

SOFTWARE OR HARDWARE? AN ECONOMIC APPRAISAL OF A WATER MANAGEMENT PROJECT

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ABSTRACT

The need for economic efficiency in the development and utilization of water resources has become an increasingly important issue as the cost of new irrigation has risen relatively to the amount of water supplied. As there are alternative ways in water control and management, this paper examines potential substitution of management for capital, studying alternatives such as canal lining pipe lines, cleaning channels using direct labour, soil compaction in beds and banks using direct labour and appointment of a Project Manager. The results show that pipeline which is more appropriate than canal lining would be only chosen if the opportunity cost of capital is judged to be less than 8.5 per cent and a combined programme of cleaning channels and Project Manager, if above this.

Introduction

The development of irrigation in the Dry Zone has evolved permitting land productivity to increase steadily. Supplemental irrigation during the wet season is followed by the construction of storage facilities to permit cultivate more land in the dry season. The cost of new irrigation has risen relative to the amount of water supplied and therefore the need for economic efficiency in the development and utilization of water resources has become an increasingly important policy issue. Therefore emphasis is being shifted towards the better use of rainfall and irrigation water and a reduction of water losses with a view to raising cropping intensity and to achieve the high yield potential of modern inputs. As there are alternative ways in water control and management, this paper examines potential substitution of management for capital.

Comparison of alternative projects even when based on good estimates may still lead to faulty project selection if an inappropriate technique is used. The Economic Cost Benefit Analysis has been used in this paper to compare alternatives and the purpose of economic appraisal is to provide a framework within which all aspect of a proposed project can be evaluated in a coordinated and systematic manner showing whether society as a whole will be better off by undertaking rather than not undertaking it or by undertaking instead of an alternative project to obtain similar ends. The way to ensure the most efficient use of public capital and other scarce resources is, in the margin, to finance no project whose benefits measured with references to the national development objectives are lower than that of the next alternative project relative to investment costs.

The Setting

The alternatives considered are the provision of (a) canal lining, (b) pipe lines, (c) the cleaning and maintenance of gravel canal by direct labour, (d) compaction of soil in beds and banks of canals by direct labour and (e) the appointment of a Project Manager for integrated rural development. The last three alternatives are mutually compatible and can be studied as one combined alternative or as three separate alternatives. In this paper thus six alternatives are examined.

Mahavillachchiya colonisation scheme (MvCS), the first tank that has been modernized under the Five Irrigation Rehabilitation Scheme, was selected as the study location. MvCS is located 18 miles north-west of *Anuradhapura* and covers an area of 4200 acres of which 2,600 acres are irrigable. A farm-business survey using a stratified random sample was carried out in May 1980 in the scheme. *Dewahuwa*, a scheme modernized by the Japanese Government, has also been selected to illustrate the likely consequences of some possible alternatives as a positive approach. A field survey was carried out in May 1980 in the *Dewahuwa* scheme.

Lining the Canals

This alternative involves the lining of the conveyance scheme with concrete or similar materials to reduce excessive seepage or erosion; to provide the necessary degree of water control; to reduce the labour required for measuring or dividing the water and to facilitate maintenance. The standard new design formula of 1 cu. sec. field channels each serving about 40 acres has been adopted in the MvCS. Compare with a conventional gravel field channel which feeds more than 40 acres, this involves a reduction of the area served by individual field channel. Since, it is not possible to re-align distributary channels and field channels due to the need for the involvement of a massive operation for the re-allocation of land, the solution seems to be the construction of two or three parallel channels each serving part of the area commanded by the original field channel. The construction of regulators in the main, distributary and field channels to increase water control in the conveyance system and the installation of parshal flumes to measure releases from the tank and water flows at various points in the system are also included in the canal lining programme.

Lined canals have a transmission efficiency of 90 per cent compared with 70 per cent of gravel canals. Assuming that farmers continue with mud sowing and a 44 per cent on-farm water use efficiency instead of the 65 per cent attainable with a strictly rotational delivery system, canal lining alone would save 3700 ac. ft. of water per year and cropping intensities would be raised to 196 per cent from 127 (Table 1 and 3).

The actual construction cost of lining canals at MvCS at 1980 price levels was 17,115 rupees per acre with an annual expenditure of 205 rupees per acre. The capital costs incurred in 1977-80 were estimated using records on actual expenditure converted to 1980 prices by using the All Sri Lanka Wholesale Price Index Numbers. Labour costs involved in 1977-80 are brought to the level of 1980 with the help of the wage rate index for government employees. Use of constant prices does not imply that the economy will not be affected by inflation in the coming years and it may be argued that different inflation ratios for the various components of input and output in the first few years could significantly affect the results of the economic appraisal. However, as it is impossible to project accurate prices for various commodities, use of a common deflator is justified as providing a standard basis for comparing the real costs and benefits accruing in different years.

The following procedures were used in estimating the future values of on-farm costs and benefits. The crop areas are based on the linear programming solutions, assuming 23.1 acre feet of water per farm available for *yala* cultivation in the case of canal lining (Vithanage 1982 b). With increasing efficiency of water use it should be possible by 1986 to cultivate a total of 4430 acres of paddy and 770 acres of pulses. Although a higher yield might be expected in *yala* in major irrigation schemes

than *maha* due to the greater number of sunshine hours, there are in fact no consistent differences in yields between *maha* and *yala* seasons in the recorded data for major irrigation schemes. It is, therefore, assumed that *maha* and *yala* yields for the possible alternatives are the same. Paddy yields are derived from historic trends for all island *maha* yields from 1951/52 to 1978/79. Out of a number of functions fitted, a semi-log function $\text{Log } Y = a + bt$ gave the best fit.

Where Y is yield in bushels per acre, a is a constant value, b is a regression coefficient and t is years from 1951/52^p.

$$\text{Log } Y = 28.14 + 1.0246 t \text{ (coefficient of determination } (R^2 = 0.87) \text{ (0.032) (0.0008))}$$

Note: standard errors are in parentheses.

To check if there had been any change in the relationship in more recent years, *Anuradhapura* district yields were examined for the 12 year period 1967/68 to 1978/79^{s3} but the regression values were similar. The results were

$$\text{Log } Y = 47.93 + 1.0222 t \text{ (} R^2 = 0.40 \text{)} \\ \text{(0.08) (0.0068)}$$

Note: standard errors are in parentheses.

Due to lack of yield data on pulses it is assumed that the growth rate of yield of pulses will be the same as for paddy. Yields between 1990 and 2009 for which projects are estimated using 2.46 per cent growth rate per annum, as it is assumed that maximum benefits will be reached by 1990 (Table 2). It may seem that the yields are being raised without any additional project inputs. However, future all island policies and measures such as the introduction of new varieties and new extension activities could have an effect on MvCS also. The incremental economic cost of herbicides and pesticides would be small as 92 and 100 per cent farmers already used herbicides and pesticides respectively in 1979/80 and the amount of herbicides necessary with mud sowing is lesser when compared with dry sowing. But, additional cost per bushel for herbicides, pesticides, sacks, transport etc. is calculated and will be discussed later. A similar regression function is used to estimate the intermediate with the project yields for 1980 to 1990 period assuming given yields of 49.1 and 78.8 bushels per acre in 1980 and 1990 respectively. (Vithanage, 1982^a).

As it is not possible to project prices for project outputs and farm inputs (in this case paddy, pulses and fertilizer) for each separate year, due to the inherent volatility of markets in agricultural products and the unpredictable nature of government intervention in these markets, projected 1990 prices, given by the Commodities and Export Division of IBRD are used throughout (Table 4). Full agricultural development with each alternative is reached in 1990 and use of 1990 prices can thus be justified. Since pulses are not traded internationally in any appreciable quantity, the Bank Group does not give a price for them. Historical comparisons of rice prices with those for pulses in Sri Lanka indicate that the price ratio remains fairly stable with pulses commanding a 50–70 per cent premium over paddy. A 60 per cent premium over paddy price is thus used to obtain the pulses price. Although there is a benefit with the salvage value of canal lining system, its present value will be very small and it is therefore ignored.

p. The Durbin Watson test $ld = \frac{\sum_{t=2}^n (e_t - e_{t-1})^2}{\sum_{t=1}^n e_t^2}$ calculation for the ratio gave 1.62. As this value is greater than the upper bound, du , at both 5 and 1% probability levels, the evidence does not support the hypothesis for positive auto correlation in the residuals. On the other hand, $4-du$ is also greater than d so that negative auto correlation of the residuals cannot be expected, i.e. the remaining variation is a result of random effects.

