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ECONOMIC IMPACT OF FOREST MANAGEMENT INSTITUTIONS ON GROUNDWATER RECHARGE IN KARNATAKA, INDIA

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ABSTRACT

Present study signifies relative hydrological and economic contribution of Joint Forest Planning and Management (JFPM) programme in semi-arid tropical India towards groundwater recharge. A majority of dugwells / open wells have failed to yield water in hardrock areas of India due to advent of deep borewells, low rainfall and poor recharge. Field data were collected for 2008 from a population of farmers possessing irrigation wells in selected villages with and without JFPM programme. Logarithmic net returns, descriptive statistics and ANOVA reveal that the net returns to land, irrigation water and expenditure for irrigation water increased due to groundwater recharge caused by the JFPM programme. JFPM has contributed towards 100 percent functioning of all borewells and dug wells with no negative externality in JFPM village valued in terms of well failure. Incremental net returns due to JFPM (of ` 13342 per acre) are at least 100 percent higher than that of watershed development Programme, WDP (of ` 6343 per acre) and JFPM + WDP (of ` 6822 per acre). Groundwater yield of dug wells was just 10 percent lower than that of deep borewells, demonstrating potential of JFPM in recharging dug wells. Groundwater cost was 35 per cent lower in JFPM compared with control village, due to groundwater recharge. Net return per rupee of cost of groundwater was the highest for JFPM dug well (` 11.3) followed by JFPM borewell (` 8.42), JFPM + WDP (` 3.26), WDP (` 3.05) and control farmers (` 1.04). JFPM has successfully recharged groundwater in irrigation wells and can be replicated in hard rock areas benefiting scores of farmers at relatively low cost.

Key words: Joint forest planning and management, Groundwater, Recharge, Watershed development programme, Externality and hardrock area.

Introduction

Considering the vanishing tree cover in the hinterlands and degradation of forests on public forest lands in India, The National Commission on Agriculture, Government of India recommended involvement of village community through 'social forestry' in 1976. Taking cue from this recommendation, the Government of Karnataka sought assistance from World Bank and ODA for the Karnataka Social Forestry Project (1984-90). This involved the 'community forestry' component involving the village community for village plantations on common lands and 'farm forestry' component supporting farmers to plant on farms towards inclusive growth (http[1]).

The National Forestry Policy of 1988 heralded the objective of soil and water conservation through afforestation and social forestry programmes (http[2]). This caused the emergence of Joint Forest Management (JFM) or Joint Forest Planning and Management (JFPM) in 1990 paving the way of forest management through state forest departments and local communities. The village forest committee (VFC) also referred as forest protection committee (FPC) and the forest department entered into a JFM agreement where villagers were to protect forest resources from fire, grazing and illegal harvesting and obtained usufruct rights of revenue from non-timber forest products in exchange in addition to a share of the revenue from timber.

Karnataka Forest Department adopted the JFPM programme in 1993 by amending the Karnataka Forest Act (KFA of 1963) to support the JFPM by enhancing the share of usufructs to 90 per cent and the share of timber to 75 per cent with the VFC. The Karnataka Forest Department constituted 3887 VFCs bringing 3,40,000 ha of degraded forests under JFPM with provisions for the involvement of local community to sustain ecological, socio-cultural, and economic benefits to rural society (http[3]). Government of Karnataka is a pioneer in introducing watershed development programme (WDP) since 1984 (http[4]) investing exclusively on soil and water conservation by the Watershed Development Department (WDD).

JFPM has contributed towards 100 per cent functioning of all borewells and dug wells and incremental net returns are at least 100% per cent higher than that of watershed development programme.

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In the study area considered, the JFPM was initiated in 2002, while the WDP was initiated in 2006. For both WDP and JFPM, the groundwater recharge is a spillover effect. In the case of JFPM, the spillover effect on groundwater recharge is due to forest development and conservation, while in the case of WDP, the spillover is due to soil and water conservation.

This article deals with the objective of analyzing the economic contribution of JFPM, not towards the conventional share of timber and non-timber forest products to village community, but towards groundwater recharge enhancing the food, livelihood and economic security of farmers involved in JFPM. The hypothesis of the study is that collective action of farmers towards soil and water conservation programmes will enhance food and livelihood security through irrigation augmented from groundwater recharge. This study was conducted during 2008, in the hard rock aquifers of semi arid tropics of Karnataka, India, fraught with low rainfall of 400 mm - 700 mm and abysmally low groundwater recharge of 5 to 10 per cent. Here as farmers devote 70 per cent of the area to food production the JFPM is addressing food security concerns through groundwater recharge for irrigation.

