Reclaiming salt-affected land through drainage in Haryana, India: a financial analysis

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Abstract

The sustainability of irrigated agriculture in India is threatened by waterlogging, soil salinity, and alkalinity. To reverse declining agricultural productivity, a combination of surface and subsurface drainage, supplemented by improved irrigation management, has been identified as the most appropriate strategy. But subsurface drainage for salinity control is costly. Therefore, its benefits in terms of sustained agricultural production must be thoroughly investigated to establish its techno-economic feasibility. The present study attempts to do this by analysing the cost of installing subsurface drainage, the direct on-farm benefits of subsurface drainage, and the financial feasibility of subsurface drainage.

The site of the study selected for this study is Haryana State. The results show that, after the installation of drainage, land use intensified because a sizeable area of formerly fallow land was brought under cultivation. They also show that the cropping pattern changed in favour of more remunerative crops and that crop yields increased. These immediate gains from drainage are helping to increase land productivity, gainful employment of the farmers and, hence, farm income. The financial and economic feasibility of drainage in waterlogged and saline areas looks favourable, provided that sufficient water is available for leaching and irrigation, and that a sustainable solution for the disposal of the low-quality drainage effluent is found. With regard to the latter, creating ponds to temporarily store drainage effluent is technically possible, while not threatening the financial feasibility of the investments in drainage. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Water logging; Soil salinity; Cropping intensities; Subsurface drainage; Drainage costs; Drainage benefits; Drainage feasibility

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1. Introduction

The twin problems of waterlogging and soil salinity are widespread in the irrigated lands of developing countries. Brundtland and Khalid (1987) reported that the available estimates show an annual global loss of 1.5 million ha of irrigated land to salinity and waterlogging. In parts of India, especially in the States of Haryana and Punjab, the sustainability of irrigated agriculture is being threatened by the emergence of waterlogging and salinity. These states are situated in the middle of the flat, topographically featureless, Trans-Gangetic alluvial plain, which stretches from Bangladesh to Pakistan. Half of India’s extensive irrigated land is located in this plain; drainage systems to control groundwater tables are virtually absent. Rainfall is low and irregular, while average temperatures are high. This set of factors is favourable for the development of water logging and salinity problems.

Unfortunately, data on the occurrence and spread of these problems are varied and sketchy. More recent estimates range from 5.5 million to 13 million ha (Datta and Joshi, 1992). Only a nation-wide survey, based on a set of clearly defined criteria, can reveal the current extent of the damage. To get an idea of the scope of the problem, one must realise that in India in 1993–94, 50 million ha of land were being irrigated, of which a good 30% was being irrigated twice a year. About 35% of the irrigated area was under canal command (Statistical Outline of India 1995–96). It is in these areas especially that waterlogging and soil salinity occur.

The origin of the problems is a distortion of the natural equilibrium between groundwater recharge and groundwater discharge, stemming from irrigation seepage and percolation losses. Main factors are the occurrence of large stretches of unlined canals and watercourses, inadequacies in water distribution and, most importantly, the absence of an adequate surface drainage network. Contributing factors are the poor quality of the groundwater, and imperfect on-farm development. To reverse the declining trend in agricultural productivity in (salt-)affected areas, a combination of surface and subsurface drainage, supplemented by improved irrigation management, has to be adopted. Through drainage, crops are protected from excessive soil-water conditions and salinity in the top soil is controlled. An additional advantage is that fields become better accessible. The effect of drainage is much stronger in rabi (mid-October–mid-April) than in kharif (mid-June–mid-October). The difference is caused either by a lack of irrigation water, or by occasional flooding from the monsoon rains, or by both (Datta and de Jong, 1991a).

Providing field drainage to control salinity is a costly proposition. The benefits, in terms of sustained agricultural production, must be carefully considered to establish whether a drainage system will be economically feasible. Currently, not enough information is available on the costs and the possible benefits of agricultural land drainage to control waterlogging and salinity. The present study attempts to determine the benefits of subsurface drainage in various small-scale systems for which there are data on the costs and on the benefits as well. It considers the cost of installing subsurface drainage systems, the direct on-farm benefits of subsurface drainage, and the financial feasibility of subsurface drainage.
2. The project sites

The study was conducted in seven small-scale drainage projects in Haryana State. Fig. 1 shows their names and locations. Data were collected over the period 1984–90 and in the case of the Ismila village till 1994. Areas drained per project ranged from 10 to 110 ha, with an average drained area of 44 ha. With the exception of Sampla and Mundlana, were community land was drained, and the HLRDC Seed Farm, the projects areas were owned by farmers. The number of co-operating farmers ranged from 12 to 28. In Ujhana, the
majority of the (small) farmers owned more than 4 ha of land. In the other villages, the size of an average holding was 3 ha.

