Factors Influencing Farmers' Willingness to Protect Groundwater from Nonpoint Sources of Pollution in the Lower Bhavani River Basin, Tamil Nadu, India

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Abstract
Farmers' perceptions about groundwater and drinking water quality are important, which influence their willingness to adopt protection measures either individually or collectively. This study attempts to capture the factors influencing farmers' perceptions and their willingness to protect groundwater from nonpoint sources of pollution, and their willingness to support the local government to supply drinking water through alternative arrangements. Six villages are identified in the Lower Bhavani River Basin, Tamil Nadu, India on the basis of their long-term groundwater nitrate concentrations and sources of irrigation. A pre-structured questionnaire survey (face-to-face interviews) has been administered to 395 farm-households across six villages during June-July, 2006. Results show that farmers' perceptions of risks related to groundwater nitrate pollution vary across the villages, and mimic the actual groundwater nitrate situation. Estimated results of binary choice Probit models show that farmers from comparatively high groundwater nitrate contaminated villages are willing to protect groundwater as compared to farmers from less affected villages. Demand for safe drinking water varies across the villages, based on the variations of socio-economic characteristics of the sample households and groundwater quality of the villages.

Keywords: Groundwater Quality, Nonpoint Source Pollution, Willingness To Protect, Rural, Water Supply, Subjective Risk Assessment, India.

Introduction
Pollution abatement strategies for water resources in India and other developing countries have given priority to point sources of pollution. However, it is increasingly becoming evident that improvement of quality of surface and ground water resources will also require the control of pollution from nonpoint sources (NPS). Nonpoint source water pollution control is particularly crucial in rural areas where groundwater is an important source of drinking water. In several parts of India, growing access to irrigation facilities along with unbalanced and overuse of nitrogenous fertilisers, unlined and open storage of livestock wastes, and insanitary disposal of human wastes have led to high concentration of nitrate in groundwater. There is limited information on the level of pesticide contamination of water sources. However, there is substantial secondary information on the level of nitrate in groundwater as well as surface water.

Consumption of nitrate contaminated drinking water poses various short and long term health hazards to various age groups (Fewtrell, 2004; WHO, 2004). Nitrate (NO_3) concentration in water used for drinking should be less than 50 milligram per litre (mg/l) (WHO, 2004). In

India water having nitrate levels greater than 100 mg/litre is considered to be harmful, if used for drinking (ISI, 1991).

Nonpoint Source Pollution Control Options

Due to large number of sources and diffused entry points, it is technically difficult and financially infeasible to monitor the contribution of individual nonpoint sources to the ambient concentration (Dosi and Zeitouni, 2001). Though monitoring and taking regulatory measures to protect groundwater is the responsibility of the Pollution Control Boards (Trivedy, 2000), there is no legal provision to regulate individual polluters. As a result, pollution control of nonpoint sources is mostly neglected in India. Economic instruments like nitrogen and pesticide taxes are not feasible in the Indian context at this time, although they have been used in some European countries (Zeijts and Westhoek, 2004 and Rougoor et al., 2001). In India, nitrogenous fertilisers have been subsidised to encourage use by farmers. This has led to overuse of fertilisers by farmers and the consequent problem of nitrate pollution of the groundwater (NAAS, 2005). Proper pricing of fertilisers may lead to more careful use (Chelliah et al., 2007). Voluntary approach like collective action to adopt best management practices (BMPs) by the farmers may be a long-term solution to control NPS groundwater pollution. Collective action is needed to ensure that restraint in the use of fertilisers is practised by all the farmers in a particular village or area.

Environmental Sustainability of Sources of Drinking Water

One of the targets of the United Nations' Millennium Development Goals (MDGs) is to "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation" (Target 10 of MDGs). Pollution from nonpoint sources (NPS) makes groundwater resources unsuitable for drinking. Thus environmental sustainability of safe sources of drinking water for future generations is at stake.

Environmental and natural resources conservation from quantitative depletion and qualitative degradation, should be an integral part of any economic and development policy, which is also one of the targets of United Nations' Millennium Development Goals (Target 9).

Both qualitative and quantitative aspects of protection of drinking water sources need to be addressed to meet the drinking water needs of the people. Major challenges that rural water supply sector in India is facing today are not only to meet the large investment requirement to augment the water supply, but also additional investment burden to tackle the water quality related problems. Achieving equity and greater access to safe drinking water for a large section of the populace will remain a distant dream, if we cannot protect our drinking water sources from all possible sources of pollution. Since groundwater serves as a decentralised source of drinking water in rural areas, the rural population become vulnerable to various water-borne diseases when groundwater is polluted. And it is mostly the poor and marginal section of the population who suffer the most, as they cannot afford to protect themselves from the impacts of pollution.

