per kWh, the fall in the net returns ranged between 51 and 61 per cent. The fall was steeper in grey zone than in white and dark zones. If the electricity was charged at Re. 0.50 per unit, the fall in net return varied between 25 and 30 per cent.

TABLE VIII. ESTIMATED IRRIGATION COSTS

(Rs.)

Particulars (1)	Dark (2)	Grey (3)	White (4)	Overall (5)
1. Annual amortised cost of investment per well	16,403	14,296	13,122	14,571
2. Variable cost per well				
(a) Operation and maintenance cost	1,341	1,222	1,135	1,230
(b) Electricity charges	540	450	522	495
3. Total cost per well per year	18,284	15,968	14,780	16,296
4. Cost of irrigation per well per acre of GIA	1,837	2,001	1,556	1,885
5. Gross irrigated area (acres)	9.95	7.98	9.5	8.64
6. Cost of production per well per acre of GIA (excludes cost of irrigation)	4,884	4,544	4,501	4,640
7. Total cost per well per acre of GIA (includes amortised irrigation cost and opportunity cost of returns foregone from dryland agriculture)	6,720	6,262	6,078	6,699
8. Gross returns per well per acre of GIA	8,422	8,288	8,024	8,694
9. Net returns per well per acre of GIA	1,702	2,026	1,946	1,995
10. Percentage fall in net returns if electricity is priced at fifty paise per kWh	29.0	29.5	25.5	30.5
11. Percentage fall in net returns if electricity is priced at one rupee per kWh	58.0	59.0	51.0	61.0

Feasibility of Investment in Groundwater Irrigation

The economic feasibility of investment on borewell irrigation was evaluated using standard discounting cash flow techniques (Table IX). The IRR was 43 per cent for an investment of Rs. 75,756 per well, indicating that the investment on groundwater irrigation is financially viable. The IRR varied among different groundwater zones from 39 per cent in grey zone to 50 per cent in white zone. The IRR for dark zone was around 44 per cent. The BCR worked out at 14 per cent discount rate was 1.23. There was no significant variation in the discounted BCRs for different zones. The NPW is positive in all the groundwater zones and ranged between Rs. 62,643 in grey zone and Rs. 75,707 in white zone.

The payback period or the time required to recover the initial investment in borewell irrigation is found to be 2.8 years. This amply indicates that the farmers could recoup their investment within three years. In reality, this factor motivated investment in groundwater irrigation by the farmers. The results pertaining to IRR and BCR, without considering the investment on failed well(s) and variable electricity charges, are comparable with the results of Jayaraman (1981) (IRR = 40 per cent, BCR = 1.12), Neelakantaiah (1991) (IRR = 31 per cent, BCR = 1.22, NPW = Rs. 44,218) and Kolavalli and Atheeq (1993) (IRR = 46 per cent, NPW = Rs. 44,294).

Sensitivity Analysis

Appraisal of investment on functional wells *per se* does not indicate the inherent rate of return since well failure is an integral part of well success. The investments on both functional

Ind. Jn. of Agri. Econ.
Vol. 50, No. 1, Jan.-March 1995

Low Yielding Irrigation Wells in Peninsular India - An Economic Analysis*

N. Nagaraj and M.G. Chandrakanth†

INTRODUCTION

The value addition by groundwater irrigation has been significant in Indian agriculture since the 1960s. In several regions it has richly contributed to food security. It is estimated that irrigation has contributed 60 per cent to the growth in agricultural productivity (Seckler and Sampath, 1985). In India, about 33 per cent of the net sown area is under irrigation (Government of India, 1994), where groundwater and surface water have equal share in the gross irrigation. A major portion of India's groundwater irrigation wells is in the hard rock areas (Saleth and Thangaraj, 1993), where both recharge and discharge potentials are presently at stake. About two-thirds of India is composed of hard rock areas and the peninsular India is predominantly hard rock. These areas have hard non-porous rocks, the igneous and metamorphic rocks, expected to store not beyond 10 per cent of the annual rainfall (Radhakrishna, 1971). In the hard rock areas, groundwater irrigation, due to its flexibility, has helped in commercialisation of farming through crop diversification and specialisation in high value crops (low and high water intensive crops).