Table 6 shows the annual incremental on farm crop production costs with each proposed alternative in 1990. The prevailing market price ratio of paddy and seed paddy was used to calculate the economic price of seeds (paddy and pulses). Fertilizer costs were extracted from tables 4 and 5. The linear programming analysis shows that the marginal value product of labour is approximately 10 rupees per day during peak labour periods at 1980 price levels and this value has been used as the economic wage rate. It is assumed that the economic cost of animal power for land preparation and threshing is equal to the financial cost as the manual labour cost composed a large part of the animal cost and as the market wage rate of labour is in fact similar to the economic wage rate. As the financial costs of labour and tractor are equal to the economic costs and the ratio of the financial cost of fuel to the economic cost is 0.93 (Tables 4, 5), it is assumed that the economic cost of tractor power for land preparation and threshing is equal to the financial cost. It is assumed that 75 and 25 per cent of land preparation and threshing will be done with the use of buffaloes and tractors respectively as buffaloes were used for 66 per cent of primary land preparation, 100 per cent of secondary land preparation and 68 per cent of threshing in *maha* 1979/80. The survey data shows that the average incremental other costs (pesticides, herbicides, sacks, transport etc.) are about 5 rupees per bushel and this value was used to calculate the miscellaneous costs.

The net effect of lining canals on public health and on the environment seems on balance to be positive. When the storage water is held in the tanks and run in the canals for a more extended period as would be possible with lined canals, mosquitoes increase. But the opening of the natural drains would remove the tail water which stagnates in low areas from the fields and so lessen the problem. The extension of the irrigation season would improve the recharge of village wells and so improve the domestic water supply.

A problem that could arise in future with lined canals is that these can be fairly easily damaged by farmers who are dissatisfied with the amount of water they are receiving and the costs of repair might be quite substantial. Such costs are not included in the projections.

Pipelines and Re-use of Drainage Water

Provision of pipelines and re-use of drainage water is another alternative considered. It involves the introduction of a 'limited demand' schedule. Water is not supplied to farmers according to the decisions of the management, but is made freely available to them at a limited flow rate. According to this concept, all other practices are based on trying to prevent the farmer from using water but no one is in a better position than the farmer to know how much water he needs. With this system, water is only actually lost from a project by evapotranspiration. All other water is translocated and should be reclaimable to facilitate the farm application process. The water losses such as those from canal seepage are reduced by the use of pipe lines and losses in farm application are tolerated and reused through use of pumps.

The physical core of this system is: the replacement of field channels by pipes; and the operation of the main and distributary canals at constant water levels maintained by float operated gates. Farmers are able to draw as much water as they require from the system, each farm having an individual outlet. Excess water is pumped back up from the drains to the canals.

This system eliminates water losses in field channels, picks up drainage water for reuse and supplies water equitably to all farms (tail enders are in fact better placed than top enders as water flows to lower lying pipes,) reduces maintenance costs and releases for cultivation the areas now occupied by the field channels. This system of continuous irrigation retains the fertilizer in the fields and fish culture could be developed in main and distributary canals when operated at constant water levels. It is compatible with the present water management and farm procedures. The current on-farm programme of water division can be continued but at a much higher level of efficiency. Each farm turnout with its screw regulating valve and weir measuring device can provide a high level of water control, unattainable with the gravel canals or lined canals with ditch turnouts. The present problem of non-uniform planting dates combined with the rotational schedule can be alleviated by more flexibly controlled water deliveries.

Existing pipeline systems in Sri Lanka are relatively new and experimental. Pilot projects on channel D-1 of Block 404 of the *Mahaweli* area H project and channel D-3 of Left Bank track 3 of the *Mahakanadarawa* scheme are currently underway to evaluate costs and limitations of a specific pipeline system.

Estimates in Table 7 for Block 404 of *Mahaweli* scheme H area indicate that civil engineering work alone would cost 5020 rupees per acre at 1980 price levels while total civil engineering work costs were originally estimated at 2938 rupees per acre for the pilot pipeline system at *Mahakanadarawa* at 1979 price levels. However, the actual cost was about 21332 rupees per acre at 1980 price levels and this figure is used to arrive at the costs in Table 9. However, these figures contrast with the estimate provided by Professor Merriam. His progress report of February 1979 states,

'The most intensive study was made of distributary channel 3 in block 302 and field channel 4 (*Mahaweli* scheme H area). This (investment cost) is estimated to cost about 1300 rupees per acre.'

According to the Irrigation Department officials, operational and maintenance costs would be similar to that with the canal lining programme, 205 rupees per acre at 1980 price levels (Table 8).

Transmission losses in field channels per mile are higher than in the main and distributary canals due to the greater surface area of the field channels. It is assumed that 50 per cent of transmission losses occur in field channels at MvCS and consequently installation of pipelines will reduce transmission losses by 50 per cent (Table 1).

It will be possible with pipelines to irrigate and cultivate the total lowland area under paddy in the *yala* season. It is assumed that paddy will be the sole crop cultivated in both seasons as farmers prefer to cultivate paddy when there is adequate availability of water (Vithanage 1982b). As in the canal lining programme, it is assumed that the additional area cultivated in *yala* will be brought in by equal instalments up to 1986. Estimation of annual benefits and costs is on a similar-basis to that used for the canal lining programme and estimates are given in Table 9. The salvage value of the pipelines is not included as a benefit as its present value would be very small. However, along with certain practical problems with installation of pipelines during the construction period some more problems could arise with operation and maintenance programmes. These will increase the costs and extend the period needed for full development.

Cleaning and Maintenance of Gravel Field Channels Using Direct Labour

The existing method of delivery to individual farms at MvCS as in other schemes consists of a ditch running at right angles to the contours on a ridge with farms located on both sides of the field channel. Control structures are located where necessary to regulate the water surface elevation in the ditch and usually drop the water surface less than 4 feet (1.2 metres) at each location. Farm water deliveries are made through turnouts in the ditch banks.

The advantages of conventional systems are their simplicity, low cost to construct and lack of special maintenance equipment requirements. Water is always visible to farmers and with experience, they will gain confidence and knowledge of proper flows in the ditches. These conventional systems have flexibility and can be converted later to more sophisticated systems. Disadvantages include losses to seepage, consumption by vegetation and easy access for unauthorised issues. Earthen ditches tend to deteriorate and are subjected to changes in flow characteristics and water manageability. Therefore, a continuing programme of maintenance is needed. Johnson *et. al.* (1978) report that improved cleaning and maintenance of the field channels is the best means for obtaining increased water supplies for farmers' fields in most countries.

Kemper (1979) estimates that the losses in the field channels of some colonization schemes in Sri Lanka could have been reduced by about 75 per cent if the channels had been properly cleaned and maintained, Direct employment of labourers is preferred to farmer maintenance in this study to achieve the goal of adequate cleaning and maintenance of field channels.^a

Assuming that proper cleaning and maintenance cut the losses in field channels only by 33 per cent, so that transmission efficiency is increased to 80 per cent from 70, and the on-farm efficiency is up to 35 per cent from 28, cultivable area of low land would be increased to 1122 acres (Table 1). The increase in on-farm efficiency can be expected as reduced possibility of water shortages with a cleaning programme will reduce the necessity to maintain a continually replenished stock of water as a buffer against possible shortages later or drying out. This alternative is compatible with the linear programming analysis's optimal plan of 7.0 acre feet of water availability in the tank in *yala* with 2767 acres of paddy and 1788 acres of pulses.

a At present the Irrigation Department officials control water allocation at the main and distributary canals and attend to the repair and maintenance of the channel system and irrigation structures. Farmers have to clean their own field channels. However, Kemper (1979) reports that 'about half of the control structures and drop structures observed on field channels, are already out of commission, having been by-passed deliberately by farmers to obtain a little more water on having been washed out as a result of lack of maintenance which the farmers were supposed to provide'. The farmers using the field channels, finally inform the Irrigation Department that the channel is not able to carry water which is rightfully theirs. Instead of insisting that the farmers do a good job of cleaning and bringing back to its designed condition, the Irrigation Department apparently accedes to their wishes and provides the rather expensive additional offtake. If specific officials insist on standing by the rules and regulations, they may be transferred on grounds of 'uncooperative attitudes towards farmers.' As a result of such cases, the morale of the Irrigation Department appears to be low and maintenance standards have fallen in consequence.

Local field channel level farmer groups were organised in late 1980 on an experimental basis at the *Mahaweli* scheme and the *Gal-Oya* scheme to motivate farmers to control water allocation and to clean and maintain field channels for themselves. It is too early to evaluate them.

