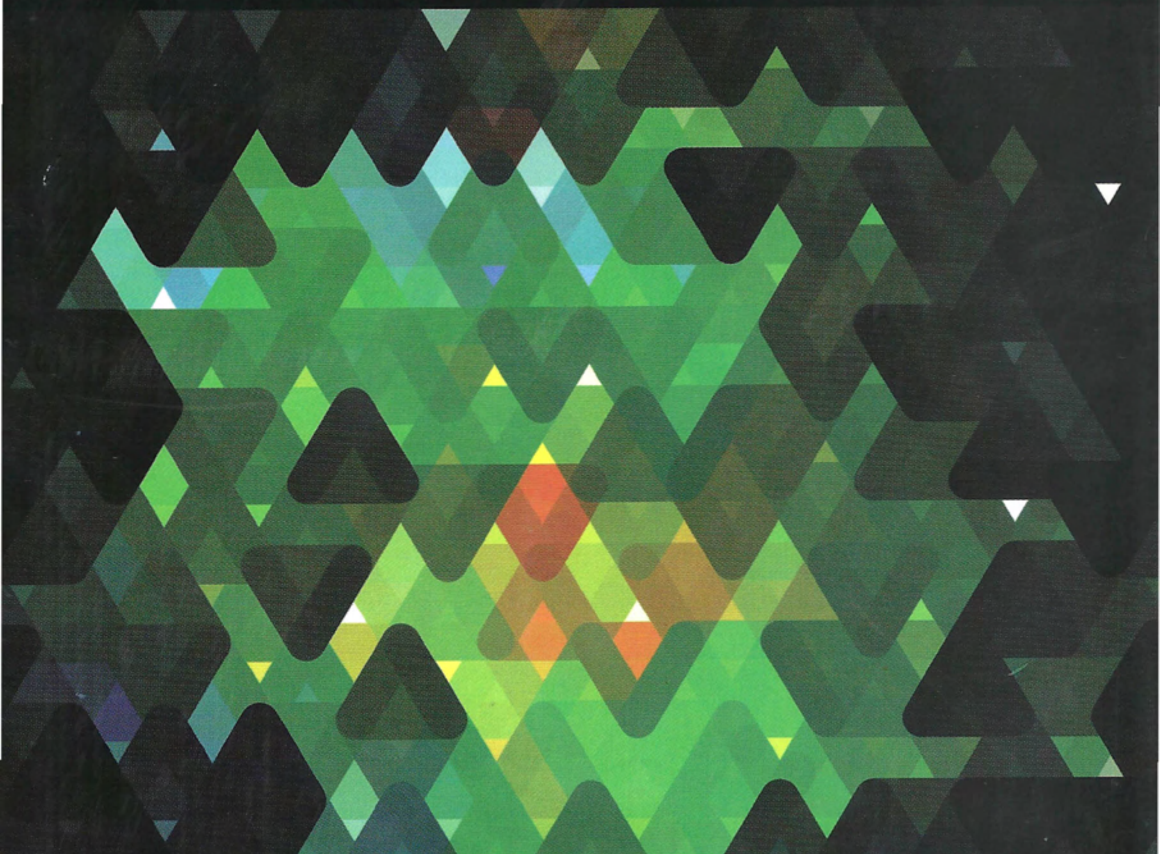
Vicissitudes of Agriculture in the Fast Growing Indian Economy: Challenges, Strategies and the Way Forward



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INDIAN SOCIETY OF AGRICULTURAL ECONOMICS

Published by
ACADEMIC FOUNDATION
in association with

Vicissitudes of Agriculture in the Fast Growing Indian Economy

Challenges, Strategies and the Way Forward

Editors

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ACADEMIC FOUNDATION
NEW DELHI

www.academicfoundation.org

First published in 2016
by

ACADEMIC FOUNDATION
4772-73 / 23 Bharat Ram Road, (23 Ansari Road),
Darya Ganj, New Delhi - 110 002 (India).
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E-mail : books@academicfoundation.com
www.academicfoundation.com

Cataloging in Publication Data--DK
Courtesy: D.K. Agencies (P) Ltd. <docinfo@dkagencies.com>

Vicissitudes of agriculture in the fast growing Indian economy
: *challenges, strategies* and the way forward / editors, C. Ramasamy and K.R. Ashok.
pages cm
Includes bibliographical references.
ISBN 9789332703360

1. Agriculture--Economic aspects--India. 2. Agriculture and state--India. *I. Ramasamy, C., 1947- editor. II. Ashok*, K. R., editor.

HD2072.V53 2016   DDC 338.10954   23

Typeset, printed and bound by The Book Mint, New Delhi.
www.thebookmint.in

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M.G. CHANDRAKANTH and K.M. BRUHAN

Externalities in Peri Urban Agriculture

Economic Analysis of Using Greywater for Irrigation in India

Introduction

The Chairman of the UN Secretary-General's Advisory Board on Water and Sanitation, observed that: ".....in many parts of the world, waste water is already used for agriculture. This practice should be encouraged, but it must be done safely, with the use of guidelines, such as the globally accepted World Health Organization guidelines for waste water reuse. Safe water reuse is a solution, since it promotes food security in the future."[1] For humans, dealing with waste water is not only challenging, but also is an opportunity, since the nutrients in waste water can be put to agriculture use and in the process also address the problems involved in treatment and disposal on the limited land.

