# FACTORS INFLUENCING FARMERS' WILLINGNESS TO PROTECT GROUNDWATER FROM NONPOINT SOURCES OF POLLUTION IN THE LOWER BHAVANI RIVER BASIN, TAMIL NADU

Sacchidananda Mukherjee[1]

## Abstract

*Pollution abatement strategies in India and other developing countries have given priority to point sources of pollution. However, it is increasingly evident that improvement of quality of surface and ground water will also require control of pollution from nonpoint sources (NPS). NPS pollution control is particularly crucial in rural areas where groundwater is an important source of drinking water. If pollution continues unabated it could pose serious risks not only for current generations but also for future generations to meet demand for safe drinking water at a reasonable cost. Regulatory approaches are not suitable to control pollution from NPS. Voluntary approach like collective action to adopt agricultural best management practices by the farmers could be a long-term solution within the existing institutional structure. 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, 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, 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.*

## 1. INTRODUCTION

Pollution abatement strategies in India and other developing countries have given priority to point sources of pollution. However, it is evident that improvement of quality of surface and ground water will also require the control of pollution from nonpoint sources (NPS). NPS 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 open defecation and urination has led to high concentration of nitrate in the 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 surface as well as ground water.

Consumption of nitrate contaminated drinking water poses various short and long term health hazards to various age groups (Fewtrell, 2004; WHO, 2004). WHO has recommended that water used for drinking should have a nitrate ($NO_3$) concentration less than 50 milligram per liter (mg/l) (WHO, 2004). In India drinking water having nitrate levels greater than 100 mg/l are considered to be harmful to human health (ISI, 1991). Sustainability of safe sources of drinking water is a major challenge that developing countries like India are

[1] Senior Scientific Officer, International Water Management Institute (IWMI), C/o, ICRISAT, Patancheru, Andhra Pradesh – 502 324, India, Email: sachs.mse@gmail.com

facing today. In India, a large section of the rural population still does not have access to safe drinking water. If the pollution from nonpoint sources continues unabated it could pose serious health risks not only for the current generations but also for future generations.

### 1.1 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).[2] 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).

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. Although several attempts have been made to control pollution from point sources, there is no substantial improvement in the quality of surface and ground water resources (Maria, 2003). 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% 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% 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.

### 1.2 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 Bhavanisagar Reservoir, the Bhavani river and three diversions from the river, viz., Arakkankottai, Thadapalli and Kalingarayan canals (known as the old system) and a canal from the reservoir known as the Lower Bhavani Project (LBP) canal, form the Lower Bhavani River Basin in Tamil Nadu (see

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[2] http://www.un.org/millenniumgoals/ – accessed on July 15, 2006.

Location Map in Appendix A). 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. Andamuthu and Subburam (1994) reported that on an average 36.43% of the groundwater samples in the LBP main canal command area had nitrate concentration more than the maximum limit of 45 mg/l fixed by the WHO in 1984. They attributed this to the usage of commercial fertilisers and high concentration of nitrate in the LBP canal water as the major source. 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.[2] 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.

Community participation in environmental conservation is a new area of research and it is in this regard that this study attempts to capture the following factors:

(a) farmers' perceptions about groundwater and drinking water quality,

(b) farmers' willingness to protect groundwater quality, and

(c) farmers' willingness to support local government to supply safe drinking water (demand for safe drinking water).

## 2. NONPOINT SOURCE POLLUTION CONTROL OPTIONS

It is not possible to use regulatory instruments (command and control approaches, standard and charges approaches) to control NPS pollution due to the large number of sources and diffuse entry points (Dosi and Zeitouni, 2001; Shortle and Horan, 2002; Shortle and Abler, 1997). It is also difficult to monitor discharges by individuals at a reasonable cost. In the case of groundwater, there is also the problem of accumulation of pollutants over time. 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.

## 3. LITERATURE REVIEW

Contingent valuation studies focused on either estimation of benefits of groundwater quality protection as a source of drinking water in general,[3] or estimation of benefits of reduction of nitrate in groundwater in particular[4] are mostly concerned with the amount that the beneficiaries are willing to pay to protect groundwater from nonpoint sources of pollution rather on the factors influencing their contingent behaviour.

Studies conducted by Napier and Brown (1993), Elnagheeb et al. (1995) and Nielson et al. (2003) give importance to the factors which influence either willingness to pay or willingness to protect groundwater quality from NPS pollution.

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[3] Mostly from the deep aquifers fitted with power pumps, mini power pumps and/or bringing water from the Bhavani River either directly or indirectly from infiltration wells. Dual water supply systems are also in operation in some regions.

Napier and Brown (1993) report that farmers who believe that pesticides and fertilisers in groundwater pose a threat to family health tend to perceive that groundwater pollution is an important environmental issue. The farmers are also more willing to force land operators to adopt groundwater protection practices. Authors argue that farm structure factors are less useful as compared to social learning factors in predicting attitudes toward groundwater protection.

Elnagheeb et al. (1995) studied the Georgia farmers' perceptions of groundwater pollution and their preferences for actions to protect groundwater. Results show that farmers who got more information from external sources (such as universities, agricultural extension agents, and TV) were more supportive of regulatory policies on fertilisers and pesticides. Authors report that farmers' knowledge about environmental impacts of agricultural practices of their own farm is poor and farmers act to guard their self-interest. If the farmers perceive that changes in practices to protect groundwater quality would lower net farm income, they become reluctant to support such a policy. If the adoption of practices to protect groundwater involves high costs, farmers who are under financial stress or debt become reluctant. Farmers who use their own well water for drinking and not sure about the safety and purity of the well water are more supportive. If the farmers perceive any risk from water consumption, they become supportive to adopt practices to protect groundwater.

Nielson et al. (2003) argue that knowledge of socio-demographic factors affecting attitudes and perceptions of risk is an important instrument in enhancing efficiencies of interventions. They found that socio-demographic factors like gender, education, place of residence and age influence individual's attitude to an environmental issue (securing future drinking water) and the extent to which individuals are willing to allocate present resources to alleviate a future problem.

Bergstrom et al. (2001), Boyle et al. (1994), and Poe and Bishop (2001) argue that in the absence of objective information, people form subjective perceptions about their water quality. Subjective perceptions of water quality are influenced by socio-economic background of the people and their access to general and specific information on water quality. General Information (GI) specific to groundwater nitrate contamination can be defined as the information related to sources of nitrates in groundwater, government standards, opportunities for mitigation, and the costs of adoption of those mitigation measures etc. Information that is specific to household's exposure to groundwater nitrate pollution - e.g., nitrate levels found in an individual's well or overall groundwater quality of the village - can be defined as Specific Information (SI). Based on socio-economic characteristics, and access to information, both general and specific information on water quality helps the households to draw a subjective assessment about water quality which mostly influences their willingness to adopt protection measures either individually (point of use purification of water) or collectively (protection of drinking water sources or willingness to support local government to set up community water treatment plant).

Ready and Henken (1999) demonstrate that a well owner's optimal self-protection from nitrate contaminated groundwater is subject to his/her subjective probability risk perceptions that the well is contaminated, which is supported by regular well test results. They show that in Kentucky, USA optimal self-protection could reduce a well owner's expected damage from nitrate contamination by 38%.

Bosch and Pease (2000) argue that producer's and consumer's risk perceptions and preferences can affect perceived costs and benefits of adoption of water quality protection measures. Uncertainty about pollution damages to water resources is likely to increase the perceived benefits of a given quantity of water quality protection practices. Public policies to reduce uncertainty about the costs and benefits of water quality protection practices may produce net social benefits.

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[4] For example, see Bergstrom and Dorfman, 1994; Caudill and Hoehn, 1992; Jordan and Elnagheeb, 1993; McClelland et al., 1992; Powell et al., 1994; Schultz and Lindsey, 1990; Sun et al., 1992; Stenger and Willinger, 1998; Lichtenberg and Zimmerman, 1999; and Boyle et al., 1994.

[5] For example, see Crutchfield et al., 1997; Edwards, 1988; Poe, 1998; Poe and Bishop, 1999; 2001; Epp and Delavan, 2001; Walker and Hoehn, 1990; Hanley, 1989.

Successful risk assessment and risk communications to the stakeholders is important to induce them to adopt measures to protect groundwater quality. Fessenden-Raden et al. (1987) argue that risk communication is neither simply one-way transfer of information nor it is a single or discrete event, but a process involving interactions over time between senders and receivers of information about a risk (vulnerability). Taking account of socio-economic characteristics, concerns and priorities of the information recipients are important aspects towards successful risk communication.

How effective provision of scientific information related to groundwater quality (laboratory water test results) could be to make farmers understand the prevailing groundwater quality situation in the sample villages – is a serious question. It is difficult for individual farmers to understand the scientific information related to nitrate concentration in their drinking water, due to lack of education, environmental awareness and also due to the fact that presence of nitrate does not change any perceptible characteristics of drinking water, like taste, colour, odour etc. On the contrary, testing of individual well for possible nitrate contamination and intimation of test results during questionnaire survey will not reveal the actual groundwater quality scenario prevailing in the village, as groundwater quality is dynamic process which varies over time and space. Therefore, instead of providing sample household specific nitrate concentration in drinking water we have provided general groundwater nitrate situation prevailing in the basin along with the sources of groundwater nitrate pollution and possible health hazards of consuming high nitrate contaminated drinking water.

## 4. CONCEPTUAL FRAMEWORK

Researchers argue that unless farmers foresee any positive distinctive private economic benefits in the adoption of environmentally benign agricultural practices, they will not adopt any of those practices to protect resources (groundwater) which is mostly under open access regime. Unlike other natural resources which fall under local common pool resources (like forestry, fisheries, grazing land, and irrigation water), private benefits of protecting groundwater are not distinct and cannot be parceled out to individuals involved in conservation. Since in India, groundwater falls mostly under free access regime and some of the services it provides have characteristics of a public good, farmers will not incur any private costs to ensure public benefits (safe drinking water).

Unlike in developed countries where small number of farmers having large land holding size and homogeneous cropping pattern, in developing countries like India, a large number of farmers having small land holding size and heterogenous cropping pattern dominate. In developed countries farmers are provided with economic incentives (conservation reserve program, countryside stewardship program etc.) to protect groundwater for comparatively large urban and semi-urban consumers. Therefore, polluter and victim (consumer) difference is distinct in developed countries and consumers' willingness to pay is often studied instead of polluters willing to pay (incur costs) to protect groundwater from farming activities. But in India, the difference between polluter and victim (consumer) is not clear, as the polluters (farmers) themselves are victims (consumers of groundwater). Therefore, we have treated individual farmers as consumer and not as producer and have studied their willingness to pay (incur costs) in terms of adoption of BMPs to protect groundwater. Our argument is that farmers will adopt environmentally benign farm practices to protect groundwater provided they perceive that their groundwater and drinking water is polluted and that could pose health hazards or risk to his/her own and family members. Farmers perceptions about groundwater and drinking water quality and possible health hazards are important which could influence their willingness to adopt measures to protect themselves individually (point of use purification) or collectively (groundwater protection or community water treatment plant).

Firstly, following Elnagheeb et al. (1995), Napier and Brown (1993) and Nielsen et al., (2003), factors influencing farmers' perceptions about groundwater and drinking water quality have been captured. In the second stage factors influencing the farmers' willingness to protect groundwater quality and willingness to support local government to supply safe drinking water have been captured through binary choice Probit models (Greene, 2003; Long, 1997). The underlying conceptual framework is as follows:

Following Hanemann's (1984) random utility framework, individual j's utility function can be written as:

$$U_j = U_j(Q_j, Y_j \mid H_j)$$

where

$U_j(.)$: utility function of j^th household
$Q_j$ : groundwater / drinking water quality of j^th household
$Y_j$ : income of j^th household
$H_j$ : socio-economic characteristics of j^th household

Since the above utility function is unobservable to us, we estimate it as follows:

$$V_j = V_j(Q_j, Y_j \mid H_j) + \varepsilon_j$$

where, e is the error term, and e~N(0,1)

Following Boyle et al., 1994 and Bergstrom et al., 2001, individual j's estimated utility function can be written as:

$$V_j(Q_j(GI_j, SI_j), Y_j \mid H_j) + \varepsilon_j$$

$$V_j(Q_j^1(GP_j^1, SP_j^1), Y_j \mid H_j) + \varepsilon_j^1 \text{ and } V_j(Q_j^0(GP_j^0, SP_j^0), Y_j \mid H_j) + \varepsilon_j^0$$

where

$V_j(.)$ : estimated utility function of j^th household

$Q_j(.)$ : in absence of actual (objective) groundwater /drinking water quality information, j^th household forms a *subjective perceptions* about its water quality based on the access to *specific* and *general information*

$GI_j$: *general information* of j^th household

$SI_j$: *specific information* of j^th household

General Information (GI) are related to possible health effects and sources of nitrates in groundwater, government standards, opportunities for mitigation, costs of mitigation etc.

