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Economic Analysis of Sub-Surface Drainage under Indira Gandhi Nahar Priyojna Command Area — A Case Study

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Abstract

This paper has attempted to ascertain whether the sub-surface drainage (SSD) in waterlogged and saline lands of Indira Gandhi Nahar Priyojna Command area is a cost-effective technique. The study has shown that waterlogging adversely affects crop yields. The cost on SSD installation in the command area comes out to be Rs 23767 per hectare. The returns on crop yields before and after the drainage system have been compared. Land utilization has been intensified after the installation of drainage, as a sizeable area of formerly fallow land has been brought under cultivation. The B-C ratio and the NPV have been found as 2.44 and Rs 34275/ha, respectively. The IRR has been found to be 25.88 per cent. These indicators have well established the financial feasibility of the project in the IGNP area.

Introduction

Of all the methods introduced in agriculture, irrigation is the most pronounced factor in increasing agricultural productivity. But, along with its several advantages, irrigation brings hazardous effects too. It is also true for the irrigation water of the Indira Gandhi Nahar Pariyojna (IGNP), which wets the arid plains of Rajasthan. The soil fertility and consequently, soil productivity are being affected by the irrigation water of IGNP. The rapid increase in waterlogging and soil salinity problems in the IGNP canal command

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area are drawing the attention of scientists, planners, and development agencies. Because of these twin problems of waterlogging and salinity, the full potential of this costly irrigation project is not being realized. Waterlogging and salinity affect farm productivity, leading to decrease in incomes, and thereby lowering of standards of living. This, in turn, affects the social and economic conditions of the farming community (Shekhawat *et al*., 2001). Sub-surface drainage is believed to be an answer to overcome the problems of waterlogging and salinity, bring back the productive capacity of soils, and restore the social and economic conditions of the farming community.

An Indo-Dutch Network Project was established to address the problems of waterlogging and soil salinity in India. It was a collaborative research project between the Dutch Government and Indian Council of Agricultural Research (ICAR). Research study was undertaken in four network centres, of which the centre in Hanumangarh (Rajasthan) was one. To carry out the research study on drainage, a pilot project was identified in the Lakhuwali village, in the IGNP (1996) command area. Along with other investigations economic studies on the control of waterlogging and salinity were conducted in this pilot area. The results of these studies are presented in this paper.

Objectives

The specific objectives of the study were:

(i) To study the effect of waterlogging on farm incomes,

(ii) To work out the installation cost of sub-surface drainage (SSD) in the pilot area, and

(iii) To study the financial viability of SSD installed in the pilot area of Lakhuwali.

Methodology

To study the effect of waterlogging on farm incomes, the watertable class-wise productivity analysis was carried out for two major crops, viz. cotton in the *kharif* season and wheat in the *rabi* season. Watertable depth was recorded fortnightly from the observation wells installed at a grid spacing of 100 metres. Seasonal average of watertable depth was taken for watertable class-wise productivity analysis. Yield was recorded from crop cutting experiments in two metre radius area near the observation well and that was converted to a hectare. The costs on inputs and labour were recorded from the farmers in a set of schedule by the survey method. From the collected data, the gross production values (GPVs), the gross margins (GMs), and the net production values (NPVs) were calculated plot by plot per hectare. The agro-economic data were processed and tabulated. Subsequently, they were matched with the corresponding data on watertable depth, and the effect of watertable on gross production values (crop yield * price), gross margin, and net production value were analyzed.

Cost on Installation of Sub-surface Drainage

The data regarding cost on installation of SSD were collected from the official records. The material cost included taxes also. The trench-digging work was done in phases by labour or on contract basis. In an area of 15 hectares, the trench-digging work was completed by employing labour and in the remaining 60 hectares, it was completed by a contractor. The cost on trench-digging work was calculated on the basis of the contractor's rate, as the employed labour was difficult to separate from other works.