Grey Water

In South Asia, only 31 per cent of the urban population is connected to piped sewer systems. Despite the vast population supported by agriculture, rate of urbanisation is phenomenal in India. According to 2001 census, the urban population formed 28.53 per cent and in 2011, increased to 31.16 per cent of the population. In 2011 census, the rate of growth of urban population was 2.3 per cent, while that of rural population was 1 per cent. The urban (rural) population grew at 2.5 per cent (1.4%) in 2001 census

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1. *http://www.ais.unwater.org/ais/pluginfile.php/62/course/section/29/proceedings-no-11_WEB.pdf*: 11

which fell to 2.3 per cent (1%) in 2011 census. Thus, the degree of fall in the rate of population growth in rural population is higher than that in urban population between the two census periods. In the process, peri-urban development is on commercial agriculture to meet the demands of vegetables, fruits and flowers with the utilisation of household sewage water, which, left to nature would have exacerbated pollution of water bodies and the environment. The household sewage water is commonly referred to as grey water, which is released from houses unconnected to sewage system, which can be treated and used for irrigation. It comprises of 50 to 80 per cent of household sewage water, which is suitable for reuse.[2] In this paper, grey water and household sewage water are used synonymously, since Magadi has only household used water in the sewage.[3]

Peri-Urban Agriculture

Given the limitation of budget allocation required for closed drainage systems in peri-urban areas in India, due to limited funds available with the *panchayats* by way of tax revenues, the household sewage water is left to nature adding to environmental pollution. UPA (peri-urban agriculture) is thus absorbing some of this grey water as farmers are using for irrigating their marginal lands to cultivate GLV (green leafy vegetables) and other vegetables for supplying to nearby urban areas, offering fresh produce with the least food miles. Urban and UPA, is thus "an activity that produces, processes, and markets food and other products, on land and water in urban and peri-urban areas, applying intensive production methods, and (re)using natural resources and urban sewages" (International Development Research Centre, 2000). It includes a wide range of activities such as horticulture, dairy farming, cattle farming, poultry, fisheries, and so on.

Long and Short Term Impacts of UPA

In India, UPA is resulting in two types of impacts: the long-term impact of: (i) gradual shrinkage of holding size due to subdivision and

2. Ibid.: 19.
3. This sewage is in no way comparable to the sewage in Bangalore Metropolis which has effluents from industries discharging effluents, let into Bellandur lake.

fragmentation of holdings, increasing demand for urban dwelling and petty business including land for industries, and (ii) the spurt in real prices of land. The short-term impact is rise in real agricultural wage. Such farmers are also unable to bear the pressures of urbanisation in retaining their land and are gradually forced to part with their land for unregulated prices in a phased manner, due to their inability to face land mafia. According to Ramalinge Gowda *et al.* (2012), in UPA and in rural agriculture, currently, wage income exceeds 50 per cent of the total income[4] and, their per capita incomes are at least 50 per cent lower than the per capita income of an average Indian.

Despite these pre-empting forces, there are farmers clinging on to agriculture to improve their economic situation in peri-urban environs, where groundwater resource is absolutely scarce. Such farmers make use of household sewage water for productive purposes by cultivating crops. The sewage water is also known to have positive impact on crop production (Scott *et al.*, 2000). This phenomenon is not uncommon in India and other developing countries, as there is growing groundwater scarcity in UPA for agriculture purpose (Scheierling, 2010). In UPA, the sewage water largely contains household sanitary, kitchen wastes and municipal sewage, and is relatively safe compared with the urban sewage which is fraught with industrial effluents. Hence, use of household sewage water for agriculture results in externality. Already the management and disposal of solid wastes and sewage water is posing great challenges for Bangalore metropolitan. Thus, efforts by farmers utilising household sewage water, complements the challenging efforts of municipalities in combating the environmental pollution. These result in reduction of: (i) environmental pollution due to productive use of household sewage water and (ii) food mile, due to enhanced food availability locally, both of which are positive externalities. In this study, a modest attempt is made to analyse the economics of cultivation of crops by farmers who are using household sewage water in Magadi, Karnataka to estimate and value the externalities involved in the process.

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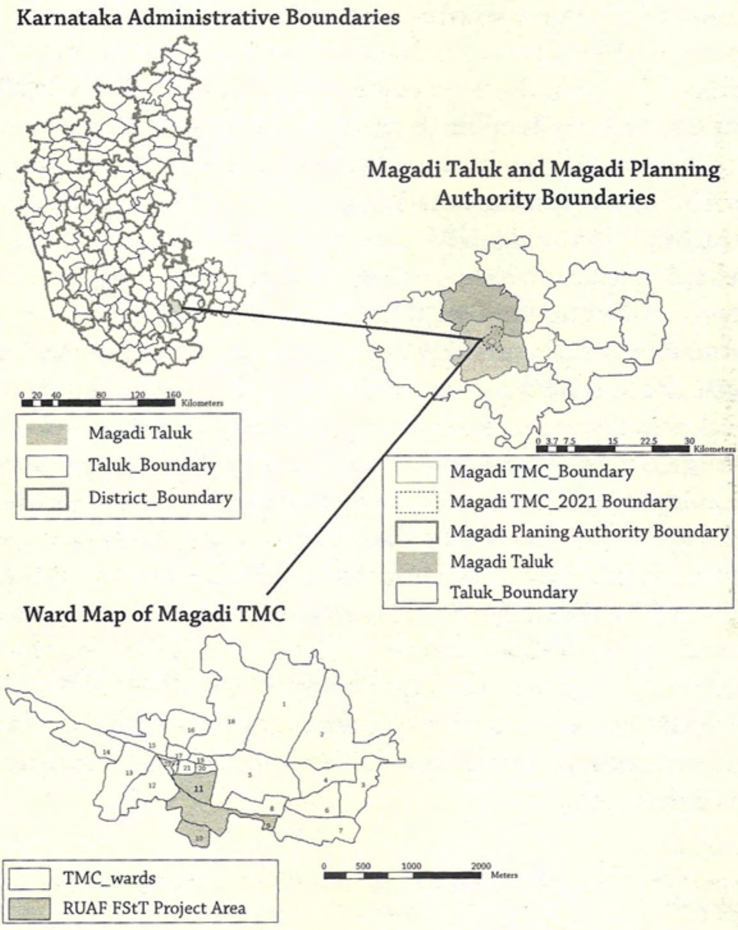
4. *http://www.toenre.com/downloads/2012_jun_epw_article_on_peri-urban_agriculture_uas_bangalore.pdf*

