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**Please send comments on this paper to the author or to:**

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**IRRIGATION MANAGEMENT NETWORK**

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# ESTIMATING THE ECONOMIC PROFITABILITY OF IRRIGATION: THE CASE OF BRAZIL

**The FAO Investment Centre**

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Italy.

# ESTIMATING THE ECONOMIC PROFITABILITY OF IRRIGATION: THE CASE OF BRAZIL

**The FAO Investment Centre**

## 1 INTRODUCTION

Many countries now face important questions about the future development of irrigation, especially decisions on the mixture of public and private activities in funding, implementation, management and maintenance. Options need to be reviewed, and priorities decided on from a portfolio of projects. Appropriate developments in infrastructure, advisory and support services should then follow this selection. At the moment, all these stages of irrigation policy development are poorly documented.

This paper describes an attempt to carry out a comprehensive review of the economic profitability of irrigation, in the case of Brazil. It is aimed mainly at specialists who wish either to question or improve on the Brazilian analysis, or to attempt a similar exercise for another country. Presentation concentrates on the principles behind the review and on methodology. The work concerned was carried out by a team from the FAO/World Bank Cooperative Programme.[1] Readers requiring more operational details or wishing to discuss specific Brazilian implications of the results are welcome to contact the team leader.

The authors are very pleased to acknowledge the cooperation of their Brazilian counterparts in the work described here. They would also like to thank the Brazilian Government for its support and for permission to release the review results to a wider readership.

## 2 BACKGROUND

Irrigated agriculture is quite sharply divided in Brazil between public schemes and private development. Public schemes, almost all located in the semi-arid northeast, comprise only some 6% of the total irrigated area,

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[1] S D Hocombe (Team Leader, Senior Adviser), M Raczynski (consultant, Irrigation Specialist) and M Mendez (Economist).

but until lately received the lion's share of Government attention and internal as well as external funds; they have often sought to respond to social as well as economic needs. Private development has only more recently been the object of special Government technical support (especially under the PROVARZEAS[2] programme), and targeted credit lines. It comprises many forms of irrigation ranging from small to large-scale, and from primitive to highly sophisticated. It is spread through most parts of the country. There has been a great diversity of performance between the two irrigation types, but with public irrigation generally tending to progress slowly and fall short of performance expectations while private irrigation, especially in recent years, has expanded fast and often given high profits. However, direct comparisons have been made difficult by regional differences in irrigation needs and opportunities, the special social needs of the impoverished northeast, as well as by the different institutional arrangements for public and private development.

It was partly for the above reasons that in 1987 the Brazilian Government decided to make a comprehensive review of the complete irrigation sub-sector before making further commitments to its development. Assisted by World Bank funding, the Review took the form of five studies:

- a study of future output and demand for basic commodities up to 2005 (rice, maize, wheat, soya beans, common beans, and cotton);
- a study of the present and possible future economic profitability of all major forms of irrigation, whether public or private;
- two separate studies of sub-sectoral legislation and institutions;
- a synthesis of all the above, leading to recommendations for future sectoral policies and development priorities.

The FAO/World Bank Cooperative Programme assisted with the second of these studies. Work took place in 1988, and although the Government's review was subsequently re-worked together with The World Bank to become a joint policy document, the FAO team's initial contribution on economic profitability was not changed.

In 1990, with hindsight, it can justifiably be claimed that the Review, and especially the estimates of economic profitability, greatly reinforced a major change in Government irrigation policy which was previously only incipient.

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[2] Varzeas are seasonally-flooded or flood-prone lowlands.

The Review advocated a shift in priorities away from an excessive focus on public schemes in the northeast, in which the Government had tended to combine the roles of instigator, financier and manager in what was often seen as a paternalistic manner, towards a much greater stress on Government as the facilitator and regulator of privately-financed irrigation. As a consequence Government plans have since moved more towards creation of satisfactory conditions for low-cost private irrigation development, through the provision of access, electricity, technical advice, credit and the like. This shift has been matched by commitments of World Bank and other external funds. It is now intended that most future Government construction of major supply works should be restricted to settings where the water source is too distant or too costly to be developed by private individuals or groups acting alone. However, in such cases a firm commitment by potential beneficiaries to repay Government costs will be a prerequisite for Government involvement, i.e. development should be demand-led. Finally, while fully public irrigation with only partial cost recovery is still not excluded *a priori* from future options, it is now recognised that special justification - usually social - is necessary. Furthermore, budgetary sources for the continuous Government funding which will be needed should be secure before new commitments are made to this type of irrigation.

## 3 WHY ESTIMATE ECONOMIC PROFITABILITY?

Programmes for irrigation development usually have multiple aims. Some of the most frequent are to reduce dependency on agricultural imports, to generate exports, to reduce fluctuations in output, to intensify production, to aid human survival in semi-arid areas in times of drought, to raise farmer incomes, to create employment, to keep parastatal or private contractors in work, or to raise political monuments. But all irrigation programmes have one thing in common; they use scarce resources, whether these be natural (water, irrigable land), managerial, or financial. Furthermore, in the case of existing irrigation, much of the financial contribution of Governments tends to be borrowed and hence must eventually be repaid.

