GROUNDWATER SCARCITY AND COPING STRATEGIES IN CHANNAGIRI TALUK OF SHIMOGA DISTRICT- AN ECONOMIC ANALYSIS

G.BASAVARAJ

DEPARTMENT OF AGRICULTURAL ECONOMICS
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE
1998

GROUNDWATER SCARCITY AND COPING STRATEGIES IN CHANNAGIRI TALUK OF SHIMOGA DISTRICT - AN ECONOMIC ANALYSIS

G.Basavaraj

Thesis submitted to
University of Agricultural Sciences, Bangalore
in partial fulfillment of the requirements
for the award of the
Degree of Master of Science (Agriculture)
in Agricultural Economics

BANGALORE **MAY 1998**

DEPARTMENT OF AGRICULTURAL ECONOMICS
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

CERTIFICATE

This is to certify that the thesis entitled **"GROUNDWATER SCARCITY AND COPING STRATEGIES IN CHANNAGIRI TALUK OF SHIMOGA DISTRICT : AN ECONOMIC ANALYSIS"** submitted by Sri. G. Basavaraj for the degree of **MASTER OF SCIENCE, (AGRICULTURE) AGRICULTURAL ECONOMICS** of the University of Agricultural Sciences, Bangalore is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Bangalore
19/03 1998

Dr.M.G.Chandrakanth
Professor and Head, Chairman, Advisory committee
Department of Agricultural Economics,
University of Agricultural Sciences, GKVK, Bangalore 560 065

Approved by:
Chairman:

Dr.M.G.Chandrakanth

Members:

Dr.Gopal Krishna Hebbar

Dr.T.R.Keshavareddy

Sri.H.Chandrashekar

ACKNOWLEDGEMENT

I wish to experss my heartfelt gratitude to all of my sample farmers of Channagiri taluk located in Goppenahalli, Bussenahalli, Kagathur and Chickganguru villages for responding to my 25 page schedule willingly with deep interest pertaining to economics of groundwater irrigation especially in areas affected by cumulative interference. I appreciate their sincere co-operation extended during the time of field data collection and for having spared their valuable time without which this study would not have been possible.

I am thankful to ***Sri. Vasudevmurthy****, Premier Irrigation Systems, Bangalore for giving an informative lecture on drip irrigation in groundwater scarce areas which made me to select Channagiri taluk of Shimoga district for this study.*

I am profoundly greatful to my mother ***Smt. Pushpavathi****, father* ***Sri Doddappa****, brother* ***Sri Mallikarjuna****, Sisters* ***Smt Chamundeshwari****,* ***Kum Sujatha****,* ***Dr Geetha*** *and* ***Kum Bharathi****, uncle* ***Sri Shashikumar*** *and nieces* ***Kum Megha*** *and* ***Sanjana*** *for bearing the burden of my absence necessitated by this research and for their encouragement throughout my study period.*

The Ford Foundation, New Delhi, provided me an opportunity to be a Junior Reserch Fellow in the project it sponsored to the Department of Agricultural Economics, University of Agricultural Sciences, Bangalore and I am grateful to them. In particular, I am thankful to ***Dr. John Ambler****, Representative of the Foundation at Vietnam and to* ***Dr. Ujwal Pradhan****, Programme officer, New Delhi for considering the research issues in groundwater irrigation influenced by interactive effects of wells, as crucial, which made the Ford Foundation grant to UAS a reality.*

I am grateful to ***Dr. N. Nagaraj****, my first major advisor, right now pursuing post doctoral research in France, for allowing me to be a Junior Research Fellow in the project sponsored by the Ford Foundation New Delhi. I am thankful for his critical comments during the period of his Chairmanship.*

I am highly indebted to ***Dr. M.G. Chandrakanth****, Professor & Head of the Department of Agricultural Economics and also my present Chairemen of the Advisory committee for his guidance and encouragement during this research. I have been richly benefitted by his critical comments, during the time of analysis and while bringing out implications. I respect his* *dedication to research by guiding me even at late hours and his encouragement to involve students in discussions apart from his hectic administrative work as Professor and Head.*

My sincere thanks to Professor ***H. Chandrashekar****, Associate Professor of Statistics, PPMC, UAS, GKVK, for pointing out several mistakes committed like lack of comparability between drip and flow irrigation farms in high well interference villages with small and large farms in low well interference villages; use of 'quarter' instead of 'quartile' in measuring equity effects and so on. He has spent a great deal of time on the thesis and has richly contributed through his thought provoking comments and suggestions.*

I am thankful to ***Dr. Gopala Krishna Hebbar****, University Head of Agricultural Economics and Coordinator, PPMC, UAS, GKVK, Bangalore and to* ***Dr. T.R. KeshavReddy****, Associate Professor, Department of Agricultural Economics for their valuable suggestions as my members of my Advisory committee.*

Sri A Ravishankar*, Scientist, at the National Center for Agricultural Economics and Policy Research, New Delhi has been involved throughout the period of the project in terms of his delivering guest lectures to research fellows. Having worked on economics of surface irrigation for his Ph.D, Sri Ravishankar was kind enough to go through the preliminary draft of the thesis and in the process offered critical comments regarding interpretation of the double benefit in terms of savings achieved from the use of drip irrigation as well as the effect of recharge from irrigation tanks on flow irrigation farms. I am thankful to him for his interest and commitment.*

I acknowledge the efforts of ***Sri. K.K. Ananda****, Systems Analyst of the Ford Foundation project for helping me to carry out the analysis of my vast data set in QPRO v.4. In fact Sri Ananda was instrumental in increasing the RAM of the PC from the existing 4 MB to 16 MB, which hastened the analysis. I appreciate his involvement in discussion with patience and for his moral support during my entire research work. He has spent several days, evenings and nights with me during analysis. I am extremely grateful to him for teaching me the computer skills and computer software packages.*

Kum. Sushma Adya*, JRF, Ford Foundation wells Project, helped me during analysis of the data and for suggesting modifications. I am thankful to her.*

I am thankful to **Kum. N.S. Preeti** for helping me in comparison of her results with the results from this thesis, and for providing the data regarding the area under arecanut in Shimoga district.

I owe my gratitude to **Dr. Basavannaiah** and **Sri. Omkarappa**, Warden, General Hostel, Channagiri for providing me accomodation in the hostel during the course of my research.

I wish to convey my thanks to **Sri. Halappa**, Manager, Syndicate Bank, Wilson Garden, Bangalore, **Sri. Narappa**, Lecturer in Kannada, Chikkaballapur, and Dr. **T.N. Prakash**, Assistant Professor, Department of Agricultural Economics, UASB, for suggesting me to check the results for calculating water use effeciency.

My special thanks to **Sri. S. Prakash, Sri. Devaraj, Sri. Parameshachar** and Sri. **Ashok** of Goppenahalli, Sri. **Basavarajappa** of Kagathur and Sri. **Basavraj** of Bussenahalli for their help during Participatory Rural Appraisal mapping and for providing the local contacts.

My friends Sriyuths Anil Yesodharan, Nagesh Rao, Sridhara, KM Sathisha, Sushma Adya, Vinu Vishwanath, Jyothi, Amitha, Preethi, for their moral support and encouragement.

I am equally thankful to my room mates Sriyuths Ashwath and Shivaram for their cooperation and my friends Sriyuths Arun, Nagesh, Gangadhar, Nataraj, RaghuPrasad, KiranChand, Rangaraju, Deepak, Manjunath prasad, Tony, Bippin and Maruthi for their encouragement and support.

Sri Chikkahanumaiah, Assistant Comptroller, Sri Krishna Reddy, Assistant, Agriculture College, GKVK, Sri Ananda Rao, Deputy Comptroller, UAS, Sri Gururajachar, Deputy Comptroller, UAS, Sri Marulasiddiah, Assistant, Sri Malliah, Assistant, have all helped by paying me the fellowship and contingency at the right time during the tenure of this fellowship and I am thankful to them.

Bangalore

20th May 1998

G.Basavaraj

CONTENTS

CONTENTS

List of Figures

GLOSSARY OF THE TERMS USED IN THE STUDY

AI: refers to the volume of groundwater spread over an area of one acre, one inch deep.

AL: Average life of an irrigation well which is the average number of years a well served (in Years) as on 1997

BW: is a borewell drilled from surface with a diameter of 6" and is provided with casing up to the required depth. The groundwater is lifted from submersible pump to the surface.

Cubic meter or M^3 refers to the volume of irrigation water applied in M^3

DCF: Discounted Cash Flow measures namely Internal Rate of Return (IRRIGATION) , Discounted Benefit Cost Ratio (DCBR) and Net Present Value (NPV), used to evaluate long term investments where in cash inflows and cash outflows are made over time. These measures incorporate the time value of money.

DW: is dug well or open well constructed with or without lining having circular/ rectangular/ square or trapezoidal shapes. The groundwater is lifted by centrifugal pump placed inside the well at some height.

STZ: Southern Transitional Zone.

GIA: is the gross area irrigated, refers to the total area by bore wells throughout the year. GIA and GAI are used synonymously to mean gross irrigated area or gross area irrigated. Since majority of the farmers in Channagiri grow arecanut which is a perennial crop, the area under arecanut is counted only once. The area under other crops which are irrigated are also considered here along with the arecanut area.

GPH: Gallons Per Hour.

HWIV: refers to a village with the largest number of wells per million cubic metre of groundwater.

LWIV: refers to a village wiht lowest number of wells per million cubic metre of groundwater.

MC: The marginal cost (MC) of an additional unit of an input applied. The MC of groundwater

is equal to the total irrigation cost on the farm divided by the total water used on the farm.

MR: Marginal returns from an additional unit of an input in acre inch of groundwater for groundwater as input and in Re. of amortized cost when irrigation cost is used as an input.

NR: Net Returns: The profits obtained net of production, irrigation and apportunity costs of dryland and negative externality costs.

QUARTER: Each consists of 25 percent of the farmers. The 25 percent of the farmers are grouped , after arranging the farmers according to the descending order of magnitude of groundwater use per farm. Thus , there are four quarters, totalling to 100 percent . Since the classification is based on groundwater use per farm, the quarters subsume the scale effect on the use of groundwater for irrigation.

SF : Small farmers are those whose GIA is less than 5 acres.

LF: Large farmers are those whose GIA is more than or equal to 5 acres.

Drip irrigation farms: Farms irrigating their arecanut crop through drip irrigation.

Flow irrigation farms: Farms irrigating their arecanut crop through flow irrigation.

INTRODUCTION

CHAPTER I

INTRODUCTION

Accessibility to investments in irrigation gets polarized due to the prohibitive costs involved in extraction, irrespective of the groundwater irrigation potential. Considering an investment of at least half a lakh rupees for an irrigation well ceteris paribus the availability of desirable volume of the right quality groundwater for a reasonable number of years, small farmers who form 70 percent of the farming community, find it difficult to mobilize funds towards the endeavor. Thus, inequity in access to groundwater irrigation exists by default. Further, access to groundwater greatly depends upon the degree of recharge which is influenced by the proximity of irrigation well(s) to surface water bodies like irrigation tanks (*katte, kola, halla, Jari, done, sone, suranga, kalyani, kunte,* and so on). Thus, inequity in access to groundwater gets exacerbated if the surface water bodies do not influence the groundwater recharge which is influenced by other hydrogeological factors. The synergistic relationship between groundwater occurrence in irrigation wells and surface water occurrence in surface water bodies is both through recharge and supplies to surface flows from groundwater aquifers. It is estimated that one third of the river flow is from groundwater aquifers and this is the most stable component of the surface water flow[1]. The synergy between surface water and groundwater resources becomes even more vital in areas dominated by hard rock geological

---

[1] *(FAO, Food Production: The critical role of water, Technical background document, World Food Summit, 1996, FAO, Rome, Italy (downloaded from http://www.fao.org/wfs/final/e/volume2/t07a1-e.htm).*

formations which receive low and erratic rainfall and where perennial sources of surface water like rivers do not exist. According to the FAO document[2].

> "In arid and semi-arid areas, where aquifers are not always or are simply connected to the river network and where surface water is rare and unevenly distributed, groundwater may provide a source of water. Groundwater generally serves as a buffer against seasonal shortfalls in rainfall. It is in this role, for example that groundwater helps to insulate the agricultural economy of the North (South) Indian subcontinent from fluctuations in the monsoon climate. However, some of the most important food producing regions are currently overpumping groundwater and depleting aquifers. The current trend shows that this is the case in most arid areas (e.g. Asia, Mexico, the Near East, North Africa and the Western United-States)".

Hence for areas which are largely distant to perennial river flow, and dominated by poor groundwater recharge due to hard rock geological formations, the synergy between surface water bodies and groundwater contributes for economic security of the farmers. In such areas, the inequity and negative externality (negexternality) endured by different classes of farmers are of prime concern for resource economics of sustainable development. It is in such areas that farmers having benefited from groundwater irrigation wish to sustain by being resilient to the increasing economic scarcity of groundwater through mechanisms to cope with scarcity. Several coping mechanisms facilitate sustenance of groundwater irrigation in hard rock areas. The prevailing crop pattern supporting the food and economic security systems of the farmers and the level of groundwater scarcity conjointly determine the profiles of coping mechanisms adopted by farmers.

---

[2] Op.cit, 1996

SCARCITY AND MARKET FORCES

Farmers operate between economic scarcity of groundwater and the market forces for crops reflected by the product prices. To be explicit, their decision making is a function of how close their marginal product of groundwater is to the ratio of price of groundwater to product price (= relative price of input to output). Further, this depends upon the technological development in water use in different types of crops. In areas dominated by narrow spaced seasonal crops, even if the efficient groundwater use structure like drip irrigation is available, it cannot be used effectively, since drip irrigation technology developed (at least in India) is not suited for narrow spaced seasonal crops.

Karnataka has a tradition of preserving two perennial crops considered to be providing good omen - the coconut and the arecanut. Coconut (garden) - the Kalpavriksha is maintained since (i) offering coconut to deities dates back to the vedas; (ii) coconut is used by people of all classes fairly regularly in their menu and (iii) all parts of the tree serve specific purposes with definite economic values. Similarly, arecanut-betelevine system provides arecanut and betel leaves, both of which are auspicious, and served with coconut to the deities and guests with reverence. Thus, both the crops have religious, traditional, commercial and economic importance to farmers cultivating them. Thus, the fact that arecanut crop is to be preserved at any cost is an institutional factor and farmers in general admit that in the long run they have stood to gain economically and instances of total loss are seldom reported[3]. While coping

---

[3] *However, there was one farmer in this study who had cut down all the areca trees on one acre of land from one fragment owing to acute scarcity of groundwater for irrigation due to failure of irrigation well. However, the farmer continued to raise arecanut in another patch as he could provide protective irrigation to the crop.*

mechanisms are a function of the relative prices, institutional and historical factors linked with the cultivation of crops like arecanut play a crucial role in deciding the water used. Despite increasing interference among irrigation wells, investment by farmers on additional well(s), drip irrigation and water delivery to cope with the scarcity bear a testimony to sustenance the cultivation of arecanut.

Earlier studies initiated by the ford foundation in the Department of Agricultural Economics dealing with groundwater scarcity as determined by the degree of well interference and groundwater exploitation, concentrated on the dry agro climatic zones of Karnataka in the taluks (and villages) where the number of irrigation wells per unit volume of groundwater are the highest (and compared with the lowest).

A major hypothesis of this study is that the magnitude of investment on coping strategies (inter alia investments on water transfers, drip irrigation, water storage tanks, water conveyance pipes and on additional wells, by farmers reflects the degree of economic scarcity of groundwater.

In Channagiri taluk of Shimoga district, groundwater extraction through borewells began since the early seventies, after the efforts to tap the resource from the existing dug wells by deepening and / or inboring failed to bear results (in villages Goppenahalli and Bussenahalli where the number of wells per MCM of groundwater is large). Basically, the groundwater irrigated agriculture in Channagiri - in these villages is targeted at sustaining arecanut - betelvine farming. Mere economics alone does not answer the factors for sustaining areca gardens at costs colossal to farmers.

In Channagiri, farmers considered owning arecanut orchard as a prestige. All the investments made by farmers to sustain areca gardens by way of frequent investments in groundwater and associated irrigation structures (systems) can be considered as farmers' efforts to be economically resilient.

Uniqueness of the Resource

The uncertainties in groundwater availability is mainly due to the hydrogeological factors like rock type, aquifer, topography of the area, surface water bodies, streams, rivers which are location specific. Surface water bodies, streams, rivers have a pervasive influence on groundwater availability and recharge which is taken as proxy to determine the availability of groundwater in the region. With all the advantages associated with surface water, there are certain inherent limitations in its use arising from inter alia disputes over surface water between states, countries; huge investments involved in major irrigation projects; inequities in access have made groundwater a vital resource.

CROPPING PATTERN

Channagiri taluk in Shimoga district (from 75°-45' to 76°-54' latitude to 13°49' to 14°10' longitude, elevation 450-800 meters), has an area of 1210 sq kms with a population of 2.57 lakhs. Red sandy loamy soils form the major soil type. The taluk is in Krishna basin and receives a low rainfall of 808 mm. Out of the net sown area of 73,014 hectares in Channagiri, 11 percent is irrigated by minor irrigation sources. The gross irrigated area is 9856 hectares of which 60 percent is irrigated by 1942 groundwater wells. The irrigation wells in Channagiri form 33 percent of the total number of wells (5907) in Shimoga district. Even though the district has the largest area (57,479 hectares) under irrigation tanks in the State (2,69,023 hectares), forming 21 percent, Channagiri has a few (133) irrigation tanks irrigating 40 percent of the irrigated area in the taluk. There are no anicuts, pickups or lift irrigation schemes operating in the taluk. The area under arecanut in Channagiri taluk is 1800 hectares.

Virtually with no support from rainfall and surface irrigation sources, farmers ventured on to cultivation of arecanut-betelvine centuries ago, largely depending upon groundwater irrigation wells. With a meager rainfall of 800 mm, the major source of recharge of groundwater is through irrigation tanks. There has been large scale encroachment of irrigation tanks and coupled with erratic distribution of rainfall, the tanks rarely fill up, which reduces the groundwater recharge. Farmers however fully recognize that their wells are recharged largely by irrigation tanks and hence application of tank silt as a tradition has continued in the area. However this also has not augmented recharge, since water flow to irrigation tanks has been affected due to series of encroachments. The erratic rainfall has exacerbated the predicament.

Arecanut a perennial commercial crop, occupies 1800 hectares. Arecanut cultivation has been lucrative and stable since many decades and the 'Bette' arecanut from Channagiri commands a good price due to its unique quality. While growers realize a net profit of around Rs. 40000 per acre, the processing of arecanut, largely attended to by women, have also been benefited as the wages are paid in kind (arecanuts) in the groundwater irrigated area of Channagiri. Here, dependence on monsoonal rainfall during the rainy season alone does not guarantee sustainability of the crop, especially during summer. Considering the crops which use large volumes of water (paddy and sugarcane), the total area under paddy has reduced marginally from 3852 hectares in 1984 to 3665 hectares in 1994, while that under sugarcane declined from 136 hectares in 1984 to 72 hectares in 1994. This shows that the total volume of water in Channagiri taluk may not have reduced significantly, due to the receipt of 800 mm rainfall in the southern transitional belt. In addition, the presence of the largest irrigation tank in the world (Shantisagara) enables farmers to maintain areas under water intensive crops such as paddy.

Even though the water availability on the basis of the entire taluk is not at stake, the groundwater scarcity is apparent in certain pockets where this study is concentrated. Even though Channagiri is classified as a white area (i.e. where less than 65 percent of the groundwater recharge is used), there are dark (Goppenahalli, Pandomatti and Devarahalli) and grey patches.

Use of groundwater for irrigation in Channagiri taluk is closely linked with the Arecanut - Betelvine cropping system. Cultivation of Arecanut has been a symbol of status since age old days. Favorable prices for arecanut and its commercial importance have increased its importance.

The major objective of this study is to examine the resource economics of groundwater use for irrigation where interactive effects of irrigation wells induce the farmers to cope with the economic scarcity of groundwater.

The specific objectives of the study are:

1. To identify and analyze the coping strategies followed by farmers in response to decline in groundwater

2. To analyze and appraise the economic feasibility of investment on the coping mechanisms

3. To examine the economic implications of groundwater scarcity on cropping pattern, employment and income.

HYPOTHESES OF THE STUDY

Objective	Hypotheses
1. To identify and analyze the coping strategies followed by farmers in response to decline in groundwater	1. Magnitude of investment on coping strategies (investments on water transfers, drip irrigation, water storage tanks, water conveyance pipes and on additional wells, Shifts in cropping pattern) reflects the degree of economic scarcity of groundwater.
	2. Farmers who have invested in water transfer from fairly long distances and/or in drip irrigation, are facing acute economic scarcity of groundwater.
2. To analyze and appraise the economic feasibility of investment on the coping mechanisms	1. The investment on coping mechanisms is economically viable even after considering the negative externality costs of cumulative well interference.
	2. Economic scarcity of groundwater has lead to shift in cropping pattern towards low water use crops.
3. To examine the economic implications of groundwater scarcity on cropping pattern, employment and income.	1. Economic scarcity of groundwater due to cumulative well interference is dampened by the influence of recharge through surface water bodies in proximity.
	2. Cumulative well interference and lack of efforts towards groundwater recharge have both lead to economic scarcity of groundwater.
	3. The income and employment are largely affected by the degree of economic scarcity of groundwater.
	4. The magnitude of investment to cope with the economic scarcity reflects the capacity to be resilient.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The research studies relating to coping mechanisms adopted by farmers in response to economic scarcity of groundwater are presented.

Study by Thamodaran, Bhide and Heady (1982) in southern parts of TamilNadu (Udangundi block in Tirunelveli district), shows that farmers have devised two methods to increase the water holding capacity of light textured soil and have succeeded in raising three crops of paddy a year in the place of a single crop of banana. The two improved water management systems involved are i. concrete system and ii. silt system. The concrete system involves laying a concrete layer two feet beneath the top soil and raising a four feet high, five inch thick masonry wall around the field. The silt system involves raising a 4 feet high, 5 inch thick masonry wall around the field followed by addition and mixing of fine silt to the existing sandy soil. The results indicated that both concrete and silt system are economically feasible in agro-climatic situation analyzed. Silt system was found to be more profitable.

Sivanappan and Kottiswaran (1985) reported 63 per cent savings in water in drip irrigation when compared to conventional surface irrigation for young coconut trees in India. Yield increased by 60 to 70 per cent within a year of installation of the drip system.

Cevik *et al* (1988) tested two irrigation methods in 1983 and 1984. Water use efficiency was greater with drip irrigation and the system saved 50 per cent water for banana crop.

Omar (1989) examined theory, history, economics, evaluation and applications of the conjunctive use of surface and groundwater. Feasibility and institutional implications of irrigated agriculture are illustrated by case histories from USA, Pakistan, China and other countries. Particular attention is paid to the concept of externality- costs borne by society or by persons other than those whose actions occasioned them. Various remedies like institutional arrangements , management methods, investments in irrigation and drainage as well as plans for pricing taxation and regulation are discussed.

Caswell *et al* (1990) conducted a study on the effects of pricing policies on water conservation and drainage in western San Joaquin Valley in California emphasizing on the relative importance of conservation. Adoption of water conserving irrigation technologies is often cited as a key to dealing with growing pressure on water supplies in Western United States. Increase in water use efficiency can be simulated through increased water prices, adoption of water conserving irrigation technologies and imposition of pollution taxes. The author concludes that environmental consideration may become a major incentive for adoption of water-conserving irrigation technologies such as drip and sprinkler irrigation methods.

Dixon and Lloyd (1990) examined groundwater extraction in Kern county of California. A detailed model of the aquifer agricultural water demand functions in Kern county is used to estimate the difference between the myopic and socially optimal solutions. In terms of discounted present value, the difference is found to be small. The study found that choice of irrigation technology is quite sensitive to water price. Cropping pattern is also influenced by water price but to a lesser degree. Water demand is found to be relatively insensitive to water price in the observed range of prices. Farmer attitudes toward groundwater were also examined. Farmers do not attribute a significant user cost to groundwater and seem to behave as though they were myopic. A primary reason is that the farmers feel their groundwater pumping has no impact on the drilling depth.

Singh (1992) discusses the policy implications for agricultural development strategy. The analysis has shown that inadequate rainfall and extension of area under paddy have been two principal reasons for decline in groundwater tables in Punjab. Changing the cropping patterns, particularly rice, for less water demanding crops, is necessary for Punjab (Singh, 1989). In this context, extension of 'sugarcane' an annual crop in place of paddy-wheat combine may be economical to the farmers and water saving as well. Two thirds of the irrigated agriculture in Punjab depends on groundwater irrigation alone. The large dip in groundwater table coupled with diminished water discharge from tubewell and increased use for non agricultural uses, rural demand and increase in gross and net area irrigated have caused depletion in groundwater.

A study conducted by K.M. Mane (1992) in Marathwada region of Maharastra on the economic analysis of different methods of irrigation in grapes has shown that the total investment on drip irrigation structure amounted to Rs. 38,387 per hectare. The net benefits obtained from vineyards under drip irrigation amounted to Rs. 1,18,503 per hectare. Under traditional method the net benefits obtained amounted to Rs. 1,02,540 per hectare. The study also indicated under drip irrigation method, there is labor saving of about 60 per cent in the costs incurred for weeding as compared to the traditional irrigation method.

A detailed study was conducted by Rao (1993) in two small watersheds in Malur taluk of Kolar district and Davanagere taluk of Chitradurga district to understand the serious implications of water level decline in hard rock areas of Karnataka state. Farmers tackled the problem of declining water levels by constructing bore wells, which actually hastened the decline of water levels because these structures, by virtue of their depth, are capable of withdrawing more water than the conventional dugwells. As a consequence, many dugwells became dry and investment in them and in pumpsets became unproductive. Thus, large numbers of farmers who had reliable dugwell irrigation a few years back are now deprived of irrigation because they did not have resources to attempt boring after the dugwell became dry or because the bore well drilling they attempted did not prove successful. Such farmers have now switched over to dry land farming and the poorer among them are supplementing their meager and uncertain farm income through agriculture labor. The over-exploitation of groundwater resource in many taluks of Bangalore, Kolar and Tumkur districts has forced abnormal drop in water levels. This has resulted in failure of dugwells and tubewells, scarcity of drinking water, an increase in electricity consumption, dropping efficiency of pumps, increase in the unit cost of wells, and negative impacts on small and marginal farmers.

Study by Kumar and Patel (1993) in Mehsana District in northern Gujarat which relies on groundwater to the extent of 96 percent indicates that, water table here has receded resulting in high investments to deepen the wells threatening the sustainability of agriculture. Field studies conducted in five villages on the impact of groundwater depletion indicate that (i) crop selection decisions were based on crop water requirement as well as profit potential and

(ii) conveyance pipes were attractive to farmers as a way to reduce water loss and expensive pumping time.

The study conducted in Vaigai basin of TamilNadu. In a survey conducted by Janakarajan (1993) reports that there is a tremendous increase in the original well depth. Out of 345 sample wells, whose original depth was less than 30 feet farmers have moved on to a higher depth range at the time of survey; 23 per cent of sample wells whose original depth was 30 feet have moved 5 feet down and about 10 per cent of the sample wells whose original depth was 50 feet were deepened upto 75 feet .

Groundwater has been heavily overdrawn in arid and semi arid regions in the northern part of China. This has led to the emergence of serious problems in the water environment such as land subsidence, intrusion of seawater, and pollution of groundwater. Sheng and Xuefeng (1993) focused on conservation in water use: control of canal seepage, adoption of low pressure pipes for water transport, leveling of agricultural land, introduction of small border irrigation, combination of water saving irrigation with inter-cropping of cotton and wheat, growing of cover crop with PVC film, using straw cover on farmland, storage of irrigation water to raise the ratio of water reuse.

Ananda (1994) conducted a study on the performance of guava under drip irrigation. The results of the study indicated that drip irrigation requires only 54 per cent of total water required under flood irrigation and this increased water use efficiency by 2.6 times as compared to flood irrigation. Drip irrigation generated a positive NPV (Rs.5,80,007) and BCR of above one (4.82) and IRR of 142 per cent at 15 per cent discount rate.