Study Area and Data

This study is based on primary data collected from farmers of Magadi which is the peri-urban Bangalore Metropolitan, in Karnataka (Figure 26.1). Magadi is located around 30 kms from Bangalore bordering Bangalore metropolis and has the rapidly growing peri-urban farming. Magadi has a salubrious climate, located at an altitude of 900 m with an annual rainfall around 800 mm. Magadi is well known for supply of fresh vegetables and flowers daily to Bangalore commencing from 3 AM.

Figure 26.1

Map of the Study Area (Magadi Town)



A reconnaissance survey of farmers in Magadi indicated that about 20 per cent of farmers use household sewage water for irrigating their crops. The household sewage water is from domestic household sewage, municipality sewage and runoff from agriculture. There are no industries around Magadi, and hence the sewage water has no industrial effluents.

Sampling

For this study, the sample comprises of a random sample of 30 farmers using HSWFF (household sewage water for irrigation) 30 farmers using GWF (groundwater for irrigation) and 30 rainfed farmers (RFs). HSWF are those who use household sewage water and/or in combination with groundwater for irrigation. GWF are those who used only groundwater (from open well, bore well and water purchased from others) for irrigation. RFs are those who mainly depended on rainfall as the source of moisture for crops. The detailed information on economics of farming was obtained for 2011, from the sample farmers by personal interviews using structured and pre-tested questionnaires. In addition, information regarding cropping pattern, existing farming system, sources of irrigation, particulars of cost of cultivation, inputs used, crop output, price of output, expenses, income from different enterprises and health costs were collected.

How Safe is the Household Sewage of Magadi?

The Chemical analysis of household sewage was performed by collecting sample of household sewage in Magadi in four places namely Kalya, Hombalammanagudi, Downtown Magadi and near Bargavati lake. The samples were subjected to chemical analysis and the results (Table 26.1 and Figures 26.2 and 26.3) indicate that all the hazardous chemicals including heavy metals are within the permissible limits in the household sewage water sample of Magadi. This is an apparent pointer to the chemical safety of the sewage water. The safety level of Magadi household sewage is largely due to the absence of industrial effluents in the drains and water ways in Magadi.

Table 26.1

Chemical Analysis of Household Sewage Water and Groundwater in Magadi

Sl. No.	Parameter	Unit	Average Value of Sewage Water Samples (n=4)	Permissible Limits for Irrigation
1	Nitrate, as NO_3^--N	mg/L	1.5	<5.0
2	Phosphate as P	mg/L	16.92	-
3	Boron	mg/L	BDL	<0.75
4	Iron	mg/L	0.035	5.0
5	Cadmium, as Cd	mg/L	< 0.02	0.01
6	Chromium, as Cr	mg/L	< 0.20	0.1
7	Copper, as Cu	mg/L	0.1425	0.2
8	Lead, as Pb	mg/L	<0.20	5.0
9	Nickel, as Ni	mg/L	<0.04	0.2
10	Zinc, as Zn	mg/L	0.048	2.0
11	Sodium as Na	mg/L	112.75	<3.0
12	Potassium as K	mg/L	236.75	-
13	Calcium as Ca	mg/L	133.05	-
14	Magnesium as Mg	mg/L	50.13	-
15	Sulphate as SO_4^{2-}	mg/L	56.85	-

Note: BDL-Below Damage Level.

Source: Fipps (2003).

Figure 26.2

Collection of Sewage Water Sample in Magadi

Figure 26.3

Pumped Sewage Water for Irrigation

Costing Household Sewage Water Irrigation

The cost of household sewage water irrigation is calculated as {[(number of hours per irrigation) X (number of irrigations per month) X (duration of crop in months) X (cost of diesel used per hour)] + (annual repair charges) + (annual depreciation cost of irrigation pump set)}. The average life of the irrigation pump set was assumed to be 10 years for computing depreciation. Fixed and variable costs are considered to calculate the total cost of production of crops. The fixed cost component includes rental value of land, depreciation on farm implement and machinery and interest on working capital. Net returns have been calculated by deducting total costs from the gross returns of the crop. The profitability is compared among HSWF, GWF and RF using ANOVA (analysis of variant).

Cost of Groundwater Irrigation

The volume of groundwater applied was computed by calculating the number of acre-inches of groundwater irrigated for each crop in all seasons. This is given by [(number of hours required per irrigation) X (frequency of irrigations per month) X (duration of each crop in months) X (average yield of irrigation well in gallons per hour)]/22611. The investments on irrigation well/s are brought to the present by compounding at 2 per cent discount rate. This gives the total current cost of the well. This current cost of the well is amortised using the rule

$$A = \frac{1 \times [(1+i)^{AL} \times i]}{[(1+i)^{AL} - 1]}$$

A= Amortised cost well; I= Initial investment on well; AL= Average life of well; i= Interest rate.

The cost per acre inch of groundwater used is calculated by dividing amortised cost of well/s by the annual groundwater pumped in acre inches for all crops cultivated by farmer. This gives unit cost of groundwater pumped for irrigation (cost per acre inch). Cost of irrigation water for each crop was then calculated by multiplying the unit cost of groundwater with total groundwater pumped in acre inches for each crop. The profitability of field crops, vegetables, flowers, livestock and dairy are analysed on per farm basis and are compared among HSWF, GWF and RF.