One reason to choose Haryana State to undertake the study was the enormous area (about 0.4 million ha) that is seriously affected by water logging and salinity. Estimates are that 2 million ha may ultimately be affected (UNDP/FAO, 1985). The affected areas are confined to the Southeast region (Rohtak, Sonipat, and Gohana districts) and, to a lesser extent, to the central region (around the cities of Hisar and Hansi).

The quantitative data available from these projects differ considerably. Only data from the Ismila Project (farmers’ fields) could be used the financial feasibility of subsurface drainage. Earlier, research data from the neighbouring Sampla Farm (experimental fields) were used for the same purpose (Joshi et al., 1987). These data can not be extrapolated to a larger scale, however, because they describe (semi-)controlled working conditions and because crops were supplied with ‘unlimited’ quantities of irrigation water.

3. Drainage installation and land reclamation costs

To draw conclusions on the financial feasibility of agricultural land drainage in Haryana State, all costs involved in reclaiming unproductive, salt-affected land need to be related to the increases in production which are possible after the installation of drainage. In other words, the land reclamation costs needs to be compared to the value of increased production.

Land reclamation costs are broken down into the following cost components:

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage installation costs</td>
<td>Earthworks, drainpipes, envelope material, labour costs</td>
</tr>
<tr>
<td>Connection costs</td>
<td>Sump construction, pump, connecting drain, pump house</td>
</tr>
<tr>
<td>Land development costs</td>
<td>Levelling, bunding</td>
</tr>
<tr>
<td>Other costs</td>
<td>Overhead costs</td>
</tr>
<tr>
<td>Annual operation and maintenance costs</td>
<td>Pump operation, system maintenance</td>
</tr>
</tbody>
</table>

These costs were monitored in case of each of the projects. Some of the costs involved show a decrease over the years. This can be understood, if it is realised that the drainage systems were installed without previous experience to benefit from. Over time, efficiency gains could be realised through the use of more suitable materials and a more efficient organisation of work and labour. The efficiency gains are taken into account when the costs of reclaiming unproductive land are compared to the benefits.

In the following sections, each of the cost components is explained in more detail. All costs are presented in 1994–95 constant prices. The section is concluded with a discussion on the total costs per cost component and the relative weight of each of the cost components.

3.1. Drainage system installation costs

Drainage system hardware consists of earth works, drain pipes (collectors and laterals), and envelope materials. To this must be added sumps, pumps, and a connection drain (see
Section 3.2). Drainage system installation costs consist of the costs of the hardware and the labour costs to put the system in place.

3.1.1. Drain spacing and depth

Earthwork costs vary with soil type, and are directly related to drain spacing and width and depth of excavation. They may also vary with the labour cost in specific locations. As the latter are never very large, they are neglected in the analyses.

Optimum drain spacing and depth of laterals and drain pipes are critical, from the perspective of both performance and costs. The optimum drain spacing in a certain group of soil types is related to drain depth. Analysis were made on the Sampla project to compare different drain depth and drain spacing relations under irrigation conditions. The results showed that a drain depth of 1.75 m controls waterlogging and salinity more efficiently when it is combined with a drain spacing of 75 m than when it is combined with drain spacing of 25 and 50 m (Joshi et al., 1987).

Later research (Singh and Kumbhare, 1990) showed that a drain depth of 1.40 m could be combined efficiently with a spacing of 67 m. Thus, taking the standard dimensions of the parcels in the study area into account, drainage system designers set the drain spacing for the other pilot projects at 67 m, whereas the drain depth has been set at 1.50 m.

3.1.2. Pipes

One only expects that the material cost of drain pipes varies with the materials used. The variation appears not to be very pronounced for standard materials for drain pipes. Depending on the material used, labour costs appeared to vary considerably, however, as certain materials are more easily applied than others. On the Sampla project reinforced drain collectors were combined with concrete laterals. In the other projects, rigid PVC collectors and corrugated PVC laterals were applied. The costs of pipes remained at about Rs. 12,000 per ha. The costs of labour required to apply the different materials decreased from approximately Rs. 6000 to approximately Rs. 4500. PVC is a much easier material to handle; this advantage translates directly into lower labour costs. The exception is the Mundlana project. In this project, the cost of the pipe material was relatively high, at Rs. 13,000 per ha, although also here concrete was substituted with PVC. The problem was the rigid PVC collector that was applied, which was relatively oversized and heavy. Also, the PVC laterals were not perforated. These laterals had to be perforated (400 holes per m!) at the project site. These conditions caused an increase in labour costs. Drainage pipes are placed in trenches, which are dug by hand. In the beginning, the trenches that were dug were relatively wide, and wider than strictly necessary. In later projects, the width of the trenches was gradually reduced. This led to a reduction of labour costs again.