Groundwater in hard rock areas is abstracted from dug wells, dug-cum-borewells, shallow borewells and deep borewells. Dug wells are open wells, typically with a depth of 30 feet and with a diameter of 25 feet. The dug wells may be lined by stone slabs in order to prevent the caving of the wells in some areas where the rock and soil strata are loose. For viability of dug wells, the minimum yield of water should be 5,000 gallons per day according to National Bank for Agriculture and Rural Development (NABARD). The water used to be lifted by traditional labour intensive lifts like *yetha*, *kapile* or persian wheel till the sixties. Later the water was lifted by centrifugal pumpsets of around 3 horse power (HP) capacity. The dug wells continued to be the dominant structures of groundwater exploitation till the mid-sixties. In the early seventies, one or more bores were drilled inside a dug well (which used to be called as dug-cum-borewell) in order to enhance the water yield. The in-bore may have depth ranging from 30 to 100 feet and centrifugal pump was the chief mode of water abstraction. The dug-cum-borewells were the dominant structures till the eighties. From the early eighties, surface borewells with diameter of 6 inches and depth around 200 feet became popular due to the use of fast rig technology. For viability of borewell, the minimum yield of water should be 1,000 gallons per hour according to NABARD.

Notwithstanding the hydro-geological thresholds of groundwater, intensive cultivation

* This study forms a part of the Ph.D. dissertation submitted by the senior author (Nagaraj, 1994) to the Department of Agricultural Economics, University of Agricultural Sciences (UAS), Bangalore under the guidance of C. Nanja Reddy, Professor and Head, Department of Agricultural Economics, UAS, Bangalore, for whom the senior author is grateful. The authors are thankful to the sample borewell farmers of Kolar and Bangalore Rural districts for sitting long hours in providing valuable information for this study; to Gurumurthy, Professor of Statistics, UAS, Bangalore; to H. Chandrashekar, Assistant Professor of Statistics, PPMC, UAS, and to the anonymous referee for valuable comments and suggestions, Venkateshappa, Field Officer, Canara Bank, Devanahalli, Suryanarayana Reddy, Field Officer, Vijaya Bank, Chikkaballapura, Venkataramanappa, Agriculture Officer, Devanahalli, Venkata Reddy, progressive farmer, Chikkaballapura, and Seenappa, Department of Inland Fisheries, UAS, Bangalore for providing logistical support for the study.

† Assistant Professor and Associate Professor, respectively, Department of Agricultural Economics, University of Agricultural Sciences, Hebbal, Bangalore - 560 024.

of water intensive commercial crops is growing unabated on an extensive scale ever since the seventies. Due to the growing demand for groundwater, substitution of labour intensive water lifts by capital intensive electrical irrigation pumpsets, and due to increasing well densities and large scale failure of dug wells, dug-cum-borewells and even of borewells (Nagaraj *et al.*, 1994) has occurred. (Historically, even though groundwater is an internal or local resource tapped from farmers' lands, it has now been transformed to an external and non-local resource, since electrical or diesel energy, which are external, have to be used to lift the water.) With such a heavy pressure on the resource and the government policy of providing electricity to lift groundwater at zero price, there has been large scale exploitation of groundwater leading to high rate of well failure and loss of investments in well irrigation. The aftermath of such losses provides a nightmarish scenario to planners and researchers, since farmers suffer from severe economic shocks and stresses.

SCOPE OF THE STUDY AND DATA BASE

This paper examines the economic feasibility of investments in groundwater irrigation, exploration, extraction and use from low yielding borewells in the hard rock areas. Towards this endeavour, we estimate investment, cost of irrigation and appraise the feasibility and economic viability of investment in different groundwater zones. This analysis deals exclusively with investment and returns pertaining to the borewell irrigated portion of the farms and does not consider the income from portions of the farms like drylands and tank fed wet lands.

We have chosen the groundwater areas in Karnataka as representative of peninsular hard rocks of India. These areas are characterised by increasing number of low yielding borewells and pose challenging problems for economic investigation (see Nagaraj *et al.*, 1994). The Kolar and Bangalore rural districts in the eastern dry agro-climatic zone of Karnataka are the leading groundwater areas of the state, with the highest intensities of exploitation (Government of Karnataka, 1993) chosen for the study. In this agro-climatic zone, taluks representing dark, grey and white groundwater zones[1] were chosen randomly. The chosen taluks are Chikkaballapur and Devanahalli in dark zone, Shidlaghatta and Doddaballapur in grey zone and Srinivasapur in white zone. In this study, irrigation wells yielding less than 1,800 gallons per hour are considered for economic analysis. Since a list of farmers who possess such low yielding wells was not available, snowball sampling was used to draw 35 farmers from each of the dark, grey and white groundwater zones constituting a total sample size of 105. The primary data collected for the study pertain to the year 1992.

