Nutrient-Based Fertiliser Subsidy: Will Farmers Adopt Agricultural Best Management Practices?

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The new nutrient-based fertiliser subsidy policy provides implicit incentives to farmers to test soil samples regularly and get crop-wise recommended doses of nutrients, and offers prospective benefits from the agro-environmental management point of view. A study of six villages in the lower Bhavani Basin in Tamil Nadu reveals that despite a strong willingness on the part of farmers to adopt agricultural best management practices, inadequate infrastructure and the high transaction costs involved in accessing such services make them reluctant to test soil samples regularly. This paper looks at the institutional, infrastructural and agronomic factors influencing farmers' willingness, and concludes that the new policy needs to be supplemented with basic agricultural extension services through public-private partnerships.

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The new nutrient-based fertiliser subsidy policy in India has decontrolled phosphatic and potassic fertilisers and fixed the amount of subsidy based on the nutrient (nitrogen, phosphorous, potash and sulphur) content of fertilisers instead of the earlier system of product-based subsidy. The policy allows the farmers to choose the right combination of fertilisers for their crop to achieve the right balance of nutrients in the soil profile.

In order to derive benefits from the new system, farmers need to know the nutrient deficiencies in their soil and the recommended nutrient-mix for prospective crops of their choice. The nutrient-based subsidy is expected to provide implicit incentives to farmers to test their soil samples regularly and get crop-wise recommended doses of nutrients (including secondary and micronutrients). The policy also offers prospective benefits from the point of view of agro-environmental management. However, in the absence of facilities for soil testing and adequate infrastructure to provide basic agricultural extension services (e g, soil testing, crop-wise recommended doses of fertilisers, information, consultation, etc), the new subsidy regime cannot garner much in terms of agro-environmental management in India. The objective of this paper is to highlight some of the critical issues pertaining to the new policy from the agro-environment management point of view, through an illustrative case study in the lower Bhavani River Basin in Tamil Nadu.

Effects of Unbalanced Application

The private costs of unbalanced application[1] of nutrients are small as compared to the perceived private benefits resulting from potential increases in crop yield. Unless the issue price[2] of nutrients becomes substantially high, such that the perceived private benefits from marginal increases in yield (if any) approaches the marginal private costs of the fertiliser doses, farmers will not apply nutrients judiciously. Moreover, unbalanced application of nutrients has both environmental costs in terms of polluted groundwater and eutrophication[3] of water bodies, and private costs (soil degradation), which farmers believe do not directly confront them. As a result, huge negative externalities result in the form of polluted groundwater (or surface water) and degraded farmlands, which are passed on to the next generations.

Application of nutrients based on soil tests not only reduces the demand for subsidised nutrients, but also prevents excessive leaching of nutrient into the groundwater. Concentration of nitrate and pesticides in surface and groundwater can be considered as indicators of non-point source pollution (Goldberg 1989). Nitrate is highly water-soluble and leaches through the soil strata without getting assimilated into the soil (ibid). There is limited information on the level of pesticide contamination of water sources in India. However, there is substantial secondary information on the level of nitrate in groundwater and surface water. Non-point source water pollution control is particularly crucial in rural areas where groundwater is an important source of drinking water, serving more than 71% of rural households (Census of India 2001).

Consumption of nitrate-contaminated water poses several short- and long-term health hazards to people of various age groups (Fewtrell 2004; World Health Organisation 2004). Nitrate (NO_3) concentration in water used for drinking should be less than 50 milligram per litre (mg/l) (WHO 2004). According to the 1991 report of the Bureau of Indian Standards (BIS), the maximum acceptable limit of NO_3 in drinking water is 45 mg/l (which is equivalent to 10 mg/l of nitrate-nitrogen). However, the maximum permissible limit for the same is set at 100 mg/l, provided there are no alternative source(s) of drinking water (BIS 1991).

In India, several case studies have shown that in various pockets groundwater is contaminated by nitrate (Majumdar 2003). In rural areas, nitrate pollution in groundwater reduces the potability of water which results in various diseases (see Gupta et al 1999, 2000a, 2000b; Bassin et al 2001; Majumdar and Gupta 2000). Indiscriminate application of nitrogenous fertiliser results in groundwater pollution in intensively cultivated areas like Punjab (Singh et al 1987).

Groundwater Nitrate Pollution in India

Paucity of data is a major challenge in understanding the degree and extent to which groundwater is polluted in India. Information available from various government agencies indicates that a large number of habitations are affected by groundwater nitrate pollution (Table 1). The data also shows that semi-arid and arid states like Rajasthan, Gujarat, Tamil Nadu and Karnataka have a large number of habitations affected by groundwater nitrate pollution.