Arun (1994), observed that farmers responded to well failure by drilling additional well(s), reducing area under high water intensive crops, shifting to the low water intensive crops like mulberry or by investing on water saving technologies like drip or sprinkler irrigation systems. The marginal willingness to pay for and additional well was Rs.48,370.

Nagaraj (1994), observed that around 71 percent of the farmers constructed earthen overground tanks to store the pumped water, to circumvent both irregular supply of power and lower discharge from the well. On an average, farmers were found to invest Rs.23000 on additional well to combat the well failure.

Nagaraj and Chandrakanth (1995) in their study on the low yielding irrigation wells of peninsular India. indicated that the adoption of an intelligent mix of water intensive (vegetables) and light water crops (mulberry) in the cropping pattern contributed to the viability of low yielding borewells. With an average holding size of 10 acres, net irrigated area of 3.6 acres and gross irrigated area of 8.64 acres, the gross and net returns per farm amounted to Rs.75,116 and Rs.31,805 respectively. In 1991 prices, the investment per borewell was Rs.75,756. The cost of production per well per acre of gross irrigated area including the amortized cost of irrigation and the opportunity cost of returns from dry land was Rs.6699 with a net return of Rs. 1995.

About 43 percent of the farmers preferred to pay electricity on pro-rata basis at a rate of 18 paise per KWH if the electricity supply was uniform.

The study conducted to analyse the impact of drip irrigation on coconut plantations by Lokesha (1996) in Bangalore district indicated that the water use efficiency (in Rs. per cubic meter) defined as the ratio of net income (in Rs. per hectare) to total water used (cubic meter per hectare) for drip irrigation was Rs.30 per cubic meter under drip irrigation system compared to Rs. 13 per cubic meter under flood irrigation. The net returns under drip irrigation system was Rs. 49,461 per hectare compared to Rs. 31,755 per hectare under flood irrigation system.

Shyamasundar (1997) in his study on the interplay of markets, externalities, institutions and equity in groundwater development- in Athani taluk has shown that farmers coped with well failure by adjusting their crop pattern in favor of less water intensive crops. The costs of deepening the original dug well ranged from Rs. 11,438 to 14,352. A logit model was used to find out the probability that the farmers will make an additional investment in well irrigation. The probability that farmers would make additional investment in well irrigation was 0.47.

A study conducted by Satisha (1997) in Madhugiri in Central dry zone of Karnataka on the coping mechanisms adopted by farmers indicated that ground water markets as was one of the coping mechanisms adopted by farmers of Channagiri. A few farmers bought groundwater to grow paddy, ragi and arecanut at a price of Rs. eight per hour for paddy, while on other hand farmers paid one third of the paddy output as crop share. The farmers irrigation wells they suffered due to cumulative interference.

Prasad (1997) lists the following coping strategies in the wake of well failure:

1. Reduction in cropped area,
2. Water sharing by farmers,
3. Fodder cultivation,
4. Shift to less water intensive crops i.e. from paddy to silk cotton,
5. Shift to crops having short gestation period namely beans, ladies finger, coriander,
6. Transfer of water through cement pipes,
7. Irrigation just to keep the soil wet,
8. Shift to tree crops such as coconut, guava, mango,
9. Deepening of wells,
10. Risk aversion through crop diversification,
11. Save half, leave half - Irrigate standing crop to the extent possible and allow the remaining crop to die,
12. Drip irrigation and
13. Secondary occupation overtakes primary occupation (eg. Dairy)

The mechanisms used to cope with scarcity of groundwater, documented by Lokanathan (1997) are:

1. Deepening of wells,
2. Installation of borewells in dugwells,
3. Decline in paddy area and increase in area under commercial crops.
4. Cropping intensity reduced from triple cropping to single cropping.
5. Decrease in number of farmers growing water intensive crops.
6. Shift in choice of paddy variety from long duration to short duration variety.
7. Increasing depth of all types of wells.
8. Recharge efforts such as desiltation of tanks, tank modernization, deepening of tanks, construction and modernization of percolation ponds.
9. Adoption of drip and sprinkler systems.

METHODOLOGY

CHAPTER III

METHODOLOGY

Sampling framework, analytical methods followed in data analyses, the factors/variables in estimation of costs of resilience, externalities and costs associated with groundwater scarcity are described here. A brief glossary of the terms used in this study is available in the first chapter. A major objective of this study is to study the economics of irrigation especially when interactive effects of well interference are present and how the farmers cope with this predicament.

3.1 SAMPLING FRAMEWORK:

This study forms a part of the major research endeavor[1] to analyse the equity issues and coping strategies in groundwater development in covering the major groundwater scarce areas of Karnataka. The eastern, northern, central, and southern dry zones have been covered in separate studies. These studies dealing with groundwater scarcity determined by the degree of well interference and groundwater exploitation, concentrated on the dry agro climatic zones of Karnataka in the taluks (and villages) where the number of irrigation wells per unit volume of groundwater are the highest (and were

---

[1]. *Ford Foundation which has sponsored this study, has also sponsored studies in the dry zones of Karnataka covering Athani, Devanahalli, Chamarajanagar, Channagiri, and Madhugiri taluks.*

compared with the lowest)[2]. A major hypothesis of this study is that the magnitude of investment on coping strategies (inter alia investments on water transfers, drip irrigation, water storage tanks, water conveyance pipes and on additional wells, by farmers reflects the degree of economic scarcity of groundwater. Among these coping strategies, information on concentration of drip irrigation sets, water transfers by farmers was available from the discussions with prime drip irrigation firms, while information on other coping strategies were not available from any source. In the next layer of analysis, it is hypothesized that those who have invested in drip irrigation and/or transferring water from fairly long distances, are facing severe economic scarcity of groundwater. With these two hypotheses, Channagiri taluk of Shimoga District in the Southern Transitional Zone was chosen for detailed analysis. Channgiri has the largest number (56) of irrigation wells per million cubic meter of groundwater, next to Hassan (60) in the Southern Transitional Zone.

---

[2] *a. Shivakumaraswamy, B., 1995, Economic implications of unsustainable use of groundwater in hard rock areas of Karnataka , M.Sc. thesis (unpublished), University of Agricultural Sciences, Bangalore.*

b.. Satisha,K,M., 1997, Resource Economics Study of Valuation of well interference externalities in central dry zone of Karnataka, M.Sc. thesis (Unpublished) University of Agricultural Sciences, Bangalore.

c. Adya, Sushma, 1998, Scarcity of groundwater for irrigation: Economics of coping mechanisms, M.Sc. thesis (Unpublished) University of Agricultural Sciences, Bangalore.

3.1.1 SELECTION OF VILLAGES

Villages with the largest number of wells per million cubic meter of groundwater are hypothesized[3] to bear the greatest interactive effects of wells. Accordingly the villages were ranked in the descending order of magnitude of the number of wells per MCM of groundwater. From among those villages with large number of wells per million cubic meter of groundwater (Goppenahalli 215), Bussenahalli (64) are chosen to represent High Well Interference Village (HWIV) (Table 3.1).

From among the villages with smaller number of wells per MCM of groundwater, Kagathur (24) and Chikganguru (27) are chosen to represent Low Well Interference Village (LWIV) (Fig 1). Kaggathur has irrigation well(s) close to the largest irrigation tank (Shanthisagara).

---

[3] *For the selection of villages in Channagiri, the villagewise availability of groundwater for irrigation was computed by using the ratio*

$$\frac{\textit{(Village Net sown area)}}{\textit{(Taluk Net sown area)}} \times \textit{(Utilizable groundwater for irrigation for Channagiri taluk)}$$

The data on net sown area for the village and the taluk pertain to 1991 census. The villagewise number of wells per MCM of utilizable groundwater was then computed (Appendix). Villages are ranked in the descending order of the number of wells per MCM of utilizable groundwater for irrigation. For the purpose of choosing the sample farmers, the top two villages Goppenahalli and Bussenahalli which had the large(st) number of wells per MCM of utilizable groundwater for irrigation were chosen to sample forty farmers representing High-Well-Interference-Village (HWIV). Among these two villages the village (Bussenahalli) with influence of irrigation tank for groundwater recharge and the village (Goppenahalli) with out the influence of tank recharge were chosen. The bottom two villages one having influence of tank and other as not having influence of tank were chosen to sample thirty eight farmers from the Low Well Interference Village (LWIV) (akin to control) - Kagathur and Chickgangoor. This contrast meant that this study is to test whether the effect of groundwater recharge through irrigation tanks will subdue the problem of well interference. Hence for contrast the villages (Kagathur and Chickgangoor) which had lowest number of wells per MCM of groundwater and one village (Kagathur) which had influence of irrigation tank recharge and another village with no influence of irrigation tank recharge (Chickgangoor) were chosen. In order to confirm, whether the villages so chosen did reflect the problems of well interference, a reconnaissance survey of each of the villages was made and farmers were contacted to confirm the prevalence of well interference phenomenon.

Table 3.1: Distribution of sample farmers in High well interference villages and low well interference villages.

Name of the village	Number of farmers	Name of the village	Number of farmers
HWIV	**42**	**LWIV**	**38**
Bussenahalli	22	Kagathur	20
Goppenahalli	20	Chikganguru	18

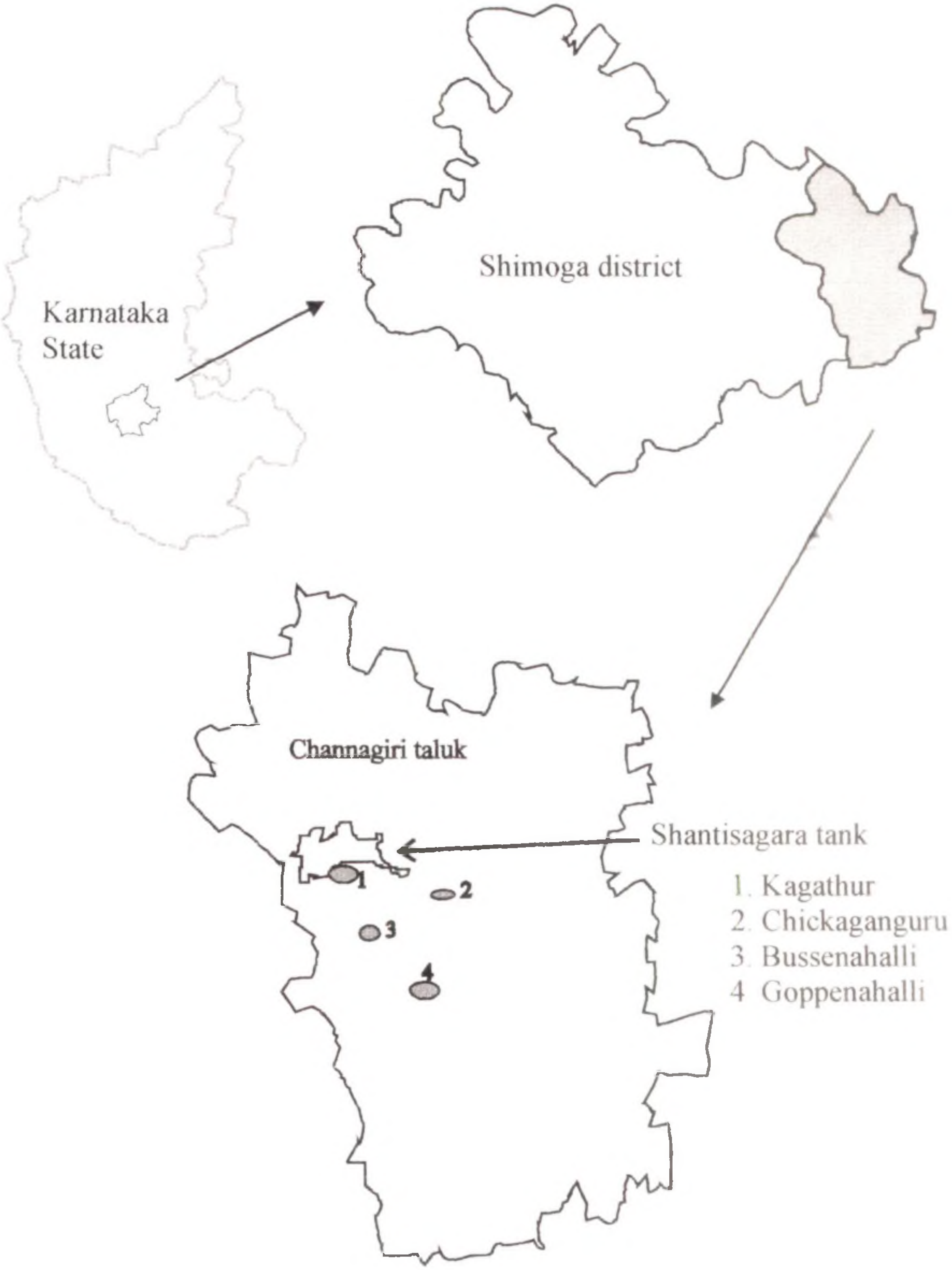


Figure 3.1: Sample villages in Channagiri taluk

In Channagiri, groundwater extraction through borewells began since the early seventies, after the efforts to tap the resource from the existing dug wells by deepening and / or inboring failed to bear results (in the HWIVs of (Goppenahalli and Bussenahalli). Basically, the irrigated agriculture in Channagiri - in the HWIV was targeted at sustaining arecanut-betelvine farming.

Participatory Rural Appraisal approach was used to map the density of wells by recording type of well(s), number of wells, depth, interwell distance and name of well owner. This map is used to locate farmers who are affected by cumulative well interference. Usually this is a discernible patch in the village and farmers located in this patch are selected for detailed study.

3.2 FEATURES OF STUDY AREA

The Southern transitional Zone (STZ) has a geographical area of 16.6 lakh hectares, with a net cultivated area of 6.75 lakh hectares with a gross cropped area of 7.88 lakh hectares. STZ has an irrigated area of two lakh hectares forming 25 percent of the net cropped area. Channagiri taluk is 2970 feet above mean sea level with a geographical area of 63,166 hectares. The taluk receives a rainfall of 800 mm of which more than 50 per cent is in the monsoon and pre monsoon season. Nearly two thirds of the district is covered by Dharwar schist, the Shimoga band forming a prominent belt from West to East and occupying a larger area. This belt is made of various types of Schist's, chiefly chlorites and in places micaceous or hornblendic, associated with volcanic rocks of different types. Also, some highly altered sedimentary rocks such as quartzite, conglomerates, limestone, shells and banded ironstone are found.

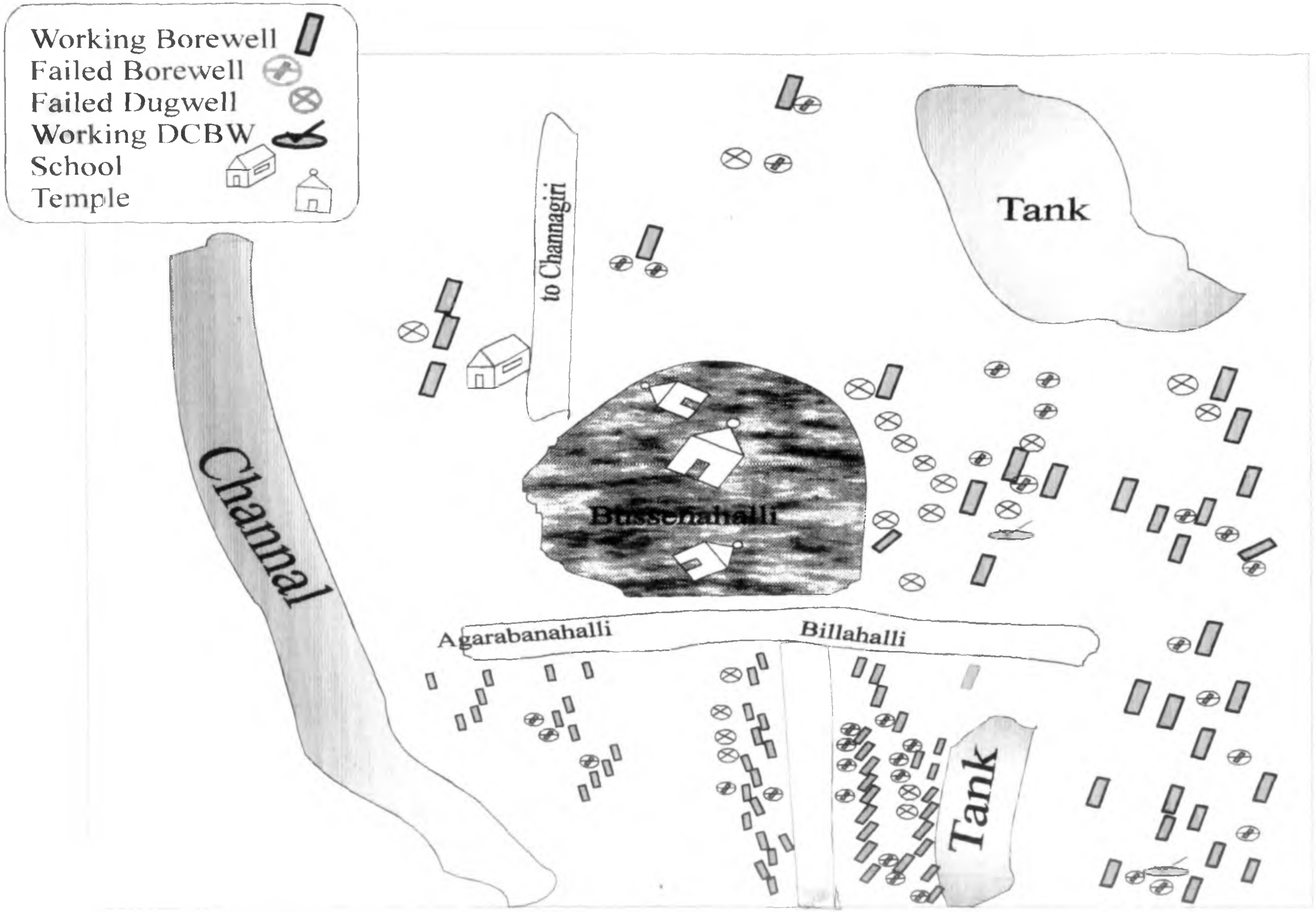


Fig 3.2 : PRA map of Bussenahalli village of Channagiri Taluk, Karnataka, 1997

Relative humidity during the mornings through out the year generally exceeds 75 per cent. Driest part of the year is the period from January to March when the relative humidity in the afternoons is below 35 per cent. The cold season is from December to February and the hot season is from March to May. The South-West monsoon is from June to September and post monsoon is from October to November when monsoon retreats. Geographical area is 1,29,976 hectares of which the total cultivated area is 71,914 hectares. The barren land is 2,077 hectares and 6431 hectares are left fallow. The total irrigated area is 23,276 hectares of which the area irrigated by canals is 13,070 hectares (56 per cent), the area irrigated by tank is 2572 hectares (11 per cent), area irrigated by dugwells is 395 hectares, a modest proportion of 1.69 per cent and while that of borewells 6468 hectares (27 per cent).

Ceteris paribus conditions

It is in order to note that the cumulative well interference needs to be studied under ceteris paribus conditions. Accordingly the data are collected for the year 1996-97 when the rainfall was good, which implies that if the problem of cumulative interference is apparent, even the year of good rainfall will not dissipate the negative externalities of cumulative interference. After choosing the villages, primary data were collected for the year 1996-97 the latest year which received good rainfall (Questionnaire is in Appendix).

3.2.1 DESCRIPTION OF HWIV

Bussenahalli, the high-well-interference-village (HWIV) is three kilometers from Channagiri. Here the problem of interference is dampened due to influence of groundwater recharge. Farmers indicated that the irrigation tank in Malahal village five kms away is helping in groundwater recharge. Here the cropping pattern is dominated by arecanut. However, the usual inter-cropping of arecanut with betelvine is not practiced. Flow irrigation to arecanut garden is the common practice.

Goppenahalli, another high-well interference village (HWIV) has the Goppenahalli tank, at present in a bad condition due to encroachment. Though the tank has been desilted due to application of silt as manure to areca garden, the impact of desiltation is not apparent as the tank bed is encroached for cultivation of arecanut. Most of the groundwater farmers in Goppenahalli have areca gardens. There are at least 600 borewells in this village. Large scale initial failures of wells experienced here is an indication of the acute problem of well interference. Inter cropping betel-vine in areca gardens is a common practice. Coconut is grown as a border crop. Apart from arecanut, other commonly cultivated dry land crops are maize and jowar.

FEATURES OF LWIV

Kagathur village is one of the low well interference village (LWIV). The irrigation wells in this village have benefited from groundwater recharge from Shantisagara. Kagathur is surrounded by the Shantisagara waters on the north west and north east. Basappanakere (tank) is to the south of the village. A few farmers on the western side of the village however experienced large scale (15 initial and natural) failures. This was reflected in the PRA mapping and during the oral history interviews. Shantisagara, the largest irrigation tank (in India) lies to the North-West of Channagiri. This tank known as 'Sulekere' till recently, was built during 11th century by Shantavva

Shantisagara tank now receives water perennially from Bhadra right bank canal (Pic. of Shantisagara).

Kagathur has a geographical area of 450 hectares with 371 hectares (33 hectares irrigated, 331 hectares dry land) under cultivation. Among the 232 farmers in the village 110 are small farmers (owning less than five acres of gross irrigated area) and 59 are large farmers (owning greater than or equal to five acres of gross irrigated area). All the open wells in the village have failed. The farmers in the sample have arecanut garden under well irrigation and grow maize on rainfed lands.

Chickganguru, another low well interference village is located 20 kms from Channagiri. The well failures here are lower compared with Kagathur. Also, the cropping pattern here differs. Shallow borewells are common. Farmers have used local rigs (in Kannada - "*mudde*" bore) to drill irrigation wells closer to irrigation tanks. These wells are still working and are providing good source of groundwater at a lower depth. Groundnut, maize, cotton, sunflower and onion are the major crops grown here. However, in recent years, farmers are shifting to arecanut due to its profitability and low cost of maintenance after establishment. The geographical area of the village is 672 hectares of which 517 hectares are cultivated. Of the 253 cultivators, 93 are large, 85 are medium and 75 are small farms.

3.3 ANALYTICAL FRAMEWORK

Estimation of the age of wells is crucial for estimating the cost of irrigation which includes the cost of externalities. The age of irrigation wells influences the costing of irrigation well, economic losses due to the failure of wells before their average life in that particular area, negative externality cost due to cumulative well interference problems and the economics of coping mechanisms adopted. A major objective of this study is to study the economics of irrigation especially as the farmers cope with the predicament of interactive effects (interference) of wells. As the cost of irrigation varies directly with the number of years of functioning of well(s), the estimation of age of wells is a vital part of the costing exercise.

3.3.1 WELL AGE AND WELL LIFE

Age of irrigation well refers to wells that were functioning at the time of collection of field data (July - August 1997). The age of the well is estimated as year 1997 minus the year of well construction or sinking or drilling. The average age of the well includes age of all those wells which are functioning at the time of obtaining field data. The average age of the well is estimated using the 'life tables' as under:

Age of the well = $S[(f_i X_i)_{,} S(f_i)$, where

f = number (frequency) of wells yielding irrigation water in each age group,

X = age group of well (0,1, 2 .3... in years). Wells constructed during 1997 and functioning are assumed to have zero age, as the effect of interference on age of these wells is difficult to be predicted or simulated.

Life of irrigation wells refers to the number of years a well already functioned. Accordingly well life is a concept applicable to the totally failed and abandoned wells. The well life is estimated as year of failure minus year of construction / sinking / drilling. All those wells which suffered from initial failure obviously have zero life. By hypotheses of this study, initial failure or failure after serving some years, are both attributed to the cumulative well interference.

Average life of the well is estimated as = $S[(f_iX_i),S(f_i)$ where, f = frequency of wells yielding irrigation water in each life group, x = life group of well (0,1.2.3.. in years) and i ranges from 1 to n, where n refers to the last year of working of the well. In this study average age or average life of wells includes the age of both failed and functioning wells. Thus, the average age of the well is used as a comprehensive indicator of the number of years a well provides irrigation service.

3.3.2 COSTING IRRIGATION DUG WELL

Groundwater is extracted from three types of irrigation wells in both HWIV and LWIV, namely Dugwells (DW), dug-cum-borewells (DCBW) and Borewells (BW). Considering the total frequency of wells, borewells are the dominating type in Channagiri.

In costing dug well (DW), DW cost is taken as the historical cost (including cost of divining, drilling / digging/ lining at the time of construction. The historical cost is compounded from the year of construction till 1997 irrespective of whether the well is working or not. This is done to estimate the total investment made by farmers in irrigation in 1997 prices. An interest rate of i = two percent represented the rate of inflation in the cost of well components like labor, pumpset, accessories and so on. Rates higher than two percent gave unrealistic results and hence were not considered.

3.3.3 AMORTIZED COST OF DUG WELL

Amortized cost of dug well is the annual fixed cost component of irrigation including the cost of well interference. As investment in groundwater irrigation is considered as a fixed cost, the neoclassical economics prescribes the rationale of treating the groundwater investment beyond the purview of decision making. However, in the village(s) considered in the study, though fixity of investment in irrigation is uncertain, due to declining age of irrigation well(s) and highly fluctuating yield in well(s) considering the low recharge, the cost of irrigation cannot treat the investment in wells as fixed. Thus, the amortized cost varies with the economic factors such as inter alia type of well, status of well i.e. - failed or working, year of construction, average age / life of well, interest rate, degree of interference, crop pattern.

Amortized cost of irrigation dugwell = [Amortized cost of dug well + amortized cost of pumpset and accessories + amortized cost of conveyance + amortized cost of overground storage structure + annual repairs and maintenance cost of pumpset and accessories]

1. Amortized cost of dug well= [Compounded cost of dugwell] X [$(1+i)^{AL}$ X i] , [$(1+i)^{AL}$ - 1]

Here, AL = Average life of well,

Compounded cost of dugwell = DW cost X $(1+i)^{(1997\text{-year of construction})}$

Amortized cost of pumpset and accessories = {[Sum of compounded cost of pumpset, pump house, overground storage structure] X [$(1+i)^{10}$ X i] , [$(1+i)^{10}$ - 1]}

The working life of pumpset, pump house, conveyance pipe is assumed to be ten years and that of overground storage structure is assumed to be five years. The interest rate is taken as two percent to represent the rate of inflation on these items.

Amortized cost of conveyance = [(Compounded cost of conveyance pipe used) X $[(1+i)^{10}$ X $i]$, $[(1+i)^{10} - 1)]$

2. <u>Amortized cost of Dug-cum-borewell</u> = (Amortized cost of DCBW + Amortized cost of pumpset + Amortized cost of conveyance + repairs and maintenance cost of well + repair and maintenance cost of pumpset and accessories.

Amortized cost of DCBW = [Estimated cost of DCBW at current prices] X $[(1+i)^{AL}$ X $i]$, $[(1+i)^{AL} - 1)]$

Amortized cost of pumpset = [Sum of Compounded cost of pumpset, pumphouse, at current prices] X $[(1+i)^{10}$ X $i]$, $[(1+i)^{10} - 1]$

The life of pumpset, pumphouse are considered to be ten years, as above.

Amortized cost of conveyance = [Compounded cost of conveyance at current prices] X $[(1+i)^{10}$ X $i]$, $[(1+i)^{10} - 1]$

The usual mode of conveyance of water is through PVC pipes.

3. <u>Amortized cost of borewell</u> = (Amortized cost of BW + Amortized cost of pumpset + Amortized cost of conveyance + repairs and maintenance cost of repair and maintenance cost of pumpset and accessories)

Compounded cost of borewell = historical cost of borewell X $[(1+i)^{(1997\text{-year of construction})}$

Amortized cost of BW= [Compounded cost of Borewell] X $(1+i)^{AL}$ X i] , $[(1+i)^{AL} - 1)]$

where AL= Average life of borewell;

Amortized cost of pumpset = [(Sum of Compounded cost of pumpset, pumphouse, at current prices] X $[(1+i)^{10}$ X i] , $[(1+i)^{10} - 1]$

As mentioned earlier, the life of pumpset, pumphouse are considered to be ten years.