Regression Analysis

Land and water are crucial resources in production and their access is crucial in UPA. The net return per farm is regressed on explanatory variables with the following estimated model:

$$Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 D_1 + \beta_4 D_2 + \beta_5 D_1 X + \beta_6 D_2 X + \varepsilon_i \qquad ...(1)$$

Here, Y = annual net returns per farm obtained from crops cultivated

X = GCA (gross cropped area) per farm in *guntas* (1 acre = 40 *guntas*)

D_1 = (1, 0) dummy variable assigned representing groundwater using farm

D_2 = (0, 1) dummy variable assigned representing household sewage water using farm

The base or reference dummy value of (0, 0) represents the rainfed farm.

Marginal productivity of the GCA on rainfed farm

$= dY/dX = \beta_1 + 2\beta_2 X$

Marginal productivity of the GCA on groundwater using farm
$= dY/dX = \beta 1 + 2\,\beta_2 X + \beta_5$
Marginal productivity of the GCA on household sewage water using farm
$= dY/dX = \beta_1 + 2\,\beta_2 X + \beta_6$

The elasticity of production with respect to GCA is calculated as equal to

$(\beta_1 + 2\,\beta_2 X + \beta_5 D_1)$ X/Y for groundwater using farms
$(\beta_1 + 2\,\beta_2 X + \beta_6 D_2)$ X/Y for household sewage water using farms
$(\beta_1 + 2\,\beta_2 X)$ X/Y for rainfed farmers

Externalities in Using Household Sewage Water

The household sewage water which reaches river system or lake inflicts external effects. Due to the scarcity of groundwater, sewage water can be a reliable and alternative source of irrigation and thus, complementing food and livelihood security of farmers. This reduces food miles benefiting peri-urban and urban consumers and demonstrates the positive external effects of household sewage water use. Correspondingly, health of consumers who consume these products as they are known to be potentially contaminated, may pose negative external effect. The producers who irrigate using household sewage water face health impacts due to their exposure. It is crucial to analyse whether the positive external effects overweigh the negative effects or vice versa and their quantification. With this framework, the impact of household sewage water on farmers and their health, savings in costs of irrigation and nutrients and increase in returns is analysed using partial budgeting framework.

Cost of Healthcare

The annual costs incurred by farm family who use household sewage water for irrigation are analysed. The health cost reflects the negative external effect. However, the cost of health care of consumers who consume crops/vegetables cultivated using household sewage water could not be obtained since it was difficult to trace the final consumer/s. The cost of illness includes the direct costs such as, cost of treatment, cost of medicines, cost of diagnosis and medical tests, imputed cost of person days lost due to illness and transportation costs. Similar data are obtained from control farmers i.e. farmers using fresh groundwater resource for irrigation.

Farm Economy

Majority of farmers in UPA are above 40 years of age with 65 per cent of them being literate with education up to primary level. Most of the peri-urban farmers are marginal farmers; with the average size of holding of less than one acre. Hence, their holding size is measured in *guntas* (each *gunta* = 33'X33'). The families are predominantly nuclear. Family labour availability towards farming was inadequate as some of the family members worked outside the farm. This is manageable since holding size is marginal.

Sources of Income

For marginal farmers of HSW, the holding size is 0.4 acre followed by RFs (0.9 acre) and GWF (1.1 acres) indicative of the relative land scarcity. The economic importance of food crops (field crops) is reducing in UPA since the field crops provided only 5 per cent of the income. For HSWF, the major portion of income is realised from non-farm income (40%) followed by horticulture crops (36%), livestock (15%), agriculture labour (10%). For GWF, major portion of income is derived from non-farm income (50%) followed by horticulture crops (34%), livestock (14%). For RFs, major income is from non-farm (63%) followed by agriculture labour wages (23%), field crops (6%). Thus, peri-urban farmers are leaning towards non-farm income, as farming provided around 50% of the income especially for HSWF and GWF and RFs derived only 5.6 per cent of their income from crop farming, and the rest from non-farm sources. The challenging task for policy makers is to strengthen the agricultural base of farmers in order to achieve sustainable food production especially in UPA.

Table 26.2

Socio-economic Status of Farmers in the Study Area

Sl. No.	*Particulars*	*HSWF (n=30)*	*GWF (n=30)*	*RF (n=30)*
1	Age Group (yrs)			
	20-30	2 (6.7)	2 (6.7)	0 (0.0)
	30-40	5 (16.7)	3 (10.0)	0 (0.0)
	40-50	10 (33.3)	9 (30.0)	6 (20.0)
	50-60	10 (33.3)	9 (30.0)	18 (60.0)
	>60	3 (10.0)	7 (23.3)	6 (20.0)
2	Family size (No.)	5.3	5.5	4.7
3	Family members involved in non-farm and agriculture labour activity	1.2	0.8	1.6
4	Literacy			
	Illiterate	7 (23.3)	10 (33.3)	12 (40.0)
	Primary	19 (63.3)	12 (40.0)	16 (53.3)
	Secondary	4 (13.4)	6 (20.0)	2 (6.7)
	Graduation	0 (0.0)	2 (6.7)	0 (0.00)
5	Land holding (Acre)			
	Owned	0.4	0.9	0.9
	Leased in	0.0	0.2	0.0
	Total	0.4	1.1	0.9
6	Farm Income from different sources (₹/yr)***			
	Field crops	0 (0.0)	1297 (1.2)	2828 (5.6)
	Horticulture crops	23467 (36.5)	37890 (34.3)	0 (0.0)
	Vegetables	13745 (21.4)	12254 (11.1)	0 (0.0)
	Flowers	967 (1.5)	11955 (10.8)	0 (0.0)
	Plantation crops	8755 (13.6)	13681 (12.4)	0 (0.0)
	Livestock*	9415 (14.6)	15953 (14.4)	4230 (8.4)
	Agricultural labour	5850 (9.1)	0 (0.0)	11433 (22.8)
	Non-farm income**	25550 (39.7)	55467 (50.1)	31700 (63.2)
	Total	64282 (100.0)	110607(100.0)	50191 (100.0)
7	Per capita income (PCI)considering income from all sources for family	12129	20110	10679
8	PCI considering only farm resources	6205	10025	1502
9	PCI considering labour and non-farm income	5924	10085	9177