State governments need to monitor regularly and report groundwater quality information in terms of number of habitations affected by various pollutants (e g, fluoride, salinity, iron, arsenic, nitrate, multiple pollutants and total number of water quality affected habitations) to the department of drinking water supply in the ministry of rural development. However, in most cases, the information was not disseminated in time or properly due to various reasons: sample survey and testing of water samples is often not completed in time; in absence of information on actual number of water quality affected habitations, data is often estimated; difficulty in identification of water quality affected habitations leads to over- or under-reporting; number of habitations affected by various water quality pollutants are not reported properly; submission of backdated information on water quality affected habitations. As a result, the number of nitrate-affected habitations varies significantly within a short period of time (as in Table 1). The information presented here is only indicative of the problem of nitrate pollution in drinking water across selected states and should be assessed keeping in mind the above limitations of data.

Table 1: Nitrate-Affected Habitations as a Percentage of Total Water-Affected Habitations across Selected States

States/UTs	As on 1 April 1999	ARWSP: NHS (2003)	As on 4 March 2003	As on 31 March 2004	As on 1 April 2006	As on 1 April 2009	As on 27 July 2010
Bihar				6.4	8.1		
Gujarat	53.2	15.0	12.8	15.3	17.0	23.5	34.9
Karnataka		5.8	19.5	19.4	20.2	0.7	7.5
Kerala		0.9		9.0	9.0	4.3	5.2
Madhya Pradesh		0.4			0.9	0.1	0.2
Maharashtra		3.5		7.8	40.6	30.3	29.7
Orissa		0.1				0.2	0.2
Punjab		0.0	0.0				
Rajasthan		17.4	8.5	19.2	24.1	2.5	2.5
Tamil Nadu	29.7	5.8	42.2	4.3	7.3		0.5
Uttar Pradesh		1.2		0.0	0.2	0.3	0.1
All India	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Sources: http://www.indiastat.com, National Habitations Survey (NHS 2003), Ministry of Rural Development (2010a; 2010b).

In 2000, the Comptroller and Auditor General of India reported that about 10% of the water sources in the state of Tamil Nadu are not potable due to excessive nitrate. Foster and Garduño (2004) reported an elevated concentration of nitrate in drinking water wells during dry season at numerous locations in Tamil Nadu. The nitrate-affected belt mainly covers the western districts such as Coimbatore and Dharmapuri, where more than 20% of drinking water wells had nitrate concentration greater than 50 mg/l and in a large number of wells nitrate concentration exceeded 100 mg/l. Infiltration or leaching of nitrate from human and animal excreta appeared to be the major cause of groundwater nitrate in these areas.

For the study, we collected district-wise data on groundwater quality from the Department of Drinking Water Supply (2004) to identify nitrate-affected districts in Tamil Nadu. The analysis showed that 792 habitations in Tamil Nadu, with a population of more than 3.90 lakhs are affected by drinking water nitrate pollution alone, and another 902 habitations with a population of more than 3.56 lakhs are affected by nitrate along with other pollutants. Nitrate-affected habitations mostly fall in the northern and north-western districts of Tamil Nadu. The nitrate-affected population of Coimbatore district is 60,635 and Erode district is 33,947, which constitutes 8.1% and 4.5%, respectively of total nitrate-affected population of Tamil Nadu. Large parts of Erode and Coimbatore districts fall within the Bhavani River Basin.

The river Bhavani is the second largest perennial river of Tamil Nadu, and one of the most important tributaries of the Cauvery. The Bhavani Sagar reservoir, the Bhavani river and three diversions from the river, viz, Arakkankottai, Thadapalli, Kalingarayan (known as old system), and a canal from the reservoir known as the Lower Bhavani Project (LBP), form the lower Bhavani River Basin. Andamuthu and Subburam (1994) reported that on an average, 36.43% of the groundwater samples in the LBP main canal command area had a nitrate concentration of more than the maximum limit (45 mg/l) fixed by the WHO in 1984. They attributed this to the usage of commercial fertilisers. Due to growing incidence of nitrate concentration in groundwater in the basin, the environmental sustainability of safe drinking water sources is at stake.

Methodology and Sample Villages

This study is based on both primary and secondary data collected from various sources. Secondary data on groundwater quality indicates that the level of nitrate in the groundwater is high (> 100 mg/l) in many pockets of Coimbatore and Erode districts, where the basin is located.

To capture the spatial variations across the basin, we selected six villages based on their sources of irrigation and long-term groundwater nitrate concentration.[4] Out of these six villages, two were from the LBP command area – Elathur, which is at the head reach of the LBP canal, and Kalingiam, which is at the middle reach of the LBP canal. Two villages use the old system – Kondayampalayam depends on the Arrakankottai canal for irrigation and Appakoodal depends on the Bhavani river for irrigation. The last two – Madampalayam and Kemganaicken Palayam – source water from groundwater. Apart from surface water sources, groundwater is also used extensively for irrigation in the villages under study.