Review of earlier work

Venkatraman and Falconer (1998) prescribed rapid expansion of JFPM in Andhra Pradesh due to impressive regeneration of forests and the resulting economic gains to local people. Lele *et al.* (2008) examined the link between stream flow, agricultural water use and economic returns to agriculture and simulated the likely impacts of regeneration of a degraded forest catchment on stream flow and the consequent impact on irrigation tank-based agriculture in a downstream village. The authors emphasized dominancy of the conventional wisdom, 'more forest is always better' in policy making in the management of forested watersheds. Many hydrologists debated the assumption of hydrological regulation service provided by the forest ecosystems. According to Envid (2000) the natural regeneration of forests, improved soil and moisture conservation and concluded that JFPM has promoted and revitalized the participatory concept among the forest dependent communities and hence made a positive beginning in initiating an alternate institutional management. Gopal and Upadhyay (2001) examined the VFCs of JFPM programme and found that awareness, motivation, provision of indemnity card, savings and improved employment and income generating activities due to JFPM increased annual income of the farm families. Haque (2003) also examined the impact assessment studies of JFM and found that rejuvenation of degraded forests with increase in forest cover, raised water table, reduced biotic pressure, increased employment generation and decreased outmigration of local people. Hence majority of the studies (Paul and Chakrabarti, 2001; Sanjay Kumar, 2002; Rishi, 2007; Bhattacharya *et al*., 2010; Singh *et al*., 2011) have addressed the explicit and usufruct benefits of JFPM, while studies on implicit benefits (Smerdon *et al*., 2009; Lele *et al.,* 2008; Envid, 2000) have not been able to recognize the significant impacts on groundwater recharge. Behera and Engel (2006) in their analysis have inferred that the shift from state to co-management in forestry is a step in the right direction considering the field realities in forest management in India. Here, the information asymmetry and the lack of accountability leading to enforcement problem including rent seeking have been put to test in addressing contribution of JFPM programme towards groundwater recharge. Considering the main mandate of JFPM programme towards forest conservation, property rights and distribution of usufruct benefits of forest, they examine these spillovers of JFPM programme which have played crucial roles in soil and water conservation in hard rock areas receiving modest rainfall in India.

Methodology

Sampling framework

This study takes cue from Behera and Engel (2006) to find empirical evidence for the spillover effects of JFPM programme analyzing the economic impact of the JFPM on groundwater recharge in Karnataka, India (Fig. 1). The major objective of JFPM is towards forest conservation and development through involvement and empowerment of village community. The sampling framework and methods used in the study are discussed.

Since groundwater recharge programmes such as WDP, JFPM are implemented by WDD and FD, singularly and jointly, and as JFPM is linked with VFC, for this study, the entire population of farmers possessing irrigation wells in the ambit of WDP, JFPM are considered. The methodology followed in the analysis of data is outlined below and follows Chandrakanth *et al*. (2004); Chaitra and Chandrakanth (2005) and Diwakara and Chandrakanth (2007).

As the focus of this study is to analyse the economic impact of JFPM on groundwater recharge, farmers possessing irrigation wells are chosen from four scenarios as under: (1) A population of (23) farmers from JFPM + WDP village, population of (42) farmers from JFPM village, population of (24) farmers from WDP

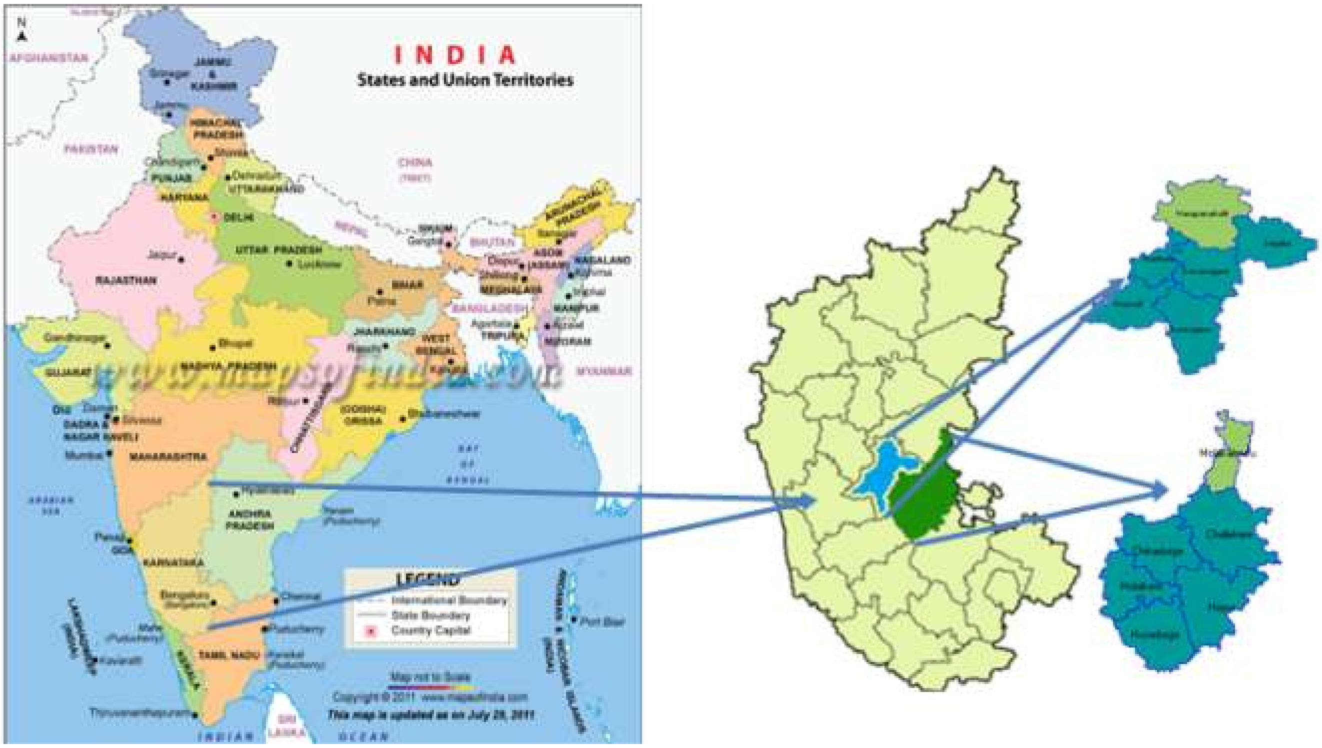

Fig. 1: Map of the study area, Davanagere and Chitradurga Districts of Karnataka State, India