CONCEPTS AND DEFINITIONS

Cropping Intensity and Irrigation Intensity

The cropping intensity index is the ratio of the gross cropped area to the net cultivated area in percentage. Since commercial crops like mulberry and grapes, perennial in nature were ably supported by well irrigation, and as perennials consumed water in all the seasons of the year, the cropped area for perennials was considered as equivalent to three times the sown area. For instance, if the area under mulberry is one hectare, the gross cropped area is treated as equivalent to three hectares for the entire year in calculating the cropping intensity. The cropping intensity considers the gross cropped area on all lands including dryland. Hence, it understates the contribution of groundwater to area irrigated. Hence, irrigation intensity (Kolavalli and Atheeq, 1993), equal to the percentage of gross irrigated area to the net irrigated area is computed. In computing these two intensities, the net irrigated area is taken as the maximum area a well can irrigate in the *kharif* (rainy) season.

Investment Particulars

The investment on irrigation borewells comprised (i) cost of drilling a borewell, (ii) cost of submersible pumpset and (iii) other costs. The borewell costs considered included mainly the cost of drilling and casing pipes, whereas the investment on submersible (irrigation) pumpsets entailed cost of pump, panel board and galvanised iron (GI) pipes. The cost incurred for the pumphouse, pipe line, overground earthen pond and well deepening are the other cost components in borewell investment. The above items are valued both at historical and current prices.

Irrigation Cost

Based on the experience of the borewell owner farmers of the study area, the economic life of an irrigation borewell is considered as ten years. The capital cost of the well was amortised for this period at 14 per cent rate of interest to arrive at the annual fixed irrigation cost (A) as:

$$A = Pv + \{ 1 - (1 + i)^{-n} \}/(i),$$

where Pv = present value of the investment, i = interest rate and n = number of years.

Evaluation of the Investment

The discounting cash flow techniques [net present worth (NPW), benefit-cost ratio (BCR), internal rate of return (IRR)] have been used to find the viability of investment in borewell irrigation. The NPW is the difference between the present value of benefits and the present value of costs. If the project implies a net benefit greater than zero, it is economically viable, as it can generate returns in excess of all the costs including the interest cost of capital. The general mathematical form of NPW is given below:

$$NPW = \sum_{1}^{n} [B_t - C_t] + [(1 + r)]^{n}$$

where, B_t = benefit in each year, C_t = cost in each year, t = number of years, r = discount rate.

The BCR is the ratio of the farm inflows and outflows in present value terms. For an investment to be worthwhile, the BCR must be more than unity. The rate of return that equates the discounted flow of annual returns with the discounted flow of annual costs is the IRR and this renders the NPW to zero. It indicates the average earning capacity of an investment over the economic life span of an investment.

The following assumptions were made in estimating the discounted cash flow measures:

(a) From the experience of the farmers of the study area, the life span of the borewell is considered as ten years and that of the submersible irrigation pumpset (SIPS) is considered as eight years.
(b) Accordingly, the SIPS will be replaced during the beginning of the eighth year, and the salvage value will be accounted for.
(c) The area irrigated by a borewell is the same in all the ten years in all the three seasons.
(d) The technology of borewell irrigated agriculture is constant.
(e) The benefit from borewell irrigation will be realised from the very first year of commissioning.
(f) In computing the total cost per acre of gross irrigated area, the net income from dryland agriculture has been considered as an opportunity cost and hence is deducted from the benefits of borewell irrigation.
(g) Discount rate of 14 per cent is considered as the opportunity cost of capital at which the stream of cash flow is discounted.
(h) The farm economy under borewell irrigation remains unchanged for the ten-year span.

RESULTS AND DISCUSSION

The cropping pattern followed and the cropping intensity on a farm depends to a large extent on the availability of irrigation in different seasons of the year, as also agronomic and other economic forces. About 45 per cent of the gross irrigated area (GIA) on the farm is occupied by commercial perennials like mulberry (for sericulture), grapes and coconuts, while 28 per cent is devoted to vegetables like potato, tomato, onion, cabbage, cauliflower, knol-khol crops. The remaining 27 per cent is occupied by food crops (Table I). During the *kharif* season, cereals and millets like paddy, *ragi* and maize are cultivated, followed by predominant vegetable cultivation in *rabi* and summer seasons. Evidently, the farmers try to ensure their food security as they want to reap their staple crops in the first crop season, even though irrigation facility and varietal diversity among food crops allow them to grow these in all the seasons. Perennials and vegetables are highly commercial and account for around 75 per cent of the gross irrigated area in all the groundwater zones, because these are highly lucrative on account of proximity to terminal markets.

