Ecological services of irrigation tanks and canals in the management of groundwater and welfare implications in hard rock areas of Karnataka

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ABSTRACT

Ecological services of irrigation tanks and canals in groundwater recharge and welfare Implications in Hard Rock Areas of Tiptur, India are studied. Farmers jointly mobilized Rs. One lakh to improve recharge by constructing a tank. Primary data from 35 farmers each from (i) farmers owning irrigation wells in system irrigation tank (GWTI), (ii) farmers owning irrigation wells in canal irrigation (GWCI), and (iii) farmers owning irrigation wells in areas not served by tanks and canals are farmers under sole irrigation (GWSI). About 33% are small farmers (< 5 acres), 50% medium (5-10 acres) and 17% large farmers (>10).

More than 70 percent of cropped area is under Coconut /Arecanut, the coping mechanism due to groundwater scarcity. The proportion of well failure in GWSI was 45% followed by GWTI (20%) and GWCI (19%). Externality cost was Rs. 957 in GWTI, Rs 863 in GWCI, and Rs. 3226 in GWSI. Net return per acre, per functioning well and per rupee of irrigation water were Rs. 12210, Rs. 96979, Rs. 18 in GWTI, Rs. 10912, Rs. 77190, Rs. 21 in GWCI, and Rs. 9292, Rs. 57665, Rs. 6 in GWSI.

Technology and institutions played a significant role in groundwater recharge. Farmers pooled their resources to invest in an irrigation tank to impound rainwater for recharge. Thus the real cost of groundwater fell from Rs. 32 per acre inch in 1986 to Rs. 15 per acre inch (2008) due to tank. Cost of groundwater (net return) per acre inch in GWTI are Rs. 34 (Rs. 365), in GWCI Rs. 44.46 (Rs. 449) and GWSI 113 (Rs. 547). Surface water recharge from tank reduced economic cost of groundwater and improved net farm income to Rs. 10.73 per acre inch for GWTI, Rs. 10.1 per acre inch for GWCI, Rs. 4.84 per acre inch for GWSI.

Key words: groundwater, recharge, hard rock area, Externality and real cost

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1. INTRODUCTION

Historically, construction of tanks and their maintenance were an creative method of conservation of water resources, and also was a strategy for human survival. Communities evolved tank management practices with incentives for individuals and community. Karnataka had a tradition of tank management by local communities with institutions “Bittuvatta” and “Kattukoduge” (Chandrakanth and Romm, 1990). The tank maintenance and management practices introduced by the State in recent years have underscored the importance of community participation. A large number of tanks in Karnataka today have become ineffective or even defunct, with decline in area irrigated and deterioration in the local ecosystem.

In Karnataka the net irrigated area under different sources of irrigation during 1998-99 was around 24.90 lakh hectares of which the canal irrigation accounted for about 40.7 percent, followed by open well irrigation (19.23 percent), tube wells (18.06 percent) and tanks (10.56 percent). Karnataka has 13,759 million cubic meters (MCM) of utilizable groundwater for irrigation every year that can irrigate 1.38 million hectares up to one meter depth. Groundwater development in the case of hard rock areas is threatened by uncertainties *inter alia* nature of rock type, type of aquifer, number and type of wells per unit of utilizable groundwater, while surface water bodies have pervasive influence on groundwater use in a specific region and overexploitation of groundwater is resulting in progressive decline in the productivity of wells, increasing the implicit cost of lifting of water due to declining water levels.

The state has 67 reservoirs, 33,934 tanks (of which 30,918 tanks are with less than 40 hectors of command area), 11,41,641 irrigation pump set (of which 11,03,533 are electrical pump sets), 4,78,369 open wells , 2,78,307 bore wells and 86,721 failed wells. Considering the source wise irrigation, 37 percent of the net area irrigated is by canals and 10.2 percent is that by tanks.

GROUNDWATER RECHARGE

Both irrigation and drinking water wells are benefited through rehabilitation. Wells in and around get recharged due to tank rehabilitation and supplement tank irrigation and, in some cases, even act as the main source of irrigation during lean period. Thus, the augmented recharge directly benefits the land owning farmers and indirectly benefits the poor and landless through an increase in employment days. The water table in both open and bore wells would be raised on a modest scale due to tank rehabilitation. Even the abandoned wells have been well-revived, leading to water markets. Even the poor farmers without wells know that the easiest way to access water for irrigation is to buy from a neighbouring well owner. The improved productivity of wells due to groundwater recharge is by far the most valuable benefit to farmers associated with tanks (Shah and Raju, 2002).

In this study, the Ecological services of irrigation tanks and canals in the management of groundwater and welfare implications were studied in Tumkur district in hard rock areas of Karnataka State. The study area is covered by the Hemavathy river basin. In addition, in parts of the central Dry agro-climatic zone of Karnataka, in the cauvery basin, the river Hemavathi is put to productive use. For example, in the process of getting the crucial and vital drinking water for the city of Tumkur, the riparian areas on either sides of the flow of the river are benefited from groundwater recharge. The river Hemavathy, a tributary of river Cauvery has its origin in Ballarayana Durga in Chikmagalore district of the Western Ghats, at 1,219 metres above MSL. The Hemavathy masonry dam is constructed in Gorur in Hassan District which impounds 78 TMC of water assuming 50 percent dependability. The reservoir fills between June and

September, during the south west monsoons. and the depletion period is October to May. The Tumkur branch canal from the Hemavathy left bank canal which brings drinking water to Tumkur city is 240 kilometers long carrying 1429 cusecs of water.

The district mainly depends upon ground water for drinking and irrigation purposes. According to CGWB About 90% of the irrigation and drinking requirements are met from ground water. This has resulted in over exploitation in about 55% area in the district. In general water levels are showing declining trend. About 1179 dug wells and 1687 bore wells have dried up in the district. Also there is decrease of potable water in fluoride-affected areas due to drying of phreatic aquifer. Hence to overcome these problems, it is recommended to adopt scientific management of ground water resource. Further development should be allowed only areas, which are categorised as safe and semi critical with caution. Mass awareness programmes should be conducted for public awareness about the limited availability of ground water resource. Farmers should be educated to grow less water intensive crops and adopt micro irrigation system. Government should provide subsidy such irrigation systems. Artificial recharge structures should be constructed in feasible areas for augmenting ground water resource and to improve ground water quality. Recharge ground water by way of artificial recharge structures like percolation tank, desilting of silted tanks, check dams, naala bunds, farm ponds and subsurface dykes. Ground water can be tapped from valley fills of Pennar and its tributaries for drinking purposes. Desilting and maintaining of tanks are utmost importance, so that the Natural recharge will take place without any hindrance and this will recharge the shallow aquifer mainly, which can be used for drinking use, which is free from fluoride in major part of the area. Sites for bore wells and dug wells should selected with the technical advice from technical qualified persons.

In the year 1998, the water was let into the newly constructed Tumkur branch canal. While the water was being conveyed to Tumkur city, the riparian villages apparently did not get the benefit of groundwater recharge as the dimension of canal was not large enough to have appreciable percolation.

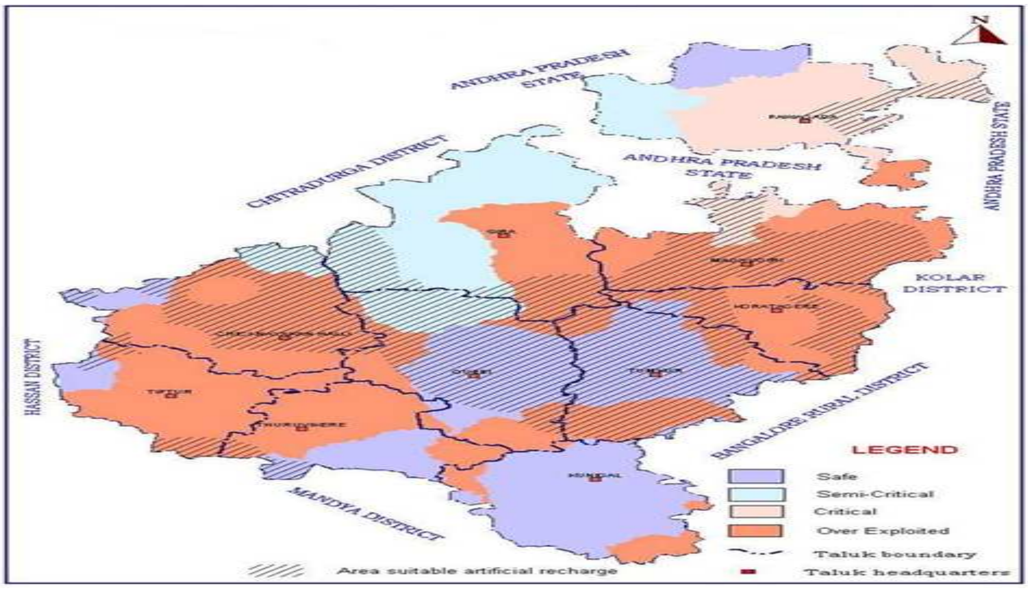

***Fig.* 1 Status of Ground water utilization in Tumkur district**.

Source: Central Ground Water Board, Ground Water Information Booklet, Tumkur District, Karnataka, South Western Region, Bangalore July 2008.