Costs in employing casual labourers to the Irrigation Department for the cleaning programme are estimated as described below. The total length of the field channels is 210,000 feet at MvCS. The channels are about 1000 to 1500 feet long and a man wielding a mamoty (hoe) should be able to shave about one inch of the soil plus all the grass crown from the bottom and sides of these channels at a rate of about 50 feet per hour and also to rebuild banks where they have been damaged by animals. Such work when done by the Irrigation Department now requires 20 hours of labour on 1000 feet canal. Assuming 50 per cent more hours as advised by the field officers at MvCS, 4200 labour hours are needed per time. This cleaning would have to be repeated about four times per year to keep the channel in good, high delivery condition. The Irrigation Department hired labour in 1980 for construction at the rate of 15 rupees per day. Consequently, the annual variable cost of cleaning and maintenance for the project would be 59466a rupees per annum. The total annual operational extension service cost and irrigation water management cost for the alternative are shown in Table 8. Annual estimates of benefits and costs with cleaning and maintenance of field channels, which is assumed to be undertaken by the government are shown in Table 10. Estimates have been prepared for 30 years as with other possible alternatives.

Compaction of Soil in Beds and Banks of Field Channels Using Direct Labour

This is a further possible alternative and will be studied separately from cleaning and maintenance of field channels. High rates of infiltration in the gravelly red brown earth soils and in the red yellow latosols which are wide spread in the Dry Zone of Sri Lanka are problems in many parts of the irrigation distribution system. Recent studies at Colorado State University show that permeabilities of soils of similar textures can be reduced to one per cent of normal values by compaction at the proper moisture content (Kempar 1979). Data indicate that the effect should last through at least one season. Organization of such work could be handled as discussed in relation to the cleaning and maintenance of channels.

According to the Irrigation Department field officers at MvCS, a man wielding a wooden log with a handle could pound 100 lineal feet per day of a channel that will carry up to 1.0 cu. sec of water with a scheme total of 3400 labour days required for both seasons. The annual variable cost would be about 178038^b rupees per annum at 1980 price levels. The annual operational cost for compaction of soil was added to the costs of the extension service and of additional fertilizer to estimate the gross incremental costs (Table 8 and 11), assuming that government would undertake the work on field channels. However, this could also be done with the help of farmers as discussed in the earlier section.

Although the studies show that permeabilities of soils can be reduced to one per cent, 85 per cent transmission efficiency is assumed, as compared with the existing 70 per cent, with compaction of soil in field channels. This programme would increase the cultivable area in *yala* to 1165 from 693 acres per year and it is assumed that the cropping pattern will be similar to the cleaning programme. Estimation of costs and benefits was similar to the pattern used in other possible alternatives (Table 11).

a $(210,000 \text{ ft.} / 50 \text{ ft. per hr.} \times 8 \text{ hrs.}) \times 15 \text{ Rs./hr. for unskilled labour plus } (1/10\text{th of unskilled labour hours}) \times 32 \text{ Rs./hr. for supervisors plus } 20\% \text{ of supervisors' cost as leave/} \times 4 \text{ times/year } 1.50 = 59466 \text{ Rupees/year.}$

b $(210,00 \text{ ft./}100 \text{ ft./day}) \times 15 \text{ Rs./hr. for unskilled labour plus } (1/10\text{th of unskilled labour hours}) \times 32 \text{ Rs./hr. for supervisors plus } 20\% \text{ of supervisor's cost as leave/} \times 3 \text{ times/year } 1.50 = 178038 \text{ Rs./year.}$

Project Manager for Integrated Rural Development

It is generally accepted in Sri Lanka, that lack of coordination of services has resulted in production from major irrigation schemes falling far below their potential. The lack of attention to the management aspect may well be the most limiting factor but it should also be the quickest and cheapest to remedy. Even with the existing infrastructure and services, cropping intensities could be greatly increased, the latent management abilities of farmers utilised, underemployment reduced and inputs more satisfactorily co-ordinated if more emphasis was to be placed on effective management.

The unavailability of fertilizers in the cooperative stores at the required time, difficulties in obtaining credit on time and inadequate institutional marketing arrangements are common complaints among farmers at both MvCS and *Dewahuwa*. About 60 per cent of the surveyed farmers at MvCS sold paddy to private traders at prices about 10 to 15 per cent lower than the guaranteed price in *maha* 1978/79 and 1979/80. All farmers interviewed complained regarding the low prices and lack of ready marketing outlets for other crops. The Irrigation Department officials are more concerned with civil engineering works than water management and there are many occasions at present when farmers do not get as much water as they require. An integrated rural development programme could remedy most of these problems through the co-ordination of all departments on the scheme.

Increased availability of fertilizer will raise the profitability of the modernization scheme. Ishikawa (1967) states that the introduction of new seed-fertilizer technology has set the stage for increased emphasis on irrigation investment. The complementarity between irrigation and fertilizer is illustrated for four Asian countries in the work of Kikuchi (1975). In all four cases the introduction of modern varieties and fertilizers approximately doubled the internal rate of return on irrigation investment and cut the cost-benefit rates in half. The water issues from the bank sluices in terms of equivalent acre feet per acre are lower when there is close coordination between the farmers and the Irrigation Department as compared with those when there is no coordination. There was an integrated rural development programme in the *Dewahuwa* Scheme up to 1975 and average paddy yields were then 74 and 72 bushels per acre in *maha* 1971/72 and 1972/73 respectively when compared with 56, 62, 65, 40 and 68 bushels in *maha* seasons from 1975/76 to 1979/80.

This need to emphasise management was identified by the FAO/IBRD Cooperative Programme in 1966, and as a result the Special Projects Programme started in Sri Lanka in 1968. Although no thorough investigation has been carried out to measure its success, it appears that the results achieved were quite variable. Discussions with personnel involved lend to suggest, as a broad generalisation, that the following problems arose: (i) little long term cooperation developed between the Project Manager and the various departments involved; (ii) often a weak chain of control and communication existed between the Land Commissioner's Department (which has overall responsibility for the special projects) and the Project Managers of individual schemes, since the latter were frequently under the Agricultural Department; (iii) no detailed plans for the overall management and development of individual schemes were drawn up, nor were Project Managers trained to cope with the management problems that arose. These points tend to suggest that the need for effective scheme management cannot be met merely by the appointment of a Project Manager. It seems necessary to outline requirements additional to the appointment of a Project Manager.

A future Project Manager, employed by a parent organization, should be responsible for the integrated rural development programme. The parent organization could be the Land Commissioner's Department or the Central Bank or the Agricultural Development Authority or Mahaweli Development Board and should be responsible for the management of all major irrigation schemes in the Dry Zone, outside the areas controlled by the statutory bodies. The parent organization would (i) be accountable to the government for the management and productivity of all major irrigation schemes at government level, (iii) appoint a Project Manager to each scheme, (iv) monitor programmes and set seasonal targets, (v) operate a disciplined organization making managers accountable for progress on the schemes, (vi) liaise with heads of departments regarding agreed targets and the methods of operation of their departments on major schemes and (vii) establish a support unit to service the managers on each scheme. The project manager should be accountable to the Government Agent and the parent body. He would have the responsibility of drawing up a programme for the development of the scheme in conjunction with the district heads of departments, for the coordination of all departments on the scheme, for operating a monitoring system and identifying all constraints to development and for representing the interests of the whole scheme to the relevant authorities. As the Project Manager reporting directly to the Government Agent, he should be able to enforce his powers on other departments.

In these circumstances, a manager of average ability should be able to increase on-farm efficiency of water use at least up to 35 per cent from the present 28 per cent, (the pessimistic on-farm efficiency rate of the tank modernization appraisal report is 44 per cent) with the new extension service and close co-ordination between farmers and the Irrigation Department. On-farm efficiency was 35 per cent in some previous years. As happened in the *Dewahuwa* scheme, it is assumed that the task of attaining this improvement should not take more than four to five seasons. This will increase the *yala* cropping acreage up to 1035 acres of paddy from 693 acres (Table 2). This possible alternative is compatible with the linear programming analysis's optimal plan of 4.4 acre feet water availability in the tank in *yala*, and 2600 acres of paddy in *maha* and 1422 acres of pulses in *yala* will be cultivated under this plan.