Whatever the mix of economic and social aims to which a Government gives ultimate priority in its irrigation strategy, it is therefore prudent when planning sub-sectoral development to estimate the economic profitability of the use of the natural and financial resources being allocated. With such estimates, comparisons can be made between irrigation alternatives, and with rainfed options if these exist. If, at national level, it is decided for social reasons to favour one of the less economically profitable forms of irrigation, the extra public cost of doing so can be identified. From the point of view of the national finance ministry or a potential lender, the justification for, and the economic implications of, the overall programme which is eventually proposed for financing are made explicit. If changes or adjustments are considered necessary they can be negotiated on a rational and quantified basis.

In practice, few irrigation sub-sector plans are based on such estimates. Most irrigation planners have little time, or perhaps inclination, to make a systematic review of the economic profitability of all technical options when formulating national irrigation strategy. Those who belong to agencies which have irrigation as their 'raison d'etre' tend to give scant attention to rainfed alternatives or even to the comparative advantage of irrigated local production versus imports. It may be enough simply to squeeze a 12% economic return out of the technical option preferred by the agency's engineers. In addition, irrigation planners usually feel that they lack the base data and analytical methods for what is seen as a complicated exercise. However, this paper suggests that meaningful analysis is possible using skills and data which can be organised fairly straightforwardly by interested groups.

## 4 THE BRAZILIAN SETTING

Brazil is a huge country with a great diversity of climate and agricultural systems. There are also many types of irrigation and irrigator, on approximately 2.3 million hectares of irrigated land. For development purposes the Government has divided the country into five regions.

The south is subtropical, typically cool, with dry winters and warm, moist summers. It has a highly developed, commercially-oriented agriculture in which both large and small farmers share. The risks of winter frost are such that there are few viable opportunities for out-of-season winter irrigation. And although supplementary summer irrigation can save farmers from disaster in a dry year, on average it gives only a small increase over the rainfed yields of the staple summer crops of the south - maize, beans and soya. As a result, irrigation development in the south has instead focused mainly on summer flooding of lowlands for rice production. Most is large-scale and mechanised, and closely integrated with cattle production; largely for reasons of weed control, lowlands are typically only planted with rice once in every three years and kept under non-irrigated pasture for the other two. More recently the Government has promoted conventional lowland rice irrigation on a smaller scale, under its PROVARZEAS programme.

The southeast region, stretching approximately from the Tropic of Capricorn to 14 degrees south is, like the extreme south, dominated by technically advanced, commercial farmers. Although it too receives most of its rainfall in the summer, winters are warmer. Hence, winter irrigation can allow the farmer to crop land reliably twice instead of once, rotating winter plantings of wheat, peas or beans with rainfed summer crops, which in the southeast also include cotton. Having justified acquisition of an irrigation system on the basis of the returns obtainable from an assured winter crop, the farmer can also use it for supplementary irrigation of summer crops if necessary. Although there is less of the extensive flooded rice characteristic of the south, the PROVARZEAS programme has made progress in all regions including the southeast, where farmers are now starting to grow beans and other crops on supplementary irrigation in winter, in rotation with the main crop of summer flooded rice.

The centre west stretches from the fringes of the Amazon basin in the west to the state of Goiás in the east, and from 8 degrees to 24 degrees south. At its westerly extreme it has a relatively well-distributed rainfall of up to 2500 mm/year and there is little need for irrigation. However, most of the centre west is *cerrado* (savanna) land, potentially productive if its natural soil acidity is corrected, but limited by a marked dry season of around six months. Rainfall in the remainder of the year averages around 1000 mm. Since cerrado soil management techniques are newly developed, much of the region is only now being opened for cultivation, mainly by advanced farmers from further south. Increasing numbers are taking advantage of the region's many perennial rivers and streams to complement their rainfed cereal, soya, bean and cotton production with dry-season irrigated cropping. The large properties and level land are well suited to centre-pivot and self-propelled irrigation systems, which have expanded rapidly in the last few years. Free of winter temperature constraints, irrigation in the cerrado can greatly increase the intensity of land use of this vast, recently occupied area. However, the region is disadvantaged economically by its distance from main consumption areas and ports.

The northeast includes Brazil's semi-arid lands, which have an irregularly distributed annual rainfall averaging from 750 mm down to 250 mm. The region contains the country's poorest farmers and numerous landless people; many farmers cultivate largely for subsistence. Unlike other regions water resources in most of the northeast are severely constrained. One major river, the Sao Francisco, dominates the region, but the topography generally requires that its water be extracted by pumping. There are few other naturally perennial rivers, and although some seasonal rivers have been regulated by the Government, a number have now run dry due to uncontrolled water extraction. There are, however, some lowland areas suitable for flooded rice, mainly in the humid coastal strip. Where water constraints can be overcome, the warm northeastern climate favours maize, beans, cotton and sugarcane, as well as year-round multiple horticultural cropping and seed production. Large public-sector irrigation schemes have been constructed and allocated both to entrepreneurs and small-scale colonists, with the aim of overcoming intermittent regional food deficits while creating employment and benefitting the rural poor. Increasing use is being made of drip and sprinkler irrigation in water-scarce areas, although not always applying very modern technology.

The northern region comprises most of Brazil's humid tropics. Irrigation needs are few, and development is limited to a small area of lowland rice.

In addition to growing staple commodities such as wheat, maize, rice, beans, soya and cotton, Brazil's irrigators have also seized on opportunities to grow high-value, especially horticultural, crops whenever markets permit. Thus, centre-pivot and other advanced systems are used to grow carrots, potatoes, salads and many other vegetables on a semi-industrial scale near to the huge urban markets of the industrial southeast. The same markets are supplied off-season with fruits, onions, melons and other vegetables from the favourable climate of the northeast. Smaller scale horticulturists are found around most towns, irrigating to supply more local demand. Expansion of tomato paste and other vegetable processing factories, especially in the northeast, has given a market opportunity for large and small-scale irrigators alike. Increasingly, irrigators in the northeast are air freighting their fruit and off-season vegetables to Europe and the USA.