Amortized cost of conveyance = [Compounded cost of conveyance at current prices] X $[(1+i)^{10}$ X i] , $[(1+i)^{10} - 1]$

The usual mode of conveyance of water is through PVC pipes.

In the above cases, average life, for conveyance and for pumpset is assumed 10 years and interest rate is assumed to be two percent to represent the inflation rate in these items. Discount rate of two percent has been used to amortize the irrigation cost, since some of the (dug) wells served for at least 25 years on an average and any higher rate of discount was found to distort the compounded cost of historical investment estimates, as mentioned earlier.

3.3.4 YIELD OF IRRIGATION WELLS

Bore well was the predominant structure yielding irrigation water in the HWIV and LWIV villages as all the dugwells and dug-cum-borewells had failed. Field measurements of the groundwater yield on a sample of 7 bore wells were taken in the kharif season (June - Aug 1997) by recording the number of seconds to fill a bucket of water of known volume. This was linearly extrapolated to obtain the groundwater yield in gallons per hour.(Table 3.2).

In order to estimate the yield of dugwell, the dugwell farmers were asked to indicate the height of water column the well would regain after 24 hours of pumping. Since most dugwells are rectangular (or square) shape, the volume of water collected per day was estimated as l x b x h,

where l = length; b = breadth and h = height of water column the dugwell regained after 24 hours of pumping

The resultant volume was converted into gallons per hour (GPH) using the conversion, 1 cubic foot = 6.2288 gallons. Finally (l*b*h*6.2288)/24 gave the yield of well in GPH from a rectangular (or square) shaped dugwell. The yield of the well is only an estimate using the volume of water impounded in the well after 24 hours of pumping. This estimate however has severe lacuna since the information on volume of water impounded in the well is sought from the farmer at the time of data collection (August 1997). The volume of water impounded in the well after 24 hours of pumping varies from season to season depending on rainfall, recharge etc.

3.3.5 ANNUAL COST OF IRRIGATION

Till recently, in Karnataka (and in most of the States in India), farmers using irrigation pumpsets (below 10 HP capacity) were not charged for the electricity used to lift irrigation water. Thus, there were no explicit costs of irrigation as there were no operational costs of payments towards use of electricity. Accordingly, as no variable costs were incurred by farmers in lifting groundwater other than repairs and maintenance to the irrigation pumpset, there would be no charges towards the cost of irrigation.

Table :3.2 Measurements on yields of borewells of seven sample farmers

(Gallons Per Hour)

Name of the farmer	Yield as reported by the farmer [a]	Yield according to field measurement [b]
Srikantachar	2000	1586
Thippeswamy	2000	1586
Nanjappa	1000	1721
Panchaksharaiah	1500	1322
Chandrashekhar	1500	1133
Basavarajappa	2000	1057
Nanjappa	1000	721
Average	1714	1148
Standard deviation	364	352
Co-Variance	0.20	0.36
Correction Factor $= \frac{[b]}{[a]}$	0.66	

NOTE:

[a] = is is the yield of borewell as indicated by the farmer according to his perception and / or information.

[b] = This is the yield of the borewell measured by the researcher during August 1997. After a few of minutes of putting on the pump, the time taken (is recorded) to fill a 15 litre bucket was recorded and this was linearly extrapolated to obtain the field measurement.

Thus, the annual cost of irrigation = Amortized cost of irrigation well + amortized cost of conveyance + amortized cost of pumpset and electrical installation + annual cost of repairs and maintenance. The labor cost of irrigation is merged wit the cost of labor for other cultural operations. The labor cost involved in irrigation is thus not considered in the cost of irrigation. The annual cost of irrigation pertains to each irrigation well on the farm and this is added across all wells on the farm. The farmers on an average possessed 5.57 irrigation borewells in HWIV of which 2.09 wells were working and possessed 2.15 irrigation borewells in LWIV of which 1.65 were working. After obtaining the total amortized cost of irrigation across all the wells and irrigation structures, this cost is apportioned for each crop, using the proportion of the irrigation water pumped for the crop to the total water pumped for all the crops on the farms.

3.4 ECONOMICS OF IRRIGATION

The cost of cultivation is the summation of (cost of human labor, bullock labor, seeds, fertilizers, plant protection measures, application of silt / manure, transportation and bagging, the amortized cost of irrigation, and the opportunity cos of working capital. The opportunity cost of working capital is taken as 10 percent.

Cost of production is cost of cultivation + opportunity cost of dry land agriculture. The opportunity cost of dry land agriculture is the net return obtainable from that parcel of land devoted to irrigation, if that parcel of land was to be cultivated on rainfed basis.

3.5 ESTIMATION OF EXTERNALITY

The positive externality in groundwater irrigation is manifested through the average age of the irrigation well(s), investments on drip irrigation, water conveyance, water storage and other structures. If positive externalities are present, the cost per acre inch of groundwater will be lower, the proportion of well failure will be lower and the average life of well(s) will be higher. If negative externality is present these components will be converse of positive externalities.

3.5.1 AMORTIZED COST MEASURE OF NEGATIVE EXTERNALITY IN DUG WELL.

The amortized cost measure of negative externality is estimated as under:

Negative Externality cost in dug well = $DW_{cost} = [AC_{DW} \text{ X } (AL - (Year_{fail} - Year_{const}))] \text{ X } (1+i)^{(1997\text{-Year of fail})}$

where, AC_{DW}= Amortized cost of Dugwell

$AC_{DW} = (DW_{cost}) \text{ X } [(1+i)^{AL} \text{ X } i)] \text{ , } [(1+i)^{AL} - 1]$

AL= Average life of dugwell estimated through life tables

$Year_{fail}$ = Year of failure of dugwell

$Year_{const}$ = Year of construction of dugwell

3.5.2 AMORTIZED COST MEASURE OF NEGATIVE EXTERNALITY IN DUG-CUM-BOREWELL.

The amortized cost measure of negative externality for dug-cum-borewell is estimated as under:

Negative externality in DCBW = $[AC_{DCBW} \text{ X}(AL\text{-}(Year_{fail} - Year_{imp}))]\text{X}(1+i)^{1997\text{-year of fail}}$

where, AC_{DCBW} = Amortized cost of DCBW

$Year_{imp}$ = Year of improvement of DCBW, which is year of first in boring.

The amortized cost of DCBW is for the number of years the DCBW did not function. This is then compounded up to 1997 from the year of improvement to obtain estimate of the negative externality cost in 1997 prices.

3.5.3 AMORTIZED COST OF MEASURE OF NEGATIVE EXTERNALITY IN BOREWELL

Negative Externality cost in borewell =

$$\text{Neg Ext } BW_{cost} = [AC_{BW} \text{ X } (AL - (Year_{fail} - Year_{const}))] \text{ X } (1+i)^{(1997 - \text{Year of failure})}$$

where, AC_{BW} = Amortized cost of borewell

$$AC_{BW} = [(BW_{cost} \text{ X } (1+i)^{AL} \text{ X } i)] \text{ , } [(1+i)^{AL} - 1]$$

BW_{cost} = Borewell cost = (historical cost of borewell) X $(1+i)^{(1997 - \text{year of construction})}$

AL= Average life of borewell estimated through life tables

$Year_{fail}$ = Year of failure of borewell

$Year_{const}$ = Year of construction of borewell

3.6 COST OF COPING MECHANISMS

Conceptually two major types of coping with the economic scarcity of groundwater can be discerned:

(i) mechanisms that emphasize on efficient use of precious groundwater resource without major change in the existing cropping pattern. Eg: adopting drip/ sprinkler irrigation

(ii) mechanisms that emphasize on changing the cropping pattern to suit the depleting groundwater resources. Eg: change towards perennial crops which come under reduced water supplies.

Coping mechanisms are the investments by farmers to cope with the predicament of cumulative well interference. The coping response can be in terms of drilling / deepening additional well(s), over ground storage structures, buying groundwater, shifts in cropping patterns, drip/sprinkler systems, water transfer or in extreme cases a total shift to rainfed farming. As some of the measures to cope with scarcity of groundwater are in unison, these investments could be considered as one lumpsum investment. The response to economic scarcity of groundwater across different size classes of farmers has been estimated to illustrate the inequity / equity faced by farmers. In order to analyze the extent of inequity in water use, quarter analysis is attempted. The farmers have been arranged in the descending order of magnitude of total water pumped. They are then divided into four quarters each containing 25 per cent of the farmers, the top 25 per cent to the bottom 25 per cent, with regard to water used.

The amortized cost of (additional) well(s) (as a coping cost) is already explained. Other coping costs such as the investment on over ground storage structures is amortized for five years, that on drip irrigation is amortized for ten years, that on conveyance pipes for water transfer is amortized for ten years, that on irrigation pump set amortized for ten years. About 35 percent of the (20) farmers (= 7) in Goppenahalli, resorted to drilling irrigation well to transfer water by laying PVC pipes over distances ranging from three to five kilometers, as the irrigation borewells on their farm had totally failed. The investment on such borewells and water transfers is also considered as a coping cost.

3.6.1 ECONOMIC FEASIBILITY OF INVESTMENT IN COPING MECHANISM

Partial budgeting and the discounted cash flow measures have been used to analyze the economic feasibility of investment in coping mechanisms. The use of drip irrigation is a major coping mechanism in the water scarce areas of Channagiri to support the arecanut crop. Most of the drip farms have also resorted to transferring groundwater over distances ranging from 3 to 5 kilometers from Maravanji village to Goppenahalli. In addition, drip irrigation is the last resort, due to large scale failure of wells in situ which has necessitated farmers to venture drilling of borewells at long distances of 3 to 5 kilometers from their farm where they could site groundwater and transfer the water. Hence the amortized cost of irrigation includes all the implicit costs of irrigation reflecting the negative externalities and the explicit costs of the functional wells and drip irrigation and other coping mechanisms

The assumptions in using partial budgeting are

1. Average arecanut farm irrigated by drip irrigation is of the size = 5 acres
2. Savings in water cost = value of the difference between water used (in acre inch) under flow irrigation and that under drip irrigation.

3. Increase in returns: is the difference in the gross returns per acre on a farm irrigated by drip farm and that under flow irrigation.

3.6.2 INTERNAL RATE OF RETURN (IRR)

The IRR is a discounted cash flow technique used in the evaluation of long term projects. The IRR is that rate of return earned by the farmer by using groundwater for irrigation. For instance if the rate of return is 10 percent, then the farmer would earn a net return of Rs. 10 for every Rupees hundred invested. This rate equates the discounted benefits with the discounted costs. It represents the average earning capacity of an investment during its economic life.

IRR is estimated using the following equation:

$IRR = S(B_n - C_n)/(1+d)^n = 0$

B_n = Annual benefits or gross returns;

C_n = Annual costs incurred (production costs and cost of groundwater);

n = Economic life of investment; d = discount rate.

The following assumptions were made in the estimation of IRR:

1. The economic life (of a arecanut garden) is assumed to be one generation cycle of 30 years. As the average life of borewell was two years in the sample, farmer is forced to drill a new well once in every two years. However, the investment on irrigation pump, conveyance, pipes, are amortized for ten years. Thus, if the second well is drilled in the third year, the investment on pump set and other accessories arise

in the 11th year, since the pumpset and other accessories of the first well will be used in the second well.

2. The investment made in the first six years, that is, till the arecanut comes to economic bearing, is considered as establishment cost.

DISCOUNTED BENEFIT COST RATIO (DCBR)

The DBCR is the ratio of the present worth of cash inflows to the present worth of cash outflows, earned and incurred during the economic life of the arecanut garden. It gives the benefits accrued for every rupee invested in the project, in present prices. An investment must be taken up only if the DBCR is greater than unity. A DCBR equal to unity indicates that every rupee of investment on the project yields a rupee of return with no surplus. A DBCR greater than one indicates that every rupee of investment made on the project yields a return greater than one rupee.

DBCR can be expressed as:

$$DBCR = \frac{\Sigma[B_n / (1+d)^n]}{\Sigma[C_n / (1+d)^n]}$$

where,

B_n = Benefits[4] or gross returns from groundwater irrigated arecanut garden in each year;

C_n = Costs[5] incurred on arecanut garden including groundwater irrigation in each year;

n = Economic life of investment on arecanut (30 years)

r = Rate of discount (computed at 17 per cent)

---

[4] *Returns include gross returns from arecanut, betelvine and coconut*

[5] *The costs include investments on drilling wells, conveyance, pumpsets, drip irrigation, storage structure and electrificationin the initial years of well cycle. For subsequent years other production costs (seeds, labour etc) are included.*

NET PRESENT VALUE(NPV)

The NPV of a project is the difference between the present worth of benefits (gross returns from arecanut garden) and the present worth of total costs incurred (investments on arecanut garden). In calculating the NPV, the cash inflows and cash outflows were discounted at 17 per cent discount rate.

NPV is estimated as :

$$NPV = (B_n - C_n)/(1+d)^n$$

where:

B_n = Benefits or gross returns from areca garden irrigated by groundwater in each year;

C_n = Costs of production and groundwater irrigation in each year;

n = Economic life of arecanut garden irrigated by groundwater (taken as 30 years)

d = discount (17 per cent)

A project / investment is considered economically and financially viable if the NPV is positive.

3.7 QUARTER ANALYSIS

Quarters are constructed to analyze the inequity / equity with regard to resource use and net returns. The analysis is conducted separately for HWIV and LWIV. The quarters provide information on the proportion of farmers realizing different proportions of gross returns, net returns, cost of irrigation and so on. For dividing into quarters the entire sample was sorted in the

the descending order of magnitude of water used per farm. Accordingly five top water users form the first quarter and five lowest water users form the last (fourth) quarter in HWIV drip farms and HWIV flow farms. The crop pattern, net returns, amortized investment, number of wells dug, proportion of successful wells, gross irrigated area and cropping patterns, elasticity of production, marginal costs and marginal returns to water are compared across the quarters. Comparison is also made between quarters. In the case of LWIV, quarters have been made for the entire sample of 38 farmers.

3.8 MARGINAL PRODUCTIVITY OF GROUNDWATER

The marginal productivity of groundwater for HWIV drip irrigation farmers and flow irrigation farmers is estimated using a gross return function of the Cobb-Douglas form:

$$\log Y = \log A + B_1 \log X_1 + B_2 \log X_2$$

where Y = gross return from the farm in rupees

X_1 = Groundwater used in acre inches on the farm per annum

X_2 = Annual cost of groundwater irrigation in Rupees per farm

Marginal productivity of groundwater is estimated by using the expression:

$MP_{X_1} = B_1 * Y/(X_1)$ estimated at arithmetic[6] mean level of gross return and groundwater used.

Price of amortized cost of irrigation = one rupee

The ratio of marginal return to marginal cost of groundwater gives an indication of the extent of divulgence of marginal return from the marginal cost.

---

[6] *The original form of gross return function is $y = \Pi a x_i \hat{} b_i$, which is of Cobb Douglas form. Linearization of this function by application of logarithms on both sides is done to obtain the BLUE estimate of the constants 'a 'and 'b_i'. Once 'a' and 'b_i are estimated, we can substitute any value of x to obtain the estimated value of y. This logic is used to estimate the marginal return at the arithmetic mean value of x_i. The marginal return is obtained by the expression MR = $(b_i X y_i)/(x_i)$. One of the values of y^ can be obtained at the arithmetic mean value of x_i. Statistically, there is no restriction that only geometric mean value of x_i and y_i should be used to estimate the marginal return. This is only a convention. In this study, the use of the artithmetic mean value of x_i at which y_i was estimated, provided a realistic value of marginal return, than that obtained by using the geometric mean value of x_i. I thank Prof Gurumurthy, Professor&Head, Dept.of statistics, UAS,GKVK,Bangalore for providing these ideas.*

Table 3.3 : Taluks with the highest and the lowest number of wells per million cubic meter of groundwater in different agro-climatic zones of Karnataka

Agro-climatic zone	Highest Number of wells per million cubic meter of groundwater		Lowest Number of wells per million cubic meter of groundwater	
	Taluk	Number of wells/mcm	Taluk	Number of wells/mcm
1. Eastern Dry	Devanahalli	322	Magadi	67
2. Southern Dry	1. Kollegal	155	KR nagar	14
	2.Chamrajnagar	116		
3. Northern Dry	1. Nargund	298	Sindhanur	17
	2. Athani	154		
4. Central Dry	Madhugiri	156	Kadur	39
5. North Eastern Dry	Afzalpur	70	Jeevargi	10
6. Southern Transition	Hassan	16	Bhadravathi	7
7. Northern Transition	Hukkeri	251	Kundagol	14
8. North Eastern Transition	Humnabad	122	Chincholi	34
9. Coastal	Sulya	90	Karwar	12
10. Hilly	Sirsi	71	Supa	2

Source: Central Groundwater Board, Southern Region, Bangalore, 1990

RESULTS

CHAPTER IV

RESULTS

Once farmers realized the benefits from well irrigation, and get adjusted to relatively higher standard(s) of living, it is difficult for them to adjust to a situation where there is no irrigation facility. Hence farmers who benefited from groundwater irrigation, bring about changes which may or may not involve further investments to remain at least on their original ISO-revenue curve. These measures are referred to as coping mechanisms-- the main foci of this study, where a modest attempt is made to study the economics of coping mechanisms adopted by farmers in Channagiri taluk.

Upon post stratification of HWIV sample farmers, it was found that all the (22 farmers) of Bussenahalli used groundwater through flow irrigation to grow arecanut. In the other HWI village of Goppenahalli all the farmers used groundwater through drip irrigation to grow arecanut. Hence, the farmers in HWIV were classified as drip irrigation farms and flow irrigation farms. But in LWI villages, this type of contrast was not available for comparison. The farmers in LWIV are classified into small farmers (< 5 acres) and large farmers (> 5 acres). Here HWIV and LWIV can not be strictly compared for lack of comparable classification.

4.1 DISTRIBUTION OF IRRIGATION WELLS

Considering the total 362 irrigation wells spread in HWI and LWI villages (263 wells in HWI and 99 wells in LWI), 151 wells (41 percent) were functioning in 1997, of which 98 percent were borewells. The overall failure rate is 57 percent. Considering the types of wells owned by farmers, of the total 362 sample wells, 329 (90 per cent) are bore wells and 33 (10 per cent) are dug wells.

Among the 237 bore wells in HWI villages of Bussenahalli and Goppenahalli, only 88 borewells (37 percent) are functioning yielding groundwater. Of these 88 working borewells, 21 farmers who have drip irrigation have 44 working borewells and 21 farmers using flow irrigation have remaining 44 working borewells, evenly distributed (Table 4.1).

Considering the 155 borewells (working and non working), in HWIV Goppenahalli drip farms, only 44 (28 percent) are working, as 96 wells (62 percent) were initial failures and 15 wells (10 percent) were natural failures. The high initial failure rate of 62 percent on drip farms is because of low recharge rate from irrigation tank.

In HWIV Bussenahalli, due to groundwater recharge, the level of economic scarcity did not induce farmers to have drip irrigation. Among the 82 borewells here, 35 bore wells (43 percent) are initial failures and 44 wells (54 percent) are working, while 3 wells (4 percent) are natural failures.

Considering the rate of initial failures in wells, of the total (263) wells in HWI villages of Goppenahalli and Bussenahalli, there were 131 (50 percent) initial failures. In HWIV Goppenahalli, all the (21) farmers adopted drip irrigation. They had 171 wells of all types with 127 (74 percent) failures. Of the 171 wells, 155 wells (91 percent) were borewells. Of these 155 borewells, 96 borewells (62 percent) were initial failures.

Table 4.1: Distribution of different types of wells in sample farms in Channagiri taluk, Karnataka 1997

Type of well	HIGH WELL INTERFERENCE VILLAGE		Total
	Farmers using drip irrigation	Farmers using flow irrigation	
	No of farmers=21	No of Farmers=21	
Dug Cum Bore Well			
Initial Failure	0 (0)	2 (20)	2 (8)
Natural Failure	16 (100)	7 (70)	23 (88)
Working	0 (0)	1 (10)	1 (4)
Total	16 (100)	10 (100)	26 (100)
Bore Well			
Initial Failure	96 (62)	35 (42)	131 (55)
Natural Failure	15 (10)	3 (4)	18 (8)
Working	44 (28)	44 (54)	88 (37)
Total	155 (100)	82 (100)	237 (100)
Grand Total	171	92	263

1. Figures in parantheses indicate percentages to the column totals
2. All dug wells have been converted to dug cum bore wells

The initial failures on non-drip farms is 35 of 82 borewells (43 percent). This low initial failure is due to the groundwater recharge from Bussenahalli and Malahal tanks. In HWI villages, among the 26 dug wells, 16 dug wells failed on drip farms (62 per cent) while nine dug wells (38 per cent) failed on non-drip-farms.

In LWI villages, there were 99 wells (92 borewells + 7 dug wells) of which 34 wells (34 percent) failed. Considering the total of 92 borewells, 63 borewells (68 percent) were functioning and 29 wells (32 percent) failed. Considering the total bore wells, 26 bore wells (28 percent) were initial failures.

In LWIV, small farmers had 36 borewells (39 percent) with 6 initial failures (17 percent). Large farmers had 56 bore wells (61 percent) of which 20 were initial failures (36 percent) (Table: 4.2). Small farmers had 28 working wells (78 percent) out of 36 borewells. Large farmers had 56 borewells of which 35 wells (63 percent) were working. Thus, both small and large farmers had a large proportion of working wells. The proportion of natural failures in LWIV for small and large farms are two and one out of 36 and 56 borewells respectively. The total number of dugwells in LWI villages are seven, of which five are owned by small farms and two by large farms. Except two dug wells, all the dug wells had failed here.

In HWIV on drip farms, the average number of wells per farm is 7.38 ~ 7 with GIA of 6 acres, as against 3.90 ~ 4 wells with a GIA of 4.37 acres on flow irrigation. In LWI, on small farms, the average number of wells per farm is 1.57 with a GIA of 3 acres and that on large farms is 3.83 wells per farm with a GIA of 9.54 acres. The average number of functional wells in HWIV per farm is 2.09 ~2 with a GIA of 6 acres on drip farms, 1.95 ~ 2 wells on a GIA of 4.37 acres on flow irrigation

1.

Table 4.2 : Distribution of different types of wells in sample farms (LWIV) in Channagiri taluk, Karnataka 1997

Type of Well	LOW WELL INTERFERENCE VILLAGES		
	Large Farmers	Small Farmers	TOTAL
Dug Cum Bore Well			
Initial Failure	0 (0)	0 (0)	0 (0)
Natural Failure	3 (60)	2 (100)	5 (71)
Working	2 (40)	0 (0)	2 (29)
Total	5 (100)	2 (100)	7 (100)
Bore Well			
Initial Failure	6(17)	20 (36)	26 (28)
Natural Failure	2 (5)	1(2)	3 (4)
Working	28 (78)	35 (62)	63 (68)
Total	36 (100)	56 (100)	92 (100)
Grand Total	41	58	99

Figures in parantheses indicate percentages to the column totals farms. In LWI villages it was 1.07 ~1 (3 acres) on small farms and 2.91~3 (9.54 acres) on large farms.

The average life of irrigation wells in HWI and LWI villages is estimated for dug, dug-cum-bore and borewell. The dug wells had served for 20 to 23 years. The life of dug cum borewell ranged from 9 to 11 years. However, since majority of dug wells and dug-cum-bore wells are not working in these villages, the extraction technology is now shifted to borewell. The life of borewell ranged from 1.88 years to 3.45 years. (Table : 4.3)

Examining the construction and failure of different types of wells between 1940 and 1997, in HWI villages, the proportion of failures of wells were virtually zero up to 1970. This is because dug wells dominated. However from early 1980's, the due to the advent of bore well rigs, the number of borewells mushroomed (Table 4.4). Correspondingly, with the drilling of borewells, the failures have also increased as indicated by 65 percent of failures during 1980-1990 and 71 percent failures during 1990-1997 in HWIV. In Low well interference villages, similarly the proportion of well failure ranges from 18 percent to 40 percent during 1980 - 1997.

4.2 DEPTH AND YIELD OF WELLS

In HWI villages, the farmers are applying groundwater through drip and flow irrigation. The depth of irrigation wells has progressively increased from the first well on to the last well in both HWI and LWI villages. There seem to be no apparent relationship between the depth of the well and their groundwater yield. Yield of groundwater is certainly not increasing, with the depth. The depth of the wells in HWI drip farms ranges from 204 feet to 383 feet, (Table 4.5) while the yield correspondingly ranges from 1750 GPH to 1393 GPH. On flow farms, the depth ranges

Table 4.3 : Average life of irrigation wells in Channagiri, Karnataka state as on 1997 (Years)

	High well interference villages	Low well intertference villages
Dug well	20.29	23
Dug cum bore well	9.04	11.4
Bore well	1.88	3.45

Table 4.4 : Number of Wells sunk and failures on Sample farms in Channagiri taluk, Karnataka State, 1997

Year	HIGH WELL INTERFERENCE VILLAGES		LOW WELL INTERFERENCE VILLAGES	
	Number of wells Sunk	Number of Failures	Number of wells Sunk	Number of Failures
1940	8	0	0	0
1950	2	0	1	0
1960	7	0	1	0
1970	4	2	2	0
1980	7	8	3	2
1990	58	38	22	4
1997	175	125	69	28

Table 4.5: Depth and yield of sample wells over the years in High well interference villages of Channagiri taluk, Karnataka 1997

Order of well	Farmers using Drip irrigation		Farmers using flow irrigation	
	Depth (Ft)	Initial Yield (GPH)	Depth (Ft)	Initial Yield (GPH)
First	204	1750(4)	193	2182(11)
Second	241	1300(10)	219	2229(12)
Third	282	1643(7)	207	1500(3)
Fourth	277	1778(9)	233	1563(8)
Fifth	311	1500(3)	266	1625(6)
Sixth	376	1458(6)	298	2167(3)
Seventh	377	1688(8)	365	
Eighth	406	1393(7)		
Ninth	383	2000(1)		

Note: Figures in Parentheses indicate the number of working wells used to find the average yield of wells in gallons per hour (GPH) ; Depth (in ft) from 193 feet to 365 feet and the yields are comparatively higher than on drip farmers. In LWI villages, the depth of the first well ranged from 164 feet and that of the last well 286 feet, with a falling yield from 2000 GPH to 1000 GPH.(Table :4.6)

4.3 CROPPING PATTERN IN HWIV

The cropping pattern in HWI and LWI villages was largely common as farmers grew arecanut on a large proportion of land. The exception was in LWI villages seasonal crops like groundnut, cotton, maize and sunflower dominated. Betelvine is the commonly cultivated intercrop along with arecanut. Coconut was also grown along the borders of the arecanut garden.

The area under arecanut for HWI drip farmers was 125 acres (100 percent) while 86 acres (94 percent) was devoted to arecanut by flow farmers (Table 4.7). A modest proportion of 2 percent was put to coconut by flow farmers. Maize, ragi, jowar were the commonly cultivated rainfed crops in HWIV. The farmers in (Bussenahalli and Goppenahalli) did not devote their irrigated land for the cultivation of seasonal crops as arecanut was highly remunerative.

4.3.1 CROPPING PATTERN UNDER LWIV

Main crops cultivated in LWI villages are arecanut, cotton, groundnut, maize, onion, chillies, sunflower and to a small extent of paddy and tomato largely for home consumption. In LWI Villages Chikganguru, seasonal crops dominated, while arecanut dominated in Kaggathur. Considering the gross irrigated area of 192 acres in LWI, 100 acres (52 percent) was put to arecanut and 92 acres (48 percent) were under seasonal crops.

Table 4.6 : Depth and Yield of sample wells over the years in Low well interference villages of Channagiri taluk, Karnataka 1997

Order of the well	Depth(Ft)	Initial yield(GPH)
First	164	2090 (30)
Second	224	2068 (11)
Third	237	1843 (8)
Fourth	246	1250 (5)
Fifth	286	1100 (10)

Note: Figures in parentheses indicate the number of working wells used to find the average yield of wells in gallons per hour (GPH) ; Depth of the well (in ft).