Increased availability of fertilizer at the correct time will increase yields. The present price ratios of paddy and fertilizer are very favourable to farmers (fertilizer prices are subsidised by 75 per cent.) Favourable price ratios are very effective in getting the farmers to apply large amounts of fertilizer if available and to reach a high production. Izumi (1972) writes in his report on 'Economic of Nitrogen Fertilizer Application of High Yielding Varieties of Paddy in Sri Lanka' that,

'even if the price of fertilizer goes up 50 percent from the present level, both the yields and the income of the paddy per acre do not make any significant changes. Under the present situation, the most important matter for paddy farmers is not the price of fertilizer but to prepare a better credit and distribution system for fertilizer.'

The Project Manager would be concerned with the availability of fertilizer for farmers at the correct time.

The relationship between fertilizer use and paddy yields can be established for the data collected in 1980 at MvCS with the aid of regression analysis. Four regression functions were tested, linear and quadratic types, based on these data as shown in Table 12. Although the coefficients of determination are relatively low for all equations as might be expected in that the level of fertilizer use is not totally responsible for yield, the best fitted function was a quadratic function ($y = a + bx - cx^2$) see Table 12). which explains that the yield responses for fertilizer follow the principle of diminishing returns when observations are in a sufficiently wide range. Given the MvCS level of use, the expected yield with this function is 49.38 bushels per acre in *maha* 1979/80, which is very close to the actual average yield of 49.1 bushels per acre. It is assumed that the yield with 66 per cent of the recommended fertilizer application will be 78.8 bushels per acre in 1990 (Vithanage, 1982 a). When the availability of fertilizer is increased, applications could be expected to rise to the recommended levels as was the case in 1973 and 1974 at the *Dewahuwa* Scheme. Even with only 90 per cent of the recommended fertilizer application, the yields would be raised up to 83.01 bushels per acre with this programme (Table 13), when compared with other possible alternatives, discussed earlier.

Other possible benefits might be obtained from an integrated rural development programme, although these are not quantified in this study. The manager would be concerned with the organization of the cleaning and maintenance of field channels, the supply of irrigation water to farm at the correct time and the provision of institutional credit for farmers to hire draught power on time. Once the manager arranges marketing outlets for crops other than paddy, the gross margin per acre for these crops will be increased and a shift to these crops in *yala* in lowland might be expected sooner than otherwise. The total area cultivated in *yala* would then be increased since these crops need less irrigation water per acre as compared with paddy. If he could arrange with the cooperative societies for more storage facilities, gunny bags and adequate cash to buy paddy during the harvesting periods, there could be more effective competition between these and the private traders.

Annual operational costs in Table 14 cover the salaries of the Project Manager, assistant, driver, maintenance and repairs of the vehicle, repairs to buildings, costs of extension service and irrigation water management. Estimation of annual benefits and costs is similar to the methods used in other possible alternatives.

Project Manager for Integrated Rural Development, and Cleaning and Maintenance of Field Channels Using Direct Labour

The incremental benefits which might be gained by combining the Project Manager option with the canal lining or pipe lines option will be very small as the total area will be cultivated in *yala* under either the canal lining or pipelines option alone. As the additional area which could be cultivated under soil compaction option over cleaning and maintenance option is only 43 acres of paddy (Table 2), it is more reasonable to combine the latter with the Project Manager option.

The combined effect of these two alternatives will increase the on-farm efficiency to 40 per cent due to the reasons discussed elsewhere. With an 85 and 40 per cent transmission and on-farm efficiencies respectively, acreage of paddy in *yala* will be increased to 1509 acres from 693 acres. This option is compatible with the linear programming analysis's optimal plan of 9.4 acre feet water availability in tank in *yala*, and 3497 acres of paddy and 1205 acres of pulses per annum will be cultivated under this plan.

Annual operational costs have been combined and estimation of annual benefits and costs are similar to the methods used earlier (Table 15).

Results of the Economic Cost Benefit Analysis

There are several ways of appraising the results of a project. The discounted cash flow (DCF) technique and net present value (NPV), benefit cost ratio (BCR), internal rate of return (IRR) and present value of cost per additional acre parameters are all used in this study.

The present value of costs and benefits at the 12 per cent discount rate shown to be the appropriate accounting rate is shown in Table 16, and Table 17 shows the NPVs at the discount rates of 5, 12 and 20 per cent, the BCRs at the 12 per cent discount rate and the IRRs for six alternatives.

The alternative involving the appointment of a Project Manager has an IRR below 12 per cent and consequently a negative NPV when discounted at this rate. It, therefore, appears economically infeasible. The remaining alternatives all have a positive NPV with the largest values obtained by the combined programme.

It can be seen, however, that when the discount rate falls below 10 per cent, the pipelines alternative produces a larger NPV than the combined programme. The present values of this option and canal lining programme are very sensitive to the rate of discount used. This is because discounting emphasises the early costs of pipelines and canal lining, and diminishes the present value of incremental benefits which are spread over the project's life. This implies that the pipeline option would be chosen if the opportunity cost of capital was judged to be less than 8.5 per cent (the cross over discount rate), and the combined programme option if above this. Given the limited investment involved it is not surprising that the NPV's for cleaning channels, soil compaction and rural development are taken separately relatively small and do not fully utilise the economic potential of the MvCS. The evidence given earlier as to the appropriate discount rate leads to the choice of the combined programme.

Where the choice is between projects (mutually exclusive projects), the general rule is to select the project, offering the highest NPV. However, in the presence of capital rationing, it is necessary to 'normalise' projects so that they are comparable. There is a significant difference between the present value of costs of alternatives. Any available capital could be invested in other mutually compatible projects and it is assumed that the rate of return to this additional bit of investment is 12 per cent, shown to be the appropriate discount rate. Even with these estimations (column 8 of Table 17) the NPV of the combined programme is above the others, and the canal lining and pipeline options have the lowest NPVs with an incremental project.

Conclusions

An investment in the hardware or physical works, such as canal lining and pipelines, is easier from the standpoint of the lending or funding agency than implementation of an investment strategy that emphasises software or management such as cleaning channels, appointment of a Project Manager for a rural development programme or a combined programme of cleaning channels and a Project Manager option. Further, hardware projects please industrial donor countries due to their high import content and please politicians and administrators as being highly visible and photogenic.

The appraisal shows that pipeline option is a more appropriate choice than the canal lining option when opportunity cost of capital is less than 15.5 per cent with given assumption. But the pipeline option would be only chosen if the opportunity cost of capital was judged to be less than 8.5 per cent (the cross over discount rate), and the combined programme option if above this. On the other hand, given the limited investment involved, cleaning channels, soil compaction and a Project Manager options taken separately do not fully utilize the economic potential.

REFERENCES

- Ishikawa, S. (1967). *Economic Development in Asian Perspective*. Economic Research Series-No. 8, Tokyo, Kinokuriya Bookstore Co.
- Izumi, K. (1972). *Economics of Nitrogen Fertilizer Application on High Yielding Varieties of Paddy in Sri Lanka*. Colombo: Agrarian Research and Training Institute.
- Japan International Co-operation Agency (1977). *Sri Lanka-Japan Rural Development Project, Dewahuwa. Final Report*. Tokyo.
- Johnson, S., Keniper, W. D. and Lowdermilk, M. K. (1978). *Solutions to Water Management Problems of the Indus Basin*, Water Resources Bulletin. University of Colombo.
- Kemper, W. D. (1979). *Apparent Investment Potentials for Increasing Food Production Through Improved Water Management in Sri Lanka*. Washington: USAID.
- Kikuchi, M., (1975). *Irrigation and Rice Technology in Agricultural Development; A Comparative History of Taiwan, Korea and the Philippines*. Unpublished Ph.D. Thesis. University of Hokaido, Japan.
- Little, I. M. Mirrlees, J.A. (1974). *Project Appraisal and Planning for Developing Countries*. London: Heinemann.
- Merriam, J. L. (1979). *Progress Report Submitted to the Department of Irrigation-12th February, 1979. Tank Irrigation Modernization Project File, Department of Irrigation, Colombo*.
- Ministry of Agriculture and Lands (1972), *Important Statistical Tables on Agriculture*. Colombo.
- Vithanage, N. (1982 a). *Analytical Techniques in Agricultural Development Planning: A critical appraisal of a project for the modernization of an irrigation scheme in Sri Lanka*. Unpublished Ph.D. Thesis. University of Leeds.
- Vithanage, N., (1982 b). *Chena-Paddy Interrelationships and Dry Sowing: The experience in an irrigation scheme in Sri Lanka*. Sri Lanka Journal of Agrarian Studies December 1982.
- World Bank (1976). *Sri Lanka Appraisal of the Tank Irrigation Modernization Project*. Washington.

