazil) to 60 (tubewells in Bangladesh). There are similarities between canal and well projects reviewed: on average canals have EERs of about 20, but in reality this may range between 1 (Senegal) and 50 Pakistan; tubewells have a marginally higher average EER, ranging between 2 and 60. If one compares expected to actual EER one can see that many projects under-perform – that is, 9 canals (at least those for which data were available), and 6 wells, some by very large amounts (for example, one project in Indonesia was expected generate an ERR of 14, but actually only achieved 2.5 to 5; another in India was expected to produce 33, but only produced 3.

Production/yield/income/employment outcomes:

Most irrigation projects report effects on production, incomes or yield (only four IBRD/World Bank-funded projects do not) but only 8 give data on all of them. 13 do not report production estimates (mainly World Bank/IBRD-funded and IFAD-funded). Of the 14 that do, all report increases in production and all but one disaggregate by crop type, but not by income or farm-size, pre-empting important distributional comparisons (i.e. effects on income and land inequality). 17 out of 27 report effects on yield (those that did not were mainly funded by the World Bank/IBRD and IDA). Most gave changes in yield by crop type, however 4 did not even present this and only 1 reports by farm-size (Martens, 1989). Regarding effects on farm-income, 9 evaluations do not give figures at all (8 of these World Bank/IBRD-funded). The majority of the remaining 18 report rises in average income – only 6 disaggregate by farm-size, 1 by crop-type, and 2 by income group.

Although potentially a very important determinant of the impact of irrigation on poverty, only 12 of the studies present effects on employment (2 of these report which socio-economic groups were affected). Almost all find reductions in unemployment/underemployment. Only one study presents data on wages.

Equity outcomes:

Only 13 studies explicitly refer to equity considerations. About half imply adverse distributional shifts (mainly those where participation with (poor) farmers was limited) mainly where large farmers and/or headenders gained at the expense of small farmers/tailenders. When disaggregated by irrigation type it appears that micro-irrigation on balance produces more equitable outcomes than the large-scale, indivisible projects, as one may expect. Gender impacts are only reported in 6 studies (4 of which are funded by the World Bank). Women may have gained in half of these cases. However, 15 studies present information regarding participation, i.e. on the influence of farmers in the project, the development of WUAs, power relations between e.g. head- and tail-enders. 8 of these studies report some degree of farmer participation, though in some cases landless labourers and tailenders may be excluded.

8. References

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