Specific Information (SI) are specific to household's exposure to groundwater nitrate pollution, includes nitrate levels found in an individual's well or overall groundwater quality of the village.

$Q_j^1 = Q_j^1(GI_j^1, SI_j^1)$ is j^th household's *subjective perceptions* about groundwater/ drinking water quality when it takes mitigation measures or adopts environmentally benign agricultural practices to protect groundwater quality

$Q_j^0 = Q_j^0(GI_j^0, SI_j^0)$ is j^th household's *subjective perceptions* about groundwater/ drinking water quality when it does not take mitigation measures or adopt environmentally benign agricultural practices to protect groundwater quality.

The probability that whether j[th] household will adopt agricultural practices or mitigation measures to protect groundwater quality or whether it will support local government to supply drinking water from alternative safe sources, can be written as:

$$\begin{aligned}
Prob(Yes=1) &= Prob(V_j(Q_j^1(GI_j^1, SI_j^1), Y_j - OP_j \mid H_j) + \varepsilon_j^1 \geq V_j(Q_j^0(GI_j^0, SI_j^0), Y_j \mid H_j) + \varepsilon_j^0) \\
&= Prob(\varepsilon_j^0 - \varepsilon_j^1 \leq (V_j(Q_j^1(GI_j^1, SI_j^1), Y_j - OP_j \mid H_j) - V_j(Q_j^0(GI_j^0, SI_j^0), Y_j \mid H_j)) \\
&= Prob(\eta_j \leq \Delta V_j) = \Phi_\eta(\Delta V_j)
\end{aligned} \quad (2)$$

where $\eta_j = \varepsilon_j^0 - \varepsilon_j^1$ and $e_j$s are iid, $e_j$~N(0,1)

Öh(.) is the standard normal cumulative density function of h

Where V = k(GI, SI, Y, H) for all j, and we estimate function k(.) through binary choice Probit and multinomial logit models.

$OP_j$ represents individual j's cost of adoption of measures which could reduce the probability of groundwater contamination (e.g., agricultural practices to protect groundwater quality) and/or costs of averting practices (point-of-use purification or contribution to local government to supply water from alternative safe sources) or costs of mitigation of exposures to polluted groundwater e.g., costs of regular community monitoring of groundwater quality.

Prob (Yes) represents the probability that individual household will adopt - (a) measures to protect groundwater quality; (b) mitigation measures in terms of taking up regular monitoring of groundwater quality (individual or community monitoring); (c) averting practices such as installing individual home water filter; and/or (d) support local government to supply water from alternative sources or setting up community water treatment plant.

## 5. METHODOLOGY AND DATA SOURCES

This study is based on both primary and secondary information collected from various sources.

### 5.1 Secondary Sources of Information

To understand the spatial, temporal and seasonal variations of groundwater nitrate concentration in the Lower Bhavani River Basin, secondary groundwater quality information (time series and cross section) have been collected from the Tamil Nadu Water Supply and Drainage (TWAD) Board, Chennai and analysed to identify "Nitrate Hot Spots" in the Basin. Information related to drinking water sources and access to drinking water was collected from the Rural Water Supply Division of the TWAD Board, Erode. Population and other demographic details were collected from the Regional Census office at Chennai.

### 5.2 Primary Household Questionnaire Survey

#### *5.2.1 Characteristics of the Sample Villages*

To capture the spatial variations across the basin, we have selected six villages on the basis of their sources of irrigation and long-term groundwater nitrate concentration. Among the 6 villages two are from the LBP command area – Elathur (ELA) at the head reach of the LBP canal and Kalingiam (KAL) at the middle reach of the LBP 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 are – Madampalayam (MDP) and Kembanickenpalayam (KNP) (**Location Map** in **Appendix A**). Apart from surface water sources, groundwater is also used extensively for irrigation in the study villages.

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).

Appakoodal (APP), Kembanickenpalayam (KNP) and Madampalayam (MDP) are highly polluted with more than 50% of the regular observation wells' samples taken by TWAD Board during May 1991 to May 2005 having $NO_3$ concentration more than 50 mg/l. Elathur (ELA), Kalingiam (KAL) and Kondayampalayam (KDP) were moderately affected with less than 25% of the regular observation wells' samples have $NO_3$ concentration more than 50 mg/l (Table 1).

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 |
| Kembanickenpalayam (KNP) (Town Panchayat) | Small dam, groundwater (open wells and bore wells) & river pumping | 47.9 | 0 – 106 | 50.0 | 4.5 |
| Madampalayam (MDP) (Village Panchayat) | Mostly rain fed and ground-water (open wells and deep bore wells) | 128.7 | 0 – 320 | 77.3 | 54.5 |
| Elathur (ELA) (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 ground-water (open wells and deep bore wells) | 24.3 | 0 – 134 | 13.0 | 4.3 |
| Kondayampalayam (KDP) (Village Panchayat) | The Arakkankottai canal and groundwater (open wells and deep bore wells) | 49.7 | 2.7 - 115 | 44.0 | 4.0 |
| Appakoodal (APP) (Town Panchayat) | The Bhavani River and groundwater (open wells and deep bore wells) | 50.0 | 10 – 105 | 53.8 | 3.8 |

*Source:* Census of India 2001; TWAD Board, Chennai and Primary Survey

### *5.2.2 Sampling Criteria*

A pre-structured questionnaire survey was administered to 395 farm households spread across the six villages in the basin during June to July 2006. The survey involves collection of both quantitative and qualitative information from the sample households. We followed the random sampling procedure to select the sample households from the nitrate-affected villages. Since stratification requires at least any one of the criteria - background nitrate concentration of drinking water of individual households, income of the households, land holding size etc., which are absent at present at the household level from the secondary sources.

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 participations of the farm households were sought for interviews, based on their availability of time. We have conducted face-to-face interviews with the head of the farm-household. Both the information leaflet and questionnaire were translated into Tamil, and a background of the objectives, scope and coverage of this study were described before starting the interviews.

The questionnaire was designed to include both qualitative and quantitative information to capture the farmers' perceptions about groundwater and drinking water quality, factors influencing farmers' willingness to protect groundwater quality from agricultural nonpoint sources of pollution and their willingness to support local government to supply safe drinking water. Socio-economic background, sources of agricultural information/ consultation /membership in participatory social institutions, willingness to adopt Best Management Practices (BMPs), existing agricultural and farm-management practices, details of crops and chemical use, animal waste management practices and access to sewage and sanitation were collected.

#### *5.2.3 Basic Sample Characteristics*

Our sample households (395) constitute 3% of the total households (13,278) of the selected villages according to 2001 Population Census, which varies from 2.3% in Appakoodal to 6.2% in Madampalayam (Table B.1 in Appendix B). Our sample population constitute 3.4% (2.6 to 6.9) of the total population of the villages. Average family size is 4.2, which is comparatively higher than population census figures.

The sample households hold 695.01 hectare of agricultural land which is 12.4% of total agricultural land of our study villages (5592.3 hectare), which varies from 8.2% in Elathur to 25.7% in Kondayampalayam. Total cropped area as a percentage of total geographical area varies from 56% in Appakoodal to 92% in Madampalayam, with an average 69%. Average land holding is 1.8 hectare which varies from 1.2 hectare for APP to 2.6 hectare for KDP (Table B.1 in Appendix B). A list of descriptive statistics is provided in Table B.2 and Table B.3 of Appendix B.

## 6. BASIC FINDINGS

### 6.1 Secondary Data Analysis

#### *6.1.1 Sources of Drinking Water*

Deep bore wells fitted with mini power pump (MPP) and power pump (PP), serve as the major sources (> 86%) of drinking water under the centralised drinking water system across the rural habitations in the basin. Since the local panchayats are not equipped to test water quality, taking curative measures are overruled; as a result people get unmonitored and unregulated quality of drinking water. Only 12% of the habitations get drinking water from surface sources, which is comparatively safe with respect to nitrate concentration.

#### *6.1.2 Access to Drinking Water*

Access to drinking water varies significantly across the blocks in the basin. Access to 40 litre of water per person per day (lpcd) is considered as the basic minimum requirement (UNDP, 2006). A large part of the basin, the rural population still do not have access to basic minimum amount of safe drinking water. When access is meagre and quality of drinking water is unmonitored and unregulated, population becomes vulnerable to various water-borne diseases. Pollution from agricultural nonpoint sources makes it more difficult to supply safe drinking water to all the rural habitations.

#### *6.1.3 Groundwater Nitrate Pollution in the Lower Bhavani River Basin – Status*

<u>TWAD Board's Hand Pump Data: 2001-2002</u>

Out of 3,129 groundwater samples (hand pumps) tested in the Basin during 2001-2002, 1,305 samples (approximately 41.7%) had nitrate concentration greater than 50 milligram per litre (mg/l). Of which 8.9% of the samples had nitrate concentration more than 100 mg/l. Out of 12 blocks in the basin, 4 blocks had average nitrate concentration more than 50 mg/l, which shows that in several pockets of the basin groundwater (drinking water sources) are polluted.

TWAD Board's Power Pump Data: 2001-2002

Out of 1,217 groundwater samples from bore wells and open wells fitted with power pump and mini power pump, 437 samples (35.9%) had nitrate concentration more than 50 mg/l which confirms that deep aquifers is also polluted in several pockets in the basin.

TWAD Board's Regular Observation Wells Data: May 1991 to May 2005

Data analysis shows that - a) post-monsoon average nitrate concentrations are higher than pre-monsoon average concentrations, which show that nitrate leaches to the groundwater during rainy seasons and b) different blocks are affected by different level of groundwater nitrate contamination, Karamadai, Bhavanisagar and Erode blocks are highly polluted.

## 6.2 Primary Household Questionnaire Survey

### *6.2.1 Sources of Drinking Water*

In study villages 27.95% (11.62% in KAL to 60.29% in KNP) of the sample households depend on their open wells to meet drinking water needs. Only 49% of the households are covered with supplied water, either through house connection (only 10.53%) or through stand posts (38.5%). Table 2 shows that 50% of our sample households depend on groundwater (shallow or deep) to meet drinking water needs. More than 82% of the households in Kembanickenpalayam depend on groundwater for their drinking water. Though it is a Town Panchayat, it cannot supply drinking water through supply network due to sparsely settled population and inadequate supply network. Since Appakoodal has its Independent Water Supply Scheme (IWSS), which draws water from the Bhavani River (1.6 million litre per day), as a result the dependence on groundwater as a source of drinking water is comparatively less, 23%. However, almost 5% of households are dependent on water tanker

Table 2: Sources of Drinking Water (in Percentage of Sample Households)[@]

| Village Name | Own Hand Pump (sdwohp) | Own Power Pump (sdwohp) | Own Open Well (sdwohp) | Supply Water – House Connection (sdwohp) | Supply Water – Sand Post (sdwohp) | Public Hand Pump (sdwohp) | Community Well (sdwohp) | Water Tanker (sdwohp) | Number of Respondents (sdwohp) |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Appakoodal (APP) | 0.00 | 3.59 | 19.74 | 0.77 | 71.28 | 0.00 | 0.00 | 4.62 | 65 |
| Elathur (ELA) | 2.43 | 16.20 | 23.26 | 14.93 | 36.69 | 2.08 | 4.40 | 0.00 | 72 |
| Kalingiam (KAL) | 31.06 | 1.52 | 11.62 | 36.36 | 0.00 | 14.14 | 2.78 | 2.53 | 66 |
| Kembanickenpalayam (KNP) | 2.21 | 18.38 | 60.29 | 0.00 | 17.65 | 0.00 | 1.47 | 0.00 | 68 |
| Kondayampalayam (KDP) | 1.30 | 11.72 | 32.03 | 9.11 | 42.71 | 2.08 | 1.04 | 0.00 | 64 |
| Madampalayam (MDP) | 3.89 | 8.89 | 19.44 | 0.83 | 66.39 | 0.56 | 0.00 | 0.00 | 60 |
| **All Villages** | **6.81** | **10.21** | **27.95** | **10.53** | **38.46** | **3.16** | **1.69** | **1.18** | **395** |

*Note:* [@] - implies adjusted for multiple responses
*Source:* Primary Survey

provided by the local industry, as they are not covered under centralised drinking water network.