Apart from the sources of irrigation, the villages differ in their level of urbanisation and socio-economic status. While Appakoodal (APP), Elathur (ELA) and Kemganaicken Palayam (KNP) are town panchayats (TPs), Kalingiam (KAL), Kondayampalayam (KDP) and Madampalayam (MDP) are village panchayats (VPs). Out of the six sample villages using three different irrigation systems – old, new and rain-fed – one TP and one VP falls under each of the systems (Table 1).

The villages of APP, KNP and MDP are highly polluted with 50% or more than 50% samples from regularly observed wells taken by the Tamil Nadu Water Supply and Drainage (TWAD) Board during May 1991 to May 2005 having NO_3 concentration more than 50 mg/l. The villages of ELA, KAL and KDP were moderately affected with less than 50% of the samples from regularly observed wells having NO_3 concentration more than 50 mg/l (Table 2).

Table 2: Groundwater Nitrate Pollution in the Study Villages

Name of the Sample Location	Source(s) of Irrigation	NO_3 Concentration (in mg/l)		% of Observations Having NO_3 Concentration	
		Average	Range	>50 mg/l	> 100 mg/l
Kemganaicken Palayam (town panchayat)	Small dam, groundwater (open wells and bore wells)	47.9	0 – 106	50.0	4.5
Madampalayam (village panchayat)	Mostly rain fed and partly groundwater irrigated (open wells and deep bore wells)	128.7	0 – 320	77.3	54.5
Elathur (town panchayat)	The LBP canal and groundwater (open wells and deep bore wells)	34.5	1 – 120	23.1	11.5
Kalingiam (village panchayat)	The LBP canal and groundwater (open wells and deep bore wells)	24.3	0 – 134	13.0	4.3
Kondayampalayam (village panchayat)	The Arakkankottai canal and groundwater (open wells and deep bore wells)	49.7	2.7 – 115	44.0	4.0
Appakoodal (town panchayat)	The Bhavani river and groundwater (open wells and deep bore wells)	50.0	10 – 105	53.8	3.8

Source: TWAD Board; primary survey by the author.

A pre-structured questionnaire survey was administered during June-July 2006 to 395 farm households spread across the six villages in the basin. The survey involved collection of both quantitative and qualitative information from the sample households. We adopted random sampling procedure to select the sample households from the nitrate-affected villages. Since there was no information on the nitrate concentration of drinking water of individual households in the household level data from secondary sources, it was not used in random sampling.

On an average, 60 farm households were selected randomly from each of the six villages on the basis of their agricultural landholding and their interest in the subject of research. Voluntary participation of the farm households was sought for interviews, based on how much time they could give and their interest in our study. Face-to-face interviews were conducted with the head of the farm household or with any other person of the family familiar with farming activities. The information leaflet and the questionnaire were both translated into Tamil (the local language) and a background of the objectives, scope, and coverage of this study were given before starting the interviews.

Sample households (395) constituted 3% of the total households (13,278) in the selected villages, and the sample population constituted 3.4% of the total population of the villages (48,230) according to the 2001 Census. The average family size was 4.2, comparatively higher than the national census figures.

The sample households held 695 hectares of agricultural land, which is 12.4% of the total agricultural land of the villages under study (5,592 hectares). Sample households in ELA owned 8.2% of the agricultural land, and the corresponding figure for KDP was 25.7%. The total cropped area as a percentage of total geographical area varied from 56% in APP to 92% in MDP, with an average of 69%. The average landholding was 1.76 hectares, which varied from 1.31 hectares for APP to 2.55 hectares for KDP.

Results show that farmers' perceptions about groundwater quality vary across the villages and mimic the actual groundwater nitrate situation. For instance, we noticed that farmers from villages which had a higher groundwater nitrate content correctly perceived their groundwater quality and were willing to protect groundwater as compared to farmers from moderately affected villages (Mukherjee 2008).

Results and Discussion

Regular monitoring of soil quality is important to conserve soil nutrients and reduce wasteful use of fertilisers. Testing soil samples once a year is recommended and crop-wise application of nutrients on the basis of recommendations made after soil tests, is considered as one of the best management practices (BMPs) in agriculture, which has significant economic and environmental benefits (Ripa et al 2006; Logan 1993; D'Arcy and Frost 2001). On an average, 42.3% of the sample households conducted soil tests, with a minimum of 26.5% in KNP and a maximum of 60.9% in KDP (Table 3, p 69). On an average, farmers conducted their last soil test almost five years back (58.9 months). There was significant variation in the average time lapsed after the last soil test (in months) across the villages – minimum in APP (32.4 months) and maximum in KNP (138.8 months).