This study is a modest attempt towards economic and ecological evaluation of the groundwater recharge in Tiptur taluk, Tumkur district of Karnataka. For comparison the irrigation wells located under canal command (GWCI) Gadabanaalli, the irrigation wells located under tank command (GWTI) Echanur, receiving the Hemavathy river water, with a water spread of 363 acres and another nearest Kibbanahalli tank which is a Non-system tank (GWSI), i.e., Irrigation wells not located under tank or canal command, which totally depends on rainfall sources have been considered. The objective of this research is to study the Ecological services of irrigation tanks and canals in the management of groundwater and welfare implications in hard rock areas of Karnataka

2. METHODOLOGY

2.1 PROFILE OF THE STUDY AREA

Tumkur district was formed in 1966 under Nandidurga division, is the seventh largest district in Karnataka encompassing a geographical area of 10,64755 ha and is situated between 12^0 45' and 14^0 20' north latitude and 76^0 20' and 77^0 31' east longitude. It is bounded by Chitradurga and Ananthpur (Andra Pradesh) district in the North, Mandya district in the South, Bangalore and Kolar district in the East and Hassan district in the West. The total population in the district is around 25,84711(as per 2001 census), out of which rural population constitutes 20.78 lakhs. Population density is 244 per sq km. The district is divided administratively into 10 taluks.

2.2 IRRIGATION

In the district there are no perennial rivers for irrigation. However, there are small rivers Shimsha and Jayamangali, flowing only during rainy season. As a result, the farmers of the district solely depend on wells and tanks for irrigation. Thus, the demand for groundwater extraction for agriculture has been increasing over time leading to overexploitation of the aquifers. There are no completed major irrigation projects in the district, but part of the command area of the Hemavathy project (The reservoir built across Hemavathy river is located near Gorur village in Hassan District) falls in Tumkur district. There are 1462 minor irrigation tanks in the district irrigating 57132 ha. The Hemavathy project which on completion is expected to irrigate 2,37,000 acres of land in Tumkur district In the process, access to surface irrigation caused positive externality in terms of improved recharge in wells located in the proximity of the channels. According to the latest statistics (2000-2001), the total irrigated area in the district is169451ha, of which the share of the open wells, bore-wells, tanks and channels accounted for 11, 55, 30 and 4 percent respectively. The rainfall in the district is 688 mm per annum most of which received during May and November. The distribution of rainfall is not uniform in the district. Agriculture is mainly rainfed.

2.3 AGRICULTURE

Out of 10,64755 ha of geographical area, 4.24 per cent occupied by forests, 7.89 per cent of Non-Agricultural land, 6.34 per cent of barren land, 5.88 percent of cultivable waste land 7.19 per cent of permanent pasture, and 1.89 percent Trees and Groves. Agriculture is heavily monsoon dependant in the study area as 80 per cent of the area is rain fed. The tanks, and bore wells are the primary sources of irrigation. As per latest data available an area of about 43 per cent was under cereals, 14 per cent under pulses, 36 per cent under oil seeds and 7 per cent under other crops in the district. (Anon, 2001)
CHOICE OF THE STUDY AREA

Tumkur district has emerged as the most over-exploited district in terms of groundwater extraction and use. Tumkur district comprises 10 taluks and comes under Central Dry Zone of Karnataka. After discussion with the groundwater experts and different institutions, the reconnaissance survey has been conducted in different parts of Tumkur district in order to locate different pockets, which are facing acute groundwater scarcity (groundwater depletion). According to the NABARD report, out of ten blocks (Taluks) in the Tumkur district, seven blocks are dark, two are grey and one is white. As compared to any other district in the State, Tumkur district has the highest number of critical blocks (dark and grey) reflecting groundwater overexploitation. This shows that about 90% of the district is under critical stage of ground water development. The Tiptur taluk with the highest net draft to utilizable recharge ratio (129%), lying under dark category, having access to channel water has been selected.

2.4 SELECTION OF THE SAMPLE VILLAGES AND SAMPLING

For identifying the sample villages, the resource persons from department of agriculture, irrigation, biodiversity, forestry (Vanavikasa) cooperative societies and Gram panchayats in the villages were approached. For comparison of the relative performance of the groundwater recharge in Tiptur taluk, Irrigation wells located under Hemavathy canal command (GWCI), the System tank command (Echanoor) (GWTI) and the groundwater wells under sole irrigation (GWSI), where the recharge is largely by rainfall (Kibbanahalli) have been chosen in consonance with study objective in the Hemavathy river sub-basin of Cauvery river basin as under:

1. Groundwater wells for irrigation located under system tank irrigation command **(GWTI):** here such wells are recharged by system irrigation tank (sample of 35 farmers)
2. Groundwater wells for irrigation located under canal command **(GWCI)**: here such wells are recharged by canal irrigation command (sample of 35 farmers)
3. Groundwater wells for irrigation located independently of tank or canal command **(GWSI)**; here such wells are recharged largely by rainfall and acts as a control situation (sample of 35 farmers).

GWTI: *Echanur village* System Tank

Echanur village in Tiptur taluk is selected for this study to represent GWTI. This village consists of an irrigation tank of 363 acres which is filled by Hemavathy water to supply drinking water to Tiptur and Arasikere. Hence, this tank filled by channel water throughout the year.

GWCI: *Gadabanaalli village located in canal command area*

Gadabanalli village is 15 Km from *Echanur village in* Tiptur taluk selected for this study. Here, the Hemavathy irrigation channel passes through the outskirts of this village supplying irrigation water to the right hand side command of the channel. Much of the village area lies on the right hand side of the channel as also in the lower elevation of the channel, and the *Gadabanaalli* area is assured of channel water at least for six months in a year in the flow process. This area designated as GWCI and is selected after discussions with the technical staff in order to estimate the impact of the channel water on groundwater recharge.

GWSI: Control village Kibbanahalli (GWSI)

Kibbanahalli village in Tiptur taluk is located 6 kms from the *Gadabanaalli village* Channel command area and is selected as control village situation for comparison. This area has similar agro climatic conditions with respect to rainfall, soil and cropping pattern as that of *Echanur* (System Tank) and *Gadabanaalli* (Channel command), but has no connectivity from the irrigation channel or irrigation tank and hence is designated as groundwater use under sole irrigation (GWSI).

2.5 SAMPLE SIZE

For this study, only farmers possessing irrigation wells in each of the three scenarios have been chosen. Hence a random sample of 35 farmers was drawn from each of the three scenarios, thus, totaling 105 well farmers were selected for the purpose of this study.

2.6 DATA BASE

The schedule prepared for this study was used to elicit primary data from the sample farmers through personal interviews during October - November 2008. The information elicited included 1) general information regarding the socioeconomic features of the respondents 2) cropping pattern 3) land holdings 4) Sources of irrigation 5) investment on irrigation wells 6) Costs and returns from crops grown under well irrigation and 7) volume of water used.

2.7 ANALYTICAL FRAME WORK

2.7.1 Measures of Central Tendency and Ratios

Weighted average was computed in respect of socio-economic features, cropping pattern, cost of cultivation and returns from crop activities and access to groundwater. Ratios and percentages were employed to analyze the cropping pattern and cropping intensity. Simple averages, ratio measures, percentages and proportions are computed in order to draw meaningful inferences and to facilitate comparison of the average farm situation in Irrigation wells located under tank command (GWTI) i.e., System tank, Irrigation wells located under canal command (GWCI) and Irrigation wells located under sole irrigation, i.e. located neither under tank or canal command (GWSI). Methodologies followed to estimate yield of wells, water use in each crop, amortized cost of irrigation are described below.

2.7.2 Well age and well life

The well age and well life were estimated using life table approach. Age of the well refers to the number of years for which wells have been functioning at the time of field data collection. The age of the well was thus estimated as (Year 2008 minus the year of well construction or drilling).

Age of well = $\sum [(f_i X_i) \div \sum (f_i)]$

Where,

f_i = frequency of wells yielding irrigation water in each age group

X_i = age group of wells (1, 2, 3...n in years)

i = ranges from 0 to n, where n refers to the longest age of well in the group

Wells constructed during 2008 and still functioning at the time of data collection were assumed to have zero age, as the effect of interference is to increase both the initial and current failures.

The average age of the well should include the age of those wells that are still functioning as well as the life of those wells that have failed. Hence average age of the well is a comprehensive indicator of the average number of years a well provides irrigation services.

Life of well refers to the total number of years a well has functioned and is now no longer functioning. 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/drilling. All those wells, which suffered from initial failure, obviously have zero life. In order to get the average age of wells, wells, which are functioning and have ceased to function and have failed, were both included and their corresponding age/life was included in finding the average

Average life of well is estimated as:

Average life of well = $\sum [(f_i X_i) \div \sum (f_i)]$

Where,

f_i = frequency of wells yielding irrigation water in each group

X_i = age group of wells (1, 2, 3...n in years)

i = ranges from 0 to n, where n refers to the last year of working of the irrigation well.