*6.2.2 Farmers' Perceptions about Groundwater and Drinking Water Quality*

Respondents were asked to rank their drinking water quality according to their perceptions. A five point Likert-type scale was constructed on the basis of five categories of perceptions, viz., very good (5), good (4), fair (3) bad (2) and very bad (1). The average drinking water quality scores with respect to the farmers' perceptions are presented in Table 3 into three categories, viz., drinking water quality of supplied water (DWQSW) - where both house connection and sand post are taken into consideration, drinking water quality of their own sources (DWQOS) - which covers own hand pump, power pump, open well; and drinking water quality of public hand pump (DWQPHP). The average score of supplied water quality is 3.9 (3.6 - 4.0), which implies that supplied water quality lies in between fair (3) to good quality (4). However in four out of six villages some farmers also reported that drinking water quality is bad (2), for example in Appakoodal – 72% and Madampalayam – 67% of the respondents though are dependent on supplied water, still their water quality satisfaction is not that much higher than the average (84 percent, Col. 6 in Table 3). Average score of own source drinking water quality varies from 2.9 to 3.9, which implies that it lies between bad (2) to good quality (4), depending on the place of residence. For example, in Kembanickenpalayam 66% of the respondents collect water from alternative sources as their own sources of drinking water are polluted (CLCTWAT). On an average 46% of the respon-

Table 3: Farmers' Perceptions about Drinking Water Quality

| Village Name | Drinking Water Quality of Supplied Water (dwqsw) * | Drinking Water Quality of Own Source (dwqos)* | Drinking Water Quality of Public Hand Pump & Public Wells (dwqphp)* | Percentage of Respondents Collect Water as their Own Source(s) of Drinking Water is Polluted (clctwat) | Percentage of Respondents are Satisfied with their Drinking Water Quality (wqs) | Percentage of Respondents think their Groundwater Quality is Polluted (gwqp) |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Appakoodal | 3.9 (2 - 4) | 2.9 (2 - 4) | —- | 42 | 85 | 43 |
| Elathur | 3.8 (3 - 5) | 3.2 (2 - 4) | 2.5 (2 - 4) | 54 | 81 | 25 |
| Kalingiam | 3.9 (2 - 4) | 3.9 (2 - 5) | 3.8 (3 - 4) | 21 | 100 | 8 |
| Kembanickenpalayam | 3.6 (2 - 5) | 3.4 (1 - 5) | 3.5 (2 - 5) | 66 | 60 | 44 |
| Kondayampalayam | 4.0 (3 - 5) | 3.8 (2 - 4) | 5.0 (5 - 5) | 30 | 92 | 11 |
| Madampalayam | 3.9 (2 - 4) | 3.0 (2 - 4) | —- | 46 | 84 | 28 |
| All Villages | 3.9 (2 - 5) | 3.4 (1 - 5) | 3.3 (2 - 5) | 46 | 84 | 28 |

*Note:* *-Respondents were asked to rank their drinking water quality according to their perceptions into five Likert-type scale, e.g., very good =5, good quality =4, fair=3, bad quality = 2, and very bad=1.

Figures in the parenthesis show the range for the corresponding average value

*Source:* Primary Survey

dents collect water, as their own drinking water sources are not potable.

Through four different questions we attempt to capture individual farmers' perceptions (subjective) about groundwater and drinking water quality. An agreement with the second question and disagreement with the other questions as shown in Table 4, show that water quality is polluted according to the farmers' perceptions. On an average 84% of the sample households are satisfied with their drinking water quality (WQS), and on an average only 28% of the sample households think that their groundwater quality is polluted (GWQP). However, in case of APP, KNP and MDP more than 40% of the sample households responded affirmatively to ground water quality being polluted. On an average 45% of the households collect water as their own source(s) of drinking water is polluted. In case of ELA, though it is moderately polluted, 54% of the sample households collect water due to water quality problem. In KNP and MDP, more than 60% of the households collect water. In APP, 43% of the sample households collect water, which goes against the actual groundwater quality perceptions as revealed to us. It is mainly due to the fact that respondents are sceptical to reveal the actual groundwater quality situation to us for the fear of intimidation from the local industry. Farmers' perceptions vary significantly across the study villages.

On an average 24% of the sample households purify water after collection for drinking and cooking purposes. In KAL only 8% and KNP 34% of the households purify water. Table 5 shows that after adjustment for multiple responses, 14% of the households boil water. However, boiling water further increase the concentration of nitrate, and is not recommended. Using plain cloth and candle type filter cannot remove nitrate

Table 4: Farmers' Perceptions about Water Quality

| Criteria | APP | ELA | KAL | KNP | KDP | MDP | ALL | F-stat |
|---|---|---|---|---|---|---|---|---|
| Do you think groundwater quality is polluted? (GWQP) (1 if 'Yes', 0 otherwise) | 0.43 | 0.25 | 0.08 | 0.44 | 0.11 | 0.40 | 0.28 | 9.5638* |
| Are you satisfied with your drinking water quality? (WQS) (1 if 'Yes', 0 otherwise) | 0.85 | 0.81 | 1.00 | 0.60 | 0.92 | 0.88 | 0.84 | 10.2054* |
| Do you collect water due to quality problem of your own drinking water source? (CLCTWAT) (1 if 'Yes', 0 otherwise) | 0.42 | 0.54 | 0.21 | 0.65 | 0.30 | 0.60 | 0.45 | 8.7589* |
| Do you purify/treat water after collection for drinking and cooking purposes? (PURIWATR) (1 if 'Yes', 0 otherwise) | 0.18 | 0.26 | 0.08 | 0.34 | 0.27 | 0.28 | 0.24 | 3.2172* |

*Note:* * - implies F-stat for mean equality test across the villages is significant at 0.01 level (2-tailed)
*Source:* Primary Survey

Table 5: Farmers' Water Purification Practices (in percentage of total number of sample farmers)

| Methods of Water Purification | APP | ELA | KAL | KNP | KDP | MDP | ALL |
|---|---|---|---|---|---|---|---|
| Filter - Plain Cloth (Y=1, N=0) | 5 | 12 | 2 | 11 | 0 | 7 | 6 |
| Boil Water (Y=1, N=0) | 10 | 14 | 4 | 21 | 25 | 11 | 14 |
| Water Filter - Candle Type (Y=1, N=0) | 3 | 0 | 2 | 1 | 2 | 11 | 3 |
| Water Filter - Others (Y=1, N=0) | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Chemical Treatment (Chlorination, Camphor, Alum, Lime etc.) (Y=1, N=0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No Purification (in %) | 82 | 74 | 92 | 66 | 73 | 72 | 76 |

*Source:* Primary Survey

from water.

Since different agricultural practices have different implications for groundwater quality, farmer's perceptions about agricultural practices and their impacts on groundwater quality have been captured through a set of variables where the farmer's responses are categorized into four groups, i.e., agree, disagree, undecided (neither agree nor disagree) and no response. Using Principal Component Analysis method of Factor Analysis, composite indices are constructed to capture farmer's perceptions on different aspects of nonpoint source groundwater pollution (e.g., BPERCEPT, AGRIPRAC, PROENV).

## 7. RESULTS

### 7.1 Factors Influencing Farmers' Perceptions about Groundwater Quality

To understand the farmers' perceptions about groundwater water quality of their area, in primary questionnaire survey the respondents were asked to reveal their opinion for the following binary choice question:

*Do you think groundwater quality is polluted? (GWQP)*

GWQP = 1 if "Yes"

*0 otherwise*

On an average only 28 per cent of the sample households think that their groundwater quality is polluted (GWQP), which varies significantly across the villages from minimum 8 per cent in KAL to maximum 44 per cent in KNP. In case of APP, KNP and MDP more than 40 per cent of the sample households responded affirmatively for GWQP.

To understand the factors influencing farmers' subjective risk perceptions about groundwater quality (GWQP), binary choice Probit models are estimated following the econometric specification as follows:

$$\Pr ob(GWQP = 1) = \Phi(x'\beta)$$

where, $\Phi$ is the cumulative distribution function of the standard normal distribution, and

$$x'\beta = \beta_0 + \beta_1 age + \beta_2 edu + \beta_3 eap + \beta_4 bpercept + \beta_5 agriprac + \beta_6 lpclandh + \beta_7 fagr\inf o$$
$$+ \beta_8 childn + \beta_9 knowbmp + \beta_{10} proenv + \beta_{11} sdwoow + \beta_{12} sdwopp + \beta_{13} sdwshc + \beta_{14} sdwssp$$
$$+ \beta_{15} dwqos + \beta_{16} dwqphp + \beta_{17} dwqsw + \beta_{18} app + \beta_{19} knp + \beta_{20} mdp$$

The results show that apart from various socio-economic characteristics of the respondent and his/her household, the characteristics of the natural resource of our concern (groundwater) - captured through various dummy variables, e.g., sources of drinking water, drinking water quality and village dummy – significantly influence the perceptions (see Table C.1 and Table C.2 in Appendix C).

Households with larger per capita landholding (lpclandh) are more likely to perceive that their groundwater quality is polluted. Per capita land holding is a measure of household's income, which shows that higher income households perceive greater risk of groundwater pollution (gwqp). Farmers having knowledge about impacts of agricultural practices on groundwater quality (agriprac) are more likely to perceive that their groundwater quality is polluted. Farmers' knowledge about agricultural and environmental best management practices (knowbmp) positively influences their perceptions. However, farmers who have latrine, use bio-fertilisers, practice organic farming, and have biogas plants - as defined as pro-environment farmers (proenv) - are less likely to accept that their groundwater quality is polluted. Irrespective of sources of drinking water, farmers perceive that their groundwater quality is polluted. Farmers having access to better drinking water quality from either their own sources (i.e., own open well, own hand pump and own power pump) or water supply sources (house connection and stand posts) are less likely to perceive that their groundwater is polluted. Households having higher number of children, less than 5 years of age, are less likely to accept that their groundwater quality is polluted. Sample households from comparatively highly nitrate affected villages, viz., APP, KNP and MDP, are more likely to accept that their groundwater quality is polluted, the opposite is true for other villages, viz., ELA, KAL and KDP. The results show that farmers' subjective perceptions about groundwater quality mimic the actual groundwater nitrate situation of the villages.

### 7.2 Factors Influencing Farmers' Perceptions about Drinking Water Quality

To understand the farmers' perceptions about drinking water quality of their own sources, in primary questionnaire survey the respondents were asked to reveal their opinion for the following binary choice question:

*Do you collect water due to quality problem of your own drinking water source? (CLCTWAT)*

*CLCTWAT = 1 if "Yes"*
*0 otherwise*

On an average 45 per cent of sample households collect drinking water as their own sources are polluted. The percentage varies significantly across the villages, from minimum 21 per cent in KAL to maximum 65 per cent in KNP.