Table 4.7 : Cropping Pattern and Gross Cropped Area in (acres) in High well and low well interference villages in Channagiri taluk , Shimoga district ,Karnataka 1997

	High well interference village			Low well interference village		
	Farmers using drip irrigation	Farmers using flow irrigation	Total	Small Farmers	Large Farmers	Total
Perennial Crops						
Number of farms	21	21	42	26	12	38
Arecanut	125.25 (100)	86 (94)	211.25	34 (75)	66 (85)	100
Coconut	0 (0)	3.5 (4)	3.5	11.5 (25)	12 (15)	23.5
Banana	0 (0)	2 (2)	2	0 (0)	0 (0)	0
GCA under Perennial crops	125.25	91.5	216.75	45.5	78	123.5
Annual Crops						
Sun Flower	0 (0)	0 (0)	0	0 (0)	10 (27)	10
Tomato	0 (0)	0 (0)	0	1 (3)	1.5 (4)	2.5
Cotton	0 (0)	0 (0)	0	5.25 (16)	0 (0)	5.25
Paddy	0 (0)	0 (0)	0	2.75 (35)	0 (0)	2.75
Maize	0 (0)	0 (0)	0	6 (19)	13 (36)	19
Ground Nut	0 (0)	0 (0)	0	11.5 (36)	8 (22)	19.5
Chillie	0 (0)	0 (0)	0	4.68 (15)	0 (0)	4.68
Avarae	0 (0)	0 (0)	0	0 (0)	4 (11)	4
Onion	0 (0)	0 (0)	0	0.5 (1)	0(0)	0.5
GCA under Annual Crops	0 (0)	0 (0)	0	31.68 (41)	36.5 (32)	68.18
Total area	125.25	91.5	216.75	77.18	114.5	191.68

Note: Gross Cropped Area in Acres here provides the same weightage for annual and perennial crops; Figures in Parentheses indicate percentage of GAI out of the Sample total gross irrigated area

In low well interference villages on small farms , the area under arecanut was 34 acres (44 percent), coconut 11 acres (14 percent) and 31 acres (42 percent) was put to seasonal crops out of 77 acres. On large farms, the area under arecanut was 66 acres (58 percent); that under coconut was 12 acres (10 percent), and 37 acres under seasonal crops (32 percent).

In LWIV, Among the annual crops, on small farms, the irrigated area under groundnut was 12 acres (36 percent) out of 32 acres of irrigated area. Large farmers devoted 13 acres to maize crop (36 percent) out of 36.5 acres of gross cropped area under annual crops. The other major annual crops in LWI villages are 5.25 acres (16 percent) of cotton, 6 acres (18 percent) under maize, 4.68 acres (14 percent) under chillies and 2.75 (8 percent) for paddy on small farms. A major proportion of 13 acres (35 percent) was under maize while sunflower constituted to the extent of 10 acres (27 percent) for large farmers. The area under groundnut was 8 acres (21 percent) while that of tomato was a modest of 1.5 acres (4 percent) out of 36.5 acres on large farms. In LWI also around 60 percent of the area was under arecanut.

4.4 COPING MECHANISMS

The amortized investment on drip irrigation system in HWI drip farms (Goppenahalli) is Rs. 931 per acre of arecanut and Rs. 5,550 per farm for an average farm size of 6 acres. The amortized cost of coping mechanism is Rs. 15,792 per acre (Rs. 94,188 per farm). The amortized cost of storage structure (with polythene sheets to reduce evaporation losses) is Rs. 371 per acre (Rs. 3,577 per farm) (Table 4.8). At present, farmers are not using the storage tanks in HWIV since they cannot use them for pumping water as drip irrigation is used. The amortized cost of PVC pipe per acre is Rs. 847 per acre and Rs. 5054 per farm.

Table 4.8 : Amortized costs on coping mechanisms in Channagiri taluk 1997

(in Rs)

	Farmers using drip irrigation	Farmers using flow irrgation	LWI-SF	LWI-LF
Number	21	21	26	12
Per farm	94,188	26,621	3,513	26,845
Per acre	15,792	6,110	1,183	2,813
Max	2,64,300	1,09,534	17,552	1,11,139
Min	2,540	0	0	0

Note : Cost of coping mechanism : Includes the annual cost of the initial investment on groundwater irrigation well (s) , deepening, casing, pumps, pumphouse, pvc pipes, storage structures, drip irrigation (if adopted) and so on

Considering farmers who are using flow irrigation, investment on additional wells as coping mechanisms includes investment on all the borewells excluding that on the first borewell. The amortized investment on additional wells in HWI drip farms is Rs. 81,369 per farm and Rs. 13,643 per acre of arecanut; The amortized investment on additional wells in HWI flow farms is Rs. 25,910 per farm and Rs. 5,946 per acre of arecanut. In HWI flow farms, the amortized cost of storage tank was Rs. 13 per acre (Rs. 615 per farm). Here storage tanks are used since farmers are applying groundwater by flow irrigation. The amortized cost of PVC pipe per acre is Rs. 150 and that per farm is Rs. 650 (Table 4.9).

In LWI villages, there were only four farmers using drip irrigation (out of the sample of 38) as relatively they had better groundwater regime due to low well interference and tank recharge (in Kagathur). Among the small farmers, one farmer invested on storage tank. The amortized investment on storage tank per acre was Rs. 186 on large farmers, and that per farm was Rs. 10,656. The investment on PVC pipes by small farmers is Rs. 225 per acre and that per farm is Rs. 666. For large farmers, the amortized cost on PVC pipes is Rs. 194 per acre and Rs. 1,855 per farm.

4.5 INVESTMENT ON IRRIGATION WELLS

In HWI flow farmers (Bussenahalli), the amortized investment per farm on irrigation wells is Rs. 47,362 and that per acre is Rs. 10,870. The amortized cost per well is Rs. 10,811 and that per functional well is Rs. 22,604. The low amortized cost per functional well is due to a low failure rate of 48 percent (among borewells) and is inturn due to groundwater recharge from the Bussenahalli irrigation tank. On drip farms, the amortized investment on irrigation wells is Rs. 1,10,504 per farm and Rs.

Table 4.9 : Components of investment in coping mechanisms in Channagire taluk, Karnataka, (1997 Rs)

	High Well Interference Villages				Low Well Interference Villages			
	Farms using Drip irrigation		Using Flow irrigation		Small Farmers		Large Farmers	
	Per acre	Per farm	Per acre	Per farm	Per acre	Per farm	Per acre	Per farm
Investment on additional wells	13,643	81,369	5,946	25,910	941	2,792	2,341	22,333
Investment on drip irrigation	931	5,550	0	0	0	0	92	881
Investment on storage tank	371	3,577	13	615	4	318	186	10,656
Investment on conveyance	847	5,054	150	653	224	666	194	1,855

18,528 per acre. The amortized cost per working well is Rs. 13,571 and that per functional well is Rs. 52,740. (Table 4.10)

In LWI villages, for small (large) farmers, the amortized investment per farm on all the wells is Rs. 13,595 (Rs. 35,203) and that per acre is Rs. 4,580 (Rs. 3,689). The amortized cost per well for small (large) farmers is Rs. 8,621 (Rs. 7,283), that per functional well is Rs. 12,624 (Rs. 12,070). Thus, farmers in HWI flow farms incur investment on drilling a functional well as incurred by LWI farmers. The area irrigated per functional well is 3.27 acres on large farms and 2.7 acres on small farms.

4.6 IRRIGATION COST

The amortized irrigation cost per farm in HWI drip farms is Rs. 1,33,584 and Rs. 22,397 per acre of arecanut. The high amortized cost of irrigation per farm is due to possession of 7.38 wells per farm, of which only 2.09 wells are functional, enduring large scale failure. The amortized cost per well is Rs. 16,405 and that per functional well Rs. 63,756. The amortized irrigation cost in flow farms is Rs. 50,401 and Rs. 11,568 per acre. The amortized cost per well is Rs. 11,505 and Rs. 24,055 per functional well (Table: 4.11). Considering the amortized cost per acre of arecanut, the HWIV drip farms are incurring twice the cost on irrigation compared with that incurred by HWIV flow farms.

Small (large) farmers of LWI villages incurred an amortized irrigation cost of Rs. 17,116 (Rs. 46,544) per farm and Rs. 5,766 (Rs. 4,878) per acre (Table: 4.12). The amortized cost of irrigation per well on LWI villages for small (large) farmers is Rs.10,854 (9,630) and per functional well the amortized cost is Rs. 15,893 and Rs. 15,958 for small and large farmers respectively.

Table 4.10 : Amortized costs on irrigation wells in 1997 prices in Channagiri taluk

	Farmers using drip irrigation	**Farmers using flow irrigation**	**LWI-SF**	**LWI-LF**
Per farm	1,10,504	47,362	13,595	35,203
Per acre	18,528	10,870	4,580	3,689
Per well	13,571	10,811	8,621	7,283
Per functional well	52,740	22,604	12,624	12,070
Area irrigated per functional well	2.84	2.07	2.75	3.27

Table 4.11 : Amortized cost of irrigation and number of irrigation wells in HWI villages of Channagiri taluk 1997 (in Rupees)

	High well interference villages	
	Farmers using drip irrigation	Farmers using flow irrigation
Number of Farmers	21	21
Gross area irrigated	125.25	91.5
Sample total	28,05,266	10,58,428
Amortized cost per farm	1,33,584	50,401
Maximum amortized investment	3,60,765	1,24,103
Minimum amortized investment	19,648	2,386
Amortized cost of irrigation per acre of GAI	22,397	11,568
Number of Failed Wells	127	45
Number of Functional Wells	44	44
Number of wells per farm	8.14	4.38
Total Number of Wells	171	92
Amortized cost of irrigation per well	16,405	11,505
Amortized cost of irrigation per functional Well	63,756	24,055
Number of bore wells per farm	7.38	4.23

Note: GAI= Gross Area Irrigated

Table 4.12 : Amortized cost of irrigation in LWI villages of Channagiri taluk, Karnataka, 1997

(in Rupees)

	SMALL FARMER	LARGE FARMER
Number of farms	26	12
Gross Area Irrigated (GIA) in acres	77.18	114.5
Total for sample	4,45,014	5,58,528
Amortized cost per farm	17,116	46,544
Maximun amortized investment	55,054	1,46,217
Minimum amortized investment	7,737	10,776
Amortized investment per acre of GAI	5,766	4,878
Number of failed Wells	13	23
Number of functional Wells	28	35
Total number of all Wells	41	58
Amortized cost of irrigation per Well	10,854	9,630
Amortized cost of irrigation per functional Well	15,893	15,958
Number of borewells per farm	1.07	2.92

Note: GAI= Gross Area Irrigated

In HWI drip farmers, the average number of wells (GIA) per farm is 7.38 (6 acres), as against 3.76 (4.37 acres) on HWI flow farms. In LWI, on small farms, the average number of wells (GIA) per farm is 1.38 (3 acres) and that on large farms is 3.83 (9.54 acres). The average number of functional wells (GIA) per farm is 2.09 (6 acres) in HWI drip, 1.95 (4.37 acres) in HWI flow farms on LWI villages it was 1.07 (3 acres) on small farms and 2.91 (9.54 acres) on large farms.

4.7 NON-IRRIGATION COST OF PRODUCTION

The non-irrigation cost of production in arecanut includes variable costs incurred on farmyard manure cost, human and bullock labor involved in weeding, inter-culture, harvest and post harvest practices in arecanut cultivation. In HWI drip farms, the per farm (per acre) non-irrigation cost of production was Rs. 60,929 (Rs. 10,214) and that in HWI flow farms it was Rs. 26,382 (Rs.6,605); LWI small farmers incurred Rs. 18,162 (Rs. 6,054) and large farms incurred Rs. 55,494 (Rs. 5,817) (Table: 4.13)

4.8 QUARTER AMORTIZED COSTS AND RETURNS FROM IRRIGATION

In HWI drip farms (Goppenahalli), the bottom 25 percent of the farmers are using only 6 percent of the total water, on 9 percent of the gross area irrigated, incurring 30 percent of irrigation cost, realizing a loss of 7 percent. The proportion of working wells is 13 percent. The net return per functional well is - Rs. 22,089. (Table :4.14)

Table 4.13 : Production costs for arecanut in HWI and LWI villages in Channagiri, Karnataka, 1997 (Rs.)

	Farmers using drip irrigation in high well inerference village	Farmes using flow irrigation in high well interference village
Avg.size of holding (Acres)	5.97	4.35
Total for the Sample	12,79,333	5,54,950
Average	60,977	26,426
Per acre	10,214	6065
	Small farmers in Low well interference village	**Large farmers in Low well interference village**
Avg. Size of holding (Acres)	3	9.54
Total for the sample	4,67,227	6,66,053
Average	17,970	55,504
Per acre	6054	5817

Note: Production cost includes cost incurred on farm yard manure, human and bullock labour costs, harvest and post harvest costs of arecanut

Table 4.14 : EQUITY ISUUES IN GROUNDWATER IRRIGATION IN CHANNAGIRI TALUK 1997 AS

LOOKED THROUGH QUARTERS (1997)

rmers using ı irrigation in HWIV	GAI Quarter	GAI /TGAI	WU (AI) Quarter	WU /TWU	NET RET Quarter	NR/ TNR	IRR COS Quarter	IC/TIC	NR/ACR	IC/ACR	TOT WELLS	NO OF FW	IC/FW	NET RET/FW	Net Ret Per ac.in	IC per AI
Quarter I	49	39	556.31	49.76	992481	50	966478	34	22055	21477	60	19	50867	52236	1784	1737
Quarter II	46	36.53	308.75	27.62	1139632	58	750227	27	24775	16309	39	9	83359	126626	3691	2429
Quarter III	19	15.17	177.85	15.91	-18679	-1	715754	26	-983	37671	44	10	71575	-1868	-105	4024
Quarter IV	11	8.98	74.99	6.71	-132534	-7	372805	13	-11781	33138	28	6	62134	-22089	-1767	4971
mers using w irrigation																
Quarter I	23	21.5	1095.92	43.32	586336	17	311314	29	27271	14479	25	14	22236	41881	535	284
Quarter II	23.25	25	726.44	28.71	748289	22	246410	23	32184	10598	20	11	22400	68026	1030	339
Quarter III	16.5	18	375.74	14.85	514849	15	188670	18	31202	11434	18	7	26952	73550	1310	502
Quarter IV	30.25	33	331.9	13.12	511648	45	312032	29	49971	10315	26	12	28366	125971	1541	940
armers in LWIV																
Quarter I	80	41.74	2278.74	62.91	1740575	70	311738	31	21757	3897	34	27	11546	64466	763	136
Quarter II	43.75	22.82	837.27	23.12	690789	25	296701	28	16946	7753	26	16	18544	38922	825	340
Quarter III	40.75	21.26	380.55	10.51	68155	6	295301	29	4696	10183	26	13	22716	10476	179	775
Quarter IV	27.18	14.18	125.5	3.47	-24115	-1	111591	11	-921	4262	11	8	11159	-2679	192	889

Note : (I) GAI gross area irrigated; (ii) WU/TWU water use to total water use; (iii) IC/TIC irrigation cost to total irrigation cost; (iv) NR/ACR net returns per acre; (v) IC/ ACR irrigation cost per acre; (vi) GAI/TGAI gross area irrigated to total gross area irrigated ; (vii) IC/FW irrigation cost per functional well ; (viii) NET RET/FW returns per functional well;

In HWI flow farms, the top 25 percent of the farmers are using 43 percent of the groundwater on 22 percent of the gross area irrigated, incurring 29 percent of the irrigation cost, realizing net return of 17 percent from 31 percent of the functional wells. The net return per functional well is Rs. 41,881. 25 percent lower than their counterparts in HWI drip farms. In the last quarter of HWI flow farms, the bottom 25 percent of the farmers use 13 percent of the remaining water on 33 percent of the areca area, incurring 25 percent of the irrigation cost realizing 45 percent of the net returns and possessing 25 percent of the functional wells. The net return per functional well is Rs. 1,25,971. Even though, HWI flow farmers are irrigating through flow irrigation, their proportion of use of groundwater is a modest 13 percent.

In the LWI quarters, the net returns per acre inch of water varies from Rs. 763 to Rs. 192. In addition, there is equity with respect to proportion area irrigated as it varies from 14 percent to 42 percent. However, there is inequity with respect to groundwater use, as the bottom quarters use only 14 percent of groundwater, the rest 86 percent used by farmers in the top two quartiles. Thus, the cause of lower net returns in LWI villages is the low accessibility to groundwater even though farmers have incurred higher irrigation cost per acre in relation to the water available. For instance the farmers are incurring around Rs.800 per acre inch of water compared to farmers in the top quartile who are incurring Rs.100 to Rs. 400 per acre inch.

4.9 MARGINAL PRODUCTIVITY OF GROUNDWATER

The marginal productivity of groundwater is derived by regressing the gross returns (Rs) from groundwater on the amortized cost of irrigation (Rs) and the volume of groundwater used (acre inches). Data from farmers in HWIV and LWIV were used to estimate the gross returns function. But the coefficient of multiple determination and the estimated coefficients for groundwater were not statistically significant. Since this was not a pragmatic finding, for the purpose of estimating the marginal productivity of groundwater, the farmers in HWI and LWI were regrouped into those farmers using drip irrigation (24) and those farmers using flow irrigation (56). The Cobb-Douglas form provided a reasonable fit for the data.

The estimated gross return function for drip farmers has statistically significant R^2 and regression coefficients. The estimated water use and amortized cost of irrigation is close to the actual water and amortized cost of irrigation. The elasticity of gross returns to groundwater is 0.55, while that to the cost of irrigation is 0.43 (Table 4.15). There is no multicollinearity between the volume of groundwater used and the amortized cost of irrigation. For every 1 percent increased in the use of groundwater, the gross returns increase by 0.55 percent, while a 1 percent increase in the cost of irrigation, result in 0.43 percent increase in gross returns.

The estimated gross return function for farmers using water through flow irrigation also has statistically significant R^2 and coefficients. The elasticity of gross returns with respect to groundwater use is 0.63 percent, and that in respect of irrigation cost is 0.52. These elasticities are comparable with those obtained for farmers using groundwater through drip irrigation. However the marginal return to the 109th acre inch of groundwater is Rs. 758, while the marginal factor cost of an acre inch of groundwater is Rs. 258 yielding an MR/MC ratio of 2.94 (Table: 4.16). This indicates that for farmers using flow irrigation, it still pays for them to invest in new sources of groundwater resource.

Table 4.15 : Co-efficients of Gross Returns function on farmers using drip irrigation and flow irrigation in Channagiri taluk , 1997

	Farmers using drip irrigation	Farmers usingFlow irrigation
Ln of groundwater used	0.5538	0.6296
	(4.53)	(4.2556)
Ln of Irrigation Cost	0.4273	0.5175
	(2.68)	(3.2060)
Ln of intercept	5.2739	3.5294
	(3.35)	(2.4475)
R^2	0.79	0.49

Note: (I) The Sample Size on HWIV drip farms is 24 and on non-drip farms is 55; (ii) The Cobb-douglas form of gross returns function is estimated. (Iii) Figures in parantheses are the t-values.

Table 4.16 : Estimation of Gross Returns Function in Channagiri taluk, Karnataka State (1997)

	Arithmetic mean Gross returns	Estimated gross returns	Water Used	Marginal return of ground water	MR/MC ratio for ground water	Irrigation Cost	Marginal return to Irrigation Cost	MR/MC of irrigation cost	Price of water	RTS
Farmers using drip irrigation	2,78,540	2,63,519	52.95	2,793	1.16	1,25,560	0.96	0.96	2,403	0.98
Farmers using flow irrigation	1,63,303	1,31,078	108.87	758	2.94	67,833	2.41	2.41	258	1.15

Note: Returns and costs are in Rupees per farm
Groundwater used in acre inches per farm
RTS: Returns to scale

Table 4.17 : Net Returns to groundwater irrigation over coping mechanisms in Channagiri, Karnataka, 1997 (Rs.)

	Farmers using Drip irrigation	Farmers using flow irrigation
Total No of farmers	21	21
Net Returns over costs of all Coping Mechanisms	40,87,557	43,66,564
Net Returns per farm	1,94,646	2,07,932
Maximum Net Returns	7,30,591	8,50,466
Minimum Net Returns	-2425	13,973
Net returns per acre	32,635	48,256

Note: Cost of coping mechanism includes the annual cost of the initial investment on groundwater irrigation well (s) , deepening, casing, pumps, pumphouse, pvc pipes, storage structure, drip irrigation (if adopted) and so on.

4.10 COPING MECHANISMS AND RESILIENCE

The investment in coping mechanisms includes amortized cost of additional well(s) beyond the first well, drip irrigation, storage structure, water conveyance pipes within the farm, water transfer through PVC pipes from groundwater source to the farm. The net return per acre over these investments on coping mechanisms on farms using drip irrigation and flow irrigation is Rs. 32,635 and Rs. 48,256 respectively (Table :4.17). The net return per acre of gross area irrigated over the amortized cost of irrigation is Rs. 15,816 on farms using drip irrigation in HWIV, while that on flow farms is Rs. 36,734 (Table :4.18). The net return per acre of gross area irrigated over the amortized cost of irrigation is Rs. 6,634 while that on large farms it is Rs. 17,147 (Table 4.19)

The Internal Rate of Return (IRR), Discounted Benefit-Cost Ratio (DBCR) and Net Present Value (NPV) of investment on well irrigation (including investment on coping mechanisms like drilling additional wells, drip system, groundwater storage structure, conveyance and water transfer) were estimated to study the economic feasibility of the investment in irrigation in arecanut.

4.11 DISCOUNTED CASH FLOW MEASURES

The discounted cash flow measures indicate that the internal rate of return[1] on HWIV farms was 20 per cent and that on LWIV farms was 27 per cent. The IRR on LWIV farms is 27 percent which is also remunerative and financially attractive. The discounted benefit cost ratio on HWIV farms is 1.5 and that on LWIV farms is 2.35

Table 4.18: Net returns obtained by farmers in HWIVusing drip and flow irrigation in Channagiri taluk, Karnataka, 1997 (in Rupees)

	Farmers using *Drip irigation*	**Farmers using *Flow irrigation***
Number of farms	21	21
Total net returns for the sample	19,80,901	33,61,122
Net Returns per farm	94,329	1,60,053
Maximum Net Returns	6,10,437	7,15,997
Minimum Net Returns	-59,439	-25,647
Net Returns Per acre of GAI	15,816	36,734
Net Returns Per Well	11,584	36,534
Net Returns Per Functional Well	45,020	76,389

Note: (i) Arecanut occupies 100 percent of the GIA in drip farms and 94 percent on flow irrigation farms. (Ii) Water used per acre of GIA is 9 and 27 acre inches on drip and flow farms respectively.

Table 4.19 : Net Returns obtained by small and large farmers in LWI villages of Channagiri taluk, Karnataka, 1997

	SMALL FARMER	LARGE FARMER
Number of farms	26	12
Sample total Net Returns	5,12,035	19,63,369
Net Returns per farm	19,694	1,63,614
Net Returns per acre of GAI	6,634	17,147
Maximum Net Returns per farm	1,25,711	3,93,661
Minimum Net Returns per farm	-24845	-21,780
Net Returns per Well	12,489	33,851
Net Returns per functional Well	18,287	56,096

Note: (I) All the functional well are borewells

(ii) 78 percent of all borewells were functional on small farms and 63 percent on large farms.

(Table 4.20). The net present value of the investment is Rs. 5,16,478. The pay back period groundwater irrigation on HWIV (LWIV) farms was 4.16 (2.78) years[1].

4.12 ECONOMIC FEASIBILITY OF INVESTMENT IN COPING MECHANISM

Partial budgeting is used to analyze the economic feasibility of investment in coping mechanisms. The partial budgeting is attempted considering the corresponding differences in increase in costs, decrease in returns, savings in costs and increase in returns between drip irrigation farms and where flow irrigation farms (Table 4.21). The partial budgeting indicates that the returns to investment on resilience made by the farmers in drip irrigation as beneficial since the difference between the contribution of drip irrigation and the flow irrigation is Rs. 33,256

4.13 IMPACT OF GROUNDWATER SCARCITY ON EMPLOYMENT

Arecanut crop is grown on 80 percent of the gross area irrigated in HWIV and on 60 percent of the gross area irrigated in LWIV. Even though the economic scarcity of groundwater has set in, farmers have still found it remunerative to continue with arecanut crop on a major portion of the well command, since the relative cost of groundwater to arecanut price is continuing to be favorable. Thus, major changes in crop pattern are not observed and obviously in employment. However, the growing scarcity of groundwater has necessitated most of the farmers in HWIV to drill irrigation well/s about 3 to 5 kilometers apart in the distant Maravanji, Gollarahatti and transfer the groundwater through PVC pipes to

---

[1] *The pay back period is computed by using the following formula:*
Sum of the discounted costs incurred during establishment stage of 6 years
The discounted net return obtained in the sixth year.

Table: 4.20 Estimated Discounted Cash Flow Measures for farmers using ground water in Channagiri taluk, Karnataka state, 1997

	High well interference villages	Low well interference villages
Net Present Worth (Rs)	1,39,090	2,58,531
Benefit Cost Ratio	1.17	1.72
Internal Rate of Return (%)	20	27
Pay Back Period (Years)	4.90	3.26

Note: **1**.IRR is estimated for 30 years of areca garden which is taken as one generation cysle **2**. As the average life of the well is 1.8 years, the farmer will have to invest in drilling and casing of an irrigation well once in two years. **3**. Pump set and accessories used in irrigation are assumed to work for 10 years **4**. Morre than 80 percent of the farmers in HWIV and more than 60 percent of the farmers in LWIV are growing arecanut.

Table 4.21: Partial budgeting to determine economics of coping strategies in arecanut garden, Channagiri taluk, Karnataka, 1997

Costs A	Returns B
Increase in costs	*Savings (decrease) in costs*
1. Amortized cost of irrigation per acre on drip irrrigation farms minus Ammort cost of irrg on flow irrigation farms = (Rs. 22,397 - Rs. 11,568) = 10,831	1. Savings in labor @ 0.4 man day X Rs. 40 perday for 300 days = Rs. 4800 on drip irrigation farms
2. Other production costs per acre in drip irrigation farms minus prod costs in flow irrigation farms = (Rs. 10214 - Rs. 6065) = Rs. 4149	2. Savings in water cost = (27-9 = 18 acre inches X Rs. 418 per acre inch of water in flow irrg = Rs. 7524 = Savings in water due to drip irrigation
Decrease in returns: = 0 A = Total = Rs. 14,980	Increase in returns = (Rs. 54,366 - Rs. 18,454) = Rs. 35,912 B = Total = Rs. 48,236
B-A=48,236-14,980= Rs. 33,256 = Net gain	

Note: The assumptions are:

1. Average arecanut farm irrigated by drip irrigation is of the size = 5 acres
2. Savings in water cost = value of the difference between water used (in acre inch) under flow irrigation and that under drip irrigation.
3. Increase in returns: is the difference in the gross returns per acre on a farm irrigated by drip farm and that under flow irrigation.

Amortized cost of irrigation per acre on drip farm = Amort.cost of investment on additional wells drip irrigation, conveyance, storage structure, pump sets, etc.

Amortized cost of irrigation per acre on flow farm = Amort.cost of investment on additional wells, conveyance, storage structure, pump sets, etc.

Savings in cost means savings due to reduction of labour for weeding and irrigation

Savings in water cost = 27 acre inches per acre on flow farms minus 9 acre inches on drip farms = 18 acre inches valued as Rs.418/- per acre inch on flow farm. The water price of Rs.418 is considered as a conservative estimate = ammortization cost of irrigation on flow farms

Increase in returns = Rs.54,366/- is the gross returns on drip irrigation farms minus gross returns of Rs.18,454/- in flow irrigation = Rs.35,912

The difference between the figures per acre in drip irrigation and flow irrigation farms indicate the effect of partial budgeting. All farms have invested in drip irrigation and water transfer since there is absolute scarcity of groundwater and there is no recharge from irrigation tank.The increase in returns is the difference in the gross returns per acre between drip irrigation farms and flow irrigation farms.