Table 1—Maximum Cultivable Area in Yala with Possible Alternatives ^a

	<i>Without project</i>	<i>With lined canals</i>	<i>With pipe lines</i>	<i>Gravel canals</i>			
				<i>Cleaning & maintenance of field channels</i>	<i>Soil compaction in field channels</i>	<i>With a Project Manager</i>	<i>With Combined programme</i>
1. Conveyance loss:							
(i) Main & Dist. channels evaporation (ac.ft.)	925	925	925	925	925	925	925
(ii) Main & Dist. channels seepage (ac.ft.) ...	1850	0	1850	1850	1850	1850	1850
(iii) Field channels evaporation (ac.ft.) ...	925	925	0	925	925	925	925
(iv) Field channels seepage (ac.ft.) ...	1850	0	0	1233	925	1850	925
Total (ac.ft.) ...	5550	1850	2775	4933	4625	5550	4625
2. Water re-use (20%) (ac.ft.) ...	3700	3700		3700	3700	3700	3700
3. Usable water in field (ac.ft.) ...	16650	20350		17267	17575	16650	17575
4. On-farm efficiency (%) ...	28	44		35	35	35	40
5. Maha field water requirement per acre (inches) ...	50.7	33.6		42.3	42.3	42.3	37.0
6. Maha field water requirement for the scheme (ac.ft.)	10833	7280		9273	9273	9273	8017
7. Water remaining for Yala (ac.ft.) ...	5817	13070		7994	8302	7377	9558
8. Yala field water requirement per acre (inches) ...	100.7	70.2		85.5	85.5	85.5	76.0
9. Maximum Yala area cultivable (ac.) ...	693	2234	2600	1122	1165	1035	1509

Note: a. assuming 18500 ac.ft. of annual tank yield.

Table 2 Annual Estimates of Economic Benefits and Costs with Canal Lining

Year	without project			with project			Incremental				
	Paddy Yield/acre (bu.)	Income ('000 Rs.)	Incremental on farm cost ('000 Rs.)	Paddy Yield/acre (bu.)	Pulses Yield/acre (lbs.)	Income ('000 Rs.)	Incremental on farm cost ('000 Rs.)	Gross benefits ('000 Rs.)	Project costs ('000 Rs.)	Gross costs ('000 Rs.)	Net benefits ('000 Rs.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	49.1	11722		49.1		11722		0	44500	44500	-44500
2	50.3	12009	20	52.90	500	14376	577	2367	532	1089	1278
3	51.5	12295	40	55.75	527	16357	1158	4062	532	1650	2412
4	52.8	12606	60	58.63	555	18472	1722	5866	532	2194	3672
5	54.1	12916	81	61.18	585	20519	2318	7003	532	2769	4834
6	55.4	13226	102	64.39	617	21858	2942	8332	532	3372	5260
7	56.8	13561	124	67.27	650	22846	3125	9255	532	3533	5752
8	58.2	13895	147	70.16	685	23842	3366	9947	532	3751	6196
9	59.6	14229	168	73.04	722	24837	3533	10608	532	3897	6711
10	61.1	14587	194	75.92	760	25835	3734	11248	532	4072	7176
11	62.6	14945	218	78.80	800	26837	3915	11892	532	4229	7663
12	64.1	15303	243	80.7	820	27485	3989	12182	532	4278	7904
13	65.7	15685	268	82.7	840	28165	4041	12480	532	4305	8175
14	67.3	16067	294	84.8	861	28860	4095	12793	532	4333	8460
15	69.0	16473	322	86.8	882	29562	4147	13089	532	4357	8732
16	70.7	16879	349	89.0	903	30309	4204	13430	532	4387	9043
17	72.4	17285	377	91.2	926	31059	4272	13774	532	4427	9347
18	74.2	17715	406	93.4	948	31808	4327	14093	532	4453	9640
19	76.0	18144	435	95.7	972	32592	4379	14448	532	4476	9972
20	77.9	18598	461	98.1	996	33409	4441	14811	532	4512	10299
21	79.8	19052	496	100.5	1020	34226	4503	15174	523	4539	10634
22	81.8	19529	529	102.9	1045	35045	4566	15516	532	4569	10947
23	83.8	20007	561	105.5	1071	35929	4633	15922	532	4604	11318
24	85.9	20508	595	108.1	1097	36814	4701	16306	532	4638	11768
25	88.0	21009	629	110.7	1124	37700	4769	16691	532	4672	12019
26	90.1	21511	663	113.5	1152	38653	4841	17142	532	4710	12432
27	92.4	22060	700	116.3	1180	39606	4914	17546	532	4746	12800
28	94.7	22609	737	119.1	1209	40561	4987	17952	532	4782	13170
29	97.0	23158	774	122.0	1239	41559	5062	18401	532	4820	13581
30	99.3	23707	811	125.0	1269	42570	5140	18863	532	4861	14002

Note: a. Economic prices of inputs and outputs are based on Tables 4 and 5; b. Col. 4 - based on 5 Rs. per additional bushel over 49.1 bu./ac.; c. Col. 8 - see Table 6; Col. 10, 532000 Rs. = 533800 Rs. + 54156 Rs. (for annual operational costs of irrigation system and extension service respectively)-35720 Rs.-20000 Rs. (as previous annual operational costs of irrigation system respectively) see table 8; e. Col. 9=Col. 7-Col. 3; Col. 11 = Col. 8 + Col. 10 - Col. 4.

Table 3—Area Under Paddy and Pulses with Possible Alternatives

Year	Canal lining		Pipe lines	Cleaning Channels		Soil Compaction		Project Manager		Combined Programme		
	Paddy (ac.)	Pulse (ac.)	Paddy area (ac.)	Paddy (ac.)	Pulses (ac.)	Paddy (ac.)	Pulses (ac.)	Paddy (ac.)	Pulses (ac.)	Paddy (ac.)	Pulses (ac.)	
1980	...	3293	0	3293	3293	0	3293	0	3293	0	3293	0
1981	...	3520	150	3674	2767	800	2774	800	2600	900	3334	240
1982	...	3747	300	4056	2767	1050	2774	1050	2600	1050	3375	480
1983	...	3974	450	4437	2767	1300	2774	1300	2600	1200	3416	720
1984	...	4201	600	4819	2767	1550	2774	1600	2600	1300	3457	960
From 1985 up to 2009	...	4430	770	5200	2767	1788	2774	1856	2600	1422	3497	1205

Source: Vithanage (1982a).

Table 4—An Estimate of Accounting Ratios for Some Traded Goods

	Construction Stage			Operational Stage		Output
	Inputs			Inputs		
	Cement	Diesel	Urea	Triple Phosphate	Muriate of Potash	
	(cwt.)	(gallon)	(tonne)	(tonne)	(tonne)	(tonne)
1. Import price, c.i.f. Colombo (US \$)	206.2	112.0	313.9
2. Export price, f.o.b. Colombo (US \$)	4.55		
3. Foreign exchange in local currency (Rs.) ^a	72.80	15.40	5022
4. Store handling, labour dues (Rs.)	-8.00	1.10	75
	(-6.40)	(0.88)	(60)
5. Ex-factory price (Rs.) ^b	64.80		2746
	(5832)		(2471)
6. Road transport to MvCs ^c (Rs.)	2.00	0.45	422
	(1.08)	(0.24)	(228)
7. Rail transport to MvCS (Rs.)		0.20	422
		(0.12)	(228)
8. Trade margin (Rs.)	17.20	2.85	140
	(12.04)	(2.00)	(98)
9. Transport from retail outlets to farm (Rs.)		20	20
		(16)	(16)
10. Transport and marketing fees from Colombo to deficit area (Rs.)			640
			(352)
11. Transport and marketing fees from MvCS to deficit area (Rs.)			400
			(-220)
12. Farm gate price (Rs.)	83.00	20.00	3373
13. Accounting price at MvCS	71.44	18.64	2845
14. Accounting Ratio	0.86	0.93	3752
			2449
			5337 ^d
15. Accounting price/economic price			2194
			0.98

Note: a. 1 US \$—16 rupees in 1980; b. SCF of 0.9 is used as accounting ratio (Vithanage, 1982 a);
c. 240 Km to MvCS from Colombo; d. milling out ratio of paddy is taken as 65%; figures in parantheses are relevant accounting prices.

Sources: Import prices of fertilizer and paddy are based on data published by the Commodities and Export Projection Division, IBRD, April 1978; export prices were from Cement Corporation and Ceylon Petroleum Corporation.