Note: Figure in parentheses indicates percentage to the total; HSWF= Household sewage water farmers; GWF= Groundwater farmers; RF= Rainfed farmer; *Livestock includes Cow, she buffalo, bullock, Goat and Sheep

** Non-farm activities are silk reeling units, working in garments, teacher, construction works, working in petrol bunk, working in APMC etc.; *** Net income is considered for crops and livestock

Per Capita Income

The per capita income from all the sources is higher for GWF (₹20,110) followed by HSWF (₹12,129) and RFs (₹10,679). Non-farm income is inversely proportional to access to water resources. Hence farmers who have access to household sewage water, had the lowest proportion of non-farm income (40% of the total), followed by GWF (50%) and RFs (63%). Thus, access to water resource was the chief trigger to retain farmers in farming in UPA and any lapse in this regard, motivated them to rely more on non-farm incomes than farm sources, due to increasing economic scarcity of labour, land and water. Gradually this resulted in seasonal/permanent outmigration to urban areas.

Cropping Intensity

In the case of HSWF, cropping intensity was the highest (273%) followed by GWF (207%) and RFs (100%). The cropping intensity of HSWF is nearly thrice that of RFs. The HSWF cultivate GLV which constitute around 70 per cent of their GCA.

Table 26.3

Cropping Intensity and Diversity of Crops in the Study Area

Sl. No.	*Group of farmers*	*Cropping intensity*	*Diversity Index (DI)*
1	Household sewage water farmers	273	0.84
2	Groundwater farmers	207	0.50
3	Rainfed farmers	100	0.90

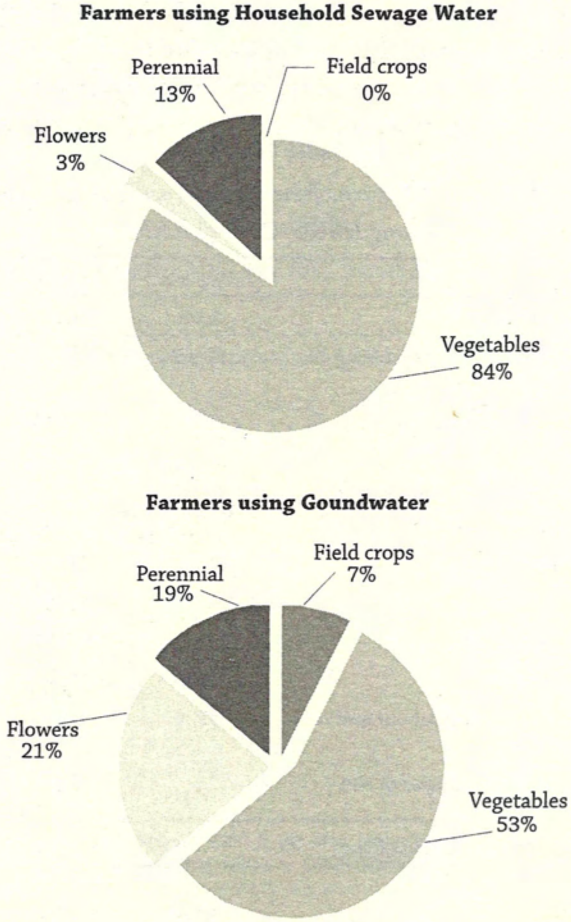
Note: Lower the index (DI), higher is the diversity.

GLVs are very short duration crops and are cultivated frequently, 4 to 5 times a year. The cropping intensity for RFs was modest as they do not have economic access to water resources and grow mainly field crops once in a year in *kharif*. The cropping diversity reveals that there was higher diversification in GWF (0.50) followed by HSWF (0.84) and RFs (0.90). The GWF have diverse cropping pattern which includes vegetables (carrot, knolkhol, radish, beans, cabbage, GLVs), followed by flower crops (chrysanthemum, china aster), perennial/

plantation crops (areca nut, coconut, beetle vine) and field crops (ragi, field bean, red gram, paddy) as shown in Figure 26.4.

Figure 26.4

Cropping Pattern in UPA Magadi



Majority of HSWF farmers cultivate sole crop of GLVs. Rainfed farmers cultivated largely ragi. Thus, even though crop pattern seems to reflect high diversity of crops for HSWF, as many crops are cultivated by a few farmers, the diversity of HSWF is low and is comparable to RFs. Since household sewage water is rich in nitrogen, essential for vegetative growth, GLVs are grown by farmers. In addition, GLVs need to be quickly marketed as they are very highly perishable. Urban areas in proximity are the fastest to reach and dispose. Thus, other vegetables such as carrots, radish were not as extensively grown as GLVs in Magadi. In addition, GLVs may have higher capacity to absorb the bacterial load compared with other vegetables. It is reported that such household sewage water contains high bacterial load that will lead to quick rotting (Sekar, 2001).