Table 4.22: Cost of bore well in Goppenahalli village of Channagiri taluk, Karnataka, 1997 (in Rupees)

Divining Cost	500
Depth in Feet	500
Cost of Drilling (Rs)	24000
Casing (feet)	40
Casing Cost (Rs)	3200
HP of Irrigation Pumpset	8
Cost of Pumpset (Rs)	25000
Electricity installation (Rs)	5000
Pump placement Cost (Rs)	23000
Total Cost	***80,700***

support arecanut crop through drip irrigation. This change has brought in savings in labor required for field application of water. The savings in labor = Savings in labor @ 0.4 man day X Rs. 40 perday for 300 days = Rs. 4800. Next, the savings in water cost is achieved as the difference between the groundwater used per acre in drip and flow farms given by (27-9=) 18 acre inches valued at the rate of Rs. 418 per acre inch of water (in flow irrigation) provides a saving of Rs. 7524.

4.14 CASE STUDY OF INVESTMENT IN WATER TRANSFER

Surface water transfer is an obvious process due to movement of vast volumes of water over huge distances between the sink and the source. But transferring relatively low volumes of groundwater to distances ranging from two to seven kilometers by (a) farmer(s) for irrigation poses economic puzzles as this involves huge transaction costs due to management of irrigation well, and convincing the farms to cooperate for inlay of water pipes.

From the sample data, it was observed that the first water transfer in Channagiri took place in 1989, while the drip irrigation was introduced during 1990. The situation became worse in the early 1990s, that water transfer became imminent, and in addition entailed investment on drip irrigation. This amounted to two types of scarcities : (1) locational scarcity of groundwater resulting in tapping of groundwater and transferring from large distances and as the available groundwater in situ was too little (2) even the water tapped from large distances is so insufficient that the farmers had to use drip irrigation to utilize the available low volume of water in an efficient manner.

4.14.1 DRIP IRRIGATION ON FARMS WITH WATER TRANSFER

In Goppenahalli, all the 21 farmers growing arecanut have fixed drip irrigation system during 1995, in response to water scarcity. The investment in drip irrigation amounts to around Rs. 12,000 per acre.

The farmers who have shifted to the drip system, were earlier irrigating the arecanut in flow system. In addition to investment in drip irrigation, around 40 percent of these drip farmers are lifting water by drilling irrigation well(s) at distances ranging between 2 kms and 7 kms from their farm. Having installed automatic starters, farmers need not put on or put off the irrigation pump and thus achieve saving in their time and energy.

The problem of water transfer is best studied with the help of a case study of a farmer in high well interference village. The farmer installed drip irrigation system and is transferring groundwater from a distance of 5 kms from Maravanji, Channagiri taluk to irrigate his arecanut crop of eleven acres at Goppenahalli. Water transfer involved purchase of land at Maravanji mainly for the groundwater appurtenant with land. The transfer of water involves huge investments in the form of purchasing land, conveyance, maintenance and other transaction costs.

4.14.2 INVESTMENTS IN IRRIGATION

The farmer (Sri Shankrappa, Goppenahalli in Channagiri taluk) possessed 11 acres of land totally under arecanut, with 6 borewells of which one was working. The working well is 500 feet deep drilled in 1995 on the 0.5 acre land purchased at a price of Rs. 15,000 located 5 kms away from his farm to exclusively tap groundwater.

The farmer has installed a 6 HP irrigation pump set with 10 stages to lift water. The age of this well is assumed as five years since, the water is used through drip irrigation, saves the farmer substantial volumes of water. The yield of the well is 1500 gallons per hour. Farmer has laid the PVC pipe by investing Rs. 1,50,000 for transfer of water.

With a failure of 5 wells on the farm, the amortized cost of irrigation (= amortized cost of working wells, failed wells, drip irrigation system, overground water storage, PVC pipe) and repairs worked out to Rs. 1,45,779 which formed 72 percent of the total cost of production (Rs. 2,02,079) (Table 4.23). The amortized cost on water transfer alone was Rs. 16,699 which accounted for 8 percent of the total cost of production. The amortized cost of investment on drip irrigation was Rs. 22265 for 11 acres of arecanut per year which formed 11 percent of the total cost of production. The non irrigation production costs were Rs. 53,900.

NET RETURNS

The farmer used 206 gallons per areca palm per year or 0.04 acre inch per plant (with the plant population being 600 trees per acre). He realized an output of 4 quintals per acre and gross return of Rs. 5,87,500. The net returns over the total cost of production was Rs. 3,85,421 from 11 acres of arecanut, which implies a net return of Rs. 35,038 per acre. The net returns over non irrigation cost was Rs. 53,3600 which implies a net return of Rs. 48,509 per acre (Table: 4.24)

Table 4.23: Costs of water transfer in Goppenahalli village, Channagiri taluk, Karnataka, 1997

(A case study of a water transfer by a farmer)

	Costs	Proportion
Amortised cost of(working wells + failed wells+ drip+ storage+ pvc)+ repairs = total irrg cost	1,45,779	73%
Amortised investment on (working and failed) wells	88,633	44%
Amortised investment on only working wells	15,516	8%
Amortised investment on only failed wells	73117	37%
Amortised costs on (working well+drip+storage + pvc)+ repairs	72,662	36%
Amortised cost of storage structure	3,182	2%
Amortised cost of drip investment	22,265	11%
Amortised cost of water transfer (=cost of pvc pipes + laying charges)	16,699	8%
Annual repair charges of irrigation wells, pumpsetss	15,000	7%
Non irrigation costs of production	53,900	27%
Total cost of production + irrigation + opportunity cost of dryland agriculture	2,02,079	100%

Note: The data for this table is from a case study of a farmer Sri. Shankarappa from Goppenahalli village, who has been transferring water from Maravanji (a nearby village). He has 11 acres under arecanut, has 6 borewells of which 5 borewells have failed and the only one well is in Marvanji village which is 4 kilometers away from his farm.

Table 4.24 : Net returns on water transfers in Goppenahalli village, Channagiri taluk, Karnataka, 1997

(A case study of a water transfer by a farmer)

(in Rupees)

	Returns
Gross Returns	5,87,500
Net returns over all cost of production	3,85,421
Net returns over non- irrigation costs	5,33,600
Net returns over irrigation costs including negative externality costs	4,41,721
Net returns over costs of working and failed wells	4,98,867
Net returns over costs on (working wells + drip + storage + pvc + repairs)	5,14,838
Net returns over production costs and working well costs and coping mechanisms	4,60,938

Note: The data for this table is from a case study of a farmer Sri. Shankarappa from Goppenahalli village, who has been transferring water from Maravanji (a nearby village). He has 11 acres under arecanut, has 6 borewells of which 5 borewells have failed and the only one well is in Marvanji village which is 4 kilometers away from his farm.

DISCUSSION

CHAPTER V

DISCUSSION

As groundwater has been considered as a free-of-cost resource both by the farmers and the policy makers, for the economics of groundwater irrigation to make a discernible impact on the cost of cultivation of crops, there is necessity to appreciate the implicit costs of groundwater, though the explicit costs are in terms of electricity price payments to the State Electricity Board. This chapter highlights all the details of the implicit costs involved in groundwater irrigation.

Physical and Economic scarcity of groundwater

Considering the fact that Channagiri taluk is located in Southern transitional zone, the agroclimatic condition and hydrogeological regimes are more favorable when compared with other dry agroclimatic zones of Karnataka. Not withstanding these benefits, the field impression and consultation with major drip irrigation actors of the state, indicated that, Channagiri is fraught with economic scarcity of groundwater and thereby forcing farmers to adopt drip irrigation as a popular mode of irrigation whenever arecanut is dominating. Accordingly, Channagiri taluk was chosen to study the economic scarcity even though the farmer here do not deserve the equity focus as much as expected, when compared with situation in other dry zones. The reason being, peasants in Channagiri are using groundwater to grow arecanut, and not any food crop or vegetable crop, in which case the market forces in arecanut may bring windfall gains to farmer and offset the effects physical or economic scarcity of groundwater so that farmers can be cheerfully resilient. Hence while physical scarcity is crucial, in all the areas where interaction effects of wells are apparent, the areas which suffer from economic scarcity of groundwater, supporting food and vegetable crops obliterate concerns of equity.

Thus, it is in order to note that the this study focus is to be more towards efficiency rather than equity for the reason that the resilience effect by the farmers are towards sustenance of commercial crops like arecanut rather than food crops.

Earlier studies in the Department of Agricultural Economics by Shirish Kulkarni, (1976) considered life of a dug well with lining to be 100 years and that without lining to be 50 years and borewell to be 25 years. In another study Jayaraman, (1981) considered the life of dug well to be 50 years and that of borewell to be 30 years. While the physical structures of dug wells (lined or unlined) and borewells may last for the assumed period, whether these wells also yield groundwater for their assumed period is a key question.

During the 70s, when the above studies were carried out, initial failures as well as premature failures of irrigation wells were not even thought of as the eventualities. Thus, with increasing policy support for minor irrigation (through NABARD refinance) on the one hand and increased investment by farmers on the other, the number of irrigation wells grew exponentially at a compound growth rate of ten percent in the Eastern Dry Zone and at significant rates in other zones too.

It is in order to compare the rate of drilling / sinking wells with the Governmental policy support. Since 1982, the energy cost of pump-lifting groundwater on pro-rata basis from irrigation wells was changed to the flat-tariff.

Farmers using groundwater for irrigation using electrical pumps needed to pay according to the number of units of electricity used (pro-rata basis), as against payment of a flat fee per year based on the Horse Power of the irrigation pump. A careful observation of the impact of the shift from pro rata to flat rate policy indicates that in Karnataka, the use of electricity for agricultural purposes increased from 390 million kilowatt hours in 1976 to 2,404 million kilowatt hours in 1987 (Chandrakanth and Romm, 1990). In addition, institutional credit for minor irrigation increased from 26 percent to 50 percent between 1968 and 1988. Specifically, the institutional credit for well irrigation increased by 16 times from Rs. 18.3 million in 1968 to Rs. 317 million in 1987; that for horticulture by 100 times from Rs. 1.23 million to Rs. 121 million. A discernible impact of this support was seen in the increase in the percentage of wells drilled with the institutional support from 26 percent to 50 percent. The refinance by NABARD increased by 6 times during the period. With the tacit support from the Rural Electrification Corporation of the Government of India, the investment on groundwater irrigation swelled. If the rate of construction / drilling irrigation wells (ten percent) could be considered as a proxy for the rate of groundwater extraction, and comparing with the modest rate of groundwater recharge of around five percent, the past and present groundwater extraction are certainly unsustainable. This can be considered as the prima facie evidence of the physical scarcity of groundwater resource.

Physical scarcity of groundwater exacerbated due to interference of wells

In the next level of analysis, the physical scarcity which is almost a general phenomenon in the hard rock areas, is exacerbated in pockets where interactive effects of irrigation wells is apparent. Interactive effects of wells arise in situations where the number of wells per unit volume of groundwater is large. In such situations, the physical scarcity of groundwater can lead to economic scarcity, by increasing the groundwater scarcity rents, negative externality costs, other transaction costs, all of which, reduce the resource economic profits from groundwater irrigation. This may have equity implications, since small farmers with meager resources will face greater economic problems due to inaccessibility to groundwater compared with large farmers, when both face the same levels of economic scarcity of groundwater. However, due to scarcity lead high initial and premature failure of irrigation wells, the life of irrigation wells has been considerably shortened. In extreme cases, as in Channagiri, the average life of irrigation wells is even below two years ! This paves the way for consideration of investment in well irrigation as a variable cost influencing the decision making. Considering these investments on wells as fixed capital, economic profits will be overestimated and make further investments attractive, as farmers fail to appreciate that they are realizing illusionary profits.

In Channagiri, groundwater extraction through borewells began since the early seventies, after all the efforts to tap the resource from the existing dug wells by deepening and / or in boring, failed to bear results (in the HWIVs of Goppenahalli and Bussenahalli). Basically, irrigated agriculture in Channagiri -in the HWIV was targeted at sustaining arecanut-betelvine farming. Here, farmers considered owning arecanut orchard as a prestige. Thus, all the investments made by farmers to sustain areca gardens by way of frequent investments in groundwater and associated irrigation structures (systems) can conveniently be considered as farmers' efforts to be resilient economically.

Hence the existence of 90 percent of all wells as borewells, of which only 47 percent (148) are functioning, gives a primary indication of the extent of economic scarcity in the study area.

In the High well interference villages (HWIV), of the total (260) wells, 89 (34 per cent) are owned by flow irrigation farms and 171 (65 per cent) were owned by drip farmers. This shows that in situation of high interactive effects of wells, when there is no recharge of groundwater, due to scarcity, and suitability of the crop for drip irrigation, farmers have conveniently switched to drip irrigation. Conversely, Bussenahalli, due to relatively better endowed groundwater, farmers are irrigating their arecanut garden through flow irrigation. This is an apparent contrast where farmers have responded to cope with scarce groundwater using drip irrigation in groundwater scarce village, have with flow irrigation in relatively better endowed groundwater village due to influence from irrigation tank. These two villages are about 10 kilometers apart.

5.1 AGE AND LIFE OF WELLS

In this study, concepts of well age and well life have been clubbed to obtain the average number of years of functioning of irrigation wells for the following reasons:

1. For initial failures, (if) the life is taken as zero (and) the amortization (formula for) cost of irrigation will be plus infinity. Again, if there are large number of initial failures, the amortized cost of irrigation will obviously be too prohibitive and adds large values to the cost of irrigation.

2. In a situation where borewells dominate, and for a few farmers who still have had dug wells which served for more than 30 years, which is higher than the average life, the positive externality realized due to larger ages, will mask the negative externality of the borewells which served far below average life, since all the negative and/or positive externalities are clubbed for each farmer. Also the productivity of dug well and borewell are not directly comparable as they tap groundwater from different levels of aquifer.

3. The outlayer farmers are those who had irrigation dug wells which served for long periods. Such outlayers have been eliminated by using the rule Mean ± (1.66 Standard Deviation) to include 90 percent of the wells assuming the normal distribution for the data. Thus, the average age includes both the age and life of wells as a comprehensive indicator of the number of years borewell / dug well functioned in a given area. Obviously, if the number of initial failures is large, then this will weigh down the age of the well. Clubbing the concepts of age and life, the average age of the well is computed separately for dug well, dug cum borewell and borewell for HWI and LWI villages.

4. The range of life for borewells in HWIV was small (0 to 15) ; and in LWIV, the range was 0 to 17, the average age was computed for HWIV and LWIV.

The overall initial failure rate for HWI and LWI villages was 55 percent and 31 percent out of 234 and 82 borewells respectively. This apparently shows the interactive effects of wells in HWI compared with LWI. Out of 234 wells of all types in

HWI villages, 85 (55 percent) were working. In LWI villages, 63 wells (76 percent) out of 82 wells were working.

Thus, each well on HWIV drip farms irrigates 2.87 acres, while on flow irrigation farm irrigates 2.24 acres, in LWI small farms 2.8 acres and 3.27 acres in LWI large farms. It is to be noted that such comparisons without considering the method of irrigation and crop pattern are untenable. Each well in HWI drip farms irrigates 2.87 acres of arecanut, but the mode is drip irrigation. In these areas, there has been no influence of groundwater recharge from the irrigation tank. On the contrary, each well in HWI flow irrigation farms, irrigates 2.24 acres, but the mode is flow irrigation. In these areas, there has been influence of groundwater recharge from irrigation tanks in proximity. This shows that the productivity of a well is greatly influenced by groundwater recharge, and using drip irrigation for a perennial crop like arecanut, will even increase the productivity by leaps and bounds due to water savings brought out by drip irrigation.

5.2 CROPPING PATTERN

Considering both HWI and LWI villages, the area devoted to arecanut is around 80 percent and 60 percent respectively, indicates that farmers are coping with groundwater scarcity by continuing to maintain a perennial crop like arecanut. It is in order to note that compared with seasonal water intensive crops like paddy and annual crops like sugarcane, perennial crops in general are low users of water. Such a coping mechanism also exists in eastern dry zone, where farmers devoted around 45 percent of the gross area irrigated to mulberry, grapes and coconuts (Nagaraj and Chandrakanth, 1995). In traditional areca growing areas, the coping mechanism is the adopting of drip irrigation. Whereas, in new areas, where areca is taking root, the cultivation of the perennial areca crop itself can be considered as a coping mechanism.

5.3 COPING MECHANISMS OTHER THAN CROP PATTERN SHIFTS

The coping mechanisms involved are the use of drip irrigation, conveying water through Poly Vinyl Chloride (PVC) pipes laid two feet below the ground for sufficiently long distances of two to five kilometers from the borewell located outside the farm, surface-water tank, covering the water tank with polythene sheets to reduce percolation losses, and drilling additional wells to meet the acute groundwater scarcity. Farmers are forced to invest at least Rs. half a lakh merely to transport groundwater from a long distance, involving risk and incurring the transaction costs of convincing the neighboring farmers and other riparian farmers beneath whose fields the PVC pipes are laid.

5.4 INVESTMENT ON IRRIGATION WELLS

It is in order to note that, the cost of groundwater irrigation is relevant for farmers in hard rock areas due to the high probability of well failure which forces the farmers to invest in additional well(s). This investment by hypothesis is due to cumulative interference. The difference in the investments between HWI and LWI can be considered as the cost of negative externality, which is an implicit cost. These negative externalities are implicitly incurred through forced investment on (i) additional well(s) since the well(s) constructed earlier failed to yield water for the expected number of years and / or (ii) water use efficient structures (like over-ground storage structures, conveyance pipes, drip irrigation, sprinkler irrigation etc) in order to at least remain on the original iso-revenue curve.

Considering drip farms in Goppenahalli, the amortized investment per farm on irrigation wells (drilling, casing, irrigation pump, GI pipe, electrical charges, pump house) is Rs. 1,10,504 and that per acre is Rs. 18,528 (Table :4.9). The amortized cost per well is Rs. 13,571 and that per functional well is Rs. 52,740. This very economic scarcity of groundwater has necessitated all these farmers to invest on drip irrigation, at an investment of around Rs. 12,000 per acre. The high investment per functional well is due to high failure rate of 71 percent (among borewells).

Considering the investment on irrigation wells and the associated paraphernalia in HWIV drip and flow irrigation farms, the investment per functional well is higher by 122 percent on drip farms compared with flow irrigation farms induced by higher probability of well failure (Table :5.1). The savings of investment per functional well to the tune of 55 percent on flow irrigation farms is due to lower well failure induced by the recharge of groundwater.

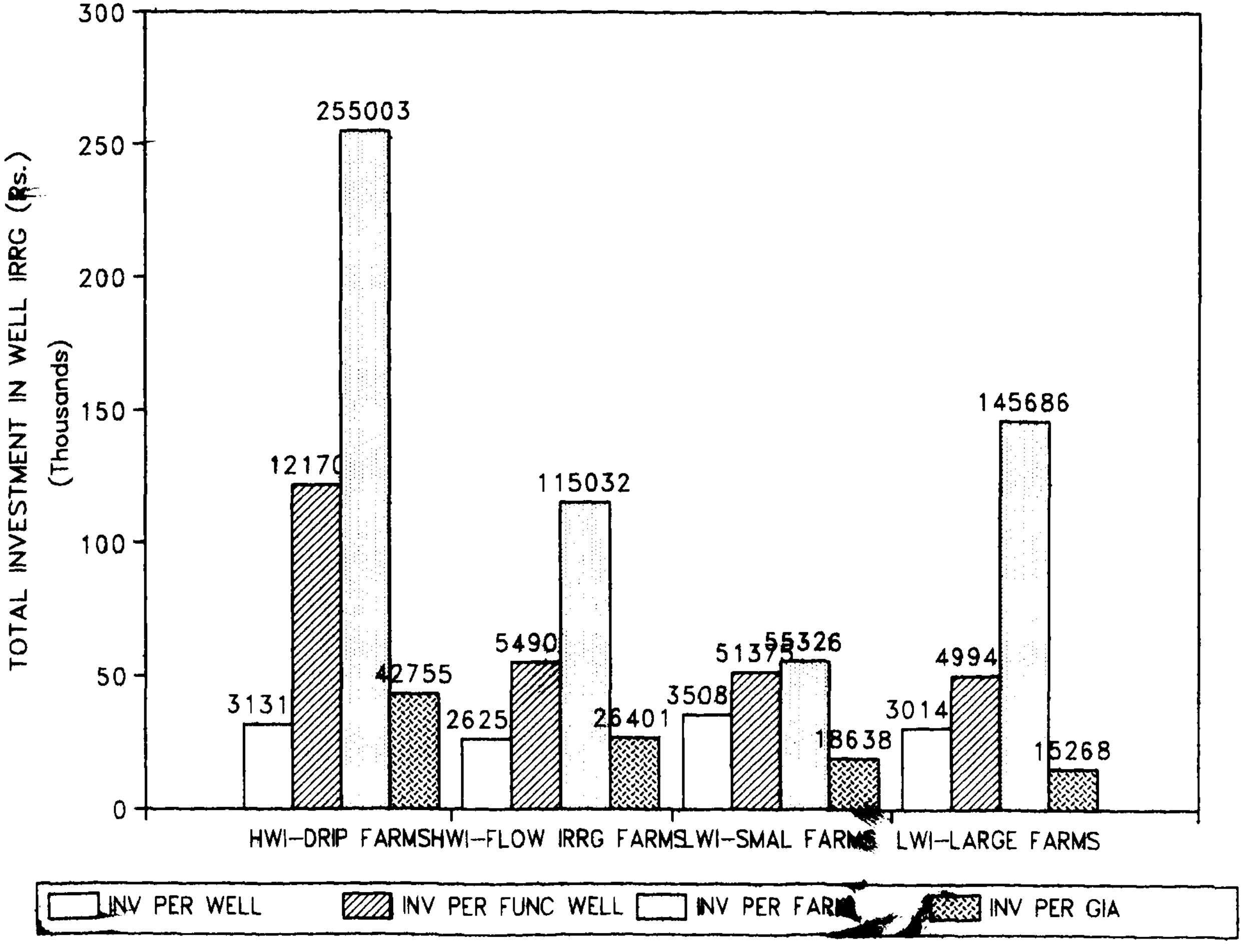
The area irrigated per functional well is 2.84 acres and 2.31 acres respectively on drip and flow irrigation farms in the high well interference area and are comparable. However, the groundwater used per acre by drip farmers is 9 acre inches per acre as they used drip irrigation, while that by flow irrigation farmers is 27 acre inches as they used flow irrigation, This clearly demonstrates that in groundwater scarcity situations, drip irrigation saves groundwater use to the tune of 66 percent, in a broad spaced perennial crop of arecanut. The marginal factor cost per acre inch of groundwater on drip farms is Rs. 2,509 while that on flow irrigation farms is Rs. 418, an increase of 500 percent. Further, there can be savings in the cost of water used if drip irrigation is adopted to the tune of 18 (i.e. 27-9) acre inches X Rs. 418 = Rs. 7524 per acre in flow irrigation farms.

Table 5.1: Investment on irrigation wells in High Well Interference Village farms in Channagiri taluk, Karnataka (*at 1997 prices*)

Farm	Total number of irrigation wells	Total number of functional wells	Total investments on all wells per farm	Investment per functional well per farm
Drip irrigation farms (in=21)	171	44 (2)	2,55,004	1,21,706
Flow irrigation farms (n=21)	92	44 (2)	1,15,003	54,901

Figures in parantheses indicate number of wells per farm.

FIG 5.1: TOTAL INVESTMENT IN WELL IRRG
BY FARMERS IN CHANNAGIRI (1997)



Thus, the huge differential in the value of groundwater between the flow irrigation - arecanut (Rs. 418 per acre inch) and that in the drip irrigation - arecanut (Rs 2509 per acre inch) of 500 percent reflects the true economic scarcity of groundwater in drip irrigation farms. Farmers using drip irrigation are saving 18 acre inches of water on every acre of arecanut over those who are applying water to arecanut with the help of flow irrigation. Considering that farmers in Goppenahalli would benefit from desiltation of tank, their water price would be Rs. 418 per acre inch similar to the water price in tank-influence village farmers using flow irrigation. Thus, the value of groundwater saved would be 18 acre inches per acre at the rate of Rs. 418 per acre inch (incurred by flow irrigation farms) = Rs. 7,524 per acre. On a conservative basis, this can be considered as positive externality, accruable due to the impact of tank desiltation and use of drip irrigation.

In the flow irrigation farms the area under arecanut is 91 acres and that in drip farms is 125 acres, which results in per farm areca area of 6 acres and 4.35 acres respectively. Thus, farmers using flow irrigation can irrigate the difference of 18 acre inches saved (by adopting drip irrigation and by encashing the benefit from desilting irrigation tanks) by applying 9 acre inches of water per acre on 2 acres (which is higher than (6 acres - 4.35 acres = 1.65 acres).

Thus, farmers within high well interference villages where there is tank influence can save the use of water to the tune of 66 percent with the adoption of drip irrigation and realize savings in the value of water used to the tune of (18 acre inches X Rs. 418) = Rs. 7524 per acre.

5.5 ECONOMICS OF IRRIGATION

In HWIV, arecanut is the major crop on all well irrigated farms inter-cropped with betelvine. In LWIV also, the crop pattern is dominated by arecanut, while seasonal crops like cotton, sunflower, onion, maize, groundnut are also grown in LWIV. While computing the cost of production, the establishment cost of arecanut, betel-vine and coconut have not been considered, as the major focus of this study was on the resource economics of well irrigation.

5.6 EXTERNALITY COST

Externality is of two types - positive and negative. Negative externality is the unreimbursed cost. The unreimbursed cost in the case of groundwater irrigation refers to the investment the farmers have to incur exclusively due to the action of other farmers. The actions of other farmers are manifested through cumulative well interference. Such investments inter alia are in terms of (i) additional well(s) since the well(s) constructed earlier failed to yield water for the expected number of years and / or (ii) water use efficient structures (like over-ground storage structures, conveyance pipes, water transfers, drip irrigation, sprinkler irrigation etc) in order to at least remain on the original iso-revenue curve. The negative externality cost (economic loss) of well failure reflects the forced investment(s) by farmers in well irrigation due to the problems of cumulative well interference. By hypothesis of this study, negative externality is manifested due to the premature failure of wells and hence they did not serve for the average expected life.

Positive externalities are uncharged benefits. The farmers whose groundwater wells, served and / or serving beyond their average age, are expected to have experienced / experiencing positive externalities. Positive externalities arise largely due to (community) efforts to augment groundwater recharge, maintenance of isolation distance keeping the number of wells already drilled/dug into account, community efforts towards reasonable use of irrigation water by adopting crop patterns and water use efficient devices which are not exploitative. While creation of positive externality largely is a function of individual and community effort, ample opportunities exist for enhancing positive externality at the individual farm level also. Such opportunities inter alia are (i) using scientific methods to site the irrigation well, (ii) drilling of well to the right depth and using casing for the right depth; (iii) use of the right capacity standard pumpset and placement of the pump at the right depth, (iv) adoption of drip irrigation practice (v) adoption of the right cropping pattern to suit to the groundwater yield, soil, topography and other agro-climatic factors; and (vi) use of the right volume of groundwater through appropriate mode to the crops grown.

Negative externality is the transaction cost of cumulative well interference experienced by the farmers over time expressed in 1997 prices. By hypothesis of the study, the well failure and the associated coping strategies are exclusively due to cumulative interference. The negative externality cost is the cost of providing irrigation after the year of failure of the first well including the first well, if the first well did not serve for the average number of years it was supposed to function. The amortized cost of negative externality in drip farms is Rs. 16,893 per acre and that for flow farms is Rs. 3,915 (Table : 5.2). This difference of 330 percent is due to the influence of groundwater recharge through irrigation tank. Thus, for every Rs. 100 of negative externality in the flow irrigation farms there will be Rs. 430 of negative externality in the drip irrigation farms. This reduction in the negative externality is despite the increase in the use of groundwater for irrigation (due to flow irrigation

Table 5.2 : Amortized Costs of Negative Externality in HWI villages of Channagiri taluk, Karnataka, 1997 (Rs)

	Farmers using Drip irrigation	**Farmers using flow irrigation**
Total NegativeExternality	-21,15,895	-3,61,506
Average Negative Externality	-1,00,757	-17,215
Total No of wells per farm	8.14	4.38
Area irrigated per functional well	2.84	2.07
Negative Externality Per Gai acre	-16893	-3915
Negative Externality per Well	-12,374	-3,929
Negative Externality per Functional Well	-48089	-8216

Note : While estimating the negative externality, the outlayers as decided by mean plus or minus 1.66 times (standard deviation) are eliminated to obtain a pragmatic estimate to arecanut) to the tune of 200 percent compared with the drip farms where groundwater is applied through drip irrigation, resulting in frugal use of groundwater.