Over 94% of Brazil's irrigation has been developed by private individuals or companies.[3] The remainder of approximately 6%, defined as public irrigation, depends on water supplies which have been developed using Government (usually Federal Government) funds, with the major works being Government-operated. In the case of the public colonisation schemes of the northeast, the Government has constructed whole systems including on-farm works, before allocating plots of around 5 hectares to poor or landless farmers (colonos).

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[3] Although at times with official credit and/or government technical advice, e.g. the PROVARZEAS programme. Some of this area may also benefit from publicly-funded drainage schemes, especially extensive rice growing in the south.

The division of Brazil's irrigated areas and estimated irrigation potential between regions, and public and private developments, is shown below. It should be noted, however, that the estimate of potential in some regions is likely to be exaggerated. In particular, although the northern region may have water resources and soils sufficient for 20 million hectares of irrigation, to irrigate such a large area may not be economically justified.

**TABLE 1: BRAZIL; ACTUAL AND POTENTIAL IRRIGATED AREA**

| Region | Irrigation Type | Present Irrigated | Technical Potential | Percent Developed |
|---|---|---|---|---|
| South | Public | 24 | 423 | 6 |
| | Private | 954 | 4,577 | 21 |
| Southeast | Public | 12 | 578 | 2 |
| | Private | 580 | 6,979 | 8 |
| Centre west | Public | 16 | 222 | 7 |
| | Private | 247 | 10,778 | 2 |
| Northeast | Public | 79 | 718 | 11 |
| | Private | 321 | 5,352 | 6 |
| North | Public | - | - | - |
| | Private | 18 | 20,000 | <1 |
| Brazil | Public | 131 | 1,941 | 7 |
| | Private | 2,120 | 47,686 | 4 |
| Total | | 2,251 | 49,627 | 5 |

Source: After Ministry of Irrigation and affiliated agencies, 1987.

The approximately 2.3 million hectares so far developed represents only about 5% of estimated technical potential. Development has been piecemeal and often fragmented. For instance, the PROVARZEAS programme, for support of private irrigation, operates in all regions and is linked to the Federal Ministry of Agriculture; it is executed through the state-level units of the National Agricultural Extension Enterprise which are linked to the agricultural secretariats of state Governments. The main public irrigation agencies, on the other hand, operate only in the northeast, and were until very recently linked to a different federal ministry. They have had little interaction with state-level irrigation. Each Government body concerned with irrigation development has tended to set its own criteria and agenda. Meanwhile, much private development in all regions has taken place in a 'laissez faire' atmosphere, with minimum Government support and no systematic application of the laws on water extraction and use. At the same time public developments in the northeast have followed a conflicting set of objectives; they have been loosely justified on social grounds, whereas if all legally-specified irrigation charges were to be collected and sales taxes paid, the beneficiaries would repay more than full irrigation costs. Nevertheless, in practice far less than the legally-specified amounts have ever been recovered.

## 5 METHODS USED FOR ESTIMATING ECONOMIC PROFITABILITY

For a complete analysis of profitability it is necessary to consider returns to all the factors of production - irrigable land, water, labour and capital - for all major types of irrigation.[4] It is true that not all these factors are overriding constraints in a given setting, and hence some results will be redundant.[5] However, to ensure full comparability it was considered better, despite the great diversity of the Brazilian setting, to attempt an analysis which was comprehensive than to risk being too selective.

To represent the various types of irrigation, hectare crop budgets were prepared which were then assembled into static farm models. The analysis thus used techniques with which the FAO/World Bank team was already familiar. After weighing the analytical complexities of including livestock activities in the analysis against the relatively low importance of irrigated fodders and pasture, it was decided, however, not to include livestock.

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[4] Return on managerial resources was considered outside the scope of the work described here.

[5] For instance, both land and water are plentiful on the cerrado and the mechanised production system substitutes labour needs with capital. On the other hand, water and irrigable land are both scarce in the northeast and high labour use, and labour returns are desirable to meet the social aims of public irrigation.

## TABLE 2: BASIC FARM MODELS FOR ANALYSIS

| Basic Model Number | Description | Hectares | Regions Represented a/ | Main Crops |
|---|---|---|---|---|
| 1 | Private, extensive flooded rice | 120 | S | Rice |
| 2 | Private, lowland (PROVARZEAS model) | 12 | ALL | Rice, food crops |
| 3 | Private or colonist small mobile sprinkler system | 10 | SE CO NE | Cereals, beans soya |
| 4 | Private, centre pivot system | 100 | SE CO | Cereals, grain, legumes, tomato |
| 5 | Privately developed or public supply, centre pivot system | 100 | NE | Cotton plus above |
| 6 | Colonist, public scheme | 5 | NE | Cotton, cereals, beans |
| 7 | Private, small-scale sprinkler system b/ | 2.5 | NE | Maize, beans, onion as cash crop |
| 8 | Private, small-scale horticulture | 5 | ALL | Leaf and root vegetables |
| 9 | Private, large-scale scale horticulture, self-propelled irrigator | 50 | SE CO NE | Above plus potato, tomato |
| 10 | Colonist, horticulture, public scheme | 5 | NE | Tomato, water-melon, onion, food crops |
| 11 | Privately developed or public supply; intensive, mainly localised irrigation | 26 | NE | Grape, papaya melon |

a/ S = south, SE = southeast, CO = centre west, NE = northeast.

b/ A recently introduced credit programme in the northeast is distributing small sprinkler kits to farmers.