2.7.3 Amortized Cost of Bore Well

In order to arrive at the annual share of groundwater irrigation cost, the well investment has been amortized. It varies with amount of capital investment, age of the well, interest rate, year of construction. Amortization cost of well was worked out by adopting the following procedure,

Amortized cost of irrigation bore well = (Amortized cost of BW + Amortized cost of pump set + Amortized cost of conveyance + Amortized cost of over ground structure + Repairs and maintenance cost of pump set and accessories)

Amortized cost of bore well = $[(\text{Compounded cost of bore well}) * (1+d)^{AA} * d] \div [(1+d)^{AA} - 1]$

Where,

AA= Average Age of bore well

BW = Bore Well

d = Discount rate considered at 2 per cent

Compounded cost of BW= Historical cost of BW* $(1+i)^{(2009\text{- year of drilling})}$

Where,

i = Compound rate of 2 per cent

A modest discount rate of two per cent is considered for amortizing the cost of irrigation well to represent the compound rate of interest in the costing well components like construction cost, drilling cost, pump set, and accessories and so on.

2.7.4 Yield of Irrigation Well

The yield of well was recorded as perceived by farmers as 1 inch = 1000 GPH, 2 inch = 2000 GPH and 3inch = 3000 GPH and so on.

2.7.5 Water use in each crop.

The number of acre-inches of water used for each crop in each season (summer, *Kharif*, *Rabi*) = [(area irrigated in each crop) * (frequency of irrigation per month) * (number of months of crop) * (number of hours for one irrigation) * (Average yield of well in GPH)] ÷ 22611.

One acre-inch is equivalent to 22611 gallons or 3630 cubic feet and one cubic feet is equivalent to 28.32 litres. Total water use per farm is total acre inches of water used in different seasons including acre inches of water used per farm for perennial crops.

2.7.6 Annual Cost of Irrigation

In Karnataka, farmers using irrigation pump sets (below 10 HP capacities) are not charged for electrical power used to pump irrigation water. Government of Karnataka however imposed a flat charge of Rs. 300 per HP per year up to 10 HP pump set since April 1997. The KPTCL / GOK have been soft towards seeking electricity dues from farmers for the reasons of political economy. Hence there are no explicit costs of pumping irrigation water, other than repair and maintenance of the irrigation pump set and well.

However, the cost of irrigation is relevant for farmers in hard rock areas due to high probability of well failure, which forces farmers to invest in additional well(s) to at least remain on the original production possibility curve. This investment on failed wells which is often due to violation of isolation distance due to interference of cones of depression can be considered as the cost (negative externality). These externalities are implicitly incurred through forced investment on (i) additional wells since wells constructed earlier failed to yield water for the expected number of years and / or (ii) water utilization structures (conveyance pipes) in order to at least remain on the original production possibility curve.

Thus, the annual cost of irrigation = Amortized cost of irrigation well + Amortized cost of conveyance + Amortized cost of pump set and electrical installation + Annual cost of repairs and maintenance.

The labour cost of irrigation is merged with the costs of other cultural operations. Thus, labour cost involved in irrigation is excluded 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. This total cost of irrigation is then apportioned to include individual crops according to the proportion of water used in each crop: Cost of irrigation per acre-inch = [Total annual cost of irrigation] ÷ [Total acre-inches of water used]. The cost of irrigation for each crop is worked out by multiplying the cost per acre-inch of water with the number of acre-inches of water applied to each crop.

2.7.7 Economics of Irrigation

The cost of cultivation is the summation of amortized cost of irrigation, cost of human labour, bullock labour, machine hours, seeds and fertilizers, application of manure, plant protection measures, bagging, and transporting, cost of irrigation for each crop. The cost of production is the cost of cultivation + interest on variable cost. Gross return for each crop is the value of the output and the by product at the prices realized by farmers.

Net returns from well irrigation are the gross returns from gross irrigated area minus the cost of production of all crops. Notably the cost of cultivation of all crops includes the cost of irrigation.

The gross cropped area (GCA) is calculated as, the sum of area under crops in all the three seasons (Kharif, Rabi and summer) +2 times the area under perennials such as coconut and arecanut. The net cropped area (NCA) is calculated as, the sum of area under crops for a season (Kharif) +one time area under perennials.

Gross irrigated area (GIA) is the sum of irrigated area under all crops in all the three seasons + 2 times the area under perennials. Net irrigated area (NIA) is the irrigated area under all crops in kharif season + 1 time the area under perennials.

Cropping intensity (CI) =(gross cropped area / net cropped area)*100
Irrigation intensity (II)=(gross irrigated area / net irrigated area)*100

Gross Returns for each crop is total value of the output at the prices realized by farmers. Net returns from well irrigated area = Gross Returns from gross irrigated area minus the cost of production of all crops (for the year 2008).

2.7.8 Annual Externality Cost

The annual externality cost (AEC) of irrigation is estimated as the difference between the amortized cost per well and the amortized cost per functioning well.

AEC=amortized cost per well minus amortized cost of functioning well.

If the amortized cost per well is same as the amortized cost per functioning well, then all wells are working and there is no well failure. But if the amortized cost per well is lower than the amortized cost per functioning well, then the difference between amortized cost per functioning well minus the amortized cost per well is considered to reflect the negative externality suffered by each irrigation well. If the failure rate is large, the gap between these two would also be more. And hence the externality cost is included as the cost of well failure due to cumulative interference of irrigation wells.

2.7.9 Net Returns per Rupee of Irrigation Cost

Net return per rupee of irrigation cost was derived to compare the net return per acre-inch of groundwater used with irrigation cost per acre-inch of groundwater. Analyzed by dividing net returns per acre-inch of groundwater used divided by irrigation cost per acre-inch of groundwater.

Synergistic role of Irrigation wells located under system tank command (GWTI) was calculated by incremental net returns per acre of gross cropped area over Irrigation wells not located under tank or canal command (GWSI) minus net returns from rain fed crops per acre of gross cropped area.

2.7.10 Net Return per Acre from Different Source

Farmers classified based on land holdings and net returns from the source like agriculture, livestock and Non-Agriculture activity was added to get sum of net returns for farmers across different categories. Overall net returns per acre from all sources.

2.7.11 Estimation of Contribution of Channel Water and Rainfall to the income of sample farmers

An attempt is made to estimate the economic contribution of channel water to the income of sample farmers. The underlying hypotheses for estimating the contribution of channel water are:

1. Net returns in Irrigation wells not located under tank or canal command (GWSI) minus net returns in Irrigation wells located under tank command (GWTI) i.e., System tank, reflect the contribution of channel water, because the GWSI received support only from rainfall.
2. Net returns in Irrigation wells located under canal command (GWCI) minus Net returns in Irrigation wells not located under tank or canal command (GWSI) i.e., reflect the contribution of channel water, because GWSI received only rainwater for recharge.

2.8 One way ANOVA

To compare the net returns per acre for three different independent sample viz. Irrigation wells located under tank command (GWTI) i.e., System tank, Irrigation wells located under canal command (GWCI) and Irrigation wells not located under tank or canal command (GWSI) one way analysis of variance was used.

The test of equality of population means is based on a comparison of two types of variability exhibited about the individual sample means within the K groups of observations is within group variability and variability among the K group means is between groups variability.

Suppose we have independent random samples of n1, n2 . . ., n_k observations from K populations. Denote by x1, x2 ….. xk the K group sample means, and by x the overall sample means.

Sum of squares:

Within group: $$SSW = \sum_{i=1}^{k} \sum_{j=1}^{ni} (x_{ij} - \overline{x_i})^2$$

Between group: $$SSG = \sum_{i=1}^{k} n_1 (\overline{x}_i - \overline{x})^2$$

Total: $$SST = \sum_{i=1}^{k} \sum_{j=1}^{ni} (x_{ij} - \overline{x})^2$$

Where,

x_{ij} denotes the j^{th} sample observation in the i^{th} group.

Then,

SST = SSW +SSG

Hypothesis test for One-way analysis of variance

Suppose independent random samples of $n_{1,}$ $n_{2,}$ $n_{3\,.\,.\,.\,.\,.,}$ n_k observations from K populations. Denote by n the total sample size, so that

$$n = n_1 + n_2 + ... + n_k$$

The mean squares as follows,

Within group: $MSW = \dfrac{SSW}{(n-K)}$

Between group: $MSG = \dfrac{SSG}{(K-1)}$

The null hypothesis to be tested is that the K population means are equal, that is,

$$H_0 : \mu_1 = \mu_2 = \cdots\cdots = \mu_k$$

Additional assumptions

1. The population variance is equal
2. Population are normally distributed

A test of significance level α is provided by the decision rule

Reject H_0 if $\dfrac{MSG}{MSW} > F_{K-1,n-K,\alpha}$

Where,

$F_{K-1,n-K,\alpha}$ is that number for which

$$P(F_{K-1,n-K} > F_{K-1,n-K,\alpha} = \alpha$$

The random variable $F_{K-1,n-K}$ follows an F distribution with numerator degrees of freedom (K-1) and denominator degrees of freedom (n-K).