The total and per hectare cost on drainage system was calculated as per the design of the drainage system. The costs in the pilot area were dependent on specific circumstances, such as shape and size of the plot, and the drain spacings applied. To make useful estimations which were applicable on a wider scale, the structure of costs on installation was analyzed. The installation costs were expressed in the cost of installing lateral drains per metre and the cost of installing collectorpipes per metre. Besides, an estimate was made of the installation costs of one manhole. Based on the cost of installing lateral drains, collector pipes and manholes, the cost of the system per hectare was specified. The assumption in this model was that drainage was applied on a somewhat larger scale.

Given a certain drain spacing, the amount of pipes required can be calculated. In the case of a 100 m spacing, the required amount of drain pipes would be equal to 10000 m^2/100 m = 100 m. The quantity of collectorpipe was estimated in a similar way. Given a maximum distance of 250 metres, collectorpipe spacing would be 500 metres. Given this distance per hectare 10000 m^2/500m= 20 m of collector pipe was needed. Based on this length, the number of manholes per hectare could be calculated.

More formally, the cost per hectare can be described with the following expressions:

$$L_{drainpipes} = 10000 \,/\, \text{drain spacing}$$

$$C_{drainpipes} = L_{drainpipes} \times c_{drainpipe/m}$$

$$L_{collectorpipes} = 10000 \,/\, \text{collectorspacing}$$

$$C_{collectorpipes} = L_{collectorpipes} \times c_{collectorpipe/m}$$

$$C_{manholes} = L_{collectorpipes} \,/\, \text{drainspacing } c_{manhole}$$

$$C_{total} = C_{drainpipes} + C_{collectorpipes} + C_{manholes}$$

where,

$L_{drainpipes}$ and $L_{collectorpipes}$ represent the required length of drainpipes and collectorpipes;

$c_{drainpipe/m}$ and $c_{collectorpipe/m}$ represent the cost of installing drainpipes and collectorpipes, per metre;

$c_{manhole}$ represents the installation cost per manhole;

$C_{drainpipes,}$ $C_{collectorpipes,}$ $C_{manholes}$ represent the per hectare cost for drainpipes, collectorpipes, manholes, and

C_{total} gives the total cost per hectare in laying the system.

Additional costs like costs for sumps, conveyance line and pumping unit were added to this amount to get the total cost per hectare.

Financial Analysis

Three criteria were used to assess the financial feasibility of investment on sub-surface drainage. These were: benefit–cost ratio (B-C ratio), net present value (NPV), and internal rate of return (IRR). The analysis was based on the following assumptions:

(a) The market rate of interest was taken as 10 % per annum.

(b) The life of the drainage system was assumed as 30 years.

(c) Only one year post-drainage yield and net returns data were actually recorded for 15 hectare area. The same returns were used for the life of the project.

(d) Project benefits were calculated by subtracting the net farm income of the pre-drainage situation from the net farm income of the post-drainage situation.

The B-C ratio, the NPV and IRR were computed with the help of Equations (1), (2) and (3), respectively.

The change in the net benefit in year j can be described as (Vrolijk 2001):

$$\Delta B_j = \sum_{i=1}^{k} [(a_{ij} \times y_{ij})p_{ij} - (a_{ij} \times c_{ij})] - \sum_{i=1}^{k} [(a_{i0} \times y_{i0})p_{i0} - (a_{i0} \times c_{i0})] \qquad \ldots(1)$$

where,

a_{ij} = Area of crop i in the year j,

y_{ij} = Yield of crop i in the year j per ha,

c_{ij} = Production cost of crop i in the year j per ha,

p_{ij} = Price of crop i in the year j,

ΔB_j = Change in net benefit in the year j, and

Subscript ‘0’ indicates the base year value pertaining to the year 1999-00.