3.1.3. Envelope material

The cost of the envelope material varied widely from one project to another. The critical factors are type of material used and volume. Both relate to costs of transportation. In Sampla and Mundlana, gravel was used. In Ujhana, gravel was also used, but not as much. This reduced the costs from Rs. 3400 to Rs. 2625 per ha. In Ismila, imported polypropylene band was used, costing Rs. 4750 per ha. In the other projects, locally produced nylon netting was used, costing Rs. 1655–1940 per ha. Clearly, local
manufacturing of synthetic envelope materials has helped to reduce costs. The additional advantage of using locally produced material is of course the generation of employment. The performance of the envelope materials was tested in the laboratory as well as in practice, and all materials were found to perform satisfactory. None of the seven pilot projects has reported serious clogging problems, nor has flushing been necessary.

These data provide us with insight in the cost per ha for drainage system hardware. They also illustrate the fact that over time more efficient approaches are developed and cost reductions are possible. For more information on the performance and costs of drain pipes made of various materials, see Kumbhare and Rao (1986).

3.2. Connection costs

In addition to the costs involved in putting a field drainage system into the ground, costs must be made to connect the system to a main drain. These consist of the costs of a sump to collect drain water, a pump to move the water from the sump into a drain, a connecting drain between the sump and the main drain, and a pump house to protect the pump. For a unit of 40 ha, the pump costs Rs. 800, the pump house costs Rs. 500, and the sump costs Rs. 700 per ha. The cost for the connecting surface drain was between Rs. 1200 and 1300 per ha. This adds up to Rs. 3250 per ha.

3.3. Land development costs

The cost of land development varies widely from project to project, and it is mainly responsible for the large variation in total costs between the projects. The critical factor is whether an area was completely abandoned, or whether it was still being used. Areas that had been completely abandoned required land levelling before and bunding after the drainage systems were installed. Average land development costs are calculated at Rs. 3024 per ha, with a range from Rs. 590 to Rs. 5890.

3.4. Operation and maintenance costs

When a project is operated, operation and maintenance costs are incurred. The operation costs are mainly from operating the pump. Average pumping costs of five small-scale projects over a number of years were calculated at Rs. 800 per ha (range: Rs. 650–1000). The pumps run almost exclusively during the monsoon season, from June to September, with a peak in July and August. This pumping regime enabled accelerated leaching. The costs of maintenance of the drainage system itself and of the sump and pump are low. Until now they have been negligible. As was said earlier, once the systems are in place, they appear not to develop clogging problems, nor did pipes or laterals need to be flushed. To be on the safe side, system maintenance costs were set at Rs. 150 per ha. So total annual operation and maintenance costs were assessed at some Rs. 950 per ha.

3.5. Overhead costs

The overhead costs are set at Rs. 2500 per ha.
3.6. Total costs

The total drainage installation and land reclamation costs were calculated for each of the projects. If land development costs are included in the analysis, they varied with a factor 3 from one project to the other. The average total cost was Rs. 29,120 per ha. The difference is largely explained by the difference in land development costs and material choice.

The average drainage installation and land reclamation costs per ha are calculated in Table 1. Both the absolute and relative contribution per cost component to the total costs are shown.

The installation costs appear to constitute the biggest cost component. Almost 70% of the total costs are spent on pipes, envelope material and the labour required to put the systems into place. Pipes are the single biggest cost factor and make up over 40% of the total investment costs. Other capital investment costs are the connecting costs (sump, pump and connecting drain). The variation in total costs is largely explained by efficiency gains that could be realised over time, when alternative, cheaper materials were selected and labour was organised more efficiently. The other factor explaining for the variation in costs is land development. These can be as high as 20% of the total costs, if abandoned land needs to be levelled and new bunds need to be erected. They are much lower if the land is still in use. This would be a reason to tackle salinity problems immediately when they occur, and not to wait until the land has been abandoned. Without the land development costs, the total costs would range from Rs. 23,800 to Rs. 28,100 per ha.