3. RESULTS AND DISCUSSION

The study was undertaken in Tiptur Taluk, in the central dry Zone of Karnataka. Part of Tiptur Taluk is in the Hemavathi River basin and the river is connected to a few irrigation tanks called system irrigation tanks in the Taluk. For this study, in order to analyze the economic role of channel water linkage in improving access to surface irrigation in three irrigation situations in Tiptur area were chosen namely, the Irrigation wells located under tank command (GWTI) i.e., System tank (Echanoor), Irrigation wells located under canal command (GWCI) (Gadabanahalli) and Irrigation wells not located under tank or canal command (GWSI) (Kibbanahalli). Here the recharge is only from rainfall and has no linkage with any river or canal or tank. The GWSI hence serves as control situation. The other control for this study is the GWTI, or the System Tank. With these two types of irrigation tanks, the GWCI is compared. As mentioned in the Methodology, the channel linkage is to impound the flowing river water for the sake of percolation, which augmented the groundwater recharge of irrigation wells under its command area.

The sample farmers owning irrigation wells in different situations such as System Tank i.e., Irrigation wells located under tank command (GWTI), Irrigation wells located under canal command (GWCI) and Irrigation wells not located under tank or canal command (GWSI are presented in detail.

3.1 Historical Profile of Irrigation Bore Wells in the study

The historical data on investment on irrigation wells by sample farmers indicates that the dug well technology phased out around 1980 in GWTI, GWCI and GWSI, as it did not yield water due to groundwater overdraft.

Considering the total 60 irrigation wells spread in GWTI, 48 wells (80 per cent) were yielding groundwater in 2008. Six bore wells suffered initial failure (10 per cent) and 6 bore wells (10 per cent) were failed after yielding water for 10 to 15 years. The overall failure rate was 20 percent in the GWTI. In the GWCI, 59 wells (81 per cent) were yielding groundwater in 2008. 8 bore wells suffered initial failure (11 per cent) and 6 bore wells (8 per cent) were failed after yielding water for 10 to 15 years. The overall failure rate was 19 percent in the GWCI. In GWSI 43 wells (55 per cent) were yielding groundwater, 15 bore wells suffered initial failure (19 per cent) and 20 bore wells (26 per cent) failed after yielding water for 10 to 12 years. (Table 1). The proportion of well failure is about 45 per cent in GWSI, but is 20 percent in GWTI and 19 percent in GWCI due to linkage from Hemavathy water channel.

It is crucial to note the change in the percentage of well failure before and after the linkage of the Hemavathy channel water during 1998. In the GWTI, the percentage of well failure was (8/34=) 23.5 percent in the pre 1998 period, while in the post 1998 period it was (4/26=) 15 percent. In the GWCI, the percentage of well failure before the linkage to Hemavathy channel was (8/44=) 18 percent, while after the linkage with Hemavathy channel was 17 percent. In the GWSI, the percentage of well failure before 1998 was (21/33=) 64 percent, while after 1998 was (14/45=) 31 percent. Accordingly in the GWTI, before 1998, the initial failure was (2/34=) 6 percent, while after 1998, it was (4/26=) 15 percent. In the GWCI area, before the Hemavathy linkage in 1998, the initial failure was (3/44=) 2 percent, while after the linkage with Hemavathy channel was 17 percent. In the GWSI the initial failure before 1998 was (1/12=) 8.3 percent, while after 1998 was (14/35=) 40 percent. However, these are not reflecting the contribution of Hemavathy channel linkage to reduction of proportion of well failure especially in the GWCI. A better measure would be to compare the percentage of well failure immediately before the Hemavathy channel linkage with immediately after the Hemavathy channel linkage. Accordingly in the GWCI, in 1996-1998 the proportion of well failure was (2/12=)

17 percent, while the proportion of well failure immediately after the Hemavathy linkage during 1999-2001 was (1/14=) 7 percent, an apparent reduction. However as the premature well failures were nil in all the three situations, there are no compelling reasons to believe that Hemavathy channel linkage lead to reduction in proportion of well failure. Thus, it is necessary to examine other economic variables, in addition to proportion of well failure.

In the GWTI and GWCI, the bore well failures have reduced after the supply of water through Hemavathy channel Thus the effect of water supply through Hemavathy linkage is apparent in GWTI and GWCI. Accordingly, the annual externality cost for GWTI and GWCI farmers was the lowest (Rs.957 and Rs. 863 respectively). However, the annual externality cost was highest for GWSI farmers (Rs.3226) by more than 200 percent. In GWSI, the annual externality cost is higher and the well failure has also increased over the time. Therefore, the need for ground water recharge in this area. The gross irrigated area per functioning well is 7.94 acres in GWTI while it is 6.20 acres in GWSI. Thus, GWSI farmers need to gear up the recharge efforts to augment their groundwater sources. The proportion of initial failures in borewells has fallen in GWTI and GWCI compared to GWSI after the supply water through channel to GWTI and GWCI in the year 1998.

3.2 DETAILS OF IRRIGATION WELLS

3.2.1 Distribution of irrigation wells across different types of farmers

In GWTI farmers, considering the distribution of wells across different holding sizes, 54 per cent are medium farmers followed by small farmers (34 per cent) and large farmers (12 per cent). Considering all the farmers, 20 per cent of the wells had failed and the remaining 80 per cent were functional at the time of data collection. Earliest well was drilled in 1984 and latest during 2008. Considering all the farmers, the average size of holding was 6.66 acres. In GWTI farmers, out of 60 bore wells, highest no of wells belong to medium farmers (36, 60 per cent.), followed by small farmers (13, 22 per cent) and large farmers (11, 18 percent). Among 36 borewells of medium farmers, 28 were yielding ground water and 8 wells were failed. Among 13 borewell 0f small farmers, 12 were yielding ground water and 1 was failed. Among 11 borewells of large farmers, 8 were yielding ground water and 3 were failed. Medium farmers had 58 per cent of working borewells followed by small farmers 25 per cent and large farmers 17 per cent (Table 2). Small farmers, possessed 25 per cent of working wells and 8 percent failed wells with an average size of land holding of 3.43 acres; the medium farmers possessed 58 per cent of working wells and 67 per cent failed wells with an average size of land holding of 6.71 acres. The large famers possessed 17 per cent of working wells and 25 per cent failed wells and the average size of holding was 16.24 acres (Table 2).

In GWCI sample farmers, 54 per cent are medium farmers followed by small farmers and large farmers (23 per cent each). Considering all the farmers, 19 per cent of bore wells had failed and the remaining 81 per cent were functional at the time of data collection. Earliest well was drilled in 1985 and latest during 2005. In GWCI, out of 73 bore wells highest no wells belongs to medium farmers (39, 53 per cent.), followed by large farmers (24, 33 per cent) and small farmers (10, 14 percent). Among 39 wells of medium farmers, 31 were yielding ground water and 8 wells were failed. In 24 well 0f large farmers 19 were yielding ground water and 5 were failed. In 10 wells of small farmers 9 were yielding ground water and 1 was failed. Medium farmers had 53 per cent of working wells followed by large farmers 32 per cent and small farmers 15 per cent (*Table 2).*

Table 1 Historical profile of wells drilled by sample farmers in GWTI, GWCI and GWSI in Tiptur 2008

Year of drilling	GWTI				GWCI				GWSI			
	Number of wells drilled	Number of Initial failures	Number of failures	Number of failed wells among drilled	Number of wells drilled	Number of Initial failures	Number of failures	Number of failed wells among drilled	Number of wells drilled	Number of Initial failures	Number of failures	Number of failed wells among drilled
1981-1985	3	0	3	3 (100)	3	0	3	3 (100)	1	0	1	1 (100)
1986-1990	10	1	1	2 (20)	10	0	3	2 (30)	11	0	10	10 (90.90)
1991-1995	4	0	2	2 (50)	19	1	0	1 (5.26)	9	0	9	9 (100)
1996-1998	17	1	0	1 (5.88)	12	2	0	2 (16.66)	12	1	0	1 (8.33)
1998-99 year of water supply connecting the Canal percolation tank												
1999-2001	5	1	0	1 (20)	14	1	0	1 (7.14)	10	3	0	3 (30)
2002-2004	15	3	0	3 (20)	14	3	0	3 (21.42)	16	4	0	4 (25)
2005-2008	6	0	0	0 (0)	1	1	0	1 (100)	19	7	0	7 (36.84)
Total	60	6	6		73	8	6		78	15	20	

Note: GWTI: Groundwater use under System percolation tank, GWCI: Groundwater use under Canal irrigation, GWSI: Groundwater use under sole irrigation, dependent only on rainfall for recharge

Irrespective of functional and failed bore wells, in GWCI 53 per cent of wells were owned by medium farmers, 33 per cent by large farmers and 14 per cent of wells were possessed by small farmers. Medium farmers possessed 52 per cent working wells and 62 per cent of failed wells. Small farmers in the sample had irrigation wells since 1990. Thus, in GWCI on an average the proportion of well success was 81 per cent and the remaining 19 percent was failure rate during 2008, at the time of data collection. The ratio of working to failed wells was 9:1 for small farmers, 3.88:1 for medium farmers and 5:1 for large farmers. Thus, *prima facie* all farmers have greater access to groundwater irrigation**.**

In GWSI sample farmers, 43 per cent are small farmers followed by medium farmers (40 per cent) and large farmers (17 per cent). Considering all the farmers, 45 per cent of bore wells had failed and the remaining 55 per cent were functional at the time of data collection. Earliest well was drilled in 1985 and latest during 2008. Out of 78 bore wells highest no of bore wells belongs to medium farmers (31, 40 per cent.), followed by small farmers (26, 33 per cent) and large farmers (21, 27 percent). Among 31 wells of medium farmers 16 were yielding ground water and 15 wells were failed. Among 26 well 0f small farmers 15 were yielding ground water and 11 were failed. Among 21 wells of large farmers 12 were yielding ground water and 9 was failed. Medium farmers had 37 per cent of working wells followed by small farmers 35 per cent and large farmers 28 per cent (Table 2). The ratio of working to failed wells was 1.36:1 for small farmers, 1.07:1 for medium farmers and 1.33:1 for large farmers. Thus, *prima facie* all farmers don't have greater access to groundwater irrigation in GWSI.