TABLE I. CROPPING PATTERN UNDER WELL IRRIGATION ACROSS DIFFERENT GROUNDWATER ZONES

Crop/Category	Dark		Grey		White		Overall	
	Area (acres)	Per cent	Area (acres)	Per cent	Area (acres)	Per cent	Area (acres)	Per cent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ragi	60.0	15.0	50.5	15.8	54.5	14.3	52.1	14.4
Paddy	16.5	4.1	12.0	3.7	17.5	4.6	13.5	3.7
Maize/popcorn	19.0	4.8	25.0	7.8	19.5	5.1	21.9	6.0
Other field crops	12.75	3.2	8.0	2.5	9.0	2.4	10.5	3.0
Vegetables	104.5	26.5	99.5	31.2	103.0	27.1	101.5	28.2
Mulberry	132.75	33.3	88.5	27.7	135.0	35.5	120.0	33.0
Grapes	30.0	7.5	19.5	6.1	13.5	3.5	22.5	6.3
Other perennials*	22.5	5.6	16.5	5.2	28.5	7.5	19.5	5.4
Total	398.0	100.0	319.5	100.0	380.5	100.0	361.5	100.0

* Three times the actual sown area is considered for comparing the gross area.

Cropping and Irrigation Intensity

The overall cropping intensity is 188 per cent and shows a modest increase over the crop intensity of 100 per cent under rainfed farming. The cropping intensity varied slightly in different groundwater zones and ranges from 177 per cent in white zone to 188 per cent in dark zone and 193 per cent in grey zone (Table II). Thus the introduction of a variety of crops in *rabi* and summer seasons due to availability of well irrigation brought a substantial increase in the cropping intensity.

TABLE II. CROPPING INTENSITY ACROSS DIFFERENT GROUNDWATER ZONES

Groundwater zones (1)	Size of holding (acres) (2)	Gross cropped area (acres) (3)	Net cropped area (acres) (4)	Cropping intensity (per cent) (5)
Dark zone	11.2	17.37	9.20	188
Grey zone	8.9	12.87	6.64	193
White zone	12.2	15.45	8.70	177
Overall	10.0	15.23	8.07	188

The average gross area irrigated per well was 8.64 acres. It varied from 7.98 acres in grey zone to 9.95 acres in dark zone and 9.50 acres in white zone. In all the cases, the irrigation intensity did not vary markedly. The irrigation intensity was nearly 240 per cent, moderately closer to the maximum possible level of 300 per cent per annum (Table III).

TABLE III. IRRIGATION INTENSITY ON FARMS UNDER BOREWELL IRRIGATION

Groundwater zones	Net area irrigated (acres)		Gross area irrigated (acres)		Irrigation intensity
	Per well	Per farm	Per well	Per farm	Per cent
(1)	(2)	(3)	(4)	(5)	(6)
Dark	4.15	4.75	9.95	11.37	239
Grey	3.28	3.75	7.98	9.13	243
White	3.93	4.50	9.50	10.85	241
Overall	3.60	4.32	8.64	10.45	240

Gross and Net Returns

The gross and net returns varied marginally across different groundwater zones of the study because of narrow differences in borewell utilisation, cost of production and land productivity. The gross annual value of the farm output was Rs. 75,116 per well and Rs. 8,694 per well per acre of GIA. The annual net return was Rs. 31,805 per well and Rs. 3,681 per well per acre of GIA (Table IV). The study by NABARD (1990) indicated that the net income per acre in the rainfed portion of the borewell irrigated farmers in Kolar district was around Rs. 475 per acre. Using this as a comparison, the net return per acre of GIA was eight fold more than that in the rainfed area.

With regard to the proportion of net returns from different crop enterprises, on an average, more than 80 per cent of the net returns were derived from the sale proceeds of commercial crops like vegetables, sericulture and grapes. The proportion of income derived from high value crops like grapes was more in dark zone, followed by grey and white zones. The contribution of net returns from vegetables to the total was more in grey zone, followed by dark and white zones. This was mainly because compared to white zone (Srinivasapur), the grey zones (Shidlaghatta and Doddaballapur) of the study area are closer to Bangalore city which obviously provides a large effective consumer demand.