Table 26.4

Comparison of Costs and Returns from Agriculture and Horticulture Crops Among HSWF, GWF and RFs

Particulars	*HSWF n=30*	*GWF n=30*	*RFs n=30*
GCA per farm (acres)	1.03	1.73	0.85
Cost of production per farm considering all crops (₹)	12157	36689	6230
Cost of production per acre considering all crops (₹)	11764	21248	7329
Gross returns per farm from all crops (₹)	35705	78027	9057
Gross returns per acre from all crops (₹)	34553	45189	10656
Net returns per farm (₹)	23548	41338	2827
Net returns per acre (₹)	22709	21107	3327
Per capita income from all sources	12129	20110	10679
Per capita farm income	6205	10025	1502
Per capita income from wage labour and non-farm income	5924	10085	9177
Net returns for HSWF per Rupee of Net return on GWF		1.65	
Net returns for HSWF per Rupee of Net return on RF		18.67	
Benefit Cost ratio	2.94	2.13	1.45

Note: HSWF= Household sewage water using famers; GWF = Groundwater using farmers; RF = Rainfed farmers.

Costs and Returns on HSWF, GWF and RFs

The performance of the three categories of farmers with respect to crops cultivated on the farm were analysed (Table 26.4). The highest cumulative GCA was under GWF 51.8 acres when compared with HSWF (31.0 acres) and RFs (25.5 acres). The net returns per acre for HSWF (₹22,709) were higher than that of GWF (₹21,107) and RFs (₹3,327). This is due to reduction in the cost of inputs especially water and fertilisers that will reflect in higher profits for HSWF. The return per rupee of investment was higher in the case of HSWF (2.94) than that of GWF (2.13) and RFs (1.45).

The results of the ANOVA (Table 26.5) indicated that the three groups of sample farmers differed significantly with regard to net returns from crops per acre and per capita income from all the sources.

Table 26.5

Results of ANOVA Comparing Net Returns and Per Capita Income (₹)

Particulars	*Mean*	*F*
Net returns per acre (only from agriculture and horticulture)		
a. HSWF	22709	31.81***
b. GWF	21107	
c. RF	3327	
Per capita income (from agriculture, horticulture, livestock agriculture labour, non-farm activities)		
a. HSWF	12668	8.78**
b. GWF	19457	
c. RF	11110	
Percapita Non-farm income		
a. HSWF	4744	NS
b. GWF	8688	
c. RF	7006	

Note: ***, **, indicate significance at 1and 5 per cent respectively; NS: Non Significant; HSWF= Household sewage water using farmers; GWF=Groundwater using farmers; RFs=Rainfed farmers.

However, there was no significant difference in per capita non-farm income among the three groups. Thus, irrespective of the type of farm, all farmers are receiving at least 50 per cent of their income from non-farm sources such as silk reeling, garments, teaching, civil works, working in petrol bunk, APMC and so on.

Economic Contribution of Household Sewage Water in Agriculture

The results of the quadratic production function (1) revealed that the marginal productivity of GCA was ₹332 for 69th *gunta* to GW farmers, ₹284 for the 41st *gunta* to household sewage water farmers and ₹43 for 37th *gunta* to rainfed farmers. The intercept dummy variable coefficients β_3 and β_4 representing shift in the net returns due to access to groundwater and household sewage water were significant. The net returns per farm due to access to groundwater shifts up by ₹14,901, while that for household sewage water shifts by ₹10,159. The interaction effect of water usage and the GCA is to increase the net return by ₹206 per *gunta* on groundwater farms, by ₹231 per *gunta* on household sewage water using farms. For every 1 percent increase in GCA, the net returns increase by 0.59, 0.56 and 0.50 per cent for GWF, RFs and HSWF respectively. Thus, even though the elasticity of production is around 0.5 to 0.6 with respect to GCA, the marginal productivity of GCA on each type of farm, the shift in net returns on different type of farms, as well as the interaction effect differed significantly (Table 26.6). Figure 26.5 shows the influence of GCA on the net returns with lowest returns from rainfed area.

Figure 26.5

Net Returns Per Farm as Function of GCA for HSWF, GWF and RFs in Magadi

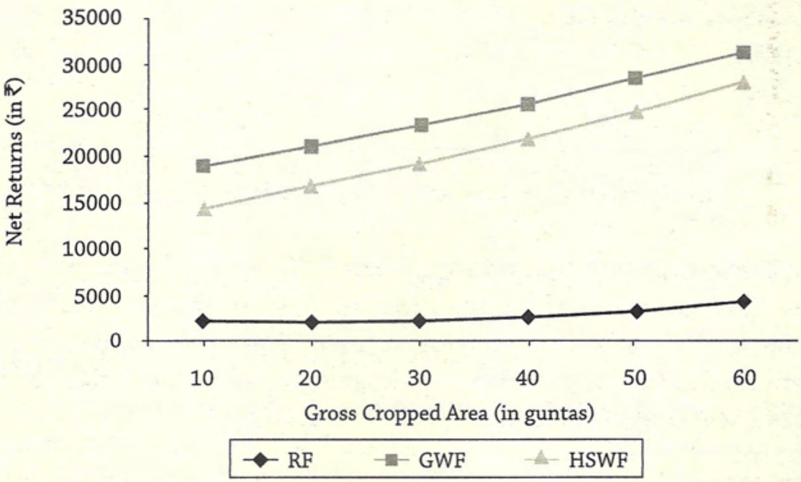


Table 26.6

Results of Regression of Net Returns per Farm in Peri-urban Agriculture (Quadratic Function-1)