The ratio of working to failed wells was 4:1 for GWTI farmers, 4.62:1 for GWCI farmers and 1.22:1 for GWSI farmers. Thus, *prima facie* GWTI and GWCI farmers have greater access to groundwater irrigation compared to GWSI farmers**.** Thus, the proportion of functioning wells in System tanks (GWTI and GWCI) is 80 percent compared to 55 percent in GWSI. This is a prima facie indicator of the role of system tanks in registering ground water recharge.

3.2.2. Age, depth and yield of irrigation Borewells

The total numbers of functioning wells were 48, 59, and 43 in GWTI, GWCI and GWSI respectively. The proportion of functioning wells was 80 per cent in GWTI, 81 percent in GWCI and it was only 55 percent in GWSI farmers. The proportion of well failure was the highest in GWSI (45 per cent) followed by GWTI (20 per cent) and GWCI (19 per cent). The percentage of well failure in GWTI is 66 percent less as compared to GWSI and 14 percent less as compared to GWCI. The percentage of well failure in GWCI is 63 percent less as compared to GWSI (Table 3). The proportion of functioning bore wells was higher in GWTI (80 per cent) as well as in GWCI (81 per cent) than that in GWSI (55 per cent). The proportion of well failure was the highest in GWSI (45 per cent) followed by GWTI (20 per cent) and GWCI (19 per cent).

The average age of borewells was 10.00 years in GWTI and 10.95 years in GWCI which is comparatively higher than GWSI (7.42 years). The average age of bore wells is 34.77 per cent more in GWTI and it is 47.57 percent more in GWCI as compared to GWSI. These differences do make a distinct impact in terms of additional net income which is much higher in GWTI and GWCI as compared to GWSI (Table 3).

Table 2 Distribution of irrigation wells across different types of farmers in GWTI, GWCI and GWSI in Tiptur 2008

Type of farmers	**Size of holding (acres)**	**No. of farmers (percentage)**	**No of working wells (proportion of working wells)**	**No of failed wells (proportion of failed wells)**	**Total no of wells**	**Range of years**
GWTI						
Small Farmers (< 5 acres)	1.75 - 4.75	12(34.28)	12 (25)	1 (8)	13(22)	1997-2008
Medium Farmers (5-10 acres)	5.00 - 9.50	19(54.29)	28 (58)	8(67)	36(60)	1985-2006
Large Farmers (> 10 acres)	11.84 - 20.00	4 (11.43)	8 (17)	3 (25)	11(18)	1984-2004
All farmers	6.66	35(100)	48 (80)	12 (20)	60(100)	1984-2008
GWCI						
Small Farmers (< 5 acres)	1.98 - 4.70	8(23)	9(15)	1(7)	10(14)	1990-2000
Medium Farmers (5-10 acres)	5.25 - 9.79	19(54)	31(53)	8(57)	39(53)	1985-2004
Large Farmers (> 10 acres)	10.04 - 16.50	8(23)	19(32)	5(36)	24(33)	1985-2005
All farmers	7.33	35(100)	59(81)	14(19)	73(100)	1985-2005
GWSI						
Small Farmers (< 5 acres)	3.00 - 4.85	15(43)	15(35)	11(31)	26(33)	1987-2006
Medium Farmers (5-10 acres)	5.00 - 8.00	14(40)	16(37)	15(43)	31(40)	1985-2007
Large Farmers (> 10 acres)	11.50 - 17.50	6(17)	12(28)	9(26)	21(27)	1986-2008
All farmers	6.31	35(100)	43(55)	35(45)	78(100)	1985-2008

Note: Figures in the parentheses indicate percentage to respective total

GWTI: Groundwater use under System percolation tank, GWCI: Groundwater use under Canal irrigation, GWSI: Groundwater use under sole irrigation, dependent only on rainfall for recharge

The average depth of borewells was lower in GWTI (285 ft) and GWCI (315 ft) while it was higher in GWSI (429 ft). As compared with GWSI, average depth of borewells in GWTI and GWCI was lower by 33.57 and 26.57 percent respectively. It was 9.52 per cent less in GWTI as compared to GWCI. This can have a noticeable impact on the overall bore well economy (Table 3).The average depth of bore wells was comparable in both GWTI (285 ft) and in GWCI (315 ft) but it was 429 feet in GWSI. However, the average age of irrigation wells was higher in GWTI (10.00 years) and GWCI (10.95 years) compared to GWSI (7.42 years). The groundwater yield of borewells was higher in the GWTI (2016 GPH) and GWCI (1877 GPH) as compared to GWSI (904 GPH). The average ground water yield is 123.01 and 107.63 per cent more in GWTI and GWCI respectively, as compared to GWSI. The average ground water yield is 7.41 per cent more in GWTI as compared to GWCI (Table 3).

The relationship between channel water linkage and yield of bore wells is understandable since the yield of wells greatly differ with degree of weathering and groundwater recharge efforts than with depth. There is a misconception that deeper the well, higher is the yield. This is disproved by poor correlation between depth and yield (Fig 2).

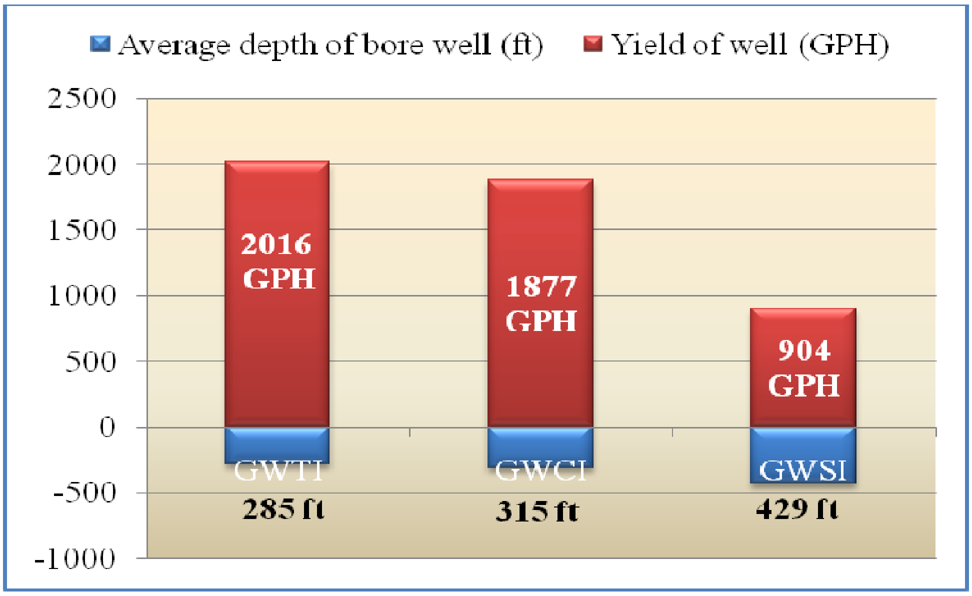

Fig.2 **Average depth (ft) and yield (GHP) of bore wells in GWTI, GWCI and GWSI, Tiptur , 2008.**

Table 3 Profile of irrigation wells of sample farmers in GWTI, GWCI and GWSI in Tiptur, 2008

Sl. No.	Particulars	GWTI (1)	GWCI (2)	GWSI (3)	Percentage change 1 over 3	Percentage change 2 over 3	Percentage change 1 over 2
1	Sample farmers (No.)	35	35	35			
2	Functioning bore wells (No.)	48 (80)	59(81)	43(55)	11.63	39.53	-18.64
3	Non functioning Bore wells (No.)	12 (20)	14(19)	35(45)	-65.71	-62.85	-14.28
4	Total bore wells (No.)	60(100)	73(100)	78(100)	-23.08	-6.41	-17.80
5	Average age of functioning wells (years) as on 2009	10.52	12.20	7.33	43.52	66.44	-13.77
6	Average life of (failed) wells (years) as on year of failure	7.92	5.64	7.54	05.04	-25.20	40.43
7	Average age of all wells (years) as on 2009	10.00	10.95	7.42	34.77	47.57	-8.68
8	Modal age of functioning wells (years) as on 2009	11.00	11.00	5.00	120.00	120.00	0.00
9	Depth of Bore wells (feet)	285	315	429	-33.57	-26.57	-9.52
10	Yield of well (Gallons per Hour- GPH)	2016	1877	904	123.01	107.63	7.41
11	Year Range of wells drilled	1984-2008	1985-2005	1985-2008			
12	Investment per well	45158	44373	55700	-18.93	-20.34	1.77
13	Investment per functioning well	51015	49040	77118	-33.85	-36.41	4.03
14	Investment per failed well	21731	22832	29385	-26.05	-22.30	-4.82
15	Amortized cost per well (Rs.)	6490	6505	8232	-21.16	-20.98	-0.23
16	Amortized cost per functioning well (Rs.)	7447	7368	11458	-35.01	-35.70	1.07
17	Annual Externality cost (Rs.) (16-15) (Rs)	957	863	3226	-70.33	-73.25	10.89
18	Amortized cost per failed well (RS)	2660	2519	4269	-37.69	-40.99	5.60

Note: Figures in the parentheses indicate percentage to the respective total GWTI: Groundwater use under System percolation tank, GWCI: Groundwater use under Canal irrigation, GWSI: Groundwater use under sole irrigation, dependent only on rainfall for recharge * Amortized cost is relatively higher due to higher rate of well failure (45 %) as against 20 % and lower age of 7.33 years in GWSI as against 12.20 years in GWCI command.