To understand the factors influencing farmers' perceptions about drinking water quality of their own sources, binary choice Probit models are estimated (Table C.3 and C.4 in Appendix C). The results show that:

- Farmers' perceptions about groundwater quality positively influence their decision to collect drinking water. Collection of drinking water from alternative sources and purification of water are the major coping mechanisms adopted by the households. Farmers who purify drinking water are more likely to collect water as their own sources are polluted.
- Irrespective of sources of drinking water, farmers agree that they collect water as their own sources are polluted. Farmers who are satisfied with their own drinking water quality are less likely to collect water from alternative sources
- Households having higher number of children (less than 5 years of age) and more economically active persons are less likely to collect water. Therefore, those families are more vulnerable to groundwater pollution, as they don't collect water from alternative safe sources.
- Sample households from KNP and MDP are more likely to collect water as their own sources are polluted. In ELA, households collect water because access to safe drinking water is limited.
- Farmers from KAL and KDP are less likely to collect water, as their own source(s) of drinking water comparatively are less polluted. In APP, households collect drinking water from stand posts as their own sources are polluted; however due to fear of facing intimidation from the local industry, households are sceptical to reveal that to us.

### 7.3 Factors Influencing Farmers' Willingness to Protect Groundwater Quality

To capture farmers' willingness to protect groundwater from nonpoint sources of pollution, in primary questionnaire survey the respondents were asked to reveal their opinion for the following binary choice question:

*Since groundwater is a major source of drinking water in this area, it should be protected from agricultural chemicals (WTPGWQ)*

*WTPGWQ = 1 if "Yes"*
*0 otherwise*

On an average 56% of the respondents revealed that they are willing to protect groundwater as a source of drinking water. Willingness to protect varies significantly across the villages, minimum 38% in KAL and KDP to maximum 78% in KNP.

To understand the factors influencing farmers' willingness to protect groundwater quality from agricultural nonpoint sources (WTPGWQ), following the theoretical model as developed in equation (2), we have estimated binary choice Probit models using the following econometric specification:

$$\Pr ob(WTPGWQ = 1) = \Phi(x'\beta)$$

where, $\Phi$ is the cumulative distribution function of the standard normal distribution, and

$$x'\beta = \beta_0 + \beta_1 age + \beta_2 edu + \beta_3 eap + \beta_4 bpercept + \beta_5 agriprac + \beta_6 fmember + \beta_7 fagr\inf o$$
$$+ \beta_8 app + \beta_9 knp + \beta_{10} mdp$$

The results (see Table C.5 and C.6 in Appendix C) show that:

- Farmers having better knowledge about impacts of agricultural practices on groundwater quality (agriprac) are willing to protect groundwater from nonpoint sources
- Farmers who are staying for long time in the sample villages and having larger per capita land holding are reluctant to protect groundwater quality
- Farmers' membership in participatory social institutions (e.g., Cooperative Milk Producers' Association, Farmers' Association etc.) positively influences their WTPGWQ, whereas sources of agricultural information (fagrinfo) negatively influence WTPGWQ across all the villages. However, when the model is corrected for the presence of heteroskedasticity, fagrinfo shows positive relationship with WTPGWQ for ELA, KAL and KDP.
- Farmers having knowledge about agricultural best management practices and their environmental impacts (benefits) are more likely to protect groundwater quality
- In all comparatively nitrate affected villages (APP, KNP and MDP), farmers' are willing to protect groundwater quality, whereas in other villages farmers are reluctant to protect groundwater quality.

## 7.4 Factors Influencing Farmers' Willingness to Support Local Government to Supply Safe Drinking Water

To capture farmers' willingness to support (WTS) local government to supply safe drinking water (demand for safe drinking water) through alternative arrangements, in primary questionnaire survey the respondents were asked to reveal their opinion for the following binary choice question:

*Since you collect drinking water due to quality of your own drinking water sources are problematic, will you support local government to supply water from alternative safe sources or to set up state-of-the-art water treatment plant, by contributing, supporting and taking initiative? (WTSGOVCW)*

$$WTSGOVCW = \begin{cases} 1 \text{ if Yes} \\ 0 \text{ otherwise} \end{cases}$$

The results show that on an average 38% (minimum 20% in KAL to maximum 58% in MDP) of the sample farmers are willing to support local government, which varies significantly across the sample villages.

To understand factors influencing farmers, binary choice Probit models are estimated. The results (see Table C.7 in Appendix C) show that:

- Irrespective of sources of drinking water, farmers are willing to support local government in terms of initiatives and contribution to supply safe drinking water
- Farmers having access to relatively good quality drinking water are reluctant to support the local government. Farmers' perceptions about their groundwater quality influence their WTS, and the households who purify water are also WTS.
- Households from APP, KAL and KDP are less likely to support government, as their own sources of groundwater quality are comparatively less polluted (KAL and KDP) or they already have good access to supplied water (APP).
- Households from ELA, KNP and MDP are willing to support government, as their own sources of drinking water is comparatively polluted (KNP and MDP), and they want to improve the access to supplied water (ELA).

## 8. CONCLUSIONS AND POLICY IMPLICATIONS

In many parts of India, intensive agricultural activities are mostly supported by excessive and unbalanced application of nitrogenous fertilisers, resulting in nonpoint source groundwater pollution. Apart from fertilisers, unlined and open storage of animal wastes and open defecation and urination has led to high concentration of nitrate in the groundwater. Protection of groundwater quality from nonpoint source pollution is crucial for sustainable access to safe drinking in rural areas. Since 90% of rural population depends on groundwater for drinking purposes, protection of groundwater will be the first step towards ensuring water security to the rural populace. Large-scale community participation is required to protect groundwater from quantitative depletion and qualitative degradation. Collective action in the adoption of agricultural best management practices is required for sustainability of safe sources of drinking water.

In India water supply authorities mostly prefer curative measures (e.g., *ex post* treatment) at a higher incremental cost of water supply from alternative safe sources as compared to precautionary measures (e.g., *ex ante* protection of drinking water sources), as a result demand for investment in infrastructure to supply drinking water to rural populace is growing astronomically. For example, Government of India (GoI)'s allocation of fund under Accelerated Rural Water Supply Programme (ARWSP) alone has gone up from Rs. 1299.91 crore in 1997-98 to Rs. 4816.66 crore in 2006-07, which shows 271% increment. GoI allocated Rs. 1039.98 crore to states during 2006-07 to tackle water quality related problems under ARWSP, which is 21.6% of total allocation of fund to states under ARWSP. According to the estimate released by the Rajiv Gandhi National Drinking Water Mission (RGNDWM) on 31$^{st}$ March 2004, in India 13,958 habitations are affected by drinking water nitrate pollution (RGNDWM, Personal Communication).

Unlike developed countries, developing countries like India cannot afford (technically and financially) to rely solely on curative measures; therefore it should protect drinking water sources by controlling pollution from all possible sources. Since, groundwater is a major source of drinking water, protection of groundwater quality from agricultural NPS should be an integral part of environmental management programmes to meet the demand for safe drinking water at a reasonable cost.

In the Lower Bhavani river basin in Tamilnadu, incidence of growing concentration of nitrate in the groundwater shows that environmental sustainability of safe drinking water sources is at stake. Similar situations also prevail in several other parts of India and other developing countries.

This study tries to understand (in *ex ante*) individual farmer's willingness to protect groundwater and the factors which influence his/her individual decision. 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. The results 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 in Appakoodal and Kembanickenpalayam, 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.

## 9. LIMITATIONS OF THE STUDY

The present study is based on individual's response, therefore it cannot predict with certainty what will be the collective initiative to protect groundwater quality or the adoption of agricultural BMPs

Ex ante this study cannot predict with certainty –

- What will be the actual adoption of groundwater protection measures by individuals?
- How many farmers will practically implement it and what will be the intensity of adoption? and
- What will be the actual impact of the adoption of measures on groundwater quality?

## 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, Vol. 14, No. 6, pp. 462-467.

Bergstrom, J. C., K. J. Boyle and G. L. Poe (2001), Economic Value of Water Quality: Introduction and Conceptual Background, Chapter 1 in Bergstrom, J. C., K. J. Boyle and G. L. Poe (Eds.) The Economic Value of Water Quality, Cheltenham, U.K. and Northampton, Mass.: Elgar.

Bergstrom, J.C. and J.H. Dorfman (1994), Commodity Information and Willingness-to-Pay for Groundwater Quality Protection, Review of Agricultural Economics, Vol. 16, No. 3, pp. 413-425.

Boyle, K. J., G. L. Poe and J. C. Bergstrom (1994), What do we know about groundwater values? Preliminary implications from a meta analysis of contingent-valuation studies, American Journal of Agricultural Economics, Vol. 76, No. 5, pp. 1055-1061.

Bosch, D.J. and J.W. Pease (2000), Economic Risk and Water Quality Protection in Agriculture, Review of Agricultural Economics, Vol. 22, No. 2, pp. 438-463.

Brandon, Carter and Kirsten Hommann (1995), The Cost of Inaction: Valuing the Economy-Wide Cost of Environmental Degradation in India, paper presented at the conference on 'Modelling Global Sustainability', United Nations University, Tokyo.

Caudill, J. D. and J. P. Hoehn (1992), The Economic Valuation of Groundwater Pollution Policies: The Role of Subjective Risk Perceptions, Working Paper No. 92-11, Department of Agricultural Economics, Michigan State University, USA.

Chelliah, Raja J., Paul P. Appasamy, U. Sankar and Rita Pandey (2007), Ecotaxes on Polluting Inputs and Outputs, Academic Foundation, New Delhi.

Comptroller and Auditor General of India (2000), State Audit Reports: Tamil Nadu, 1999-2000, Chapter 3: Civil Departments, Page. 42, available at: http://cag.nic.in/reports/tn/rep_2000/civil_ch3.pdf

Crutchfield, S.R., J.C. Cooper and D. Hellerstein (1997), Benefits of Safer Drinking Water: The Value of Nitrate Reduction, Agricultural Economic Report No. 752, Economic Research Service, U.S. Department of Agriculture, Washington DC, USA.

Dosi, C. and N. Zeitouni (2001), Controlling Groundwater Pollution from Agricultural Non-point Sources: an Overview of Policy Instruments, Chapter 6 in Dosi, C. (ed.), Agricultural Use of Groundwater: Towards Integration between Agricultural Policy and Water Resources Management, Economics, Energy and Environment, Vol. 17, Kluwer Academic Publishers, Dordrecht.

Edwards, S.F. (1988), Option Price for Groundwater Protection, Journal of Environmental Economics and Management, Vol. 15, No. 4, pp. 475-487.

Elnagheeb, A.H., J.L. Jordan and V. Humphrey (1995), The Structure of Farmers' Perceptions of Ground Water Pollution, Journal of Agriculture and Applied Economics, Vol. 27, No. 1, pp. 224-237.

Epp, D.J. and W. Delavan (2001), Measuring the Value of Protecting ground Water Quality from Nitrate Contamination in Southeastern Pennsylvania, Chapter 4 in Bergstrom, J.C., K.J. Boyle and G.L. Poe (Eds.) (2001), *The economic value of water quality,* New Horizons in Environmental Economics. Cheltenham, U.K. and Northampton, Mass.: Elgar.

Fessenden-Raden, J., J.M. Fitchen and J.S. Heath (1987), Providing Risk Information in Communities: Factors Influencing What Is Heard and Accepted, Science, Technology & Human Values, Vol. 12, No. 3/4, pp. 94-101.

Fewtrell, Lorna (2004), Drinking Water Nitrate, Methaemoglobinaemia and Global Burden of Diseases: A Discussion, Environmental Health Perspectives, Vol. 112, No. 14, pp. 1371-1374.

Foster, S. and H. Garduño (2004), India - Tamil Nadu: Resolving the Conflict Over Rural Groundwater Use Between Drinking Water & Irrigation Supply, Case Profile Collection Number 11, Sustainable Groundwater Management Lessons from Practice, Global Water Partnership Associate Program, The World Bank, Washington D.C., USA.

Freeman, M. (1990), Water Pollution Policy, in Portney, P. (ed.), Policies for Environmental Protection, Resources for the Future, Washington D. C., USA.

Greene, William H. (2003), *Econometric Analysis*, 5th Edition, Pearson Education, New Delhi.