To arrive at budgets and models all accessible local data sources were reviewed. These included project feasibility studies and recent contract awards, publications in the development literature, models prepared by consultants for a recent World Bank loan to support private irrigation in the south, southeast and centre west, and a 1983 FAO/World Bank review of irrigation in the northeast. Irrigation specialists in development agencies, extension, research, and the private sector were interviewed.

Local consultants then carried out a series of field studies in areas, or on types of system for which supplementary information appeared a priority need. On the basis of all this information, eleven basic models were defined to represent irrigation in Brazil and these are summarised in Table 2. Where a model spans several regions over which the crop mix would change (e.g. winter wheat in the south being substituted by winter beans further north), the cropping pattern used for analysis represents a weighted mean over the range. Because of the diversity of horticultural crops only a few representative species were included in the models. For instance, lettuce as a proxy for all leaf vegetables, carrot as a typical root vegetable, and tomato as a processing crop.

For each model the method of water supply (gravity flow, pumped from a surface or groundwater sourcc), and the method of distribution and on-field application were also specified. Where there were considered to be technical alternatives with major cost or water use profitability implications -for instance, gravity versus pumped supply, or sprinkler versus furrow application - variants of the model were specified. Because of the markedly greater irrigation needs in the semi-arid northeast than elsewhere in Brazil, and the lower potential evapotranspiration in the south, northeastern variants with a higher irrigation volume were also specified for models 2, 3, 8 and 9, and southern variants with lower volumes were specific for models 2 and 8. In addition, because of the greater distance of the centre west from major consumption centres and ports, variants were made for some of these models assuming transport costs equivalent to 1000 km, instead of the 250 km assumed for all base models. Taking account of these variants, the eleven basic models, as defined by cropping pattern, were expanded to 34 for eventual analysis. For analysis, the following were defined for each model:

- size of the irrigated farm;
- annual crop areas, yields, cropping intensity and total agricultural output;
- an indication of which are winter and which are summer crops;
- estimated total water requirements for each crop (Hargreaves' method);

- an estimate of the proportion of this total which would, depending on region and season, need to be met by irrigation;
- off-farm water supply works, with an estimate of the total area served by these works if, as on a public scheme, they would supply more than one property;
- on-farm works and irrigation equipment;
- on the basis of the above definitions, the estimated overall profitability of irrigation;
- hectare budgets for each crop divided between purchased inputs, services[6], other materials and hired or family labour.

For the purposes of calculation all irrigation infrastructure costs were updated to the present before analysis. This allowed old and new systems to be directly compared, although at the same time it also eliminated any advantages which would otherwise have accrued to old systems because of their sunk costs. The analysis effectively examined the question, therefore, of what would be the economic profitability of a given system if built today, as well as used at today's levels of performance.

Using the above data the total cost of meeting water requirements was calculated. This was done by combining amortisation of the capital costs of the system over an appropriate period[7] at the prevailing opportunity cost of capital with its estimated annual operation and maintenance costs (usually a fixed annual percentage of capital cost of the infrastructure specified). Total water cost was expressed per farm per annum, as well as per thousand cubic metres taken from the source. Crop production costs were calculated per hectare, and then per annum for the whole farm. Together, these calculations gave the annual fixed and variable costs of irrigation, plus all other variable crop production costs. The team abandoned attempts to include the remaining fixed elements of the annual production cost - amortisation of productive farm infrastructure other than the irrigation system, and farm management overheads. Firstly, there were virtually no sources of information, and secondly it was felt that for most models these costs would be insignificant in relation to the total of other costs.

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[6] For simplicity, contract hire rates were used for all machine operations.

[7] Useful life was assumed to vary from 3 years for sprinkler heads, up to 20 years for pumps, and 50 years for dams and main canals.

Examples of the forms used to tabulate the data before processing are given as tables 3, 4 and 5.

To produce figures comparable with the output projections generated by the output/demand study for the rainfed sub-sector and existing irrigated land, it was then necessary to estimate the improvements in profitability which would be obtained on new irrigated areas by 2005. To make these calculations it was assumed that:

- models which are, at present, relatively far from their maximum technical potential (assumed to be models 1, 3, 6 and 7) would increase their crop yields at a compound rate of 2% per year and cropping intensities at 1% per year;

- for the remaining models, all of which could be considered as already closer to their maxima, increases would be limited to 1% per year and 0.5% per year respectively;

- the resultant gains in gross production value would be obtained on relatively favourable terms. Costs would rise by one dollar for every two dollars of gain in gross value.

The work was done at a time when Brazilian inflation was about 20% per month. All local costs and prices were therefore converted to US dollars at the exchange rate of the day for which they were quoted. Although dollars were traded in the black market at a premium of about 55%, at the time the official conversion rate was preferred to avoid making judgements on the views of speculators about the future course of Brazil's crawling peg system of exchange rate adjustment.