Annual Externality cost for GWTI farms was (Rs. 957) is lower by 70 per cent as compared to GWSI farms (Rs. 3226). Annual Externality cost for GWCI farms was (Rs 863), lesser by 73 per cent as compared to GWSI farms because the proportion of failed wells was less in GWTI and GWCI. In the GWCI the proportion of well failure was 62 percent below that of GWSI. The age of functioning wells was 66 percent higher than the GWSI. The depth of borewells was 27 percent lower and the yield of well was 108 percent higher than GWSI. Considering economic parameters, the investment per functioning well was 36 percent lower, the amortized cost per well was 21 percent lower, the amortized cost per functioning well was 36 percent lower and more importantly the annual externality cost was 73 percent lower. The externality cost per well in GWSI was Rs. 3226, it was a mere Rs. 826 in the GWCI. These are apparent indicators of economic performance of GWCI over GWSI. And are clear pointers of groundwater recharge. Thus, the Irrigation Department of the Government needs to examine the possibilities of such linkages from the Hemavathy channel to help the farmers cultivating perennial crops since these crops are low water users compared to annual and seasonal crops. In addition, it is relatively economical to adopt drip and sprinkler irrigation for perennial crops compared to annual and seasonal crops.

3.2.3 Economics of groundwater irrigation

In this study all the sample farmers owned functioning bore wells. The number of functioning bore well per farm was highest in GWCI (1.71) followed by GWTI (1.37) and GWSI (1.23). The grass irrigated area of sample farmers was higher in GWCI (424.44 acres) higher by 59.05 per cent as compared to GWSI (266.85 acres) and the same is higher by 42.87 per cent in GWTI (381.25 acres) as compared to GWSI. Gross irrigated area per farm among sample farmers was higher in GWCI (12.13 acres) higher by 59.19 per cent as compared to GWSI (7.62 acres) and the same is higher by 42.91 per cent in GWTI (10.89 acres) as compared to GWSI. However the Gross irrigated area per functioning well among sample farmers was higher in GWTI (7.94 acres) higher by 28.06 per cent as compared to GWSI (6.20 acres) and the same is higher by 15.96 per cent in GWCI (7.19 acres) as compared to GWSI.

The net irrigated area of sample farmers was higher in GWCI (223.46 acres) higher by 64.90 per cent as compared to GWSI (135.51 acres) and the same is higher by 28.32 per cent in GWTI (173.89 acres) as compared to GWSI. Net irrigated area per farm among sample farmers was higher in GWCI (6.38 acres) higher by 64.86 per cent as compared to GWSI (3.87 acres) and the same is higher by 28.42 per cent in GWTI (4.97 acres) as compared to GWSI. The net irrigated area per functioning well among sample farmers was also higher in GWCI (3.72 acres) higher by 18.10 per cent as compared to GWSI (3.15 acres) and the same is higher by 14.92 per cent in GWTI (3.62 acres) as compared to GWSI (Table 4).

The irrigation intensity was highest in GWTI 219.25 percent followed by GWCI 189.94 per cent and GWSI 180.24 percent. Groundwater extracted per well in GWTI was 241 acre inches, higher by 82.58 per cent compared to GWSI (132 acre inches) and it was 34.85 per cent higher in GWCI (178 acre inches) when compared to GWSI (132 acre inches). The ground water extracted per rupee of irrigation cost was higher in GWTI (0.049 Acre inches) and GWCI (0.046 Acre inches) as compared to GWSI (0.012 Acre inches) higher by 317 and 292 per cent in GWTI and GWCI respectively as compared to GWSI. The cost per acre inch of groundwater is lower in GWTI (Rs.34) and GWCI (Rs. 45) than in GWSI (Rs.113) which is another impact of channel water linkage.

The ground water extracted per acre of gross irrigated area was higher in GWTI (30.34 acre inches) higher by 42.17 per cent as compared to GWSI (21.34 acre inches) and the same is higher by 17.90 per cent in GWCI (25.16 acre inches) as compared to

GWSI. The Amortized cost per acre inch of groundwater used was lower in GWTI (Rs. 33.66) lower by 70.14 per cent as compared to GWSI (Rs. 112.74) and the same was lower by 60.16 percent in GWCI (Rs. 44.46) as compared GWSI.

The net return per acre of gross irrigated area was higher in GWTI (Rs. 12210) higher by 31.40 per cent as compared to GWSI (Rs. 9292) and the same is higher by 17.43 per cent in GWCI (Rs. 10912) as compared to GWSI. In GWTI and GWCI, annual externality cost is lower by 70 per cent and 73 per cent respectively; as compared to GWSI. At the same time the Net returns per acre in GWTI and GWCI is higher by 33 per cent and 13 per cent respectively compared to GWSI. Both these parameters are indicators of the effect of channel water on ground water recharge and the corresponding benefits to farmers (Fig 3).

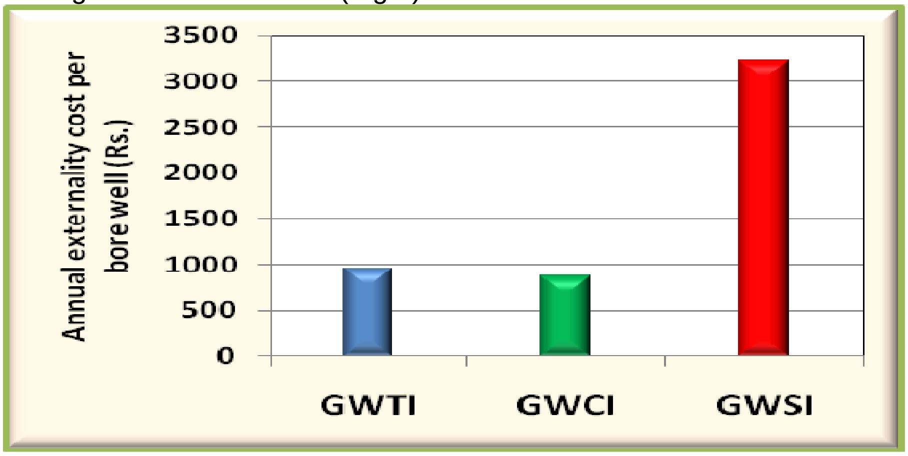

***Fig.* 3 Annual Externality cost per well in GWTI, GWCI and GWSI, Tiptur , 2008.**

The net return per farm from irrigated crops was higher in GWTI (Rs. 133000) higher by 87.73 per cent as compared to GWSI (Rs. 70845) and the same is higher by 86.78 per cent in GWCI (Rs. 132325) as compared to GWSI. The net returns per functioning well was higher in GWTI (Rs. 96979) higher by 68.18 per cent as compared to GWSI (Rs. 57665) and the same is higher by 33.86 per cent in GWCI (Rs. 77190) as compared to GWSI. Net return per rupee of irrigation cost was Rs. 20.60 in GWCI, higher by 221.37 per cent as compared to GWSI (Rs 6.41). It was higher by 177.54 per cent in GWTI (Rs. 17.79) as compared to GWSI *(Table 4)*.

The groundwater extracted per rupee of investment on irrigation in GWCI is 292 percent higher than that in GWSI. Thus, the net return obtained per rupee of irrigation investment in GWCI is 221 percent higher over GWSI. Similarly the net return per functioning well is 34 percent higher in GWCI over GWSI. The net return per acre is 24 percent higher in GWCI and that per acre of gross irrigated area is 17 percent higher. Thus, these reiterate the need for linking non system tanks to the Hemavathy channel wherever possible.