TABLE IV. ANNUAL GROSS AND NET RETURNS FROM EXCLUSIVELY BOREWELL IRRIGATED AREA OF THE FARMS

Groundwater zones	Gross returns (Rs.)			Net returns (Rs.)		
	Per well	Per farm	Per acre of GIA	Per well	Per farm	Per acre of GIA
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dark	83,795	95,766	8,422	33,331	53,278	3,350
Grey	66,138	83,144	8,288	30,465	41,106	3,818
White	76,230	93,654	8,025	31,606	48,265	3,681
Overall	75,116	90,855	8,694	31,805	48,265	3,681

Borewell Investment

The historical years of well investment ranged from 1984 to 1991, the modal year being 1989 (Table V). The investment per well at historical prices worked out to Rs. 60,155. Among the different components of investment in groundwater development, the drilling cost accounted for 33 per cent (Rs. 20,130), while the cost of irrigation pumpset with all accessories formed the major item of investment (43 per cent). This shows that the extraction component is more expensive than the exploration component. (In addition, this also leads to richer pay-off for developing extraction technologies which in fact could be reduced through competition and technical improvement.)

For a comparative analysis of investment with the returns realised at current prices, the data on historical prices were updated by using 1991-92 price. At current prices, the drilling cost of Rs. 22,801 forms 30 per cent of the total investment. The submersible irrigation pumpset costs Rs. 33,595 (44.4 per cent) and miscellaneous costs are Rs. 19,360 (25.6 per cent) (Table VI). The investment on borewell at current prices is 10 per cent higher than the investment at historical prices matching with the present inflation rate of 10 per cent.

The borewell drilling and pumpset installation together accounted for more than 70 per cent of the total investment. A majority of the farmers invested in conveyance and distribution system. The distribution system consisted of plastic (PVC) pipes laid over the ground and the cost incurred on distribution system was a modest 9 per cent (Rs. 5,315). The PVC pipes were used for carrying the groundwater from the source to the different plots which were fragmented and scattered. The number of fragments, on an average, was three and the average length of conveyance pipe laid on the farm was about 1,000 feet. The study area suffers from groundwater scarcity as well as from the erratic supply of electricity. The above-ground storage structures for water are built to cope with the vagaries of electricity supply and the low discharge from wells. The additional costs of irrigation under such circumstances like expenses on deepening wells, repairs to pump, cost of automatic starters all together accounted for 7 per cent of the investment. This investment level was relatively higher in the case of dark zone as compared to grey and white zones, mainly because of increased depth and the use of higher HP pumpset, besides higher drilling charges. Thus the hypothesis of investment cost of borewell being invariant across different groundwater zones is rejected.

TABLE V. INVESTMENT ON BOREWELL AT HISTORICAL PRICES IN DIFFERENT GROUNDWATER ZONES

(Rs.)

Particulars (1)	Dark (2)	Grey (3)	White (4)	Overall (5)
A. Cost of drilling				
1. Water divining charges	345	184	229	265
2. Transportation of rig	555	460	431	485
3. Drilling charges	15,350	13,550	11,800	13,560
4. Casing cost	6,565	6,305	4,582	5,820
Sub-total	22,815	20,499	17,042	20,130
	(35)	(34.5)	(31)	(33.0)
B. Cost of irrigation pumpsets				
5. Pump cost	13,643	12,800	12,436	12,950
6. Panel board	2,137	1,836	2,000	1,995
7. Cable wire cost	2,340	2,040	1,950	2,115
8. GI pipes	5,696	5,366	4,852	5,300
9. Cost of accessories	546	526	585	550
10. Installation	771	651	653	695
11. Energisation	1,500	1,600	1,600	1,560
12. Deposit to State Electricity Board	460	340	390	400
Sub-total	27,093	25,159	24,466	25,565
	(41)	(42.5)	(44)	(43)
C. Other costs				
13. Pump house cost	2,980	3,500	3,300	3,255
14. Pipe line cost	4,943	5,046	5,948	5,315
15. Repair of the pump	2,682	2,444	2,270	2,460
16. Deepening charges	2,561	1,193	860	1,540
17. Water storage structure	2,525	1,420	1,732	1,890
Sub-total	15,691	13,603	14,110	14,460
	(24)	(23)	(25)	(24)
Grand Total	65,599	59,261	55,618	60,155
	(100)	(100)	(100)	(100)

Figures in parentheses are percentages to the total.

TABLE VI. INVESTMENT ON BOREWELL AT CURRENT PRICES

(Rs.)