### Table 1

Drainage installation and land reclamation costs, per cost component, per hectare, in 1994–95 constant prices—seven pilot projects in Haryana

<table>
<thead>
<tr>
<th>Cost component</th>
<th>Average costs (Rs.)</th>
<th>Relative costs (Rs.)</th>
<th>Range (Rs.)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage installation costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipes</td>
<td>12,200</td>
<td>41.9</td>
<td>12,010–12,930</td>
<td></td>
</tr>
<tr>
<td>Envelop material</td>
<td>2,870</td>
<td>9.9</td>
<td>1,660–4,750</td>
<td>depending on the material applied</td>
</tr>
<tr>
<td>Labour</td>
<td>4,930</td>
<td>16.9</td>
<td>4,400–5,980</td>
<td></td>
</tr>
<tr>
<td>Connecting costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sump</td>
<td>700</td>
<td>2.4</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td>800</td>
<td>2.7</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Pump house</td>
<td>500</td>
<td>1.7</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Connecting drain</td>
<td>1,250</td>
<td>4.3</td>
<td>1,250</td>
<td></td>
</tr>
<tr>
<td>Land development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levelling and bunding</td>
<td>3,370</td>
<td>11.6</td>
<td>1,250–5,890</td>
<td></td>
</tr>
<tr>
<td>Other costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhead</td>
<td>2,500</td>
<td>8.6</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>Total investment costs</td>
<td>29,120</td>
<td>100.0</td>
<td>25,820–33,870</td>
<td></td>
</tr>
<tr>
<td>Annual operation &amp; maintenance</td>
<td>950</td>
<td>–</td>
<td>800–1,150</td>
<td></td>
</tr>
</tbody>
</table>
If in the future more and larger drainage systems are developed, the costs per ha can decrease substantially. Over the 4 years that the project sites were developed, efficiency gains in the order of Rs. 3500 per ha and more could be realised already. For example, the Ismilha project, which has cost some Rs. 29,000 (including land development, pump, pump house, sump, connecting surface drain, and overhead costs), could now be constructed for around Rs. 24,000. The overhead costs can be expected to decrease to 50% of their present level because added experience allows for more efficient working methods. Development costs can be reduced further when economy of scale advantages can be gained. Today, pipes are manufactured in a factory that operates at below optimal capacity. Also, wrapping envelope material around pipes is now taking place in the field; it could be done in the pipe factory at lower cost. It is calculated that the costs of pipes with envelop material wrapped around the pipes at the factory can be Rs. 12,000 per ha. Moreover, there is room for an increase in labour efficiency of the order of 10–20%. All in all, the total costs of future subsurface drainage systems could be reduced to Rs. 20,000 per ha (excluding land development).

4. Drainage benefits

The installation of a subsurface drainage system enables the control of the watertable level and the desalinisation of the soils by leaching, either with irrigation water or with the monsoon rains. Operational research on Sampla project showed that salinity in the surface layer decreased rapidly after drainage, from about 50 dS m\(^{-1}\) in 1984 to about 5 dS m\(^{-1}\) in 1991 (Rao et al., 1991).

In all small-scale pilot projects in Haryana State, most of which are run by the farmers, the short-term effects of subsurface drainage were a considerable increase in cropping intensity, a shift in the cropping pattern towards more remunerative crops, a remarkable increase in crop yields, and an increase in the productivity of fertilisers. The combined result of these changes was a substantial increase in farm incomes. Of course, the results of these pilot areas must be interpreted carefully; the number of sample farms was rather small because the study areas were fairly small, and, apart from those on Ismilha, the data were collected during a relatively short period.

Rainfall in these areas is relatively low and erratic, and supplementary irrigation is applied in a bid to satisfy crop-water demand. As irrigation water is scarce and is less available during years of low rainfall, the total amount of water supplied to the crops varies considerably from year to year and from one crop season to another. Observations showed that there is a strong correlation between gross farm income (crop production) and annual rainfall (irrespective of its distribution). This does not hold true for individual crops, however. To compare crop yields with and without drainage in Ujhana and Bhanabrahamana, we used time series of crop-yield data and rainfall data from Sub-Divisions of the Districts where the projects are, to assess whether the increases in crop yields were due to drainage or to the weather. For Ismilha, a proper with and without comparison is possible, because 28 farms in this project were monitored extensively over 8 years, starting just before the installation of a subsurface drainage system in 28 of the 98 ha that
were jointly cultivated, and continuing for 7 years after drainage. The 70 ha that did not need drainage served as the control area.

4.1. Cropping intensities

The farmers in the project areas reported that, before the installation of drainage, the land lay fallow during kharif season and land use was confined to some areas during rabi season. In general, no crops are grown during the summer season (mid-April–mid-June). The main reason why the land lay fallow during kharif was the excessively high watertable, which led to waterlogging and secondary salinisation. Soil salinity also prevented the farmers from achieving any sustained crop production during rabi. Annual cropping intensities in the various areas ranged from 0 to 40%.