village and population of (15) farmers from control village (which had WDD, JFPM or any other recharge program) are selected for comparison between JFPM + WDP, JFPM, WDP and control*. Accordingly Bandekatte in Molakalmur taluk representing the village situation of both JFPM and WDP; Adavimallapur in Harapanahalli taluk representing the village situation with JFPM programme; Hirehalli in Molakalmur taluk representing the village situation with WDP are chosen for field study. The Eigalbasapur village in Harapanhalli taluk was chosen to represent the situation with no groundwater recharge programme such as JFPM/WDP/any other programmes control village for contrast and comparison.

All the villages in the study are located in the dry agroclimatic zones of Karnataka with hard rock areas receiving a modest rainfall of 400 to 700 mm with rainy days ranging from 20 to 40 in a year. These villages have similar in terms of major cropping patterns and are in proximity and have similar topography, rainfall and ground water recharge. Field data are personally collected from the population of farmers possessing irrigation wells in the selected villages during 2008-09. The four different scenarios are thus JFPM + WDP, JFPM, WDP and control (without JFPM / WDP programme). The information on economic features of farmers, cropping pattern, land holdings, irrigation, investment on irrigation wells, costs and returns from crops and livestock are obtained.

Economics of irrigation

Amortized cost of irrigation well

The amortized cost of irrigation well is the annual fixed cost component of irrigation water. However, due to increasing probability of well failure in the hard rock areas, this fixed cost is treated as variable cost, as the farmer has to reinvest in a well that yields water. The amortized cost depends on type of well (open well or borewell), whether failed or functioning, year of construction, average age, average life of well and the interest rate chosen. For this study concerning the groundwater and forests as natural resources, a discount rate of 2 per cent has been considered (Chaitra and Chandrakanth, 2005).

Amortized cost of irrigation borewell = [Amortized cost of borewell + Amortized cost of pumpset and accessories + Amortized cost of conveyance + Annual repair and maintenance cost of pumpset and accessories]

Amortized cost of borewell = [(Compounded cost of borewell)*$(1+i)^{AL}$* i] $[(1+i)^{AL} - 1]$

*As investment on wells is colossal, not all farmers can afford to invest on irrigation wells and not all farmers whose well/s failed can invest on another well. Hence the proportion of farmers possessing irrigations wells varies.

Here,

AL = Average life of borewells in years = Year of failure – year of construction or year of drilling; Compounded cost of borewell =

$$[(\text{Borewell cost}) * (1+i)^{(2008\text{-Year of construction})}]$$

Age of a well refers to the year of 2008 minus year of drilling or construction, as the well is functioning at the time of field data collection. However life of a well refers to the year of failure minus the year of construction or drilling

Amortized cost of pumpset and accessories = {[(Sum of compounded cost of pumpset + pumpset house + electricity at current price)* $(1+i)^{15}$ * i] [$(1+i)^{15}$ – 1]}

The working life of pumpset and pump house is assumed to be 15 years.

Amortized cost of conveyance = {[(Compounded cost of conveyance pipe used) * $(1+i)^{15}$ * i] + [$(1+i)^{15}$ – 1]}. The working life of conveyance pipe is assumed to be 15 years. The usual mode of conveyance of groundwater is through PVC pipes.

Yield of Irrigation borewells and dugwells

In India, farmers using irrigation pump sets to lift water are not charged for electrical energy to lift irrigation water as a populist policy of the Government. Thus, there are no electrical or water meters installed in order to obtain some accurate measurement of water used for irrigation. Hence, the way to find the volume of water used for irrigation is by estimating water extracted as detailed below.

The yield of borewells is estimated by recording the number of seconds required to fill a bucket of known volume and is then converted to gallons per hour by using conversion of 4.5 liters =1 gallon, 1 minute = 60 seconds, 1 hour = 60 minutes.

The yield of dugwells is measured by recording the height of water column of the dug well which would regain within 24 hours of pumping. For cylindrical dug wells, volume of water is estimated as ($\pi * r^2 * h$), where, r = radius of the dug well, h = height of the water column regained (in feet). For rectangular dug wells volume of water is estimated as (l*b*h), where l=length of well, b=breadth of well and h=height of water column regained in 24 hours in cubic feet. The resultant volume of water in cubic feet is converted to gallons by using the conversion, 1 cu ft = 6.2288 gallons. Finally, the yield of water in gallons per hour (GPH) from the dug well is given by the formula, (l*b*h*6.2288) ÷24 or ($\pi * r^2 * h * 6.2288 \div 24$).