Out of 395 sample households, only 167 households (42.3%) tested their soil samples. Of these, 66 households (39.5%)

accessed the soil testing services facilitated by the local sugar mills and another 56 households (33.5%) accessed the government soil testing laboratories (Table 4). Depending on both direct costs and transaction costs involved in accessing the soil testing facilities provided by different agencies/institutions, farmers avail of the service according to their convenience and affordability. For example, in APP, 87.9% of soil tests are conducted through local sugar mills, whereas in MDP 90.5% of the soil tests are conducted by government soil testing laboratories. MDP is located nearer to Coimbatore and APP is located just adjacent to a sugar mill. In KNP more than 22% and in KDP more than 15% of soil tests are conducted by the Tamil Nadu Agricultural University (TNAU), Coimbatore and other colleges which facilitated soil-testing services free of costs. Private soil testing laboratories also played an important role. Transaction costs of public soil testing services are high. As a result, most farmers who could not afford these costs, either in terms of time and/or money, did not test their soil samples. Agricultural extension services provided by different agencies and institutions (public, private, non-governmental organisations) are complementary to each other. For example, in KNP and KDP, a large section of the farmers have accessed government agricultural agencies or institutions (e g, TNAU, Coimbatore and Government Soil Testing Laboratory, Erode) and at the same time they also depended on private soil testing laboratories and sugar mills to get their soil samples tested. Therefore, a public-private-NGO partnership could be a viable option to provide basic agricultural extension services to the farmers.

Table 3: Farmers' Adoption of Agricultural Best Management Practices

Description	APP	ELA	KAL	KNP	KDP	MDP	All
% of farmers tested soil samples	50.8	41.7	39.4	26.5	60.9	35.0	42.3
Average time lapsed after last soil test (in months)	32.4 (1-120)	71.1 (1-180)	44.9 (10-180)	138.8 (1-240)	37.2 (1-120)	72.0 (12-120)	58.9 (1-240)
Average number of plots	1.5 (1-3)	2.5 (1-5)	1.9 (1-5)	2.4 (1-5)	2.2 (1-5)	2.0 (1-4)	2.1 (1-5)
Average landholding size (in hectare)	1.31	1.75	1.58	2.09	2.55	1.23	1.76

Source: Primary survey conducted by the author.

Table 4: Farmers Using Soil Testing Facilities (as % of sample farmers)

Soil Testing Centre	APP	ELA	KAL	KNP	KDP	MDP	All
Krishi Vigyan Kendras (KVKs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TNAU, Coimbatore	0.0	3.3	7.7	22.2	15.4	4.8	8.4
Private soil testing laboratory	3.0	6.7	0.0	22.2	17.9	0.0	8.4
Industry (local sugar mills)	87.9	20.0	61.5	0.0	38.5	0.0	39.5
Government soil testing laboratory	0.0	50.0	23.1	44.4	20.5	90.5	33.5
Others (students from Agricultural University, MYRADA, cannot remember)	9.1	20.0	7.7	11.1	7.7	4.8	10.2

Source: Primary survey conducted by the author.

The results of our primary household questionnaire survey reveal that on an average, the sample farmers pay Rs 47 per sample for soil testing (Table 5). The fee varies from Rs 5 to Rs 400 depending on the institution/agency from where soil samples are tested. Apart from direct costs of soil testing, farmers also incur indirect costs in terms of time and money spent on visiting the test centre, and also on receiving results and recommendation on crop-wise fertiliser doses. Farmers also reveal the inconvenience of multiple visits to get the test results and recommendations, and at times do not even bother to collect these results, as they cannot afford the multiple visits. Farmers who cultivate sugar cane get free soil testing service from the local sugar mills, and farmers who can afford a high fee for soil tests get their soil samples tested from private soil testing laboratories and/or private agricultural consultants. Sometimes students from agricultural universities visit the villages and take soil samples from the farmers' fields, but often they do not give the test results or recommendations. This does not benefit the farmers in any way, and gradually they have begun to oppose these activities. On an average a farmer has to spend 12 hours for a one-time testing of his/her soil samples. The time spent varies across the villages, from two to 50 hours, depending on the distance from the nearest towns. Opportunity costs of time spent are substantial, on an average Rs 150 per test.[5] On an average, three samples are tested in a single visit, as a result cost of soil testing would be Rs 141 (= 3*47). The average transport cost is Rs 70, which raises the average total cost for a one-time testing of soil samples to Rs 361.