In this study the positive externality is subsumed to manifest through the average age of irrigation well(s) influenced inter alia by degree of well interference, the degree of groundwater recharge induced by management of irrigation tank, the crop pattern, the mode of application of water and so on. If positive externalities are apparent, the cost per acre inch of groundwater which is its scarcity rent, will be lower, the proportion of well failure will be lower and the average life of well(s) will be higher.

POSITIVE EXTERNALITY AND NEGATIVE EXTERNALITY IN DRIP AND FLOW IRRIGATION FARMS

The irrigation cost per acre and net returns per acre on flow irrigation farms is almost 50 percent of the irrigation cost per acre on drip irrigation farms.(Fig 5,2 & 5.3) The net returns are lower on drip farms largely due to higher irrigation costs expended as the farmers had to invest on an average on eight irrigation wells on drip irrigation farms, while the flow irrigation farms invested only on four irrigation wells. The drip irrigation farmers here are facing two types of negative externalities : (1) the necessity to invest on larger number of (8) wells to get two working wells and (2) their very location in Goppenahalli village which is not experiencing the groundwater recharge through the lone irrigation tank, which is causing the farmers to locate irrigation wells 2 to 5 kilometers away from their farm and to shift the groundwater through PVC pipes adding extra financial burden. However, the positive externality which drip irrigation farmers could experience in future is the huge savings in groundwater use in arecanut which in turn will reduce the groundwater extraction from the borewell(s). Since the drip irrigation farms are using 9 acre inches per acre of arecanut as against 27 acre inches per acre by flow irrigation farms, then without loss of generality, it can be safely concluded that each well on a drip irrigation farm is saving the investment on two working borewells which is the positive externality. Conservatively, as the cost of a working borewell is Rs. 55,000 (on flow irrigation farms), then the positive externality due to drip irrigation in terms of savings achieved in investment on two wells is Rs. 1,10,000 (Tables 5.3 and 5.1).

Thus, if farmers using flow irrigation in HWIV who realizing the benefits of tank recharge, apply water effectively through water use efficient technologies (such as drip), they can use groundwater on a sustainable basis which can lower the negative externalities, enhance the life of the irrigation well and lower the cost of irrigation.

Farmers in LWI villages experienced a relatively lower level of negative externality as compared with farmers of HWI villages. The amortized cost of negative externality for small (large) farmers is Rs. 5,724 (Rs. 9,443) per farm and Rs. 1928 (Rs 990) per acre respectively (Table 5.4).

This shows that there is great inequity in sharing the negative externality per acre; small farmers are bearing a negative externality cost, which is 100 percent higher than that faced by large farmers.

Table 5.3 : Comparative economics of groundwater irrigation in Channagiri taluk, Karnataka, 1997

Features	Farms using drip irrigation	Farms using flow irrigation	LWI-Small farms	LWI-Large farms
1. Irrigation cost per acre (Rs)	22,397	11,568	5,766	4,878
2. Net returns per acre (Rs)	15,816	36,734	6,634	17,147
3. Irrigation cost as percentage of total cost	68	65	48	45
4. Net returns per acre inch of groundwater (Rs)	1,772	1,328	319	973
5. Groundwater used per acre (Acre inches)	9	27	18	20
6. Irrigation cost per acre inch	2,509	418	277	277

Fig 5.2: ECONOMICS OF GROUWATER FOR FARMERS USING DRIP AND FLOW IRRIGAITON IN CHANNAGIRI TALUK, KARNATAKA, 1997

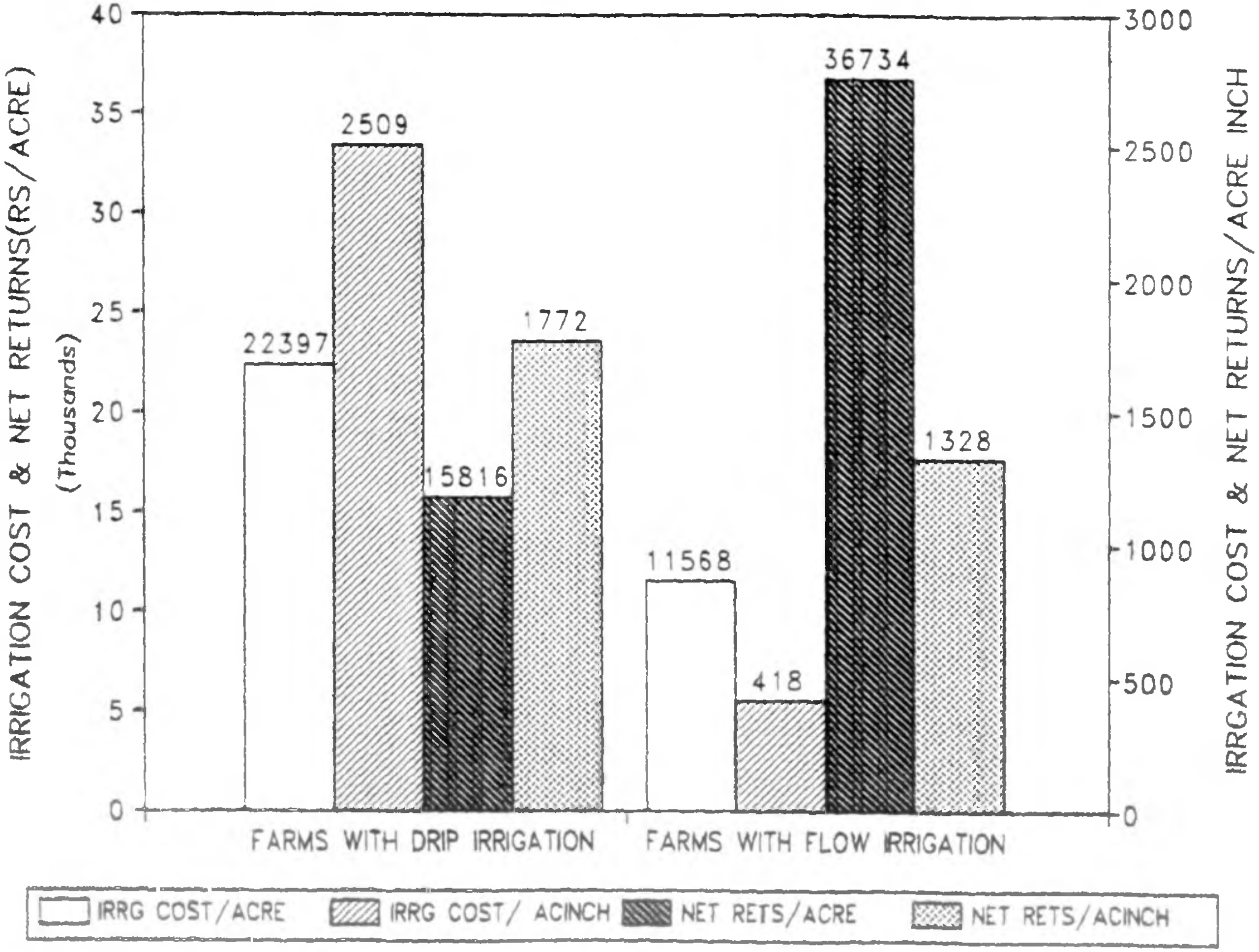


FIG 5.3: ECONOMICS OF GROUNDWATER FOR SMALL & LARGE FARMS IN LWIV CHANNAGIRI

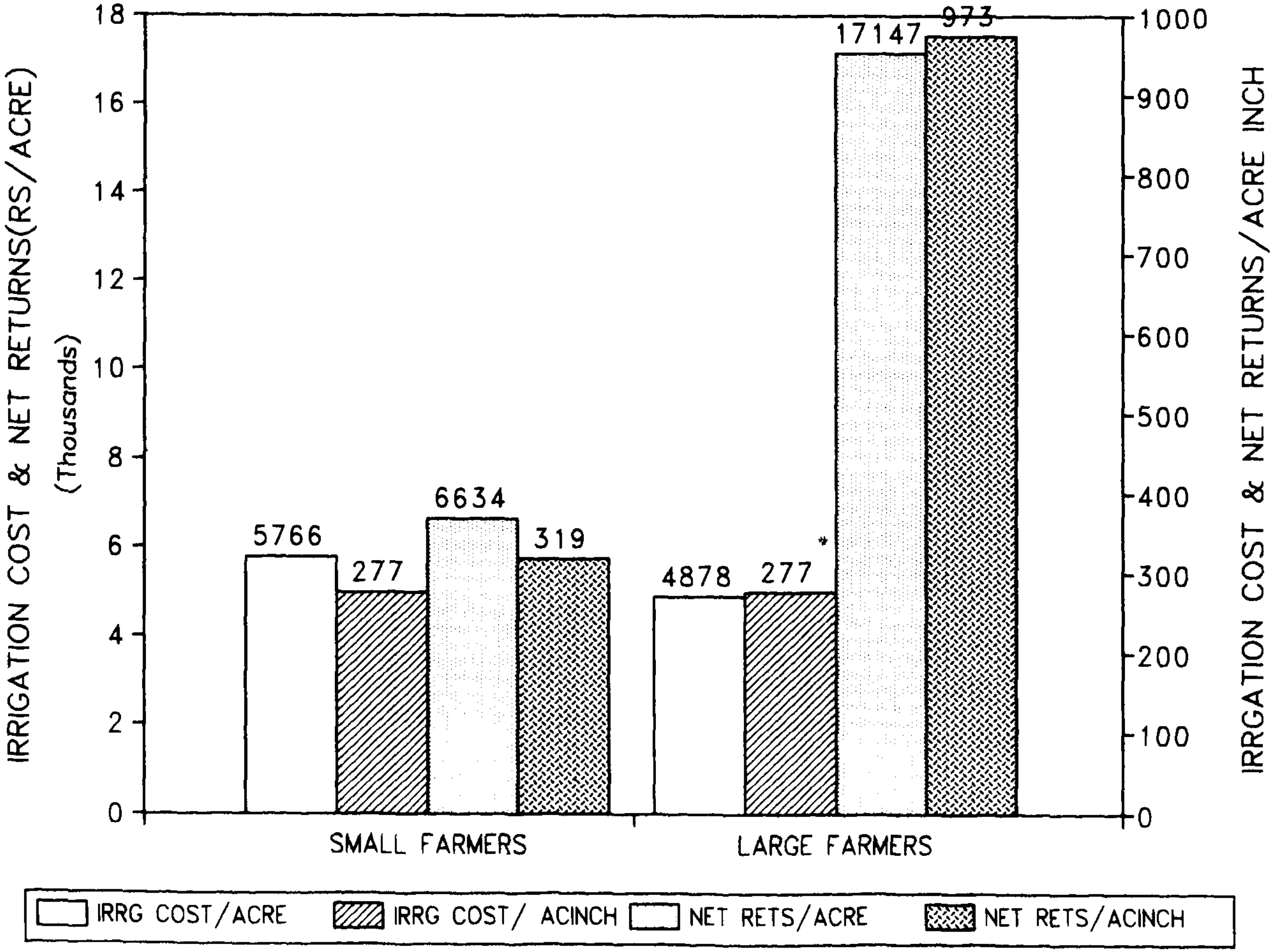


Table 5.4 : Amortized Costs Of Negative Externality in irrigation in LWI villages in Channagiri taluk Karnataka, 1997 (Rupees)

	Small Farmer	Large Farmer
Total Negative Externality for the sample	-1,48,833	-1,13,317
Total No. of wells per farm	1.57	4.83
Total No. Of acres per well	1.88	1.97
Area irrigated per functional well	2.75	3.27
Negative Externality Per farm	-5,724	-9443
Negative Externality Per acre of GAI	-1928	-990
Negative Externality Per Well	-3630	-1954
Negative Externality Per Functional Well	-5315	-3238

The amortized cost of negative externalities reflect one side of the economic scarcity of groundwater. The other side can be examined by analyzing and comparing the net returns realized per acre of gross irrigated area in HWI with LWI farmers.

A comparison of the irrigation cost per acre of GIA in flow irrigation farms of high well interference village with the small farms in low well interference village, the former incurs Rs. 2 for every rupee one incurred by the later. Similarly the irrigation cost per acre inch and groundwater used in HWI is greater than that in LWI small and large farms. Thus, the negative externality in terms of amortized cost is higher in HWI when compared with LWI and this amply supports the hypothesis that well interference increases the cost of negative externality. However, when net returns per acre of GIA in HWI flow farms are compared with that in LWI, the HWI-flow farms are realizing Rs. 5.48 for every one rupee realized by LWI small farmers.

Thus, even if HWI flow irrigation farmers are compared with LWI large farmers, the HWI flow irrigation farmers realize Rs. 2.14 for every one rupee of net return earned by LWI large farmers. A comparison of the HWI flow irrigation farmers with all farmers in LWI, the former realize Rs. 2.84 for every rupee realized by the later (Fig 5.4). This indicates that the positive externality due to tank influence offsets the higher cost of irrigation (Rs. 22,397 per acre in HWI-drip farms) due to high well interference and results in larger net returns per acre in HWI flow irrigation farmers when compared with LWI farmers (Table 5.5).

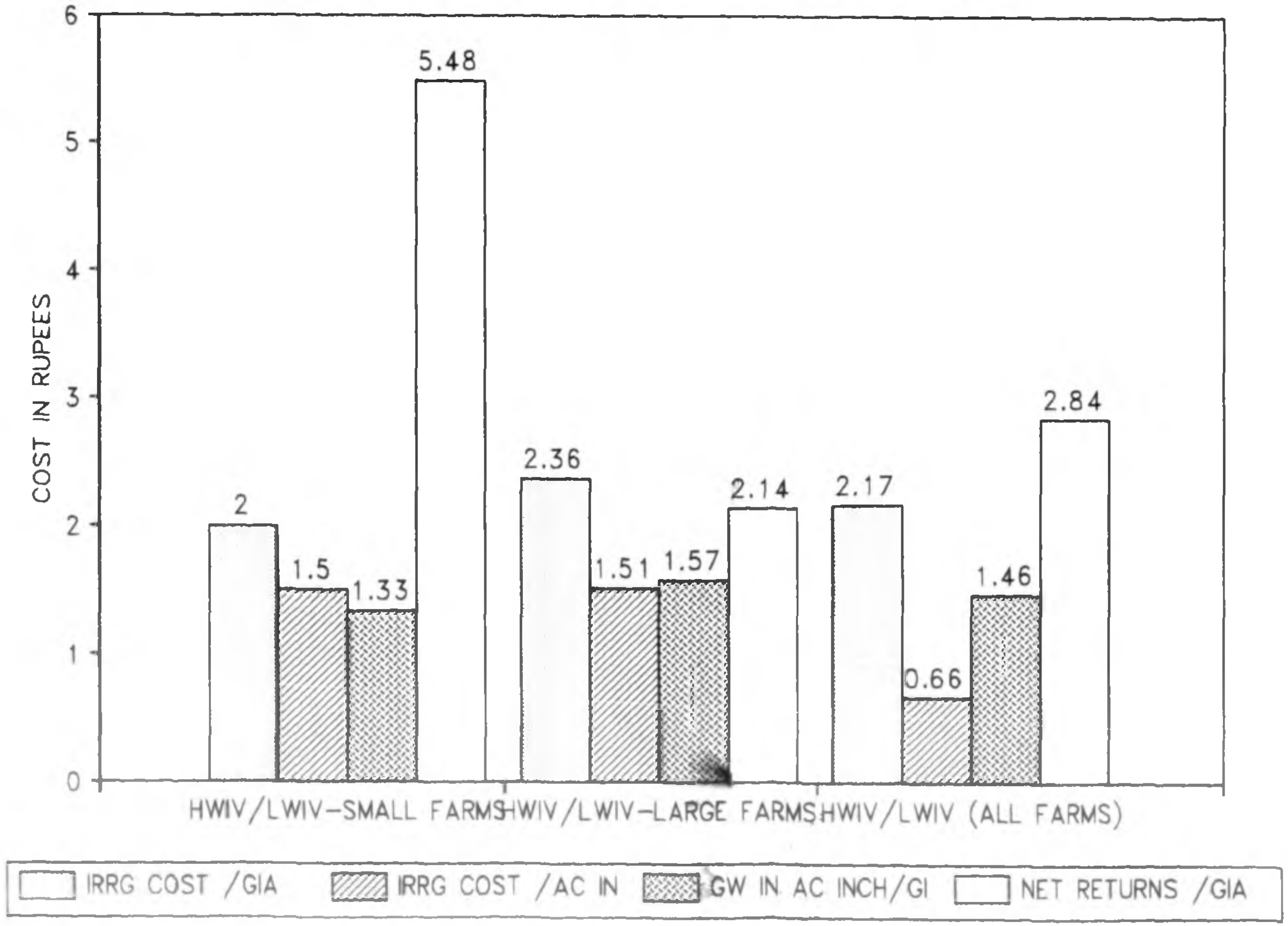
Table 5.5 : Magnitude of Relative Externality faced by farmers in Channagiri taluk, Karnataka, 1997

Farmers	Irrg cost per acre of GIA (H/L)	Irrigation cost per acre inch	Groundwater in acre inches per acre of GIA	Net returns per acre of GIA
1. Flow irrigation farms in HWIV / Small farmers in Low Well Interference Village	2.00	1.50	1.33	5.4
2. Flow irrigation farms in High Well Interference Village / LWI large farms	2.36	1.51	1.57	2.1
3. Flow irrigation farms in High Well Interference Village / All farms in LWIV	2.17	0.66	1.46	2.8

Note: H/L= Irrigation cost per acre of GIA on HWIV farm by Irrigation cost per acre of GIA on LWIV farm

Each figure in the table is a ratio, for instance, 2.8 = Net returns per acre of GIA on flow irrigation farm in HWIV by Net returns per acre of GIA on flow irrigation farm in LWIV

FIG 5.4: EXTERNALITY IN FLOW IRRG IN
HWIV OVER LWIV FARMS IN CHANNAGIRI 1997



5.7 EQUITY ISSUES

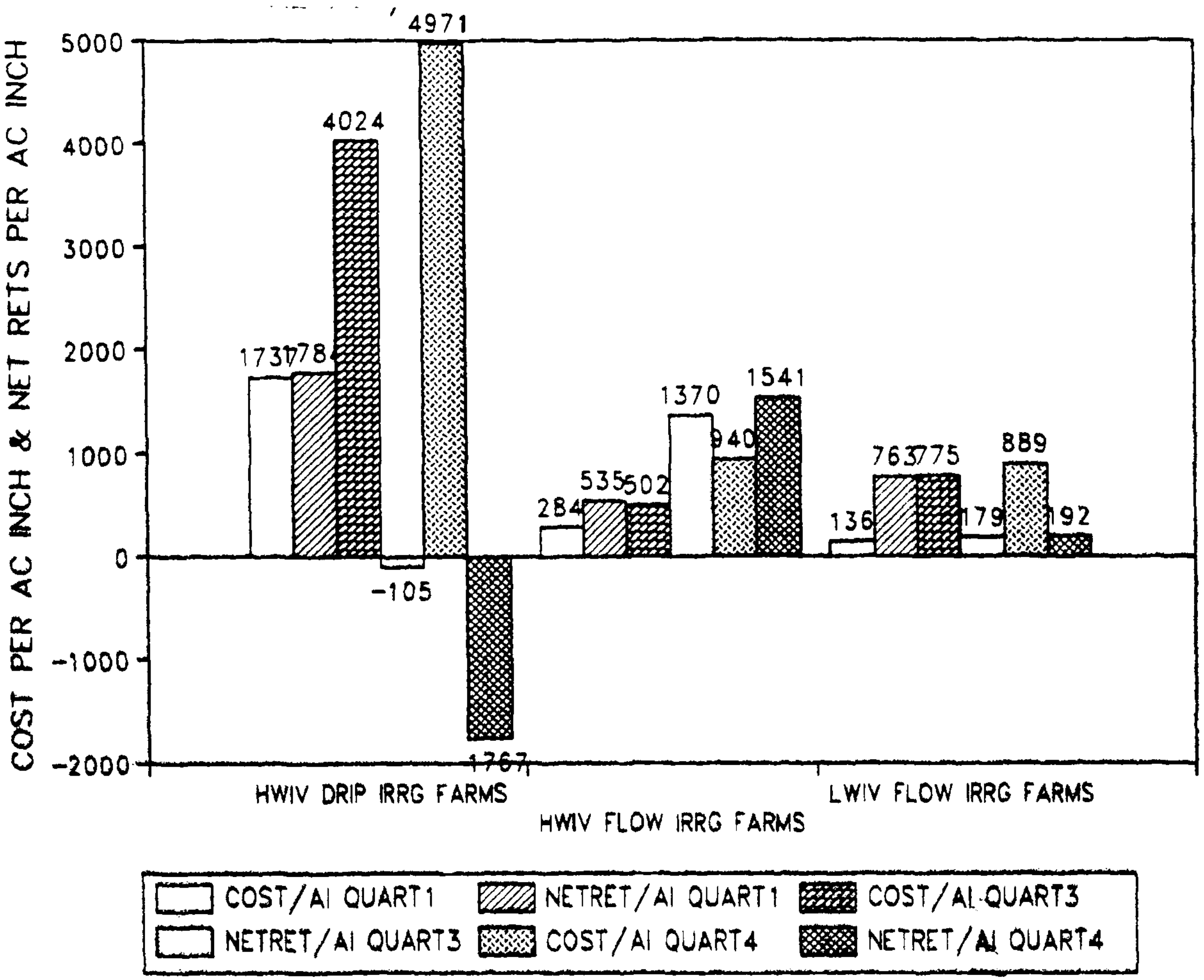
The equity issues in access to groundwater irrigation can be examined by analysing key economic factors determining the extent of groundwater irrigation across quarters in drip farms and flow irrigation farms in HWI and Small & large farms in LWI villages. In HWI, on drip irrigation farms, inequity in access to groundwater is reflected in the first quarter, as the top 25 percent of the farmers have access to 50 percent of the groundwater, and to 39 percent of land under arecanut, incurring 34 percent of the irrigation cost, realizing a net return of 50 percent and owning 43 percent of functional wells. The net return per functional well is Rs. 52,236. Here, the net return per acre inch of groundwater is Rs. 1784. The farmers in the first and second quarter using drip irrigation have realized higher net returns per acre inch of water compared to flow irrigation farms. Even though the drip irrigation dampened the negative externalities in net returns in the first two quarters. This shows that though the drip irrigation in HWIV plays a crucial role in reducing the negative externality, due to relatively higher rate of failure of wells due to well interference, the farmers have suffered losses to the tune of Rs.105 per acre inch in third quarter and Rs. 1800 per acre inch in the fourth quarter. This is precisely because, the cost per acre inch of water is Rs. 4000 to Rs. 5000 in the third and fourth quarters as compared to around Rs. 2000 in the top two quarters (Table:5.6).

In the HWI flow irrigation farms, farmers in the top two quarters are endowed with greater access to groundwater, and realized 70 per cent reduction in the net returns per acre inch of water when compared with the farmers in the HWIV drip irrigation quarters. In the second quarter, farmers are using 27 percent of groundwater on 38 percent of area under arecanut, incurring a cost of 27 percent,

Table 5.6 : Comparison of scarcity rent of groundwater and net returns to groundwater in Karnataka

Area	Cost of groundwater = Scarcity rent per acre inch Rs.	Net return per acre inch of groundwater Rs.
SOUTHERN TRANSITION ZONE - CHANNAGIRI TALUK*		
HIGH WELL INTERFERENCE - NO TANK INFLUENCE VILLAGE - GOPPENAHALLI (Drip irrigation farmers growing arecanut)		
QUARTER 1	1737	1784
QUARTER 2	2429	3691
QUARTER 3	4024	-105
QUARTER 4	4971	-1767
HIGH WELL INTERFERENCE - TANK INFLUENCE VILLAGE - BUSSENAHALLI (farmers growing arecanut using flow irrigation)		
QUARTER 1	284	535
QUARTER 2	339	1030
QUARTER 3	502	1370
QUARTER 4	940	1541
LOW WELL INTERFERENCE VILLAGE - KAGATHUR & CHIKKAGANGURU (farmers growing arecanut and seasonal crops using flow irrigation)		
QUARTER 1	136	763
QUARTER 2	340	825
QUARTER 3	775	179
QUARTER 4	889	192

FIG 5.5: INEQUITY IN SCARCITY RENT AND NET RETURNS PER ACRE INCH OF WATER IN CHANNAGIRI TALUK, KARNATAKA, 1997



realizing a net return of 58 percent and owning 20 percent of the functional wells. Thus, farmers in the second quarter on an average are relatively water use efficient. The net return per functional well is Rs. 1,26,626.

In the HWI drip farms, farmers in the first quarter, used 50 percent of total groundwater, when compared with 43 percent by flow irrigation farms; similarly the comparisons of irrigated area are 39 percent and 22 percent; that of irrigation cost are 34 percent and 29 percent, the net returns, 50 percent and 17 percent) and functional wells, 43 percent and 31 percent). These comparisons reflect that, even though water use and irrigation cost are comparable in relative terms, the net returns per acre are inequitable in HWI-flow farms, since the top quarter farmers realized only 17 percent of all the net returns. However, in absolute terms, the net returns are comparable (Rs. 22,055 and Rs. 27,271) (Fig 5.5).

In the HWI drip farms, the farmers in the third and fourth quarters incurred losses around Rs. 983 and Rs. 11,781 per acre respectively, since they shared a relatively low proportion of area under arecanut (16 percent, 9 percent) and relatively low proportion of water use (16 percent, 6 percent), resulting in larger irrigation cost per acre (Rs. 37,671, Rs. 33,138).

While sampling, there was absolutely no bias towards choosing farmers who had followed drip irrigation or any other coping mechanism. As 50 percent of all the farmers in HWIV invested on drip irrigation, this demonstrates that, there is a serious secular overdraft of groundwater in HWI village of Goppenahalli. Here 33 percent of the farmers have purchase land in Maravanji, Vaddanahal, Gollarahatti villages which is as far as 5 kilometers away and have drilled wells to transfer this water through PVC pipes and to irrigate arecanut prudently through drip irrigation.

It is in order to note that even though these HWI drip farms had an irrigation tank in Goppenahalli, there was no recharge of groundwater as no surface water reached the tank. Moreover, this tank was desilted by farmers by applying the silt to their arecanut garden, surface water was seldom found, since encroachments around the Goppenahalli tank were apparent. In this village, there are more than 600 borewells, and a majority of them have failed to yield groundwater at present (1997). In addition, the farmers also indicated about the receding rainfall in the recent years as a reason for low water flow to the tank. Farmers opined that, during 1992, the Goppenahalli tank was overflowed and this recharged their wells for almost three years.

A comparison of scarcity rent per acre inch (or cost per acre inch) of groundwater with the net returns per acre inch of groundwater in the first third and fourth quarters indicate that, for the top 25 percent of groundwater users, the net return is more than the cost per acre inch of water in both HWIV and LWIV situations.

In drip irrigation farms of HWIV, the farmers in the fourth quarter, are incurring cost of Rs.4971 per acre inch of groundwater while realizing a loss of Rs.1767 per acre inch.

On flow irrigation farms of HWIV, farmers in first, third and fourth quarters, their net returns per acre inch of water is more than the cost per acre inch.