The overall net present value of investing in this drainage project was calculated from Equation (2):

$$NPV_{project} = -C_{total} + \sum_{j=1}^{J} \frac{(\Delta B_j - c_{mj})}{(1+r)^j} \qquad \ldots(2)$$

where,

$NPV_{project}$ = Net present value of project

C_{total} = Total installation costs

c_{mj} = Maintenance costs in year j, and

r = Discounting rate

The internal rate of return (r) is the discounted rate at which NPV is zero. This was computed as per Equation (3):

$$IRR = -C_{total} + \sum_{j=1}^{J} \frac{(\Delta B_j - c_{mj})}{(1+r)^j} = 0 \qquad \ldots(3)$$

The benefit- cost ratio of an investment being the ratio of the discounted value of all cash inflows to the discounted value of all cash outflows during the life of the project and was computed as per Equation (4) :

$$\sum_{j=1}^{J} \frac{(\Delta B_j - c_{mj})}{(1+r)^j} \qquad \ldots(2)$$

$$BCR = \frac{\sum_{j=1}^{J} \frac{(\Delta B_j - c_{mj})}{(1+r)^j}}{C_{total}} \qquad \ldots(4)$$

Results

A pre-drainage baseline survey on the socio-economic aspects of farmers of Lakhuwali pilot area was conducted in the year 1998 and the data pertained to the year 1997-98. There were 36 households in the pilot area. A majority of them [34] were Muslims. The average household had a size of 8.8 members. Ninety per cent of the boys and 42 per cent of the girls of the age between 6 and 14 years were receiving school education in the pilot area. Thirty-one per cent of the population in the pilot area was literate. The average size of holding was 5.2 ha, out of which 2.3 ha was in the pilot area and 2.9 ha was out side it. All land in the pilot area was waterlogged. The depth of watertable in the pilot area was less than 1.5 m and the area also suffered from soil salinity. Cotton in the *kharif* and wheat in the *rabi* were the main crops grown in the area. Fifty-nine per cent area in *kharif* and 56 per cent area in *rabi* were kept fallow in the pilot area. The annual cropping intensity was 85 per cent. The average yields were very low and consequently, the net returns were also very low in the case of cotton, paddy and wheat crops. There was a net loss in the case of mustard and barley in the pilot area.

Gross and Net Returns in Relation to Watertable Depth

The returns per hectare were calculated for different watertable classes, which were based on the depth of watertable (Table 1, Col.1). The loss caused due to waterlogging was estimated by subtracting the net returns per hectare in each of the higher watertable class from the net returns of watertable class I. The latter class was taken as the reference level. It contained the so-called non-affected land. The results have been presented in Tables 1 to 4 for the two seasons of wheat and cotton. It could be observed from the Tables 1 to 4 that the average decrease in GPV, GM and NPV in wheat in 1997-98 was 79 per cent, 116 per cent and 148 per cent, respectively. It was 62 per cent, 76 per cent and 83 per cent in the year 1998-99 in GPV, GM and NPV, respectively. In the case of cotton, the average decrease in

Table 1. Gross and net production values, gross margins and gross and net income losses in wheat production due to high watertable in the *rabi* season of 1997-98

Watertable class	No. of plots	Average GPV (Rs/ha)	Average GM (Rs/ha)	Average NPV (Rs/ha)	Average decrease in GPV (Rs/ha)	Average decrease in GM (Rs/ha)	Average decrease in NPV (Rs/ha)
I (> 90 cm)	1	12750	7710	4685	-	-	-
II (60-90 cm)	5	5161	1357	-238	7589 (59%)	6353 (82%)	4923 (105%)
III (30-60 cm)	20	1925	-1865	-2766	10825 (85%)	9575 (124%)	7451 (159%)
IV (< 30 cm)	7	1362	-2503	-3194	11388 (89%)	10213 (132%)	7879 (168%)
Over all	33	2624	-1222	-2248	10126 (79%)	8932 (116%)	6933 (148%)

GPV= Gross production value
GM = Gross margins
NPV= Net present value
Figures within the brackets denote percentages

Table 2. Gross and net production values, gross margins and gross and net income losses in cotton production due to high watertable in the *kharif* season of 1998-99