Availability of Soil Testing Facilities

Table 6 shows the government soil testing facilities available in Coimbatore and Erode districts and the level of capacity utilisation. There is one fixed and one mobile unit each for Coimbatore and Erode districts and soil testing capacity across the laboratories is constant. The capacity utilisation was very high which shows that existing soil testing laboratories are not adequate to cater to all the farmers. This might be the cause for the high transaction costs associated with soil testing.

In the absence of better access to soil testing facilities and reluctance to conduct soil tests regularly, on an average 46.3% of the sample farmers apply fertilisers on the basis of recommendations made by the fertiliser dealers, and 32.5% on the basis of recommendations of their relatives and neighbours. Another 21% of the farmers apply common doses of fertilisers on the basis of

Table 5: Direct and Transaction Costs of Soil Testing

Description	No of Observations	Minimum	Maximum	Average
Cost per sample (in Rs)	30	5	400	47
Transport costs (in Rs)	12	20	200	70
Time spent (in hour)	5	2	50	12
No of samples tested	27	1	5	3

Source: Primary survey conducted by the author.

Table 6: Capacity of Government Soil Testing Laboratories in Coimbatore and Erode Districts

Year	District	Fixed Soil Testing Laboratory			Mobile Soil Testing Laboratory		
		Sample Analysing Capacity (Number of Samples Per Annum)	Number of Samples Analysed	Capacity Utilisation (%)	Sample Analysing Capacity (Number of Samples Per Annum)	Number Samples Analysed	Capacity Utilisation (%)
1999-2000	Coimbatore	39,600	39,807	100.5	18,000	18,044	100.2
	Erode	33,000	34,592	104.8	18,000	18,359	102.0
2003-04	Coimbatore	39,600	39,787	100.5	18,000	18,366	102.0
	Erode	33,000	33,009	100.0	18,000	11,105	61.7
2004-05	Coimbatore	39,600	39,603	100.0	18,000	18,071	100.4
	Erode	33,000	33,104	100.3	18,000	11,075	61.5
2005-06	Coimbatore	39,600	36,450	92.0	18,000	18,085	100.5
	Erode	33,000	33,027	100.1	18,000	13,789	76.6
2006-07	Coimbatore	39,600	40,352	101.9	18,000	18,468	102.6
	Erode	33,000	22,793	69.1	18,000	18,412	102.3

Source: Compiled from year-wise data available at http://www.indiastat.com.

their own experience/judgments (Table 7). However, on an average, 84% of the farmers reveal that they know the recommended doses of fertilisers for their crops, which varies significantly across the sample villages from minimum 62% in KNP to 98% in KDP. Apart from commercial fertilisers, farmers apply large quantities of farm yard manure on their farmlands, for which they do not cut back their commercial fertiliser consumption (manure is not credited); as a result groundwater becomes vulnerable to excess nitrogen leaching from farmlands.

Table 7: Sources of Consultation for Application of Fertilisers

Sources of Consultation	APP	ELA	KAL	KNP	KDP	MDP	All
% of farmers consulting other farmers/ relatives/neighbours	31.3	24.7	22.5	35.5	37.0	21.9	28.8
% of farmers applying common doses	5.1	14.2	5.8	34.1	14.3	39.4	18.6
% of farmers consulting fertiliser dealers	48.2	46.2	56.6	25.5	40.9	28.6	41.2
% of farmers consulting others (private consultants, agriculture students, etc)	0.0	1.0	0.0	0.5	0.0	0.0	0.3
% of farmers which does not consult	15.4	13.9	15.2	4.4	7.8	10	11.1

Source: Primary survey conducted by the author.

When the government does not provide basic agricultural extension services to all the farmers, due to financial and other constraints, whatever little services the government provides becomes a private good for a group of farmers. Through political, social and economic influence, a small group of farmers mostly benefit from the public provision of agricultural extension services. As a result, only a few farmers admitted that agricultural extension officers (AEOs) visit their village regularly, and they get free agriculture-related consultancy services from the AEOs. On an average, 20% of the sample households benefited from the AEOs' visits, which varies significantly across the villages from 13% in KNP and MDP to 34% in KDP (Table 8).

Table 8: Farmers' Willingness to Adopt Agricultural Best Management Practices

Description	APP	ELA	KAL	KNP	KDP	MDP	ALL
% of farmers admit that AEOs visit village regularly	18	17	24	13	34	13	20
% of farmers willing to apply fertilisers according to the recommendations made after soil tests	46	35	36	24	52	25	36
% of farmers willing to pay Rs 50/sample for soil test	88	72	73	47	86	60	71
% of households using bio-fertilisers	32	49	42	24	55	08	35
% of households practising organic farming	20	06	27	12	34	02	17

Source: Primary survey conducted by the author.