Access to safe drinking water is vital for human well-being (UNDP, 2006). People exposed to polluted drinking water are vulnerable to various water borne diseases. Costs associated with mortality and morbidity of water-borne diseases are high. For example in India water borne diseases annually put a burden of USD 3.1 to 8.3 million in 1992 prices (Brandon and Hommann, 1995).

The Comptroller and Auditor General of India (2000) reports that about 10 per cent of water sources in the state of Tamil Nadu are not potable due to excessive nitrate. The nitrate-affected belt is mainly in the western districts of Tamil Nadu. Foster and Garduño (2004) reported elevated concentration of nitrate in drinking water wells during dry season at numerous locations in Tamil Nadu. In Coimbatore and Dharmapuri districts of western zone, more than 20 per cent of drinking water wells had nitrate concentration greater than 50 mg/l and in large number of wells nitrate concentration exceeded 100 mg/l. They attributed infiltration or leaching of nitrate from human and animal excreta as the major cause of groundwater nitrate in those areas. Controlling pollution from nonpoint sources will be the first step towards sustainable access to safe drinking water in rural areas. In this study, we use the Lower Bhavani River Basin in Tamil Nadu as a case study of nonpoint source pollution.

Nitrate Pollution in the Lower Bhavani River Basin, Tamil Nadu

The Bhavani river is the second largest perennial river of Tamil Nadu, and one of the most important tributaries of the Cauvery river. The Lower Bhavani River Basin is an extensively irrigated area, and farmers apply nitrogenous fertilisers way above the doses recommended by the Tamil Nadu Agricultural University (Shanmugam and Mukherjee, 2004). As a result high concentration of nitrate has been reported both in shallow and deep aquifers. Secondary data on groundwater quality indicates that the level of nitrates in the groundwater is high (> 100 mg/liter) in many pockets of Coimbatore and Erode districts of Tamil Nadu in which the basin is located. Due to growing incidence of groundwater nitrate concentration in the basin, the environmental sustainability of safe drinking water sources is at stake. In some instances the public water supply authority has provided drinking water from alternative sources to nitrate affected rural habitations. However, a large section of the society is still dependent on decentralised drinking water systems and exposed to high nitrate contaminated drinking water. It is expected that drinking nitrate-contaminated water may have various short and long term health impacts. However, due to inadequate secondary health information it cannot be confirmed.

Objectives

Community participation in environmental conservation is a new area of research and it is in this regard that this study attempts to understand (in *ex ante*) individual farmers' perceptions about groundwater quality, and factors which influence his/her individual decision to protect groundwater either individually (through adoption of agricultural BMPs) or collectively - by supporting local government to supply safe drinking water through alternative arrangements. This is the first step to study the possible emergence of collective action. The decision to cooperate in collective action is an individual's decision where his/her economic motives, socio-economic background and other factors play a crucial role. Apart from individual specific factors, social connectivity (social capital) and factors like information/consultation sources play a crucial role in his/her decision.

Methodology

To capture the spatial variations across the basin, we have selected six villages on the basis of their water availability, sources of irrigation, intensity of agriculture (as measured by total cropped area as a percentage of total area), intensity of irrigation (as measured by irrigated area as a percentage of total cropped area), long-term groundwater nitrate concentration and level of urbanisation. The villages differ in their sources and access to drinking water.

However, all the villages have access (to a limited extent) to safe drinking water from TWAD Board's Combined Water Supply Schemes (CWSS) running from the Bhavani river. Among the 6 villages two are from the Lower Bhavani Project (LBP) canal command area – Elathur (ELA) at the head reach of the canal and Kalingiam (KAL) at the middle reach of the canal, two are from the old system – Kondayampalayam (KDP) depends on Arrakankottai canal for irrigation and Appakoodal (APP) depends on the Bhavani river for irrigation and two are from rain fed and groundwater irrigated area – Madampalayam (MDP) and Kembanickenpalayam (KNP). Apart from the sources of irrigation, villages differ with respect to their level of urbanisation and socio-economic status. Appakoodal, Elathur and Kembanickenpalayam are Town Panchayats (TP) and Kalingiam, Kondayampalayam and Madampalayam are Village Panchayats (VP). Out of six sample villages from three irrigation systems – old system, new system and rain fed area - one TP and one VP falls under each of the system (Table 1). Groundwater data analysis shows that Appakoodal, Kembanickenpalayam and Madampalayam have comparatively higher groundwater nitrate concentration - more than 50 per cent of the samples have NO_3 concentration more than 50 mg/l. Elathur, Kalingiam and Kondayampalayam have comparatively lower groundwater nitrate concentration - less than 25 per cent of the samples have NO_3 concentration less than 50 mg/l. Average groundwater nitrate concentration for Madampalayam is comparatively higher (for all seasons) than other five villages selected for our case studies.