Costing of Irrigation well

Groundwater is extracted from borewells and dugwells. In the estimation of cost of irrigation well, the cost is taken as historic cost of well including cost of drilling / digging, lining / casing at the time of construction or sinking. The historical cost is compounded from the year of construction to the year 2008 for all the wells irrespective of whether the well has failed or has been functioning due to cumulative interference externality responsible for reducing the life/age of wells. This is attempted to estimate the total investment made by farmers in groundwater irrigation at 2008 prices. An interest rate of 2 per cent representing the social discount rate is considered in the estimation of the cost of well components like labour, pumps set, and accessories.

Annual cost of irrigation

The annual cost of irrigation = amortized cost of irrigation well + amortized cost of conveyance+ amortized cost of pumpset and accessories + annual cost of repairs and maintenance+ amortized cost of groundwater storage structures.

Cost of irrigation per acre-inch = [Total amortized cost of irrigation] / [Total acre-inches of water used]. The cost of irrigation is worked out by multiplying the cost per acre-inch of water with the number of acre-inches of water used (one acre inch = 22611 gallons of water).

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. If the amortized cost per well is same as the amortized cost per functioning well, then all wells with a farmer are functioning and there is no well failure due to cumulative interference externality. But if the amortized cost per well is lower than the amortized cost per functioning well, then the difference between the two 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 large. And hence the externality cost is included as the cost of cumulative interference of irrigation wells.

Net returns per rupee of irrigation cost

Net return per rupee of irrigation cost is derived to compare the net return per acre-inch of groundwater used with irrigation cost per acre-inch of groundwater. It is analyzed by dividing net return per acre-inch of groundwater used by irrigation cost per acre-inch of groundwater.

Estimation of costs and returns

The cost of cultivation is obtained by summing the expenditure on human labor, bullock labor, machine hours, seeds, fertilizers, plant protection chemicals, manure, transportation and bagging, packing, the annual cost of irrigation in each crop and the opportunity cost of working capital. The opportunity cost of working capital is estimated at 4.5 per cent. Cost of production is cost of cultivation + amortized cost of irrigation + interest on variable cost. Net returns of irrigated crops is estimated by adding the irrigation cost and the amortized cost of irrigation wells for all wells in the farms across the volume of water used for irrigation.

Irrigation intensity

Gross irrigated area (GIA) is the sum of irrigated area under all crops in all the three seasons on the farm. Net irrigated area (NIA) is the irrigated area under all crops in rainy/ *winter* season + 1 time area under perennials. Irrigation intensity (II) = (gross irrigated area / net irrigated area)*100.

Logarithmic net returns function for water use per acre in acre inch, area under Chilli seed production and study area

Net return function was used to capture the influence of (a) water used per acre, (b) area under chilli seed production and (c) study area

Dummy variable is the intercept dummy to differentiate the study area that is only- JFPM, JFPM + watershed, only-watershed and control area.

The logarithmic regression model was used to measure the effect of water use per acre and area under chilli seed production and study area on net return per acre. The estimated net return function is:

$$\ln Y = a + b_1 \ln X_1 + b_2 X_2 + b_3 D_1 + b_4 D_2 + b_5 D_3$$

Where, Y = Net return per acre (`)

X_1 = Water use per acre (acre inches)

X_2 = area under chilli seed production (acres)

D_1 = Dummy variable (1 for only JFPM area, 0 otherwise)

D_2 = Dummy variable for JFPM + watershed area (1 for JFPM+ watershed area, 0 otherwise)

D_3 = Dummy variable for only watershed area (1 for only watershed area, 0 otherwise)

There are four regions / areas and three dummy variables differentiate them.

Results and Discussion

Age, Depth and yield of irrigation wells

The proportion of functioning borewells is higher in JFPM village (100 per cent) and in JFPM + WDP village (94 per cent) than in WDP village (66 per cent). The proportion of well failure is highest in WDP village (34 per cent) followed by JFPM + WDP (6.5 per cent) and control village (6 per cent).The groundwater yield of borewells is highest in JFPM + WDP and JFPM village than WDP and control village. The average age and average depth of borewells is comparable in both JFPM as well as in non-JFPM villages (Table 1).

An Unique feat of dug wells in JFPM village

In the JFPM village, there are 21 farmers possessing dug wells constructed during the period 1990-2007. It is heartening to note that 100 per cent of the dug wells are functioning in the JFPM village, with an appreciable age of 7 years with the lowest amortized cost and with zero externality, as there are no well failures as compared to control village (Fig. 2). This is because of high water availability due increased recharge from JFPM. And investment per well and investment per functioning well is also same because all dugwells are functioning with no failure due to efforts of JFPM. In fact, dug wells are not existent in JFPM + WDP and in WDP villages, since borewells dried them away due to cumulative interference. Height of water column in the dug wells per day in kharif is 24 feet, 21 feet in rabi and 19 feet in summer. This shows that due to JFPM there is significant improvement in groundwater useful for both irrigation and domestic purpose including drinking water reducing drudgery for farm women also reducing their time in fetching potable water for the farm family, which is usually done by farm women. Current yield of the wells in the JFPM and JFPM +WDP has increased significantly compared to their initial yield (Table 1). This also shows that there is significant ground recharge in both JFPM and JFPM +WDP.