Testing of soil and getting crop-wise recommended doses of fertilisers do not necessarily ensure that the farmers will follow the recommendations. Thus, in order to understand the farmers' willingness to apply the recommended doses of fertilisers on the basis of soil tests, their preferences have been captured through a binary choice survey. The results show that on an average 36% of the farmers who have conducted their soil tests are willing to apply fertilisers according to the recommendations made. This varies from 24% in KNP to 46% in APP (Table 8). Some households have tested their soil samples on an earlier occasion but are not willing to apply fertilisers according to the recommendations made, mainly due to their perception that application of fertilisers in recommended doses does not improve the crop productivity. At times, this is also due to their reluctance to incur the costs associated with the soil tests.

In order to assess the farmers' willingness to pay (WTP) for soil testing, we conducted a binary-choice contingent valuation survey (with constant bid). The bid amount – Rs 50 per sample – was set on the basis of a pilot survey carried out among a few farmers from KNP. Agricultural experts at TNAU also suggested that we set the WTP amount at Rs 50 per sample. The results show that on an average, 71% of the sample farmers are willing to pay Rs 50 per sample for soil test, which varies from 47% in KNP to 88% in APP (Table 8). Even if farmers are willing to pay for the soil test, the high transaction costs and inadequate facilities make them reluctant to test their soil samples.

Table 8 shows that on an average, 35% of the sample households are using bio-fertilisers (like rhizobium, azospirillum, phosphobacterium, etc) for their crops. On an average 17% of the sample households practice organic farming (using neem cake, margosa cake, green manure, *Panchyagavya*, *Dasagavya*, etc). With some exceptions, as the size of the landholding increases, the percentage of farmers using bio-fertilisers and organic farming also increases. It is found that access to irrigation facilities is the major hindrance in the adoption of improved agricultural practices like bio-fertilisers and organic farming.

The results show that farmers in the basin are willing to adopt the agricultural BMPs, but several factors (institutional, infrastructural, socio-economic, agronomic, etc) influence their willingness (or reluctance). The degree of adoption of agricultural BMPs – soil testing, bio-fertilisers, organic farming – varies across our study villages based on access to agricultural extension services, access to reliable source(s) of irrigation, proximity to the cities/towns, groundwater quality, etc. To understand the factors influencing farmers' willingness to adopt agricultural BMPs, we estimate binary choice Probit models with the primary survey based data. The results are described below.

Farmers' Willingness

The results show that farmers who have access to multiple sources of agriculture-related information and consultations are more willing to apply fertilisers according to the recommendations made after soil tests. Farmers' memberships in social participatory institutions (e g, cooperative milk producers' associations, farmers' cooperative society, self-help groups,[6] water users' association, farmers' association) positively influences their willingness. Perceptions about the potential impact of agricultural practices on groundwater quality and their own groundwater quality assessment positively influence their willingness. Farmers who are willing to pay for soil tests and have tested their soil samples recently are willing to adopt the best management practices, and those with several years of experience in agriculture, as revealed by their age, are willing to adopt the changes; however, farmers with a large herd size are reluctant to adopt the changes.

Paying for Soil Tests: The results show that the farmers' level of education, number of economically active persons in the family, perceptions about agricultural practices and their impact on groundwater quality positively influence their willingness to pay for soil tests. Farmers who are willing to participate in government supported or sponsored farm management/training programmes are willing to pay for soil tests. However, higher the per capita landholding, lower the willingness, and farmers who have knowledge about improved agricultural practices are less likely to pay for soil tests. Farmers from ELA, KNP and MDP are reluctant to pay for soil test, whereas the farmers from APP, KAL and KDP are willing to pay Rs 50 per sample for soil tests. The willingness of farmers to pay for soil tests is area-specific and is captured through village dummies. The size of landholding, area under cultivation of sugar cane, possible benefits from the visits of AEOs to the village, access to soil testing services are the major factors which influence an individual farmer's willingness/ reluctance to pay for soil tests.

Adopting Bio-fertilisers: Willingness to adopt bio-fertilisers depends on farmers' income from animal husbandry, sources of agricultural information, knowledge of BMPs, fertilisers depot owners,[7] and the right perception about vulnerability of groundwater quality from non-point sources in their area. The knowledge that cutting down of fertilisers from the current level would not affect the crop productivity enhances their willingness to adopt bio-fertilisers. Farmers who benefit from the AEOs' visits, and are willing to avail of government support to adopt BMPs and get training, consult other farmers for agriculture-related issues are reluctant to adopt bio-fertilisers. Sample farmers from moderate nitrate-affected villages (ELA, KAL and KDP) are willing to adopt bio-fertilisers compared to the other three villages. Given all other factors which are captured through village dummies, willingness to adopt of bio-fertilisers is area-specific and access to reliable source of irrigation plays an important role here. As ELA and KAL are irrigated by the LBP canal and KDP is irrigated from the Arakkankottai channel (a diversion from the Bhavani river), all the three villages have relatively reliable sources of irrigation as compared to the other villages.