Variables	*Coefficients*	*Marginal effects (in ₹)*		
Intercept	2658.66 (3642)	Intercept		2658.66
GCA (*guntas*)	-52.28 (96.8)	Marginal productivity with respect to GCA	GWF HSWF RF	332 284 43
Square of GCA	1.29*** (0.40)			
Dummy for GWF	14900.9*** (4501.7)	Dummy for GWF		14901***
Dummy for HSWF	10158.79** (4397.7)	Dummy for HSWF		10159**
Slope dummy for GWF	205.65** (102.8)	Slope dummy for GWF		206**
Slope dummy for HSWF	230.99** (102.6)	Slope dummy for HSWF		231**
Adjusted R^2	0.89			
N	90			

Note: ***, ** indicate Significance at 1 and 5 per cent respectively, Figures in parenthesis are SE; GWF = Groundwater using farmers; HSWF=Household sewage water using farmers; 1 *gunta*=33 feet X 33 feet (40 *guntas* make an acre, 100 make a hectare); Arithmetic mean area with groundwater irrigation=69 *guntas*; Arithmetic mean area with household sewage water irrigation=41 *guntas*; Arithmetic mean area under rainfed farming=37 *guntas*.

What is crucial is to note that the economic performance of HSWF is even better than GF, since groundwater is expensive, while household sewage water is free, except for pumping cost wherever needed. Given the high cost of groundwater irrigation as the farms frequently face initial and premature well failures in hard rock areas and in addition due to marginal sized holdings, the utilisation of household sewage water for irrigation is economically viable. From Ramalinge Gowda *et al.* (2012), urbanisation has two apparent impacts on agriculture in the short and long run. The long run impact is on increased land values which have already resulted in reduced holding size. The short term impact is on rise in agricultural labour wages. Given the shrinking size of land holding especially in peri-urban agriculture, the only viable alternative available for the farmer to expand agriculture is through intensive farming possible by increasing the cropping intensity *via* irrigation intensity.

Therefore the MP (marginal productivity) of access to water is compared with marginal productivity of land. Since MP of land is already higher than that of water, the differential between the MP of land and MP of access to water is taken as the normative increase in the cropping intensity through intense water use on short duration crops such as GLV. For instance, if the MP of land is higher than the MP of access to water by 50 percent, the cropping intensity needs to be increased by 50 per cent over the existing level, merely by cultivating short duration commercial crops on the existing land, so that farmer does intensive cultivation and benefits from it.

Common Ailments of Sample Farmers which Impinge on Health

The common ailments by members of the farm family are common fever, cough, cold, headache, muscle pain, BP, and diabetes. The common disease specific to HSWF and GWF is dengue fever. Specific diseases found only in the case of HSWF are dysentery and rashes on legs and hands. There were no significant differences between the annual per capita health expenditure among the three groups, except between HSWF and RF. In addition, the annual per capita health expenses are also modest ranging from ₹99 for rainfed farmers to ₹102 for household sewage water using farmers. It is crucial to note that relatively the HSWF are spending more on health expenses than the other two types of farmers (Table 26.7).

Table 26.7

Annual Per Capita Health Costs Incurred by Farmers (ANOVA)

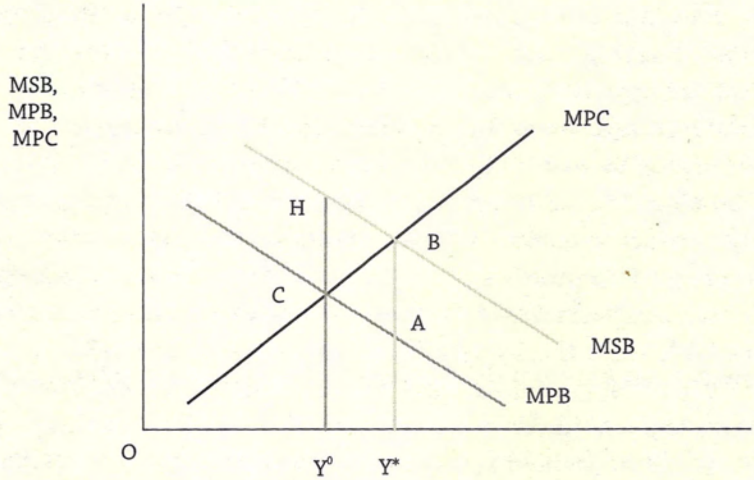
Sl. No.	*Particulars*	*F*
1	Between household sewage water using farmers (₹202) and groundwater using farmers (₹133)	1.894^{NS}
2	Between groundwater using farmers (₹133) and rainfed farmers (₹99)	0.879^{NS}
3	Between household sewage water using farmers (₹202) and rainfed farmers (₹99)	4.633**

Estimation of Externality in Using Household Sewage Water

A farmer who has taken up efforts to use household sewage water to cultivate crop (output plotted on X axis), receives the MPB (marginal private benefit) (Figure 26.6). His optimal use of household sewage water produces output OY^0, the intersection of MPC (marginal private cost) with MPB. Since the farmer uses household sewage water for growing crops, he has in fact contributed to the Society, by way of enhancing environmental quality reflected in MSB (marginal social benefit) the shifted curve to the right of MPB, through reducing environmental pollution. Thus, it is now optimal for the farmer to produce the output at the level of OY^*, where his MPC intersects with the MSB. However, the farmer does not produce output OY^*, since the Society does not recognise the MSB, which is due to use of Household sewage water, reducing the environmental pollution and still under-produces to the level of OY^0 resulting in the deficit use of household sewage water to the tune of OY^* - OY^0, the magnitude of inefficiency due to reduced level of use of household sewage water producing the output. Here, the total social benefit foregone (in the principle of opportunity cost) = Y^0 Y^*BH is the total social cost, as the farmer does not use household sewage water to produce the output to the level of OY^*. Accordingly the society loses benefit equal to the area under MSB curve for that missed level of use of household sewage water (= OY^*–OY0). Thus, in the process, the total cost not incurred=total benefit= Y^0 Y^*BC in the sense of opportunity cost principle. Therefore, the foregone social benefit is the total social cost and the non-incurred total private cost is the total private benefit. The difference between the total benefit (=total cost not incurred) and the total cost (=foregone social benefit) is given by Y^0 Y^*BH–Y^0 Y^*BC = CBH = welfare loss. In order to motivate farmer to pursue using household sewage water for irrigation to produce crops, to the tune of OY^*, subsidy equivalent to MSB-MPB=HC needs to be incentivised. The purpose of this explanation is to prove that positive externality also leads to inefficiency and welfare loss, akin to negative externality.