In LWIV, as flow irrigation is the common mode of irrigation, even though the well interference is lower, the costs per acre inch are higher than the net returns per acre inch of water for the third and fourth quarters. These results indicate that the size of arecanut crop largely determines the magnitude of well being of the

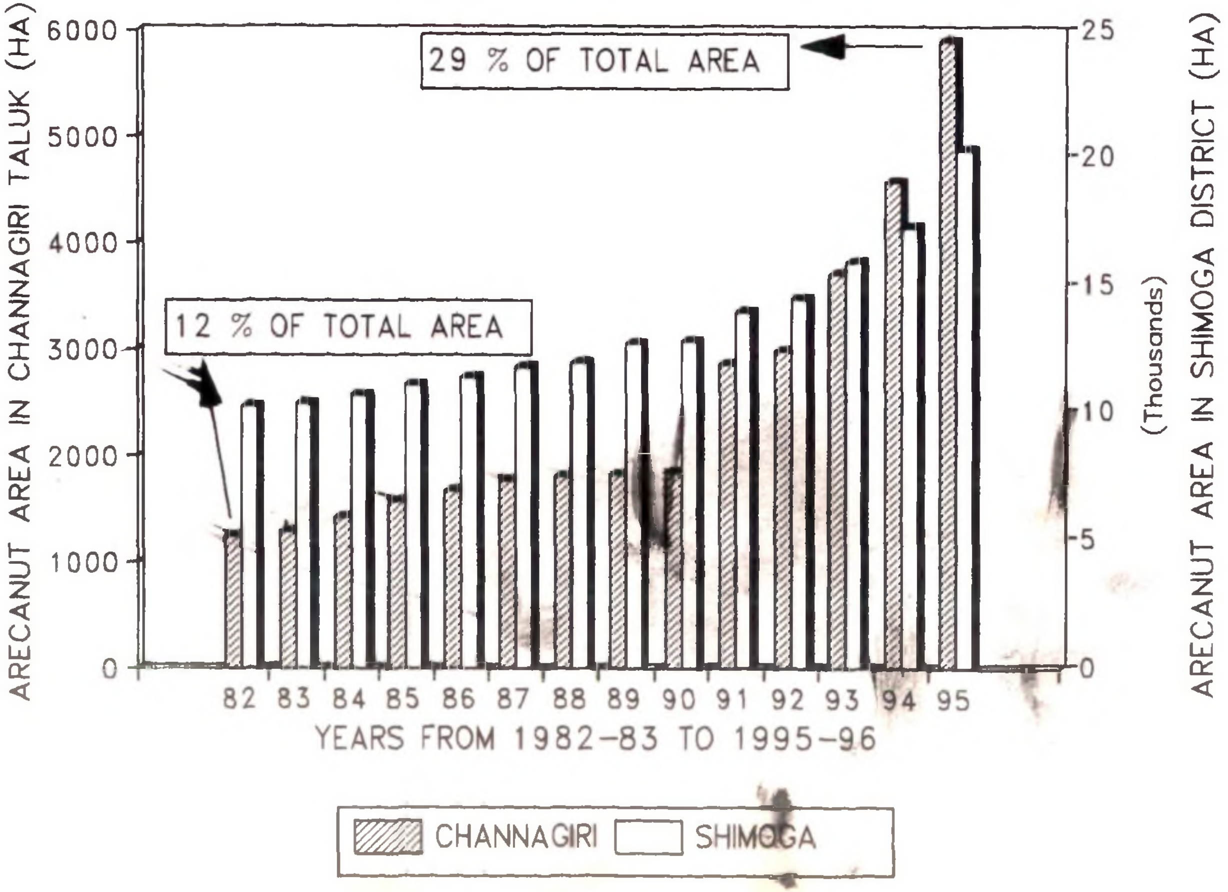
the size of arecanut crop largely determines the magnitude of well being of the farmers, as the risk of price fall is not appreciable. This is the reason only the area under arecanut in Channagiri has registered the highest CGR of 11.7 percent and at present occupies 29 percent of the areca area in Shimoga district in which Thirthahalli taluk was the leader earlier.

GROWTH OF ARECA AREA IN CHANNAGIRI TALUK AND SHIMOGA DISTRICT

Cultivation of arecanut is a matter of tradition in Shimoga district and Channagiri taluk in this district is no exception to this tradition. In the top two taluks, Thirthahalli and Channagiri, areca area in Channagiri formed 12 percent and that in Thirthahalli formed 33 percent of the area in Shimoga district during 1982-83. During 1995-96, the arecanut area in Channagiri formed 29 percent and that in Thirthahalli formed 20 percent. Thus, Channagiri taluk has proved to be catching up at an exponential rate with regard to area under arecanut, a perennial crop. If cultivation of low water intensive perennial crop is any indication of farmers' ingenuity to cope with the increasing scarcity of groundwater, then Channagiri farmers testify the economic scarcity of groundwater (Fig 5.6). However, crossing the thresholds of scarcity results in increasing costs of irrigation. A comparison of the costs of irrigation between Channagiri and in the Eastren Dry Zone, incorporating the costs of well interference indicates that the cost of irrigation in Channagiri is at least 10 times higher.

Considering the period 1982-83 to 1995-96, in Channagiri taluk, the area increased from 1,237 (10,232) hectares to 5,896 (20,280) hectares, with a compound growth rate of 11.7 (5.00) percent over the 14 years. The simple growth rate of area in Channagiri is 27 percent and that in Shimoga is 7 percent in the same period. Thus,

FIG 5.6: GROWTH IN ARECANUT AREA IN CHANNAGIRI TALUK & SHIMOGA DISTRICT(HA)



the rate of expansion of area under arecanut in Channagiri taluk is 134 percent higher than that in Shimoga district. Consultation with farmers and grass root people from Channagiri indicated that the expansion of arecanut in Channagiri is taking place with the rapid exploitation of groundwater from irrigation borewells. Nevertheless, this alternative is better than cultivation of water intensive crops like paddy and sugarcane. In reiteration, Channagiri with high compound growth rate in areca area of 11.7 percent and contributing the largest proportion of area under arecanut (29 percent) in Shimoga district, provides an enigmatic situation, since the spurt in arecanut area has largely been with the exploitation of groundwater in the region. This bears a testimony to the results of the study which in unambiguous terms measures the economic scarcity of groundwater, which can be linked with the mushrooming of irrigation wells to support the expansion of area under arecanut.

5.8 VALUE OF GROUNDWATER

The value of groundwater is considered as its scarcity rent reflecting the degree of economic scarcity of groundwater with the present level of acute groundwater scarcity, not even in their dream, farmers in Channagiri can think of marketing their groundwater. Instead, the farmers ventured to invest their sweat and bread to tap whatever they could, '*fastest with the mostest*' as enunciated by Wantrup (1962):

> "Resource tenure is not well defined in these cases. Definite property rights belong only to those who are in possession--that is, who get there "*fastest with the mostest*". Every user tries to protect himself against others by acquiring ownership through capture in the fastest possible way. Deferred use is always subject to a great uncertainty:others may capture the resource in the meantime. If the allowance for this uncertainty of tenure is

Larger variations can be expected when comparison is made in terms of net returns realized per acre inch of groundwater used. In Channagiri, the net returns per acre inch varied from Rs. - 1,767 to Rs. 3,691. In Malur, the net returns per acre inch varied from Rs. 298 to Rs. 3,477. This again indicates that the capacities of farmers to respond to negative externalities in groundwater imposed due to cumulative well interference varies widely and depends upon the crop pattern, degree of recharge influence from irrigation tank, and the degree of well interference. Arecanut crop has facilitated farmers in Channagiri to drill large number of wells per farm and it could be safely assumed that the number of wells per farm is the largest in Channagiri in the entire state of Karnataka.

5.9 MARGINAL PRODUCTIVITY OF GROUNDWATER

Though there is a vast negative externality of Rs. 16,893 per acre due to cumulative well interference in HWIV, on drip irrigation farms, the marginal return to the 53rd acre inch of groundwater (Rs. 2,793) of groundwater is comparable with the marginal factor cost per acre inch of groundwater (Rs. 2,403). Similarly the marginal return to one rupee spent at Rs. 1,25,560 on irrigation cost is Re.0.96, comparable to the marginal factor cost of irrigation (1 rupee). The ratio of marginal return to marginal cost of groundwater was around one and that to amortized cost of irrigation was close to one. This shows that the drip irrigation has helped farmers to achieve efficiency in using groundwater. The large degree of negative externality on drip irrigation farm is due to hefty investment made by farmers to strike groundwater as a Herculean task to save their precious areca plantation. It is to be noted that drip irrigation here is by default and not by choice, due to heavy failure of wells to yield any water (in Goppenahalli). Though there is water saving in drip irrigation, the negative externality is due to other investment on well irrigation.

For farmers using groundwater through flow irrigation, there is a modest negative externality of Rs. 2,202 per acre. This negative externality for flow irrigation farmers is around 700 percent lower than that experienced by farmers using drip irrigation and this is due to the augmentation of groundwater supplies by the recharge through the irrigation tank. The potential for using groundwater through flow irrigation is indicated by the MR/MC ratio of 2.94 with respect to groundwater used and 2.41 with respect to irrigation cost. Nevertheless, it is in order to recapitulate the groundwater savings to the tune of 66 percent due to drip irrigation achieved by these farmers despite their location in high well interference.

In the Eastern Dry Zone[1], as well as in this study where the groundwater scarcity is acute, the MR/MC ratio is above unity for gross returns as a function of groundwater and irrigation cost. A major bottleneck in using such gross return function is that it was not subjected to the constraint of groundwater availability. Thus, the estimated gross return function assumes that groundwater is available (i.e. groundwater is not scarce) and that the irrigation cost captures the economic scarcity of groundwater and farmers can afford to pay for it. If the gross return function can be subjected to the constraint that groundwater availability is X1 number of acre inches per farm, and / or the constraint that farmer does not have capital beyond X2 Rupees, then the resulting maximization using the Lagrange multiplier technique will be a pragmatic indicator of the maximized returns subject to the constraint of availability X acre inches of groundwater. This exercise however, has not been attempted in this study.

---

[1] *Sushma Adya, 1997, op.cit*

5.10 COPING MECHANISMS AND RESILIENCE

If groundwater can be considered as a common pool fugitive resource without any properly definable, exclusive, permanent, enforceable and transferable property rights, then with the shallow knowledge base about the availability of groundwater in hard rock areas, farmers are regularly and heavily investing in irrigation wells. A major factor contributing to this is the large internal rate of return from different commercial crops. In addition, rapid breakthrough in extraction technology, has led to unsystematic and rapid development in groundwater extraction. In response to unsystematic exploitation and growing demand for arecanut, the investments on well irrigation can be referred as Resilience investment.

5.11 RESILIENCE

Resilience is defined to mean the propensity of a system to retain its organizational structure following perturbation, arising from weather, physical-chemical factors, other organisms, or human activities. It is a measure of the stability of structure, process and function rather than the component populations of an ecological system (Holling 1973). Resilience is a response to the externality imposed due to interactive effects of irrigation wells. Farmers respond to externality through investments on the mechanisms to cope with externality. Even with high probability of well failure of 40 percent in hard rock areas.(Nagaraj and Chandrakanth 1995) investment on drilling wells against all the odds of ground water scarcity, is the prima-facie case of resilience.

Considering the sizeable net returns realized between Rs. 32,000 and Rs. 48,000 per acre (Table :4.17) exclusively over the coping costs incurred by farmers, it is unlikely that farmers shun irrigation due to high costs of coping mechanism. This is precisely the net return to the negative externality portion of the resilience investment. Even considering the costs of production per acre and adding them to coping costs, the net returns realized over coping costs and production costs range between Rs. 22,000 and Rs. 41,935. This indicates the net returns to full resilience investment.

5.12 DISCOUNTED CASH FLOW MEASURES

The discounted cash flow measures are comparable in both HWIV and LWIV farms. This shows that investment in irrigation and associated coping mechanisms are feasible even with a low average life of 1.88 years for a borewell. The internal rate of return[2] on HWIV farms was 20 per cent and that LWIV farms was 27 per cent. Thus, even considering the negative externality induced investment on drilling new borewells once in every two years, and investment on irrigation pumpset and paraphernalia once in every ten years, for thirty years of arecanut, the IRR of 20 percent is highly remunerative. But here too, since uncertainty in striking groundwater is not included, the IRR of 20 percent needs to be underplayed. There is no guarantee that, even though farmer is financially capable of drilling a well once in every two years, he/she would strike groundwater. The IRR on LWIV farms is 27 percent which is also remunerative and financially attractive.

---

[2]. *The assumptions used in estimating the internal rate of return are as under:*
a. The economic life of a arecanut garden is assumed to one generation cycle of 30 years. As the average life of borewell was two years in the sample, farmer is forced to drill a new well once in every two years. However, the investment on irrigation pump, conveyance, pipes, are amortized for ten years. Thus, if the second well is drilled in the third year, the investment on pump set and other accessories arise in the 11th year, since the pumpset and other accessories of the first well will be used in the second well.

b. The investment made in the first six years, that is, till the arecanut comes for economic bearing, is considered as establishment cost.

The discounted benefit cost ratio on HWIV farms is 1.5 and that on LWIV farms is 1.72. The net present value of the investment is Rs.1,39,090 in HWIV farms while that on LWIV farms it was Rs 2,58,531. The pay back period groundwater irrigation on HWIV (LWIV) farms was 4.90 (3.26) years[3].

5.13 ECONOMIC FEASIBILITY OF INVESTMENT IN COPING MECHANISM

The drilling of irrigation well(s), use of drip irrigation to support the existing arecanut plantation are the major coping mechanism in the water scarce areas of Channagiri. About 33 percent of irrigation farms have resorted to transferring groundwater over distances ranging from 3 to 5 kilometers from Maravanji to Goppenahalli since they totally failed in their attempts to get a successful well on their farms in Goppenahalli. In addition, the use of drip irrigation is necessitated as a last resort due to large scale failure of wells in situ which again necessitated farmers to venture drilling of borewells at distances of 3 to 5 kilometers from their farm and transfer their water. Hence the amortized cost of irrigation here includes all the implicit costs of irrigation including historic well failures reflecting the negative externalities, and the explicit costs of the functional wells and drip irrigation and other coping mechanisms. The partial budgeting clearly indicates the returns to resilience investments made by the drip irrigation farmers is beneficial since they implicitly indicate a difference of Rs. 33,256 per acre.

---

[3]. *The pay back period is computed by using the following formula:*

$$\frac{\text{Sum of the discounted costs incurred during establishment stage of 6 years}}{\text{The discounted net return obtained in the sixth year.}}$$

5.14 WATER TRANSFER AND IMPLICATIONS

Due to favorable relative prices of Arecanut in relation to scarcity rent of water, the demand for groundwater-arecanut farming will continue to rise unabated. Already there are signs of secular overdraft in Goppenahalli which has forced farmers to search for groundwater sources outside their village transferring water from a distance of two thousand to seven thousand meters, even with the advent of drip irrigation technology. This problem will exacerbate unless concerted efforts are made to improve the recharge. The cost of water transfers forms 33 per cent of the cost of irrigation with the working well. Even with the existing hydrogeological literacy of farmers, they would always prefer to invest in drilling well(s) in their own farm. Accordingly, the existence of a large number of wells (11) on the farms who have transferred water, is a testimony for the optimism to strike groundwater. However, as 40 per cent of the (sample) farmers in the groundwater scarce area have resorted to shift their investment far beyond their farm in search of modest volumes of groundwater testifies their risk taking behavior.

SUMMARY

CHAPTER VII

SUMMARY

The decision making by farmers in the wake of economic scarcity of groundwater is influenced by the availability of groundwater and the dictated market forces for crops reflected by the relative price of groundwater to output price. Explicitly, their decision making is a function of how close the marginal cost of groundwater is to the marginal return to groundwater. Farmers invest in coping mechanisms in order to reach their MR=MC threshold and with the increasing interference among irrigation wells, the MC and MR gap goes on widening.

Channagiri taluk of Shimoga district is known traditionally for the cultivation of Arecanut in Karnataka. Unlike the western ghats and other parts of Shimoga district where Arecanut is grown under assured rainfall conditions, farmers in Channagiri grow arecanut using groundwater. Located in the Southern transitional Zone of Karnataka, Channagiri, according to the rain guage statistics, ought to receive rainfall ranging from 800 mm to 1000 mm. In addition, this taluk is endowed with the largest irrigation tank (Shantisagara).

Recent years have witnessed acute scarcity of groundwater to support arecanut a low water intensive perennial crop. Farmers growing arecanut are caught in the clutches of arecanut cutter; between the need to sustain the arecanut garden on the one hand and the increasingly expensive groundwater resource on the other. Having caught in the predicament farmers cope with the economic scarcity of groundwater by being resilient to the situation. In this process, inequity and negative externality (negexternality) are endured by different classes of farmers. These are the prime concern, in the resource economics of sustainable development and to analyze the costs associated with coping mechanisms.

The magnitude of investment on coping strategies (inter alia) investments on drilling additional wells, water transfers, drip irrigation, water storage tanks, and water conveyance pipes, by farmers is hypothesized to reflect the degree of economic scarcity of groundwater. The coping strategies and investments are also hypothesized to vary with the degree of influence of irrigation tanks in the recharge of groundwater. Channagiri taluk in the Southern Transitional Zone was selected for this study as discussion with drip irrigation firms indicated that the problems of groundwater scarcity here were acute and farmers made frantic efforts to be resilient to retain their arecanut crop. For instance, a few farmers were buying up agricultural lands in places which are 2 to 5 kilometers from their farm, in search of groundwater by drilling irrigation well(s) and were transferring water, to their farm and were applying this water through drip irrigation to arecanut. These attempts were made after all their earlier attempts to tap groundwater on their farm failed.

The specific objectives of the study are:

1. To identify and analyze the coping strategies followed by farmers
2. To analyze and appraise the economic feasibility of investment on the coping mechanism
3. To examine the economic implication of groundwater scarcity on cropping pattern, employment and income.

For this study, 42 farmers from High well interference village (HWIV) Bussenahalli and Goppenahalli were selected after a detailed PRA mapping. As a contrast, 38 farmers from low well interference village LWIV Kagathur and Chikganguru have been studied.

The methodology to analyze the different coping mechanisms of farmers due to groundwater scarcity and the associated costs involved to appraise the economic feasibility of investment on coping mechanisms is provided by estimating the following:

1. Implicit cost of groundwater irrigation which includes transactions costs of well failure and associated negative externalities is computed by considering amortized cost of groundwater irrigation.
2. The negative externality cost incurred resilient on the original iso-revenue curve
3. In-equity involved due to groundwater scarcity.
4. Discounted cash flow measures and
5. Partial budgeting analysis to study the economic feasibility of the investment in well irrigation to support arecanut cultivation.

RESULTS AND DISCUSSION

Upon post stratification of farms in high well interference villages, it was found that in Bussenahalli, all the 21 sample farmers were using groundwater through flow irrigation to grow arecanut. In the other high well interference village of Goppenahalli, all the 21 sample farmers were using groundwater through drip irrigation to grow arecanut. Hence, the farmers in HWIV were classified as flow irrigation farms and drip irrigation farms. In Low well interference villages, this type of contrast was not available for comparison. The farmers in LWI were classified in to small farmers (< 5 acres of GAI) and large farmers (>5 acres of GAI). Hence farms in HWIV and LWIV cannot strictly be compared for lack of comparable classification parameters. Crop pattern in HWI and LWI villages was dominated by arecanut on 85 percent and 60 percent of cropped area respectively. Farmers possessed 7.38 wells on an average farm size of 6 acres in drip farms as against 3.76 wells on 4.37 acres in flow irrigation farms. In LWI, on small farms, the average number of wells per farm is 1.38 with a GIA of 3 acres and that on large farms is 3.83 with a gross irrigated area of 9.54 acres.

The coping mechanisms involved largely are drilling additional well(s), use of drip irrigation, conveying water through Poly Vinyl Chloride (PVC) pipes, construction of water storage tank, covering the storage tank with polythene sheets to reduce percolation losses, to meet the acute groundwater scarcity and so on.

In Goppenahalli most of the 20 farmers growing arecanut fixed drip irrigation system during 1995, in response to water scarcity. The investment in drip irrigation amounts to around Rs. 12,000 per acre. The amortized investment on drip irrigation system is Rs. 931 per acre of arecanut and Rs. 5,550 per farm for an average farm size of 6 acres.

Investment on additional wells as coping mechanisms includes investment on all the borewells excluding the first. The amortized cost on all additional wells in HWI drip farms is Rs. 81,369 per farm or Rs. 13,643 per acre of arecanut. The amortized investment on additional wells in HWI flow farms is Rs. 25,910 per farm (Rs. 5,946 per acre of arecanut). It was found that the influence of irrigation tank in flow farms drastically reduced the amortized cost of additional wells. The annual net returns per acre realized exclusively over such coping mechanisms is between Rs. 32,000 and Rs. 48,000. Hence farmers who have benefited from groundwater irrigation to a large extent will be the most vulnerable if they face lack of access to groundwater due to cumulative interference.

The negative externality costs incurred by farmers can be considered by the farmers' efforts to be resilient. Considering the costs of production per acre and adding the cost of coping with groundwater scarcity, the net returns per acre realized over coping costs and production costs ranged between Rs. 22,000 and Rs. 41,935 on HWI drip farms and HWIV flow farmers respectively.

The amortized irrigation cost per farm in HWI- drip farms is Rs. 1,33,584 and Rs. 22,397 per acre of arecanut. The high amortized cost of irrigation on drip farms is due to the possession of 7.38 wells per farm, of which only 2.09 wells were functional, experiencing large scale well failure. The amortized cost per well is Rs. 16,405 and that per functional well Rs. 63,756. The amortized irrigation cost in HWI-flow farms is Rs. 50,401 and Rs. 11,568 per acre. The amortized cost per well is Rs. 11,505 and Rs. 24,055 per functional well.

Small (large) farmers of LWI villages incurred an amortized irrigation cost of Rs. 17,116 (Rs. 46,544) per farm and Rs. 5,766 (Rs. 4,878) per acre. The amortized cost of irrigation in LWI villages on small (large) farmers is Rs.10,854, (9,630) per well and that per functional well the amortized investment was Rs. 15,345 and Rs. 15,958 for small and large farms respectively.

The discounted cash flow measures are comparable in both HWI and LWI farms. Thus, investment in irrigation and associated coping mechanisms are economically feasible, even though the average life of well is around 2 years. The internal rate of return on HWI farms was 20 per cent and that on LWI farms was 27 per cent. Thus, even considering the negative externality - induced investment on drilling new borewell once in every two years, the investment on irrigation for arecanut cultivation is remunerative.

The discounted benefit cost ratio on HWIV farms is 1.17 and that on LWIV farms is 1.72. The net present value of the investment is Rs. 1,39,090 in HWIV is lower compared with LWIV farms of Rs. 2,58,531. The pay back period groundwater irrigation on HWIV (LWIV) farms was 4.90 (3.26) years.

The partial budgeting indicates that the returns to investment on resilience made by the farmers in HWI-drip farms as beneficial since the difference between the contribution of drip irrigation and the flow irrigation is Rs. 33,256.

IMPLICATIONS

In high well interference villages, even though the proportion of the cost of irrigation out of the total cost is around 65 percent on both drip irrigation and flow irrigation farms, and though the drip farms could save groundwater to the tune of 200 percent when compared with flow irrigation farms, as the cost of irrigation on drip irrigation farms was 50 percent higher than that on flow irrigation farms and as the net returns per acre on drip irrigation farms were lower by 50 percent, compared with flow irrigation farms, the positive externalities due to the use of drip irrigation was more than offset by the availability of greater volume of groundwater on flow irrigation farms attributed to the groundwater recharge in the irrigation tank in the proximity. Thus, recharge of groundwater through irrigation tank could reduce the irrigation cost by 50 percent on per acre basis. When the irrigation cost is considered on the basis of cost per acre inch of groundwater, the advantages realized by farmers in villages with the influence of irrigation tank are insurmountable: farmers are saving to the tune of 500 percent in the cost per acre inch of water. This savings will not however be reflected when net returns per acre inch of water are considered.

Considering the farmers in Low Well Interference villages, the net returns per acre realized by large farmers are Rs. 17,147 when compared to Rs. 6,634 realized by small farmers, bringing serious equity implications to the fore. Even though the volume of groundwater used per acre in acre inches is (18, 20), cost of irrigation per acre inch (Rs. 277, Rs. 277) irrigation cost per acre (Rs. 5766 and Rs. 4878), the irrigation cost as a proportion of total cost (48 percent, 45 percent), for small and large farmers are comparable, the large farmers are realizing 160 percent higher net returns compared with small farmers. Since all the large farmers are growing arecanut, while other crops dominate on small farms.

Thus, on flow irrigation farms the influence of irrigation tank in groundwater recharge could reduce the irrigation cost per acre by 50 percent and cost per acre inch of water by around 500 percent, it is desirable to promote

(i) transfer of surface water from Shantisagara irrigation tank to the neighboring small irrigation tanks through aqueducts to promote groundwater recharge

(ii) adoption of drip irrigation in areas where there is no influence of irrigation tank, and thereby achieve savings in irrigation water to the tune of 200 percent (9 acre inches per acre of arecanut when drip irrigation is used, as against 27 acre inches per acre of arecanut, when flow irrigation is used).

REFERENCE

REFERENCES

Adya, Sushma.., 1998, Scarcity of groundwater for irrigation : Economics of Coping mechanisms, M.Sc., thesis (unpublished) University of Agricultural Sciences, Bangalore.

Anonymous, 1980-1996, Annual Crop Reports, Directorate of Economics and Statistics, Government of Karnataka, Bangalore.

Ananda, P., 1994, Performance of Guava Under Drip Irrigation, M.Sc. (Agri) thesis (Unpublished), University of Agricultural Sciences, Bangalore.

Arun, V., 1994, Estimation and Internalization of Externalities in Groundwater Irrigation in Hard Rock Areas of Karnataka, M.Sc. (Agri) thesis (Unpublished), University of Agricultural Sciences, Bangalore.

Caswell, Margriet, Erik, Lichtles and Zilberman, David, 1990, The effects of pricing policies on water conservation and drainage, American Journal of Agricultural Economics 72(4):

Census Report, 1994, Department of Census, Government of India, Kendriya Sadana, Bangalore.

Cevik, B., Kaska, N., Tekinel, O., Pekmezci, S., 1988, Comparison of drip and basin irrigation system in banana orchards on the southern coast of Turkey, Acta Horticulture, 288: 213-218

Chandrakanth, M.G and Jeff Romm, 1990, Groundwater depletion in India-Institutional and Management Regimes, *Natural Resource Journal*, 60(3): 485-502

Satisha, K.M., 1997, Resource Economics Study of Valuation of Well Interference Externalities in Central Dry Zone of Karnataka, M.Sc., thesis (Unpublished) University of Agricultural Sciences, Bangalore.

Sheng,F., and Xuefeng., Effective approaches for relaxing the crisis of Groundwater Proceedings of the Workshop on Water management : India's Groundwater Challenge held at VIKSAT, December 14-16, Ahmedabad.

Shyamasundar,M,S., 1997, Interplay of Markets, Externalities, Institutions and Equity in Groundwater Development - An Economic study in the hard rock areas of Karnataka, Ph.D. thesis (unpublished) University of Agricultural Sciences, Bangalore

Shivakumarswamy, BE., 1995, Economic implications of unsustainable use of groundwater in hard rock areas of Karnataka, M.Sc. thesis (unpublished) University of Agricultural Sciences, Bangalore.

Singh, Baldev, 1992, Groundwater Resources and Agricultural Development Strategy: Punjab Experience, *Indian Journal of Agricultural Economics*, 47: 105-113

Sivanappan, R.K., Rajagopal, A. and Palaniswamy, D., 1978, Response of Chilly to drip irrigation, *Madras Journal of Agricultural Sciences*

Sivanappan,R.K., and Kottiswaran, S.V., 1985, Drip irrigation for coconuts in India, Proceedings of the third International Drip / Trickle Irrigation Congress: American Society of Agricultural Engineers, Michigan, USA : 200-203.

Srinivas, G., S., *et al.*, Over Exploitation of Groundwater in parts of South-Interior Karnataka- Effects and methods for its replenishment, Proceedings of the Workshop on Water management: India's Groundwater Challenge held at VIKSAT, December 14-16, Ahmedabad.