Table 2 shows the decline in area of land left fallow after the installation of drainage systems in the project areas. After drainage was installed, the situation improved significantly and gradually less land was left fallow. In Bhana-Brahamana, the amount of fallow land during kharif declined from 77% in 1988–89 to 34% in 1989–90, the first year drainage installation. In Ujhana, where relatively large farms prevail, kharif fallow remained very high in the first 2 years after drainage installation, but in Mundlana (village community land) it declined from about 100% to only 3% in a few years. In Ismila, the amount of fallow land during kharif in 1986–87 was almost 100%. That amount declined to 68% in 1987–88, after drainage was installed. It declined further to 43% during 1990–91 and to a low 38% in 1993–94.

Land fallow in rabi decreased drastically after drainage: in Ismila a shift from around 40%–100% cropping intensities were observed, and in Bhana-Brahamana cropping intensities changed from less than 40% to almost 60% a few years after the installation of a drainage system. In the larger farms of the Ujhana project, the cropping intensity remained at a level of around 85%. In the village community land of Mundlana, the cropping intensity increased from 0% to almost 100%. The above-mentioned changes in the cropping intensities in rabi took place between the year before and the year after the installation of a subsurface drainage system.

It should be observed that the increase in annual cropping intensity was hampered by a number of (very) dry years, namely 1986–87 (238 mm), 1987–88 (202 mm), and 1989–

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ujhana</td>
<td>98 14</td>
<td>97 19</td>
</tr>
<tr>
<td>Bhana-Brahamana</td>
<td>100 62</td>
<td>77 54</td>
</tr>
<tr>
<td>Ismila</td>
<td>68 59</td>
<td>78 0</td>
</tr>
</tbody>
</table>

* In Mundlana, the rabi fallow declined from 100 to 3% (see Section 4.1).
In contrast, the year 1990–91 had 575 mm, and the year 1993–94 had 939 mm. The conspicuous shift in land use illustrates the immediate gain from drainage.

4.2. Cropping patterns

Before and shortly after the installation of drainage, the cropping pattern during rabi included wheat and barley for the most part. Improved conditions on the fields allowed farmers to gradually replace barley by wheat, which is a more remunerative crop. Table 3 shows the details.

The relative importance of other crops remained stable, with the exception of mustard, which generally became more prominent in the rabi cropping pattern also. Other crops include sugar cane, peas, methi (a pulse) and berseem (Egyptian clover; a fodder).

In non-affected Ismila, wheat was relatively stable throughout the years, at 57–67%. Barley was the second important crop, with a contribution of 15–20%.

A significant change in the kharif cropping pattern of Ismila was observed. Jowar (sorghum) was always present on about 15% of the fields. In 1993 suddenly 42% of the area was planted with jowar. It is difficult to explain this increase by relating it to improved water and salt management, even more so because the drainage system in this project was already 5 years in place. The increased importance of jowar is more likely explained by pointing at the increased availability of fresh water.

4.3. Crop yields

Besides an increase in cropping intensity and a shift in the cropping pattern towards more remunerative crops, the installation of subsurface drainage also resulted in a general increase in crop yields. Unfortunately, data from before the installation of the drainage systems in Ujhana and Bhana-Brahamana are not available; data from the years in which the drainage system kept water tables low and gradually leached out salts are available, however. From Ismila 8-year data series on yields are available, both from drained fields and from non-affected fields. In interpreting these data, the yearly variation in crop yields due to the weather has been duly taken into account.
The following are the main observations regarding yields:

- More than 200% increase in wheat yields was measured in drained fields in Ismila in the period 1986–87 till 1992–93 (the drainage system was installed in 1986–87); the corresponding figure for non-affected (no water logging or salinity problems) fields is negligible;
- After 8 years, the wheat yields in drained fields in Ismila are still 15–20% lower than in non-affected fields;
- The two other areas, Ujhana and Bhana-Brahamana, showed an increase in wheat yields of 30–40% in the first 4 years after drainage installation;
- In the drained fields, barley became gradually less important, and sample farmers stopped growing it altogether;
- Barley yields in the non-affected fields in Ismila remained stable;
- Mustard yields in drained fields in Ismila increased by 50%; they remained the same in non-affected fields;
- Mustard yields also increased in Bhana-Brahamana, with 30% nominally in the first year, despite the fact that the desalinisation process had not yet been completed and that the rainfall was dramatically lower than the year before;

Clearly the increase in yield of the all-important crop of wheat after drainage system installation is substantial. Also mustard yields improved after drainage. Mustard is also a cash crop for the farmers.