Adopting Organic Farming: The results show that farmers with a higher workforce participation rate, larger area under sugar cane cultivation, agricultural information from sources like television, newspapers, magazines, radio, agri-expo, etc, who consult government AEOs, are aware of environment-related BMPs, have access to drinking water from tankers supplied by local industries or panchayat offices, are willing to adopt organic farming. Those willing to participate in government-sponsored training programmes related to adoption of bio-fertilisers and bio-pesticides are willing to adopt organic farming. Factors that negatively influence their willingness are agricultural consultation of relatives, membership in cooperative societies and self-help groups. Farmers reluctant to adopt organic farming are those who perceive that the groundwater is polluted, who have resided in their respective villages for a long time, who believe that cutting down of fertilisers from the current level would affect the crop productivity, and who use own open well as a source of drinking water.

Key Findings and Conclusions

The study shows that farmers' willingness to test soil samples is high (as revealed by their willingness to pay for soil test). However, inadequate infrastructure and high transaction costs involved in accessing the facilities make them reluctant to test their soil samples regularly. The farmers prefer to access the free soil testing service provided by the local sugar mills and/or to test their samples from private soil testing labs. Therefore, exploring the possibilities of setting up soil testing facilities with private and NGO partners or students from agricultural universities could be a viable option.

In the absence of formal agricultural extension services, on an average 46.3% of our sample farmers apply fertilisers on the basis of the recommendation made by the fertiliser dealers, and 32.5% depend on their relatives and neighbours. In the absence of better agricultural extension services, farmers may not cut down their applications of fertilisers voluntarily due to the risk associated with nutrient deficiency of the crops. Therefore, the new nutrient-based subsidy policy should have a component of agricultural extension services with environmental education and awareness for the farmers. While farmers' willingness to adopt bio-fertilisers and organic farming is high, lack of sources of information/consultations make them reluctant to adopt them. Therefore, provision of basic agricultural extension services at village level could make the new fertiliser policy more relevant for the farmers.

Though farmers are willing to pay for soil test, there is no such agency which could provide the service at demand. Public-private-NGO partnership in the provision of basic agricultural extension services could be helpful to encourage farmers to adopt agricultural BMPs. By providing training and certification, government could encourage agricultural science graduates to provide basic agricultural services to the farmers at a reasonable cost.

Therefore, the new policy, though in the right direction, requires a supplementary programme to provide farmers with basic agricultural extension services and empowers them with information, consultations and demonstrations. The linking of agricultural policy, fertiliser policy, water policy and environmental policy is very important from the point of view of sustainable development of land and water resources.

NOTES

1 Throughout the paper, we use the term "unbalanced application" to imply both using less than optimum quantity of fertilisers as well as excessive application of nutrients.

2 The price at which farmers purchase the fertilisers.

3 Defined as "excessive nutrients in surface water body, usually caused by runoff of nutrients (fertilisers, animal waste, sewage) from the land, which causes a dense growth of plant life; the decomposition of the plants depletes the supply of oxygen, leading to the death of animal life".

4 Groundwater quality information was collected from the TWAD Board, Chennai for the period May 1991 to May 2005, where sampling for regular observation wells is carried out twice in a year (May/June for pre-monsoon and December/ January for post-monsoon) to capture the seasonal, temporal and spatial variations of groundwater nitrate concentration of the basin.

5 It is calculated based on the wage rate for agricultural labourers prevalent in the basin during 2006, which is Rs 100/head/day. Labourers spend on an average 8 hours per day, therefore the opportunity cost of 12 hours implies 1.5 days, which is equivalent to Rs 150.

6 Memberships in some recently started institutions like women self-help groups (SHGs) and some agriculture related SHGs like Integrated Pest Management, Kamdhenu Ullavar Mandalam, are relatively better as compared to traditional institutions.

7 On an average 31% of sample farmers (minimum 21% in KNP and maximum 44% in KAL) consult owners of fertiliser depots to make decision related to their agricultural practices (application of fertilisers and pesticides, etc).

references

Andamuthu, R and V Subburam (1994): "Nitrate Contamination in Ground Water of Lower Bhavani Project Main Canal Command Area in Tamil Nadu", *Indian Journal of Environmental Protection*, 14(6): 462-67.

Bassin, J K, A B Gupta, A Gupta, R C Gupta, S K Gupta, A K Seth and M L Sharma (2001): "Recurrent Diarrhea in Children Living in Areas with High Levels of Nitrate in Drinking Water", *Archives of Environmental Health*, viewed on 10 May 2005 (http://www.encyclopedia.com/doc/1G1-79124886.html).