Particulars (1)	Dark (2)	Grey (3)	White (4)	Overall (5)
A. Cost of drilling				
1. Water divining charges	600	600	600	600
2. Transportation of rig	555	460	431	485
3. Drilling charges	16,940	14,905	12,870	15,000
4. Casing cost	7,575	7,275	5,287	6,720
Sub-total	25,670	23,240	19,188	22,801
	(32.4)	(30.6)	(27.3)	(30.0)
B. Cost of irrigation pumpsets				
5. Pump cost	14,000	13,000	13,500	14,000
6. Panel board	2,200	2,200	2,000	2,200
7. Cable wire cost	3,080	2,860	2,500	2,820
8. Automatic starter	600	600	600	600
9. GI pipes (@ Rs.40/ft)	12,000	10,600	9,280	10,600
10.Cost of accessories	600	600	750	750
11.Installation	800	750	750	750
12.Energisation	1,600	1,600	1,600	1,600
13.Deposit to State Electricity Board	450	375	450	425
Sub-total	35,330	32,585	31,480	33,595
	(44.6)	(42.8)	(44.8)	(44.4)
C. Other costs				
14. Pump house cost	4,000	4,000	4,000	4,000
15. Pipe line cost	5,482	8,272	8,175	7,300
16. Repair of the pump	2,682	2,444	2,270	2,560
17. Deepening charges	3,000	2,500	2,200	2,500
18. Water storage structure	3,000	3,000	3,000	3,000
Sub-total	18,162	20,216	19,645	19,360
	(23.0)	(26.6)	(27.9)	(25.6)
Grand Total	79,164	76,041	70,313	75,756
	(100)	(100)	(100)	(100)

Figures in parentheses are percentages to the total.

The investment level at historical prices incurred by the well owners was compared with the 1992 unit cost of the borewell worked out by the NABARD. In the hard rock areas of the study area the unit cost worked out by NABARD was around Rs. 43,500 per well. The investment of nearly Rs. 67,000 at historical prices leaves a gap of Rs. 6,750 considering the farmer's margin money of 25 per cent (Table VII). Bridging this gap may help in the utilisation of the loan effectively from the initial year itself without any financial distress.

TABLE VII. COMPARISON OF BOREWELL INVESTMENT WITH UNIT COST OF NABARD

(Rs.)

Particulars (1)	Investment at historical prices (unit price) (2)	NABARD's unit cost (1992) (3)
Borewell	22,801	19,000
Submersible irrigation pumpset	33,535	24,500
Well deepening, repairs, Water conveyance and storage costs	11,300	-
Total	67,636	43,500

Irrigation Cost

The variable costs of irrigation comprised expenses incurred towards repairs and maintenance and replacement of pump parts, panel board and other electrical accessories. The flat rate electricity tariff was also included in the variable cost. On an average, the total cost of irrigation per annum was Rs. 16,296 which included amortised cost of the initial investment of Rs. 14,571 and the variable cost of drawing water (repairs and maintenance charges) of Rs. 1,230 and the flat rate charge for electrical power of Rs. 495. The amortised capital cost accounted for 89.5 per cent. The annual operating expenses which included operation and maintenance and electricity charges (flat rate) together accounted for 10.5 per cent of the total annual cost of irrigation. This provides an indication that the farmer's response to payment towards electricity may be inelastic up to certain thresholds of pro-rata or flat rates of electricity due to a high proportion of amortised fixed cost. The cost of irrigation per well as well as per acre of GIA was relatively higher in dark zone than in grey zone and white zone on account of deeper borewells which entailed higher investment. On an average, to provide irrigation per acre of GIA the annual irrigation cost was Rs. 1,885, which amounted to about 29 per cent of the cost of cultivation (Table VIII).

The cost involved to provide irrigation per acre of GIA was relatively higher in grey zone than in dark zone and white zone. This is because the area irrigated per well is relatively low in grey zone compared with the other zones. However, the irrigation cost varied in a narrow range across different groundwater zones.