Handa, B.K. (1986), Pollution of ground waters by nitrates in India, Bhu-Jal News, Quarterly Journal of Central Groundwater Board, New Delhi, July-September, pp. 16-19.

Hanemann, M. (1984), Welfare evaluations in contingent valuation experiments with discrete responses, American Journal of Agricultural Economics, Vol. 66, pp. 332-341.

Hanley, N.D. (1989), Problems in valuing environmental improvement resulting from agricultural policy changes in Dubgaard, A. and A. Nielson (eds.), Economic aspects of environmental regulation in agriculture, Wissenschaftsverlag, Vauk Kiel, Kiel.

ISI (1991), *Indian Standard Specifications for Drinking Water.* IS 10 500, Indian Standards Institute, New Delhi.

Jordan, J.L. and A.H. Elnagheeb (1993), Willingness to Pay for Improvements in Drinking Water Quality, *Water Resources Research*, Vol. 29, No. 2, pp. 237-245.

Lichtenberg, E. and R. Zimmerman (1999), Farmers' Willingness to Pay for Groundwater Protection, *Water Resources Research*, Vol. 35, No. 3, pp. 833-841.

Long, J. Scott (1997), Regression Models for Categorical and Limited Dependent Variables, 2nd Edition, Sage Publications, USA.

Maria, A. (2003), The costs of water pollution in India", paper presented at the conference on 'Market Development of Water & Waste Technologies through Environmental Economics, October 30-31, 2003, Delhi.

McClelland, G.H., W.D. Shulze, J.K. Lazo, D.M. Waldman, J.K. Doyle, S.R. Ellliot, and J.R. Irwin (1992), Methods for Measuring Non-Use Values: A Contingent Valuation Study of Groundwater Clean-Up, Methods for Measuring Non-Use Values Report, USEPA; Washington D.C.

NAAS (2005), Policy Options for Efficient Nitrogen Use, Policy Paper No. 33, National Academy of Agricultural Sciences, New Delhi.

Napier, T. L. and D. E. Brown (1993), Factors affecting attitudes toward groundwater pollution among Ohio farmers, Journal of Soil and Water Conservation, Vol. 48, No. 5, pp. 432-439.

Nielsen, J.B., D. Gyrd-Hansen, I.V. Kritiansen and J. Nexoe (2003), Impact of Socio-demographic Factors on Willingness to Pay for the Reduction of a Future Health Risk, Journal of Environmental Planning and Management, Vol. 46, No. 1, pp. 39-47.

Poe, G.L. and R.C. Bishop (2001), Information and the Valuation of Nitrates in Ground Water, Portage County, Wisconsin, Chapter 3 in Bergstrom, J.C., K.J. Boyle and G.L. Poe (Eds.), The Economic Value of Water Quality, Cheltenham, U.K. and Northampton, Mass.: Elgar.

Poe, G.L. and R.C. Bishop (1999), Valuing the Incremental Benefits of Groundwater Protection when Exposure Levels are Known, Environmental and Resource Economics, Vol. 13, No. 3, pp. 341-367.

Poe, G. L. (1998), Valuation of Groundwater Quality Using Contingent Valuation-Damage Function Approach, Water Resources Research, Vol. 34, No. 12, Pp. 3627-33.

Powell, J.R., D.J. Allee and C. McClintock (1994), Groundwater Protection Benefits and Local Community Planning: Impact of Contingent Valuation Information, American Journal of Agricultural Economics, Vol. 76, No. 5, pp. 1068-1075.

Ready, R.C. and K. Henken (1999), Optimal Self-Protection from Nitrate-Contaminated Groundwater, American Journal of Agricultural Economics, Vol. 81, No. 2, pp. 321-334.

Rougoor, C.W., H. Van Zeijts, M.F. Hofreither and S. Bäckman (2001), Experiences with Fertilizer Taxes in Europe, Journal of Environmental Planning and Management, Vol. 44, No. 6, pp. 877-887.

Schultz, S.D. and B.E. Lindsay (1990), The Willingness to Pay for Groundwater Protection, Water Resources Research, Vol. 26, No. 9, pp. 1869-1875.

Shanmugam, K. R. and S. Mukherjee (2004), Fertilizer Use Efficiency of Farms in the Bhavani River Basin, paper presented at the National Seminar on Environmental Issues and Natural Resources Management, Gobi Arts and Science College, Erode, Tamil Nadu.

Shortle, J.S., and R.D. Horan (2002), The Economics of Nonpoint Pollution Control, in Hanley, N. and C. Roberts (eds.), Issues in Environmental Economics, Oxford, UK: Blackwell Publishing.

Shortle, J.S. and D.G. Abler (1997), Nonpoint Pollution, in Folmer, H. and T.H. Tietenberg (eds.), The International Yearbook of Environmental and Resource Economics 1997/98, Cheltenham, UK: Edward Elgar.

Stenger, A. and M. Willinger (1998), Preservation Value for Groundwater Quality in a Large Aquifer: A Contingent - Valuation Study of the Alsatian Aquifer, Journal of Environmental Management, Vol. 53, No. 2, pp. 177-193.

Sun, H., J.C. Bergstrom and J.H. Dorfman (1992), Estimating the Benefits of Groundwater Contamination Control, Southern Journal of Agricultural Economics, Vol. 24, No. 2, pp. 89-107.

Trivedy, R. K. (2000), Legislation Controlling Quality of Freshwater in India, Journal of Industrial Pollution Control, Vol. 16, No. 1, pp. 131-143.

UNDP (2006), Human Development Report 2006 - Beyond scarcity: Power, poverty and the global water crisis, United Nations Development Programme, New York, USA.

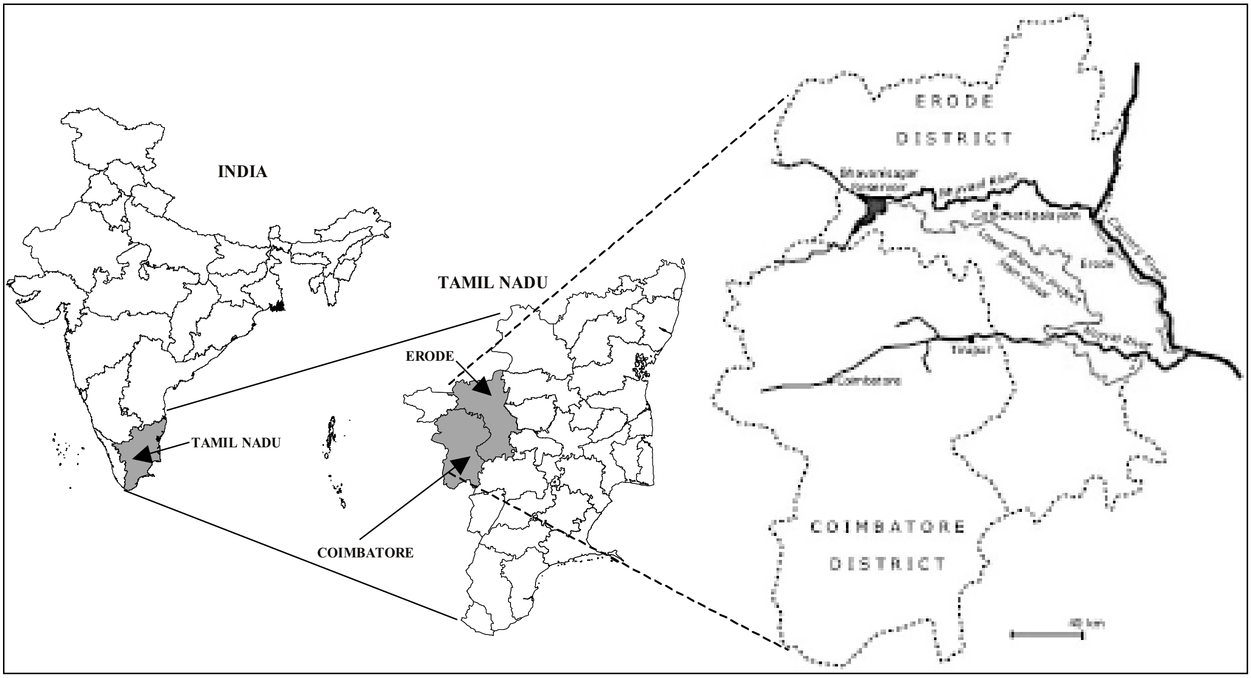
Walker, D.R. and J.P. Hoehn (1990), The Economic Damages of Groundwater Contamination in Small Rural Communities: An Application to Nitrates, North Central Journal of Agricultural Economics, Vol. 12, No. 1. pp. 47-56.

WHO (2004), Guidelines for Drinking-water Quality – Third Edition – Volume 1 – Recommendations, Chapter 12, Section 94, Page 417-420, World Health Organisation, Geneva.

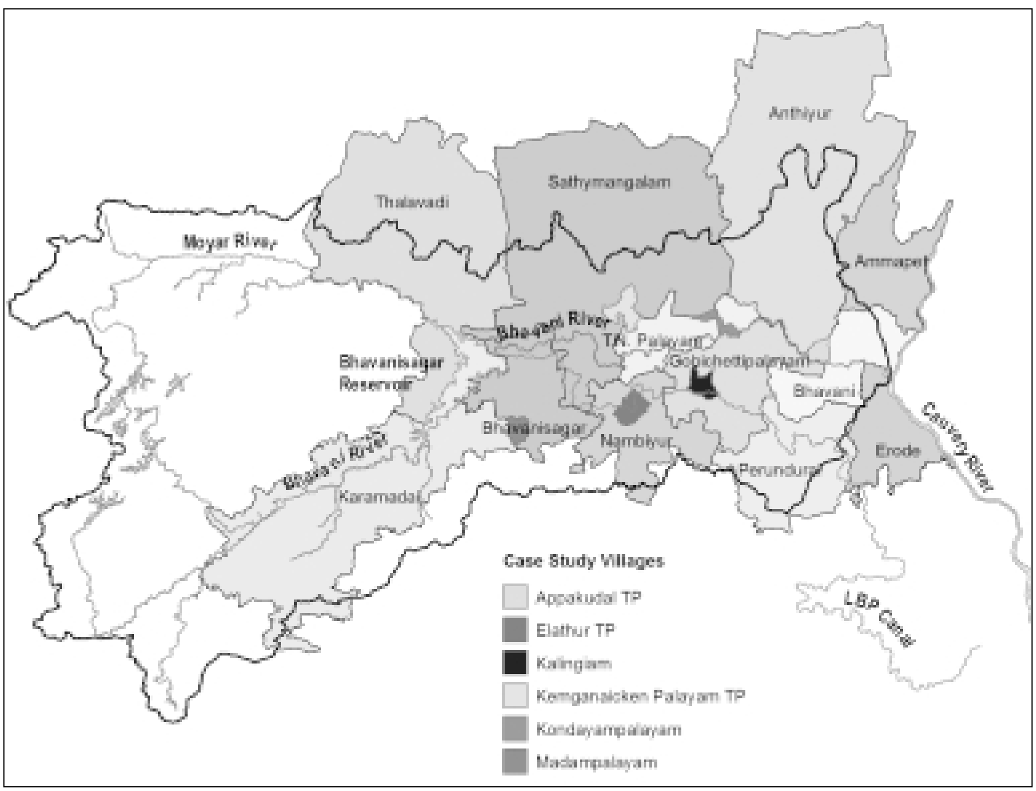
Zeijts, Henk van and Henk Westhoek (2004), Experiences with taxes / levies on fertilisers and pesticides in European countries, Netherlands Environmental Assessment Agency, the Netherlands.