BIS (1991): *Indian Standard Specifications for Drinking Water: IS 10 500* (New Delhi: Bureau of Indian Standards).

Census of India (2001): *State-wise Percentage Distribution of Households by Source of Drinking Water in Rural and Urban Areas in India-2001,* viewed on 15 May 2007 (www.indiastat.com).

Comptroller and Auditor General of India (2000): *State Audit Reports: Tamil Nadu, 1999-2000*, Chapter 3: Civil Departments, p 42, viewed on 5 May 2005 (http://cag.nic.in/reports /tn/rep_2000/civil_ch3.pdf).

D'Arcy, B and A Frost (2001): "The Role of Best Management Practices in Alleviating Water Quality Problems Associated with Diffuse Pollution", *The Science of the Total Environment*, 265(1-3): 359-67.

Department of Drinking Water Supply (2004): "List of Water Quality Affected Habitations as Reported by States (as on 31 March 2004) – As Per Quality Survey 2000", viewed on 5 May 2006, available at http://ddws.nic.in/ wq/main.asp

Fewtrell, Lorna (2004): "Drinking Water Nitrate, Methaemoglobinaemia and Global Burden of Diseases: A Discussion", *Environmental Health Perspectives*, 112(14): 1371-74.

Foster, S and H Garduño (2004): *India – Tamil Nadu: Resolving the Conflict Over Rural Groundwater Use between Drinking Water and Irrigation Supply*, Case Profile Collection Number 11, Sustainable Groundwater Management Lessons from Practice (Washington DC, US: Global Water Partnership Associate Programme, The World Bank).

Goldberg, V M (1989), "Groundwater Pollution by Nitrates from Livestock Wastes", *Environmental Health Perspectives*, 83: 25-29.

Gupta, S K, R C Gupta, A B Gupta, A K Seth, J K Bassin and A Gupta (1999): "Adaptation of Cytochrome-b5 Reductase Activity and Mathaemoglobinaemia in Areas with High Nitrate Concentration in Drinking-Water", *Bulletin of World Health Organisation*, 77(9): 749-53.

– (2000a): "Recurrent Acute Respiratory Tract Infections in Areas With High Nitrate Concentrations in Drinking Water", *Environmental Health Perspectives*, 108(4): 363-66.

– (2000b): "Metheamoglobinaemia in Areas with High Nitrate Concentration in Drinking Water", *National Medical Journal of India*, 13: 58-61.

Logan, T J (1993): "Agricultural Best Management Practices for Water Pollution Control: Current Issues", *Agriculture, Ecosystems and Environment*, 46(1-4): 223-31.

Majumdar, D and N Gupta (2000): "Nitrate Pollution of Groundwater and Associated Human Health Disorders", *Indian Journal of Environmental Health*, 42(1), 28-39.

Majumdar, D (2003): "The Blue Baby Syndrome: Nitrate Poisoning in Humans", *Resonance*, viewed on 5 May 2005. (http://www.iisc. ernet.in/ academy/resonance/Oct2003/pdf/ Oct2003p20-30.pdf).

Ministry of Rural Development (2010a): "Quality Affected Habitations", Department of Drinking Water and Sanitation, available at http://indiawater. gov.in/IMISweb/Reports/rws/ Rep_Quality AffectedHabitationStatewise2010.aspx?Rep = Y

– (2010b): "Problem of Contaminated Drinking Water", Press release, 3 August 2010, available at http://pib.nic.in/ release/release. sp? relid= 64016

Mukherjee, Sacchidananda (2008): "Economics of Agricultural Nonpoint Source Water Pollution: A Case Study of Groundwater Nitrate Pollution in the Lower Bhavani River Basin, Tamil Nadu", unpublished PhD thesis, Madras School of Economics (Chennai: University of Madras).

National Habitations Survey (2003): "Contamination-Wise Number of Quality Affected Habitations", available at http://ddws.gov.in/habquery/rep_affected_group.asp

Ripa, M N, A Leone, M Garnier and A L Porto (2006): "Agricultural Land Use and Best Management Practices to Control Nonpoint Water Pollution", *Environmental Management*, 38(2): 253-66.

Singh, I P, B Singh and H S Bal (1987): "Indiscriminate Fertiliser Use vis-á-vis Groundwater Pollution in Central Punjab", *Indian Journal of Agricultural Economics*, 42(3): 404-10.

WHO (2004): *Guidelines for Drinking-Water Quality,* (Third Edition, Vol 1 – Recommendations), World Health Organisation, Geneva, Switzerland.

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