With respect to assessing yield increases over time, two additional factors must be taken into account. Firstly, one should realise that desalinisation of the affected land takes time, so that the increase in the yield due to drainage in the first year will generally be modest. Thereafter, the yield grows faster, to approach the level of adjacent non-affected land in 3–4 years after drainage. Secondly, the yearly variation in crop yields due to weather should be weighted when analysing yield data. District data were analysed to establish the optimal rainfall for crop production. This was calculated at 700–900 mm. Here, 200 mm led to a reduction of 45% in the yield, and at the other extreme, 1200 mm to a reduction with 20%, etc. If the rainfall factor is weighted in the analyses, the increase in wheat in Ujhana and Bhana-Brahamana appeared not to be 25%, but 40%. Barley is less sensitive in the analyses, because the crop is more salt resistant. Other crops would respond in the same way.

The observed lower yields for wheat in comparison to adjacent fields that were not affected by salinisation may be due to the fact that physicochemical soil properties other than salinity need more time to improve after land reclamation. Also farmers continue to give priority to activities in their better, non-affected land even after their salt-affected land has been reclaimed. Only after they have finished the work on the better land will they start to work on the recently drained plots.

**4.4. Relation between fertiliser, salinity and yields**

In the absence of drainage problems, the productivity of land is related mainly to the application of irrigation water and fertilisers and to proper agricultural practises. The productivity of poorly-drained saline land, however, is related mainly to the degree of
salinisation (Maass and Hoffmann, 1977). To establish the relationship between wheat yield and soil salinity, data on crop yield, fertiliser input (chemical and animal), and soil salinity were collected in the Ismila area during the 1988–89 cropping season. In total, 27 crop cuttings and as many soil samples were taken from different plots. Data on fertiliser application in these plots were also collected. With these data, two regression analyses were done, with crop yield being the dependent factor in both. The independent factor was soil salinity in the first and fertiliser application in the second. The results indicated that about 54% of the variation in yield was due to soil salinity, and that 28% was due to fertiliser application. Subsequently, a multiple regression analysis was done to find the combined effect of both factors. The results indicated that 59% of the variation in wheat yield can be explained by these two variables. In all three analyses, the coefficient of the determinant was statistically significant (1% probability level).

4.5. Financial feasibility

The data on benefits and costs in the Ismila project were used to calculate the financial feasibility of subsurface drainage. For this purpose, the (economic) lifetime of the drainage system was set at 30 years, as usual.

4.5.1. IRR levels

To assess the potential for improving the financial performance of future drainage projects, estimates for ‘present’ and ‘future’ cost levels and actual (historical) costs were used. The costs of the various project components are shown in Table 4. The parameters describing the Ismila project were taken as point of departure.

The result of a cost-benefit analysis of the Ismila project, whereby the actual (historical) project costs were combined with the partly measured and partly projected project benefits was an internal rate of return (IRR) of 8%. Evaluation of the effect of the alternative, more plausible, scenario for the project benefits produced an internal rate of return of 9%. The above cost-benefit analyses were repeated for ‘present’ and ‘future’ investment levels. The resulting IRR’s for the two alternative investment levels, each

Table 4
Actual, present, and future investment costs of an Ismila-type subsurface drainage project, in Rs. per hectare, in 1994–95 constant prices

<table>
<thead>
<tr>
<th>Cost components</th>
<th>Actual costs</th>
<th>Present costs</th>
<th>Future costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage system</td>
<td>22250</td>
<td>18500</td>
<td>15500</td>
</tr>
<tr>
<td>Land development</td>
<td>1250</td>
<td>1250</td>
<td>1250</td>
</tr>
<tr>
<td>Pump, pump house, and sump</td>
<td>2000</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Connecting drain</td>
<td>1250</td>
<td>1250</td>
<td>1250</td>
</tr>
<tr>
<td>Overhead cost</td>
<td>2500</td>
<td>1250</td>
<td>1250</td>
</tr>
<tr>
<td>Total</td>
<td>29250</td>
<td>24250</td>
<td>21250</td>
</tr>
</tbody>
</table>
combined with the two alternative scenarios for the expected project benefits, are almost 10 and 10.5%, and 10.5 and 11.5%, respectively.