Economic Impact of channel water in the study area is reflected through cost of irrigation and net return to groundwater used. Irrigation cost per acre inch of groundwater used was lower in GWTI and GWCI (Rs.34 and Rs. 45 respectively) as compared to non GWTI (Rs.113). This shows that there is positive impact of channel water on cost and returns. Net return per rupee of irrigation cost was higher in GWTI and GWCI compared to GWSI by 175 per cent and 221 percent respectively **(Fig 4 to Fig 7).**

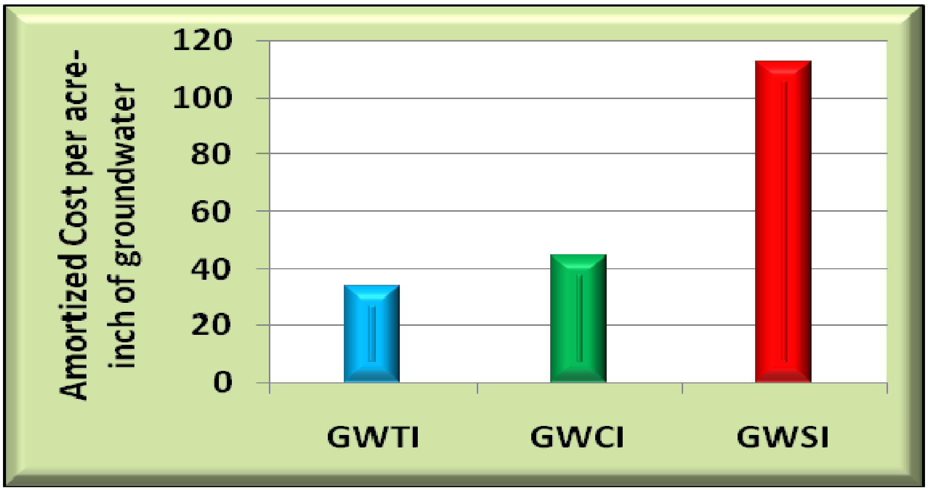

***Fig.* 4 Amortized Cost per acre-inch of groundwater in GWTI, GWCI and GWSI, Tiptur , 2008.**

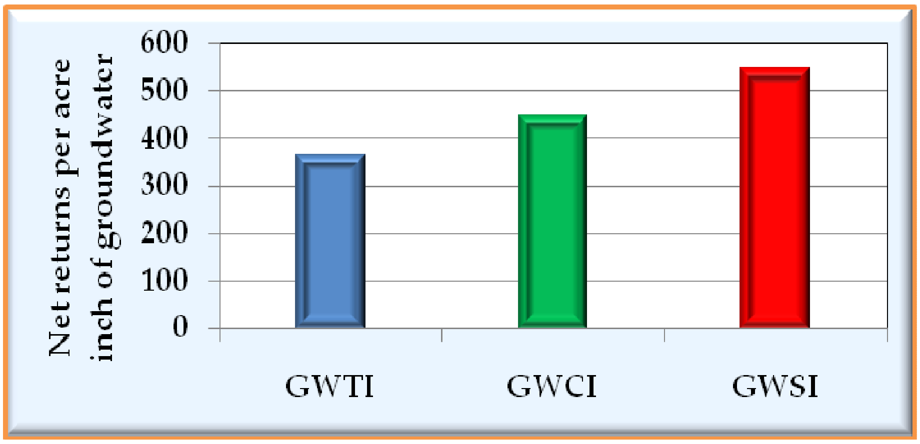

***Fig.* 5 Net returns per acre inch of groundwater in GWTI, GWCI and GWSI, Tiptur, 2008**.

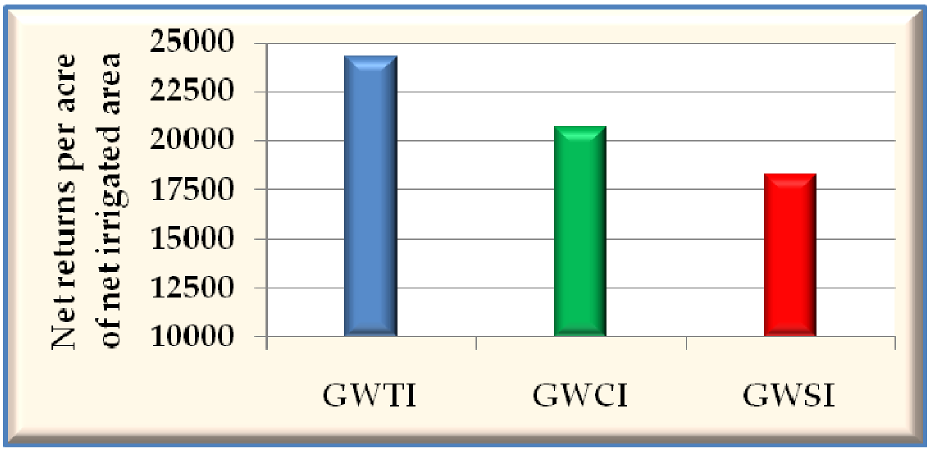

***Fig.* 6 Net returns per acre of irrigated area in GWTI, GWCI and GWSI, Tiptur , 2008.**

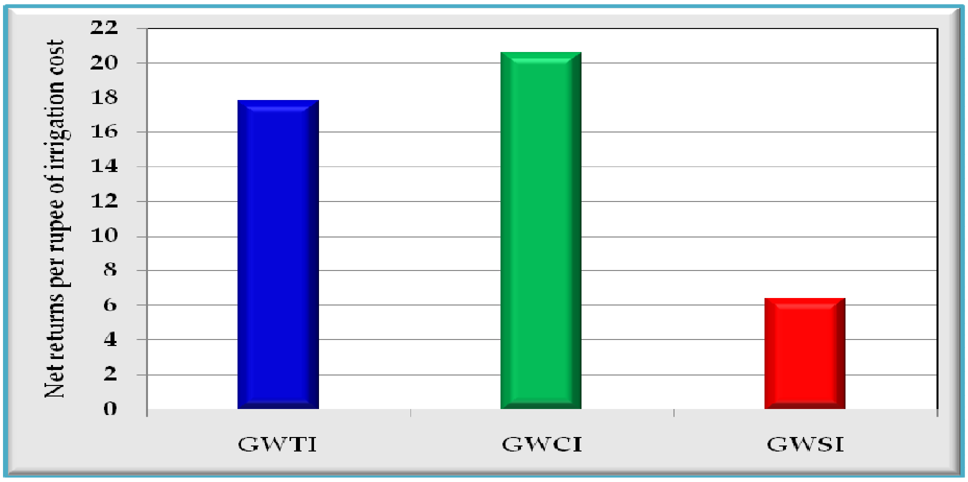

Fig. **7 Net returns per rupee of irrigation cost in GWTI, GWCI and GWSI, Tiptur , 2008.**

In the GWCI the proportion of well failure was 62 percent below that of GWSI. The age of functioning wells was 66 percent higher than in the GWSI. The depth of Borewells was 27 percent lower and the yield of well was 108 percent higher than in GWSI. Considering economic parameters, the investment per functioning well was 36 percent lower, the amortized cost per well was 21 percent lower, the amortized cost per functioning well was 36 percent lower and the annual externality cost was 73 percent lower. The externality cost per well in GWSI was Rs. 3226; it was a mere Rs. 826 in the GWCI. These are apparent indicators of economic performance of GWCI over GWSI. And are clear pointers of groundwater recharge. Thus, the Irrigation Department of the Government needs to examine the possibilities of such linkages from the Hemavathy channel to help the farmers cultivating perennial crops since these crops such as Coconut and Arecanut are perennial crops and are low water users compared to annual and seasonal crops. In addition, it is relatively economical to adopt drip and sprinkler irrigation for perennial crops compared to annual and seasonal crops.

3.2.4 Environmental economic impact of groundwater recharge

For this study the sample farmers were those who possessed irrigation wells. The Net irrigated area was higher by 28 per cent in GWTI and 65 per cent in GWCI as compared to GWSI. However the Gross irrigated area per farm is higher in GWTI (10.89 acres) and GWCI (12.13 acres), higher by 43 per cent and 59 per cent respectively over GWSI (7.62 acres). This is due to greater access to groundwater.

Environmental economic impact of channel water is reflected through cost of irrigation, cost and net return to groundwater used. Amortized cost per acre-inch of groundwater used was lower in GWTI (Rs. 34) as well as in GWCI (Rs. 45) as compared to GWSI (Rs. 113). This shows that there is positive impact of channel water. Net return per gross irrigated area in GWTI and GWCI was higher by 31 per cent and 17 per cent respectively as compared to that of GWSI. Net return per rupee of irrigation cost was Rs. 17.79 and Rs. 20.60 in GWTI and GWCI respectively; this was higher by 178 per cent and 221 per cent as compared to GWSI (Rs. 6.41).

The groundwater extracted per rupee of investment on irrigation in GWCI is 292 percent higher than that in GWSI. The net return obtained per rupee of irrigation investment in GWCI is 221 percent higher over GWSI. Similarly the net return per functioning well is 34 percent higher in GWCI over GWSI. The net return per acre is 24 percent higher in GWCI. Thus, these reiterate for the effect of linking Non-System tanks to the Hemavathy channel.