Table 5—Economic Costs of Components of Possible Alternatives

	<i>Canal</i>	<i>Operational stage annual costs ('000 Rs.)</i>					<i>Accounting ratio</i>	
	<i>lining construction ('000 Rs.)</i>	<i>Canal lining</i>	<i>Pipe lines</i>	<i>Cleaning channels</i>	<i>Soil compaction</i>	<i>Project Manager</i>		<i>Combined programme</i>
A. Project cost								
1. Cement ...	4150 (3569)							0.86
2. Diesel fuel	2400 (2232)	193.5 (180)	193.5 (180)	7.0 (6.5)	7.0 (6.5)	38.0 (35.3)	38.0 (35.3)	0.93
3. Unskilled labour	6400 (3712)	51 (30)	51 (30)	63 (36.5)	158 (91.6)	16 (9.3)	63 (36.5)	0.58
4. Skilled labour	4120 (4120)	94 (94)	94 (94)	47 (47)	71 (71)	67 (67)	79 (79)	1.0
5. Expatriate salaries	3520 (2816)							0.8
6. Equipment and vehicles	19380 (19380)	191.5 (191.5)	191.5 (191.5)	7.0 (7.0)	7.0 (7.0)	38.0 (38.0)	38.0 (38.0)	1.0
7. Buildings ...	2000 (1109)							0.55
8. Others	2530 (2277)	2 (1.8)	2 (1.8)	5 (4.5)	5 (4.5)	7 (6.3)	7 (6.3)	0.9
9. Total ...	44500 (38511)	532 (497)	532 (497)	129 (102)	248 (181)	166 (156)	225 (195)	
B. Incremental Crop production cost								
10. Seeds ...		172 (168.6)	173 (169.5)	103 (100.9)	120 (117.6)	65 (63.7)	127 (124.5)	0.98
11. Fertilizer		1262 (1173.7)	1295 (1204.4)	985 (916.1)	1007 (936.5)	1294 (1203.4)	1637 (1522.4)	0.93
12. Others		2263 (2036.7)	2332 (2098.8)	1475 (1327.5)	1549 (1394.1)	1016 (914.4)	1785 (1606.5)	0.9
13. Total ...		3697 (3379)	3800 (3473)	2563 (2345)	2676 (2448)	2375 (2182)	3549 (3253)	

Note: a. It is assumed that construction cost of pipelines has the same ratio of economic to social cost as canal lining.

b. Figures in parentheses are relevant accounting prices.

Table 7—Cost Estimates of Pipe Line Projects

		<i>Mahakandarawa Tract 3, Left Bank Distributary 10 (105.5 acres) (Rs.)</i>	<i>Mahaweli Scheme H area Block 404 (327.5 acres) (Rs.)</i>
1. Earth Excavation	...	1800	147870
2. Spun Pipe with laying	...	173368	984400
3. Valves with fixing	...	1500	152843
4. Flow meters with fixing	...	5000	19840
5. Turnout Structures	...	22800	171289
6. Spillway on the level of top canal	...	11600	30000
	Sub total	(232268)	(1506842)
	Cost per acre (Rs.)	2202	4601
7. Regulating reservoir			
i. Earthwork	...	n.g.	65250
ii. Spillway	...	n.g.	4833
iii. Nerypic Gate	...	n.g.	45167
iv. Inlet and outlet	...	n.g.	21667
v. Broad creased weir	...	n.g.	933
vi. Pumps	...	30000	n.g.
vii. Pumps House construction	...	5000	n.g.
8. General			
i. Temporary sheds for stores and watchers	...	1000	n.g.
ii. Temporary sheds for overseers	...	3600	n.g.
iii. Watchers	...	1800	n.g.
iv. Transport and contingencies	...	36332	n.g.
	Total	310000	1621189
	Cost per acre (Rs.)	2938	5020

Note: n.g. not given.

Sources: Col.1—Estimates given by D. J. Bewan, Water Management Specialist, to the Anuradhapura Chief Engineer on 13th August, 1979; Col. 2, estimates given by the Mahaweli Development Board on 6th June, 1980.

Table 8—Costs Involved other than Direct Investment with Possible Alternatives

	<i>Fixed Investment</i> (‘000 Rs.)	<i>Annual fixed and</i> <i>variable cost (Rs.)</i>
1. New extension programme—for all alternatives	3350	
(i) Skilled labour		43325
(ii) Vehicles and fuel		6500
(iii) Others		4331
Total ...		54156
2. Irrigation Department with gravel canals		
(i) Technical Asst. (1) 800 Rs./mth ...		9600
(ii) Labourers (4) 250 Rs./mth ...		12000
Leave and travel 20% ...		5320
(iii) Motor cycle (1) 500 hrs./yr. 14 Rs./hr ...		7000
(iv) Building repairs and renewals ...		1000
Contingencies 10% ...		800
Total ...		35720
3. Irrigation Department with lined channels and pipe lines		
(i) Skilled labour		64000
(ii) Unskilled labour		60000
Leave and travels 20% ...		24800
(iii) Equipment and vehicles contingencies 10%		350000
Contingencies 10% ...		35000
Total ...		533800

Note: a. Increased cost of fertilizer is given in Table 6.

Source: a. Cost on extension service, World Bank Appraisal Report (1976) op. cit. and Dept. of Agriculture.

b. Cost on water management, Dept. of Irrigation.

Table 9—Annual Estimates of Economic Benefits and Costs with Pipelines

Year	With Project		Incremental			
	Income (‘000 Rs.)	Incremental on farm Costs (‘000 Rs.)	Gross Benefits (‘000 Rs.)	Project costs (‘000 Rs.)	Gross costs (‘000 Rs.)	Net benefits (‘000 Rs.)
1	11722		0	55462	55462	—55462
2	14091	589	2082	532	1101	981
3	16394	1169	4099	532	1661	2438
4	18860	1760	6254	532	2232	4022
5	21375	2389	8459	532	2840	5619
6	24275	2996	11049	532	3426	7623
7	25361	3201	11800	532	3609	8191
8	26450	3405	12555	532	3790	8765
9	27536	3616	13307	532	3970	9337
10	28622	3814	14035	532	4152	9883
11	29708	4018	14763	532	4332	10431
12	30424	4068	15121	532	4357	10764
13	31178	4120	15493	532	4384	11109
14	31970	4174	15903	532	4412	11491
15	32724	4226	16251	532	4436	11815
16	33553	4284	16674	532	4467	12207
17	34382	4342	17079	532	4497	12582
18	35099	4406	17384	532	4532	12852
19	36079	4458	17935	532	4555	13380
20	36984	4520	18386	532	4591	13795
21	37889	4583	18837	532	4619	14218
22	38793	4645	19264	532	4648	14616
23	39774	4713	19767	532	4684	15083
24	40754	4780	20246	532	4717	15529
25	41734	4848	20725	532	4751	15974
26	42790	4921	21279	532	4790	16489
27	43445	4993	21785	532	4825	16960
28	44901	5046	22292	532	4841	17451
29	45994	5142	22836	532	4900	17936
30	47125	5220	23418	532	4941	18477

Note: a. without project income and on farm cost, and with project yields are given in table 2;
b. economic prices of inputs and outputs are based on tables 4 and 5; Col. 3—see table 6;
Col. 5, 532000 Rs. = 533800 Rs. + 54156 Rs. (as annual operational cost of irrigation system and extension service respectively) - 35720 Rs. - Rs. 20000 Rs. (as previous annual operational costs of irrigation system and extension service respectively), see table 8.

Table 10—Annual Estimates of Economic Benefits and Costs with Cleaning and Maintenance of Field Channels

Year	With Project		Incremental			
	Income (‘000 Rs.)	Incremental on farm costs (‘000 Rs.)	Gross Benefits (‘000 Rs.)	Project costs (‘000 Rs.)	Gross costs (‘000 Rs.)	Net benefits (‘000 Rs.)
1	11722		0	3350	3350	-3350
2	11604	375	-405	129	484	- 889
3	12556	628	261	129	717	- 456
4	13551	1176	945	129	1245	- 300
5	14521	1581	1605	129	1628	- 23
6	15653	2009	2427	129	2036	391
7	16377	2183	2816	129	2188	628
8	17112	2356	3217	129	2336	881
9	17854	2530	3625	129	2489	1136
10	18600	2703	4013	129	2638	1375
11	19355	2876	4410	129	2789	1621
12	19825	2926	4522	129	2814	1708
13	20315	2978	4630	129	2839	1791
14	20830	3032	4763	129	2867	1896
15	21324	3084	4851	129	2981	1960
16	21858	3142	4979	129	2922	2057
17	22401	3199	5116	129	2951	2165
18	22941	3264	5226	129	2987	2239
19	23508	3316	5364	129	3010	2354
20	24097	3378	5499	129	3046	2453
21	24684	3441	5632	129	3074	2556
22	25277	3503	5748	129	3103	2645
23	25913	3551	5906	129	3119	2787
24	26550	3638	6042	129	3172	2870
25	27191	3706	6182	129	3206	2976
26	27877	3779	6366	129	3245	3121
27	28563	3851	6503	129	3280	3223
28	29253	3924	6644	129	3336	3308
29	29968	4000	6810	129	3355	3455
30	30703	4078	6996	129	3396	3600

Note: a. Without project income and on-farm costs, and with project yields are given in table 2; b. Economic prices of inputs and outputs are based on tables 4 and 5; Col. 3, see table 6; Col. 5. 129000 Rs. of annual operational cost = 59000 Rs. (for cleaning channel programme) + 54156 Rs. (for extension service) + 35720 Rs. (for irrigation system) — 20000 Rs. (as previous extension service cost), see table. 8.