4.5.2. IRR methodology

In calculating the financial feasibility the following applied:

The assumption is that the pump has to be replaced every tenth year, at a cost of Rs. 800 per ha; the operation and maintenance costs were set at Rs. 950 per ha: Rs. 800 for operating the system and Rs. 150 for maintaining it;
Project benefits were calculated by subtracting the annual net production value per hectare of (salt-)affected land without drainage (NPV-affected) from the annual net production value per hectare of the formerly affected land with drainage (NPV-drained). Thus, NPV-drained minus NPV-affected equals benefit;
The net per-ha income of the farmers was assessed by supplementing the net production values with the value of the costs of family labour; these are in the order of Rs. 3300 per ha on affected land, and Rs. 3500 per ha on non-affected land;
Average NPV-drained, which was obtained in the first 7 years after drainage, was calculated from the data collected in a series of 14 (two in a year) consecutive farm surveys amongst the same group of farmers;
NPV-affected (the continuation of the situation without drainage over the same period) was derived from the collected data on the non-affected, non-drained land of the same group of farmers; this was possible because it had been observed that before drainage 25–30% of the affected land was still under cultivation, producing about the same yields as the non-affected land albeit at a higher (20%) cost;
For Year 8, NPV-drained and NPV-affected were calculated by taking the average of the four preceding years; It was safe to do this because the yield levels in Years 4 through 7 stabilised after the desalinisation of the formerly salt-affected land was completed, and rainfall in this period was not so far from the average that it could have had a marked influence on crop yields;
From Year 8 up to and including the Year 20 after project implementation, the average net production value per hectare with drainage is supposed to grow by 2% a year; this is equal to the average growth rate of the major agricultural crops in Haryana for the last 15 years (the 2% growth rate is the average for all affected and non-affected land in Haryana);
As drained land falls in the category of non-affected land, an alternative calculation was made based on a growth rate of 3% a year;
For both alternatives, the (highly conservative) assumption was that the per-ha net production value from Year 21 through Year 30 will remain constant;
The average NPV-affected is supposed to decrease at a rate of 1% a year over the whole project lifetime; this assumption is also conservative (the average decrease in yields of the major agricultural crops grown in Rohtak district is about 1% a year);
In real problem areas, the annual decrease will be greater — some 2% a year; therefore, apart from the conservative scenario that combines a growth of 2% a year in the drained area and a decrease of 1% a year in the affected, non-drained area, we also evaluated an alternative scenario that assumed a 3% growth rate a year in the drained area and a 2% decrease a year in the affected, non-drained area.
4.5.3. Costs involved in disposing of drain effluent and the IRR

Thus far, costs involved in disposing of low-quality drainage water was not included in the analyses. As the Yamuna river is the only outlet available for excess rainwater and saline drainage effluent, the disposal of the drainage effluent is a major constraint to reclaiming waterlogged saline soils in Haryana. Strict standards have been set to ensure the quality of the river water, which is meant for domestic and industrial use in downstream urban areas (e.g. in Delhi). Accordingly, ways to dispose of drainage water safely or to use it in the project areas must be found.

Farm ponds for storing and evaporating drainage water are one alternative. Research in two regions of Haryana showed that 5% of the drained area, excavated to a depth of 1 m, will meet the capacity requirement for the storage and subsequent disposal of the post-monsoon drainage effluent. The IRR will drop by 1.5% if the costs of constructing farm ponds for temporary storage of drainage effluent in 5% of the farm area are taken into account. Still, results are quite encouraging and even more so if we take into account that the average net production value per hectare in the problem area before drainage was a quarter of that obtained in the non-affected area. In reclaiming abandoned areas, one can expect considerably higher IRR’s. In draining areas where the problems of waterlogging and soil salinity are in the first stages, however, one must expect lower economic results.

Other research indicated that drainage water can be applied safely for irrigation after it has been mixed in a 1:2 ratio with fresh irrigation water (Sharma et al., 1992). In Egypt, decades of experience have been gained with mixing low-quality drain water with fresh irrigation water. This practice can also contribute to reduce the amount of drainage effluent.

5. Discussion

The above assessment of the financial feasibility of the Ismila project, and the results of the other small-scale projects, call for some discussion on the project costs and the observed and expected benefits. Before beginning such a discussion, however, one must note that the databases on costs and benefits are much stronger in this case than they are usually. The investment costs, and the project benefits over the first 7 years after drainage have been measured, and the projected costs and benefits for the remaining part of the economic lifetime of the project have been assessed in a very conservative way.

A number of factors will cause the costs of drainage system to be installed in the future to be less than they were observed to be at the project sites. In addition there are other considerations.

Increasing the scale of operations will lower the costs of drainage installation and will result in lower IRR’s.