The gross return per acre of GIA was over Rs. 8,694. The cost of cultivation with the inclusion of irrigation cost component was around Rs. 6,699 which leaves a surplus of Rs. 1,995 as net returns. The farmers in the study area were charged a fixed sum of money (flat rate) for electricity to pump irrigation water depending on HP of the irrigation pumpset installed. Hence, an attempt was made to include the cost of electricity by estimating the number of pumping hours. The results show that with the inclusion of variable electricity charges at the rate of Re. 1 per kWh, the electricity cost worked out to Rs. 1,031 per acre of GIA per year for a 5.5 HP pumpset. If electricity costs are included at the rate of Re. 1

wells and failed wells have to be considered for a meaningful appraisal. Further, electricity for irrigation is highly subsidised and a fixed factor and hence is not finally reflected in the cost of irrigation. At the Power Ministers Conference held at New Delhi in 1993, it was recommended to all State Governments to price the electricity for irrigation pumpsets at 50 paise per kWh. A sensitivity analysis has been attempted to assess the effect of including the investment on failed well(s) and the cost of electricity priced at 50 paise per kWh on the IRR, BCR and NPW.

TABLE IX. DISCOUNTED CASH FLOW MEASURES UNDER VARIOUS ASSUMPTIONS

Measures at estimated costs and return (1)	Dark (2)	Grey (3)	White (4)	Overall (5)
1. Without considering the investment on failed wells and variable charges on electricity				
Internal rate of return	44	39	50	43
Benefit-cost ratio	1.23	1.26	1.28	1.23
Net present worth (Rs.)	72,607	62,643	75,707	65,414
Payback period (years)	2.9	3.0	2.7	2.8
2. Sensitivity analysis (considering the investment as failed wells and variable charges on electricity)				
Internal rate of return				
(i) Investment on functional well + non-functional well	33	31	39	33
(ii) Investment on functional well + variable electrical charges	36	32	41	35
(iii) (ii) + Investment on non-functional well	27	25	32	26
Benefit-cost ratio				
(i) Investment on functional well + non-functional well	1.17	1.20	1.23	1.17
(ii) Investment on functional well + variable electrical charges	1.15	1.17	1.19	1.15
(iii) (ii) + Investment on non-functional well	1.10	1.11	1.14	1.10
Net present worth				
(i) Investment on functional well + non-functional well	59,763	51,514	65,956	54,165
(ii) Investment on functional well + variable electrical charges	53,555	46,768	57,290	47,951
(iii) (ii) + Investment on non-functional well	40,720	35,639	47,539	36,704

Notes: 1. Variable electricity expenses have been estimated at the rate of 50 paise per kWh.
2. The cost of non-functional well is around 20 per cent of the investment on functional well.
3. The investment to be recovered in payback period includes the investment on non-functional well.

If the investment on failed wells and electricity charges are reckoned with, then the scenario would be different in respect of IRR, BCR and NPW. On an average, if the investment on failed wells plus the investment on functional wells plus the electricity charges at the rate of 50 paise per kWh are considered, the IRR dips from 43 to 26 per cent. If the investment on failed wells plus the investment on functional wells alone (without electricity charges) are considered, the IRR would be around 35 per cent. The BCR also reduced from 1.23 to 1.10 and NPW from Rs. 65,414 to Rs. 36,704 with the inclusion of electricity charges and investment on failed wells.

SUMMING UP

The farmers' adoption of an intelligent mix of water intensive and light water crops in the cropping pattern was a vital factor contributing to economic viability of low yielding wells. The cropping patterns practised in the regimes of low yielding borewells clearly reflect that they are highly water intensive and are exclusively market oriented. The cropping intensity was around 188 per cent, while the irrigation intensity was 240 per cent. The average size of the holding was 10 acres with the net and gross irrigated area per well being 3.6 acres and 8.64 acres respectively. The annual gross and net returns per well amounted to Rs. 75,116 and Rs. 31,805 respectively. The average investment per borewell at current prices amounted to Rs. 75,756. Since borewell costs were colossal, large farmers constituted a major proportion of well owners. The cost of production per well per acre of gross irrigated area (including the amortised cost of irrigation and opportunity cost of returns foregone from dryland agriculture) was Rs. 6,699 and the net returns per well per acre of gross irrigated area was Rs. 1,995. If electricity costs were to be valued at 50 paise per kWh, the net returns would fall by 30 per cent. Even considering the investment on functional wells, non-functional wells and the expenditure on electricity charges, the IRR worked out to 33 per cent, the BCR to 1.10 and the NPW to Rs. 36,704. Such lucrative returns are largely responsible for increasing the effective demand for borewell irrigation in hard rock areas.

Around 43 per cent of the farmers preferred to pay electricity on pro-rata basis at the rate of 18 paise per kWh only if the electricity supply is uniform and 57 per cent of the farmers still preferred flat rate basis. Hence electricity may be priced and better supply of electricity be ensured during the day time in a few selected areas on pilot basis for possible extension to other areas. This may help in the efficient use of water besides better management of scarce water.