# APPENDIX A

Location Map 1: The Lower Bhavani River Basin, Tamil Nadu




Location Map 2: Location of the Case Study Villages in the Lower Bhavani River Basin, Tamil Nadu




*Source:* GIS, TWAD Board, Chennai and Mats Lannerstad

# APPENDIX C

Table C.1: Factors Influencing Farmers' Perceptions about Groundwater Quality

| Dependent Variable: GWQP | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Homoscedastic Probit Estimation | | | | Heteroscedastic Probit Estimation | | | | | |
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| constant | -0.5675 | -1.01 | | | -1.0724 | -2.77 *** | | | | |
| age | -0.0106 | -1.47 | -0.0030 | -1.47 * | 0.0043 | 0.83 | | | 0.0008 | 0.83 * |
| edu | 0.0078 | 0.37 | 0.0022 | 0.37 * | -0.0011 | -0.06 | | | -0.0002 | -0.06 * |
| eap | 0.0423 | 0.53 | 0.0121 | 0.53 * | -0.0407 | -0.64 | | | -0.0078 | -0.63 * |
| lpclandh | 0.2282 | 1.93 * | 0.0654 | 1.91 * | 0.2093 | 3.19 *** | | | 0.0404 | 3.24 *** |
| bpercept | 0.0034 | 1.35 | 0.0010 | 1.36 * | 0.0234 | 4.97 *** | -0.0136 | -4.33 *** | 0.0013 | 1.69 * |
| agriprac | 0.0084 | 2.76 *** | 0.0024 | 2.75 *** | 0.0112 | 4.33 *** | | | 0.0022 | 4.45 *** |
| fagrinfo | -0.0051 | -2.14 ** | -0.0015 | -2.13 ** | -0.0037 | -2.02 ** | | | -0.0007 | -1.92 * |
| sdwoow‡ | 0.9358 | 3.13 *** | 0.2805 | 3.11 *** | 0.6913 | 2.71 *** | | | 0.1437 | 2.27 ** |
| sdwopp‡ | 1.2952 | 3.82 *** | 0.4522 | 3.74 *** | 1.1310 | 4.84 *** | | | 0.3130 | 3.75 *** |
| sdwshc‡ | 0.7243 | 2.08 ** | 0.2401 | 1.88 * | 0.4227 | 1.58 | | | 0.0950 | 1.34 * |
| sdwssp‡ | 1.1297 | 3.17 *** | 0.3062 | 3.32 *** | 0.6198 | 2.00 ** | | | 0.1165 | 1.94 * |
| dwqos | -0.3724 | -4.40 *** | -0.1068 | -4.48 *** | -0.3253 | -4.49 *** | | | -0.0627 | -3.58 *** |
| dwqphp | 0.4358 | 3.65 *** | 0.1250 | 3.61 *** | 0.4655 | 5.50 *** | | | 0.0897 | 4.68 *** |
| dwqsw | -0.2213 | -2.66 *** | -0.0635 | -2.61 *** | -0.1698 | -2.93 *** | | | *-0.0327* | *-2.63* *** |
| *childn* | *-0.5528* | *-3.74* *** | *-0.1585* | *-3.72* *** | *-0.6114* | *-5.24* *** | | | *-0.1179* | *-4.54* *** |
| *knowbmp* | *0.0085* | *3.49* *** | *0.0025* | *3.50* *** | *0.0126* | *4.93* *** | | | *0.0024* | *4.61* *** |
| *proenv* | *-0.0085* | *-3.64* *** | *-0.0024* | *-3.59* *** | *-0.0029* | *-1.50* | *-0.0198* | *-3.82* *** | *-0.0052* | *-4.94* *** |
| *app‡* | *0.7167* | *2.97* *** | *0.2393* | *2.70* *** | *0.6184* | *2.06* ** | | | *0.1498* | *1.68* * |
| *knp‡* | *0.9514* | *3.63* *** | *0.3256* | *3.33* *** | *0.3585* | *1.17* | | | *0.0792* | *1.02* * |
| *mdp‡* | *0.9328* | *3.77* *** | *0.3215* | *3.47* *** | *0.7738* | *3.21* *** | | | *0.1984* | *2.51* ** |
| *Number of Obs:* | *395* | | | | *395* | | | | | |
| *Wald* $chi^2$ *(df):* | *99.78* | *(20)* *** | | | *114.04* | *(20)* *** | *26.43* | *(2)* *** | | |
| *Pseudo* $R^2$*:* | *0.2717* | | | | | | | | | |
| *Log pseudo-likelihood:* | *-171.53* | | | | *-155.06* | | | | | |
| *Predicted Probability (at mean):* | | | *0.2082* | | | | | | 0.1139 | |

*Note:* ‡- implies that marginal effect is for discrete change of dummy variable from 0 to 1
***, ** & * - implies that estimated z - stat is significant at 0.01, 0.05 and 0.10 level respectively

Table C.2: Factors Influencing Farmers' Perceptions about Groundwater Quality

| Dependent Variable: GWQP | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Homoscedastic Probit Estimation | | | | Heteroscedastic Probit Estimation | | | | | |
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| constant | 0.653 | 1.18 | | | -0.6267 | -1.66 * | | | | |
| age | -0.0124 | -1.68 * | -0.0035 | -1.68 * | 0.0038 | 0.83 | | | 0.0007 | 0.85 * |
| edu | 0.0021 | 0.1 | 0.0006 | 0.1 * | 0.0039 | 0.23 | | | 0.0008 | 0.23 * |
| eap | 0.0285 | 0.36 | 0.0079 | 0.36 * | -0.0429 | -0.76 | | | -0.0083 | -0.75 * |
| lpclandh | 0.2751 | 2.3 ** | 0.0764 | 2.26 ** | 0.2154 | 2.87 *** | | | 0.0417 | 3.11 *** |
| bpercept | 0.0043 | 1.8 * | 0.0012 | 1.8 * | 0.0242 | 4.92 *** | -0.0137 | -4.15 *** | 0.0015 | 2.06 ** |
| agriprac | 0.0076 | 2.71 *** | 0.0021 | 2.67 *** | 0.0099 | 4.17 *** | | | 0.0019 | 4.38 *** |
| fagrinfo | -0.0052 | -2.16 ** | -0.0014 | -2.15 ** | -0.0039 | -2.07 ** | | | -0.0008 | -2.08 ** |
| sdwoow‡ | 0.8398 | 2.72 *** | 0.2443 | 2.66 *** | 0.7348 | 3.12 *** | | | 0.154 | 2.69 *** |
| sdwopp‡ | 1.1438 | 3.27 *** | 0.3908 | 3.04 *** | 1.1382 | 4.67 *** | | | 0.3164 | 3.77 *** |
| sdwshc‡ | 0.9959 | 2.45 ** | 0.334 | 2.25 ** | 0.4968 | 2.14 ** | | | 0.1148 | 1.8 * |
| sdwssp‡ | 1.2427 | 3.46 *** | 0.3245 | 3.65 *** | 0.7564 | 2.91 *** | | | 0.1423 | 2.82 *** |
| dwqos | -0.3457 | -3.87 *** | -0.096 | -3.93 *** | -0.3277 | -4.65 *** | | | -0.0634 | -3.8 *** |
| dwqphp | 0.4845 | 4.06 *** | 0.1345 | 4.13 *** | 0.4514 | 4.81 *** | | | 0.0874 | 4.05 *** |
| dwqsw | -0.2953 | -3.3 *** | -0.082 | -3.25 *** | -0.1657 | -3.12 *** | | | -0.0321 | -2.99 *** |
| childn | -0.568 | -3.73 *** | -0.1577 | -3.76 *** | -0.6015 | -5.49 *** | | | -0.1165 | -4.97 *** |
| knowbmp | 0.0093 | 3.78 *** | 0.0026 | 3.84 *** | 0.0122 | 4.64 *** | | | 0.0024 | 4.35 *** |
| proenv | -0.0081 | -3.35 *** | -0.0022 | -3.35 *** | -0.0036 | -2.23 ** | -0.0196 | -3.44 *** | -0.0053 | -4.36 *** |
| ela‡ | -0.5668 | -2.59 ** | -0.133 | -3.06 *** | -0.6325 | -2.92 *** | | | -0.0958 | -3.13 *** |
| kal‡ | -1.5751 | -3.39 *** | -0.263 | -6.72 *** | -0.4276 | -0.83 | | | -0.0695 | -0.97 * |
| kdp‡ | -1.222 | -4.65 *** | -0.2264 | -6.8 *** | -0.5488 | -2.24 ** | | | -0.0845 | -2.47 ** |
| Number of Obs: | 395 | | | | 395 | | | | | |
| Wald chi$^2$ (df): | 98.17 | (20) *** | | | 116.43 | (20) *** | 20.82 | (2) *** | | |
| Pseudo $R^2$: | 0.2861 | | | | | | | | | |
| Log pseudo-likelihood: | -168.14 | | | | -155.68 | | | | | |
| Predicted Probability (at mean): | | | 0.1973 | | | | | | 0.1146 | |

*Note:* as in Table C.1.

Table C.3: Factors Influencing Farmers' Perceptions about Drinking Water Quality

| Dependent Variable: CLCTWAT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| constant | -1.7866 | -3.99 *** | | | -1.0819 | -2.36 ** | | |
| age | 0.0081 | 1.20 | 0.0032 | 1.20 | 0.0055 | 0.80 | 0.0021 | 0.80 |
| edu | -0.0007 | -0.04 | -0.0003 | -0.04 | 0.0203 | 1.16 | 0.0080 | 1.16 |
| eap | -0.2043 | -2.82 *** | -0.0802 | -2.82 *** | -0.1697 | -2.36 ** | -0.0667 | -2.36 ** |
| pcincact | 0.0000 | -1.68 * | 0.0000 | -1.68 * | 0.0000 | -1.34 | 0.0000 | -1.34 |
| gwqp‡ | 1.1713 | 6.40 *** | 0.4408 | 7.34 *** | | | | |
| puriwatr‡ | 0.5541 | 2.78 *** | 0.2181 | 2.84 *** | 0.4900 | 2.63 *** | 0.1934 | 2.67 *** |
| wqs‡ | | | | | -0.5913 | -2.83 *** | -0.2324 | -2.93 *** |
| proenv | 0.0031 | 1.49 | 0.0012 | 1.49 | 0.0012 | 0.62 | 0.0005 | 0.62 |
| sdwwti‡ | 1.7285 | 4.23 *** | 0.5178 | 8.93 *** | 1.9361 | 3.95 *** | 0.5379 | 10.40 *** |
| sdwohp‡ | 0.5869 | 2.05 ** | 0.2308 | 2.12 ** | 0.5679 | 2.30 ** | 0.2235 | 2.38 ** |
| sdwphp‡ | 1.1701 | 3.72 *** | 0.4233 | 4.87 *** | 1.0685 | 3.57 *** | 0.3931 | 4.44 *** |
| sdwssp‡ | 1.0926 | 4.87 *** | 0.4055 | 5.39 *** | 1.2178 | 5.96 *** | 0.4474 | 6.75 *** |
| childn | -0.3496 | -2.21 ** | -0.1372 | -2.22 ** | -0.4450 | -2.95 *** | -0.1750 | -2.96 *** |
| ela‡ | 0.9590 | 4.45 *** | 0.3658 | 4.99 *** | 0.8062 | 3.94 *** | 0.3120 | 4.25 *** |
| knp‡ | 1.5343 | 5.27 *** | 0.5337 | 7.51 *** | 1.6184 | 5.93 *** | 0.5521 | 8.72 *** |
| mdp‡ | 0.6547 | 2.88 *** | 0.2563 | 3.02 *** | 0.7104 | 3.10 *** | 0.2768 | 3.29 *** |
| Number of observations: | 395 | | | | 395 | | | |
| Wald $chi^2$ (df): | 124.98 | (15) *** | | | 94.68 | (15) *** | | |
| Pseudo $R^2$: | 0.3071 | | | | 0.2358 | | | |
| Log pseudo-likelihood: | -188.51 | | | | -207.89 | | | |
| Predicted Probability (at mean): | | | 0.4285 | | | | 0.4324 | |

*Note:* as in Table C.1.