Watertable class	No. of plots	Average GPV (Rs/ha)	Average GM (Rs/ha)	Average NPV (Rs/ha)	Average decrease in GPV (Rs/ha)	Average decrease in GM (Rs/ha)	Average decrease in NPV (Rs/ha)
I (>120 cm)	2	18594	13811	12568	-	-	-
II(90-120 cm)	7	9648	4555	3459	8946 (48%)	9256 (67%)	9109 (72%)
III (60-90 cm)	8	3708	-921	-1961	14886 (80%)	14732 (107%)	14529 (116%)
IV (< 60 cm)	0	-	-	-	-	-	-
Overall	17	7905	3067	1980	10689 (57%)	10744 (78%)	10588 (84%)

Table 3. Gross and net production values, gross margins and gross and net income losses in wheat production due to high watertable in the *rabi* season of 1998-99

Watertable class	No. of plots	Average GPV (Rs/ha)	Average GM (Rs/ha)	Average NPV (Rs/ha)	Average decrease in GPV (Rs/ha)	Average decrease in GM (Rs/ha)	Average decrease in NPV (Rs/ha)
I (> 90 cm)	3	20171	13902	10466	-	-	-
II(60-90 cm)	7	7295	2994	1591	12876 (64%)	10908 (78%)	8875 (85%)
III (30-60 cm)	15	5955	2082	809	14216 (70%)	11820 (85%)	9657 (92%)
IV (< 30 cm)	4	5220	481	-972	14951 (74%)	13421 (96%)	11438 (108%)
Overall	29	7648	3304	1752	12523 (62%)	10598 (76%)	8714 (83%)

GPV, GM and NPV was 57 per cent, 78 per cent and 84 per cent, respectively in the year 1998-99 and it was 57 per cent, 72 per cent and 94 per cent, respectively for the year 1999-2000. The returns decreased with the rise in watertable.

The salient features of the sub-surface drainage system installed in the Lakhuwali village have been presented in Table 5 and the layout has been depicted in Fig.1.

Table 4. Gross and net production values, gross margins and gross and net income losses in cotton production due to high watertable in the *kharif* season of 1999-2000

Watertable class	No. of plots	Average GPV (Rs/ha)	Average GM (Rs/ha)	Average NPV (Rs/ha)	Average decrease in GPV (Rs/ha)	Average decrease in GM (Rs/ha)	Average decrease in NPV (Rs/ha)
I (>120 cm)	4	20610	13078	7179	-	-	-
II(90-120 cm)	4	13455	6894	3181	7155 (35%)	6184 (47%)	3998 (56%)
III (60-90 cm)	11	5554	1215	-1434	15056 (73%)	11863 (91%)	8613 (120%)
IV (< 60 cm)	4	1035	-2320	-4121	19575 (95%)	15398 (118%)	11300 (157%)
Overall	23	8761	3651	399	11849 (57%)	9427 (72%)	6780 (94%)

Table 5. Salient features of SSD system installed in pilot area of Lakhuwali

Sl No.	Parameters	Description
1.	Total area under SSD system	75 ha
2.	Type of drainage system	Pipe drainage system with pumped outlet
3.	Design drainage discharge	1 mm/ day
4.	Drain depth	1.2 m
5.	Aquiclude depth	10 m
6.	Allowable watertable depth	0.8 m
7.	Hydraulic conductivity	1.5 m/ day
8.	Drain radius	0.05 mm
9.	Lateral spacing	100 m area 37.5ha 150 m area 22.5ha 200 m area 15.0ha
10.	No. of lateral drains	26 each of 250m length, perforated PVC pipe of 100 mm dia
11.	Envelope material	300- 350 mm geotextile nonwoven
12.	Length of collectorpipes	1500 m
13.	Size of collectorpipes	100mm, 160 mm and 200 mm
14.	Manholes	1 m dia, 17 No.
15.	Sump	4 m dia, 3 m depth
16.	Conveyance system	1112 m with pumped outlet to GDC
17.	Years of installation	15 ha- 2000, 60 ha- 2001