Figure 26.6

Positive Externality Leading to Underproduction in Farming Using Household Sewage Water for Irrigation



Empirical Estimation of Positive Externality Using Partial Budgeting

In this study partial budgeting framework (Table 26.8) has been used to estimate the positive externality = MSB, due to use of HSW to cultivate crops in peri-urban Magadi. The Debit side includes health costs and decrease in returns due to use of household sewage water; and Credit side includes savings and increase in net returns due to use of household sewage water for irrigation. This exercise could not be done for individual farms, since all the farms would not have all the components of credit and debit side.

Hence, this exercise is attempted at the aggregate level considering all the sample farmers of the study area. The credit minus debit figure is spread across the gross area differential under both the types of irrigation in order to obtain the externality on per acre basis. On the debit side, the annual health cost of both HSWF and GWF were considered as externality cost. Thus, the difference in annual health cost of HSWF and GWF was ₹6,200 for all the farms. The result of partial budgeting analysis indicated that this is a positive externality of ₹12,352 per acre for all the farms.

Table 26.8

Estimation of Externality Due to Recycling of Household Sewage Water for Irrigation in Peri-urban Agriculture

Debit (A) (for all farms)	*Credit (B) (for all farms)*
Increase in cost due to use of household sewage water for irrigation Externality cost: Annual health cost of all farmers using household sewage water for irrigation (₹27,680) minus the annual health cost of all farmers using groundwater for irrigation (₹21,480) = ₹6,200	*Decrease in cost due to use of household sewage water for agriculture:* Total cost of HSWF minus Total cost of GWF =₹364,701 – ₹11,00,683 =₹-735,982
Decrease in returns due to use of household sewage water for agriculture = Total net returns of HSWF minus total net returns of GWF = ₹703,995 - ₹11,75,609 = ₹–471,614	*Increase in net returns due to use of household sewage water for agriculture* 0
A = ₹6200 + ₹471,614 = ₹ 477,814	B = ₹735,982 + 0 = ₹735,982

Net returns from recycling household sewage water in agriculture for all farms

= B-A = ₹735,982 - ₹477,814 = ₹258,168

Increase in net returns from recycling household sewage water for agriculture over groundwater irrigation per acre = ₹258,168/(gross area irrigated of 51.85 acres under household sewage water irrigation minus gross area irrigated of 30.95 acre with groundwater irrigation being 20.90 acres) = ₹12,352 per acre.

Note: HSWF= Household sewage water farms; GWF=Groundwater farms.

The net returns from (horticulture) crops on household sewage water using farms was ₹22,709 per acre and in addition are generating ₹12,352 per acre as positive externality. This positive externality of ₹12,352 per acre forms 54 percent of the net returns or ₹0.54 of positive externality per every rupee of net return earned by the household sewage water using farmer. This level of positive externality is not observed as also not valued by farmers and the society. Hence there is under production of crops using household sewage water in Magadi. Due to positive externality, MPB shifts up to indicate MSB. This leads to under production of GLV (taken as representative crop since 70% of GCA is under GLV) as market fails to capture MSB and thus, a subsidy of ₹12,352/acre needs to be offered to encourage farmers towards utilisation of household sewage water for cultivation of crops in Magadi and thereby reduce the negative external effects.

Thus, the subsidy of ₹12,356 is actually the value of under production due to suboptimal use of household sewage water for irrigating crops. Since GLV is the main crop of HSWF, in terms of quantity, given the price of GLV being ₹12 per kg, the value of under production of ₹12,352 translates to 1030 Kgs of GLV (=₹12,352/₹12). From 1.02 acres, which is the average gross area planted to GLV, using household sewage water, 2400 kgs of GLV can be obtained (according to field data from Magadi). Thus, 1030 kgs of under production of GLV forms 43 per cent (=1030/2400)*100 of the output per acre. Since the average GCA of GLV cultivation by farmers using HSW in Magadi is 1.02 acres, every HWW farmer cultivating GLV, is under producing to the tune of 43 per cent of capacity due to presence of positive externality, due to market failure. This can be rectified by subsidising household sewage water to the tune of ₹12,352 per acre. Already at present, only 20 per cent of the household sewage water is currently being used in peri-urban Magadi for irrigation by the farmers, which is a prima facie indicator of the positive externality leading to under production.

Conclusion

There is a general apathy towards use of untreated household sewage water to cultivate crops. Such apathy is understandable if the urban sewage is used, akin to the use of Bellandur tank sewage water for agriculture, which includes heavy metal affluent. However, the existing level of use of household sewage water is below 20 per cent considering both area and volume basis. This needs to be substantially improved through awareness since the household sewage water has no heavy metals and is close to organic. Household sewage water farmers should be incentivised to the tune of ₹12,352 per acre or ₹309 per *gunta* so as to motivate them to use household sewage water for irrigation. Non-farm income opportunities such as silk reeling and other vocations need to be enhanced for HSWF to augment their income.

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Appendix A-26.1

Farmer Cultivating Areca and Betelvine Using Sewage Water

Appendix A-26.2

Crops Grown Using Groundwater in Magadi Peri-urban Area