Chandrakanth *et al*. (2004), in their WDP impact study in the Basavapura watershed highlighted that the yield of borewells increased by 24 per cent, that of open or dug wells increased by 69 per cent; 44 per cent of the open/dugwells which dried up, got recharged due to WDP; irrigation cost per acre inch of groundwater decreased by 48 per cent due to the increased availability of groundwater after WDP; net return per acre inch of groundwater increased by 30 per cent; net returns per acre of irrigated area increased by 96 per cent; net returns per acre of GIA increased from ` 7,298 to ` 10,505 (by 44 per cent) for small farmers after WDP.

Why the externality cost is zero in JFPM village

The externality cost is zero for farmers in JFPM village since all the dug wells are functioning and there is no failed well (Figure 2). However, the externality per well

Fig. 2: Clockwise: Farmer using manual lift to lift groundwater from dugwell; copious yield of water in dugwell; dugwell put to various uses; dug well connected with manual lift in JFPM village where the JFPM has been responsible in rejuvenation of all dug wells in the village; Source: Vikram Patil (2009)

in the case of JFPM + WDP village is though the second lowest being Rs.506, due to the impact of both JFPM and the WDP, the externality should have been at least zero. The reason for this difference is that the JFPM village began the programme to plant trees on the hill slopes of the JFPM village from 2002 when the JFPM was implemented, while in the JFPM + WDP village, the JFPM component of intensive tree planting began in 2006, four years later.

Why dugwells are sustainable compared with borewells in the hard rock areas

The dugwells capture the water recharge from the upper layers of the soil and enables the farmers to plant their crops considering the water availability, since the groundwater in dug well is visible, unlike borewell. In addition, the water extraction from dug well is through manual lifts such as Pershian wheel or Picota or Yetha (which have now vanished) or using centrifugal pumpset which extract groundwater in a sustainable manner compared with the submersible pumpsets. The water quality in dug wells for irrigation is also relatively better compared with deep tube wells. The cost of dugwell construction is 32 per cent lower compared with that of borewell. The net returns from dugwell is 74 per cent higher compared with net return from borewell in JFPM village. The net irrigated area per dug well is around 1 acre, while that of borewell is 2 acres. The groundwater extracted per dug well is 43 acre inches while that from borewell is 54 acre inches. The proportion of well failure in dugwells and borewells in JFPM is zero, while that in WDP is 34 per cent for borewell (Table 1). All these show that dugwells are a sustainable technology if the efforts to recharge groundwater are as seriously attempted as in JFPM. Thus JFPM has supported groundwater sustainable technologies considering both demand and supply sides of water.

Particulars of groundwater resource

The net irrigated area per functioning well of farmers is higher in JFPM + WDP (4.47 acres) by 24.17 per cent, 43.33 per cent lower in JFPM with borewells (2.04 acres), 72.78 per cent lower in JFPM with dugwells (0.98 acres) and 8.06 per cent lower in WDP (3.31 acres) as compared to control village (3.6 acres). Gross irrigated area per farm is also higher in JFPM + WDP (10.74 acres) by 79 per cent, 22.17 per cent lower in JFPM with borewells (4.67 acres), 67.50 per cent lower in JFPM with dugwells (1.95 acres) and 24.33 per cent higher in WDP (7.46 acres) as compared to control village (6 acres)

Fig. 3: Clockwise Failed dugwell in Control village; Trees planted in JFPM village; Failed dugwell in Congrol village, another failed dug well in Control village; Source: Vikram Patil (2009)

(Table 2).

Environmental economic impact of JFPM

The environmental economic impact of JFPM programme is reflected through cost of irrigation, cost and net return to groundwater used. Irrigation cost per acre-inch of groundwater used is lower in JFPM + WDP (` 127) as well as in JFPM (` 204 in the case of borewells; ` 153 in dugwells) as compared to WDP village (` 221) and control village (` 239). This shows that there is positive impact of JFPM and JFPM +WDP development programmes.

Net return per farm is higher in JFPM + WDP and JFPM by 7 per cent and 632 per cent compared to that of WDP and control village respectively. Net return per rupee of irrigation cost is ` 3.26 and ` 9.65 in JFPM + WDP and JFPM village higher by 6.89 per cent and 827.88 per cent respectively as compared to WDP (` 3.05) and control village (` 1.04) respectively (Table 2). The huge difference in net return in JFPM is due to the crop pattern adopted supported by the availability of irrigation water in the dug wells.

Net returns per farm

Maize, groundnut and onion are the major crops in JFPM + WDP and WDP village which occupy at least 80 per cent of gross irrigated area for farmers. In JFPM village, maize, chilli seed production and jowar are the crops which occupy around 93 per cent of gross irrigated area. In control village maize and sunflower are the major crops grown which occupy 78 per cent of gross irrigated area. The gap in overall net returns between the farmers in JFPM + WDP and those in WDP is around ` 18,470. While the gap in overall net returns between the farmers in JFPM and control village is around ` 38,806. The overall net return per acre of net cropped area for farmers in JFPM + WDP (` 13,068) is lower than farmers in JFPM (` 20,044) (Table 2). The crop pattern in JFPM village (Fig 4) indicates the enterprising nature of farmers. The trees planted in JFPM+WDP village along with forest nursery can be glimpsed in Fig 5.