3.3 Incremental net return per acre due to Channel water linkage in GWTI, GWCI over GWSI in 2007-08

The incremental net return per acre in GWTI has been positive for the sample farmers over GWCI. It was higher for small farmers (Rs. 11995) compared to medium (Rs. 3640) and large farmers (Rs. 968). The overall incremental net return per acre in GWTI over GWCI was Rs. 4617. When the incremental net return is computed between GWTI and GWSI, it was positive for all sample farmers. Here too, the incremental returns are relatively higher for small and medium farmers (Rs. 17350 and Rs. 11450 respectively) than for large farmers (Rs. 2295). The overall incremental net return per acre in GWTI over GWSI was Rs. 9972. The incremental net return is computed between GWCI and GWSI here too, the incremental returns are relatively higher for small and medium farmers (Rs. 5355 and Rs. 7810 respectively) than for large farmers (Rs. 1327). The overall incremental net return in GWCI over GWSI was Rs. 5355. This reiterates that canal water supply to GWTI and GWCIs has contributed substantially to net returns per acre compared with those farmers who are not connected with canal water (GWSI) *(Table 5)*.

Table 4 Economics of groundwater irrigation for sample farmers in GWTI, GWCI and GWSI in Tiptur, 2008

Sl. No	Particulars	GWTI (1)	GWCI (2)	GWSI (3)	Percentage change (1 to 3)	Percentage change (2 to 3)
1	Number of farmers owning functioning wells	35	35	35		
2	Number of functioning wells	48	59	43	11.63	37.21
3	Number of functioning wells per farm	1.37	1.71	1.23	11.38	39.02
4	Gross irrigated (acre)	381.25	424.44	266.85	42.87	59.05
5	Gross irrigated per farm (acre)	10.89	12.13	7.62	42.91	59.19
6	Gross irrigated per functioning well (acre)	7.94	7.19	6.20	28.06	15.96
7	Net irrigated area (acre)	173.89	223.46	135.51	28.32	64.90
8	Net Irrigated area per farm (acre)	4.97	6.38	3.87	28.42	64.86
9	Net irrigated area per functioning well (acre)	3.62	3.72	3.15	14.92	18.10
10	Irrigation intensity (per cent)	219.25	189.94	180.24	21.64	5.38
11	Groundwater extracted per farm (Acre inches)	330	305.12	162.72	102.80	87.51
12	Groundwater extracted per well (Acre inches)	241	178	132	82.58	34.85
13	Ground water extracted per rupee of irrigation cost (Acre inches)	0.0488	0.0459	0.0117	317.09	292.31
14	Groundwater extracted per acre of gross irrigated (Acre inches)	30.34	25.16	21.34	42.17	17.90
15	Groundwater extracted per acre of net irrigated (Acre inches)	66.51	47.79	42.03	58.24	13.70
16	Amortized cost per acre-inch of groundwater used (Rs.)	33.66	44.46	112.74	-70.14	-60.56
17	Net returns per acre inch of groundwater used (Rs.)	365	449	547	-33.27	-17.92
18	Net returns per acre of gross irrigated (Rs.)	12210	10912	9292	31.40	17.43
19	Net returns per acre of net irrigated (Rs.)	24264	20726	16748	44.88	23.75
20	Net returns per farm from irrigated crops (Rs)	133000	132325	70845	87.73	86.78
21	Net return per functioning well (Rs.)	96979	77190	57665	68.18	33.86
22	Net returns per rupee of irrigation cost (ratio)	17.79	20.60	6.41	177.54	221.37

GWTI: Groundwater use under System percolation tank, GWCI: Groundwater use under Canal irrigation, GWSI: Groundwater use under sole irrigation, dependent only on rainfall for recharge

Table 5: Incremental net returns per acre to GWTI over GWCI and GWSI in Tiptur, 2008.

Type of farm	GWTI over GWCI = (Rs. 26692 – Rs. 22075 = Rs. 4617)	GWTI over GWSI = (Rs. 26692 – Rs. 16720 = Rs. 9972)	GWCI over GWSI = (Rs. 22075 – Rs. 16720 = Rs. 5355)
Small farmers	11995	17350	5355
Medium farmers	3640	11450	7810
Large farmers	968	2295	1327
Overall	4617	9972	5355

***Note*:** Incremental net return in GWTI over GWSI = net return per acre from all sources in GWTI minus that in GWSI.
GWTI: Groundwater use under System percolation tank, GWCI: Groundwater use under Canal irrigation, GWSI: Groundwater use under sole irrigation, dependent only on rainfall for recharge

3.4 Statistical validation of the results

ANOVA is to compare means of different population. Multiple pair wise comparisons were made to assess the difference in net returns per farm across different groups (GWTI, GWCI and GWSI farmers). It was observed that the exists significant difference between GWTI and GWSI farmers net income per farm and also between GWCI and GWSI farmers net income per farm but not between GWTI and GWCI farmers net income per farm *(Table 6)*. The net return per farm from all sources in GWTI and GWCI are significantly higher over that in GWSI as indicated by ANOVA.

Table 6: One way ANOVA for net returns per farm from agriculture across different categories of sample farmers in GWTI, GWCI and GWSI in Tiptur, 2008

Sl. No.	Particulars	Mean	F statistic
1	Net returns per acre from all the sources for all the sample farmers in 2007-08		
	a. GWTI	138298	11.806**
	b. GWSI	77511	
2	Net returns per acre from all the sources for all the sample farmers in 2007-08		
	a. GWCI	137045	13.014**
	b. GWSI	77511	
3	Net returns per acre from all the sources for all the sample farmers in 2007-08		
	a. GWTI	138298	0.0044
	b. GWCI	137045	

Note: ***, ** and * indicate significance at 1, 5 and 10% respectively

GWTI: Groundwater use under System percolation tank, GWCI: Groundwater use under Canal irrigation, GWSI: Groundwater use under sole irrigation, dependent only on rainfall for recharge

Using ANOVA, it was found that the net return per acre in GWTI differed significantly across three types of sample farmers in the GWSI. Further net returns per acre for farmers in GWCI differed significantly with farmers in GWSI. The net return per acre in GWTI is not significantly different from GWCI because both these areas are connected with Hemavathy channel water. Thus the major objective of channel water is achieved with the increasing income of the farmers given the access to water. The net return per acre from all sources in GWTI and GWCI are significantly higher over that in GWSI as indicated by ANOVA.

The net return per acre from all the sources in GWTI (Rs. 26692) and GWCI (Rs. 22075) were significantly higher over GWSI (Rs. 16720). This apparently shows the significant economic performance. This shows that GWTI and GWCI have performed better than GWSI. The reason for this economic performance is attributable as under

1. Farmers realized Rs. 17.79 and Rs. 20.60 as net return per rupee of irrigation cost in GWTI and GWCI, the highest compared to GWSI Rs. 6.41.
2. The realization of Rs. 15359 and Rs. 13935 net returns per acre of GCA in GWTI and GWCI which is higher compared to GWSI Rs. 9890.
3. Only GWTI farmers extracted higher water per well (241 acre inches) compared to other two groups.
4. In GWTI and GWCI the percentage of well failure was around 20 per cent but in GWSI it was 45 per cent.
5. In GWTI and GWCI, gross cropped area of farmers was the highest compared to GWSI farms.
6. The investment per functioning well In GWTI and GWCI was Rs. 51015 and Rs. 49040 respectively which is lower compared to GWSI (Rs. 77118).

4. Policy Implication

This study apparently is a pointer towards the role of channel water linkage in promoting ground water recharge. The farms served by System Tank (GWTI) and Canal command (GWCI) have registered the highest net returns compared with farms in GWSI. This indicates the supremacy of the performance of GWTI and GWCI in heralding agricultural development due to recharge from irrigation tank and canal commands.

Recharging groundwater in GWSI can be augmented through canal water linkage and thus reduces the groundwater extraction cost. Hence efforts should be made by policy makers in this direction especially in river basin areas where such intrabasin transfers are possible.

Hemavathy canal project provides irrigation water for Right Bank Canal command. In rainy season, this area is fully flooded with water and at the same time the farmers of Left Bank Canal command are struggling to receive even drinking water. Thus, water needs to be put to productive and efficient use by linking channel water with irrigation tanks rendering them as percolation tanks where ever feasible. This will increase ground water recharge and improve socioeconomic status of the farmers besides protecting the ground water table.

Irrigation Department needs to rationalize distribution of water for all the areas under Hemavathy command considering the agroclimatic conditions and economic needs. Further there is need to provide impetus to farmers adopting water use efficient technologies like drip/sprinkler irrigation. Government should devise policies to facilitate farmers to shift to low water intensive economic crops.

Government should invest on rehabilitation of Gokatte, small tanks in villages to improve the ground water recharge. The construction of rain water harvesting structures and excavation of tank silt from the existing tanks will also improve ground water recharge. Thus there is a strong need to identify the non system irrigation tanks in river basin areas of Hemavathy river to explore the possibilities of linking irrigation tanks with the river flow as followed in the neighboring states, wherever feasible for the benefit of the farming and rural communities.

The Irrigation Department needs to examine the possibilities of linking irrigation tanks in Hemavathy command area through channels from Hemavathy reservoir. This will ensure water availability throughout the year for irrigation well farmers through groundwater recharge and facilitate to cultivate crops including perennial commercial crops like Coconut and Arecanut since, these crops are low water users compared to annual and seasonal crops.

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Plate 1: A view of Artificial System Percolation Tank