For small-scale projects manual labour is especially suitable. Manual labour has a number of distinct advantages: only the plots that really need it will be provided with a subsurface drainage system, one can involve the beneficiaries much more easily in project construction and operation, and a substantial part of the installation costs is in the form of wages for the manual labourers. But, in places, the extent and the urgency of the problem
call for mechanisation. Whether mechanisation is feasible depends on many factors, and it has still to be investigated.

As was concluded earlier, using local factories to manufacture PVC pipes and synthetic drain envelope materials will definitely lower the costs.

The construction of farm ponds will have financial consequences, and it will take land away from agriculture. Therefore, the amount of drainage effluent should be kept as low as possible by trying to improve irrigation efficiency, and by irrigating with a mixture of fresh water and drainage water.

Project benefits depend on the pre-drainage level of production in the prospective project areas, on the effective control of the watertable, and on the pace of desalinisation. These are the prerequisites for a rapid increase in agricultural production in the reclaimed areas. Results from various pilot projects have shown that desalinisation is a matter of only a few seasons. IRR’s are highest for land that is completely non-productive. On the other hand, costs are also higher, as land development is more demanding. Whether abandoned land or affected, but still productive, land is to be reclaimed first must depend on the outcome of local decision making processes.

Wheat yield levels in the drained area of Ismila are still lower than in the non-affected area (10–20%). This might be because the farmers give priority to cultivating their non-affected land. They work their recently drained land only after they have finished with their non-affected land. In areas with higher production potentials, and in areas where higher levels of production technology are applied (and, consequently, where incomes are higher), one can expect better economic results from reclaiming waterlogged and saline land than in Ismila. An increase in the gross production value of 10–15% would boost the IRR by 2%. In reclaiming such barren areas as Sampla, Mundlana, and Kole Khan, one can expect to obtain better results than in reclaiming areas that are still partly cultivated. The IRR could reach levels of over 20%. Nevertheless, if an area is affected by soil salinity, the relatively lower lying parts will be affected most, and they will eventually be abandoned if yield levels fall too much. In the relatively higher-lying parts, which are much less affected or not at all, crop production can continue, especially if sufficient irrigation water is available for leaching. In general, under such conditions some 25–35% of an area affected by waterlogging and soil salinity could remain in production. Ismila is a very representative project in this respect.

The present IRR for Ismila is encouraging, but it can be improved considerably for similar projects if the various cost-lowering measures are implemented. A full economic analysis of Ismila and similar projects will probably show higher IRR’s than the financial analysis shows. In most regions, the project costs will decrease if the labour for installation, operation, and maintenance of the systems is valued at its opportunity cost. On the other hand, subtracting the substantial farmers’ subsidies, especially those on fertilisers and canal irrigation water, will increase the costs. Even so the benefits may still increase because some crops grown in the area are valued below world market price levels, and consequently they are taxed (Gulati and Sharma, 1991). In the long run, the gap between the results of the financial and economic evaluations will narrow because of the current economic policy of the Government of India. In future, the main factors determining the difference between the two might be the difference between the real (economic) price and the market price of labour, and the subsidy on irrigation water.
6. Concluding remarks

The results for Ujhana and Bhana-Brahamana show clear tendencies, and in spite of its small scale, the Ismila case constitutes hard evidence of the financial feasibility of small-scale, manually-installed subsurface drainage projects for reclaiming salt-affected areas. The expectation is that even stronger evidence will be provided by a study, now in progress, of 250 sample farms. The study area covers some 5000 ha, with greatly varying levels of waterlogging and salinity. Research has been going on for several years. The results will become available in the course of 2000.

A thorough investigation is needed of whether or not drainage as a preventive measure is economically feasible. While conducting such an investigation, one should realise that the basic mistake made by the irrigation planners and the politicians is to design and construct irrigation projects without providing facilities for draining the surplus water. Sooner or later, this will inevitably result in waterlogging and salinisation of the soil, especially if the groundwater is of poor quality. The proper time for installing a subsurface drainage system depends on how rapidly the watertable rises after the start of irrigation. Watertable measurements are being taken throughout Haryana State, and research on the effect of high groundwater levels and secondary salinisation on crop production is being done on experimental fields and in a 5000 ha pilot project at Gohana, in the Rohtak District (Datta and de Jong, 1991b).

Constructing irrigation projects without proper drainage systems means constructing non-sustainable projects. In the ex ante evaluation, this results in IRR's that are too high for the non-sustainable irrigation systems only and too low for the drainage component, if this becomes necessary after a grace period. This, in turn, leads to a lack of funding for drainage, as drainage is not considered economically feasible. It is high time that the planners and policy makers take another look at land drainage and reconsider their views, which are based on information that is incomplete and therefore misleading.

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