For low yielding borewells, promotion of low water requiring crops and water efficient devices like drip and sprinkler would go a long way in saving electrical power, improving water use efficiency, minimising the wastage of water and achieving overall sustainability. Hence, financial assistance may be extended to the farmers who wish to use water efficient devices, as they involve high initial investment. Institutional alternatives promoting group investments by willing small and marginal farmers through co-operative efforts could be a desirable proposition for reaping cumulative benefits from borewell irrigation in hard rock areas. If sustainable use of groundwater is the goal, then irrigation literacy[2] needs to be promoted on a war footing.

Received October 1994. *Revision accepted February 1995.*

NOTES

1. In order to regulate the agricultural credit for drilling irrigation wells, the State Department of Mines and Geology periodically examines the groundwater utilisation status in all the taluks of Karnataka. A dark taluk is one where the groundwater utilisation is above 85 per cent of the recharge. In such taluks, the financing institutions are not permitted to approve requests for irrigation well loans from the farmers. A grey taluk is one where the groundwater utilisation is between 65 and 85 per cent of the recharge. In such taluks, financing institutions may selectively approve request for irrigation loans from the farmers. A white taluk is one where the groundwater utilisation is below 65 per cent. Here there is no restriction on financing for well irrigation by financial institutions. In this study taluk is considered as zone.

2. By irrigation literacy we mean educating the farmers with respect to effective and efficient utilisation of scarce groundwater for different crops, time, frequency and volume of irrigation, low water intensive crops, water saving techniques in farming, the choice of right capacity and type of irrigation pumpset, use of HDPE pipes instead of galvanised

iron pipes for lifting groundwater, use of the right horse power, the right number of stages required for lifting the water, standard submersible pumps and foot valves, the placement of the pump at the right depth, use of capacitors and other technical details.

REFERENCES

Government of India (1994), *Agricultural Statistics at a Glance*, Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi, pp. 81-82.

Government of Karnataka (1992), *Status of Groundwater Exploitation and Methodology for Recharging of Aquifers in Over-Exploited Areas of Bangalore, Kolar and Tumkur Districts*, Drought Monitoring Cell, Department of Science and Technology, Bangalore.

Jayaraman, B. (1981), *Comparative Economics of Investment in Borewell and Openwell - A Case Study in Bangalore District of Karnataka*, M.Sc(Agri.) Thesis, University of Agricultural Sciences, Bangalore (Unpublished).

Kolavalli, S. and L.K. Atheeq (1993), *Access to Groundwater: A Hardrock Perspective*, Paper presented in the Workshop on Water Management: "India's Groundwater Challenge", organised at Vikram Sarabhai Centre for Development Interaction, December 14-16, Ahmedabad.

Nagaraj, N. (1994), *Groundwater Irrigation from Low Yielding Borewells in Hard Rock Areas of Karnataka - An Economic Analysis*, Ph.D. Thesis, University of Agricultural Sciences, Bangalore (Unpublished).

Nagaraj, N.; M.G. Chandrakanth and Gurumurthy (1994), "Borewell Failure in Drought-Prone Areas of Southern India: A Case Study", *Indian Journal of Agricultural Economics*, Vol. 49, No. 1, January-March.

National Bank for Agriculture and Rural Development (NABARD) (1990), *Borewell Financing in Chitradurga and Kolar Districts - Karnataka (An Ex-Post Evaluation Study)*, Evaluation Study Series No. Bangalore-2, Regional Office, Bangalore.

Neelakantaiah, S. (1991), *A Study on Investment in Groundwater Irrigation and Resource Use-Efficiency in Dodda-ballapur Taluk of Bangalore Rural District, Karnataka*, M.Sc(Agri.) Thesis, University of Agricultural Sciences, Bangalore (Unpublished).

Radhakrishna, B.P. (1971), "Problems Confronting the Occurrence of Groundwater in Hard Rocks", in Geological Society of India (1971), *Groundwater Potential in Hard Rock Areas of India*, Seminar Volume, Bangalore, pp. 27-44.

Saleth, R. Maria and M. Thangaraj (1993), "Distribution Pattern of Lift Irrigation in India: An Analysis by Hydro-Geological Regions", *Economic and Political Weekly*, Vol. 28, No. 39, September 25, pp. A-102 - A-110.

Seckler, David and R.K. Sampath (1985), *Production and Poverty in Indian Agriculture*, Report submitted to Indian Mission of United States Agency for International Development, New Delhi.