Thamodaran,R., Bhide Shashanka and Heady, Earl,O., 1982, An Economic Analysis of water Management systems in Southern Tamil Nadu-Production function and programming approach, *Indian Journal of Agricultural Economics.*

927

DEPARTMENT OF AGRICULTURAL ECONOMICS,
UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE

QUESTIONNAIRE FOR 'EQUITY ISSUES IN GROUNDWATER DEVELOPMENT-AN INSTITUTIONAL ANALYSIS OF FAILED WELLS IN KARNATAKA' PROJECT
(Data for crop year 1993-94)

(Note: PRA exercise has to be done for mapping all the wells, year of well construction, well depth, well yield, year of well failure, interwell distances, well interference & so on before farmer interviews. Group interview should be conducted during PRA itself preferably)

Interviewer: __________Date of interview___/___/199__; Time of interiew____AM/PM

I. 1. **Zone :** NET/ND/CD/ED/SD/NT. 2. **Taluk** ____________ 3. **Village**_____________

4. **P. O.** ___

5. i) **Name of the farmer** _______________S/o.________________Education_____

Nucleus /Joint family (tick)

ii) Name of the lessee (if land + well water is leased out by farmer)______

II. Family particulars:

Family Size : ____________

	Male	Female
No. of Adults		
No. of Children		

Income from working outside the farm (Salary, petty business etc.)

Occupation	**Monthly income in (Rs.)**
1.______________	1.______________
2.______________	2.___________
3.______________	3.______________

III. Land asset: Total Land _____**Acres ,** ______**Guntas**

Type of land	**Size (in acre + gunta)**	**No. of plots**	**Major soil type**
1. Dry land			
2. Tank irrigated			
3. Canal irrigated			
4. Well irrigated			
5. Permanent fallow			

Soil types: 1 - red soil, 2 - sandy loam, 3 - black soil, 4 - clay loam

IV. Write a brief sketch of the farm with particular reference to wells

1. Location of different types of well (s), well plot, Conveyance structure, Overhead water storage structures.
2. Movement of water between and among plots and crop lands
3. All other details which are required to get picturesque glimpse of the farm which aid in analysis

FARM MAP WITH DETAILS OF ALL WELL (S) AND WELL IRRIGATION

V. Inventory, identification, reasons for improvement of all wells on the farm

Well type	Location & identity	Year of construction	Year of improvement	Type of improvement	Year of failure (not year of interference)
Dug well					
1		19____	19____		19____
2		19____	19____		19____
3		19____	19____		19____
4		19____	19____		19____
5		19____	19____		19____
Surface borewell					
6		19____	19____		19____
7		19____	19____		19____
8		19____	19____		19____
9		19____	19____		19____
10		19____	19____		19____
11		19____	19____		19____
12		19____	19____		19____
13		19____	19____		19____

Note : 1. For identification of each well, you may write in farmer's own description - like well near road as 'Raste Bhavi'; Well near garden as 'Thotada Bhavi'; borewell near home as 'Mane bore'; etc.
2. For wells which are working and which are not interfered, just mention that this is a working well and has no problems.

Reason for working/not working of well (write well no.)	
1. Densely spaced wells	☐
2. Initial failure	☐
3. Water intensive crops -name the crops	☐
4. Frequent power cuts / load shedding	☐
5. Decreasing number of rainy days	☐
6. Ill-distributed rainfall	☐
7. Decreasing quantum of rainfall	☐
8. Tanks not desilted-poor gw recharge	☐
9. Well interference	☐
10. Use of high capacity pump than needed	☐
11. Did not drill at the point shown by geologist	☐
12. Did not drill at the point shown by local diviner	☐
13. Because of irrigation intensive crop pattern	☐
14. Well is located outside the command area of irrigation tank	☐
15. Irrigation tanks are not regularly filled up	☐
16. The irrigation well is close to a successful public drinking water well	☐
17. Siltation in the borewell	☐
18. Caving in loose soil	☐
19. Interference from dug well	☐
20. Interference from dug-cum-borewell	☐
21. Interference from borewell(s)	☐
22. Excessive pumping	☐
23. Spurt in no. of wells around	☐

VI(a). Wellwise Investment particulars for all wells on the farm (used, unused and failed wells).For more number of wells, attach additional sheets

Particulars	Well no.__________		Well no. __________		Well no. __________	
	Magnitude	Investment	Magnitude	Investment	Magnitude	Investment
(i) Original well type :						
1. Type : Dug / Bore well	DW/BW		DW/BW		DW/BW	
2. Year of construction	19______		19______		19______	
3. Divining method (specify)						
4. Digging/drillingdepth (ft)						
5. Dugwell diameter(ft)						
6. Dugwell Lining Length(ft)						
7. Borewell casing(ft)						
8. Pump HP / Stages ex: 5 / 7						
9. Pump house cost						
10. All Electrical expenses						
11. Other extra costs (specify)						
12. Pump placement from top-ft						
13. Initial Well yield (mattu per day or GPH)						
(ii). Well improvement (if any)						
1. Year	19		19		19	
2. Reason/s for improvement*						
3. Depth (ft) (ghum/garanda)						
4. Diameter (ft)						
5. Lining (for dug well) (ft)						
6. Yield before deepening (mattu per day or GPH)						
7. Yield after deepening (mattu per day or GPH)						
iii Repairs to well (like removing silt, loose soil etc)	Year		Year		Year	
iv. BORES INSIDE WELL	Year | Depth | Cost		Year | Depth | Cost		Year | Depth | Cost	
1						
2						
3						
4						

*. Give the numbers assigned for reasons for failure in Table V (see previous page)

VI(a). Wellwise Investment particulars for all wells on the farm (used, unused and failed wells).For more number of wells, attach additional sheets

Particulars	Well no.________		Well no. ________		Well no. ________	
	Magnitude	Investment	Magnitude	Investment	Magnitude	Investment
(i) Original well type :						
1. Type : Dug / Bore well	DW/BW		DW/BW		DW/BW	
2. Year of construction	19______		19______		19______	
3. Divining method (specify)						
4. Digging/drillingdepth (ft)						
5. Dugwell diameter(ft)						
6. Dugwell Lining Length(ft)						
7. Borewell casing(ft)						
8. Pump HP / Stages ex: 5 / 7						
9. Pump house cost						
10. All Electrical expenses						
11. Other extra costs (specify)						
12. Pump placement from top-ft						
13. Initial Well yield (mattu per day or GPH)						
(ii). Well improvement (if any)						
1. Year	19		19		19	
2. Reason/s for improvement*						
3. Depth (ft) (ghum/garanda)						
4. Diameter (ft)						
5. Lining (for dug well) (ft)						
6. Yield before deepening (mattu per day or GPH)						
7. Yield after deepening (mattu per day or GPH)						
iii Repairs to well (like removing silt, loose soil etc)	Year		Year		Year	
iv. BORES INSIDE WELL	Year Depth Cost		Year Depth Cost		Year Depth Cost	
1						
2						
3						
4						

*. Give the numbers assigned for reasons for failure in Table V (see previous page)

VI(a). Wellwise Investment particulars for all wells on the farm (used, unused and failed wells).For more number of wells, attach additional sheets

Particulars	Well no.________		Well no. ________		Well no. ________	
	Magnitude	Investment	Magnitude	Investment	Magnitude	Investment
(i) Original well type :						
1. Type : Dug / Bore well	DW/BW		DW/BW		DW/BW	
2. Year of construction	19______		19______		19______	
3. Divining method (specify)						
4. Digging/drillingdepth (ft)						
5. Dugwell diameter(ft)						
6. Dugwell Lining Length(ft)						
7. Borewell casing(ft)						
8. Pump HP / Stages ex: 5 / 7						
9. Pump house cost						
10. All Electrical expenses						
11. Other extra costs (specify)						
12. Pump placement from top-ft						
13. Initial Well yield (mattu per day or GPH)						
(ii). Well improvement (if any)						
1. Year	19		19		19	
2. Reason/s for improvement*						
3. Depth (ft) (ghum/garanda)						
4. Diameter (ft)						
5. Lining (for dug well) (ft)						
6. Yield before deepening (mattu per day or GPH)						
7. Yield after deepening (mattu per day or GPH)						
iii Repairs to well (like removing silt, loose soil etc)	Year		Year		Year	

iv. BORES INSIDE WELL	Year	Depth	Cost	Year	Depth	Cost	Year	Depth	Cost
1									
2									
3									
4									

*. Give the numbers assigned for reasons for failure in Table V (see previous page)

927

VI (b) Funds and default position

Particulars of fund raising	Well no. ________		Well no. ________		Well no. ________	
	How many	Funds Rs.	How many	Funds Rs.	How many	Funds Rs.
1. By sale of land (acre)						
2. Sale of jewels (grams)						
3. Sale of livestock (no)						
4. From dairy / poultry						
5. Sale of trees (no. of)						
6. Sale of perennials						
7. Savings from farm net returns						
8. Relatives and friends						
9. From Banks / Co-ops.						
10. Total outstanding debts due to well and IPsets on the farm						

VII. Repairs

1. Repairs to pump (in 1993-94): ....Rupees for ....no. of pumps :

Reasons for Pump repair : ....

2. Repairs to Motor (in 1993-94):................................Rupes for ....no. of motors

Reason/s for motor repair ....

3. Repairs to panelboard for 1993-94:..........................Rupees for ....no. of panel boards

Reasons for repair of panel board...

4. Investment on Conveyance structure on the farm:

a) Pipe type :PVC/GI/HOPE/Other:.............length(ft) ....cost ....no. of bends..........

b) Channel type : Cement lined/kutcha /other...........:length (ft).................. cost.......................................

c) Year of major investment on conveyance structure..

5. Over ground storage structure a: Year :.19.........

b) Dimension : length x breadth x depth all in ft : ..............X....................X..............

c) Cost (Rs)..................

VIII. Area irrigated and well yield during 1993-1994 (acres, guntas)

Particulars	Well No.	Well No.	Well No.	Well No.
1. Wateryield in Mattu per day or in GPH in KHARIF				
2. Net area irrigated in KHARIF				
3. Water yield in Mattu per day or in GPH in RABI				
4. Net area irrig in RABI				
5. Wateryield in Mattu per day or in GPH in SUMMER				
6. Net area irrigaed in SUMMER				

IX. Wellwise, seasonwise crops and area irrigated during 1993- 94

Season	Well No._____ Area irrigated	Well No._____ Area irrigated	Well No. _____ Area irrigated	Well No. ____ Area irrigated
Kharif Crop : 1				
2				
3				
4				
5				
6				
Rabi crop : 1				
2				
3				
4				
5				
Summer crop : 1				
2				
3				
4				
5				
Perennial crop : 1				
2				
3				
4				
5				

VIII. Area irrigated and well yield during 1993-1994 (acres, guntas)

Particulars	Well No.	Well No.	Well No.	Well No.
1. Wateryield in Mattu per day or in GPH in KHARIF				
2. Net area irrigated in KHARIF				
3. Water yield in Mattu per day or in GPH in RABI				
4. Net area irrig in RABI				
5. Wateryield in Mattu per day or in GPH in SUMMER				
6. Net area irrigaed in SUMMER				

IX. Wellwise, seasonwise crops and area irrigated during 1993- 94

Season	Well No._____ Area irrigated	Well No._____ Area irrigated	Well No. _____ Area irrigated	Well No. ____ Area irrigated
Kharif Crop : 1				
2				
3				
4				
5				
6				
Rabi crop : 1				
2				
3				
4				
5				
Summer crop : 1				
2				
3				
4				
5				
Perennial crop : 1				
2				
3				
4				
5				

X. PRE INTERFERENCE - SCENARIO (attach additional sheet for each interfered well on the farm):

Well No.1/2/3/4/5/6/7/8/9/10___:YEAR of interference 19___; Well type DW/DCBW/BW

Crop	Area	Production	Irrig Method	No. of irrigations per month
Kharif				
1				
2				
3				
4				
5				
Rabi				
1				
2				
3				
4				
5				
Summer				
1				
2				
3				
4				
5				
Perennials				
1				
2				
3				
4				
5				

X. PRE INTERFERENCE - SCENARIO (attach additional sheet for each interfered well on the farm):

Well No.1/2/3/4/5/6/7/8/9/10___:YEAR of interference 19___; Well type DW/DCBW/BW

Crop	Area	Production	Irrig Method	No. of irrigations per month
Kharif				
1				
2				
3				
4				
5				
Rabi				
1				
2				
3				
4				
5				
Summer				
1				
2				
3				
4				
5				
Perennials				
1				
2				
3				
4				
5				

XI. Details of neighboring wells which are within 800 feet or even beyond, which affect the yield of the farmer's well (s):

Interfering well	Dug or bore well	Year of sinking	Year of interference	Its depth in feet	Distance in feet	Yield of interfering well	Crop irrigated by interfering well	Area irrigated by interfering well
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Your Notes and observations on interference :

XII. Coping mechanisms

Coping Mechanism	Details of the mechanism adopted	Year	Investment (Rs.)	Own amount (Rs.)	Borrowed amount(Rs.)	Status Work/ Aban	Why did you adopt the mechanism * & Remarks
1. Crop pattern changes	from ______ to__________	19___					1 - Cope with reduced yield ____
2.Pump hours	Changed from __hrs to __hrs	19___					2 - To conserve water ____
3.No. of irrigations	Reduced from ______ to __________	19___					3 - Due to Electricity short supply
4. Drip system	No. of drips etc ________	19___				Work/ aban	4 - Well failure____
5. Sprinkler system	No. of sprinklers etc _____	19___				Work/ aban	5 - Inadeq well water _____
6. Change to HDPE OR PVC from GI	Length of pipes etc ______	19___				Work/ aban	6 - Well interference ______
7. Built overground storage	Pucca or kutcha	19___				Work/ aban	7 - Crops use less water ____
8.Total shift to dryland agriculture	Present crop pattern___Net income_____	19___					8 - To maintain pre int net income___
9. Shift to another occupation	Occupation__ Net income per year ____	19___				Work/ aban	9 - Others specify___ ________
10. Cooperative pumping with neighbor's help	Nature of cooperation _________	19___				Work/ aban	
11. buying water for irrigation	Water price __________	19___				Work/ aban	

XIII. Wellwise costs and returns from Crop enterprises on the farm for 1993 - 94
Use separate sheets for each well; WELL NO. 1/2/3/4/5/6/7/8/9/ WELL TYPE ________
3. OVERGROUNDSTORAGE STRUCTURE when water from wells are pooled-used ___

(I). WATER USE EFFICIENCY ON THE FARM	Season________ Crop ________ area __________		Season ________ Crop ________ area __________		Season ________ Crop ________ area __________	
	Quantity	**Value**	**Quantity**	**Value**	**Quantity**	**Value**
1. Method of irrigation						
2. Frequency of Irrigation once in every month						
3. Hours to irrigate this crop						
(II). COST PARTICULARS						
1. Human labor for all operations (man days)						
2. Bullock labor (bp days)						
3. Machine hours						
4. Seeds/ planting material						
5. Manure (cart loads)						
6. Fertilizer type (kgs)						
____________________						
____________________						
____________________						
7. Plant protection chemicals						
9. Bagging, transport, packing, marketing costs						
10. Main product (Kgs/qntls/tonnes/baskets)						
11. Price of mainproduct						
12. Bye product Kgs/qntls/ tonnes/baskets						

Note : I. Method of Irrigation: 1 - Flood; 2 - Flow; 3 - Basin; 4 - Drip; 5 - Sprinkler
II. If the crop is Mulberry/grapes/perennial, get cost for one crop.

XIII. Wellwise costs and returns from Crop enterprises on the farm for 1993 - 94
Use separate sheets for each well; WELL NO. 1/2/3/4/5/6/7/8/9/ WELL TYPE ________
3. OVERGROUNDSTORAGE STRUCTURE when water from wells are pooled-used ___

(I). WATER USE EFFICIENCY ON THE FARM	Season__________ Crop __________ area __________		Season __________ Crop __________ area __________		Season __________ Crop __________ area __________	
	Quantity	**Value**	**Quantity**	**Value**	**Quantity**	**Value**
1. Method of irrigation						
2. Frequency of Irrigation once in every month						
3. Hours to irrigate this crop						
(II). COST PARTICULARS						
1. Human labor for all operations (man days)						
2. Bullock labor (bp days)						
3. Machine hours						
4. Seeds/ planting material						
5. Manure (cart loads)						
6. Fertilizer type (kgs)						
________________________						
________________________						
________________________						
7. Plant protection chemicals						
9. Bagging, transport, packing, marketing costs						
10. Main product (Kgs/qntls/tonnes/baskets)						
11. Price of mainproduct						
12. Bye product Kgs/qntls/ tonnes/baskets						

Note : I. Method of Irrigation: 1 - Flood; 2 - Flow; 3 - Basin; 4 - Drip; 5 - Sprinkler
II. If the crop is Mulberry/grapes/perennial, get cost for one crop.

XIII. Wellwise costs and returns from Crop enterprises on the farm for 1993 - 94
Use separate sheets for each well; WELL NO. 1/2/3/4/5/6/7/8/9/ WELL TYPE ________
3. OVERGROUNDSTORAGE STRUCTURE when water from wells are pooled-used ___

(I). WATER USE EFFICIENCY ON THE FARM	Season__________ Crop __________ area ___________		Season _________ Crop _________ area ____________		Season _________ Crop __________ area _____________	
	Quantity	**Value**	**Quantity**	**Value**	**Quantity**	**Value**
1. Method of irrigation						
2. Frequency of Irrigation once in every month						
3. Hours to irrigate this crop						
(II). COST PARTICULARS						
1. Human labor for all operations (man days)						
2. Bullock labor (bp days)						
3. Machine hours						
4. Seeds/ planting material						
5. Manure (cart loads)						
6. Fertilizer type (kgs)						
________________________						
________________________						
________________________						
7. Plant protection chemicals						
9. Bagging, transport, packing, marketing costs						
10. Main product (Kgs/qntls/tonnes/baskets)						
11. Price of mainproduct						
12. Bye product Kgs/qntls/ tonnes/baskets						

Note : I. Method of Irrigation: 1 - Flood; 2 - Flow; 3 - Basin; 4 - Drip; 5 - Sprinkler
II. If the crop is Mulberry/grapes/perennial, get cost for one crop.

XIII. Wellwise costs and returns from Crop enterprises on the farm for 1993 - 94
Use separate sheets for each well; WELL NO. 1/2/3/4/5/6/7/8/9/ WELL TYPE ________
3. OVERGROUNDSTORAGE STRUCTURE when water from wells are pooled-used ___

(I). WATER USE EFFICIENCY ON THE FARM	Season__________ Crop __________ area ___________		Season __________ Crop __________ area ___________		Season __________ Crop __________ area ___________	
	Quantity	**Value**	**Quantity**	**Value**	**Quantity**	**Value**
1. Method of irrigation						
2. Frequency of Irrigation once in every month						
3. Hours to irrigate this crop						
(II). COST PARTICULARS						
1. Human labor for all operations (man days)						
2. Bullock labor (bp days)						
3. Machine hours						
4. Seeds/ planting material						
5. Manure (cart loads)						
6. Fertilizer type (kgs)						
________________________						
________________________						
________________________						
7. Plant protection chemicals						
9. Bagging, transport, packing, marketing costs						
10. Main product (Kgs/qntls/tonnes/baskets)						
11. Price of mainproduct						
12. Bye product Kgs/qntls/ tonnes/baskets						

Note : I. Method of Irrigation: 1 - Flood; 2 - Flow; 3 - Basin; 4 - Drip; 5 - Sprinkler
II. If the crop is Mulberry/grapes/perennial, get cost for one crop.

XIV. Economics of Crops on lands other than well irrigated land

Type of crop	Dry/ Wet/ Garden	Crop Economics								
		Kharif			Rabi			Summer		
		Acre	Output	Cost	Acre	Output	Cost	Acre	Output	Cost
Seasonal										
1										
2										
3										
4										
5										
6										
7										
8										
ii.Perennial										
Tamrind										
Jack										
Euplis										
Coconut										
Mulberry										
Pomegranate										
Bare										
1										
2										
3										
4										

XV (a). Other Assets

I. Farm Machinery & equipment	
1) Bullock cart (No.)	
2) Sprayer (No.)	
3) Power tiller (No.)	
4) Tractor (No.)	
5) Sericulture equipments	**Value**
6) Sericulture house	**Yes / No**
II. Livestock	
1) Bullocks (No.)	
2) Cows (No.)_______	**Litre/day**
3) Buffaloes(No.)____	**Litre/day**
4) Sheep_(No.)	
5) Goats_(No.)	
6) Poultry_(No.)	
7) Other_(No.)	

III. Perennials	
1) Tamarind (No.)	
2) Jack (No.)	
3) Mango (No.)	
4) Casuarina (No.)	
5) Eucalyptus (No).	
6) Coconut (No.)	
7) Others 1.	
Others 2.	
3/IV. Other assets	
1) Television	
2) Mixie	
3) Telephone	
4) Two wheeler	
5) Four wheeler	
6) Stereo Radio	

XV(b). Other income earning activities

Income earning activity	Volume of business - 1993-94	Net income per year
1. Land leasing (acres)	1. Leased in______acres 2. Only land Leased out ____acres 3. Land + well water leased out_____acres	Rs. _________ Rs.__________ Rs.__________
2. Sale of groundwater (water market)	Price of groundwater: Basis for Charging 1. @ Rs._____ per acre 2. @ Rs.___ per crop for ____,____crops 3. @ Rs. ___ per hr for _____hrs 4. @ Rs._____per irrigation	___Crops _____
3. Money lending	Amount lent Rs._______	
4. Any other (specify)		

XVI. : Vagaries of electricity supply

Season	Well usage		Problems faced with respect to electricity	Problems faced wrt to pump/motor repairs	Solutions if any
	No. of wells	Hours of pumping per day			
Kharif					
Rabi					
Summer					

XVII. General condition of pumps, volves, suction, delivery pipes and other technical details (open ended questions and answers expected)

(a) HP RATING

1. How did you decide on HP, no. of stages, type of pump ______________________

2. Pumps have ISI mark ? Yes/No

(b) Electricity pricing

1. Do you have automatic starter ? Yes/No.

2. Indicate the number of hours you use the pump for irrigation per day if electricity is supplied regularly :

Tariff rate	Pump hrs per day	No. of days per year	Reasons for your choice of flatrate or pro rata
1. Flat tariff @ Rs.100/HP/year			
2. Flat tariff @ Rs.500/HP/year			
3. Flat tariff @ Rs.1000/HP/year			
4. Flat tariff @ Rs.1500/HP/year			
5. Prorate @ 25 paise per unit			
6. Prorate @ 50 paise per unit			
7. Prorate @ 75 paise per unit			
8. Pro Rata @ Rupee 1 per unit			
9. Electricity & Water rate			

(c) What crops you wish to grow with your existing well (s) if there is adequate water and adequate power supply ?

Crop/s	Area in acres	Reasons for choice of crop and acreage
1		1 - Higher net returns as compared to other crops
2		2 - Assured remunerative price
3		3 - To avoid labor problem
4		4 - Familiar with this crop
5		5 - Have been cropping since long time
6		6 - Crop is less risky
7		7 - Requires less investment
8		8 - Requires less care
9		9 - Has better marketing facilities
10		10 - Can get crop within three months or in short time
11		11 - others specify

XVIII. Groundwater management

1. What lessons did you learn when the first well failed in your village ? ______________

2. When deciding crops to grow, do you consider the water required by the crop(s) ?

   Yes / NO. If No, Why ______________________________

3. Quality of your groundwater? Good/Acceptable/Poor

4. Whom do you enquire regarding irrigation information like: frequency to irrigate, how much to irrigate, depth of irrigation for different crops in different soil types during different stages of crop etc) ____

5. Do you have enough water to sell to other farmer (s)?: Yes /NO

   If yes, (a) whom do you want to sell_________________________ (write name, relationship, and location of the farm to whom it is sold)

   (b) Any preference for selling to a particular buyer ? _____________________________

   (c) What is the price (cash + kind) that you expect for your water _________________

6. If you do not have adequate water, do you want to buy from your neighbor if he/she has water to sell? Yes/No

   If Yes, how much are you willing to pay for your neighbor's water _________________

7. If water availability is less in your well in any year:

Do you (a) grow low water crops; (b) plant high water crops on few acres
(c) reduce the frequency of irrigation (d) reduce over all pump hours
(e) change irrigation method (f) None of the above (g) Any other _______

8. Can you predict the water yield from your well in the next year ? Yes/No

If yes, How ____

9. Indicate how the following factors influence the water yield in your well ?

Factors	How many Mattu or GPH will		
	Increase	Decrease	Your actions for increase/decrease
a. By pumping of your well			a) Reduce area under irrigation ________
b. Pumping by nearby farmers/wells			b) Shift to less water intensive crops ____
c. Monsoon rainfall			c) Changing method of irrigation _______
d. Desilting tank			d) Reduce irrigation frequency _________
e. Using tank as only percolation tank			e) Reduce volume of water application ___________________
f. Any other factor			f) any other ___________________

10. Do you consider well construction/pumping by your neighbors as a threat to your ground water yield ? Yes / No . If Yes, how do you know ? ____________________

a) Personal observation of pumping or crop pattern ; b) fall in water table
c) failed well ; d) reduced water outflow during pumping ; e) others: _________

Then: Do you pump more to prevent water from flowing to neighbours' well (s): Yes / No

11. If neighbor (s) drilled many wells and decrease your water yield, what do you wish to do ?

(a) Discuss with neighbors and come to a settlement amicably

(b) Want to drill or construct more well(s)

(c) Want to deepen well(s)

(d) Think there is need for a legislation regarding pumping and interwell distance ?

(d) Any other

12. Do your neighbors request you to reduce your groundwater pumping? Yes / No

If yes, in what way did you respond ? ________________________________

13. What Do you think will happen to your water yield and depth to water in the coming year?____

14. Reactions on groundwater regulation.

Rules	Response	Type of Penalty	Type of Incentive
1. Interwell distance	Yes/No_____		
2. Open well depth	Yes/No_____		
3. Borewell depth	Yes/No_____		
4. Fixing electrical meter	Yes/No_____		
5. Fixing both electrical & water meter	Yes/No_____		
6. Not to grow paddy	Yes/No_____		
7. Not to grow Sugarcane	Yes/No_____		
8. Not to grow Banana	Yes/No_____		
9. Not to grow other water intensive crop (Name of crop/s__________)	Yes/No_____		
10. (Over) pumping by yourself	Yes/No_____		
11. (Over) pumping by neighbour(s)	Yes/No_____		
12. Drilling (deeper) by yourself	Yes/No_____		
13. Drilling (deeper) by neighbour(s)	Yes/No_____		
14. Using (high) HP IP set	Yes/No_____		
15. Adopt sprinkler/drip irrigation	Yes/No_____		
16. Participation in Desilting irrigation tank	Yes/No_____		
17. Cooperate with neighbours for proper sharing of water	Yes/No_____		

16. General information

1. Land rent Rs/acre/year:

Dry land ___________; Well irrigated land ___________; Wet land ___________

2. Wage rate Rs/day :

Man labor ____________ (with food / without food)

Women labor _________ (with food / without food)

Bullock labor _________ (with food / without food)

3. Private Interest rate Rs. ______per Rs.100 per month.

4. Bullockcart hire charges/day __________________________

5. Power tiller hire charges/hour __________________________

6. Tracter hire charges/hour __________________________

7. Income from perennial crops

Tree / Orchard crop	Income per tree	Income per acre
1. Tamarind		
2. Jack		
3. Mango		
4. Casuarina (survay)		
5. Eucalyptus (Nilagiri)		
6. Coconut		
7. Pomogranet		
8. Bare (elachi hannu)		
9. Sapota		
10. Guava		
11. Flower _________		

Village price information

Crop	Price
1. Paddy (Rs. / qtl.)	
2. Sugarcane (Rs. / ton)	
3. Mulberry (Rs. / basket)	
4. Tomato (Rs. / Kg)	
5. Cabbage (Rs. / Kg)	
6. Onion (Rs. / Kg)	
7. Cauliflower (Rs. / Kg)	
8. Chillies (Rs. / Kg)	
9. Potato (Rs. / Kg)	
10. Greens (Specify______)	
11. Carrot (Rs. / Kg)	
12. Other ______________	
13. Other ______________	

Signature of the interviewer (Date __________ Time______ am/pm)

DO WRITE YOUR FIELD OBSERVATIONS & IMPRESSIONS IN THE LAST PAGE ON THE SAME DAY OF DATA COLLECTION, IN THE EVENING/NIGHT. DO NOT FORGET TO VISIT THE FARMER'S FIELD FOR MAPPING THE WELLS & FINDING WELL YIELD.