Table C.4: Factors Influencing Farmers' Perceptions about Drinking Water Quality

| Dependent Variable: CLCTWAT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| constant | -0.4545 | -1.09 | | | 0.3615 | 0.87 | | |
| age | 0.0067 | 1.03 | 0.0026 | 1.03 | 0.0032 | 0.48 | 0.0013 | 0.48 |
| edu | 0.0003 | 0.02 | 0.0001 | 0.02 | 0.0183 | 1.04 | 0.0072 | 1.04 |
| eap | -0.2119 | -2.89 *** | -0.0832 | -2.88 *** | -0.1892 | -2.66 *** | -0.0743 | -2.66 *** |
| pcincact | 0.0000 | -1.88 * | 0.0000 | -1.88 * | 0.0000 | -1.45 | 0.0000 | -1.45 |
| gwqp‡ | 1.2016 | 6.56 *** | 0.4507 | 7.59 *** | | | | |
| puriwatr‡ | 0.5160 | 2.71 *** | 0.2034 | 2.75 *** | 0.4562 | 2.57 ** | 0.1802 | 2.60 *** |
| wqs‡ | | | | | -0.6130 | -2.95 *** | -0.2407 | -3.06 *** |
| proenv | 0.0041 | 2.01 ** | 0.0016 | 2.01 ** | 0.0027 | 1.39 | 0.0010 | 1.39 |
| sdwwti‡ | 1.6343 | 3.84 *** | 0.5048 | 7.54 *** | 1.7407 | 3.75 *** | 0.5188 | 8.14 *** |
| sdwohp‡ | 0.6427 | 1.70 * | 0.2519 | 1.78 * | 0.6617 | 2.11 ** | 0.2589 | 2.22 ** |
| sdwphp‡ | 1.3133 | 3.68 *** | 0.4610 | 5.18 *** | 1.2592 | 3.59 *** | 0.4470 | 4.88 *** |
| sdwssp‡ | 0.7341 | 3.89 *** | 0.2803 | 4.08 *** | 0.8115 | 4.59 *** | 0.3083 | 4.85 *** |
| childn | -0.2953 | -1.96 * | -0.1159 | -1.97 ** | -0.3770 | -2.59 *** | -0.1480 | -2.61 *** |
| app‡ | -0.9216 | -4.47 *** | -0.3176 | -5.36 *** | -0.7693 | -3.65 *** | -0.2736 | -4.26 *** |
| kal‡ | -1.5011 | -3.64 *** | -0.4518 | -5.82 *** | -1.5840 | -4.15 *** | -0.4674 | -6.91 *** |
| kdp‡ | -0.8913 | -3.80 *** | -0.3088 | -4.63 *** | -1.0112 | -4.72 *** | -0.3417 | -5.97 *** |
| Number of observations: | 395 | | | | 395 | | | |
| Wald chi$^2$ (df): | 132.78 | (15) *** | | | 97.94 | (15) *** | | |
| Pseudo $R^2$: | 0.2950 | | | | 0.2210 | | | |
| Log pseudo-likelihood: | -191.80 | | | | -211.92 | | | |
| Predicted Probability (at mean): | | | 0.4284 | | | | 0.4293 | |

Note: as in Table C.1.

Table C.5: Factors Influencing Farmers' Willingness To Protect Groundwater Quality

| Dependent Variable: WTPGWQ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Homoscedastic Probit Estimation | | | | Heteroscedastic Probit Estimation | | | | | |
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| Constant | 0.2559 | 0.66 | | | 0.0850 | 0.83 | | | | |
| Age | -1.1E-05 | 0.00 | -4.4E-06 | 0.00 | 0.0006 | 0.53 | | | 0.0006 | 0.54 |
| Edu | 0.0150 | 0.84 | 0.0059 | 0.84 | 0.0058 | 1.42 | | | 0.0063 | 1.69 * |
| Pclandh | -0.1813 | -0.87 | -0.0711 | -0.87 | -0.1039 | -1.87 * | | | -0.1138 | -2.35 ** |
| Eap | 0.0517 | 0.79 | 0.0202 | 0.79 | 0.0118 | 0.63 | | | 0.0129 | 0.70 |
| Reside | -0.0073 | -3.50 *** | -0.0029 | -3.50 *** | -0.0034 | -3.03 *** | -0.0135 | -3.22 *** | -0.0045 | -6.68 *** |
| Bpercept | 0.0110 | 5.30 *** | 0.0043 | 5.30 *** | 0.0085 | 2.35 ** | -0.0277 | -2.78 *** | 0.0076 | 3.84 *** |
| Agriprac | 0.0071 | 2.75 *** | 0.0028 | 2.75 *** | 0.0021 | 2.46 ** | | | 0.0024 | 3.53 *** |
| Fmember | 0.0034 | 1.65 * | 0.0013 | 1.65 * | 0.0004 | 0.99 | -0.0082 | -2.61 *** | -0.0001 | -0.12 |
| Fagrinfo | -0.0045 | -2.19 ** | -0.0018 | -2.19 ** | -0.0001 | -0.18 | | | -0.0001 | -0.18 |
| app‡ | 0.7608 | 3.72 *** | 0.2698 | 4.35 *** | 0.1954 | 1.66 * | | | 0.2138 | 2.52 ** |
| knp‡ | 0.6172 | 2.69 *** | 0.2251 | 3.01 *** | 0.0959 | 1.67 * | | | 0.1057 | 1.87 * |
| mdp‡ | 0.9065 | 4.35 *** | 0.3105 | 5.35 *** | 0.1722 | 1.79 * | | | 0.1890 | 2.83 *** |
| Number of observations: | 395 | | | | 395 | | | | | |
| Wald $chi^2$ (df): | 85.18 | (12) *** | | | 14.08 | (12) *** | 19.10 | (3) *** | | |
| Pseudo $R^2$: | 0.1876 | | | | | | | | | |
| Log pseudo-likelihood: | -219.944 | | | | -204.54 | | | | | |
| Predicted Probability (at mean): | | | 0.5750 | | | | | | | |

*Note:* as in Table C.1.

Table C.6: Factors Influencing Farmers' Willingness To Protect Groundwater Quality

| Dependent Variable: WTPGWQ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Homoscedastic Probit Estimation | | | | Heteroscedastic Probit Estimation | | | | | |
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| Constant | 1.0776 | 2.64*** | | | 0.2326 | 1.76 * | | | | |
| Age | -0.0014 | -0.22 | -0.0005 | -0.22 | 0.0005 | 0.49 | | | 0.0006 | 0.49 |
| Edu | 0.0126 | 0.69 | 0.0049 | 0.69 | 0.0045 | 1.31 | | | 0.0058 | 1.60 |
| Pclandh | -0.1325 | -0.60 | -0.0519 | -0.60 | -0.0880 | -1.63 | | | -0.1135 | -1.98 ** |
| eap‡ | 0.0518 | 0.81 | 0.0203 | 0.81 | 0.0078 | 0.54 | | | 0.0101 | 0.59 |
| reside | -0.0072 | -3.55*** | -0.0028 | -3.55 *** | -0.0031 | -2.49 ** | -0.0156 | -3.69 *** | -0.0048 | -6.55 *** |
| bpercept | 0.0113 | 5.58*** | 0.0044 | 5.56 *** | 0.0069 | 2.31 ** | -0.0303 | -2.23 ** | 0.0074 | 2.97 *** |
| agriprac | 0.0059 | 2.34** | 0.0023 | 2.35 ** | 0.0015 | 2.43 ** | | | 0.0019 | 3.03 *** |
| fmember | 0.0031 | 1.58 | 0.0012 | 1.58 | 0.0003 | 0.82 | -0.0077 | -2.39 ** | 0.0000 | -0.05 |
| fagrinfo | -0.0039 | -1.95* | -0.0015 | -1.95 * | 0.0001 | 0.15 | | | 0.0001 | 0.15 |
| ela‡ | -0.5616 | -2.96*** | -0.2211 | -3.04 *** | -0.1142 | -1.83 * | | | -0.1434 | -2.38 ** |
| kal‡ | -0.8427 | -4.20*** | -0.3252 | -4.57 *** | -0.1139 | -1.55 | | | -0.1428 | -2.21 ** |
| kdp‡ | -0.9681 | -4.76*** | -0.3683 | -5.36 *** | -0.1471 | -1.76 * | | | -0.1820 | -2.76 *** |
| Number of observations: | 395 | | | | 395 | | | | | |
| Wald $chi^2$ (df): | 85.58 | (12)*** | | | 12.17 | (12) *** | 16.58 | (3) *** | | |
| Pseudo $R^2$: | 0.1916 | | | | | | | | | |
| Log pseudo-likelihood: | -218.875 | | | | -204.83 | | | | | |
| Predicted Probability (at mean): | | | 0.5743 | | | | | | 0.4517 | |

*Note:* as in Table C.1.

Table C.7: Factors Influencing Farmers' Willingness to Support (Demand for) Local Government to Supply Safe Drinking Water

| Dependent Variable: WTSGOVCW | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Homoscedastic Probit Estimation | | | | Heteroscedastic Probit Estimation | | | |
| Explanatory Variables | Coeff. | z-stat | Marg. Effect | z-stat | Coeff. | z-stat | Marg. Effect | z-stat |
| constant | -0.4028 | -0.89 | | | -1.3667 | -3.01 *** | | |
| age | 0.0064 | 0.92 | 0.0024 | 0.91 | 0.0062 | 0.87 | 0.0023 | 0.86 |
| edu | -0.0089 | -0.46 | -0.0033 | -0.46 | -0.0128 | -0.66 | -0.0047 | -0.66 |
| eap | -0.1480 | -1.97 ** | -0.0540 | -1.97 ** | -0.1585 | -2.10 ** | -0.0579 | -2.10 ** |
| pcincact | 0.0000 | -1.63 | 0.0000 | -1.63 | 0.0000 | -1.53 | 0.0000 | -1.53 |
| proenv | 0.0054 | 2.58 ** | 0.0020 | 2.59 ** | 0.0059 | 2.83 *** | 0.0022 | 2.84 *** |
| childn | -0.4150 | -2.57 ** | -0.1514 | -2.60 *** | -0.3954 | -2.46 ** | -0.1445 | -2.49 ** |
| puriwatr | 0.6648 | 3.57 *** | 0.2528 | 3.54 *** | 0.6815 | 3.62 *** | 0.2595 | 3.59 *** |
| gwqp‡ | 0.9056 | 5.08 *** | 0.3410 | 5.13 *** | 0.9136 | 5.16 *** | 0.3442 | 5.25 *** |
| wtpgov | 0.2018 | 2.37 ** | 0.0736 | 2.37 ** | 0.2137 | 2.49 ** | 0.0781 | 2.49 ** |
| dwqos | -0.1041 | -1.99 ** | -0.0380 | -2.00 ** | -0.1018 | -1.91 * | -0.0372 | -1.91 * |
| dwqphp | -0.3965 | -1.80 * | -0.1446 | -1.81 * | -0.3963 | -1.77 * | -0.1448 | -1.78 * |
| dwqsw | -0.2281 | -3.12 *** | -0.0832 | -3.12 *** | -0.2374 | -3.13 *** | -0.0867 | -3.14 *** |
| sdwcw‡ | 1.0575 | 1.76 * | 0.4023 | 1.99 ** | 1.0119 | 1.71 * | 0.3867 | 1.91 * |
| sdwohp‡ | 0.9496 | 2.46 ** | 0.3636 | 2.58 ** | 0.7266 | 2.51 ** | 0.2798 | 2.52 ** |
| sdwphp‡ | 1.6851 | 4.21 *** | 0.5825 | 6.43 *** | 1.5383 | 4.44 *** | 0.5471 | 6.23 *** |
| sdwssp‡ | 1.5040 | 5.07 *** | 0.4962 | 6.05 *** | 1.5844 | 5.10 *** | 0.5190 | 6.21 *** |
| sdwwti‡ | 1.3879 | 2.54 ** | 0.4989 | 3.52 *** | 1.2992 | 2.48 ** | 0.4748 | 3.25 *** |
| app‡ | -1.0328 | -4.65 *** | -0.3008 | -6.17 *** | | | | |
| kal‡ | -1.3905 | -3.20 *** | -0.3674 | -5.28 *** | | | | |
| kdp‡ | -0.7816 | -3.23 *** | -0.2429 | -4.03 *** | | | | |
| ela‡ | | | | | 1.0923 | 4.83 *** | 0.4141 | 5.22 *** |
| knp‡ | | | | | 0.9286 | 3.33 *** | 0.3554 | 3.45 *** |
| mdp‡ | | | | | 0.9204 | 4.03 *** | 0.3530 | 4.21 *** |
| Number of observations: | 395 | | | | 395 | | | |
| Wald $chi^2$ (df): | 130.87 | (20) *** | | | 131.75 | (20) *** | | |
| Pseudo $R^2$: | 0.3073 | | | | 0.3047 | | | |
| Log pseudo-likelihood: | -182.33 | | | | -183.02 | | | |
| Predicted Probability (at mean): | | | 0.3361 | | | | 0.3376 | |

Note: as in Table C.1.