Capital, operation and maintenance costs of irrigation works were converted to economic values by applying a conversion factor of roughly 0.9, to represent the removal of taxes, duties and subsidies. Most agricultural inputs (seeds, fertilizers and pesticides) were valued at import parity prices using multi-year averages from other importing markets - mainly the USA - and recent price quotations from Brazilian importers. Unit machinery operating costs for construction of irrigation works were derived from recent Government equipment rental costs, applying separate conversion factors to capital costs, fuel and labour to bring them to economic values. The opportunity cost of capital was assumed to be 11%. Since there were no reliable data on regional labour markets, shadow wage rates for farm labour were calculated from real daily wages for each region, adjusted for assumed regional unemployment. Unemployment rates were assumed to be 5% with 10% underemployment outside the northeast, and twice these figures within the northeast. On the basis of available data, wages in the northeast were assumed to be 60% of those elsewhere.

Tradeable agricultural products were valued at border prices, based on import or export parity using six-year average world prices for the commodity concerned. Non-tradeable items - beans and horticultural crops - were valued at average local market prices.

The analysis was run on a standard desk-top computer using Lotus 123. The following were quantified for each model, for the present situation and 2005:

- total economic benefit generated by the model;
- total economic costs of the model;
- net economic benefit generated per hectare of land cropped;
- net economic benefit generated per thousand $m^3$ of water abstracted from the source;
- net economic benefit generated per man/day of labour used.

By taking account of water use for each crop within the model, it was also possible to derive an economic cost of production in US$ per ton for that commodity at present, and in 2005 under the system represented by the model.

## 6 SUMMARY OF RESULTS

Table 6 shows the estimates of present and future economic profitability of irrigation, ranked from models with the highest ratio of net benefit to total costs to those with the lowest ratio. The following are the key findings:

**Basic Commodities (rice, maize, wheat, soya, beans, cotton):** Present gross economic benefits from models growing basic commodities (rice, maize, soya, beans and cotton) are seldom greater than 1.5 times total costs (a value of 0.5 or more for BN/CT in the tables), while the less efficient forms of irrigation at present fail to cover their costs when these are calculated in economic terms. Under the future scenarios the most efficient models based on these crops generate a gross benefit equivalent to about 1.75 times total costs (BN/CT = 0.75), but the three least profitable models (all representing colonos on public irrigation perimeters in the northeast) remain heavily in deficit.

**High Value Crops:** Present economic benefits from models producing fruits and vegetables are always more than 1.5 times total costs and sometimes by over 2.5 times. These figures rise to a minimum of 1.7 times and a maximum of three times economic costs under the future scenarios.

**Public Water Supply:** Because of generally high capital, and operation and maintenance costs, variants on a given model which depend on a publicly-financed primary supply are generally less economically efficient than variants assuming private development of the water source.

**Colonisation Schemes in the Northeast:** These public schemes are doubly penalised by (a) depending on public water supplies, and (b) by growing mainly low-value crops at low yields and cropping intensities. They are the least profitable of all forms of irrigation in purely economic terms. However, model 10 shows the better prospects from higher-value crops.

**Economic Costs of Water Supply:** Supply costs range from about US$ 30 to US$ 47 per 1000 m$^3$ for models depending on public supplies and between US$ 13 and US$ 50 per 1000 m$^3$ for private supplies. Net economic benefit generated per 1000 m$^3$ of water averages around US$ 20 for low-value crops at present (range US$ 38 to US$ -31) and is estimated to average around US$ 30 (range US$ 57 to US$ -4) for these crops in future. For high-value crops estimated net returns on water range from at least US$ 50 per 1000 m$^3$ up to US$ 400 per 1000 m$^3$.

**Net Economic Returns per Year on Irrigable Land:** Economic returns average around US$ 250 hectares (range US$ 670 to US$ -530) for low-value crops at present, rising to about US$ 350 hectares (range US$ 1000 to US$ -250) in the future. Corresponding figures for high-value crops are US$ 2000 hectares (range US$ 1200 to over US$ 4500) at present, with the average reaching about US$ 3000 hectares in the future.

Table 7 summarises estimated irrigated production costs per ton for wheat, maize, beans and rice for a selection of models. It shows that the estimated present economic cost of irrigated production per ton of these basic commodities often exceeds their economic value. Only for the relatively low cost model 2, or highly efficient (centre pivot) private models are present estimated costs less than the value of output. Future scenarios show some improvements, but gains are limited.

For comparison, Table 7 also includes estimated rainfed production cost for the same commodities based on re-working of the output/demand study data by a subsequent World Bank mission (January 1989). The irrigated farm models with low cost or high technical efficiency are also able to produce beans and rice at economic costs per ton which are lower than for rainfed. For wheat and maize, however, rainfed costs are below those of any irrigation model. This implies that irrigation would not be the preferred strategy to fill any future supply gaps for these two commodities. It would not, however, preclude the use of efficient irrigation for out-of-season production, or for growing seed crops of wheat or maize, in both of which situations irrigation would bring clear technical advantages over rainfed production.

The sort of guidance which such results can give to those responsible for sectoral policy is readily appreciated. For instance they highlight:

- the need, if irrigation is to be an economically viable means of producing basic commoditites such as wheat, maize or cotton, to encourage only those forms of irrigation which are either cheap or technically efficient;

- the low probability that further investment in public irrigation in the northeast for colonos will yield acceptable economic returns, for so long as these farmers grow only such basic commodities;

- the need, therefore, for there to be important parallel social benefits from public irrigation of low-value crops by colonos in the northeast, in order to justify the economic losses which further investments of this type are likely to incur;

- the economic desirability of encouraging a shift in irrigated cropping patterns from basic commoditites to high-value crops;

- the particular importance of such a shift for existing public irrigation by colonos in the northeast, if the present drain on the economy by public schemes is to be reversed;

- the close implied connection between expansion of the more profitable forms of irrigation and the size, location and organisation of markets for high-value processing or horticultural crops - which must therefore receive close attention in future sectoral plans.