Table 11—Annual Estimates of Economic Benefits and Costs with Compaction of Soil in Beds and Banks of Field Channels

Year	With Project		Incremental			
	Income (‘000 Rs.)	Incremental on farm costs (‘000 Rs.)	Gross benefits (‘000 Rs.)	Project costs (‘000 Rs.)	Gross costs (‘000 Rs.)	Net benefits (‘000 Rs.)
1	11722	0	0	3350	3350	-3350
2	11631	385	-378	248	613	-981
3	12584	786	289	248	994	-705
4	13580	1194	974	248	1382	-408
5	14625	1650	1709	248	1817	-108
6	15790	2101	2564	248	2247	317
7	16521	2276	2960	248	2400	560
8	17263	2453	3368	248	2554	814
9	18012	2629	3783	248	2709	1074
10	18767	2804	4180	248	2858	1322
11	19530	2979	4585	248	3009	1576
12	20004	3029	4701	248	3034	1667
13	20499	3081	4814	248	3061	1753
14	21018	3135	4951	248	3089	1862
15	21517	3192	5044	248	3118	1926
16	22056	3244	5177	248	3143	2034
17	22604	3302	5319	248	3173	2146
18	23148	3367	5433	248	3209	2224
19	23721	3419	5577	248	3232	2345
20	24314	3481	5716	248	3267	2449
21	24907	3571	5855	248	3323	2532
22	25505	3606	5976	248	3325	2651
23	25948	3673	6141	248	3360	2781
24	26790	3741	6282	248	3394	2888
25	27437	3809	6428	248	3428	3000
26	28130	3881	6619	248	3466	3153
27	28822	3979	6762	248	3527	3235
28	29518	4027	6909	248	3538	3371
29	30239	4102	7081	248	3576	3505
30	30980	4180	7273	248	3617	3656

Note: *a.* Without project income and on farm costs, and with project yields are given in table 2; *b.* Economic prices of inputs and outputs are given in tables 4 and 5; *c.* Col. 3, see Table 6; Col. 5, 248000 Rs. of annual operational costs = 178000 Rs. (for soil compaction programme) + 54156 Rs. (for extension service) + 35720 Rs. (for irrigation system) - 20000 Rs. (as previous extension service cost), see table 8.

Table 12 Regression Functions Applied to Fertilizer (cwt. per acre)—Paddy Yield (bu./acre) Responses, Survey Farms, Mahavillachchiya, Maha 1979/80

	R^2	standard error of		
		a	b	c
Left Bank				
1. $y=40.1 + 8.39 x$	0.38	8.52	2.61	
2. $y=37.32 + 18.42 x - 4.57 x^2$	0.44	8.34	8.01	3.46
3. $\log y=38.9 + 0.15 x$	0.37	0.08	0.03	
4. $\log y=50.12 + 0.14 \log x$	0.34	0.08	0.03	
Right Bank				
1. $y=38.65 + 7.60 x$	0.32	12.11	2.22	
2. $y=35.50 + 13.89 x - 1.78 x^2$	0.35	12.12	6.75	1.81
3. $\log y=38.02 + 0.21 x$	0.31	0.11	0.02	
4. $\log y=47.86 + 1.32 \log x$	0.34	0.11	0.03	
Whole Scheme				
1. $y=39.56 + 7.59 x$	0.32	10.62	1.64	
2. $y=36.96 + 13.45 x - 1.83 x^2$	0.36	10.50	4.47	1.30
3. $\log y=38.90 + 0.20 x$	0.31	0.10	0.02	
4. $\log y=48.98 + 1.26 \log x$	0.32	0.10	0.02	

Note: y, yields per acre;
 x, fertilizer cwt. per acre;
 a, constant term;
 b and c, regression coefficients of x and x^2 ;
 R^2 , coefficient of determination.

Source: *Field Survey, May 1980.*

Table 13 Paddy Yields with Different Levels of Fertilizer p for the Whole Scheme, Survey Farms, Mahavillachchiya, Maha 1979/80

Fertilizer Amount cwt/acre	per cent of fertilizer recommendation	Yield per acre (bushels)	With Fertilizer		
			Additional Cost (Rs.)	Additional income (Rs.)	Marginal increase in net income (Rs.)
(i) 0	0	35.96			
(ii) 1.083	33	49.39	60.65	497.20	436.55
(iii) 2.166	66	57.49	121.30	821.20	263.35
(iv) 2.925	90	60.61	163.80	946.00	82.30
(v) 3.250	100	61.30	182.00	973.60	9.40
(vi) 3.668q	113	61.60	205.41	985.60	-11.41
(vii) $\frac{(iv)}{(iii)} \times 100$		105.43			
(viii) 3.285r		61.40			

Note: p. the function used is $y = a + bx - cx^2$;

q. maximum yield, $\frac{dy}{dx} = 0 = b - 2cx$;

r. optimum yield for farmers, $\frac{dy}{dx} = \text{price of fertilizer/price of paddy} = b - 2cx$

Source: Field Survey, May 1980.

Table 14 Annual Estimates of Benefits and Costs with a Project Manager for Intergrated Rural Development

Year	With Project				Incremental			
	Paddy Yield/ ac. (bu.)	Pulses Yield/ ac. (lbs.)	Income ('000 Rs.)	Incremental on farm costs ('000 Rs.)	Gross benefits ('000 Rs.)	Project costs ('000 Rs.)	Gross costs ('000 Rs.)	Net benefits ('000 Rs.)
1	49.10		11722			3350	3350	-3350
2	53.68	500	11235	354	-774	166	500	-1274
3	56.89	529	12102	696	-193	166	722	- 915
4	60.16	559	13004	1008	398	166	1214	- 816
5	63.42	592	13947	1300	1031	166	1385	- 354
6	66.69	626	14779	1616	1553	166	1680	- 127
7	69.95	663	15524	1813	1963	166	1855	108
8	73.22	701	16274	2008	2379	166	2027	352
9	76.48	742	17033	2203	2804	166	2201	603
10	79.74	785	17799	2438	3212	166	2410	802
11	83.01	832	18581	2592	3636	166	2540	1096
12	85.05	852	19037	2633	3734	166	2556	1178
13	87.14	873	19505	2676	3820	166	2574	1246
14	89.29	895	19987	2717	3920	166	2589	1331
15	91.48	917	20478	2763	4005	166	2607	1398
16	93.74	939	20981	2808	4102	166	2625	1477
17	96.04	963	21500	2855	4215	166	2644	1571
18	98.40	986	22025	2902	4310	166	2662	1648
19	100.82	1011	22570	2954	4426	166	2685	1741
20	103.30	1035	23122	3001	4524	166	2706	1818
21	105.85	1061	23695	3052	4643	166	2722	1921
22	108.45	1087	24276	3105	4747	166	2752	1995
23	111.12	1114	24875	3178	4868	166	2783	2085
24	113.85	1141	25485	3211	4977	166	2782	2195
25	116.65	1169	26112	3269	5103	166	2806	2297
26	119.52	1198	26755	3327	5244	166	2830	2414
27	122.46	1227	27411	3384	5351	166	2850	2501
28	125.47	1258	28087	3447	5478	166	2876	2602
29	128.56	1289	28780	3509	5622	166	2901	2721
30	131.72	132	29484	3572	5777	166	2927	2850

Note: *a.* economic prices of inputs and outputs are based on tables 4 and 5; *b.* without project income and on-farm costs are given in table 2; *c.* Col. 5, see table 6; *d.* Col. 7 166000 Rs. of annual operational cost 96,000 Rs. (for the project manager's programme)+54156 Rs. (for extension service) + 35720 Rs. (for irrigation system) — 20000 Rs. (as previous extension service cost.), see table 8.