The contribution of wage employment and livestock is modest in all scenarios and agriculture contributed the most to the farmers' incomes. Farmers in JFPM + WDP and JFPM village are largely engaged in agriculture in their farm and hence have no spare time for wage employment (Table 3).

Incremental net returns due to WDP and JFPM programs

Due to low irrigation cost incurred by the farmers, the actual incremental net returns per acre are relatively higher for them in JFPM village (` 13342) compare to JFPM + WDP (` 6366) and WDP (` 6343) villages. The actual incremental net returns per acre in JFPM + WDP and WDP villages are almost on par due to the fact that the JFPM programme in JFPM + WDP village was started

Fig. 4: Farmer cultivating chilli seeds in JFPM village using dugwell irrigation; Source: Vikram Patil (2009)

Table 1: Details of irrigation borewells in JFPM + WDP, JFPM, WDP and control villages

Sl. No	Particulars	Borewell				Dugwell			
		JFPM + WDP	JFPM	WDP	Control	JFPM + WDP	JFPM	WDP	Control
1	Number of farmers	24 (60)	42 (180)	23 (53)	15	-	21	-	2
2	Number of functioning wells	29 (93)	24 (60)	27 (80)	15	-	21	-	0
3	Number of failed wells	2 (100)	0 (-100)	14 (1300)	1	-	0	-	2
4	Total number of wells	31 (94)	24 (50)	41 (156)	16	-	21	-	2
5	Proportion of well failure	6.45 (3.20)	0.00 (-100)	34.15 (446)	6.25	-	0	-	100
6	Initial yield of Groundwater	1603	1850	1763	2010	-	1430	-	1500
7	Current yield of groundwater (GPH)	1914 (16)	2125 (29)	1176 (-29)	1650	-	1938	-	0
8	Depth of dug well (ft)	-	-	-	-	-	26	-	42.5
9	Diameter of the dug well(ft)	-	-	-	-	-	20	-	25
10	Depth of bore wells(ft)	239 (-4)	230 (-8)	262 (5)	249	-	26	-	42.5
11	Range of year of construction (earliest well- latest well)	1988 -2007	1995 -2007	1990 -2007	1988 2006	-	1990 2007	-	1980 1988
12	Investment per well (`)	65518 (7)	47592 (-22)	54952 (-11)	61375	-	32333	-	10000
13	Investment per functioning well(`)	70036 (7)	47592 (-27)	160930 (146)	65467	-	32333	-	-
14	Amortized cost per well (`)	9597 (-0.95)	9682 (-0.07)	8532 (-12)	9689	-	5608	-	2720
15	Amortized cost per functioning well (`)	10103 (-2)	9682 (-6)	12331 (19)	10335	-	5608	-	-
16	Annual externality cost (`)	506 (-58)	0(-100)	6047 (405)	1198	-	0	-	NA

Note: GPH- Gallons per hour, percentage change= JFPM over Non-JFPM village; J+W = JFPM + WDP; J= JFPM; W=WDP and C = control. Figures in the parenthesis represent percentage change over control village.Source: Vikram Patil (2009)

only in 2006 (Table 3). The log linear model used to estimate the returns indicated that the estimated incremental net returns matched with the actual incremental net returns in all the three situations, validating the model.

Overall contribution of WDP and JFPM programs

Estimated contribution of WDP and JFPM Programs

The results of the production function analysis reveal that the estimated contributions of JFPM, JFPM+WDP and WDP to the net returns per acre are statistically significant at 5 per cent. In addition the coefficients of groundwater used and area under chilli seed production are also significant at 5 per cent. For a 1 per cent increase in groundwater irrigation, the net return from farm increases by 0.51 per cent. For 1 per cent increase in the area under chilli seed production, the net return per acre increases by 0.31 per cent. Due to JFPM the estimated net return is ` 13,413, that due to JFPM + WDP is ` 6822 and that due to WDP is ` 8595 per acre. The higher net return from JFPM is also due to the year of initiation of the programme as the JFPM was initiated in 2002, while the JFPM + WDP was initiated in 2006 (Table 4).

As the difference between the estimated contribution obtained from regression analysis and the actual contribution from soil and water conservation programmes (JFPM, JFPM+WDP, WDP) are comparable, the regression used is a realistic representation of the empirical experience (Table 4).

Once again, it is in order to mention that the unique feature in JFPM is presence of 21 functioning dugwells and 24 functioning borewells with zero failures for the entire population of 42 farmers. The reasons for impressive economic performance of JFPM over other soil and water conservation programmes are attributable to:

- Realization of net return of ` 9.65 per ` of irrigation cost, the highest compared to all

Table 2: Particulars of groundwater resources in JFPM + WDP, JFPM, WDP and control villages