Table 1. Groundwater Nitrate Pollution in the Study Villages.

Name of the Sample Location	**Source(s) of Irrigation**	**NO_3 Concentration (in mg/l)**		**% of observation having NO_3 Concentration**	
		Average	**Range**	**>50 mg/l**	**> 100 mg/l**
Appakoodal (APP) (Rural Town Panchayat)	The Bhavani river and groundwater (open wells and deep bore wells)	50.0	10 – 105	53.8	3.8
Elathur (ELA) (Rural Town Panchayat)	The Lower Bhavani Project (LBP) canal and groundwater (open wells and deep bore wells)	34.5	1 – 120	23.1	11.5
Kalingiam (KAL) (Village Panchayat)	The LBP canal and groundwater (open wells and deep bore wells)	24.3	0 – 134	13.0	4.3
Kembanickenpalayam (KNP) (Rural Town Panchayat)	Small dam, groundwater (open wells and bore wells) & river pumping	47.9	0 – 106	50.0	4.5
Kondayampalayam (KDP) (Village Panchayat)	The Arakkankottai canal and groundwater (open wells and deep bore wells)	49.7	2.7 - 115	44.0	4.0
Madampalayam (MDP) (Village Panchayat)	Mostly rain fed and groundwater (open wells and deep bore wells)	128.7	0 – 320	77.3	54.5

Source: Census of India (2001), TWAD Board, Chennai and Primary Survey

A detailed questionnaire survey has been carried out among 395 farm households spread across six villages in the Lower Bhavani River Basin during June to July, 2006. Both qualitative and quantitative information collected through face-to-face interviews with the head of the farm households. On an average 60 farm households were selected randomly from each of the six villages on the basis of their availability of own agricultural land and interest in the subject of our research. Voluntary participation of the farm households was sought for interviews, based on their availability of time. Both the information leaflet and household questionnaire schedule were translated into Tamil, and a background of the objectives, scope and coverage of this study was described before starting the interviews. Apart from household questionnaire survey, various information related to land use pattern and drinking water schemes/systems of the villages were collected from the village agriculture office and village *panchayat* office respectively.

Results

The estimated results of binary choice Probit models show that:

- Farmers from comparatively high groundwater nitrate contaminated villages correctly perceive (subjective) their groundwater quality and they are willing to protect groundwater quality as compared to farmers from less affected villages. Therefore, it shows that any groundwater quality protection programme from nonpoint sources of pollution should take into consideration the site characteristics and socio-economic characteristics of the stakeholders.
- Farmers' groundwater quality perceptions vary across the villages and mimic the actual groundwater nitrate situation. Households depending on their socio-economic characteristics, social- and information-network and the characteristics of the resource (alternative sources and quality of drinking water) derive a subjective risk assessment of their groundwater quality. Regular monitoring of groundwater quality, assessment (objective) of risks of consuming contaminated groundwater and communication of risks to the stakeholders could help the farmers to take measures/initiatives either individually or collectively to protect groundwater from NPS pollution.
- Demand for safe drinking water varies across the villages, based on the variations of socio-economic characteristics of the sample households and groundwater quality. However, with reference to farmers' willingness to protect groundwater quality, their willingness to support local government shows different results. For example, farmers from villages having higher concentration of groundwater nitrate, are willing to protect groundwater quality and reluctant to support local government. *However, adoption of demand driven approach for provision of drinking water may not be suitable specifically when the risk of consuming contaminated drinking water is not commonly perceived by the consumers, as the presence of nitrate does not change the taste, odour, colour or any other commonly perceivable quality/characteristics of drinking water.*
- Farmers' knowledge about impacts of agricultural practices on groundwater quality significantly influences their perceptions about groundwater quality and willingness to protect groundwater. Therefore, provision of agricultural information and education along with basic agricultural extension services could induce the farmers to protect groundwater from NPS Pollution.
- Both socio-economic characteristics of the households and the characteristics of the subject (groundwater or drinking water) significantly influence the farmers' perceptions. Knowledge of agricultural BMPs and their impacts on environment positively influences farmers' perceptions and willingness.

- Farmers' perceptions about groundwater quality influence their willingness to support local government to supply safe drinking water. Irrespective of sources of drinking water, farmers are willing to support local government
- Memberships in social participatory institutions and sources of agricultural information, significantly influences farmers perceptions and willingness.

The role of stakeholders and their voluntary participation in agro-environmental management in general and water resources conservation/management in particular is a new area of research, at least for a developing country like India. The study will be useful for policy since there are many areas in India and other developing countries which are facing similar groundwater pollution problems. The issue of groundwater pollution from nonpoint sources is a growing concern not only for a relatively water scarce country like India, but also for water abundant countries around the world.

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