Table 15—Annual Estimates of Benefits and Costs with a Combined Programme

Year	With Project		Incremental			
	Income (‘000 Rs.)	Incremental on farm costs (‘000 Rs.)	Gross benefits (‘000 Rs.)	Project costs (‘000 Rs.)	Gross costs (‘000 Rs.)	Net benefits (‘000 Rs.)
1	11722		0	3350	3350	-3350
2	13274	524	1265	225	729	536
3	14550	935	2255	225	1120	1135
4	15897	1499	3291	225	1664	1627
5	17304	2064	4388	225	2208	2180
6	18779	2505	5553	225	2628	2925
7	19716	2734	6155	225	2835	3320
8	20659	2923	6764	225	3011	3753
9	21607	3193	7378	225	3250	4128
10	22663	3411	8076	225	3442	4634
11	23532	3650	8587	225	3657	4930
12	24109	3691	8806	225	3673	5133
13	24702	3714	9017	225	3691	5326
14	25312	3775	9245	225	3706	5539
15	25933	3821	9460	225	3724	5736
16	26572	3867	9693	225	3743	5050
17	27226	3913	9941	225	3761	6180
18	27894	3960	10179	225	3779	6400
19	28582	4013	10438	225	3803	6635
20	29283	4059	10685	225	3823	6852
21	30006	4110	10954	225	3839	7116
22	30744	4163	11215	225	3859	7356
23	31502	4236	11495	225	3880	7615
24	32275	4269	11767	225	3899	7868
25	33068	4327	12059	225	3923	8136
26	33882	4385	12371	225	3947	8424
27	34708	4442	12648	225	3967	8681
28	35571	4505	12962	225	3993	8969
29	36446	4567	13288	225	4018	9270
30	37340	4630	13633	225	4044	9589

Note: a. Without project income and on-farm costs are given in table 2; b. With project yields are given in table 14; c. Economic prices of inputs and outputs are based on tables 4 and 5; d. Col. 3, see table 6; Col. 5, 225000 Rs. of annual operation cost, 96,000 Rs. (for the project manager programme) + 59,000 Rs. (for cleaning channel programme) + 54156 Rs. (for extension service) + 35720 Rs. (for irrigation system) - 20000 Rs. (as previous extension service cost), see table 8.

Table 16 Annual Present Value of Economic Benefits and Costs of Alternatives (at 12 per cent discount rate)

Year	Benefits ('000 Rs.)						Costs ('000 Rs.)					
	Canal Lining	Pipe lines	Cleaning Channels	Soil Compaction	Project Manager	Combined Programme	Canal Lining	Pipe lines	Cleaning Channels	Soil Compaction	Project Manager	Combined Programme
1	0.0	0.0	0.0	0.0	0.0	0.0	39738.5	49527.6	2991.5	2991.5	2991.5	2991.5
2	1886.5	1659.4	-322.8	-301.3	-318.8	1008.2	867.9	877.5	385.7	488.6	398.5	581.0
3	2832.1	2918.5	185.8	205.8	2.1	1605.6	1174.8	1182.6	510.5	707.7	514.1	797.4
4	3730.8	3977.5	601.0	619.5	448.4	2093.1	1395.4	1419.6	791.8	879.0	772.1	1058.3
5	4310.9	4796.2	910.0	969.0	639.0	2488.0	1570.0	1610.3	923.1	1030.2	785.3	1251.9
6	4376.4	5601.8	1230.5	1299.9	787.4	2815.4	1709.6	1737.0	1032.3	1139.2	851.8	1332.4
7	4196.8	5333.6	1272.8	1337.9	887.3	2782.1	1596.9	1631.3	989.0	1084.8	838.5	1281.4
8	4018.6	5072.2	1299.7	1360.7	961.1	2732.7	1515.4	1531.2	943.7	1031.8	818.9	1216.4
9	3829.5	4803.8	1308.6	1365.7	1012.2	2663.5	1406.8	1433.2	898.5	977.9	794.6	1173.2
10	3621.9	4519.3	1292.2	1346.0	1034.3	2600.5	1311.2	1336.9	849.4	920.3	776.0	1108.3
11	3413.0	4237.0	1265.7	1315.9	1043.5	2464.5	1220.6	1243.3	800.4	863.6	729.0	1049.6
12	3130.8	3886.1	1162.2	1208.2	959.6	2263.1	1099.4	1119.7	723.2	779.7	656.9	944.0
13	2857.9	3547.9	1060.3	1102.4	874.8	2064.9	985.8	1003.9	650.1	701.0	589.4	845.2
14	2622.6	3260.1	976.4	1015.0	803.6	1895.2	888.3	904.5	587.7	633.2	530.7	759.7
15	2395.3	2973.9	887.7	923.1	732.9	1731.2	797.3	811.8	529.1	570.6	477.1	681.5
16	2189.1	2717.9	811.6	843.9	668.6	1580.0	715.1	728.1	476.3	512.3	427.9	610.1
17	2011.0	2493.5	746.9	776.6	615.4	1451.4	646.3	656.6	430.8	463.3	386.0	549.1
18	1832.1	2259.9	679.4	706.3	560.3	1323.3	578.9	589.2	388.3	417.2	346.1	491.3
19	1676.0	2080.5	622.2	646.9	513.4	1210.8	519.2	528.4	349.2	374.9	311.5	441.1
20	1540.3	1912.1	571.9	594.5	470.5	1111.2	469.2	477.5	316.8	339.8	281.4	397.6
21	1411.2	1751.8	523.8	544.5	431.8	1018.7	422.1	429.6	285.9	309.0	253.1	357.0
22	1287.8	1598.9	477.1	496.0	394.0	930.8	379.2	385.8	257.5	276.0	228.4	320.3
23	1178.2	1462.8	437.0	443.3	360.2	850.6	340.7	346.6	230.8	248.6	205.9	287.1
24	1076.2	1336.2	398.8	414.6	328.5	776.6	306.1	311.3	209.4	224.0	183.6	257.3
25	984.8	1222.8	364.7	379.3	301.1	711.5	275.6	280.3	189.2	202.3	165.6	231.5
26	908.5	1127.8	337.4	350.8	277.9	655.7	249.6	253.9	172.0	183.7	150.0	209.2
27	824.7	1023.9	305.6	317.8	251.5	594.5	223.1	226.8	154.2	165.8	133.9	186.4
28	754.0	936.3	279.0	290.2	230.0	544.4	200.8	203.3	140.1	148.6	120.8	167.7
29	680.8	844.9	252.0	262.0	208.0	491.7	178.3	181.3	124.1	132.3	107.3	148.7
30	622.5	772.8	230.9	240.0	190.6	449.9	160.4	163.1	112.1	119.4	96.6	133.5
Total	66260.1	80129.1	20168.5	21074.2	15669.4	44908.7	62942.9	73131.2	17442.7	18916.2	15922.5	21859.9

Table 17 NPV, BCR, IRR and Present Value of Cost per acre of Alternatives with the Economic Cost Benefit Analysis

	NPVs of alternatives					BCR at 12% DR	IRR	Present Value of cost at 12% DR		NPV with an incremental project b (^{'000} Rs.)
	at 5% DR	at 12% DR	at 20% DR	Total a	per addi- tional acre (Rs.)					
	(^{'000} Rs.)	(^{'000} Rs.)	(^{'000} Rs.)	(^{'000} Rs.)	(Rs.)					
1. Canal lining ...	65601	3317	-16763	1.05	12.8	62943	40845	13505		
2. Pipelines ...	90000	6998	-20119	1.10	13.4	73131	38349	6998		
3. Cleaning and maintenance of field channels ...	16435	2726	- 1274	1.16	16.2	17443	40659	58415		
4. Compaction of soil in beds and banks of field channels ...	15622	2158	- 1678	1.11	15.2	18916	40077	56373		
5. Project manager for integrated rural development ...	8483	-1040	- 3278	0.94	10.5	15923	46557	56169		
6. Combined programme (3 x 5) ...	65175	23049	8870	2.05	730	21860	26789	74320		

Note: a. see table 16; b. (i) investment in an incremental project (10188000 rupees of canal lining)=highest present value of cost (73131000 rupees of pipelines) - present value of cost of relevant alternative (62943000 rupees of canal lining); (ii) the NPV with an incremental project = the NPV of the relevant alternative (3317000 rupees of canal lining) + investment in an incremental project (10188000 rupees of canal lining.)