The results also provide planners with some general figures on economic value added from irrigation, which could be used in deciding the allocation of water resources between competing demands of agricultural and non-agricultural uses.

# 7 CONCLUSIONS: ADVANTAGES AND LIMITATIONS

The main advantage of the analysis was that it attempted to compare the economic profitability of all major forms of irrigation in Brazil on a common base. Due to the past fragmentation of institutional responsibilities and programmes this had never previously been done. As a result arguments on the relative merits of alternative development options - e.g. public irrigation in the northeast versus private irrigation in the south - had previously tended to be settled on a subjective rather than an objective basis. More rational decisions were possible subsequently, and at the time of writing seem likely to be followed up by appropriate programmes of technical and financial assistance.

The major limitation, as in all such modelling exercises, is that the outcome depends on the quality of the estimates on which the calculations are based. This is already important in determining the credibility of the normally simple models used in ordinary project analysis. Fallibility is, unavoidably, magnified in a more complex exercise of the type described here. Furthermore, to formulate such an exercise, if dependent on field surveys to generate all the base data, would be extremely time-consuming. The team responsible was fortunate in having had wide previous exposure to irrigation in Brazil over a number of years. It worked with high-calibre local counterparts and benefitted from the accumulated experience of a range of outside experts who were also assisting the Government. Local data sources happened to cover some of the types of irrigation on which the team's personal experience was the most limited. A team starting a similar exercise in another country might not have all these advantages.

Nevertheless, two positive final points can be made. Firstly, both the setting and the range of irrigation types are likely to be less complex in most other developing countries. Secondly, the Brazilian analysis presented here, which is a first run and not the culmination of a series of approximations or the product of any 'massaging' of the numbers, is remarkably clear cut in its indications. This leads the team to believe that the method of analysis used in the case of Brazil is both replicable and valid. Indeed, similar analytical approaches have since been used by the FAO Investment Centre for irrigation reviews in Chad, Malawi and Venezuela, and have also made useful contributions to clarifying future development options and priorities.

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## TABLE 3: BRAZIL - NATIONAL IRRIGATION SECTOR REVIEW

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### STUDY 2: IRRIGATION PROFITABILITY
### A Description of Model Farm

Model: .................................................................. Number: ........................

**Situation Present**

Type: .................................................................. Operator: ........................

Farm physical area (hectares): ...........................................................................

Farm irrigable area (hectares): - Total ........................................................

- Developed ................................................

| Crop/Product | Area planted (ha/year) | Average Yield (t/year) | Total Output (t/year) | Gross economic value (US$ '000/year) |
|---|---|---|---|---|
| .................... | ................. | .......... | .......... | ...................................... |
| .................... | ................. | .......... | .......... | ...................................... |
| .................... | ................. | .......... | .......... | ...................................... |
| .................... | ................. | .......... | .......... | ...................................... |
| .................... | ................. | .......... | .......... | ...................................... |
|  | **Total** ................. |  | **Total** |  ................................ |

Water Source: ............................................................................................

Method of supply to farm: ......................................................................................

Method of supply to field: ......................................................................................

Method of distribution in field: ...............................................................................

## TABLE 4: WATER USE AND COSTS

Model: ..................................................... Number: .......................................................

**Annual Water Use**

| **Crop, No ha** | **Evapotranspiration** | **Overall Efficiency** | **Total Water Use** |
|---|---|---|---|
| ........................ | .................................. | ............................... | .............................. |
| ........................ | .................................. | ............................... | .............................. |
| ........................ | .................................. | ............................... | .............................. |
| **Farm total (m$^3$/year)** | .................................. | | |

**Annual Economic Cost of Water Supply**

| **Off-farm works** | **Area Served (hectares)** | **Total Cost, Year Built (US$ '000)** | **Allocated Cost to Model (US$ '000/year)** | | |
|---|---|---|---|---|---|
| | | | **Amortisation** | **O & M** | **Total** |
| ............... | ....................... | ........................................... | ....................... | ............. | ......... |
| ............... | ....................... | ........................................... | ....................... | ............. | ......... |
| ............... | ....................... | ........................................... | ....................... | ............. | ......... |
| **Sub-total** | ....................... | | | | |

| **On-farm works** | **Units** | **No** | **Unit Cost (US$)** | **Total Cost (US$ '000)** | **Annual Cost to Model (US$ '000/yr)** | | |
|---|---|---|---|---|---|---|---|
| | | | | | **Amortisation** | **O & M** | **Total** |
| ............... | ......... | ........... | ................. | ..................... | ....................... | ............. | ......... |
| ............... | ......... | ........... | ................. | ..................... | ...................... | ............. | ......... |
| ............... | ......... | ........... | ................. | ..................... | ...................... | ............. | ......... |
| **Sub-total** | ....................... | | | | | | |

**Total annual economic cost of water (US$ '000/yr)** ............................................................

**Economic cost of water per m$^3$ (US$)** .............................................................................

**TABLE 5: CROP HECTARE BUDGETS (US$) continued**

**Labour (man day equivalents)**

| | Quantity | | | Economic Cost | |
|---|---|---|---|---|---|
| | F | M | Total | Per Unit | Total |
| - land prep | | | | | |
| - plant | | | | | |
| - maintain | | | | | |
| - harvest | | | | | |
| - post-harvest | | | | | |
| Sub-totals | | | | | |
| - total family | | | | | |
| - total hired | | | | | |
| Sub-total inputs | | | | | .......... |
| **Total Variable Costs (excluding water)** | | | | | |
| **Water Costs (from Section B)** | | | | | |
| **Fixed Cost Allowances (footnotes)** | | | | | |
| - amortisation, non-irrigation farm infrastructure | | | | | |
| - farm management | | | | | |
| **Total Economic Production Cost** | | | | | .......... |

## TABLE 5: CROP HECTARE BUDGETS (US$)

Model: ..................................................................