Source: Gaur and Chandra (2001)

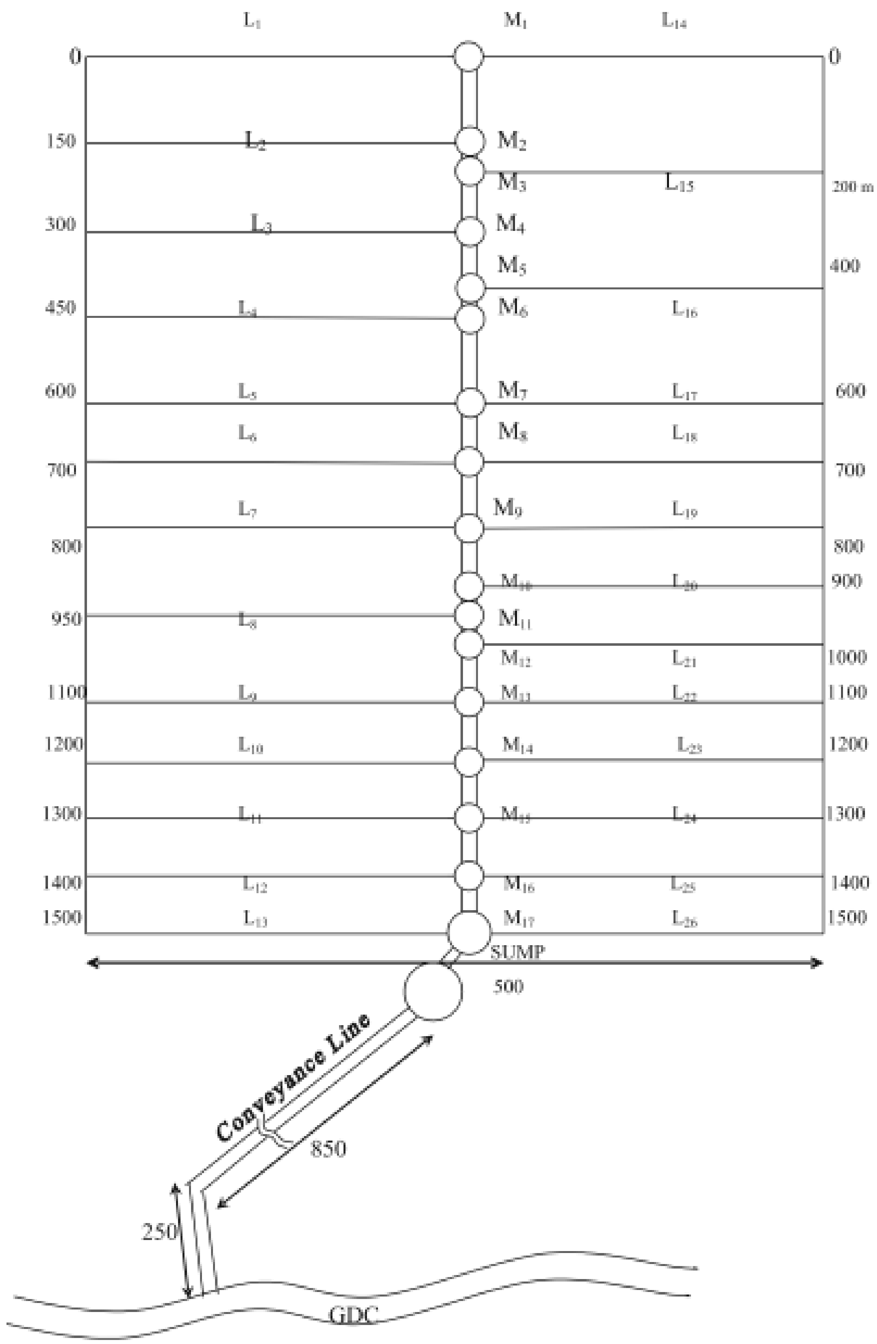

Fig. 1. Layout of sub-surface drainage system in Indira Gandhi Nahar Priyojna Canal command area

Cost on Installation of Sub-surface Drainage

The total cost on installation of SSD was Rs 17,82,564/- for the whole pilot area of 75 hectares. The cost on per hectare basis came to be Rs 23,767/-. The details of costs on sub-surface drainage system at the Lakhuwali pilot area have been presented in Table 6.