Particulars	JFPM + WDP	JFPM		WDP	Control
		Bore well	Dug well		
Groundwater extracted per farm (Acre inches)	77.83 (58.90)	59.81 (22.11)	43.11 (-11.98)	48.56 (-0.86)	48.98
Groundwater extracted per well (Acre inches)	61.73 (26.03)	53.79 (9.82)	43.11 (-11.98)	39.57 (-19.21)	48.98
Number of farmers owning functioning wells	23	21	21	22	15
Number of functioning wells	29 (93.33)	24 (60.00)	21 (40.00)	27 (80.00)	15
Net irrigated area (acre)	129.5 (139.81)	49.00 (-9.26)	20.50 (-62.04)	89.5 (65.74)	54
Net irrigated area per functioning well (acre)	4.47 (24.17)	2.04 (-43.33)	0.98 (-72.78)	3.31 (-8.06)	3.6
Gross irrigated area (acre)	247 (174.44)	98.00 (8.89)	41.00 (-54.44)	179 (98.89)	90
Gross irrigated area per functioning well (acre)	8.52 (42.00)	4.08 (-32.00)	1.95 (-67.50)	6.63 (10.50)	6
Gross irrigated area per farm (acre)	10.74 (79.00)	4.67 (-22.17)	1.95 (-67.50)	7.46 (24.33)	6
Irrigation intensity (per cent)	190.73 (14.44)	200.00 (20.00)	200.00 (20.00)	200 (20.00)	167
Groundwater used per acre of gross irrigated area (acre inches)	7.25 (-11.15)	12.82 (57.11)	22.08 (170.59)	5.97 (-26.84)	8.16
Cost per acre inch of groundwater used (`)	127 (-47.06)	204 (-14.38)	154 (-35.39)	221 (-7.14)	239
Net returns per farm (`)	32148 (165.03)	102615 (746)	74913 (518)	30059 (148)	12130
Net returns per acre inch of groundwater used (`)	413 (67)	1716 (593)	1738 (602)	675 (172)	247
Net returns per acre of gross irrigated area (`)	2993 (48)	21989 (988)	38370 (1799)	4030 (99)	2021
Net returns per acre of net irrigated area (`)	5709 (69)	43978 (1205)	76740 (2178)	8060 (139)	3369
Net returns per rupee of groundwater cost (ratio)	3.26 (213)	8.42 (710)	11.30 (986)	3.05 (192)	1.04

Note: Net return per rupee of irrigation cost was derived to compare the net return per acre-inch of groundwater used with cost per acre-inch of groundwater (net return per acre-inch of groundwater used/ irrigation cost per acre-inch of groundwater). The figures in the parentheses indicate the percentage change over the Control village situation. Source: Vikram Patil (2009).

scenarios due to groundwater recharge dampening the cost of groundwater.

- The realization of the highest net return per acre compared to other 3 scenarios due to availability of groundwater and farmers' entrepreneurial ability in choosing crops supported by recharged groundwater in wells.
- JFPM farmers have used higher volume of groundwater per acre of gross cropped area compared to JFPM+WDP and WDP (15 acre inches).
- In JFPM, all the (dug and bore) wells are functioning and there is virtually no failure of irrigation wells due to recharge of groundwater from JFPM activities which resulted in zero externality cost and efficiency in groundwater recharge, extraction and use.
- The highest yield of dugwell (1938 GPH) and yield of borewell (2125 GPH) in JFPM village across all the types of soil and water conservation programmes.
- Due to impressive groundwater recharge in JFPM the cost of (dug) well construction is the lowest being ` 32,333 and groundwater is available at just two feet below the ground level due to impressive recharge.
- Finally the net returns per ` of ground water used is the highest in JFPM being ` 11.3 for dug well farms, ` 8.42 for borewell farms, followed by ` 3.26 for borewell farms in JFPM+WDP village; `

Table 3: Net returns per farm from different sources in JFPM + WDP, JFPM, WDP and control villages

Sources Net cropped area per farm	JFPM + WDP	JFPM	WDP	Control
Net cropped Area (NCA)	220.00	196.00	196.00	122.50
Net return per acre of NCA (`)	13068	20044	13045	6702
Percentage of Net returns from Agriculture	92.81	94.89	96.53	81.60
Percentage of Net returns from Livestock	6.56	3.97	3.47	7.43
Percentage of Net returns from wage income	0.63	1.13	0	10.96
Net return per farm (`)	125002	93539	106532	54733
Actual incremental net returns per acre over control (`)	6366	13342	6343	-
Estimated incremental net returns per acre over control (using Regression analysis) (`)	(Antilog of (7.928+0.9) = 8.828) = 6822	= (Antilog of (7.928 +1.576) = 9.504) = 13,413	= (Antilog of 7.928 + 1.131) = 9.059) = 8595	-

Note: Figures in the parentheses indicate percentage to the respective total; Incremental net returns per acre over control = net return per acre from all sources in respective programme village minus net returns per acre from all the sources in control village. Source: Vikram Patil (2009)

3.05 for borewell farms in WDP village and ` 1.04 for borewell farms in control village.