Crop: ..................................................................

| | Quantity | | Economic Cost | |
|---|---|---|---|---|
| **Inputs** | **Units** | **No** | **Per Unit** | **Total** |
| - seeds | kg | | | |
| - pl material | no | | | |
| - fert 1 .... | kg | | | |
| - fert 2 .... | kg | | | |
| - fert 3 .... | kg | | | |
| - fest 1 .... | | | | |
| - pest 2 .... | | | | |
| - pest 3 .... | | | | |
| - pest 4 .... | | | | |
| Sub-total inputs | | | | .......... |
| **Machinery (includes driver)** | | | | |
| - animal | hr | | | |
| - tractor, heavy | hr | | | |
| - tractor, light | hr | | | |
| - harvestor | hr | | | |
| - threshing | hr | | | |
| - ........... | | | | |
| - ........... | | | | |
| Sub-total machinery | | | | .......... |
| **Materials and others** | | | | |
| e.g. | | | | |
| - ........... | | | | |
| - ........... | | | | |
| - transport | | | | |
| - drying | | | | |
| Sub-total materials and others | | | | .......... |

**TABLE 6: RESULTS OF IRRIGATION MODELS, RANKED IN ORDER OF THE RATIO OF NET BENEFITS TO TOTAL COSTS**

| BASIC MODEL | AREA | WATER SOURCE | SYSTEM | NET BENEFIT | | | |
|---|---|---|---|---|---|---|---|
| (INT or interior = transport costs equivalent to 1000 km) | | | | (1987 DATA) | | | FUTURE |
| | | | | 000's US$ per ha | US$ per 000 $m^3$ | BN/CT ratio to total costs | BN/CT ratio to total costs |
| **9**<br>Private producer; 50 ha; potatoes, carrot, onion tomato, lettuce, beans | NE | pump lift | centre pivot or self-propelled traveller | 3.27 | 229.3 | 1.69 | 2.04 |
| | SE, CO | pump lift | | 3.09 | 250.5 | 1.47 | 1.78 |
| | NE | public perimeter | | 3.01 | 141.9 | 1.38 | 1.69 |
| **11**<br>Private producer; 26 ha; grape, mango, melon, etc | NE | pump lift | drip or conventional sprinkler | 4.77 | 406.1 | 1.36 | 1.36 |
| **8**<br>Private producer; 5 ha; lettuce, carrot, tomato, onion, etc | NE | pump lift | furrows | 2.58 | 150.2 | 1.01 | 1.21 |
| **10**<br>Settler; 5 ha; tomato, beans, watermelon, corn | NE | public perimeter | furrows | 1.21 | 60.9 | 0.88 | 1.19 |
| **8**<br>Private producer; 5 ha; lettuce, carrot, tomato, onion, etc | NE | pump lift | conventional sprinkler | 2.39 | 186.6 | 0.87 | 1.08 |
| **7 (KIT)**<br>Private producer; 2.5 ha; lettuce, carrot, onion, etc | NE | well, creak or river | conventional sprinkler | 0.56 | 54.4 | 0.73 | 1.28 |

| (TABLE 6: continued) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| **8**<br>Private producer; 5 ha; lettuce, carrot, tomato, | SE, CO | pump lift | furrow | 1.97 | 131.6 | 0.62 | 0.78 |
| onion, etc | S | pump lift | furrow | 1.98 | 149.9 | 0.62 | 0.78 |
| **5**<br>Private producer; 100 ha; cotton, soybeans, wheat, beans, tomato | NE | pump lift | centre pivot | 0.67 | 38.8 | 0.55 | 0.79 |
| **8**<br>Private producer; 5 ha; lettuce, carrot, tomato, | S | pump lift | conventional sprinkler | 1.8 | 183.2 | 0.54 | 0.7 |
| onion, etc | SE, CO | pump lift | | 1.8 | 160.8 | 0.54 | 0.7 |
| **2 - Interior**<br>Private producer; 12 ha; rice, corn, beans | INT<br>SE, CO | river diversion | furrow by gravity | 0.29 | 24.4 | 0.54 | 0.75 |
| **5 - Interior**<br>Private producer;100 ha; cotton, soybeans, wheat, beans, tomato | NE | pump lift | centre pivot | 0.64 | 37.2 | 0.53 | 0.77 |
| **2**<br>Private producer; 100 ha; rice, corn, beans | S | river diversion by gravity; | flood furrow | 0.27 | 25.1 | 0.5 | 0.71 |
| | NE, INT | pump lift | | 0.23 | 17.4 | 0.39 | 0.61 |
| | SE, CO | river diversion by gravity | | 0.21 | 17.3 | 0.38 | 0.57 |
| | SE, CO, INT | | | 0.21 | 17.6 | 0.34 | 0.39 |
| | S | pump lift | | 0.2 | 18.6 | 0.33 | 0.53 |