# APPENDIX B

Table B.1: Sample Villages and Basic Sample Characteristics

| Name of the Sample Location | Total Number of 2001 Census House holds | Number of Sample House holds | Percentage of Census House holds | Total Population (Population Census 2001) | Sample Population | Percentage of Census Population | Census Family Size | Average Sample Family Size | Agricultural Area (in hectare) | Total Land Holding of Sample Households (in hectare) | Percentage of Agricultural Area of the Village (in hectare) | Average Land Holding of the Sample Households (in hectare) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kembanickenpalayam (KNP) | 2,752 | 65 | 2.4 | 10,308 | 273 | 2.6 | 3.7 | 4.2 | 1,477.4 | 85.4 | 5.8 | 1.3 |
| Madampalayam (MDP) | 1,164 | 72 | 6.2 | 4,348 | 301 | 6.9 | 3.7 | 4.2 | 742.3 | 126.1 | 17.0 | 1.8 |
| Elathur (ELA) | 2,166 | 66 | 3.0 | 7,678 | 275 | 3.6 | 3.5 | 4.2 | 708.3 | 104.2 | 14.7 | 1.6 |
| Kalingiam (KAL) | 2,580 | 68 | 2.6 | 9,386 | 299 | 3.2 | 3.6 | 4.4 | 1,058.8 | 141.9 | 13.4 | 2.1 |
| Kondayampalayam (KDP) | 2,042 | 64 | 3.1 | 6,988 | 260 | 3.7 | 3.4 | 4.1 | 584.5 | 163.5 | 28.0 | 2.6 |
| Appakoodal (APP) | 2,574 | 60 | 2.3 | 9,522 | 248 | 2.6 | 3.7 | 4.1 | 1,021.0 | 73.9 | 7.2 | 1.2 |
| Total | 13,278 | 395 | 3.0 | 48,230 | 1,656 | 3.4 | 3.6 | 4.2 | 5,592.3 | 695.0 | 12.4 | 1.8 |

*Source:* Census of India, 2001 and Primary Survey

Table B.2: Descriptive Statistics

| | APP | ELA | KAL | KNP | KDP | MDP | ALL | F-stat | Prob. |
|---|---|---|---|---|---|---|---|---|---|
| No. of Obs. | 65 | 72 | 66 | 68 | 64 | 60 | 395 | (df: 5, 389) | |
| | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | | |
| Age (in completed years) (age) | 44 ± 13 (23 - 66) | 50 ± 12 (25 - 80) | 42 ± 13 (21 - 71) | 44 ± 12 (20 - 82) | 47 ± 13 (22 - 76) | 51 ± 12 (28 - 80) | 46 ± 13 (20 - 82) | 5.3844 | 0.0001 |
| Education (in years) (edu) | 7.5 ± 5.6 (0 - 18) | 6.9 ± 5.1 (0 - 18) | 6.7 ± 4.9 (0 - 17) | 8.5 ± 3.4 (0 - 15) | 7.6 ± 5 (0 - 16) | 5.1 ± 4.7 (0 - 15) | 7.1 ± 4.9 (0 - 18) | 3.6340 | 0.0032 |
| Economically active person in a family (eap) | 1.9 ± 1.3 (1 - 9) | 1.9 ± 1.1 (1 - 5) | 1.9 ± 1.1 (1 - 7) | 1.6 ± 0.7 (1 - 3) | 1.9 ± 1 (1 - 4) | 1.5 ± 0.7 (1 - 4) | 1.8 ± 1 (1 - 9) | 2.1789 | 0.0558 |
| Per capita land holding (in hectare) (pclandh) | 0.34 ± 0.27 (0.03 - 1.82) | 0.42 ± 0.31 (0.05 - 2.02) | 0.4 ± 0.32 (0.08 - 1.35) | 0.49 ± 0.42 (0.1 - 3.04) | 0.63 ± 0.53 (0.1 - 3.04) | 0.33 ± 0.25 (0.04 - 1.42) | 0.44 ± 0.38 (0.03 - 3.04) | 5.9585 | 0.0000 |
| Per capita income (in Rs./Year) (pcincact) | 7,613 ± 5,764 (1,000 – 33,333) | 8,688 ± 11,505 (1,000 – 66,667) | 10,699 ± 8,865 (250 – 41,149) | 9,239 ± 9,512 (1,250 – 60,400) | 11,706 ± 10,124 (1,667 – 58,796) | 8,235 ± 9,123 (375 – 40,000) | 9,362 ± 9,403 (250 – 66,667) | 1.7781 | 0.1163 |
| Residing in the village (in years) (reside) | 83 ± 32 (1 - 100) | 80 ± 29 (1 - 100) | 81 ± 33 (4 - 100) | 57 ± 42 (10 - 200) | 68 ± 41 (1 - 100) | 89 ± 24 (5 - 100) | 76 ± 36 (1 - 200) | 7.9073 | 0.0000 |
| Having children (below 5 years of age) in the family (child) | 0.05 ± 0.21 | 0.15 ± 0.36 | 0.12 ± 0.33 | 0.28 ± 0.45 | 0.11 ± 0.31 | 0.13 ± 0.34 | 0.14 ± 0.35 | 3.3616 | 0.0055 |
| Number of children (below 5 years of age) in the family (childn) | 0.06 ± 0.30 (0 - 2) | 0.21 ± 0.53 (0 - 2) | 0.20 ± 0.59 (0 - 3) | 0.50 ± 0.97 (0 - 4) | 0.13 ± 0.38 (0 - 2) | 0.22 ± 0.61 (0 - 3) | 0.22 ± 0.62 (0 - 4) | 4.1491 | 0.0011 |
| Area under sugarcane cultivation (in hectare) (areasugar) | 2.50 ± 1.75 (0 - 8) | 0.89 ± 1.36 (0 - 6) | 2.29 ± 2.69 (0 - 18) | 1.69 ± 2.42 (0 - 13) | 2.29 ± 2.58 (0 - 10) | 0.00 ± 0.00 (0 - 0) | 1.62 ± 2.20 (0 - 18) | 14.7348 | 0.0000 |
| Herd Size (in cows/ buffalo/bullock unit) (animal) | 3.0 ± 2.7 (0 - 10) | 3.4 ± 2.2 (0 - 9) | 4.1 ± 3.2 (0 - 15) | 5.3 ± 3.9 (0 - 21) | 3.1 ± 1.7 (0 - 7) | 2.0 ± 1.8 (0 - 8) | 3.5 ± 2.9 (0 - 21) | 10.9970 | 0.0000 |

*Note:* Figures in the parenthesis show the range for the corresponding average value.

Table B.2: Descriptive Statistics

| | APP | ELA | KAL | KNP | KDP | MDP | ALL | F-stat | Prob. |
|---|---|---|---|---|---|---|---|---|---|
| | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | Mean ± Stdev | | |
| Factor Score of Farmers' Source of Agriculture Related Information (fagrinfo) | 6.48 ± 41.25<br>(-59.36 - 66.83) | -2.59 ± 34.56<br>(-59.36 - 66.83) | -4.81 ± 38.71<br>(-61.01 - 66.83) | -5.40 ± 27.88<br>(-59.36 - 66.83) | 20.21 ± 37.98<br>(-59.36 - 66.83) | -14.05 ± 33.56<br>(-59.36 - 42.91) | 0 ± 37.2<br>(-61.01 - 66.83) | 6.9473 | 0.0000 |
| Factor Score of Farmers' Sources of Consultations related to Agricultural Practices (fconsult) | -24.16 ± 13.87<br>(-34.18 - 38.88) | -0.96 ± 27.6<br>(-34.18 - 68.43) | -8.28 ± 24.8<br>(-34.18 - 45.36) | 41.49 ± 32.76<br>(-34.18 - 106.74) | -9.77 ± 19.65<br>(-34.18 - 48.98) | -0.18 ± 27.88<br>(-34.18 - 66.29) | 0.00 ± 32.42<br>(-34.18 - 106.74) | 51.8694 | 0.0000 |
| Factor Score of Membership in Social and Community Institutions (fmember) | -14.57 ± 29.29<br>(-36.43 - 40.41) | 6.64 ± 39.77<br>(-36.43 - 141.18) | -0.38 ± 39.81<br>(-36.43 - 131.59) | 6.44 ± 18.06<br>(-36.43 - 55.32) | 6.32 ± 42.88<br>(-36.43 - 131.59) | -5.81 ± 33.79<br>(-36.43 - 88.2) | 0.00 ± 35.61<br>(-36.43 - 141.18) | 3.9903 | 0.0015 |
| Factor Score of Farmers' Knowledge on Farm Management Practices (knowbmp) | 4.76 ± 43.65<br>(-78.35 - 49.59) | -13.84 ± 42.26<br>(-92.69 - 49.59) | 2.84 ± 43.48<br>(-92.69 - 49.59) | 6.96 ± 38.94<br>(-92.69 - 49.59) | 27.24 ± 30.82<br>(-55.74 - 49.59) | -28.62 ± 37.81<br>(-92.69 - 49.59) | 0.00 ± 43.14<br>(-92.69 - 49.59) | 14.5786 | 0.0000 |
| Factor Score of Farmers' Adoption of Agricultural Best Management Practices (BMPs)(proenv) | -5.20 ± 46.82<br>(-43.31 - 135.33) | -9.25 ± 36.68<br>(-43.31 - 99.05) | -4.33 ± 44.92<br>(-43.31 - 135.33) | 15.84 ± 45.58<br>(-43.31 - 135.33) | 28.37 ± 45.9<br>(-43.31 - 135.33) | -26.73 ± 26.65<br>(-43.31 - 90.02) | 0.00 ± 45.1<br>(-43.31 - 135.33) | 13.7812 | 0.0000 |
| Factor Score of Farmers' Willingness to Participate in Government Sponsored Training Programme (wtpgov) | -0.11 ± 1.01<br>(-2.95 - 0.64) | 0.14 ± 0.92<br>(-3.32 - 0.64) | -0.48 ± 1.26<br>(-3.32 - 0.64) | 0.37 ± 0.69<br>(-3.32 - 0.64) | 0.06 ± 0.9<br>(-3.32 - 0.64) | 0.00 ± 0.97<br>(-3.32 - 0.64) | 0.00 ± 1.00<br>(-3.32 - 0.64) | 5.7051 | 0.0000 |
| Area under sugarcane cultivation (in hectare) (areasugar) | 2.50 ± 1.75<br>(0 - 8) | 0.89 ± 1.36<br>(0 - 6) | 2.29 ± 2.69<br>(0 - 18) | 1.69 ± 2.42<br>(0 - 13) | 2.29 ± 2.58<br>(0 - 10) | 0.00 ± 0.00<br>(0 - 0) | 1.62 ± 2.20<br>(0 - 18) | 14.7348 | 0.0000 |
| Herd Size (in cows/ buffalo/bullock unit) (animal) | 3.0 ± 2.7<br>(0 - 10) | 3.4 ± 2.2<br>(0 - 9) | 4.1 ± 3.2<br>(0 - 15) | 5.3 ± 3.9<br>(0 - 21) | 3.1 ± 1.7<br>(0 - 7) | 2.0 ± 1.8<br>(0 - 8) | 3.5 ± 2.9<br>(0 - 21) | 10.9970 | 0.0000 |

*Note:* Figures in the parenthesis show the range for the corresponding average value.