Conclusion and policy implications

This study analyzed the impact of JFPM, WDP and JFPM + WDP programme in hard rock areas of peninsular India on groundwater recharge. The JFPM being community driven integrated forest development project with strong institutional collaboration and co-ordination among various agencies aimed at alleviation of poverty, improved skills and employment opportunities of farmers. The net return per farm and net return per rupee of irrigation cost is significantly higher in JFPM compared to other situations due to increased availability of groundwater due to recharge from JFPM activities, demonstrating the positive impact of JFPM on groundwater recharge. JFPM farmers performed

Fig. 5: Clockwise – Trees planted in JFPM+WDP village; Another picture of trees planted in JFPM + WDP village; Woman worker irrigating tree seedlings in JFPM+WDP nursery in the study villages; *Source: Vikram Patil (2009)*

Table 4: Regression coefficients of Logarithm of Net return function

Regression results	Coefficients	Standard Error	t Stat
Intercept = Ln a	7.928	0.583	13.6*
D_1 = 1 for JFPM, O otherwise	1.576	0.307	5.134*
D_2= 1 for JFPM + Watershed, O other wise	0.9	0.186	4.841*
D_3=1 for Watershed, O otherwise	1.131	0.191	5.909*
LnX_1= Water used per acre (acre inches)	0.506	0.214	2.368*
X_2 = area under chilli seed production (acres)	0.611	0.277	2.21*
F			53.76*
R Square			0.737
Adjusted R Square			0.723
Observations (N=)			104

*Note: *Significant at 5 percent; Source: Vikram Patil (2009)*

economically and hydrologically better than other farmers.

This study apparently signifies the economic impact of joint forest planning and management in augmenting soil and water conservation efforts towards recharge of groundwater for irrigation in the hard rock areas of India, especially on reviving the traditional sustainable groundwater structures such as dug wells. The JFPM efforts have registered the highest net returns to farmers when compared with watershed programme alone and watershed programme along with JFPM. This indicates the clear supremacy of the performance of JFPM in heralding agricultural output in consonance with groundwater conservation (Chandrakanth, 2009, 2012). The heartening lesson is the existence of successful dug wells / openwells in the JFPM village which are par excellence in relation to the net returns and other economic yardsticks.

The study is a clear pointer towards the positive economic performance of JFPM when compared with other three scenarios (JFPM + WDP, WDP and control). The amortized cost of irrigation is the lowest and net returns per acre inch of groundwater are the highest on JFPM farms compared with other farms. The ongoing JFPM activities in different parts of Karnataka villages need to be further heralded with commitment, transparency and support by the government. The dug wells which used to be the most sustainable way of groundwater extraction in the yesteryears, are becoming a rarity due to advent of fast rigs, economic scarcity of labour and poor efforts towards groundwater recharge. The JFPM experience in this study has demonstrated that dugwell can be economically and hydrogeologically successful and can be considered for replication in other parts of hard rock areas with similar harsh agroclimatic conditions benefiting scores of marginal and small farmers at relatively low costs.

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कर्नाटक (भारत) के वन प्रबंधन संस्थानों के भूमि जल को पुनः चालू करने का आर्थिक समाधान

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सारांश

वर्तमान अध्ययन में सम-शुष्क उष्णकटिबंधी भारत में भूमि जल को पुनः चालू करने के लिए संयुक्त वन योजना एवं प्रबंधन (जे एफ पी एम) कार्यक्रम के आपेक्षिक जलविज्ञानीय एवं आर्थिक योगदान का महत्व बताया गया है। गहरे बोरवेल्स की शुरूआत, कम वर्षा तथा कम रिचार्ज के कारण भारत में कुओं में पानी कमी हो गई है। 2008 से जे एफ पी एम कार्यक्रम या उसके बिना कुओं की सहायता से सिंचाई करने वाले किसानों का डाटा एकत्र किया गया। लघुगणकीय शुद्धआय, वर्णनात्मक सांख्यिकी तथा एनोबा से पता चलता है कि भूमि से शुद्ध प्राप्ति, सिंचाई का पानी और उस पर होने वाले व्यय का कारण जे एफ पी एम द्वारा भूमि जल का रिजार्च किया जाना है। कुओं के असफल हो जाने पर जे पी एफ एम ने सभी बोरवेल्स के कार्य पर 100 प्रतिशत योगदान दिया और बिना नकारात्मक प्रभाव के कुओं की खुदाई की। जे एफ पी एम के वृद्धिकारक शुद्ध लाभ (रू. 13342 प्रति एकड़) है जो जलागम विकास कार्यक्रम की तुलना डब्ल्यू डी पी (रू. 6343 प्रति एकड़) तथा जे एफ पी एम+डब्ल्यू डी पी (रू. 6822 प्रति

एकड़) में कम से कम 100 प्रतिशत अधिक हैं। खोदे गये कुओं का भूमि जल उत्पाद गहरे बोरवेल्स की तुलना मे 10 प्रतिशत कम था। जिससे खोदे गये कुओं को रिचार्ज करने में जे एफ जी एम क्षमता का पता चलता है। चयनित गांव की तुलना में, भूमिजल रिजार्च होने के कारण जे एफ पी एम के भूमि जल की लागत 36% कम थी। भूमि जल की लागत प्रति रूपये के हिसाब से जे एफ पी एम द्वारा खोदे गये कुएं में सबसे अधिक (रू.11.3) थी जिसके बाद जे एफ पी एम बोरबेल (रू. 8.42) जे एफ पी एम + डब्ल्यू डी पी (रू.3.26) डब्ल्यू डीपी (रू.3.05) तथा सामान्य किसान (रू.1.04) का स्थान रहा। जे एफ पी एम ने सिंचाई के कुओं में भूमि जल को सफलतापूर्वक रिचार्ज किया। इस प्रयोग को दोहराकर किसानों को अपेक्षाकृत कम लागत पर पानी मुहैया कराया जा सकता है।

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