| (TABLE 6: continued) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| (2 continued) | NE | pump lift | flood furrow | 0.15 | 11.1 | 0.25 | 0.44 |
| 4<br>Private producer; 100 ha; cotton, soybean, corn, beans tomato, wheat | SE, CO, INT | pump lift | centre pivot | 0.28 | 20.9 | 0.25 | 0.45 |
|  | SE, CO |  |  | 0.24 | 17.4 | 0.21 | 0.4 |
| 5<br>Private producer; 100 ha; cotton, soybeans, wheat, tomato, beans | NE | public perimeter | centre pivot | 0.33 | 14.5 | 0.21 | 0.43 |
| 1<br>Private producer; 120 ha; rice, soybeans | S | river diversion by gravity; | flood furrow | 0.05 | 5.83 | 0.09 | 0.37 |
|  | S | pump lift |  | -0.01 | -0.62 | -0.01 | 0.28 |
| 3<br>Private producer; 10 ha; soybeans, beans, wheat | NE, INT | pump lift | conventional sprinkler | -0.11 | -8.9 | -0.13 | 0.2 |
|  | SE, CO, INT |  |  | -0.13 | -12.4 | -0.15 | 0.16 |
|  | NE |  |  | -0.16 | -12.5 | -0.18 | 0.13 |
|  | SE, CO |  |  | -0.18 | -16.78 | -0.2 | 0.09 |
| 6<br>Settler; 5 ha; corn, beans, cotton | NE | public perimeter | furrows | -0.31 | -14.79 | -0.33 | -0.02 |
|  | NE |  | conventional sprinkler | -0.35 | -23.45 | -0.35 | -0.06 |
| 3<br>Settler; 10 ha; soybeans, wheat, beans | NE | public perimeter | conventional sprinkler | -0.53 | -30.76 | -0.43 | -0.17 |

**TABLE 7: COMPARISONS OF IRRIGATED AND RAINFED PRODUCTION COSTS FOR WHEAT, MAIZE, BEANS AND RICE, 1989**

| | |
|---|---|
| Wheat | **Price per ton US$ 182** |
| a. | Rainfed, fully mechanised, winter crop, yield 1.7+/ha, in regions S, SE, Southern CO, production costs US$ 169 per ton. |
| b. | Irrigated Production, in models: |
| (3) | NE, pump lift, conventional sprinkler, private, 10 ha, (with soybean and beans), yield 2 t/h, production costs US$ 426 per ton; |
| (4) | SE, CO, pump lift, centre pivot, private, 100 ha, (with cotton, soybeans, maize, beans, tomatoes), yield 3 t/h, production costs US$ 207 per ton; |
| (5) | NE, pumping from water source, centre pivot, private, 100 ha, (with cotton, soybeans, beans, tomatoes), yield 3 t/h, production costs US$ 203 per ton; |
| **Maize** | **Price per ton US$ 140** |
| a. | Rainfed, fully mechanised, in regions S, SE, CO, yield 3.1 t/ha, production costs US$ 85 per ton. |
| b. | Irrigated production, in models: |
| (2) | SE, CO, river diversion by gravity, flood furrow irrigation, private, 12 ha (with rice, beans), yield 3.5 t/ha, production costs US$ 117 per ton. |
| (6) | NE, public perimeter, conventional sprinkler, private, 6 ha, (with beans and cotton), yield 4.0 t/ha, production costs US$ 183 per ton. |
| **Beans** | **Price per ton US$ 485** |
| | Rainfed: |
| (i) | S, SE, CO, part-mechanised, yield 0.85 t/h, production costs US$ 427 per ton. |
| (ii) | NE, animal traction, fertiliser, yield 0.65 t/h, production costs US$ 419 per ton. |

**(TABLE 7: continued)**

| | |
|---|---|
| | Irrigated production, in models: |
| (2) | SE, CO, river diversion by gravity, flood furrow, private, 12 ha (with rice, corn), yield 1.6 t/h, production costs US$ 306 per ton. |
| (4) | SE, CO, pump lift, centre pivot, private, 100 ha, (with cotton, soybeans, corn, tomatoes, wheat), yield 1.6 t/h, production costs US$ 430 per ton. |
| (3) | NE, pump lift, conventional sprinkler, public perimeter, settler, 10 ha, (with soybeans, wheat), yield 1.2 t/h, production costs US$ 654 per ton. |
| (5) | NE, pump lift, centre pivot, private, 100 ha, (with cotton, soyabeans, wheat, tomatoes), yield 1.6 t/h, production costs US$ 389 per ton. |
| (6) | NE, public perimeter, conventional sprinkler, settler, 5 ha, (with corn, cotton), yield 1.0 t/h, production costs US$ 750 per ton. |
| **Rice** | **Price per ton US$ 127** |
| | Rainfed upland rice, Amazon fringes, favourable rainfall, yield 1.65 t/ha, production costs US$ 101 per ton. |
| | Irrigated production, in models: |
| (2) | SE, CO, river diversion by gravity, flood furrow, private, 12 ha, (with corn, beans), yield 5 t/ha, production costs US$ 92 per ton. |
| (1) | S, river diversion by gravity, flood furrow, private, 120 ha, (with soybean), yield 5 t/ha, production costs US$ 125 per ton. |