Three lateral spacings were kept while installing the SSD system. These spacings were 100m, 150m and 200m. The area in 100m, 150m and 200m spacings was 37.5 ha, 22.5 ha, and 15 ha, respectively. The cost on SSD in relation to lateral spacings of 100m, 150m and 200m was Rs 25400, Rs 21000 and Rs 18900, respectively (Table 7).

Changes in Yield Levels

The sub-surface drainage system was installed in an area of 15 hectares in October 2000 and in the remaining 60 hectares in September 2001. The

Table 6. Details of cost on sub-surface drainage system in Lakhuwali

Sl. No.	Name of the item	Specifications	Quantity	Rate (Rs/unit)	Amount (Rs)
1.	Pipes				
	(a) Lateralpipes	Corrugated & perforated	6500 m	41.70	271050
	(b) Collectorpipes	200 mm dia	300 m	257.00	77100
		160 mm dia	900 m	120.00	108199
		100 mm dia	300 m	57.00	17100
2.	Envelope material	Geotextile	3035 m^2	82.50	250392
3.	Binding wire		51.94 kg		4016
4.	Trench-digging (earth work) for·				
	• Collectorpipes		1500 m	55.00	82500
	• Lateralpipes		6500 m	37.50	243750
5	Inspection chambers	1 m dia.	17 Nos	4000	68000
6.	Sump	4 m dia.	1 No.		319173
7.	Conveyance line				
	(a) Pipes	200 mm dia.	850 m	257.00	218450
		160 mm dia.	250 m	120.00	30000
		100 mm dia.	12 m	57.00	684
	(b) Trench digging		1100 m	55.00	60500
			12 m	37.50	450
8.	Pump house	12×9 feet			16200
9.	Pumping unit	10 HP engine	1 No.		15000
10.	Total costs				1782564

Table 7. Unit cost on installation of sub-surface drainage system in IGNP canal command area

Particulars	Cost Rs/m or Rs/ unit	Lateral spacing					
		100 m		150 m		200 m	
		Length/ No. of units/ha	Cost Rs/ha	Length/ No. of units/ha	Cost Rs/ha	Length/ No. of units/ha	Cost Rs/ha
Lateralpipes with envelop and installation	120	100	12000	66	7900	50	5900
Collectorpipes including installation	190	20	3800	20	3800	20	3800
Manholes	4000	0.2	800	0.13	500	0.1	400
Sub-total			16600		12200		10100
Other costs*			8800		8800		8800
Total costs			25400		21000		18900

*Other costs (sump Rs 320000, conveyance line Rs. 310000, pump house and pumping unit Rs 31000; total cost = Rs 661000) were for 75 hectares and on per hectare basis, the cost came to be Rs 8800.

monitoring could be done in 15 ha area for two seasons for watertable depth, cropped area and crop yield. Changes in cropped area, yield and net returns before and after the drainage in 15 ha area have been presented in Table 8. It could be observed from Table 8 that yields of paddy and wheat increased significantly during the post-drainage period. It was 95 per cent in paddy and 113 per cent in wheat. Similarly, the cropping intensity also increased from 60 to 160 per cent during the post-drainage period. The change in net returns was Rs 7157/ha. This paper considered only the impact of sub-surface drainage on the net income of beneficiary farmers via reclamation of soil. The post-SSD crop yields were thus not the optimum yield levels. For attaining the optimum yield level, other inputs such as cultural practices, quality of seeds, type and doses of fertilizers, availability of irrigation water, soil type and numerous other variables which play important role, need to be considered.

Financial Analysis

The objective of the financial analysis was to determine whether agricultural producers were better off with the project. The financial evaluation process was conducted from the perspective of the farmers. Only income received directly by the farmer at the farm gate prices was

Table 8. Changes in cropped area, yield and net returns before and after drainage in 15 ha area

Treatment	Season	Crop	Area (ha)	Yield (q/ha)	Net returns (Rs)
Pre- drainage	Kharif	Paddy	1.1	14.2	2712
		Cotton	2.9	5.3	7366
	Rabi	Wheat	5.0	11.5	4500
	Net returns from 15 ha area				14578
	Cropping intensity				60 %
Post- drainage	*Kharif*	Paddy	12.0	27.7	79440
	Rabi	Wheat	8.5	24.4	39440
		Barley	3.0	18.0	3600
		Mustard	0.5	2.1	-550
	Net returns from 15 ha area				121930
	Cropping intensity				160 %
Change in net returns					107352
Change in net returns per hectare					7157

used to measure the financial benefits. For the analysis, local market prices of products and inputs were used, which included subsidies and taxes. All costs associated with the project and realized by the farmer, regardless of who else in the community benefited from this increased economic activity, were considered as project associated costs. Cash flow was also a major component of the financial analysis. If the producers do not realize a financial gain, they obviously would not adopt the new opportunities available to them, regardless of the resulting societal benefits.

The internal rate of return (IRR) of the drainage system must be higher than the opportunity cost of capital, which was assumed to be 10 per cent. The B-C ratio should be > 1, and the Net Present Value (NPV) > 0. To examine whether the project met the above criteria, the cost and benefit streams for 30 years were discounted at the rate of 10 per cent. The B-C ratio and the NPV were estimated to be 2.44 and Rs 34275/ha, respectively. The IRR was calculated to be 25.88 per cent, which was sufficiently higher than the market rate of interest. The cash flow and the present value of cash flow have been depicted in Annexure I.

Conclusions

The study has concluded that waterlogging has adversely affected the crop yields in the study area. On an average the cost of installation of sub-surface drainage in the command area has been estimated to be Rs 23767/ha. The indicators of financial viability, i.e. NPV (Rs 34275/ha), B-C ratio (2.44) and IRR (25.88 %) of the project have been found to be quite high. These indicators have well established the financial viability of the project in the area.

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Annexure I

Cash flow and present value of cash flow of the project

(Rs/ha)

Year	Installation cost	Increase in revenue	Yearly maintenance cost	Cash flow	Present value of cash flow	Cumulative present value
0	23767	0	0	-23767	-23767	-23767
1		7157	1000	6157	5597	-18170
2		7157	1000	6157	5088	-13081
3		7157	1000	6157	4626	-8455
4		7157	1000	6157	4205	-4250
5		7157	1000	6157	3823	-427
6		7157	1000	6157	3475	3048
7		7157	1000	6157	3160	6208
8		7157	1000	6157	2872	9080
9		7157	1000	6157	2611	11691
10		7157	1000	6157	2374	14065
11		7157	1000	6157	2158	16223
12		7157	1000	6157	1962	18185
13		7157	1000	6157	1783	19968
14		7157	1000	6157	1621	21590
15		7157	1000	6157	1474	23064
16		7157	1000	6157	1340	24404
17		7157	1000	6157	1218	25622
18		7157	1000	6157	1107	26729
19		7157	1000	6157	1007	27736
20		7157	1000	6157	915	28651
21		7157	1000	6157	832	29483
22		7157	1000	6157	756	30239
23		7157	1000	6157	688	30927
24		7157	1000	6157	625	31552
25		7157	1000	6157	568	32120
26		7157	1000	6157	517	32637
27		7157	1000	6157	470	33107
28		7157	1000	6157	427	33534
29		7157	1000	6157	388	33922
30		7157	1000	6157	353	34275